Department of Energy
Carlsbad Area Office
P. O. Box 3090
Carlsbad, New Mexico 88221

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Dear Colleague:

DOE/WIPP 95-2135
Rev 0

The Carlsbad Area Office (CAO) has completed the Engineered Alternatives Cost/Benefit Study (EACBS). Enclosed is a copy for your information. The EACBS was commissioned to examine a wide array of alternatives for Engineered Barriers that may be used to satisfy the Assurance Requirements of 40 CFR 191. The following are examples of barrier alternatives that were considered:

- Backfilling the repository
- Use of incineration and vitrification technologies
- Compaction of wastes
- Changes in repository configuration

We plan to discuss this report in detail with the Environmental Protection Agency at a Technical Exchange Meeting in the near future. If you have any questions regarding the EACBS, please contact James Maes of my staff at (505) 234-7470.

Sincerely,

James A. Mewhinney
for Michael H. McFadden
Assistant Manager
Office of Regulatory Compliance

Enclosure

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Revision 0

Engineered Alternatives Cost/Benefit Study Final Report

September 1995

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

ENGINEERED ALTERNATIVES COST/BENEFIT STUDY
DRAFT REPORT

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Prepared for:

U.S. Department of Energy-Carlsbad Area Office
Contract #DE-AC04-86AL31950

September 1995

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EXECUTIVE SUMMARY

The Waste Isolation Pilot Plant (WIPP) is a United States Department of Energy (DOE) project designed to demonstrate the safe disposal of Transuranic (TRU) waste in deep, geologic, bedded salt. The WIPP site is located in southeastern New Mexico. By law (U.S. Congress, 1992) the WIPP site has been withdrawn from public use and has been set aside for use in the safe disposal of TRU waste. Also by law, disposal of TRU waste must comply with rules and regulations promulgated by the U.S. Environmental Protection Agency (EPA). The disposal system design consists of multiple barriers, both natural and man-made, located in a geologic salt deposit, 2,150 feet (655.3 meters) below ground. These barriers were selected because of their ability to permanently isolate the waste from the accessible environment as required to comply with subparts B and C of Title 40 Code of Federal Regulations Part 191 (40 CFR 191). As a part of the assurance requirements, 40 CFR §191.14 requires that barriers of different types shall be used to isolate the waste. The WIPP design uses both a geologic (natural) and engineered barriers for waste isolation as specified by these regulations. However, to provide additional confidence in containment prediction calculations used to demonstrate compliance with the containment requirements, Engineered Alternatives (EA) could be used as additional assurance measures beyond those used to meet the containment requirements. This report uses the term EA to represent engineered barriers that are technically feasible processes, technologies, methods, repository designs, or waste from modifications which make a significant positive impact on the disposal system in terms of reducing uncertainty in performance calculations or improving long-term performance. These EAs, if used, function as barriers to the release of radioactive material.

The DOE has initiated a cost/benefit study to evaluate EAs for potential use as assurance measures. The purpose of this report is to provide the DOE with cost and benefit information for use in the selection or rejection of EAs, specifically should it be determined that additional barriers are needed for assurance purposes. This study includes a qualitative assessment of estimated cost, potential risks, benefits, and relative repository performance impacts from the implementation of EAs, and where appropriate, the impact on the entire waste management complex (as a system) was considered. This report is entitled, the Engineered Alternatives Cost/Benefit Study (EACBS).

The EACBS evaluated EAs using the following assumptions and guidance.

- The present baseline design of the disposal system and its predicted performance meet the containment requirements of 40 CFR 191 without additional EAs. The baseline does not include waste processing above that required by the WIPP Waste Acceptance Criteria (WAC) and does not include backfill as an option.

- The information presented in this report is to be used to select or reject EAs for assurance purposes only and not for demonstrating compliance with the containment requirements.

- The results of the EACBS analysis are qualitative. However, both qualitative and quantitative methods are used to generate the output information.

- The output of the EACBS compares the results of the EA analysis with the baseline and not to each other. Numeric ranking of EAs is not provided.

- The EA analysis uses a multi-factor approach that evaluates the cost; the risk, both incidental and accidental; and the benefit and schedule impacts that could be expected from the implementation of each individual EA. The factors are not ranked or weighted.

- TRU waste destined for WIPP can be grouped into three basic waste forms, sludges, solid organics, and solid inorganic materials.

- All waste shipped to WIPP will meet the WAC. WAC requirements reflect any necessary waste treatment or processing restrictions.

The DOE has previously evaluated EAs. For example, the Engineered Alternatives Task Force (EATF) Final Report (DOE 1991a) contained analyses of EAs for use in meeting 40 CFR 191 containment requirements. The EATF focused the analysis on an EA's ability to reduce gas generation and its impact on human intrusion scenarios. The EACBS study differs from the EATF in that the EACBS analysis generates information to be used for meeting assurance requirements rather than to address compliance with containment requirements through their inclusion in the compliance baseline. The EACBS analysis also includes information on system wide cost, risks, and public confidence.

The approach used in the EACBS was to screen potential EAs compiled from previous studies, proposed regulations, and input elicited from stakeholders. The screening process used a working group composed of technical professionals from various fields to compare the proposed EAs to an EA definition and then to determine if those EAs that meet the definition also meet regulatory and technological feasibility criteria. The output of the screening process is a list of EAs that did not meet the definition and/or screening criteria along with the justification for their rejection, and a list of EAs retained for further consideration. This list of retained EAs was then optimized to determine which EAs would be further analyzed using a multi-factor approach.

The screening processes evaluated 111 proposed EAs and screened them to a field of 54. The 54 EAs retained were further screened by the DOE using feasibility and effectiveness criteria to provide the final set of 18 EAs used by the EACBS. The 18 EAs agreed upon by the DOE for the EACBS evaluation consisted of nine basic alternatives and nine variations. The variations originated in the screening process and are noted with a letter following the original ID number. The 18 final EAs along with a brief description of each EA are listed below. Complete details of the screening process can be found in Section 2.3.1 of this report.

Analyzed Engineered Alternatives

Baseline

For EA comparison, the baseline is considered to be the current WIPP disposal system design. For each EA and the baseline waste meeting the WAC is emplaced in rooms that are 13 feet (3.96 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long and access drifts in waste stacks of seven-pack drums (three high) and Standard Waste Boxes (three high). No backfill is included in the baseline.

#1—Supercompact Organics and Inorganics

Solid organic and inorganic wastes are sorted to remove items that cannot be compacted. Sorted waste is pre-compacted in 35-gallon (132.6 liters) drums and then supercompacted. Usually, the contents of four supercompacted drums are placed in a 55-gallon (208-liter) drum. Sludges are not processed.

#6—Shred and Compact Organics and Inorganics

Solid organics and inorganics are shredded and compacted in 55-gallon (208-liter) drums using a mechanical shredder and a low pressure compactor. Sludges are not processed.

#10—Plasma Processing of All Wastes

All wastes are processed through a mechanical shredder and the input waste stream is controlled to ensure a suitable metal to non-metal ratio. The waste is processed through a Plasma Arc Centrifugal Treatment System and placed into 55-gallon (208-liter) drums.

#33—Sand Plus Clay Backfill

A mixture of medium grained sand and granulated clay is used as backfill. The mixture is placed around the waste stack and between the drums filling the void space between drums and unmined host salt in waste emplacement panels. A 50 percent void space is assumed.

#35a—Salt Aggregate (Grout) Backfill

A salt aggregate grout mixture is used as backfill to fill the void spaces between drums and unmined host salt in waste emplacement panels. This backfill consists of a cementitious-based salt aggregate grout with crushed salt aggregate and is pumped around the waste stack and between the drums filling the void spaces. A 20 percent void space is assumed.

#35b—Cementitious Grout Backfill

A cementitious grout backfill consisting of ordinary Portland cement, sand and fresh water is pumped around the waste stack and between the drums filling the void space. A 20 percent void space is assumed.

#77a—Supercompact Organics and Inorganics, Salt Aggregate/Grout Backfill, Monolayer of 2000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long

Alternatives #1 and #35a are combined. The room height is lowered from 13 feet to 6 feet (3.96 meters to 1.83 meters) and only one layer of drums is emplaced in the room.

#77b—Supercompact Organics and Inorganics, Clay-Based Backfill, Monolayer of 2000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long

Alternatives #1 and #111 are combined. The room height is lowered from 13 feet to 6 feet (3.96 meters to 1.83 meters) and only one layer of drums is emplaced in the room.

#77c—Supercompact Organics and Inorganics, Sand/Clay Backfill, Monolayer of 2000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long

Alternatives #1 and #33 are combined. The room height is lowered from 13 feet to 6 feet (3.96 meters to 1.83 meters) and only one layer of drums is emplaced in the room.

#77d—Supercompact Organics and Inorganics, CaO Backfill, Monolayer of 2000 drums in a room that is 6 feet (1.83 meters) high, 33 feet (10.06 meters) wide, and 300 feet (91.44 meters) long

Alternatives #1 and #83 are combined. The room height is lowered from 13 feet to 6 feet (3.96 meters to 1.83 meters) and only one layer of drums is emplaced in the room.

#83—Salt Backfill with CaO

A backfill of commercially available granulated lime (also called quick lime which consists of CaO) and crushed salt are placed around the waste stacks and between the drums filling the void space. A 50 percent void space is assumed.

#94a—Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, No Backfill

EA 94a includes two processes to treat the TRU waste. The first is an enhanced cementation process of previously solidified and "as generated" sludge. Existing sludges are fed into a mechanical crusher/shredder. The crushed waste is mixed with an enhanced cement and the product is poured into 55-gallon (208-liter) drums. Newly generated sludges are solidified with the enhanced cement. The second process shreds solid organic and inorganic wastes and adds clay to the shredded waste. This waste product is packaged in 55-gallon (208-liter) drums.

#94b—Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, Sand/Clay Backfill

Alternative #94a and #33 are combined.

#94c—Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, Cementitious Grout Backfill

Alternative #94a and #35b are combined.

#94d—Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, Salt Aggregate Grout Backfill

Alternative #94a and #35a are combined.

#94e—Enhanced Cement Sludges, Shred and Add Clay-Based Materials to Organics and Inorganics, Clay-Based Backfill

Alternative #94a and #111 are combined.

#94f—Enhanced Cement Sludges, Shred, and Add Clay-Based Materials to Organics and Inorganics, CaO/Salt Backfill

Alternative #94a and #83 are combined.

#111—Clay-Based Backfill

A backfill consisting of commercially available pelletized clay is placed around the waste stack and between the drums, filling the void space. A 50 percent void space is assumed.

Table E-1 lists the 18 alternatives with reference to specifications for waste form, backfill and room dimensions. The 18 EAs were analyzed with respect to the following eight factors as described in the proposed rule 40 CFR §194.44. For analytical consistency, Factors 1 and 9 from 40 CFR §194.44 have been combined in the EACBS.

1. Effects of EAs on long-term performance of the disposal system. This factor analyzes the EA's ability to limit water and radionuclide movement to the accessible environment and the potential consequences of human initiated processes or events.

2. The increased or reduced uncertainty in compliance assessment.

3. The impact on public and worker exposure to radiation (at WIPP and off-site) both during and after the incorporation of an EA.

4. The increased ease or difficulty in future removal of the waste from the WIPP disposal system.

5. The increased or reduced risk (incidental and accidental exposure) of transporting the waste to the WIPP.

6. The increased or reduced public confidence in the performance of the disposal system.

TABLE E-1

SUMMARY OF ENGINEERED ALTERNATIVES EVALUATED BY EACBS RELATIVE TO THE BASELINE

Identifier	Alternative	Sludges	Solid Organic	Solid Inorganic	Backfill	Facility Design
0	Baseline	As received	As received	As received	None	Baseline
1	Supercompact waste	As received	Supercompacted	Supercompacted	None	Baseline
6	Shred and compact	As received	Shred and Compact	Shred and Compact	None	Baseline
10	Plasma processing of all waste	Plasma Processed	Plasma Processed	Plasma Processed	None	Baseline
33	Sand plus clay backfill	As received	As received	As received	Sand Plus Clay Backfill	Baseline
35.a	Salt aggregate grout backfill	As received	As received	As received	Salt Aggregate Grout Backfill	Baseline
35.b	Cementitious grout backfill	As received	As received	As received	Cementitious Grout Backfill	Baseline
77.a	Supercompact organics and inorganics, clay-based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Salt Aggregate Grout Backfill	6'X33'X300'
77.b	Supercompact organics and inorganics, clay-based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Clay-based backfill	6'X33'X300'
77.c	Supercompact organics and inorganics, clay-based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Sand/clay backfill	6'X33'X300'
77.d	Supercompact organics and inorganics, clay-based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Salt plus CaO Backfill	6'X33'X300'
83	Salt backfill with CaO	As received	As received	As received	Salt plus CaO Backfill	Baseline
94.a	Enhanced cement sludges, shred and cement organics and inorganics, no backfill	Enhanced Cement	Shred and add clay	Shred and add clay	No backfill	Baseline

TABLE E-1 (Concluded)

SUMMARY OF ENGINEERED ALTERNATIVES EVALUATED BY EACBS RELATIVE TO THE BASELINE

Identifier	Alternative	Sludges	Solid Organic	Solid Inorganic	Backfill	Facility Design
94.b	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Clay/sand backfill	Baseline
94.c	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Cementitious Grout	Baseline
94.d	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Salt Aggregate Grout	Baseline
94.e	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Clay	Baseline
94.f	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Salt plus CaO Backfill	Baseline
111	Clay-Based Backfill	As received	As received	As received	Clay-Based Backfill	Baseline

7. The increased or reduced total DOE waste management system cost and schedule impacts.

8. The impact on other waste disposal programs.

The following discussions outlines the analysis and results for each EA with respect to the eight factors.

Factor 1—Effects of EAs on Long-Term Performance of the Disposal System

Factor 1 deals with the impacts that an EA is predicted to have on the long-term performance (not specific to the regulatory requirements) of the disposal system. Impacts are predicted using the Design Analysis Model (DAM), which considers the coupled processes of brine inflow, creep closure, gas generation, and radionuclide migration under undisturbed conditions. The consequences of three human intrusion scenarios are also considered. The DAM was originally developed by the EATF (DOE, 1991a). The three human intrusion scenarios postulate the existence of future boreholes that inadvertently penetrate the waste rooms and panels (waste horizon). These scenarios are the same as those considered in the 1992 Performance Assessment, and are fully described in SNL/NM (1993). These three scenarios are referred to in the EACBS as E1, E2, and E1E2. This factor is evaluated by considering the impacts of each EA on the following:

- Relative changes in the cumulative 10,000-year release of radionuclides based purely on the quantity of cuttings released to the surface from each of the three human intrusion scenarios

- Relative changes in the cumulative 10,000-year release of radionuclides into the overlying Rustler Formation from each of the three human intrusion scenarios.

The impacts of each EA are expressed as changes in the parameters described above relative to the baseline, which is defined as unprocessed waste emplaced in disposal panels with no backfill.

Although both disturbed and undisturbed conditions are simulated, the greatest consequences of releases are expected to occur as a result of human intrusion. Therefore, the study places emphasis on the effects of EAs on mitigating releases from the human intrusion scenarios.

Factor 2—The Increased or Reduced Uncertainty in Compliance Assessment

Factor 2 estimates the EAs ability to treat uncertainty relative to the quantity of radioactive materials that are expected to be transported to the accessible environment as a result of human intrusion scenarios. This factor estimates the uncertainties by systematically manipulating the DAM input parameters from the Factor 1 analyses using a Monte Carlo simulation for each EA analyzed. The results of Factor 2 are then used in conjunction with those of Factor 1 to characterize the potential for an EA to provide additional assurance in the performance of the disposal system.

Treatment of uncertainty in compliance assessment can be realized by reducing both the magnitude of radioactive materials released to the accessible environment and characterizing the

potential variability in that quantity. Factor 1 addresses the magnitude of reduction through a Measure of Relative Effectiveness (MRE) for cuttings removal to the surface and groundwater transport to the Culebra Dolomite via the borehole, given scenarios E1, E2, or E1E2 occur. A MRE is a unitless factor that expresses the change in the magnitude of releases with respect to the baseline disposal system design. Factor 2 addresses the ability of the EAs to treat the uncertainty about these estimates of release quantity by treating the uncertainty about predictions of quantities of radioactive material that might be released as a result of the intrusion scenarios. Therefore, increasing the confidence in the performance of the disposal system.

Factor 3—The Impact on Public and Worker Exposure to Radiation Both During and After the Incorporation of an EA

This factor characterizes the human-health risks (incidental and accidental exposure) associated with the implementation of an EA, including those impacts realized at the WIPP site and generator or disposal facilities that handle TRU or TRU-mixed waste. Potential impacts include radiation effects (both occupational exposures and the release of material resulting from an off-normal accident scenario), effects from the release of hazardous material, and, in the case of individuals within the facilities, ordinary industrial hazards. Impacts are considered for the following five groups of individuals at the WIPP and at the generator/disposal sites:

- Workers directly involved with handling, processing, or storing TRU waste (generally referred to as "workers")
- Other workers in the facility who are not directly involved with the TRU waste (referred to as "co-located workers")
- The co-located worker who receives the highest exposure to radiation or hazardous material from TRU waste activities
- All members of the public who live within 50 miles (80.5 kilometers) of the facility where the TRU waste is being handled, processed, or stored (generally referred to as "public")
- The member of the public located off-site who receives the highest exposure from activities associated with TRU handling, processing, or disposal (often called the Maximum Off-Site Individual or MOI).

Factor 4—The Increased Ease or Difficulty in Future Removal of the Waste from the WIPP Disposal System

For the purpose of this report, waste removal is defined as the activity involving recovery of the waste after repository closure. In assessing the waste removal activities, the waste inventory and physical properties for each EA determine the underground panel geometry that would in turn determine the time required for underground removal (mining of the waste). Underground waste removal considers the compressive strength and density of the waste form as well as the consolidation of the backfill expected to occur after a specified period of time (if applicable). The occupational hazards for industrial accidents include the conventional hazards due to underground mining accidents, hazardous waste exposure, and radioactive waste exposure.

Factor 5—The Increased or Reduced Risk of Transporting the Waste to the WIPP

The transportation risk factor consists of the human-health impacts due to radiation- and hazardous-material exposures that could potentially result from transporting CH- or RH-TRU waste. The risk factor is defined in terms of the radiological, chemical, and non-radiological/non-chemical impacts of either normal, incident-free transportation or transportation accidents. Not all of the EAs impact transportation; backfill only alternatives are not analyzed using this factor. The results break down the total number of shipments from each storage/generator site and present the exposures to the public and workers. Where applicable, reported transportation risks and exposures are in the same units used in Factor 3.

Factor 6—The Increased or Reduced Public Confidence in the Performance of the Disposal System

This study was conducted in two phases to identify both historic and current public concerns about WIPP's postclosure performance. During Phase 1, existing public commentary was examined to identify concerns about postclosure WIPP. These comments and concerns were further analyzed to determine the relative frequency of the concerns and the persistence of concerns over time. Data sources included:

- The WIPP FSEIS (DOE, 1990b)
- Response to Comments for Amendments to 40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and TRU Radioactive Wastes (EPA, 1993)
- Public Hearings on EPA's Proposed Rule 40 CFR Part 194, Criteria for the Certification and Determination of the WIPP's Compliance with Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and TRU Radioactive Wastes, March 21-24, 1995 (EPA, 1995)

During Phase 2, comments were collected during a series of focus group discussions and interviews in which participants were invited to share their concerns.

The combined findings from Phase 1 and Phase 2 analyses serve as considerations for selecting engineered alternatives that would address expressed public concerns. A qualitative assessment is made using the comment categories (comments were segregated based on the general nature of the concern) and determining which EAs address the concerns within these categories.

Factor 7—The Increased or Reduced Total DOE Waste Management System Cost and Schedule Impacts

Factor 7 analyzed increased or reduced cost and schedule impacts from implementation of EAs on the total DOE waste management system. The cost consists of summarized waste processing, transportation, backfill, and emplacement handling for the selected alternatives. The analyzed costs include a comparative analysis of the incremental change in cost of the screened alternatives relative to the repository baseline. This analysis estimates the level of funding that must be appropriated, the estimated manpower for the activities, and a conceptual schedule that provides start and stop dates for each EA analyzed. Cost was analyzed by developing process

flow diagrams that segment the alternative into conceptual elements. The costs for the alternatives were developed on the basis of waste quantities and required throughput rates to meet the schedule constraints.

The schedule analysis provides a measure of the time required to implement an EA relative to the baseline. The schedule includes the incremental change of implementing an alternative on the baseline.

Factor 8—The Impact on Other Waste Disposal Programs

This factor includes an assessment of the impacts that the EAs will have on other DOE waste processing and disposal programs, including programs for LLW and low-level mixed waste (LLMW). Major impacts are assessed based on the additional volumes of waste that are projected to be generated by TRU waste processing with respect to each EA.

OVERALL CONCLUSION OF THE EACBS

After a decision is made concerning the use of EAs at WIPP for additional assurance purposes, any subsequent selection of EAs will be made using total disposal system knowledge. The EACBS provides comparative information concerning cost, schedule, worker and public radiological/chemical and accidental/incidental risks, disposal system performance impacts, public perception, waste removal impacts, and other waste disposal system impacts. The process for the selection or rejection of EAs will use this and other related information to weigh the relative importance and to determine which EAs will be implemented. The information in this report should not be used as the sole bases for the selection/rejection of any individual EA.

Table E-1 summarizes the 18 EAs analyzed in the EACBS. Each alternative was evaluated using the eight factors. The analysis results were compiled in a tabular summary and converted into quantifiable performance measures. Some factors were reported with one measure, while other factors could not be adequately expressed with a single measure. Table E-2 summarizes the performance measures and units presented for each factor. Table E-3 summarizes selected output information from the analysis of each EA and the baseline with respect to the eight factors.

The product from the evaluation of each factor was integrated into a qualitative result called a performance vector, that expresses the performance of an EA with respect to the baseline. As is the case for any analysis, these results are conditional on the models, data, and assumptions used in the analysis. Models, data and assumptions used in the analysis are described in Chapter 3.0. These models, data, and assumptions are based on the best available current information, and are considered to be appropriate for the purposes of this study. Technological understanding of many topics considered in this analysis is advancing rapidly, however, and it should be noted that changes in the modeling system or the model input, such as possible changes in our understanding of the future performance of specific EAs, could lead to somewhat different results. Table E-4 summarizes the results of the EACBS analysis and provides the performance vectors for each of the selected EAs plus the baseline repository design.

The EAs can be separated into three general categories, Waste Processing, Backfill, and Combination of these alternatives. The following observations were noted from the results of this analysis.

1

TABLE E-2

PERFORMANCE MEASURES REPORTED

EA FACTOR	PERFORMANCE MEASURE	UNITS
1) Long term Repository Performance	Measure of relative effectiveness (MRE) of repository performance compared to the baseline.	Ratio of the mean value EA performance to the baseline
2) Uncertainty in Compliance Assessment	Measure of the relative uncertainty (MRU) of repository performance compared to the baseline.	Ratio of the range factor for EA performance to the baseline
3) Worker & Public Risk[a]	Facility worker risk	FTE-rem excess fatalities, construction and operation injuries and fatalities
	Maximum co-located worker risk	rem, excess cancer fatalities
	Co-located worker collective risk	Person-rem excess fatalities[b]
	Maximum off-site individual risk	rem, excess cancer fatalities
	Collective off-site public risk	Person-rem excess fatalities[b]
4) Impact on Waste Removal	Measure of relative difficulty of waste removal compared to the baseline.	Qualitative ranking.
5) Transportation Risk[a]	Transport crew collective radiological, nonaccident risk	Person-rem, latent cancer fatalities
	Public collective radiological, nonaccident risk	Person-rem, latent cancer fatalities
	Public maximum individual radiological, nonaccident risk	rem, latent cancer fatalities
	Public and crew collective radiological, accident risk	Person-rem, latent cancer fatalities
	Public and crew collective chemical risk	EPRG-2 ratio
	Public and crew collective non-rad, non-chemical risk	injuries, fatalities
6) Public Confidence	Listing of citizen concerns about repository performance	Not applicable
7) System Cost & Schedule[a]	Waste storage costs	1994 dollars
	Waste treatment costs	1994 dollars
	Waste transportation costs	1994 dollars
	WIPP waste placement and backfill costs	1994 dollars
	Start of WIPP operations	Date of first waste placement
	Completion of WIPP operations	Date of closure
8) Impact on Other Disposal Systems	Secondary waste volumes	Percentage change in estimated secondary waste volumes relative to the DOE low level and low level mixed waste

[a]For EAs that involve waste treatment, results are reported separately for decentralized, regionalized and centralized locations.
[b]Other units of measure are also used for non-radiological risk.

TABLE E-3

SUMMARY OF ANALYSIS RESULTS

Factor Output	Factor Number	Baseline	EA 1 Supper-compact	EA 6 Shred and Compact	EA 10 Plasma	EA 33 Sand & Clay BF	EA 35a Salt Agg. BF	EA 35b Cement Grout BF	EA 77a SuperC Salt Agg. BF	EA 77b SuperC Clay Base BF	EA 77c SuperC Sand Clay BF	EA 77d SuperC CaO BF	EA 83 CaO BF	EA 94a Shrd/Cly Sludge No BF	EA 94b 94 a + Clay Sand BF	EA 94c 94a + Cement Grout BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Waste Backfill Compressive Strength (MPa)	NA	25.2	24.5	25.1	24.1	15.2	21.1	21.1	19.4	12.2	12.2	18.3	20.1	24.7	14.7	20.6	20.6	14.7	19.7	15.2
Emplacement Volume Impact (% Emplaced or Amount not Emplaced m^3)	NA	100% emplaced	100% empleced	100% empleced	100% emplaced	100% emplaced	100% emplaced	100% emplaced	41,655	41,655	41,655	41,655	100% emplaced	27,177	27,177	27,177	27,177	27,177	27,177	100% emplaced
Backfill Properties -																				
Initial Density (Kg/m^3)	NA	NA	NA	NA	NA	1,590	1,884	1,884	1,884	1,000	1,590	1,193	1,193	NA	1,590	1,884	1,884	1,000	1,193	1,000
Initial Porosity (%)						40.0	31.3	31.3	31.3	62.5	40.0	44.8	44.8		40.0	31.3	31.3	62.5	44.8	62.5
Solid Density (Kg/m^3)						2,650	2,741	2,741	2,741	2,670	2,650	2,162	2,162		2,650	2,741	2,741	2,670	2,162	2,670
MRE (unitless)	1																			
E1		1.0	0.93	0.95	0.00078	0.74	0.40	0.40	0.44	0.56	0.73	0.79	0.83	0.69	0.66	0.45	0.45	0.53	0.67	0.54
E2		1.0	1.4	1.1	0.0093	2.0	1.1	1.1	0.56	2.3	2.1	0.30	0.30	1.1	0.86	0.46	0.46	0.88	0.30	2.1
E1E2		1.0	1.0	1.0	0.00076	0.99	0.04	0.04	0.083	0.93	0.98	0.032	0.050	1.0	0.99	0.089	0.089	0.49	0.012	0.56
Cuttings		1.0	.26	0.79	0.12	0.92	0.40	0.40	0.21	0.22	0.21	0.22	0.94	0.57	0.52	0.30	0.30	0.53	0.54	0.94
Uncertainty E1	2																			
5th Percentile		NA	0.92	0.92	0.0004	0.73	0.40	0.40	0.43	0.55	0.72	0.60	0.83	0.68	0.64	0.44	0.44	0.52	0.26	0.53
95th Percentile			0.94	0.96	0.0012	0.78	0.42	0.42	0.47	0.59	0.78	0.81	0.84	0.72	0.69	0.47	0.47	0.56	0.68	0.55
Uncertainty E2	2																			
5th Percentile		NA	0.61	0.75	0.0009	0.31	0.18	0.18	0.091	0.45	0.37	0.009	0.009	0.19	0.14	0.03	0.03	0.16	0.005	0.33
95th Percentile			2.08	1.75	0.0549	1.99	1.09	1.09	0.87	2.35	2.06	0.83	0.84	1.08	1.61	0.88	0.88	1.62	0.75	2.18
Uncertainty E1E2	2																			
5th Percentile		NA	1.0	1.0	0.0003	0.99	0.009	0.009	0.011	0.37	0.98	0.012	0.012	0.37	0.22	0.01	0.01	0.024	0.009	0.024
95th Percentile			1.0	1.0	0.0066	0.99	0.75	0.75	0.98	0.98	0.98	0.438	0.76	1.0	0.99	0.98	0.98	0.99	0.045	0.99
Uncertainty Cuttings	2																			
5th Percentile		NA	0.25	0.75	0.11	0.91	0.40	0.40	0.21	0.21	0.21	0.21	0.94	0.56	0.52	0.29	0.29	0.53	0.53	0.93
95th Percentile			0.26	0.80	0.18	0.92	0.40	0.40	0.21	0.22	0.21	0.22	0.94	0.57	0.52	0.30	0.30	0.53	0.54	0.94
WIPP Worker Rad Risk	3																			
FTE-Rem		322.85	322.85	322.85	322.85	345.27	357.23	357.23	342.07	340.15	343.99	338.23	339.29	322.85	346.77	366.20	343.78	342.28	339.29	342.28
Excess Fatalities		0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.14	0.15	0.14	0.14	0.14	0.14
WIPP Indust. Accidents	3																			
Injuries		53.63	44.05	44.05	33.20	64.50	70.81	70.81	55.53	49.80	51.77	51.06	66.45	53.63	67.04	69.14	69.56	61.83	63.25	62.53
Fatalities		0.16	0.13	0.13	0.10	0.29	0.30	0.30	0.15	0.15	0.15	0.25	0.28	0.16	0.39	0.21	0.49	0.18	0.28	0.18

TABLE E-3 (continued)

SUMMARY OF ANALYSIS RESULTS

Factor Output	Factor Number	Baseline	EA 1 Supper-compact	EA 6 Shred and Compact	EA 10 Plasma	EA 33 Sand & Clay BF	EA 35a Salt Agg. BF	EA 35b Cement Grout BF	EA 77a SuperC Salt Agg. BF	EA 77b SuperC Clay Base BF	EA 77c SuperC Sand Clay BF	EA 77d SuperC CaO BF	EA 83 CaO BF	EA 94a Shrd/Cly Sludge No BF	EA 94b 94 a + Clay Sand BF	EA 94c 94a + Cement Grout BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Waste Processing Risk	3																			
Centralized Scenario																				
Off-site Population																				
Cancer Fatalities		$1.94x10^{-4}$	$4..24x10^{-4}$	$4.24x10^{-4}$	$8.99x10^{-1}$	NA	NA	NA	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	NA	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	NA
Cancer Incidence		$5.51x10^{-8}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$3.39x10^{-7}$				$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$		$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	
Workers																				
Cancer Fatalities		$7.78x10^{-1}$	$1.10x10^{+0}$	$1.20x10^{+0}$	$1.34x10^{+0}$				$1.10x10^{+0}$	$1.10x10^{+0}$	$1.10x10^{+0}$	$1.10x10^{+0}$		$1.20x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	
Cancer Incidence		$1.30x10^{-5}$	$3.49x10^{-5}$	$3.80x10^{-5}$	$1.69x10^{-4}$				$3.49x10^{-5}$	$3.49x10^{-5}$	$3.49x10^{-5}$	$3.49x10^{-5}$		$3.80x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	
Construct/Op Fatalities		2.81	3.79	4.08	5.29				3.79	3.79	3.79	3.79		4.08	4.08	4.08	4.08	4.08	4.08	
Waste Processing Risk	3																			
Regionalized Scenario																				
Off-site Population		$1.94x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$4.79x10^{+0}$	NA	NA	NA	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	NA	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	NA
Cancer Fatalities		$5.51x10^{-8}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.19x10^{-7}$				$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$		$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	
Cancer Incidence																				
Workers		$7.78x10^{-1}$	$9.92x10^{-1}$	$8.12x10^{-1}$	$9.10x10^{-1}$				$9.92x10^{-1}$	$9.92x10^{-1}$	$9.92x10^{-1}$	$9.92x10^{-1}$		$8.12x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	
Cancer Fatalities		$1.30x10^{-5}$	$3.15x10^{-5}$	$2.58x10^{-5}$	$3.73x10^{-5}$				$3.15x10^{-5}$	$3.15x10^{-5}$	$3.15x10^{-5}$	$3.15x10^{-5}$		$2.58x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	
Cancer Incidence		2.81	3.83	3.45	7.18				3.83	3.83	3.83	3.83		3.45	3.45	3.45	3.45	3.45	3.45	
Construct/Op Fatalities																				
Waste Processing Risk	3																			
Decentralized Scenario																				
Off-site Population		$1.94x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$4.60x10^{+0}$	NA	NA	NA	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	NA	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	NA
Cancer Fatalities		$5.51x10^{-8}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.06x10^{-7}$				$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$		$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	
Cancer Incidence																				
Workers		$7.78x10^{-1}$	$9.54x10^{-1}$	$7.91x10^{-1}$	$1.17x10^{+0}$				$9.54x10^{-1}$	$9.54x10^{-1}$	$9.54x10^{-1}$	$9.54x10^{-1}$		$7.91x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	
Cancer Fatalities		$1.30x10^{-5}$	$3.03x10^{-5}$	$2.51x10^{-5}$	$4.81x10^{-5}$				$3.03x10^{-5}$	$3.03x10^{-5}$	$3.03x10^{-5}$	$3.03x10^{-5}$		$2.51x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	
Cancer Incidence		2.81	4.05	3.78	9.73				4.05	4.05	4.05	4.05		3.78	3.78	3.78	3.78	3.78	3.78	
Construct/Op Fatalities																				
Mining Advance Rate (m/Shift)	4	1.8	1.8	1.8	1.9	2.0	1.9	1.9	4.2	4.5	4.5	4.2	1.9	1.8	2.0	1.9	1.9	2.0	1.9	2.0
Removal Risk	4																			
Fatal Accidents		0.58	0.58	0.58	0.58	0.53	0.56	0.56	0.26	0.24	0.24	0.25	0.56	0.58	0.53	0.56	0.56	0.53	0.55	0.53
Non- Fatal Accidents		11.74	11.66	11.73	11.62	10.74	11.31	11.31	5.15	4.83	4.83	5.09	11.22	11.69	10.69	11.26	11.26	10.69	11.17	10.74

TABLE E-3 (continued)

SUMMARY OF ANALYSIS RESULTS

Factor Output	Factor Number	Baseline	EA 1 Supper-compact	EA 6 Shred and Compact	EA 10 Plasma	EA 33 Sand & Clay BF	EA 35a Salt Agg. BF	EA 35b Cement Grout BF	EA 77a SuperC Salt Agg. BF	EA 77b SuperC Clay Base BF	EA 77c SuperC Sand Clay BF	EA 77d SuperC CaO BF	EA 83 CaO BF	EA 94a Shrd/Cly Sludge No BF	EA 94b 94 a + Clay Sand BF	EA 94c 94a + Cement Grout BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Trans Rad Risk[1]	5																			
Decentralized (CH only)																				
Worker		$6.69x10^{+2}$	$5.81x10^{+2}$	$5.47x10^{+2}$	$7.16x10^{+2}$	$6.69x10^{+2}$	$6.69x10^{+2}$	$6.69x10^{+2}$	$5.81x10^{+2}$	$5.81x10^{+2}$	$5.81x10^{+2}$	$5.81x10^{+2}$	$6.69x10^{+2}$	$4.25x10^{+2}$	$4.25x10^{+2}$	$4.25x10^{+2}$	$4.25x10^{+2}$	$4.25x10^{+2}$	$4.25x10^{+2}$	$6.69x10^{+2}$
Person-Rem		$2.68x10^{-1}$	$2.32x10^{-1}$	$2.19x10^{-1}$	$2.86x0^{-1}$	$2.68x10^{-1}$	2.6810^{-1}	2.6810^{-1}	$2.32x10^{-1}$	$2.32x10^{-1}$	$2.32x10^{-1}$	$2.32x10^{-1}$	2.6810^{-1}	$1.70x10^{-1}$	$1.70x10^{-1}$	$1.70x10^{-1}$	$1.70x10^{-1}$	$1.70x10^{-1}$	$1.70x10^{-1}$	2.6810^{-1}
LCF																				
Public		$4.00x10^{+3}$	$3.47x10^{+3}$	$3.27x10^{+3}$	$4.27x10^{+3}$	$4.00x10^{+3}$	$4.00x10^{+3}$	$4.00x10^{+3}$	$3.47x10^{+3}$	$3.47x10^{+3}$	$3.47x10^{+3}$	$3.47x10^{+3}$	$4.00x10^{+3}$	$2.55x10^{+3}$	$2.55x10^{+3}$	$2.55x10^{+3}$	$2.55x10^{+3}$	$2.55x10^{+3}$	$2.55x10^{+3}$	$4.00x10^{+3}$
Person-Rem		$2.00x10^{+0}$	$1.74x10^{+0}$	$1.64x10^{+0}$	$2.14x10^{+0}$	$2.00x10^{+0}$	$2.00x10^{+0}$	$2.00x10^{+0}$	$1.74x10^{+0}$	$1.74x10^{+0}$	$1.74x10^{+0}$	$1.74x10^{+0}$	$2.00x10^{+0}$	$1.28x10^{+0}$	$1.28x10^{+0}$	$1.28x10^{+0}$	$1.28x10^{+0}$	$1.28x10^{+0}$	$1.28x10^{+0}$	$2.00x10^{+0}$
LCF																				
Accident		$8.01x10^{+1}$	$5.92x10^{+0}$	$7.59x10^{+1}$	$1.21x10^{+0}$	$8.01x10^{+1}$	$8.01x10^{+1}$	$8.01x10^{+1}$	$5.92x10^{+0}$	$5.92x10^{+0}$	$5.92x10^{+0}$	$5.92x10^{+0}$	$8.01x10^{+1}$	$5.76x10^{+1}$	$5.76x10^{+1}$	$5.76x10^{+1}$	$5.76x10^{+1}$	$5.76x10^{+1}$	$5.76x10^{+1}$	$8.01x10^{+1}$
Person-Rem		$4.01x10^{-2}$	$2.96x10^{-3}$	$3.80x10^{-2}$	$6.05x10^{-4}$	$4.01x10^{-2}$	$4.01x10^{-2}$	$4.01x10^{-2}$	$2.96x10^{-3}$	$2.96x10^{-3}$	$2.96x10^{-3}$	$2.96x10^{-3}$	$4.01x10^{-2}$	$2.88x10^{-2}$	$2.88x10^{-2}$	$2.88x10^{-2}$	$2.88x10^{-2}$	$2.88x10^{-2}$	$2.88x10^{-2}$	$4.01x10^{-2}$
LCF																				
Trans Chemical Risk	5																			
Decentralized																				
Max. Individual		$1.21x10^{+0}$	$1.80x10^{+0}$	$1.20x10^{+0}$	$2.10x10^{-5}$	$1.21x10^{+0}$	$1.21x10^{+0}$	$1.21x10^{+0}$	$1.80x10^{+0}$	$1.80x10^{+0}$	$1.80x10^{+0}$	$1.80x10^{+0}$	$1.21x10^{+0}$	$8.10x10^{-1}$	$8.10x10^{-1}$	$8.10x10^{-1}$	$8.10x10^{-1}$	$8.10x10^{-1}$	$8.10x10^{-1}$	$1.21x10^{+0}$
Trans Non-Rad/Chem Risk	5																			
Decentralized																				
Injuries		$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$	$6.61x10^{+1}$
Fatalities		$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$	$4.87x10^{+0}$
Percent of Comments Addressed by EA	6	NA	33%	33%	40%	31%	36%	36%	33%	33%	33%	33%	36%	42%	42%	42%	42%	42%	42%	36%
Total System Cost	7																			
Decentralized ($x10^6$)		4,483	5,219	4,955	6,704	4,538	4,569	4,569	5,280	5,250	5,257	5,255	4,536	7,624	7,675	7,703	7,703	7,667	7,673	4,529
Regionalized ($x10^6$)		4,335	4,824	4,607	5,742	4,391	4,421	4,421	4,884	4,855	4,861	4,859	4,388	6,835	6,886	6,913	6,914	6,877	6,883	4,381
Centralized ($x10^6$)		4,029	4,177	4,129	4,725	4,084	4,115	4,145	4,237	4,208	4,214	4,213	4,082	4,982	5,032	5,060	5,061	5,024	5,030	4,075
Schedule Impact - Delayed Emplacement Relative to Baseline Startup	7	No Delay	9yrs.	8yrs.	9yrs.	No Delay	No Delay	No Delay	9yrs.	9yrs.	9yrs.	9yrs.	No Delay	9yrs.	9yrs.	9yrs.	9yrs.	9yrs.	9yrs.	No Delay
Other Waste Generation	8																			
Secondary (m^3)		32,729	118,040	118,040	21,848	32,729	32,729	32,729	118,040	118,040	118,040	118,040	32,729	131,625	131,625	131,625	131,625	131,625	131,625	32,729
LLW/LLMW (m^3)		16,365	59,020	59,020	10,924	16,365	16,365	16,365	59,020	59,020	59,020	59,020	16,365	65,813	65,813	65,813	65,813	65,813	65,813	16,365

[1]Only the Decentralized scenario is shown here. The Centralized scenario results for all EAs are the same as the baseline reported here. The Regionalized scenario analysis output is shown in Table 3-44.

- Waste Processing alternatives (EA # 1,6 & 10) were analyzed for the three processing scenarios (centralized, regionalized, and decentralized). Each scenario has inherent benefits and detriments. In general, processing alternatives impact the entire waste disposal system, involving the generator/storage sites, waste transportation, other waste disposal systems, and the WIPP waste handling system. Processing alternatives have higher cost, greater risks, and present increased schedule delays in comparison to baseline or backfill only EAs. In general, processing EAs have a marginal performance impact on the repository except for plasma processing (EA# 10) which shows a significant increase in repository impact, however, at the expense of the highest potential risk for all of the EAs analyzed.

  Centralized Processing—Since the centralized scenario processes all waste at one facility, the construction and operational costs are the lowest of the three waste processing scenarios. Operational and construction incidents and fatalities and public and worker chemical and radiological exposure risks are higher than the baseline. Transportation impacts are similar to the baseline. The centralized scenario has the highest potential to impact system wide disposal operations. Since one facility processes all waste, this facility becomes a potential choke point for the entire system.

  Regionalized Processing—The regionalized scenario processes waste at five generator/storage sites. The cost to implement regionalized EA scenarios are significantly higher than the centralized and slightly lower than the decentralized scenarios. In general, the worker and public radiological/chemical exposure risks are slightly higher than the centralized and lower than the decentralized scenarios. Transportation chemical exposure risks are slightly lower than the baseline since the waste is processed into a more inert matrix prior to shipment to WIPP. Accident and radiation risks are similar to the baseline.

  Decentralized Processing—For the scenario, processing is performed at the ten major generator/storage sites. The scenario has the highest cost of the three processing scenarios (as much as $1 billion difference between the centralized and decentralized for EA# 77a-d). The operation/construction incidents and fatality rates are generally higher than both the centralized and regionalized (baseline included).

- Backfill alternatives (EA# 33, 35a, 35b, 83 and 111) have the least impact on the entire waste disposal system. The WIPP waste handling system is impacted; waste transportation, generator/storage sites, and other waste disposal systems are not affected. Cost, schedule radiation and chemical exposure are similar to the baseline estimates. Backfill alternatives improve long-term disposal system performance.

- Combination alternatives contain both multiple processing alternatives and/or backfill alternatives. These alternatives (EA# 77a through 77d and 94a through 94f) have benefits and detriments associated with each individual alternative type. The overall cost and schedule impacts are the highest of the EAs. Transportation, worker and public risks (radiological, chemical accidental and incidental) are also the highest of all EAs. The overall impact of combination EAs on long-term disposal system performance are comparable to that associated with the backfill and processing only alternatives.

WIPP ENGINEERED ALTERNATIVES IMPACT VECTOR ELEMENTS

TRU WASTE DISPOSAL SCENARIO		LONG TERM COMPLIANCE CONFIDENCE		PUBLIC HEALTH RISK				WORKER HEALTH		DISPOSAL SYSTEM COSTS					WIPP SCHEDULE			
										TRU WASTE								
						At WIPP						At WIPP						
Seq. No.	Engineered Alternative Case #	Cutings Scenarios	Water Scenarios	At Generator	In Transport	*Before Closure*	*After Closure*	At Generator	At WIPP	At Generator	In Transport	Storage & Treatment	Placement & Backfill	IMPACT ON OTHER WASTE DISPOSAL SYSTEMS	First Waste	Closure	WASTE REMOVAL CAPABILITY	PUBLIC ACCEPTANCE
1	Baseline-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
2	33-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	❒	▲	▲	▲	▲	▲
3	35a-1	◑	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	❒	▲	▲	▲	▲	▲
4	35b-1	◑	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	❒	▲	▲	▲	▲	▲
5	111-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	❒	▲	▲	▲	▲	▲
6	83-1	▲	◑	▲	▲	▲	▲	▲	▲	▲	▲	▲	❒	▲	▲	▲	▲	▲
7	1-1	◑	▲	▲	▲	❒	▲	▲	■	▲	▲	■	◑	❒	■	▲	◑	▲
8	77a-1	◑	▲	▲	▲	❒	▲	▲	■	▲	▲	■	▲	❒	■	▲	◑	▲
9	77b-1	◑	▲	▲	▲	❒	▲	▲	■	▲	▲	■	▲	❒	■	▲	◑	▲
10	77c-1	◑	▲	▲	▲	❒	▲	▲	■	▲	▲	■	▲	❒	■	▲	◑	▲
11	77d-1	◑	◑	▲	▲	❒	▲	▲	■	▲	▲	■	▲	❒	■	▲	◑	▲
12	6-1	▲	▲	▲	▲	❒	▲	▲	■	◑	▲	■	◑	❒	■	▲	▲	▲
13	94a-1	◑	▲	▲	▲	❒	▲	▲	■	◑	▲	■	▲	❒	■	▲	▲	▲
14	94b-1	◑	▲	▲	▲	❒	▲	▲	■	◑	▲	■	❒	❒	■	▲	▲	▲
15	94c-1	◑	▲	▲	▲	❒	▲	▲	■	◑	▲	■	❒	❒	■	▲	▲	▲
16	94d-1	◑	▲	▲	▲	❒	▲	▲	■	◑	▲	■	❒	❒	■	▲	▲	▲
17	94e-1	◑	▲	▲	▲	❒	▲	▲	■	◑	▲	■	❒	❒	■	▲	▲	▲
18	94f-1	◑	◑	▲	▲	❒	▲	▲	■	◑	▲	■	❒	❒	■	▲	▲	▲
19	10-1	●	●	▲	▲	■	▲	▲	■	◑	▲	■	◑	◑	■	▲	▲	▲

SCENARIO TREE LEGEND:

Super C: Supercompaction of all waste, except sludges

S&C: Shreding and compaction of all waste, except sludges

SCC: All wastes other than sludges are shredded and repackaged with clay. Sludges are cemented.

SAG: Salt Aggregate Grout

CG: Cemenitious Grout

IMPACT VECTOR RANKING:

● Performance is significantly better than the corresponding baseline performance.

◑ Performance is marginally better than the corresponding baseline performance.

▲ Performance is approximately the same as the corresponding baseline performance.

❒ Performance is marginally worse than the corresponding baseline performance.

■ Performance is significantly worse than the corresponding baseline performance.

[a] The Centralized Processing Scenario was selected because it generally produces the lowest increase in cost, schedule impacts, and health risks with respect to the baseline case–results for the regionalized and decentralized scenarios are found in Section 3.0.

Figure E-4

Summary of WIPP Engineered Alternative Evaluation Results for Centralized Processing Scenario[a]

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LIST OF ABBREVIATIONS/ACRONYMS

Am	americium
ANL-E	Argonne National Laboratory-East
ANL-W	Argonne National Laboratory-West
BIR	Baseline Inventory Report
CaO	calcium oxide
CCDF	complementary cumulative distribution function
CFR	Code of Federal Regulations
CH	contact-handled
Ci	curie
CPLM	costs per loaded mile
CPM	critical path method
DAM	Design Analysis Model
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOE-CAO	U.S. Department of Energy, Carlsbad Area Office
DOT	U.S. Department of Transportation
DRZ	disturbed rock zone
EA	Engineered Alternative
EACBS	Engineered Alternatives Cost Benefit Study
EAMP	Engineered Alternatives Multidisciplinary Panel
EASWG	Engineered Alternatives Study Working Group
EATF	Engineered Alternatives Task Force
EM-PEIS	Environmental Management Programmatic Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERPG-2	Emergency Response Planning Guideline-2
ETEC	Energy Technology Engineering Center
FEIS	Final Environmental Impact Statement
FSEIS	Final Supplement Environmental Impact Statement
FTE	full-time equivalent
IDB	Integrated Data Base
INEL	Idaho National Engineering Laboratory
IR	incident rate(s)
KAPL	Knolls Atomic Power Laboratory
LANL	Los Alamos National Laboratory
lb/ft^3	pounds per cubic meter
LBL	Lawrence Berkeley Laboratory
LCF	latent cancer fatality
LESAT	Lockheed Martin Environmental Systems and Technologies Co.
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOC(s)	level(s) of concern
LWA	Land Withdrawal Act
m^3	cubic meter
MB139	Marker Bed 139

LIST OF ABBREVIATIONS/ACRONYMS *(Continued)*

MEI	Maximum Exposed Individual
MOI	Maximum Off-Site Individual
MPa	megaPascals
m/s	meters per second
MRE	Measure of Relative Effectiveness
mrem/hr	millirem per hour
MU	Missouri University
MWIR	(Interim) Mixed Waste Inventory Report
NACEPT	National Advisory Council on Environmental Policy and Technology
nCi/g	nanoCuries per gram
NEPA	National Environmental Policy Act
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
OASIS	Organic and Sludge Immobilization System
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
PA	Performance Assessment
PACT	Plasma Arc Centrifugal Treatment
PDSTP	Preliminary Draft Site Treatment Plan
PEL	permissible exposure limit
PERT	Project Evaluation and Review Technique
PLCC	planning life cycle cost
PPE	personal protective equipment
preops	preoperations
psi	pounds per square inch
Pu	plutonium
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
SARF	Supercompaction and Repackaging Facility
SEIS	Supplement Environmental Impact Statement
SNL/NM	Sandia National Laboratories/New Mexico
SPM	System Prioritization Method
SRS	Savannah River Site
SVOC	semivolatile organic compound
SWB	standard waste box
Th	thorium
TI	Transport Index
TLV(s)	threshold limit value(s)
TRU	transuranic
TRUPACT-II	Transuranic Package Transporter-II
U	uranium

LIST OF ABBREVIATIONS/ACRONYMS *(Continued)*

VOC	volatile organic compound
WAC	Waste Acceptance Criteria
WID	Westinghouse Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WMFCITRUW	Waste Management Facility Cost Information for Transuranic Waste
WSRIC	(RFETS) Waste Stream and Residue Identification and Characterization

LIST OF APPENDICES

Appendix	Title
A	Initial Engineered Alternatives Screening Candidates
B	Engineered Alternative Pass List
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1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

An Engineered Alternative (EA) is defined as a technologically feasible process, technology, method, repository design, or waste form modification which makes a significant positive impact on the disposal system, and in general terms, as an engineered barrier or group of engineered barriers. A "Barrier" is defined in Title 40, Code of Federal Regulations (CFR) Part 191 (40 CFR 191) as,

> "...any material or structure that prevents or substantially delays movement of water or radionuclides towards the accessible environment. For example, a barrier may be a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around the waste, provided that the material or structure substantially delays movement of water or radionuclides" (EPA, 1993a).

An engineered barrier is further defined in the Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act (LWA) as,

> "...backfill, room seals, panel seals, and any other manmade barrier component of the disposal system" (U.S. Congress, 1992).

Both natural and engineered barriers are presently incorporated in the disposal system design of WIPP. EAs may be used to provide additional confidence that the WIPP disposal system will comply with the containment requirements in 40 CFR 191. This additional confidence measure defines the term assurance used throughout this report.

The Department of Energy (DOE) has initiated this EA cost benefit study (EACBS) to provide a technical basis for the selection and rejection of EAs for the WIPP should it be determined that additional barriers are needed for assurance purposes. This study includes a qualitative assessment of estimated costs, potential risks, benefits, and relative repository performance impacts resulting from the implementation of EAs. This assessment was made by first identifying candidate EAs and then screening alternatives using a defined process to determine which EAs should be retained for further detailed analysis. The detailed analyses were designed and conducted so as to determine the relative benefits and detriments on the DOE transuranic (TRU) waste management system. Performance related benefits at WIPP were considered, but were not the only impacts assessed. The results of the study will provide DOE with cost and benefit information for use in the selection of additional engineered barriers for the WIPP if it is determined to be desirable.

The selection/rejection of EAs for use at WIPP will be made using the best available information and will take into consideration the importance of many relevant factors. Examples of these factors are disposal system performance, cost, and risk to the public and workers from radiological/chemical and transportation related incidents and accidents. Since the relative benefit of an EA is dependent on those factors that carry the most importance, which are determined by the DOE decision maker, this study does not quantitatively rank nor recommend EAs for possible

use at WIPP. The EACBS provides non-weighted information and, where possible, qualitatively compares an EA's impact with respect to the existing baseline for WIPP.

1.2 BACKGROUND

1.2.1 WIPP Description and Mission Statement

The WIPP, a research and development facility of the DOE, is located in the Northern Delaware Basin in southeastern New Mexico (Figure 1-1). The WIPP is a proposed underground repository designed and constructed for the disposal of TRU radioactive wastes. TRU wastes are generated from DOE defense-related activities, including weapons production research, and development. Currently, the majority of these wastes are generated and/or stored at ten DOE sites across the country (DOE, 1994c).

The majority of TRU waste is material contaminated with alpha emitting radionuclides (e.g., plutonium-239) with half lives greater than 20 years and concentrations greater than 100 nanocuries per gram (nCi/g) of waste (DOE, 1994c). TRU wastes are classified as either contact-handled (CH) or remote-handled (RH) (DOE, 1994c), depending on the dose rate at the surface of the waste container. CH-TRU waste containers have an external dose rate less than 200 millirem per hour (mrem/hr) at the surface of the container. CH-TRU waste constitutes the vast majority (~97 volume percent) (DOE, 1995e) of the overall TRU waste inventory destined for WIPP. The WIPP repository and the waste to be stored at WIPP are described below.

1.2.1.1 The WIPP Repository

Detailed descriptions of the geology and hydrology of the WIPP site have been published in numerous documents (DOE, 1990b; Lappin, 1988; Lappin et al., 1989). The WIPP repository is located 2,150 feet below the surface in a bedded salt (halite) formation of Permian age known as the Salado Formation (Figure 1-2). The basis for the selection of the WIPP site and an analysis of its environmental impacts were presented in the WIPP Final Environmental Impact Statement (FEIS) (DOE, 1980) and supplemented with more current information in the Final Supplement Environmental Impact Statement (FSEIS) (DOE, 1990b). Figure 1-3 shows a three-dimensional layout of the repository in relation to the support facilities on the surface. The WIPP rooms and panels are excavated in the salt beds of the Salado. A panel consists of seven waste emplacement rooms and associated access drifts as shown in Figure 1-3.

After the waste is emplaced in the WIPP disposal rooms, natural closure occurs due to the creep (plastic flow) of the surrounding salt formation. This creep is in response to the pressure gradient that exists between the far-field pressure away from the repository (referred to as the lithostatic pressure or the pressure at the depth of the repository due to overlying rock) and the pressure in the repository (which, after excavation, is initially at atmospheric pressure). In a freshly excavated room under atmospheric pressure, this creep is of the order of a few inches per year. Under expected conditions, complete closure of the repository occurs, and the waste is safely and permanently isolated from the surrounding environment.

1.2.1.2 Waste Description

TRU waste to be disposed of at the WIPP consists of newly generated and/or retrievably stored waste in drums or boxes at major DOE facilities across the United States. Examples of

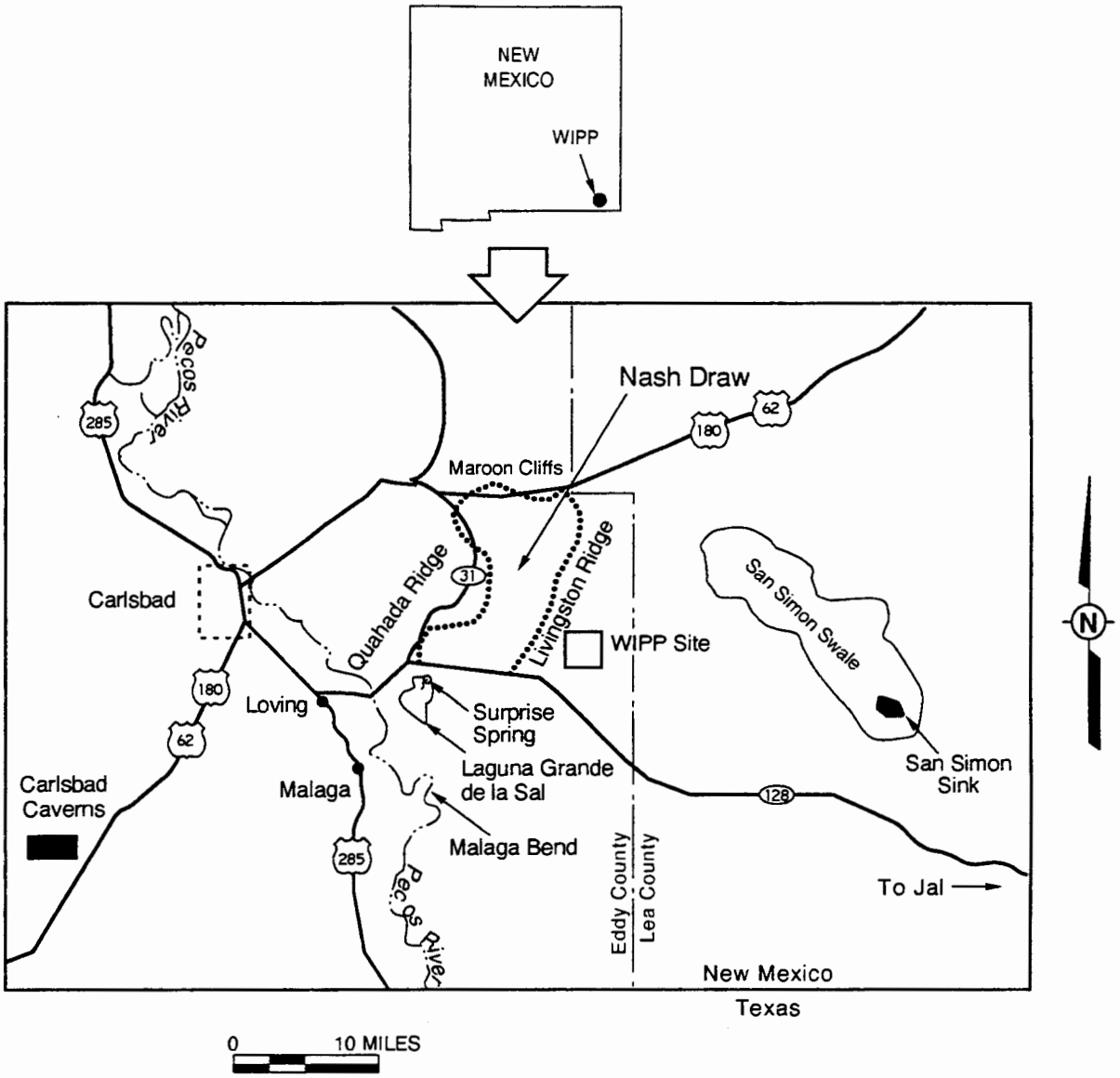

Figure 1-1

WIPP Location in Southeastern New Mexico (Rechard, 1989)

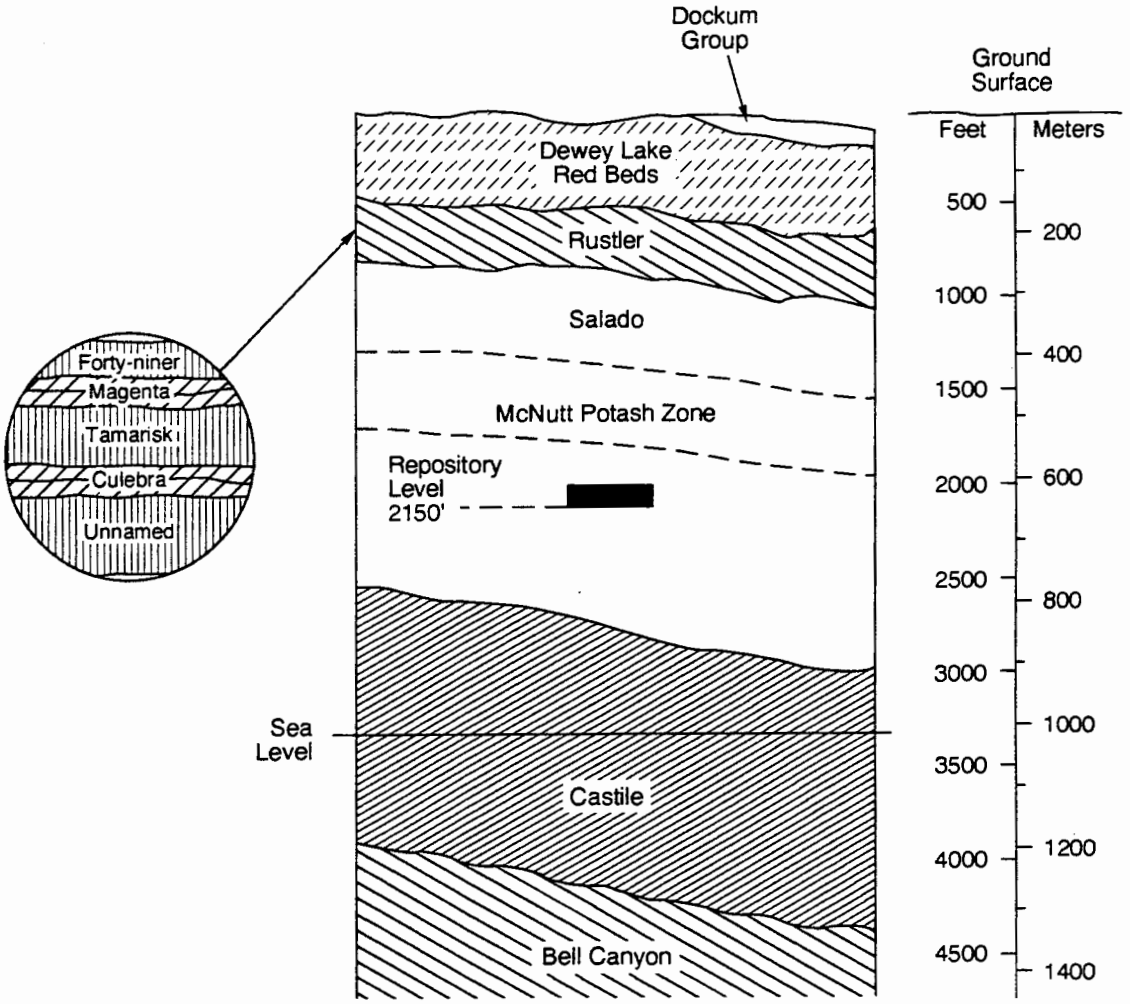

Figure 1-2

Level of WIPP Repository and Generalized Stratigraphic Column (Rechard, 1989)

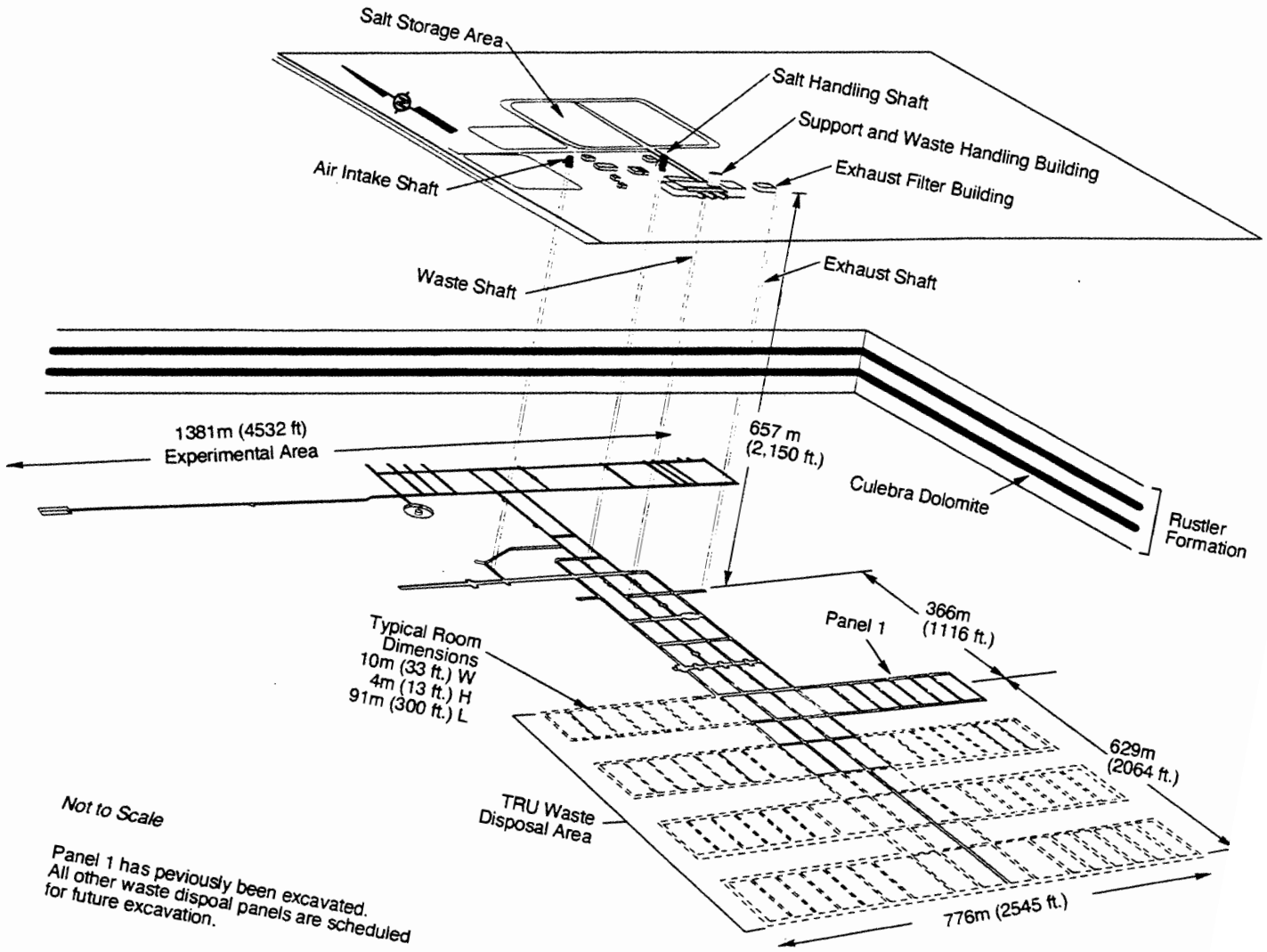

Figure 1-3
Proposed WIPP Repository Showing Both TRU Disposal Areas and Experimental Areas (Nowak et al., 1990)

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processes that generate the waste are plutonium recovery operations, glove box operations, and the operation of on-site analytical and research and development laboratories. The waste destined for the WIPP site is either solid or solidified material and can be grouped into three major waste forms:

- Sludges
- Solid organic (combustible) waste
- Solid inorganic (glass/metal, etc.) waste.

Sludges are predominantly inorganic solidified wastes with some form of solidifying or stabilizing agent, usually a cement-based material. A small percentage of sludges designated as "organic sludges" may contain organic solvents in greater than trace (>1 weight percent) quantities (DOE, 1994f). Solid organic waste consists of organic materials (sometimes referred to as "combustible" waste) such as paper, plastic, tissues, plywood, etc. Solid inorganic waste consists of metals, glass, and a small percentage of other noncombustible material. All waste types are in a chemically stable and nonreactive form (DOE, 1990c) and have been stored and handled at the waste generator and disposal sites for over four decades. The wastes generated at the different sites are generally comparable, and for the most part, can all be grouped under the three waste forms listed above (DOE, 1990c).

The waste is generally packaged in plastic bags (polyethylene and/or polyvinyl chloride) that are placed inside the waste containers (55-gallon steel drums or larger metal boxes) (DOE, 1994f). These different layers of confinement serve as barriers for radioactive materials in the waste. The waste containers are fitted with carbon composite filters to prevent the build-up of gas pressure in the containers, while retaining any particulates inside the containers (NRC, 1994).

Waste characterization (the constituents and properties) of TRU waste is based on process knowledge and records information, and information from past and current sampling programs in place at the DOE sites. The available waste characterization information has been comprehensively summarized in a number of documents (e.g., DOE, 1995e, DOE, 1994f; DOE, 1990c).

1.2.2 Past EA and Related Studies

Prior to the DOE initiating this cost benefit study, designed to provide additional information for use in selecting or rejecting EAs for the WIPP, Performance Assessment (PA) (SNL, 1993), EA effectiveness and feasibility studies (DOE, 1991a), and other repository performance studies have been conducted at WIPP.

Preliminary performance assessment analyses of the WIPP's long-term performance undertaken in the late 1980s indicated that two potential problems could lead to the inability of demonstrating compliance: (1) gas generation in the repository leading to excess pressure that could serve as a driving force for transport to the boundary, and (2) future inadvertent human intrusion events. The identification of these problems led to a list of associated performance parameters and an associated list of design enhancements including modifications to the facility, to the waste forms, and/or other design variations. These candidate design enhancements are referred to as engineered alternatives and were evaluated for their feasibility of reducing or eliminating gas generation and/or the consequences of human intrusion events. An evaluation of the risk to human health was not part of this PA assessment.

The DOE established the Engineered Alternatives Task Force (EATF) in September of 1989, and chartered it to identify and screen potential EAs with respect to both effectiveness and feasibility of implementation to address the concerns about gas generation and human intrusion. The EATF, in turn, chartered an Engineered Alternatives Multidisciplinary Panel (EAMP) which screened an initial 64 alternatives to 36. The EATF then combined these candidates into 14 logically consistent and potentially viable "engineered alternatives." These 14 candidates, plus a baseline, were evaluated with respect to relative effectiveness and feasibility in addressing gas generation and inadvertent human intrusion impacts. The EATF issued its final report in July 1991 (DOE, 1991a). In order to maximize the benefits of the EATF evaluations and to provide timely integration of EATF activities with SNL PA, these programs were conducted in parallel. The overall purpose of the alternatives evaluation by the EATF was to enhance performance of the WIPP to meet regulatory requirements for containment.

This EACBS differs from the EATF study in two fundamental ways. First, in the current study, EAs are assessed against eight specific factors (as prescribed in 40 CFR 194) that provide the data and information for use in selecting or rejecting an EA based on a set of screening criteria. Second, the 1991 EATF study was aimed at identifying alternatives which, if needed, would improve disposal system performance to the point where compliance with quantifiable standards was achieved. The current study begins with the assumption that regulatory compliance can be demonstrated with the current baseline and that these alternatives could be used to enhance the performance of the WIPP disposal system through treatment of the uncertainty about the qualitative performance predictions.

1.2.3 Regulatory Topics

The WIPP disposal system must demonstrate compliance with the requirements imposed by several regulations. The DOE must demonstrate compliance with Subparts B and C of 40 CFR 191. These regulations call for a PA to be used to predict the expected cumulative releases of radionuclides to the accessible environment over 10,000 years. The PA uses numerical modeling to predict whether the performance of the disposal system can reasonably be expected to meet the requirements of 40 CFR 191. The numerical modeling is supported by experimental programs and expert judgement as appropriate. Results of the PA are quantitative in nature and will indicate whether the WIPP design meets the numerical performance measures specified in the 40 CFR 191 standard. Therefore, the calculated results of a final PA can only be used to indicate that the disposal system does or does not comply. This point is important because the results of the EACBS are not in a form that will lend themselves to such comparative analysis using alternative PA results.

The 40 CFR 191 regulations also specify that assurance measures will be implemented at WIPP. These assurance measures provide additional confidence and thereby complement compliance with the containment requirements of 40 CFR § 191.13. Assurance measures planned for the WIPP include active institutional controls, monitoring, passive institutional controls, and both natural and engineered barriers. Natural and engineered barriers that are currently part of the baseline include the favorable geology; hydrology, and the shaft sealing system. The EACBS was designed to identify candidate EAs that could be used to address the assurance requirements by providing the information necessary to allow a decision for their use beyond that necessary to meet the regulatory containment requirements. As part of the assurance requirements, EAs may be complementary to the numerical performance predictions by adding

confidence to prediction of the disposal system performance through treatment of the uncertainty associated with the calculated performance prediction.

A distinction between compliance with the numerical requirements for containment and assurance must be maintained. Compliance relates to the regulatory performance limits applicable to the WIPP, whereas assurance relates to enhancing performance or reducing uncertainty associated with a compliance determination. This study assumes the baseline repository design is compliant with all 40 CFR 191 requirements. If an EA is selected by the DOE based on information in this report, utilization of the EA will be in addition to the engineered barriers already incorporated in the baseline.

1.3 PROGRAM DRIVERS

This study is intended to provide potential valuable measures to be used for enhancing repository performance or reducing uncertainty associated with a compliance determination should the DOE determine that such steps are justifiable. A proactive approach was used through the assessment of recent DOE, EPA, and NACEPT interactions that concluded that investigating the potential benefits and detriments of additional engineered barriers is a logical and responsible endeavor.

2.0 PROGRAM APPROACH

2.1 METHOD USED TO ANALYZE ENGINEERED ALTERNATIVES

The EACBS uses a multi-step process to assess and analyze EAs. The basic approach identifies EAs to be considered in the analysis, screens this list to determine that the EA meets specific criteria, and then analyzes each EA in a multifactor analysis producing cost, scheduling, and benefit/detriment information. This process is illustrated in Figure 2-1 and is described further in this section.

The EACBS is composed of these five basic components.

- Identify Potential Engineered Alternatives—A list of potential engineered alternatives is generated. The list is composed of potentially viable alternatives from previous studies and stakeholder input. This list is found in Appendix A.

- Screen Engineered Alternatives—EAs were screened to eliminate alternatives that did not meet a specified criterion for system benefit or detriment. A multidisciplinary working group was used to define the criteria and screen the alternatives. The result of the screening process was a list of potential EAs to include in the cost/benefit analysis and a list of EAs that were rejected from further evaluation. Those EAs that were rejected were qualified with the reason for rejection. The EAs and the reasons for rejection are found in Appendices B and C.

- Optimize Remaining Engineered Alternatives—The EAs that passed the screen were optimized based on technological feasibility and effectiveness to determine the set of EAs for use in the EACBS.

- Analyze Optimized EAs against Eight Factors—The optimized list of EAs were analyzed against the eight factors prescribed in Section 1.0. The output of the analysis was compiled and summarized. The methods, processes, and assumptions used in the analyses were documented.

- Summarize Results—A complete summary of the factor analysis output is presented. The output of the study compares the results from the EA analysis with respect to the baseline.

The EA screening and selection process was designed to allow EAs, from any source, to be considered and independently evaluated. If an EA was to be further analyzed, the EA was independently assessed and documented with respect to each of the eight factors. This approach was taken to ensure that the EACBS would not be influenced by the source of the EAs, the number of EAs analyzed, or their performance. It also ensures that the analysis would be repeatable which allows additional EAs to be analyzed in the future.

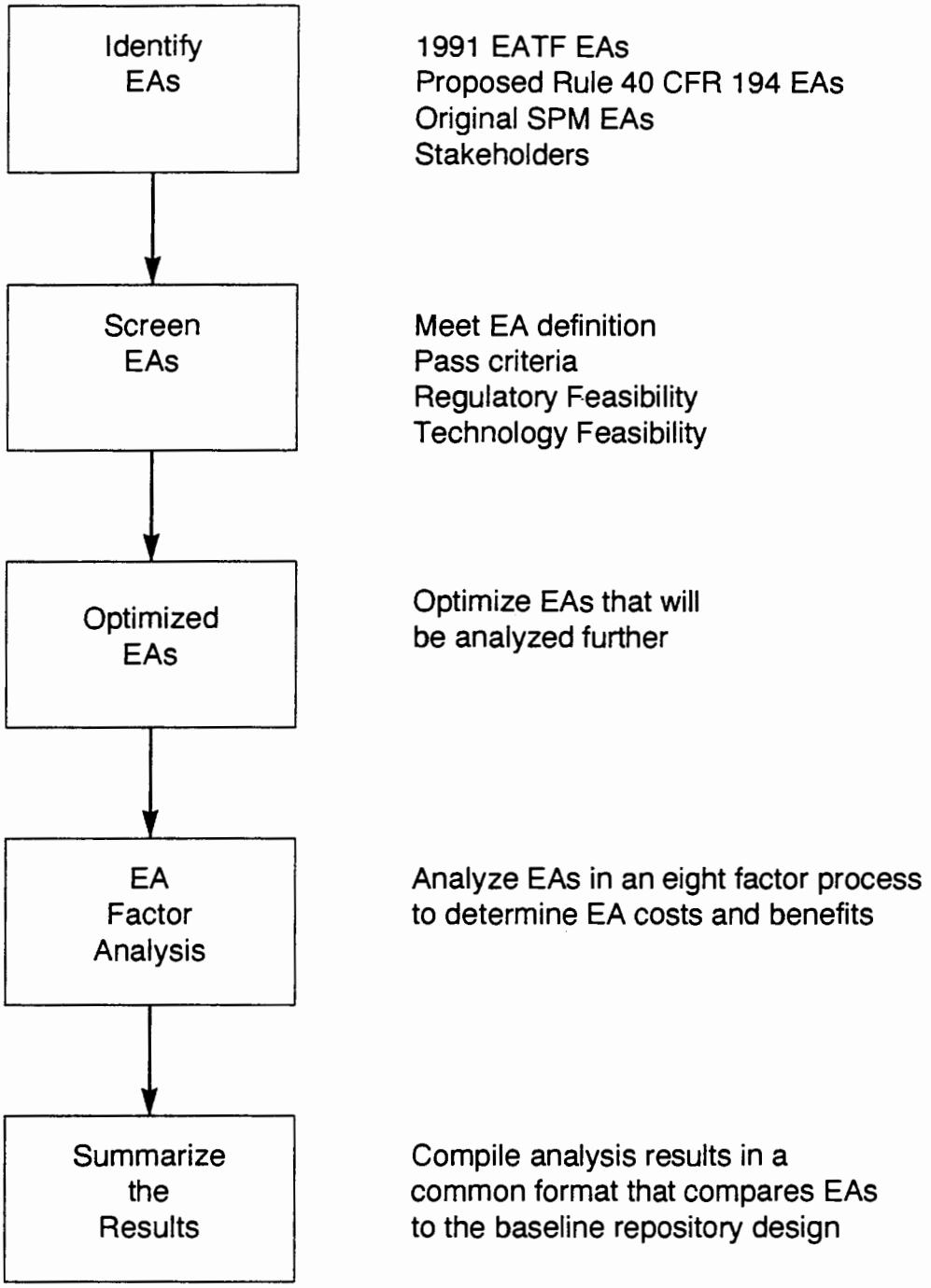

Figure 2-1
EACBS Program Flow Chart

The EACBS identifies potentially valuable measures by analyzing EAs with respect to the following factors:[1]

1. Effects of EAs on long-term performance of the disposal system—This factor analyzes the EA's ability to limit water and radionuclide movement towards the accessible environment and the consequences of human initiated processes or events (human intrusion).

2. The increased or reduced uncertainty in compliance assessment

3. Impact on public and worker exposures to radiation (at the WIPP and off site) both during and after incorporation of an EA

4. The increased ease or difficulty in future removal of the waste from the WIPP disposal system

5. The increased or reduced risk of transporting the waste to the WIPP (radiation and chemical exposures, incidental and accidental)

6. The increased or reduced public confidence in the performance of the disposal system

7. The increased or reduced total DOE waste management system cost and schedule impacts

8. The impact on other waste disposal programs from the incorporation of an EA.

In addition to the factors listed above, the EACBS includes analyses which evaluated:

- Existing waste that is already packaged
- Existing waste that is not yet packaged
- Existing waste that is in need of repackaging
- To-be-generated waste.

2.2 IDENTIFICATION AND SCREENING OF ENGINEERED ALTERNATIVES

2.2.1 Engineered Alternatives Identification

A list of candidates was compiled from the previous EA studies and the proposed rule 40 CFR 194. The list includes the following.

- Sixty-four individual EAs, 14 EA combinations and a baseline found in the Final Report of the Engineered Alternatives Task Force (DOE, 1991a). These are the individual technologies and combinations considered in the original EATF study.

[1]These evaluation factors are prescribed in the EPA proposed rule 40 CFR Part 194. However, Factors 1 and 9 as listed in 40 CFR 194 have been combined in the EACBS.

- Twenty EAs initially considered in the System Prioritization Methodology (SPM).
- Ten EAs found in the proposed rule 40 CFR §194.44.
- Stakeholder input from focus group and technical exchange meetings.

A complete list of the initial EAs can be referenced in Appendix A and was used as input for the screening process. Each EA is identified by a unique number that is used throughout the entire study. During the screening process, selected EAs were refined to allow more detailed evaluation of the results with respect to the technologies associated with the specific EA. These EAs used the same assigned number as the original but a lower case letter was added. This allowed changes to be tracked throughout the study. An example includes EA# 4—Wet Oxidation. The Engineered Alternatives Screening Working Group (EASWG) determined that wet oxidation alone was not a viable EA in and of itself because the resulting treated waste would need to be solidified to be shippable and accepted at WIPP. For this reason, EA # 4 was split into 4a—Wet Oxidation and Cement Solid Organics and 4b—Wet Oxidation and Vitrify Solid Organic Waste. In addition to those EAs passing the screening process, the EASWG added two EAs to the list.

Formal requests were made by the DOE to WIPP stakeholders to provide input into the screening process. During the development of the EACBS, stakeholders suggested EAs, such as vitrification and alternate container materials, for consideration in the EACBS. No new EAs were suggested by stakeholders that were not already being considered in the study.

2.2.2 Screening Process

A two-tiered approach was used to screen the initial list of EAs. The first tier consisted of qualitatively comparing conceptual technologies to a precise definition of an EA. The second tier consisted of qualitatively comparing those conceptual technologies that met the definition of an EA with a must satisfy criteria. One hundred and eleven EAs (109 plus 2 added by the EASWG), including combinations of EAs, were subjected to the screening process listed in Appendix A. Two lists were generated, one listing the EAs that passed, the other listing those rejected based on not meeting the definition of an EA. The screening process is illustrated in Figure 2-2.

2.2.2.1 Screening

The screening process conducted by the EASWG is described in detail in "Engineered Alternatives Cost Benefit Study Screening Report," Appendix D. The EASWG was comprised of a professional facilitator and technical professionals from the following fields:

- Waste management
- Waste processing
- Probabilistic risk assessment
- Transportation engineering
- Environmental engineering
- Mine engineering
- Radiation risk assessment
- Chemical engineering
- Cost/schedule assessment
- Public relations.

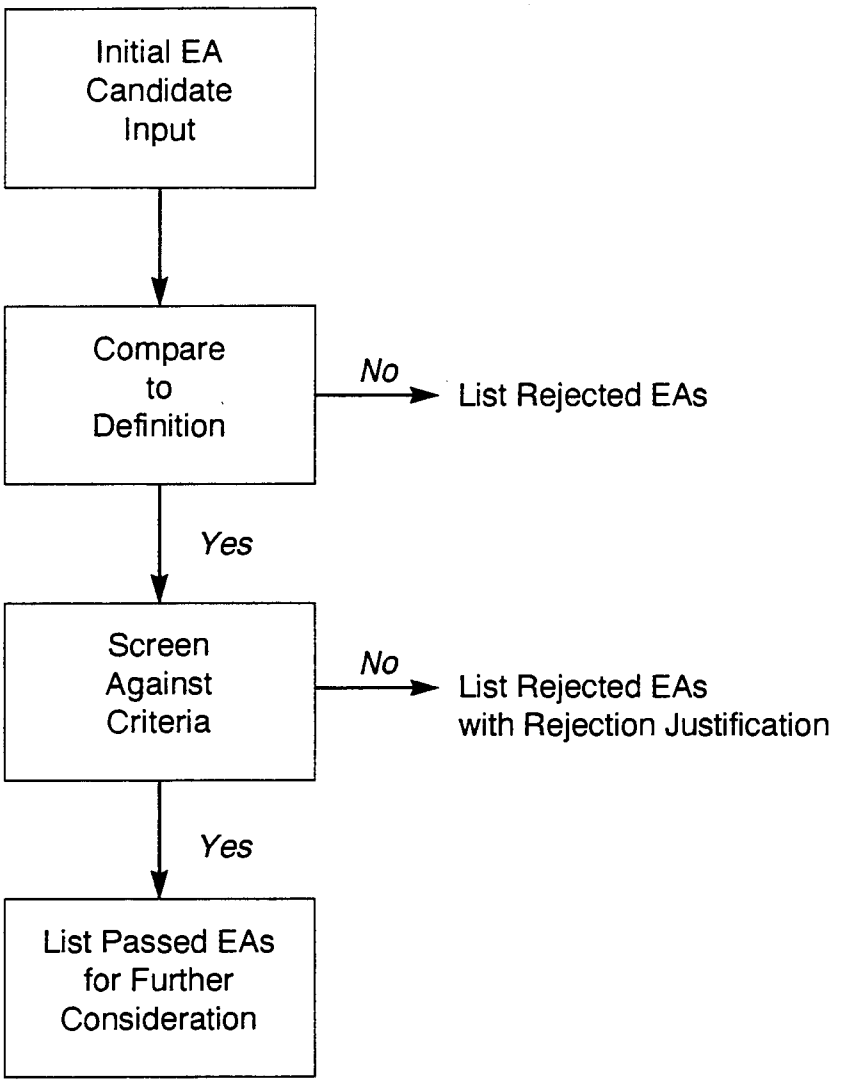

Figure 2-2
EACBS Screening Process

The individuals chosen to participate in the EASWG activities had technical experience in the fields listed and had direct knowledge of the WIPP project and/or other DOE waste management programs. Additional information regarding the details of the screening process, identification of the individuals assigned to the EASWG, and resumes of their experience can be found in Appendix D.

The EASWG met on April 24, 25, and 26, 1995 and again on May 1, 2, and 3, 1995.

From a review of the scoping report (Appendix D) the working group broke the screening process down into the following steps:

1. Review the definition of an EA.
2. Review the screening criteria.
3. Review the EA candidates and their definitions.
4. Outline the screening process.
5. Compare the EA candidates to the EA definition. Document the results.
6. Determine if the EAs that met the definition also meet the screening criteria.
7. Document the results.

The components of the EA screening process are discussed in the following sections.

2.2.2.2 Engineered Alternative General Definition

The EASWG first developed the definition of an EA for use at WIPP, this definition states:

> An EA is a technically feasible process, technology, method, repository design, or waste form modification which makes a significant positive impact on the disposal system in terms of reducing uncertainty or improving long-term performance. An EA must meet the definition of a "barrier" (engineered or man-made aspect of definition) as defined in 40 CFR 191 and the final waste form must meet the WIPP Waste Acceptance Criteria (WAC).

To meet the definition, an EA must satisfy at least one of the following conditions.

- Reduce permeability of the waste stack.
- Increase the shear strength of the waste form.
- Reduce the total gas produced from the waste form by:
  - Reducing corrosion potential or rate
  - Reducing microbial activity
  - Isolating or lowering available water/brine contact with the waste[2]
- Reduce the transport rate of radionuclides.
- Reduce the consequences of human initiated processes or events.

[2]Radiolysis gas generation is not a critical issue and is not a significant factor in gas generation (WID, 1995b).

- Reduce the solubility of the radionuclides.

2.2.2.3 Screening Criteria

The EASWG based the screening criteria on those used in the EATF. The EATF, in developing its final report (DOE, 1991a), used a process which subjected EAs to a "must satisfy" criteria consisting of three elements:

- Regulatory compliance and permitting
- Availability of technology
- Schedule of implementation.

In reviewing the criteria used previously, the EASWG concluded that the EATF criteria are based on feasibility and abbreviated two of the titles to Regulatory Feasibility and Technological Feasibility. The EASWG also noted that the scheduling criterion is inherent in each of the feasibility criteria and therefore did not consider schedule as a separate requirement.

Regulatory Feasibility requires that the technology of EAs being considered must be licensable or permittable in today's political climate. The EA or technology must have a likelihood to demonstrate regulatory compliance including local, state, or federal permits to operate. Technological Feasibility requires that the EA must have been demonstrated at a minimum of laboratory bench scale and must have the potential for full-scale implementation in the future (Appendix D). All EAs that were eventually analyzed in the EACBS contain technologies that were beyond bench scale.

2.2.2.4 Review Engineered Alternatives and their Definitions

The EASWG reviewed the EAs listed in Appendix A and made adjustments to the list, as appropriate. Some of the original titles were modified to expand on which waste types were used with the technologies. Some of the definitions were clarified or expanded to update advancements in technologies since 1991. The following summarizes these adjustments:

EA 4—Wet Oxidation

EA 4, Wet Oxidation, was divided into 4a (Wet Oxidation and Cement) and 4b (Wet Oxidation and Vitrify). Wet oxidation alone would not meet the WAC of no free liquids. Cementation and Vitrification represented two technologies for stabilizing the waste and meeting the criterion.

EA 11—Melt Metals

EA 11, Melt Metals, was divided into 11a (Melt Metals) and 11b (Melt Metals and Partition Actinides with Frit). EA 11a (Melt Metals) provides for casting the metals into ingots prior to disposal in the WIPP. EA 11b (Melt Metals and Partition Actinides with Frit) provides for adding glass frit to partition the radionuclides into slag, removing the slag for disposal at WIPP and casting the metal into ingots for disposal in an low-level waste (LLW) facility.

EA 16—Acid Digestion

EA 16, Acid Digestion, was divided into 16a (Acid Digestion and Cement) and 16b (Acid Digestion and Vitrify) for the same reasons that initiated dividing EA 4 into two separate EAs.

EA 110—Enhanced Solidification of Sludges

EA 110, Enhanced Solidification of Sludges, was developed when the EASWG recognized that cementation had been used along with other process enhancements for EAs but that no single EA employed an enhanced cementation process for sludges.

EA 111—Clay Base Backfill

EA 111, Clay Base Backfill, provides for using both swelling (i.e., bentonite) and non-swelling clays with or without other backfill additives (grout or salt).

2.2.2.5 Outline the Screening Process

The following outline was developed by the EASWG for screening EAs:

1. Compare EA to definition and determine if the EA is positive or detrimental to the disposal system.

2. Identify duplicate EAs and delete.

3. Compare remaining EAs to screening criteria
   a. Regulatory Feasibility
   b. Technological Feasibility.

This outline is illustrated in Figure 2-2.

2.2.2.6 Compare the Engineered Alternative Candidates to the EA Definition

The EASWG compared each of the EAs to the general definition of an EA. Two lists were developed based on this review. The "pass" list identified those EAs that met the definition. The "reject" list identified those EAs that did not meet the definition. The reject list documented the working group's rationale for determining why the specific EA did not met the general definition. The original reject list can be found in Appendix D. The pass list is addressed in more detail in Section 2.2.3 below.

2.2.2.7 Compare the Engineered Alternatives to the Screening Criteria

The Pass list EAs were then individually evaluated against the screening criteria defined as Regulatory Feasibility and Technological Feasibility. Some of the Pass list EAs where screened out as a result of evaluating their properties against these two criteria.

2.2.2.8 Description of Screening Output

The pass list described above is comprised of 54 total EAs. Appendix B contains a list of the EAs

which passed the EA definition and screening criteria. Included in Appendix B is a brief description of individual EAs and a justification for the EASWG's assigning each EA to the pass list.

None of the EAs identified in proposed rule 40 CFR 194 (EA 100 through EA 109) were assigned to the Pass List. The justifications for rejecting these EAs were either that the individual EAs where duplicate to EAs on the Pass List or that the EA was inherent in other EAs on the Pass List. For a detailed explanation of each EA that was rejected, see Appendix C.

2.2.3 Engineered Alternatives Optimization

The EACBS began with 111 potential EAs and used the screening process described in Section 2.2.2, Screening Methods, to screen this list down to 54. The initially screened EAs were further optimized to determine the optimal set of EAs to focus upon. The optimization of EAs was needed to determine which EAs should be included in the benefit/detriment analysis based on relative potential importance.

The optimization was done with two steps. First, an optimization method was developed and EA recommendation made. The DOE-CAO then used the optimization information to identify the final list of EAs to be considered in the EACBS analysis.

2.2.3.1 Initial Optimization

A method was developed to optimize the list of 54 screened alternatives found on the pass list. This method based EA selection on alternatives that were very feasible, very effective, or combinations of these attributes. The method selected EAs that addressed all disposal system performance parameters, both singly and in combinations. The method scored the 54 EAs in technological and regulatory feasibility categories, as well as effectiveness in the four general categories of performance; gas generation, actinide solubility, waste permeability, and waste shear strength. Once the qualitative assessments were completed by the EASWG, an objective statement was made and criteria developed. Based on the criteria and relative scores, a recommendation of EAs for further analysis was made. Appendix D describes the initial optimization process in detail and presents the qualitative assessment of EA feasibility and effectiveness along with the list of 14 optimized EAs.

2.2.3.2 Second Optimization

The list of 14 EAs was reviewed by DOE-CAO and further processed into a list of nine EAs plus nine EA variations. This process took into account recent SPM analysis results concluding that gas generation, a disposal system performance parameter, is not a critical issue for the WIPP repository. This method eliminated parameters that are primarily concerned with reduction in gas generation potential and added several alternatives that will provide benefit related to actinide solubility, waste strength, and waste permeability—issues that have been found to be critical performance parameters. The salt backfill alternative #12 was removed because salt is used in improving disposal system performance and in other selected EAs as a filler material.

During the DOE-CAO review, modifications were made to the nine selected EAs. These modifications considered other backfills in the combination EAs and modified some of the original backfills. Appendix A, Table A-3 details the changes made to the original list of 14 EAs and

briefly describes the modifications. The finalized list of 18 EAs used in the EACBS are referenced in Table 2-1. The results of the screening and optimization process are summarized in Figure 2-3. This figure illustrates the EAs that were selected for additional analysis after each round of evaluation.

2.2.3.3 Conclusion

Optimization of EAs initially assessed the technological and regulatory feasibility for the 54 EAs. A qualitative assessment was made on the effectiveness of each EA in addressing gas generation, actinide solubility, waste permeability, and waste strength. The EACBS chose not to include transportation and consequence of human intrusion in this assessment. The results of this assessment were used to recommend 14 initial EAs to the DOE-CAO. The DOE used the initial optimization information and recent information from the SPM and other related studies to further identify the EAs. This resulted in the 18 final EAs that were analyzed in the EACBS.

2.3 PROGRAM PARAMETERS AND GUIDING ASSUMPTIONS

The EACBS was performed using a well defined set of guiding assumptions, EA definitions, and parameter values. These values, assumptions, and definitions are discussed below.

2.3.1 Engineered Alternatives Definitions

The baseline and the 18 final EAs were evaluated by the EACBS and are described in detail in the following subsections. Table 2-2 summarizes and compares the characteristics of each of the EAs.

The 18 EAs are composed of nine basic EAs and nine variations of those basic EAs (see Table 2-1). Only the baseline and the nine basic EAs are described to preclude redundancy.

2.3.1.1 Baseline Treatment to the WIPP WAC

The baseline for managing TRU waste includes retrieving waste from earth-covered storage, characterizing the waste in accordance with the requirements of the Transuranic Waste Characterization Quality Assurance Program Plan (QAPP) (DOE, 1995d), treating and repackaging the waste only as necessary to meet the requirements of the WIPP WAC (DOE, 1991c), storing the waste, certifying that the waste meets WIPP WAC requirements, and shipping the waste to WIPP for disposal. Each of the DOE sites that stores and/or generates TRU waste will be responsible for developing the capabilities needed to characterize and ship its TRU waste. Smaller sites may send their waste to larger sites for treatment and interim storage pending shipment to WIPP.

Characterization of TRU waste packages includes:

- Nondestructive assay—Techniques used to identify and quantify radionuclides in TRU waste.

- Radiography—A nondestructive testing method that utilizes X-rays to inspect and determine the physical form of waste.

1

TABLE 2-1

EAS ANALYZED IN THE EACBS

ID Number	Description
#1	Supercompact Organics and Inorganics, no backfill, as received sludges.
#6	Shred and Compact Organics and Inorganics, no backfill, as received sludges.
#10	Plasma Processing of All Waste, no backfill.
#33	Sand Plus Clay Backfill, as received waste.
#35a	Salt Aggregate Grout Backfill Around Drums, as received waste.
#35b	Cementitious Grout Backfill, as received waste.
#77a	Supercompact organics and inorganics, salt aggregate/grout backfill, monolayer of 2000 drums in a 6- x 33- x 300-foot room.
#77b	Supercompact organics and inorganics, clay based backfill, monolayer of 2000 drums in a 6- x 33- x 300-foot room.
#77c	Supercompact organics and inorganics, sand/clay based backfill, monolayer of 2000 drums in a 6- x 33- x 300-foot room.
#77d	Supercompact organics and inorganics, salt/CaO backfill, monolayer of 2000 drums in a 6x33x300 foot room.
#83	Salt backfill with CaO, as received waste.
#94a	Enhanced cement sludges, shred and add clay based material to organics and inorganics, no backfill.
#94b	Enhanced cement sludges, shred and add clay based material to organics and inorganics, sand/clay grout backfill.
#94c	Enhanced cement sludges, shred and add clay based material to organics and inorganics, cementitious grout backfill.
#94d	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.
#94e	Enhanced cement sludges, shred and add clay based material to organics and inorganics, clay based backfill.
#94f	Enhanced cement sludges, shred and add clay based material to organics and inorganics, CaO/Salt backfill.
#111	Clay Based Backfill, as received waste.
Baseline	Baseline disposal system design, no backfill, treatment to WIPP WAC.

Original List of Potential Engineered Alternatives

EATF-1	EATF-29	EATF-57	SPM-E
EATF-2	EATF-30	EATF-58	SPM IT-1
EATF-3	EATF-31	EATF-59	SPM IT-2
EATF-4	EATF-32	EATF-60	SPM IT-3
EATF-5	EATF-33	EATF-61	SPM IT-4
EATF-6	EATF-34	EATF-62	SPM IT-5
EATF-7	EATF-3 5	EATF-63	SPM IT-6
EATF-8	EATF-36	EATF-64	SPM IT-7
EATF-9	EATF-37	EATF-Baseline	SPM IT-8
EATF-10	EATF-38	EATF-Alt. 1	SPM IT-9
EATF-11	EATF-39	EATF-Alt. 2	SPM IT-10
EATF-12	EATF-40	EATF-Alt. 3	SPMEATF-8
EATF-13	EATF-41	EATF-Alt. 4	SPMEATF-9
EATF-14	EATF-42	EATF-Alt. 5	SPM DOE-1
EATF-15	EATF-43	EATF-Alt. 6	SPM DOE-2
EATF-16	EATF-44	EATF-Alt. 7	CFR-100
EATF-17	EATF-45	EATF-Alt. 8	CFR-101
EATF-18	EATF-46	EATF-Alt. 9	CFR-102
EATF-19	EATF-47	EATF-Alt. 10	CFR-103
EATF-20	EATF-48	EATF-Alt. 11	CFR-104
EATF-21	EATF-49	EATF-Alt. 12	CFR-105
EATF-22	EATF-50	EATF-Alt. 13	CFR-106
EATF-23	EATF-51	EATF-Alt. 14	CFR-107
EATF-24	EATF-52	SPM-Baseline	CFR-108
EATF-25	EATF-53	SPM-A	CFR-109
EATF-26	EATF-54	SPM-B	EASWG-110*
EATF-27	EATF-55	SPM-C	EASWG-111*
EATF-28	EATF-56	SPM-D	

Potential Engineered Alternatives After First Round of Screening

EATF-1	EATF-63
EATF-2	EATF-64
EATF-3	EATF-Alt. 1
EATF-4a	EATF-Alt. 2
EATF-4b	EATF-Alt. 3
EATF-5	EATF-Alt. 4
EATF-6	EATF-Alt. 5
EATF-7	EATF-Alt. 6
EATF-8	EATF-Alt. 7
EATF-9	EATF-Alt. 8
EATF-10	EATF-Alt. 9
EATF-11a	EATF-Alt. 10
EATF-11b	EATF-Alt. 11
EATF-12	EATF-Alt. 12
EATF-15	EATF-Alt. 13
EATF-16a	EATF-Alt. 14
EATF-16b	SPM-C
EATF-19	SPM IT-2
EATF-22	SPM IT-3
EATF-29	SPM IT-4
EATF-33	SPM IT-5
EATF-35	SPM IT-7
EATF-36	SPM IT-8
EATF-38	SPM IT-9
EATF-51	SPM IT-10
EATF-53	EASWG-110
EATF-60	EASWG-111

Potential Engineered Alternatives First Optimized List

EATF-10
EATF-12
EATF-33
EATF-35
EATF-53
EATF-60
EATF-63
EATF-Alt. 9
EATF-Alt. 10
SPM-C
SPM IT-4
SPM IT-9
SPM-IT-10
EASWG-110

Final List of Engineered Alternatives for the EACBS Analysis

EATF-1
EATF-6
EATF-10
EATF-33
EATF-35a
EATF-35b
EATF-Alt. 12a
EATF-Alt. 12b
EATF-Alt. 12c
EATF-Alt. 12d
SPM-C
SPM IT-9a
SPM IT-9b
SPM IT-9c
SPM IT-9d
SPM IT-9e
SPM IT-9f
EASWG-111

EATF = Engineered Alternative Task Force
CFR = Code of Federal Regulations
SPM = System Prioritization Method
EASWG = Engineered Alternatives Study Working Group
* = Added by the EASWG

Stake holder inputs not included, however all stateholder EAs were duplicates of those listed in this table.
For additional detail see Section 2.2.1

Figure 2-3
Summary of Engineering Alternative screening Process Results

TABLE 2-2

SUMMARY OF ENGINEERED ALTERNATIVES EVALUATED BY EACBS RELATIVE TO THE BASELINE

Identifier	Alternative	Sludges	Solid Organic	Solid Inorganic	Backfill	Facility Design
0	Baseline	As received	As received	As received	None	Baseline
1	Supercompact waste	As received	Supercompacted	Supercompacted	None	Baseline
6	Shred and compact	As received	Shred and Compact	Shred and Compact	None	Baseline
10	Plasma processing of all waste	Plasma Processed	Plasma Processed	Plasma Processed	None	Baseline
33	Sand plus clay backfill	As received	As received	As received	Sand Plus Clay Backfill	Baseline
35.a	Salt aggregate grout backfill	As received	As received	As received	Salt Aggregate Grout Backfill	Baseline
35.b	Cementitious grout backfill	As received	As received	As received	Cementitious Grout Backfill	Baseline
77.a	Supercompact organics and inorganics, salt aggregate grout backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Salt Aggregate Grout Backfill	6X33X300
77.b	Supercompact organics and inorganics, clay based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Clay based backfill	6X33X300
77.c	Supercompact organics and inorganics, clay based backfill, monolayer of 2000 drums	As received	Supercompact	Supercompact	Sand/clay backfill	6X33X300
77.d	Supercompact organics and inorganics, salt plus CaO backfill monolayer of 2000 drums	As received	Supercompact	Supercompact	Salt plus CaO Backfill	6X33X300
83	Salt backfill with CaO	As received	As received	As received	Salt plus CaO Backfill	Baseline
94.a	Enhanced cement sludges, shred and cement organics and inorganics, no backfill	Enhanced Cement	Shred and add clay	Shred and add clay	No backfill	Baseline

TABLE 2-2 (Concluded)

SUMMARY OF ENGINEERED ALTERNATIVES EVALUATED BY EACBS RELATIVE TO THE BASELINE

Identifier	Alternative	Sludges	Solid Organic	Solid Inorganic	Backfill	Facility Design
94.b	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Clay/sand backfill	Baseline
94.c	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Cementitious Grout	Baseline
94.d	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Salt Aggregate Grout	Baseline
94.e	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Clay	Baseline
94.f	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill	Enhanced Cement	Shred and Add Clay	Shred and Add Clay	Salt plus CaO Backfill	Baseline
111	Clay Based Backfill	As received	As received	As received	Clay Based Backfill	Baseline

- Sampling and analysis of headspace gas—the collection and analysis of samples of headspace gas. Headspace gas will be analyzed to determine the quantities of hydrogen, methane, and listed volatile organic compounds (VOCs) in the gas.

- Sampling and analysis of homogenous solids and soil/gravel—the collection and analysis of representative samples of waste materials classified as homogenous solids and soil/gravel. The samples will be analyzed to quantify the amounts of VOCs, semi-volatile organic compounds (SVOCs) and metals in the samples.

- Visual examination—as a quality control check on radiography, a statistically selected portion of the waste containers must be opened and visually examined.

The WIPP WAC sets limits on the amounts of free liquids, particulates, and pyrophoric materials (pyrophoric radionuclides) that are acceptable in TRU waste packages, and identifies items that are prohibited from being in TRU waste packages, including explosives and compressed gasses. If waste packages contain items that do not meet the WIPP WAC, as determined by radiographic examination, then the waste packages will be opened and the nonconforming items will be removed and treated such that they will meet the WIPP WAC requirements (e.g., liquids will be solidified, particulates will be stabilized, and compressed gas containers will be punctured). Treatment and repackaging will only be done to the extent required to meet the requirements of the WIPP WAC. For this study, it was assumed that all newly generated sludges will be cemented, and that some of the stored sludges will require re-cementing to meet WIPP WAC requirements. Wastes will be stored and managed in accordance with site-specific requirements.

2.3.1.2 Alternatives #1 and #77—Supercompact Solid Organic and Solid Inorganic Wastes

For this study, the supercompaction process is modeled after the Supercompaction and Repackaging Facility (SARF) which is in operation at the Rocky Flats Environmental Technology Site (RFETS) (DOE, 1995c). The SARF is the only supercompaction facility in the United States specifically designed to treat TRU waste. Only solid organic and solid inorganic wastes are suitable for supercompaction. In this alternative, sludges will be solidified as in the baseline according to existing procedures to meet WIPP WAC requirements.

In the SARF process, waste is first emptied into a glovebox where it is sorted to remove items which cannot be supercompacted (e.g., unpunctured aerosol cans). The incompatible items will be either treated such that they can be supercompacted (e.g., puncturing the aerosol can), or packaged such that they meet WIPP WAC requirements and sent to WIPP for disposal without supercompaction. Items suitable for supercompaction are then compacted into a 35-gallon (132-liter) drum using a low-force (30 metric ton) compactor. The compacted 35-gallon (132-liter) drums are then transferred to the supercompactor. The supercompactor applies a high force (1,500 to 2,000 metric tons) to the 35-gallon (132-liter) drum to compact the waste material into a smaller volume. The compacted drum, called a "puck," is then transferred to a 55-gallon (208-liter) drum for final packaging to WIPP WAC requirements. On average, 4 pucks can be packaged into each 55-gallon (208-liter) drum. The volume reduction ratio for supercompaction is assumed to be 2.9:1. The final waste density is assumed to be 104.8 pounds (lb) (47.5 kg)/per cubic feet (ft^3), compared to an initial density of approximately 33.3 lb (15.1 kg)/ft^3. Density is increased over that resulting simply from the volume reduction ratio because of the additional metal from the compacted drums.

With the exception of adding supercompaction, all of the other elements of the baseline are part of this alternative, including waste retrieval, waste characterization, waste storage, waste certification, and transportation. The waste placed in the repository will be load managed such that the radionuclide inventory per panel will be identical to the baseline.

2.3.1.3 Alternative #6—Shred & Compact Solid Organic and Solid Inorganic Wastes

For this study, the shred & compaction process is modeled after commercially available techniques that have been successfully used for low-level waste and TRU waste (Moghissi et al., 1986; Owens, 1995). Only solid organic and solid inorganic wastes are suitable for shred and compaction. In this alternative, sludges will be solidified as in the baseline according to existing procedures to meet WIPP WAC requirements.

The initial waste processing step is size reduction, using a shredder, such that no individual waste item has a dimension greater than 4 inches. The shredded waste is then compacted into a 55-gallon (208-liter) drum using a low-force (30 metric ton) compactor. This process is repeated, adding more waste to the drum and compacting it, until the drum is full. Once the drum is full, a lid is installed and the drum is sent to storage. The volume reduction ratio for shred and compaction is assumed to be 1.3 : 1. The final waste density is assumed to be 48.3 lb (21.9 kg)/ft^3, compared to an initial density of approximately 33.3 lb (15.1 kg)/ft^3.

With the exception of shredding and compacting waste, all of the other elements of the baseline are maintained in this alternative, including waste retrieval, waste characterization, waste storage, waste certification, and transportation. The waste placed in the repository will be load managed such that the radionuclide inventory per panel will be the same as the baseline.

2.3.1.4 Alternative #10—Treat All Wastes in Plasma Melter

For this study, the plasma melting process is modeled after the Plasma Arc Centrifugal Treatment (PACT) system that has been developed by Retech, Inc., and will be used by Lockheed Martin Environmental Systems and Technologies Co. (LESAT) as part of the Pit 9 Comprehensive Demonstration (LESAT, 1995) at the Idaho National Engineering Laboratory (INEL). This treatment technology is applicable to all waste types, and to achieve optimum operations, it is desirable to process sludges, solid organic, and solid inorganic wastes simultaneously (Nielsen, 1995).

The first step in the plasma melter system is size reduction of the waste using a shredder, such that no individual waste item has a dimension greater than 4 inches. A magnetic separator then removes most of the iron and steel from the shredded waste so that the amount of iron in the final waste form can be controlled to be less than 30 weight percent. This control is important to assure a uniform final waste form. Shredded waste will then be transferred to 55-gallon (208-liter) drums and stored temporarily until it is sent to the PACT system for treatment. The iron and steel that was separated from the waste will also be packaged in 55-gallon (208-liter) drums and stored until it is sent to the PACT system for treatment.

The PACT process is a thermal process that treats waste materials using a rotating crucible into which waste material is introduced for treatment. Treatment of the material will be accomplished with the use of a transferred arc plasma torch operating in an oxygen-rich environment. The operation of the torch in this environment will bring the waste to a molten state, destroy any

organic materials, and oxidize or immobilize any heavy metals. The molten slag will then be poured into 55-gallon (208-liter) drums and allowed to cool. Upon cooling, the final molten slag becomes a non-leachable "glass". Plasma melting results in a volume reduction ratio of approximately 3 : 1 (Nielsen, 1995), and the final waste form is assumed to have a density of 100.5 lb (45.6 kg)/ft^3 compared to an initial average density of 33.1 lb (15 kg)/ft^3.

With the exception of adding the PACT system, all of the other elements of the baseline are maintained in this alternative, including waste retrieval, waste characterization, waste storage, waste certification, and transportation.

2.3.1.5 Alternative #33—Sand Plus Clay Backfill

For this alternative the waste is treated and emplaced in the same manner as for the baseline. A backfill consisting of a mixture of medium grained sand and granulated clay is placed around the waste stack and between the drums filling the void space within the rooms. The backfill is 70% sand and 30% clay by volume. The clay is commercially available granulated kaolinite or illite. The sand and clay are prepared in a hopper or drum mixer and are pneumatically placed around the waste stack after the waste is emplaced. Because of the inefficiencies associated with pneumatically placing a dry fine to medium grained material, a void space of 50% is assumed.

The clay is added to the sand to reduce the hydraulic conductivity of the backfill and impede the flow of brine and the mobility of radionuclides.

The backfill is placed to a height of about 1.96 ft (0.6 m) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 1.64 ft [0.5 m]). The total volume of backfill material for the entire underground is approximately 3.7 million ft^3 (104,000 m^3). The hydraulic conductivity of the sand plus clay backfill is expected to range from 6 x 10^{-7} meter per second (m/s) at 0 psi stress to 9 x 10^{-9} m/s at 2,200 psi stress.

2.3.1.6 Alternative #35a—Salt Aggregate Grout Backfill

For this alternative the waste is treated and emplaced in the same manner as for the baseline. A cementitious based grout backfill using crushed salt as the aggregate and simulated WIPP brine as the added water, is pumped around the waste stack and between the drums filling the void space within the rooms. Some inefficiencies will occur in placing the grout backfill so a void space of 80% is used.

Crushed salt and simulated WIPP brine are used in the grout in order to reduce chemical incompatibilities that occur between WIPP brine and normal Portland cement based grouts and concretes (Gulick and Wakeley, 1989). The grout mix will be based on the BCT-1F mixture from Gulick and Wakeley (1989).

The backfill is placed to a height of about 1.96 ft (0.6 m) above the top of the waste stack (SNL/NM 1991) and will fill the space between the waste drums and the room walls (approximately 1.64 ft [0.5 m]). The total volume of backfill for the entire underground is approximately 5.9 million ft^3 (166,000 m^3) (calculated by 0.8 x 7,346,352 ft^3 [208,000 m^3]). The

hydraulic conductivity of the salt aggregate grout backfill is assumed to be constant throughout the range of expected stresses at 1.3×10^{-12} m/s.

2.3.1.7 Alternative #35b—Cementitious Grout Backfill

For this alternative the waste is treated and emplaced in the same manner as for the baseline. A cementitious grout backfill using ordinary Portland cement, sand aggregate, and fresh water, is pumped around the waste stack and between the drums filling the void space within the rooms. Some inefficiencies will occur in placing the grout backfill so a void space of 80% is assumed.

The backfill is placed to a height of about 1.96 ft (0.6 m) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 1.64 ft [0.5 m]). The total volume of backfill for the entire underground is approximately 5.9 million ft^3 (166,000 m^3). The hydraulic conductivity of the cementitious grout backfill is assumed to be constant throughout the range of expected stresses at 1.3×10^{-12} m/s.

2.3.1.8 Alternative #83—CaO and Crushed Salt Backfill

For this alternative the waste is treated and emplaced in the same manner as for the baseline. A backfill consisting of commercially available granulated CaO (quick lime) and crushed salt aggregate is pneumatically placed around the waste stack and between the drums filling the void space within the rooms. The mixture consists of less than 10% CaO and 90% crushed salt aggregate. Because of the inefficiencies associated with pneumatically placing a dry material, a void space of 50% is assumed.

The lime is added to increase the pH of the brines in the repository environment and lower radionuclide solubility. At a pH of approximately 8.5 (30 grams CaO/liter of brine) the solubility and mobility of the radionuclides decreases significantly. Higher concentrations of CaO (higher than approximately 10%) will raise the pH of the brine above the optimum range (a pH of 10.0) at which point the solubility and mobility of the radionuclides begins to increase.

The backfill is placed to a height of about 1.96 ft (0.6 m) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 0.5 m). The total volume of backfill for the entire underground is approximately 3.7 million ft^3 (104,000 m^3). The hydraulic conductivity of the CaO and crushed salt backfill is assumed to range from 7×10^{-2} m/s at 0 pound per square inch (psi) stress to 1×10^{-11} m/s at 2,200 psi stress.

2.3.1.9 Alternative #94—Enhanced Cementation of Sludges, Shred and Add Clay to Solid Organic and Solid Inorganic Wastes

This alternative includes two treatment techniques: (1) sludges will be solidified with engineered cement to improve performance as a waste form, and (2) the solid organic and solid inorganic wastes will be shredded and clay will be added to reduce the void space in the final waste form. For the purposes of this study, the enhanced cementation process will be modeled after existing facilities that solidify radioactive sludge wastes. No facility in the United States is known to shred waste and add clay before storage and/or disposal. However, the required technologies are commonly used in industry and it is anticipated that this treatment system could be developed with little difficulty. For this study, the shred/add clay process will be modeled after facilities that

shred and add cement-based grout to waste. The required equipment should be similar to that now used by shred/add grout and shred/add clay facilities, and the operating costs will be adjusted to account for the difference in materials costs between grout and clay.

The first step in the enhanced cementation process is size reduction of sludges that were previously solidified. Size reduction will be accomplished using a standard industrial crusher/shredder. The crushed waste will then be placed into transfer containers and loaded into a feed hopper. The waste will then be fed from the hopper and mixed with enhanced cement and placed into 55-gallon (208-liter) drums. Newly generated sludges would not be processed for size reduction but would go directly to the feed hopper, similar to the method currently being use to solidify sludges. The exact formula for the enhanced cement has not been determined, but possibilities include sulphur-polymer cement, portland cement with additives, and portland cement mixed with fiberglass. This process has a volume increase ratio of 2.5:1. The density of the final waste form is assumed to be 40.8 lb (18.5 kg)/ft^3 compared to an initial density of 32.3 lb (14.6 kg)/ft^3.

The first step for the shred/add clay process, is size reduction of the incoming waste stream using a shredder, such that no individual waste item has a dimension greater than 4 inches. The shredded waste will then be placed into transfer containers and loaded into a feed hopper. The waste will then be fed from the hopper and mixed with clay (e.g., kaolin) pellets and placed into 55-gallon (208-liter) drums. It is assumed that the clay will fill 80% of the initial void volume in the waste package. The final density of the waste is assumed to be 78.5 lb (35.6 kg)/ft^3 compared to an initial average density of 33.3 lb (15.1 kg)/ft^3. There is also assumed to be no net change to the waste volume (i.e., treatment of one drum of waste results in one drum of treated waste).

With the exception of adding the enhanced cementation and shred/add clay waste processing steps, all of the other elements of the baseline are maintained in this alternative, including waste retrieval, waste characterization, waste storage, waste certification, and transportation.

2.3.1.10 Alternative #111—Clay Based Backfill

For this alternative, waste is treated and emplaced in the same manner as for the baseline. A backfill consisting of commercially available pelletized kaolinite or illite clay (DOE, 1995a) is place pneumatically around the waste stack and between the drums filling the void space within the rooms. Pelletized clay is used to reduce potential dust inhalation safety issues. Because of the inefficiencies associated with pneumatically placing a dry material, a void space of 50% is assumed.

The clay is used to reduce the hydraulic conductivity of the backfill and impede the flow of brine and the mobility of radionuclides.

The backfill is placed to a height of about 1.96 ft (0.6 m) above the top of the waste stack (SNL/NM, 1991). The total volume of backfill for the entire underground is approximately 3.7 million ft^3 (104,000 m^3). The hydraulic conductivity of the clay based backfill is assumed to range from 1 x 10^{-10} m/s at 0 psi stress to 2 x 10^{-13} m/s at 2,200 psi stress.

2.3.2 Program Assumptions

Throughout the analysis of EAs many assumptions were made relative to waste inventory, waste processing, and waste characteristics. Assumptions were used in the basic program approach, the screening process and the actual analysis within the factors. Many of these assumptions are specific to the screening process or factor and are described in the respective screening and analysis factor sections (see Chapter 3.0). The following describes the common guiding assumptions used throughout the EACBS.

- The baseline repository design is in compliance with 40 CFR 191. EAs evaluated in this study will be used to provide additional assurance for a disposal system that is compliant with the containment requirements.

- The analysis is a tool to assess cost and benefit of EAs, not to recommend or rank alternatives. Weighting of factors was not performed as part of this study.

- The output of the EACBS will provide the DOE with information that will allow for the selection or rejection of an EA if additional engineered barriers are desirable.

- For waste processing EAs that increase the actinide concentration in the waste (i.e., volume reduction EAs), rooms and panels will be load managed to maintain the baseline actinide inventories for each room and panel. The waste containers are assumed to be evenly distributed throughout the rooms and panels.

- Schedule analysis was performed to determine the outer bound impact. Emplacement of waste would start only after processing/treatment facilities were on-line. No waste was assumed to be emplaced prior to this date even if the EA did not process all of the waste (i.e., sludges could be emplaced prior to the startup of a shred and grout facility). The baseline, however, did assume waste would be emplaced prior to completion of WIPP WAC treatment facilities. The baseline analysis reports the date processing facilities are on-line, however waste would be emplaced prior to this date.

- All waste processing EAs are performed on 100% of the affected wastes. No EA is assumed to be performed on a percentage of the waste available for processing by the EA. This represents the upper end impacts with the baseline being the lower end. Any variation in the processed waste percentage would fall between these bounds.

- The operational period is assumed to be at least 35 years. The waste processing facilities are assumed to operate for 20 years. These operational periods were assumed because most processing EAs have a nine year startup cycle. This assumes a startup and 20 year processing operation followed by decommissioning could be completed within a 35 year time frame.

- For the EACBS, the waste volume is assumed to be 6.2 million (M) ft^3 (0.175 M m^3). If an EA reduces the waste volume, only 6.2 M ft^3 (0.175 M m^3) of waste will be treated, not the amount that would produce 6.2 M ft^3 (0.175 M m^3) of treated waste. For EAs that increase the waste volume after treatment, only

6.2 M ft^3 (0.175 M m^3) of treated waste will be emplaced, the amount of waste generated in excess of 6.2 M ft^3 (0.175 M m^3) would not be emplaced.

- The reduction of the probability of human intrusion is not considered in the EACBS. Only the consequences of an intrusion event were analyzed. No EA was considered that may reduce the probability of human intrusion, since that type of assurance measure is being considered in passive marker studies.

2.3.3 Alternative Waste Processing Configurations

In addition to the screened EAs, three waste processing site configurations were analyzed. These configurations, called decentralized, regionalized, and centralized, are based on the Draft Environmental Management Programmatic Environmental Impact Statement (EM-PEIS) analysis, and vary by the number of installations at which the selected waste processing facilities would be located. Generally, those installations which have the largest volumes of waste were selected as the locations for treatment of waste under the decentralized and regionalized alternatives. Table 2-3 summarizes the site waste transfers for each of these configurations. RH-TRU waste was only analyzed for the decentralized case.

As shown in Figures 2-4 and 2-5, the decentralized configuration evaluated characterizing and packaging TRU waste at all sites where TRU waste is generated, and shipping CH-TRU waste from the sites with smaller amounts to the nearest of the 10 sites with the largest amounts of TRU waste for treatment and interim storage prior to shipping to WIPP. The RH-TRU waste will be stored at six sites.

As shown in Figure 2-6, the regionalized configuration analyzes the impacts of consolidating CH-TRU waste at the five sites with the largest inventories of waste, and treating the waste in accordance with the various engineered alternatives at these five sites prior to shipping to WIPP.

In the centralized configuration, CH-TRU waste is characterized and packaged at all generating sites and shipped to WIPP for treatment and disposal, as shown in Figure 2-7.

2.3.4 Baseline Definition

The baseline condition is defined as the current design and disposal scheme for the WIPP. The baseline disposal system is described in Section 1.2.1 of this report and the current Final Safety Analysis Report for the WIPP (DOE, 1991b). The baseline includes multiple barriers, both natural and engineered, that isolate the waste from the accessible environment and provide confidence that the performance predictions associated with the containment requirements of 40 CFR 191.13 are met.

2.3.4.1 Baseline Parameters

The WIPP baseline conditions important to the EACBS are:

- The WIPP capacity is 6.2 million ft^3 by volume. The baseline volumes of sludges, organics, and inorganics are projected from current waste inventories.

- No waste processing is required beyond that to meet the WAC.

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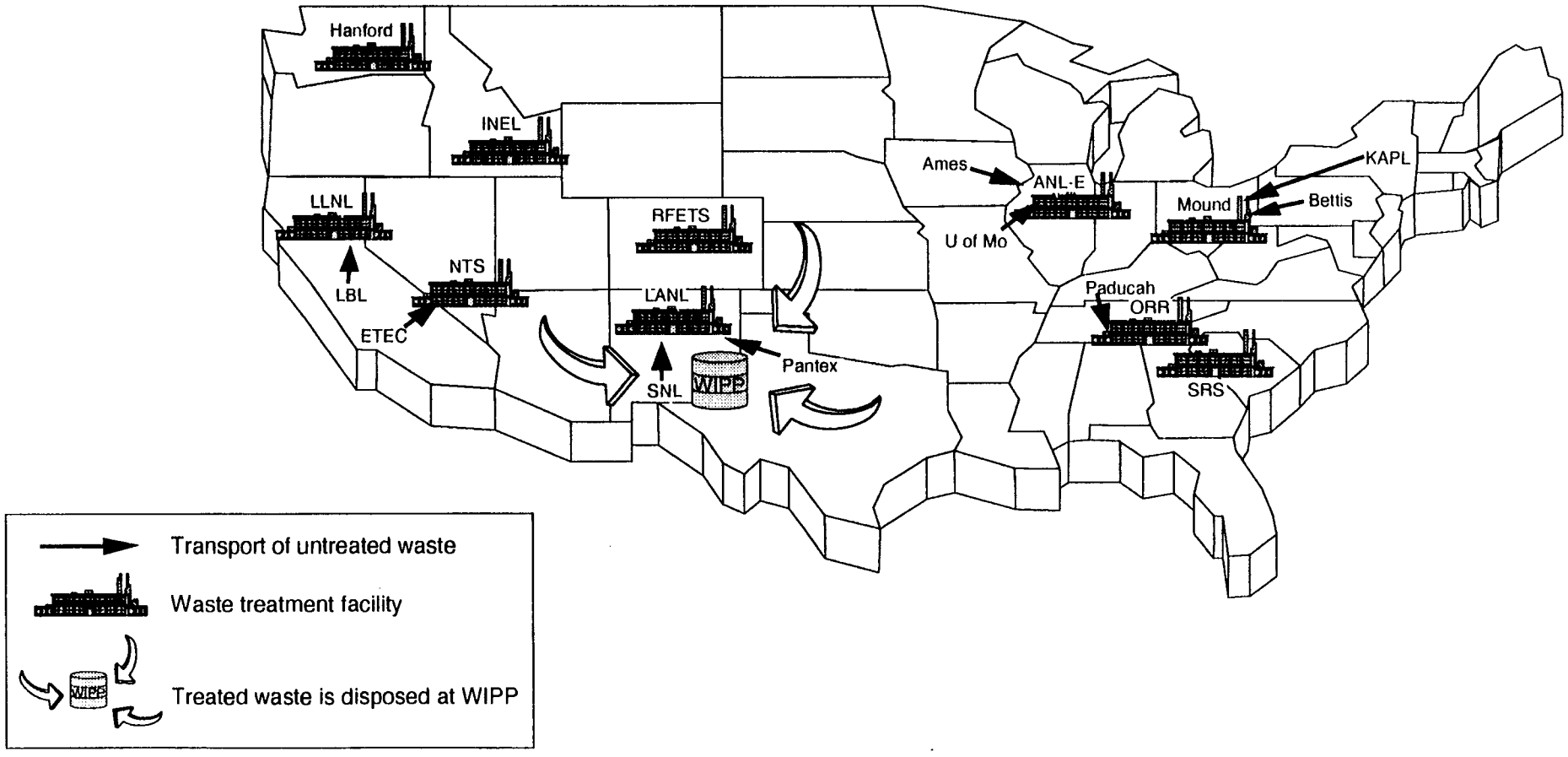
TABLE 2-3

WIPP ENGINEERED ALTERNATIVES SITE WASTE TRANSFERS

	Decentralized			
SITE	CH	RH	Regionalized	Centralized
ANL-E	WIPP		SRS	WIPP
Ames	ANL-E		SRS	WIPP
Battelle Columbus		ORR		WIPP
Bettis	Mound	ORR	SRS	WIPP
ETEC	NTS		INEL	WIPP
Hanford	WIPP	WIPP	WIPP	WIPP
INEL	WIPP	WIPP	WIPP	WIPP
KAPL	Mound	ORR	SRS	WIPP
LANL	WIPP	WIPP	WIPP	WIPP
LBL	LLNL		Hanford	WIPP
LLNL	WIPP		Hanford	WIPP
Mound	WIPP		SRS	WIPP
U. of Mo.	ANL-E		SRS	WIPP
NTS	WIPP		INEL	WIPP
ORR	WIPP	WIPP	SRS	WIPP
Paducah	ORR		SRS	WIPP
Pantex	LANL		LANL	WIPP
RFETS	WIPP		WIPP	WIPP
SNL/NM	LANL		LANL	WIPP
SRS	WIPP	WIPP	WIPP	WIPP



G95\EEC\Decent-1870.ppt

Figure 2-4

Decentralized Configuration for Contact-Handled Transuranic Waste Treatment

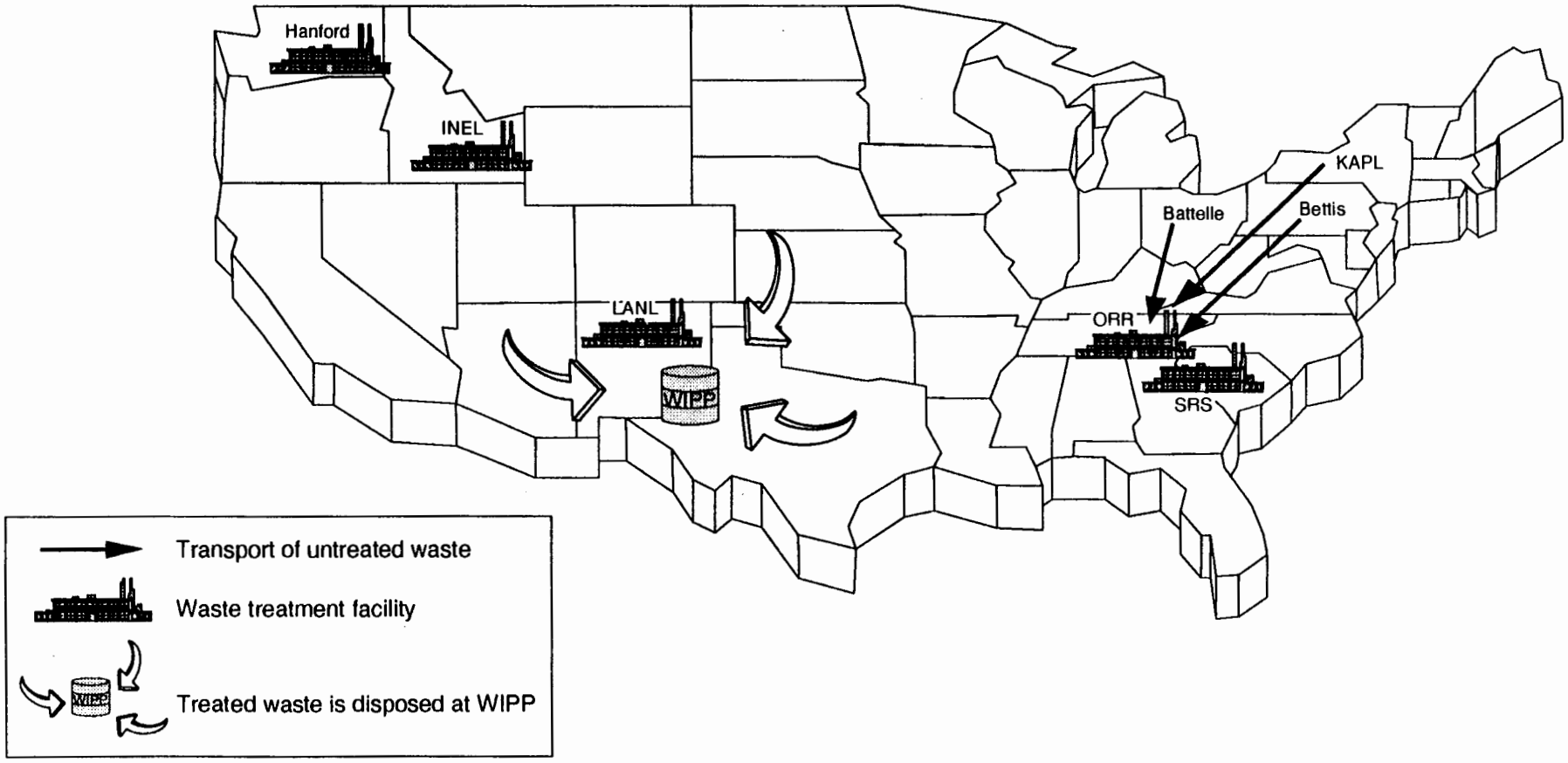


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Figure 2-5

Decentralized Configuration for Remote-Handled Transuranic Waste Treatment

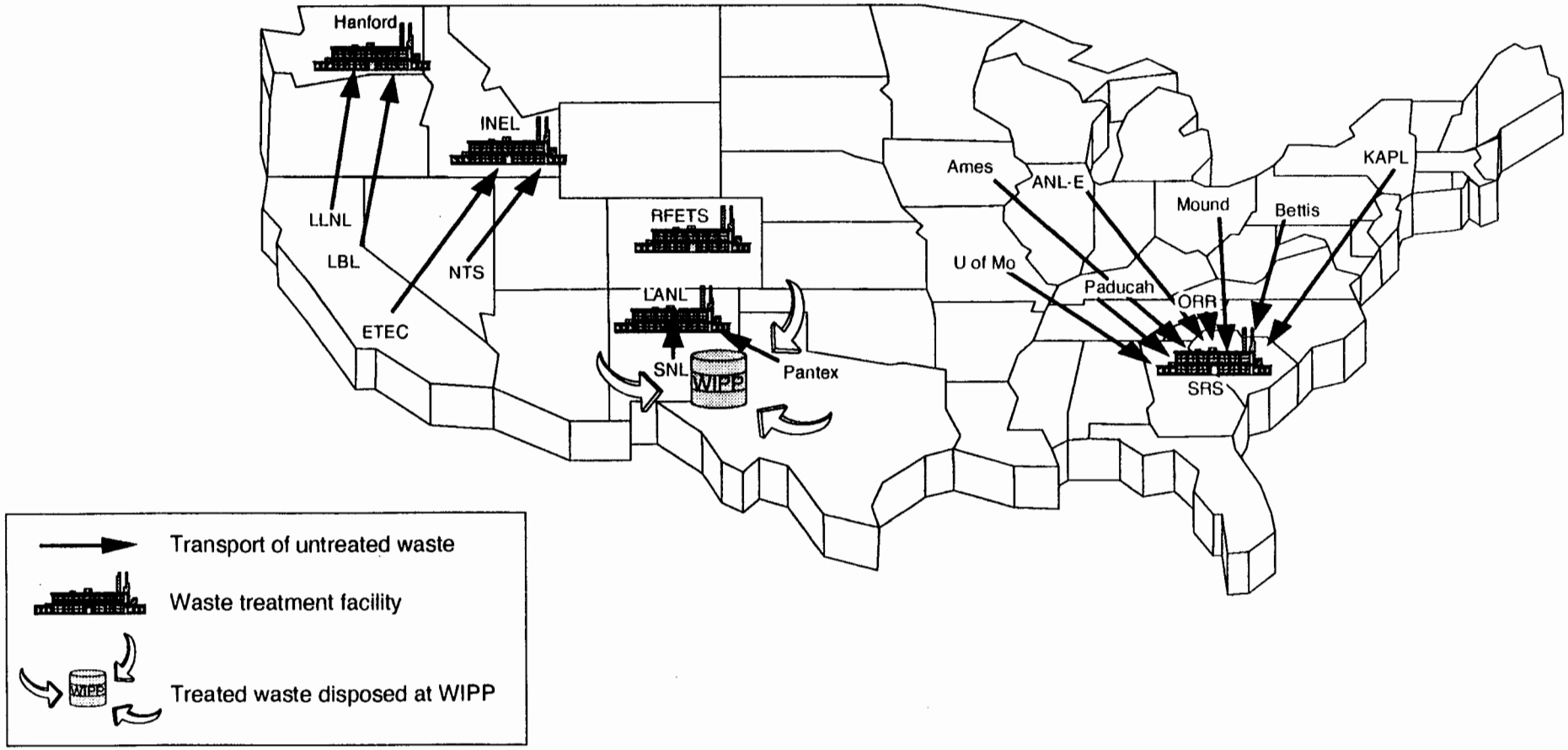

Figure 2-6

Regionalized Configuration for Contact-Handled Transuranic Waste Treatment

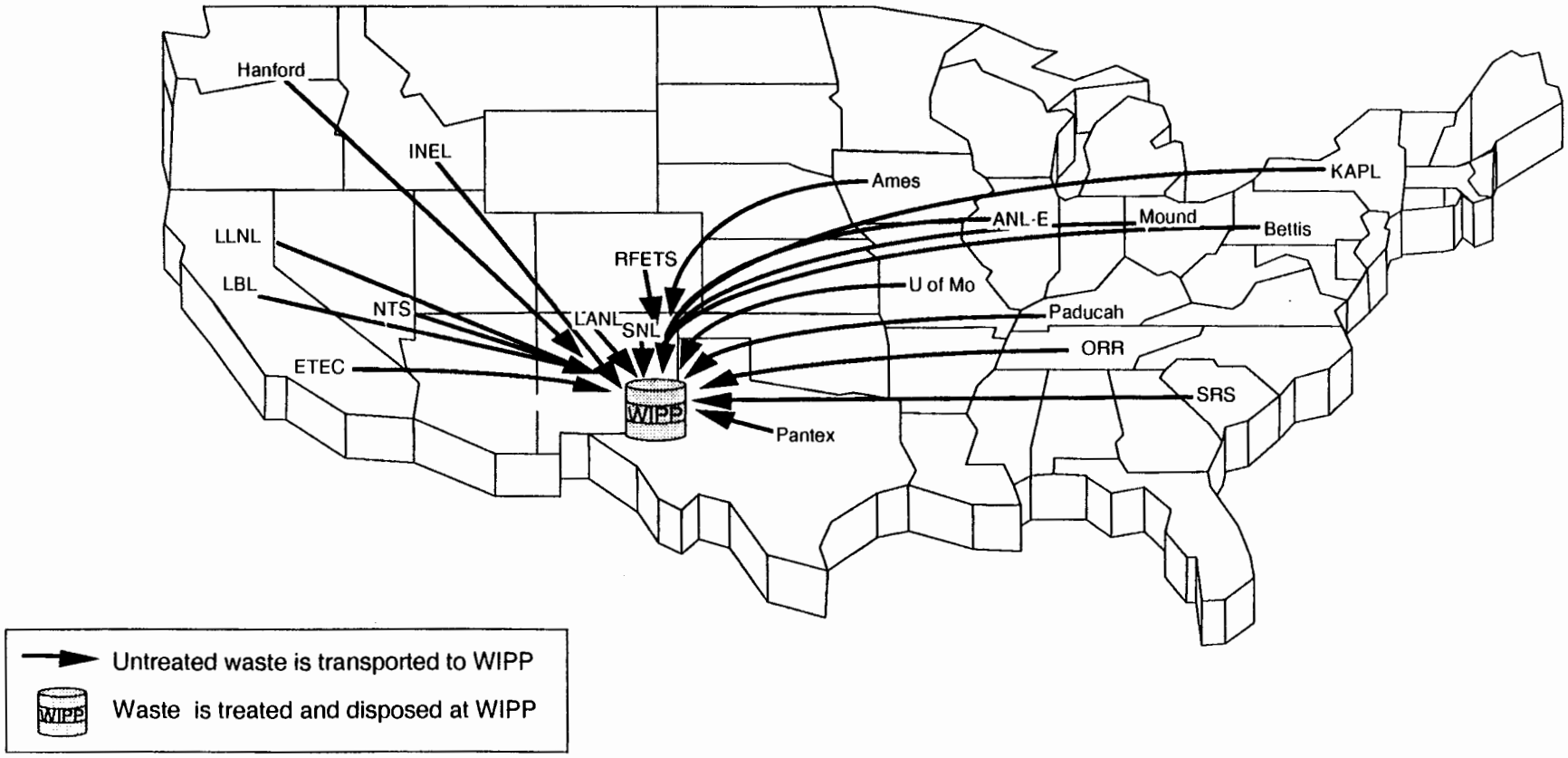

Figure 2-7
Centralized Configuration for Contact-Handled Transuranic Waste Treatment

- The WIPP will be ready to accept waste in 1998.
- No backfill is used in waste disposal areas.

The baseline for waste management is assumed to be decentralized. Processing and packaging of TRU waste to meet the WAC are performed at all 16 DOE sites where these wastes are currently stored or generated. Following processing and packaging, the waste would be shipped from sites with small amounts of waste to the 10 DOE sites with the largest amount of waste for interim storage. This strategy approximates the current DOE TRU waste management policy. The 10 major DOE waste sites are listed in Table 2-4.

TABLE 2-4

TEN MAJOR DOE WASTE GENERATOR/STORAGE SITES

1	Argonne National Laboratory-East (ANL-E)
2	Hanford Site
3	Idaho National Engineering Laboratory (INEL)
4	Lawrence Livermore National Laboratory (LLNL)
5	Los Alamos National Laboratory (LANL)
6	Mound Plant
7	Nevada Test Site (NTS)
8	Oak Ridge Reservation (ORR)
9	Rocky Flats Environmental Technology Site (RFETS)
10	Savannah River Site (SRS)

For waste to meet the WIPP WAC in the baseline, aqueous liquids must be stabilized and small particulates immobilized. Organic liquids will be stabilized by organic stabilization (use of a binding agent, such as calcium silicates, to form a solid). Solid process residue will be sorted for non-compliant items, corrosive and reactive materials will be neutralized and deactivated. Noncompliant particulates will be immobilized by solidification (i.e., cement). Sludges will be sorted and repackaged if they exceed wattage limits. Soils will be grouted if particulates exceed the WIPP WAC limits.

2.3.4.2 Common Analysis Parameters

There are many common parameters used throughout the analysis, such as waste inventories, masses, densities and forms for each EA, backfill volumes, emplacement geometries and physical properties, radionuclide inventories, waste emplacement work-off schedules, waste processing rates, and number of shipments and mileage for CH-TRU and RH-TRU waste. This information is shown in Tables 2-5 through 2-10, respectively.

TABLE 2-5

SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Total Backfill (m^3)	Excavated Area Volume (m^3)	Salt Volume (m^3)	No. of Panels
0	Baseline	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	0	207,406	289,814	10
1	Compact Waste	54,389	26,019	13,438	93,846	9,385	45,097	93,846	0	0	207,406	363,092	10
6	Shred and Compact	54,389	56,498	29,181	140,068	14,007	67,308	140,068	0	0	207,406	316,870	10
10	Plasma Processing of All Waste	10,767	24,532	12,671	47,970	4,797	23,051	47,970	0	0	207,406	408,968	10
33	Sand Plus Clay Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	103,703	207,406	82,408	10
35.a	Salt Aggregate Grout Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	165,925	207,406	82,408	10
35.b	Cementitious Grout Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	165,925	207,406	82,408	10
77.a	Supercompact organics and inorganics, salt-aggregate grout backfill, monolayer of 2,000 drums, in 6- x 33- x 300-ft rooms	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	93,604	117,006	41,697	10
77.b	Supercompact organics and inorganics, clay based backfill, monolayer of 2,000 drums, in 6- x 33- x 300-ft rooms	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	58,503	117,006	41,697	10

Refer to footnotes at end of table.

TABLE 2-5 (Continued)

SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Total Backfill (m^3)	Excavated Area Volume (m^3)	Salt Volume (m^3)	No. of Panels
77.c	Supercompact organics and inorganics, sand plus clay-based backfill, monolayer of 2,000 drums, in 6- x 33- x 300-ft rooms	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	58,503	117,006	41,697	10
77.d	Supercompact organics and inorganics, CaO based backfill, monolayer of 2,000 drums, in 6- x 33- x 300-ft rooms	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	58,503	117,006	41,697	10
83	Salt Backfill with CaO	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	103,703	207,406	82,408	10
94.a	Enhanced cement sludges, shred and add clay to organics and inorganics, no backfill	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	0	0	289,814	10
94.b	Enhanced cement sludges, shred and add clay- based material to organics and inorganics, sand plus clay backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	103,703	207,406	82,408	10

Refer to footnotes at end of table.

TABLE 2-5 (Continued)

SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Total Backfill (m^3)	Excavated Area Volume (m^3)	Salt Volume (m^3)	No. of Panels
94.c	Enhanced cement sludges, shred and add clay- based material to organics and inorganics, cementitious grout backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	165,925	207,406	82,408	10
94.d	Enhanced cement sludges, shred and add clay- based material to organics and inorganics, salt aggregate grout backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	165,925	207,406	82,408	10
94.e	Enhanced cement sludges, shred and add clay-based material to organics and inorganics, clay backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	103,703	207,406	82,408	10
94.f	Enhanced cement sludges, shred and add clay- based material to organics and inorganics, CaO backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	103,703	207,406	82,408	10
111	Clay Based Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	103,703	207,406	82,408	10

Refer to footnotes at end of table.

TABLE 2-5 (Concluded)

SUMMARY OF WASTE INVENTORIES

*Unaccepted Waste Volume is the volume of CH-TRU waste that will not fit in the WIPP underground with the present panel configuration and assumptions.

Assumptions:

- Backfill filling efficiency is assumed to be 80% for fluid backfill materials and 50% for dry backfill materials
- The allowable volume of waste per panel is 16,712 cubic meters
- There are 12.54 room equivalents per panel
- Available backfill volume per panel is 732,446 ft^3 = 20,741 m^3
- The backfill height for the 77 series alternatives is assumed to be ≈0.6 m over the top of the waste and the waste is ≈0.9 m high for a total height of 1.467 m (SNL SAND91-0893/3, page 3–13)
- The total available backfill volume per panel for 77 series alternatives is = 11,701 m^3
- The volume of a waste drum is 7.35 ft^3 = 0.21 m^3.

Source: DOE, 1995e (see Appendix O for additional details).

TABLE 2-6

WIPP ENGINEERED ALTERNATIVES MASS AND VOLUME OUTPUT

	Sludges			Solid Organics			Solid Inorganics		
Case #	Total Mass (kg)	Total Volume (m^3)	Density (kg/m^3)	Total Mass (kg)	Total Volume (m^3)	Density (kg/m^3)	Total Mass (kg)	Total Volume (cu.m)	Density (kg/cu.m)
Baseline	30,921,720	54,389	569	47,234,933	74,339	635	13,007,073	38,396	339
Alternative 1	30,921,720	54,389	569	51,958,427	26,019	1,997	14,307,781	13,438	1,065
Alternative 6	30,921,720	54,389	569	51,958,427	56,498	920	14,307.781	29,181	490
Alternative 10	16,929,945	10,767	1,572	47,234,933	24,532	1,925	13,007,073	12,671	1,027
Alternative 94	53,329,327	81,566	654	111,139,691	74,339	1,495	30,604,513	38,396	797

Source: DOE, 1995e (see Appendix O for additional details).

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TABLE 2-7

BACKFILL PROPERTIES FOR ENGINEERED ALTERNATIVES

Backfill Material (Alternatives Used)	Initial Density (kg/m^3)	Initial Porosity (%)	Solid[a] Density (kg/m^3)
70% Sand Plus 30% Clay (Alt. 33, 77c, 94b)	1,590[b]	40.0[b]	2,650[c]
Salt Aggregate Grout (Alt. 35a, 77a, 94d)	1,884[d]	31.3[d]	2,741[c]
Cementitious Grout (Alt. 35b, 94c)	1,884[d]	31.3[d]	2,741[c]
Clay Based (Alt. 111, 77b, 94e)	1,000[e]	62.5[f]	2,670[g]
Crushed Salt Plus CaO Backfill (Alt. 83, 77d, 94f)	1,193[h]	44.8[h]	2,162[h]

[a]Solid density is the density after consolidation to 0% porosity.
[b]Peck, R.B., W.E. Hanson, and T.H. Thornburn, 1974, *Foundation Engineering*, 2nd ed., John Wiley & Sons, New York, New York, 514 pp.
[c]Calculated from initial density and porosity.
[d]Coons, W., A. Bergstrom, P. Gnirk, M. Gray, B. Knecht, R. Pusch, J. Steadman, B. Stillborg, M. Tokonami, and M. Vaajasaari, 1987, "State-of-the-Art Report on Potentially Useful Materials for Sealing Nuclear Waste Repositories," *STRIPA Report 87-12*, prepared for the Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden.
[e]Nowak, E.J., Sandia National Laboratories, 1990, Personal Communication.
[f]Calculated from initial density and solid density.
[g]Morris, D.A., and A.I. Johnson, 1967, "Summary of Hydrologic and Physical Properties of Rock and Soil Materials, as Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey, 1948–60," *Geological Survey Water-Supply Paper 1839-D*, U.S. Government Printing Office, Washington, D.C.
[h]Case, J.B., P.C. Kelsall, and J.L. Withiam, 1987, "Laboratory Investigation of Crushed Salt Consolidation," *Proceedings of the 28th U.S. Symposium on Rock Mechanics*, June 1–July 1, 1987, Tucson, Arizona.

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TABLE 2-8

WIPP ACTINIDE INVENTORY (FROM DOE, 1995e)

Nuclide	CH (Curies)	RH (Curies)	Total (Curies)
Pu-238	$1.89 \times 10^{+06}$	$3.53 \times 10^{+03}$	$1.89 \times 10^{+06}$
Pu-239	$3.85 \times 10^{+05}$	$6.41 \times 10^{+03}$	$3.91 \times 10^{+05}$
Pu-240	$7.22 \times 10^{+04}$	$1.74 \times 10^{+02}$	$7.24 \times 10^{+04}$
Pu-241	$1.01 \times 10^{+06}$	$9.06 \times 10^{+02}$	$1.01 \times 10^{+06}$
Pu-242	$1.27 \times 10^{+03}$	1.48×10^{-02}	$1.27 \times 10^{+03}$
U-233	$1.38 \times 10^{+03}$	$8.57 \times 10^{+02}$	$2.24 \times 10^{+03}$
U-235	2.88	5.66	8.54
U-238	$1.88 \times 10^{+01}$	$1.31 \times 10^{+01}$	$3.19 \times 10^{+01}$
Am-241	$2.23 \times 10^{+05}$	$5.30 \times 10^{+02}$	$2.24 \times 10^{+05}$
NP-237	$8.82 \times 10^{+01}$	1.18×10^{-02}	$8.82 \times 10^{+01}$
Th-232	6.07×10^{-01}	7.09×10^{-03}	6.14×10^{-01}
Cf-252	$1.85 \times 10^{+02}$	$5.11 \times 10^{+01}$	$2.36 \times 10^{+02}$
Totals	$3.58 \times 10^{+06}$	$1.25 \times 10^{+04}$	$3.60 \times 10^{+06}$

Source: DOE, 1995e.

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TABLE 2-9

ENGINEERED ALTERNATIVES WASTE EMPLACEMENT WORK-OFF SCHEDULE FOR CH WASTE
(Only EAs with Waste Processing Shown)

EA#	Processing Scenario	Number of Shipments to WIPP[1]	Number of TRUPACTS Processed/Emplaced per Day[2]
Baseline, 33, 35 (a-b), 83, 111	Decentralized	19,944	7.12
	Regionalized	19,941	7.12
	Centralized	17,401	6.21
Alternative 1	Decentralized	19,571	6.94
(Compact)[3]	Regionalized	19,548	6.93
	Centralized	17,401	8.70
Alternative 6	Decentralized	18,794	8.52
(Shred & Compact)[3]	Regionalized	18,838	8.58
	Centralized	17,401	8.70
Alternative 10	Decentralized	17,174	5.72
(Plasma) Based on 25 yr. due to 100% waste being processed[3]	Regionalized	17,186	5.80
	Centralized	17,401	8.70
Alternative #77a	Decentralized	19,571	6.99
(Super Comp, monoL	Regionalized	19,548	6.93
6-ft rm, Salt Aggreg BF)[3]	Centralized	17,401	8.70
Alternative 77b	Decentralized	19,571	6.94
(Super Comp, monoL	Regionalized	19,548	6.93
6-ft rm, Clay BF)[3]	Centralized	17,401	8.70
Alternative 77c[3]	Decentralized	19,571	6.94
(Super Comp, monoL	Regionalized	19,548	6.93
6-ft rm, Clay BF)[3]	Centralized	17,401	8.70
Alternative 77d	Decentralized	19,571	6.94
(Super Comp, monoL	Regionalized	19,548	6.93
6-ft rm, CaO BF)[3]	Centralized	17,401	8.70

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TABLE 2-9 (Continued)

ENGINEERED ALTERNATIVES WASTE EMPLACEMENT WORK-OFF SCHEDULE (Only EAs with Waste Processing Shown)

EA #	Processing Scenario	Number of Shipments	Number of TRUPACTS Processed/Emplaced per Day
Alternative 94a	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, no BF)[3]	Centralized	17,401	8.70
Alternative 94b	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, Sand/Clay BF)[3]	Centralized	17,401	8.70
Alternative 94c	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, Sand/Clay BF)[3]	Centralized	17,401	8.70
Alternative 94d	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, Sand/Clay BF)[3]	Centralized	17,401	8.70
Alternative 94e	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, Sand/Clay BF)[3]	Centralized[4]	17,401	8.70
Alternative 94f	Decentralized[4]	33,225	9.70
(Cement Sldg, shred	Regionalized[4]	33,214	9.70
& Clay, Sand/Clay BF)[3]	Centralized	17,401	8.70

[1]The number of shipments is based on the number of shipments to the WIPP only.
[2]The number of TRUPACTS is based on a 35 year operational life for WIPP.
[3]The emplacement activity is 25 years based on a 10 year lag for waste processing activities.
[4]The waste emplacement activity exceeds the 35 year operational due to 28.6 years for TRUPACT II processing.

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TABLE 2-10

ENGINEERED ALTERNATIVES WASTE PROCESSING RATES

(Only EAs with Waste Processing Shown)

Alternatives	Sludges (m^3)	Solid Organics (m^3)	Solid Inorganics (m^3)
Baseline	2,719	3,717	1,920
Alternative 1	2,719	1,301	672
Alternative 6	2,719	2,825	1,459
Alternative 10	538	1,227	634
Alternative 94	4,078	3,717	1,920

3.0 FACTORS ANALYSES

Chapter 3.0 is organized by subsections as a function of the analysis of each of the eight factors listed below. These eight factors were summarized from the nine evaluation factors prescribed in the proposed rule 40 CFR 194. For consistency in analyses, Factors 1 and 9 have been combined for use in the EACBS.

1. Effects of engineered alternatives on long-term performance of the disposal system.

2. The increased or reduced uncertainty in compliance assessment

3. Impact on public and worker exposures to radiation (at the WIPP and off site) both during and after incorporation of an EA

4. The increased ease or difficulty in future removal of the waste from the WIPP disposal system

5. The increased or reduced risk of transporting the waste to the WIPP (radiation and chemical exposure, both incidental and accidental)

6. The increased or reduced public confidence in the performance of the disposal system

7. The increased or reduced total DOE waste management system cost and schedule impacts

8. The impact on other waste disposal programs from the incorporation of an EA.

3.1 FACTOR 1: EFFECTS OF ENGINEERED ALTERNATIVES ON LONG-TERM PERFORMANCE OF THE DISPOSAL SYSTEM

3.1.1 Definition of Factor 1

Factor 1 deals with the impacts that an EA is predicted to have on the long-term performance of the disposal system. Impacts are predicted using the Design Analysis Model (DAM), which considers the coupled processes of brine inflow, creep closure, gas generation, and radionuclide migration under undisturbed conditions, and also considers the consequences of three human intrusion scenarios. The three human intrusion scenarios considered by the simulation postulate the existence of future boreholes that inadvertently penetrate the waste horizon and affect the containment and isolation characteristics of the TRU waste disposal system. These scenarios are the same as those considered in the PA conducted by SNL/NM, and are fully described in SNL/NM (1993) and Appendix E. These three scenarios are referenced in the EACBS as E1, E2, and E1E2. Section 2.1 specifies that this factor also analyzes the movement of water. This is indirectly addressed within the radionuclide movement analysis because radionuclide movement is partially driven by water/brine movement. Factor 1 is evaluated by considering the impacts of each EA on the following:

- Relative changes in the release of radionuclides in drill cuttings from each of the three human intrusion scenarios

- Relative changes in the cumulative 10,000-year release of radionuclides into the overlying Rustler formation from each of the three human intrusion scenarios

The impacts of each EA are expressed as changes in the above parameters relative to the baseline, which is defined as untreated waste (except as required by the WIPP WAC) emplaced in disposal panels with no backfill.

Although both disturbed and undisturbed conditions are simulated, the study places emphasis on the effects of EAs on mitigating releases from human intrusion scenarios. Releases to the accessible environment are not predicted to occur during undisturbed performance.

The following parameters are considered as part of the Factor 1 analysis.

Porosity and Permeability of the Waste/Backfill Composite Material

The permeability of the waste/backfill composite material in the room is a major factor in controlling the flow of contaminated brine in a waste disposal room toward a human intrusion drill hole that penetrates the room. In addition, a reduction in the initial porosity or void volume of the room will result in a faster approach to lithostatic pressure, due to a reduction in the volume available for gas expansion and a reduction of the time period over which brine can flow along a pressure gradient towards the disposal rooms.

Most EAs provide a moderate to large reduction in porosity of the waste/backfill composite material. Reductions in porosity translate into reductions in permeability in a non-linear manner. Supercompaction provides only a slight decrease in permeability, whereas plasma processing of the waste or addition of clay to the backfill provides a larger decrease in permeability.

Brine Inflow Rates

Limited amounts of brine have been observed to flow into the underground excavations in response to the transient pressure gradient imposed by the excavations (Deal et al., 1989). The undisturbed units of the Salado Formation within the repository horizon contain 0.60 percent by weight (1.56 percent by volume) brine (Deal et al., 1989). This source of this brine is probably Permian seawater that became trapped in the evaporite sequence at the time of deposition. The majority of the brine observed to seep into the underground excavations is predominantly local brine that became redistributed within the disturbed rock zone (DRZ) that forms around the excavations.

Brine inflow is a process of concern because it provides a medium for the potential transport of radionuclides. Human intrusion events can create a potential pathway for the migration of contaminated brine towards the accessible environment. Brine contacting the waste is assumed to dissolve the five actinide elements of concern (plutonium [Pu], neptunium [Np], uranium [U], thorium [Th], and americium [Am]) at concentrations equal to their respective solubility limits (reference Appendix G).

Brine inflow is also a process of concern because the water will react with steel drums, standard waste boxes, and iron and aluminum waste materials, to form iron and aluminum oxides plus hydrogen gas. The two likely reactions involving iron are predicted to be (SNL/NM, 1993):

$$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2 \qquad 3.1$$

and

$$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2 \qquad 3.2$$

It is important to note that water (or brine) is required for this reaction to occur, and that water (or brine) is consumed by the reaction. The reaction is thus self-limiting because, as long as there is metal in the room, any brine that flows into a room will be converted into metal oxide plus hydrogen gas. Accumulation of brine in a room will only occur if the brine inflow rate is greater than the metal corrosion rate, or if all of the metals have already been completely corroded.

Shear Strength of the Waste/Backfill Composite

One significant pathway for the release of radionuclides in response to human intrusion events is the direct removal of drill cuttings to the surface. The total volume of waste (V) that is brought to the surface in response to a drilling event is calculated by:

$$V = \pi \bullet (\text{effective radius of borehole})^2 \bullet \text{height of waste} \qquad 3.3$$

The effective radius of the borehole is equal to the actual radius of the drill bit plus any waste surrounding the borehole that might spall or erode into the borehole in response to the action of the drill bit or the circulation of drilling mud. The actual radius of the drill bit is an assumed value that is based on current oil field drilling practices. The second component of the effective radius term is controlled in part by the shear strength of the waste/backfill composite. Alternatives that increase the shear strength of the waste (such as supercompaction or plasma processing) or backfill (such as grout) will result in the removal of a smaller volume of waste to the surface in response to a drilling event, reducing the radiological consequences of the intrusion event.

Radionuclide Solubility

One pathway considered for the release of radionuclides to the accessible environment is the dissolution of the radionuclides in brine that may come in contact with the waste, followed by transport of the contaminated brine to the accessible environment. Brine can be transported via fractures caused by excessive pressurization of the repository by gas generation, or by pathways created by future inadvertent human intrusions. A key factor controlling the release of radionuclides by these mechanisms is the solubility of the radionuclides in brine. For this study, solubility is defined in this case as the maximum mass of a given actinide element that can dissolve in a unit volume of brine of a specified composition. The solubilities of the relevant actinide elements are complex functions of several parameters, however, they all show similar behavior with respect to pH, showing a decrease in solubility as the pH is raised above neutrality, generally reaching a solubility minimum in the range of 8.5 to 10.

The ability of brine to transport radionuclides could be greatly reduced if the pH of any brine that accumulates in the repository is raised from the ambient value of around 6.1 to a value that is

closer to the solubility minimum range. Engineered alternatives that buffer the pH to a higher, more favorable value by the addition of lime (calcium oxide, or CaO) or portland-type cement (which contains a major percentage of hydrated lime [portlandite, or $Ca(OH)_2$]) to either the drum contents or backfill, are expected to result in improved performance because of lower actinide solubilities.

Sorption of Actinides on Backfill Material

Clay materials have a well known affinity under certain conditions to adsorb actinides. The net effect of this process is usually to either permanently immobilize the actinide, or retard the migration of the actinide relative to the average flow rate of a non-sorbing solute. In the repository, this retardation can provide additional time for radioactive decay to occur, thus reducing the total activity released.

A large amount of experimental data on sorption of radionuclides on clay minerals exists, however, most of this information is only applicable to dilute groundwater. Salado brines have extremely high concentrations of Mg^{+2}, K^+, Na^+, Cl^-, SO_4^{-2}, etc. Total dissolved solids in Salado brines are in the range of 370,000 mg/l compared to values in the range of 1,000 mg/l or less for drinking water. Sorption processes in the presence of these brines are quite different than processes occurring in dilute groundwater. No data was found to be available to simulate sorption of actinides on clay minerals in the presence of Salado brines, so this process was not considered. This approach is consistent with the SNL PA methodology which also concluded that "data to quantify actinide sorption on the various substrates under WIPP-specific physicochemical conditions are not available", and that "predicting sorption under WIPP-specific conditions is not feasible" (SNL, 1995).

The net effect of not considering this process is to minimize the predicted effectiveness of EAs that involve the addition of clay to the drums or backfill. The effects of clay on reducing initial void volume and decreasing the permeability of the waste/backfill composite are considered.

3.1.2 Methodology Used to Evaluate Factor 1

This section provides a description of the conceptual model of long-term repository performance that serves as the basis for the DAM. The numerical implementation of the conceptual model is described in Appendix E. The section concludes with a listing of the input parameter values and description of the criteria used to evaluate the effectiveness of alternatives during human intrusion events.

3.1.2.1 General Description of the Processes Simulated by the Design Analysis Model

The DAM was originally developed for the EATF (DOE, 1991a) and was subsequently updated for the EACBS. The DAM simulates processes occurring in the repository (rooms, panels, access drifts, and shaft seals) for the 10,000-year regulatory period defined in 40 CFR Part 191 (EPA, 1993) under both undisturbed and disturbed (human intrusion) conditions.

The behavior of the repository as simulated by the DAM is divided into the following time periods:

- Repository under Atmospheric Pressure—During this time atmospheric pressure is maintained within the repository.

- Repository Pressurization from Atmospheric to Peak Pressure—This phase is characterized by the processes associated with increasing gas pressure and presence of brine.

- Repository after Peak Pressure—This phase is characterized by the long-term processes that continue once peak pressures are reached in the repository, interrupted only by a human intrusion event.

The processes simulated by the DAM are discussed in detail in Appendix E.

Repository under Atmospheric Pressure

The excavation of underground openings at the WIPP horizon results in a predictable disturbance of the equilibrium state of the Salado. This deviation from equilibrium causes creep closure of the surrounding salt, resulting in the formation of a DRZ adjacent to surrounding openings. Creep closure is the viscoplastic response towards equilibrium by the rock under a deviatoric stress. Deviatoric stresses are the normal and shear stresses that remain after subtracting a hydrostatic stress, equal to the mean normal stress, from each normal stress component (Goodman, 1980).

The DRZ is defined as the zone of rock in which mechanical properties and hydrologic properties have changed in response to the excavation. The term "near-field" is used to describe the zone of rock within the DRZ, and the term "far-field" is used to describe the rock outside the DRZ in which intrinsic parameters such as porosity and permeability are undisturbed from pre-excavation values. Observations have defined a DRZ extending laterally throughout the excavation and varying in thickness from 1 to 5 meters, depending on the size and age of the opening. The "disturbed" zone exists above and below the repository (Figure 3-1), while the "intact" zone is undisturbed, and exists beyond the area affected by the excavations.

A panel, consisting of seven rooms and associated access drifts, will be filled with the waste containers (either drums or boxes). In most of the EAs that were evaluated, a backfill material (e.g., salt, clay, or grout) is used to fill the space around and between the waste containers. The waste and backfill material is referred to as "waste/backfill composite" or "composite". The purpose of adding the backfill varies depending on the alternative. Reasons for including backfill include: minimizing void volume in the room, reducing the permeability of the composite, increasing the shear strength of the composite, absorbing brine, and controlling the pH of any brine that may come in contact with the waste. Dry backfill is assumed to be emplaced at a 50 percent void space, and wet backfill (grout) is assumed to be emplaced at an 80 percent void space.

During excavations and waste emplacement, atmospheric pressure is maintained within the repository. Since the atmospheric pressure is substantially lower than the lithostatic pressure in the surrounding rocks, a depressurization of the Salado around the repository will occur. This will be manifested by a gradual decrease in pressure from the far-field pore pressure in the intact Salado to atmospheric pressure in a panel. Naturally occurring gas (nitrogen and methane) is present in brine from the Salado, and has been observed to exsolve from the brine in response to depressurization.

Underground experience at the WIPP with the presence and movement of brine within the Salado has yielded an understanding of brine movement in salt. The presence and movement of brine

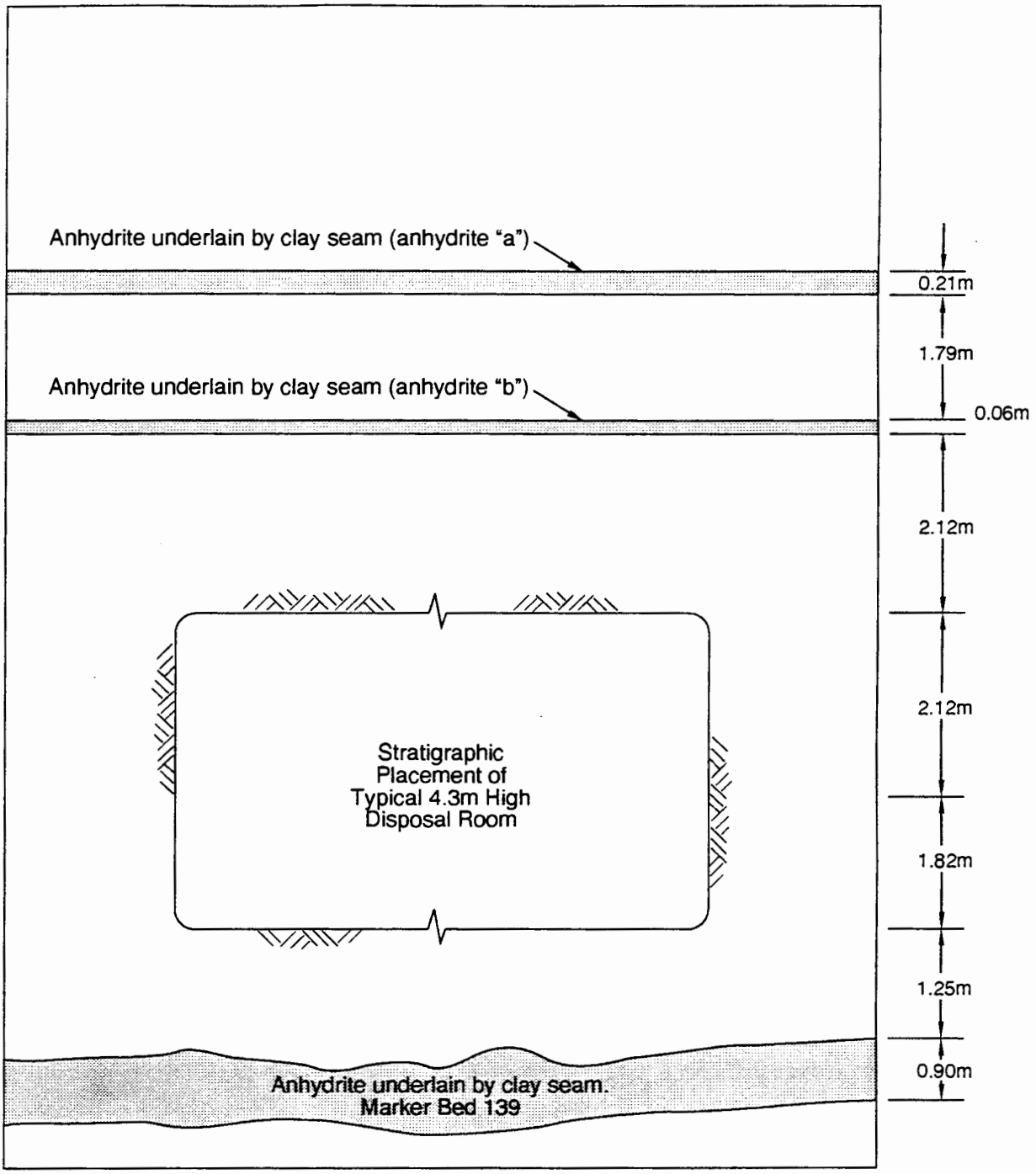

Figure 3-1

Stratigraphy at the Repository Horizon (Modified from Lappin et al. [1989])

in the Salado adjacent to the underground workings is evidenced by small "weeps" (brine encrustations) that commonly develop on the walls of an excavation shortly after it is mined. These "weeps" are a result of the difference in pressure between the surrounding halite and the atmospheric pressure within the rooms, and cease over time. In general, the brine inflow rate is less than the evaporation potential caused by mine ventilation, resulting in humid, but brine-free conditions in the repository.

In-situ brine flow experiments are used to measure the permeability of the Salado. The brine flow rates into sealed boreholes are in the range of 0.43 gallons (1.64 L)/yr to 0.792 gallons (3 L)/yr as steady states are approached. These rates have been used to calculate far-field Salado permeabilities that fall within the range of 10^{-21} to 10^{-20} m^2, using a poroelastic Darcy flow model (Lappin et al., 1989). On the basis of preliminary data, the far-field permeability of the anhydrites appears to be one to three orders of magnitude higher than that of the intact pure halite.

Emplacement of the waste within a panel is followed by closure of the access drifts and finally, sealing the shafts with a multi-component seal system. The goal of the sealing system is to limit groundwater from the overlying units from flowing down the shafts, and limit brine and/or gas from flowing up the shafts. This objective is accomplished by a combination of short-term seals in the form of concrete plugs, and long-term seals in the form of salt that has reconsolidated due to creep closure.

Repository Pressurization from Atmospheric to Peak Pressure

As long as the generated stress results in pressures below lithostatic within the repository, the Salado will continue to creep due to deviatoric stresses, thereby reducing the room dimensions.

The creep will continue and could eventually compact the waste/backfill composite. At some point the closure force will be resisted by the combination of two different mechanisms. The first of these is the ability of the particular waste/backfill composite to physically function to resist the force of compaction, manifested by its effective stress. A calculation of the effective stress and other properties is discussed in Appendix F. The effective stress is the stress that is transferred between the solid particles of the waste/backfill composite. The other mechanism is the effect of gas pressure within the void spaces. The increasing gas pressure provides a second component of internal stress resisting creep. As creep ceases, additional development of the DRZ will cease and may actually begin to reverse as fractures induced during the formation of the DRZ will begin to heal.

The small amounts of brine will continue to migrate toward the panels as long as there is an adequate pressure differential between the waste disposal panels and the undisturbed Salado. As described previously, corrosion of drums and metals in the waste under anoxic conditions will consume brine (if present), producing hydrogen gas in the process which contributes to pressurization. In addition, microbial activity is assumed to consume cellulosic materials (paper and wood), and perhaps other organic materials (plastic and rubber) in the waste as well, producing carbon dioxide and methane, and to a lesser extent nitrogen, hydrogen sulfide, hydrogen, and carbon monoxide. The hydrogen sulfide will probably be consumed by reacting with the metals or their corrosion products to form sulfide minerals. Radiolysis of brines, cellulosic materials, plastics, and rubbers will consume water and degrade the organics to produce limited amounts of hydrogen, oxygen, carbon monoxide gas, and carbon dioxide. Carbon dioxide may be removed from the gas phase by reacting with cementitious materials present as part of the

waste or backfill to form carbonate minerals (calcite, siderite, magnesite, etc.). The combination of gas generation due to the mechanisms described above, and the decrease in void volume due to creep closure, will result in pressurization of the panels.

Increased gas generation will increase the partial pressures of the gases and their solubilities in brine. This will cause additional gas to dissolve in the brine that may be present in the room. The increased concentration of gases in the brine will be the driving force for diffusion of gases into the intact Salado.

In addition to diffusion, advection into the Salado could occur as the gas pressure increases within the panel. This process involves the migration of gases under a pressure gradient from the room into the more permeable anhydrite units adjacent to the underground openings. The ability of these Salado units to advect gases will depend on: (1) the intrinsic permeability of each unit; (2) the relative brine and gas saturations of these units; (3) any capillary or threshold-pressure effects involved in gas displacement of brine already present; and (4) the amount of localized depressurization which exists due to the operational phase. Ongoing work suggests the threshold-pressure within the intact Salado halites may be as high as 8 megaPascal (MPa). Therefore, the sum total of the threshold pressure and the in-situ pore pressure will probably prevent gas advection into the halite. However, if some fractures exist within the DRZ that connect the panel to the anhydrite beds, gases will be dissipated due to the higher permeability (therefore lower threshold pressure) of the anhydrite units. Advective processes would allow some gas to escape from the panels, thus lowering the pressure in the disposal rooms.

The proposed short-term seals consisting of concrete plugs and possibly clay materials are designed to function for approximately 100 years after decommissioning. The long-term seals are made of crushed salt that is chemically and mechanically compatible with the host rock formation. Creep closure of the surrounding intact host rock consolidates and densifies the crushed salt to a condition comparable to the preexcavation intact salt.

Repository after Peak Pressure

No further brine inflow would take place once the pressures in the panel equal or exceed the far-field pressure of the Salado. Any brine accumulated in the panel would continue to be consumed at some rate by anoxic corrosion and would facilitate microbial degradation, assuming corrodible metals and organic materials are still present in the facility. These gas generation processes could, under some sets of conditions, create a peak pressure exceeding lithostatic. In addition, once the water present in the brine is consumed, reactions of carbon dioxide with cementitious materials would also cease, since these reactions require water.

The mechanical resistance to closure prevents further creep during the late phase, resulting in a cessation of waste/backfill compaction. This mechanical resistance is made up of two components: (1) the stress of compaction and (2) the interstitial fluid pressure. When the sum total of these components becomes greater than the lithostatic pressure, the deviatoric stresses are eliminated and creep ceases. At this point, the void volume becomes fixed at a constant value.

Gas advection will continue as long as the pressure within the panel is such that a driving force into the Salado is maintained. Once the pressure in the repository returns to lithostatic, the driving force is terminated and the system reaches a steady state condition.

Radionuclide Release Rate From Waste

A solubility-limited source term was assumed in the model. The assumption, which is consistent with the Sandia PA approach, presumes that any brine that contacts the waste immediately dissolves the five actinide elements at concentrations equal to their solubilities in brine, provided that sufficient actinide inventory is available. This is a reasonable assumption for untreated waste, because the actinides are mostly present as surface contamination, and are readily available for dissolution by intruding brine. The assumption may be less reasonable for plasma-processed waste because the actinide release rate from this waste form may be limited by the dissolution rate of the glass. The solubility-limited approach for the plasma processing alternative was still used because the leach rate of this waste form in WIPP brine is unknown.

Radionuclide Solubility

Solubility data on actinide-bearing solids were compiled for this study from published experimental investigations to estimate radionuclide concentrations in brine contacting TRU waste. Based on the most recent revision of the BIR for WIPP (DOE 1995e), actinides of interest that have isotopes with half-lives of 20 years or more are Th, U, Np, Pu, and Am, which occur in the waste primarily as oxides (Weiner, 1995). The remaining radionuclides summarized in the WTWBIR have very short half lives (less than 6 years) or are present in quantities insufficient to affect the release limits allowed under 40 CFR §191.13. Therefore, the radio-elements considered in the Factor 1 analysis are limited to Th, U, Np, Pu, and Am solids.

A discussion on radionuclide solubility is presented in Appendix G and Appendix H. This discussion is divided into two parts: 1) a summary of literature studies on the actinides of interest (Appendix G) and 2) a summary of the statistical approach used to select the mean solubility values and their 95 percent confidence intervals for Th, U, Np, Pu, and Am at the pH values of interest (Appendix H).

Two pH values are of interest for the EACBS solubility analysis: a pH of 6.1 (baseline), which corresponds to the average pH values observed in indigenous Salado brine, and a pH of 8.3, which is the approximate pH established in Salado brine by the brucite ($Mg(OH)_2$) buffer when a limited amount of lime is added to the backfill. Specific information on the effects of the addition of lime on the pH of Salado brine is presented in Appendix H.

3.1.2.2 Input Parameter Values Used in Factor 1 Analysis

This section provides listings of the input parameter values that were used in the DAM for the baseline case and each of the EAs. Table 3-1 is a list of input parameter values that are the same for each of the EAs. Table 3-2 is a list of parameter values that change for some or all of the EAs. The definition and unit of measure for each parameter in both tables are provided as footnotes at the end of each table.

3.1.2.3 Criteria Used to Evaluate Effectiveness of Alternatives

This section describes the criteria used to evaluate the effectiveness of alternatives in improving repository performance under human intrusion scenarios.

1

TABLE 3-1

LIST OF CONSTANT PARAMETERS USED IN THE DESIGN ANALYSIS MODEL

Parameter[a]	Value	Parameter[a]		Value
CB	0.596875		Hydrogen	0
KANH	18		Nitrogen	0.25532
PANH	10.36		Oxygen	0
TEMP	300	RATIO	Carbon Dioxide	0.42553
PF	146.10		Carbon Monoxide	0
NU	4.95		Water	0
CW	0.5523E-18		Methane	0.31915
CH	0.1464E-18	RHTORW		0.7
HHUMRATE	0.0	RBOR		0.177500
HINURATE	0.6	TIMBORHOL		4,999
BHUMRATE	0.01	PTHL		91.440002
BINURATE	0.1			
BIOSTOIC	0.835			

[a]Footnotes:

CB	=	Brine inflow rate at atmospheric pressure (in cubic meters per panel per year).
KANH	=	Negative log of the permeability of anhydrite (in square meters).
PANH	=	Pore pressure in anhydrites (in kiloPascals).
TEMP	=	Room temperature (in Kelvin).
PF	=	Lithostatic pressure plus tensile strength of intact salt (in atmospheres).
NU	=	Stress constant (unitless).
CW	=	Horizontal strain rate (unitless).
CH	=	Vertical strain rate (unitless).
HHUMRATE	=	Rate of hydrogen gas generation due to anoxic corrosion of metals under humid conditions (in moles of hydrogen per drum of waste per year).
HINURATE	=	Rate of hydrogen gas generation due to anoxic corrosion of metals under inundated conditions (in moles of hydrogen gas per drum of waste per year).
BHUMRATE	=	Rate of microbial gas generation under humid conditions (in moles of biogas per kilogram of cellulosics per year).
BINURATE	=	Rate of microbial gas generation under inundated conditions (in moles of biogas per kilogram of cellulosics per year).
BIOSTOIC	=	Stoichiometry factor for microbial gas generation process (in moles of biogas generated per mole of cellulosics consumed).
RHTORW	=	Stoichiometry factor for anoxic corrosion process (in moles of hydrogen gas generated per mole of water consumed).
RBOR	=	Radius of borehole (in meters).
RATIO	=	Mole fraction of given gas generated microbially (unitless).
TIMBORHOL	=	Time of intrusion (in years).
PTHL	=	Distance between boreholes for the E1E2 intrusion scenarios (in meters).

TABLE 3-2

LIST OF VARYING PARAMETERS USED IN THE DESIGN ANALYSIS MODEL

	Parameter[a]									
EA	Width	Height	Length	VPNL	DENSINIT	VB	MOLCAOH2	WSTPOR	E0	ADIF
Baseline	10.05840	3.96240	91.44	45,700	0.01071	0.0	7.2E+05	0.90753	4.86848	31,756
1	10.05840	3.96240	91.44	45,700	0.02035	0.0	7.2E+05	0.82625	2.12332	31,756
6	10.05840	3.96240	91.44	45,700	0.01362	0.0	7.2E+05	0.88369	3.6656	31,756
10	10.05840	3.96240	91.44	45,700	0.03155	0.0	0.00	0.78524	1.52840	31,756
33	10.05840	3.96240	91.44	45,700	0.03248	0.0	7.2E+05	0.67661	1.65587	31,756
35a	10.05840	3.96240	91.44	45,700	0.04265	186.2	2.0E+08	0.58205	1.25758	31,756
35b	10.05840	3.96240	91.44	45,700	0.04265	186.2	2.0E+08	0.58205	1.25758	31,756
77a	10.05840	1.82880	91.44	21,093	0.05552	109.2	1.2E+08	0.45717	0.75743	27,077
77b	10.05840	1.82880	91.44	21,093	0.03237	0.0	402,053	0.68561	1.81487	27,077
77c	10.05840	1.82880	91.44	21,093	0.04465	0.0	402,053	0.55545	0.99069	27,077
77d	10.05840	1.82880	91.44	21,093	0.03640	0.0	2.2E+07	0.58309	1.12269	27,077
83	10.05840	3.96240	91.44	45,700	0.02658	0.0	3.4E+07	0.69637	1.82875	31,756
94a	10.05840	3.96240	91.44	45,700	0.01461	0.0	1.4E+07	0.87625	3.38930	31,756
94b	10.05840	3.96240	91.44	45,700	0.03567	0.0	1.4E+07	0.65108	1.46194	31,756
94c	10.05840	3.96240	91.44	45,700	0.04584	186.2	2.2E+08	0.55661	1.12818	31,756
94d	10.05840	3.96240	91.44	45,700	0.04584	186.2	2.2E+08	0.55661	1.12818	31,756
94e	10.05840	3.96240	91.44	45,700	0.02690	0.0	1.4E+07	0.74404	2.35614	31,756
94f	10.05840	3.96240	91.44	45,700	0.02978	0.0	4.7E+07	0.67082	1.60961	31,756
111	10.05840	3.96240	91.44	45,700	0.02370	0.0	7.2E+05	0.76966	2.72883	31,756

TABLE 3-2 (Continued)

LIST OF VARYING PARAMETERS USED IN THE DESIGN ANALYSIS MODEL

	Parameter[a]									
EA	Plutonium	Uranium	RADSOL Americium	Neptunium	Thorium	CLRNC	NDE	H2MAX	BIOMAX	RADFRAC
Baseline	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	1.29	80,519	7.0E+07	3.0E+06	3.00
1	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	2.46	45,194	8.2E+07	3.0E+06	1.50
6	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	1.72	67,478	8.2E+07	3.0E+06	2.60
10	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	3.08	26,585	3.7E+07	303.3	1.00
33	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	7.0E+07	3.0E+06	3.00
35a	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	7.0E+07	3.0E+06	2.00
35b	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	7.0E+07	3.0E+06	2.00
77a	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.36	25,080	4.6E+07	1.7E+06	1.50
77b	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.36	25,080	4.6E+07	1.7E+06	1.50
77c	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.36	25,080	4.6E+07	1.7E+06	1.50
77d	1.0E-07	3.98E-03	3.16E-04	1.99E-04	5.0E-08	0.36	25,080	4.6E+07	1.7E+06	1.50
83	1.0E-07	3.98E-03	3.16E-04	1.99E-04	5.0E-08	0.71	80,519	7.0E+07	3.0E+06	3.00
94a	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	1.29	80,519	9.5E+07	3.0E+06	2.30
94b	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	9.5E+07	3.0E+06	2.30
94c	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	9.5E+07	3.0E+06	1.75
94d	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	9.5E+07	3.0E+06	1.75
94e	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	80,519	9.5E+07	3.0E+06	2.30
94f	1.0E-07	3.98E-03	3.16E-04	1.99E-04	5.0E-08	0.71	80,519	9.5E+07	3.0E+06	2.30
111	5.0E-04	3.2E-02	4.0E-02	2.5E-02	7.9E-08	0.71	85,019	7.0E+07	3.0E+06	3.00

TABLE 3-2 (Continued)

LIST OF VARYING PARAMETERS USED IN THE DESIGN ANALYSIS MODEL

[a]Footnotes:

Width	=	Room width (in meters).
Height	=	Room height (in meters).
Length	=	Room length (in meters).
VPNL	=	Volume of panel (in cubic meters).
DENSINIT	=	Initial waste density (in pounds per cubic inch).
VB	=	Initial brine volume (in cubic meters).
MOLCAOH2	=	Moles of calcium hydroxide present in a panel (in moles of calcium hydroxide per panel).
WSTPOR	=	Porosity of the waste and backfill at zero stress (unitless).
E0	=	Initial void ratio (unitless).
ADIF	=	Total surface area for diffusion (in square meters).
RADSOL	=	Radionuclide solubility (in moles per liter).
CLRNC	=	Initial clearance between waste stack and roof of room (in meters of air gap).
NDE	=	Number of drum-equivalents per panel (unitless).
H2MAX	=	Maximum moles of hydrogen generated from anoxic corrosion (in moles of hydrogen).
BIOMAX	=	Maximum biogas potential based on amount of cellulosics present (in kilograms of cellulosics per panel).
RADFRAC	=	Erosion factor used to calculate the effective radius of a borehole as a means for determining quantity of waste in cuttings (unitless). RADFAC x RBOR = effective radius.

Describing the release of radionuclides from the disposal system can be complex because the five actinides of concern have different solubilities, and the specific isotopes of concern have different inventories and half-lives. A convenient method of describing release is through the use of an equation termed the "EPA sum rule". This equation can be expressed as:

$$Q = \Sigma \left[\frac{Q_i}{RL_i} \right], \qquad 3.5$$

where:

Q = Total normalized release
Q_i = Predicted release of isotope i
RL_i = Release limit for isotope i.

This equation expresses the combined normalized release of each isotope of concern as a single value, which is convenient for comparison of the various alternatives with the baseline. The release limit term RL_i is based on the individual isotope release limits provided in 40 CFR 191, which allows a certain number of "units" of release of each isotope normalized to the total inventory of alpha-emitting transuranic isotopes with half-lives greater than 20 years (EPA, 1985).

For each EA, separate Q values are calculated for the cuttings release and the groundwater pathway for each of the three scenarios, providing four Q values for each EA. The Q values for cuttings release are based on the volume of cuttings brought to the surface, and the activity of each radionuclide contained in that volume. The model considers the density of the exhumed waste, compaction of the waste from creep closure, radionuclide decay, and contributions from erosion of the waste surrounding the borehole by circulating drilling fluid.

Cuttings releases from each of the three scenarios are based on the assumption that each scenario occurs one time at 5,000 years after facility closure. These predicted releases cannot be directly compared to the EPA Standard because the results are not weighted by the probabilities of scenario occurrence as the Standard requires.

The Q values for the groundwater pathway are also based on a cumulative 5,000 year release, assuming that each scenario occurs one time at 5,000 years after facility closure. Releases are calculated from the cumulative flux of each radionuclide into the Culebra at the point of borehole intersection. These predicted releases to groundwater cannot be compared with the EPA Standard for two reasons. As is the case with the cuttings release, the results are not weighted by the probabilities of scenario occurrence. In addition, results are based on cumulative radionuclide flux into the Culebra, whereas the Standard considers cumulative radionuclide flux across the 16 square mile (41.42 square kilometer) land withdrawal boundary. Thus, any attenuation of radionuclides within the Culebra along a flow path from the point of borehole intersection to the land withdrawal boundary from processes including advection, dispersion, retardation, matrix diffusion, and decay, are not considered in the model.

A parameter called the "Measure of Relative Effectiveness" (MRE) was then defined using the DAM for each alternative, scenario, and mode of release (cuttings and groundwater pathway) in order to quantitatively compare the relative merits of each alternative with respect to human intrusion events. This factor is a measure of the relative improvement in the performance of the

alternative design, compared to the baseline design. The ratio of the cumulative release of radionuclides for an engineered alternative to the release under baseline conditions is the MRE for that particular alternative. In other words:

$$\text{Measure of Relative Effectiveness} = \frac{\text{Normalized Cumulative Release of Radionuclides Using the Alternative Design}}{\text{Normalized Cumulative Release of Radionuclides Using the Baseline Design}} \qquad 3.6$$

or

$$MRE = \frac{Q_{Alternative}}{Q_{Baseline}} \qquad 3.7$$

Six MREs are calculated for each scenario, consisting of cuttings and groundwater pathway releases for each of three scenarios (E1, E2, and E1E2). For the baseline, the MRE is equal to 1. The lower the value of this factor, less than 1, the more effective the alternative is in improving repository performance relative to the baseline. Values greater than 1 indicate that the alternative yields higher radionuclide releases than the baseline design.

The MREs provide an accurate measure of the relative changes in long-term performance, even though they are calculated from Q values that do not address EPA requirements for the consideration of the probability of release scenarios. The absolute Q values do not consider the probability of scenario occurrence, but none of the alternatives affect those probabilities. Since the MRE is calculated as a ratio of Q values, the effects of scenario probabilities cancel, yielding an accurate relative index. Likewise, the absolute Q values for the groundwater pathway do not consider the effects of radionuclide transport processes in the Culebra, but none of the EAs affect those processes. Since the MRE is calculated as a ratio of Q values, the effects of those Culebra transport processes cancel, yielding an accurate relative index.

3.1.2.4 Comparison between the SNL Performance Assessment Model and the Engineered Alternatives Design Analysis Model

Most of the conceptual models and input parameter values used in the EA study were based on the SNL performance assessment (PA) approach as documented in the SNL 1992 PA Update (SNL, 1992) and the SNL System Prioritization Method Position Papers. The majority of the differences between the EA and PA approaches are required by the relative nature of the EA approach compared to the absolute nature of the SNL PA model. The goal of the EA study is to quantify the relative differences in performance between the baseline case and the various alternatives. This is achieved by calculating a measure of relative effectiveness (MRE) for each alternative which is a measure of the extent to which the EA increases or decreases the cumulative 10,000-year radionuclide release relative to the baseline case.

The goal of the PA methodology is to quantify the predicted performance of the baseline case for comparison against the requirements of 40 CFR 191. This is achieved by calculating the cumulative 10,000 year radionuclide release.

Several processes simulated in the PA model have significant effects on absolute results but little to no effects on relative results. These processes have not been included in the DAM. Specific differences between the PA and EA models are discussed below.

Human intrusion probabilities—The PA model randomly selects intrusion times based on a general failure rate function that is described using a Poison distribution. This is required to quantify the absolute cumulative 10,000-year release. The DAM assumes that each of the three intrusion scenarios occur once at 5000 years after facility closure. None of the alternatives evaluated by the EA study affect the rate or frequency of intrusions, so the probability and rate of intrusion are considerations that can be neglected by the EA study (see Section 3.1.3.1). Doubling the rate of intrusion will roughly double the absolute predicted releases, but will not change the relative benefits offered by an EA.

Spatial domain—The PA model predicts the cumulative 10,000-year radionuclide release across the 16 square mile (41.42 square kilometer) land withdrawal boundary. This requires simulating groundwater flow and radionuclide transport process that will occur along potential flow paths through the Culebra Dolomite from the point of borehole intersection to the unit boundary. The DAM predicts the cumulative 10,000-year radionuclide release into the Culebra at the point of borehole intersection and does not consider processes in the Culebra. None of the alternatives evaluated by the EA study affect flow or transport in the Culebra so the attenuation of radionuclide within the Culebra does not change the relative benefits offered by an EA.

Gas generation rates—For gas generation rates, the "expected" values for humid and inundated conditions cited in the Gas Generation Position Paper (November 15, 1994 Draft) was used as the median values in the DAM but the ranges from the position paper were not. The range of values in the SNL Position Paper for microbial gas generation in an inundated environment is 0 to 5 moles/drum/yr (m/d/y). This range represent the possible range of values for an individual randomly selected drum. It is inappropriate to sample on this range if there are 85,000 drums in a panel that are in communication with each other. The probability of all 85,000 drums generating gas at a rate of 5 m/d/y is insignificant. In addition, the high generators will tend to cancel the low generators. Under these conditions, the appropriate range to sample on is a measure of the error of the mean rather than the full range of possible values for individual drums.

Radionuclide solubilities—For radionuclide solubilities, the Actinide Source Term Position Paper (March 31, 1995 draft) discusses several different conceptual models but recommends the Inventory Limits with Realistically Conservative Maximum Concentrations Model. This model assumes large arbitrary values and does not consider the effects of changing pH. Some of the alternatives utilize pH buffers (CaO or portland grout) to raise the pH of brine that may come in contact with the waste and thereby reduce actinide solubilities. The EA study requires a source term approach that can assess the effects of pH shifts on actinide solubilities. The selected approach was to base solubilities on published experimental values in brine or saline systems as a function of pH. A summary of the published experimental values is provided in Appendix G, and the statistical analysis and results of the experimental data evaluation is provided in Appendix H.

Release of drill cuttings during human intrusion events—One component of release during human intrusion events is the direct transport of waste to the surface by the action of an exploratory drill bit. The SNL PA methodology considers three separate physical processes that can influence the quantity of waste brought to the surface by drilling events. These processes are:

- Cuttings—waste contained in the cylindrical volume created by the cutting action of the drill bit passing through the waste
- Cavings—waste that erodes from the borehole wall in response to the upward-flowing drilling fluid within the annulus
- Spallings—waste introduced into the drilling fluid caused by the release of waste-generated gas escaping to the lower-pressure borehole.

The SNL PA model plans to considers all three of the above processes but currently only the first two are implemented (Butcher et al., 1995). The DAM also only considers the first two of the above processes.

3.1.3 Results of Analysis of Factor 1

Results of long-term performance are provided in Table 3-3.

Discussion and interpretation of the human intrusion results and their uncertainties is provided in detail in Section 3.2.

3.1.3.1 Effects of Intrusions at Times Other Than 5000 Years

The absolute quantitative releases from human intrusion events are dependent on the timing, probability, and frequency of the events. However, the relative benefits of the EAs (as calculated by the MREs) are not very sensitive to the timing of the EAs and are totally independent of the probabilities and frequencies of the events.

Comparisons of the alternatives are based on the assumption that each of the three human intrusion events occur once at 5000 years. The effects of this simplifying assumption was evaluated by performing additional simulations for the baseline and nine selected alternatives at 200, 2000, and 7000 years. The results of this limited sensitivity analysis on the effects of intrusion time are discussed below for each scenario.

Cuttings release—The calculated MREs from cuttings release is the same at 2000, 5000, and 7000 years. The MREs at 200 years differ by several percent from the MREs at later years because the composite material in the rooms at 200 years is still in the process of consolidating from creep closure, and this consolidation occurs at differing rates for each alternative. Consolidation of the composite material is complete by 2000 years, so the MREs remain constant thereafter.

E1 groundwater pathway scenario—The E1 (Castile brine) scenario MRE results are also sensitive to time in the early years because of on-going compaction and the effects of compaction on permeability. Once the composite material fully compacts, the permeability reaches a constant value and results are insensitive to time.

1

TABLE 3-3

MEASURE OF RELATIVE EFFECTIVENESS FOR RELEASES TO THE CULEBRA DOLOMITE AND TO THE SURFACE UNDER THE THREE INTRUSION SCENARIOS

			Normalized Quantity Transported to Culebra Dolomite (by Intrusion Scenario)			Normalized Quantity of Radionuclides Released to Surface Through Cuttings for Each Intrusion Scenario
Waste Processing	Backfill	Engineered Alternative Number	E1	E2	E1E2	E1, E2, or E1E2
None	None	Baseline	1.0	1.0	1.0	1.0
	Sand & Clay	33	0.74	2.0	0.99	0.92
	SAG	35a	0.40	1.1	0.040	0.40
	CG	35b	0.40	1.1	0.040	0.40
	Clay	111	0.54	2.1	0.56	0.94
	CaO & Salt	83	0.83	0.30	0.05	0.94
Super C	None	1	0.93	1.4	1.00	0.26
	SAG	77a	0.44	0.56	0.083	0.21
	Clay	77b	0.56	2.3	0.93	0.22
	Sand & Clay	77c	0.73	2.1	0.98	0.21
	CaO & Salt	77d	0.79	0.30	0.032	0.22
S & C	None	6	0.95	1.1	1.0	0.79
EC/SC	None	94a	0.69	1.1	1.0	0.57
	Sand & Clay	94b	0.66	0.86	0.99	0.52
	CG	94c	0.45	0.46	0.089	0.30
	SAG	94d	0.45	0.46	0.089	0.30
	Clay	94e	0.53	0.88	0.49	0.53
	CaO & Salt	94f	0.67	0.30	0.012	0.54
Plasma	None	10	0.00078	0.0093	0.00076	0.12

LEGEND:

Super C:	Supercompaction of all waste, except sludges
S&C:	Shredding and compaction of all waste, except sludges
EC/SC:	Enhanced cementation of sludges. Shred and add clay based materials to organics and inorganics
SAG:	Salt aggregate grout
CG:	Cementitious grout

Consolidation of the composite material is complete by 2000 years, so the MREs remain constant thereafter.

E2 groundwater pathway scenario—No releases are predicted for the E2 scenario until the fluid pressure in the room is sufficient to transport brine to the level of the Culebra. At 200 years, the pressure is too low to drive releases, but by 2000 years, pressure is high enough to yield releases. MREs remain constant after that point.

E1E2 groundwater pathway scenario—All three of the scenarios evaluate flow releases over the time frame of intrusion until the 10,000-year regulatory limit. An intrusion at 5000 years allows 5000 years of flow to occur, but an intrusion at 7000 years allows only 3000 years of flow to occur. In the case of the E1E2 scenario, the flow occurs between two boreholes within a panel.

Depending on the cumulative volume of brine flow that occurs, the radionuclide releases from each alternative fall into two categories: inventory-limited releases and solubility-limited releases. Inventory-limited releases occur when a large enough cumulative volume of brine flows through the affected portion of waste to cause the release of the entire actinide inventory in the affected volume of waste over the regulatory period of performance. Solubility-limited releases occur when brine flow rates or radionuclide solubilities do not allow the entire inventory within the affected volume to be released over the regulatory period of performance.

Results for the baseline case at all times evaluated (200, 2000, 5000 and 7000 years) show inventory-limited releases. Results for some of the alternatives (33, 1, 6, and 94a) also show inventory-limited releases for the E1E2 scenario at all times evaluated. The MREs for these alternatives do not show a dependence on time of intrusion because an inventory-limited release for the alternative is divided by the inventory-limited release for the baseline, yielding a constant ratio that is independent of time.

Other alternatives (83 and 10) have MREs that show a sensitivity to time of intrusion because the releases for these alternatives are solubility-limited. When a release that is a function of brine flow or radionuclide solubility is compared to a release that is a function of inventory, the time over which the release takes place becomes a sensitive variable. Under these conditions, the MRE decreases (improved performance) at later years because the window of time over which cumulative releases are integrated is shorter.

The results of this sensitivity analysis show that in general, the MREs are insensitive to the time of intrusion once the physical properties (density and permeability) of the composite material in the room reaches a steady-state condition. This occurs sometime between 200 and 2000 years. One exception is the results of the E1E2 scenario for some alternatives. For these cases, the improvement offered by those alternatives relative to the baseline case increases when the intrusion event occurs at later years. Even for these alternatives, performing the comparisons at times other than 5000 years would not change the relative ranking of the MRE results.

3.2 FACTOR 2: UNCERTAINTY IN COMPLIANCE ASSESSMENT

3.2.1 Definition of Factor 2

Factor 2 estimates the EA's ability to treat uncertainty relative to the quantity of radioactive materials that will be transported to the accessible environment as a result of scenarios that intrude into the disposal system. The results of Factor 2 may then be used in conjunction with those of Factor 1 to characterize capability of an EA to provide additional assurance that the disposal system complies with the requirements of 40 CFR 191.13(a).

Treatment of uncertainty in compliance assessment can be realized by reducing both the quantity of radioactive materials released to the accessible environment and the statistical variability about that quantity. As described in Section 3.1, Factor 1 addresses the magnitude of reduction through the analysis of the MRE for cuttings removal to the surface and groundwater transport to the Culebra via the borehole, given scenarios E1, E2, or E1E2 occur. Factor 2 addresses the ability of the EAs to treat the uncertainty regarding these processes. By lowering the uncertainty of predictions of quantities of radioactive material that might be released as a result of an intrusion scenario, one can provide additional assurance in the prediction that the disposal system will perform as expected.

The EPA requires that the results of the formal performance assessment be incorporated, to the extent practicable, into a single complementary cumulative distribution function (CCDF) that indicates the probability of exceeding various levels of summed normalized releases (EPA, 1985). Several such CCDFs are provided in SNL, 1992. The mean MREs calculated by Factor 1 can be interpreted as the factor by which the entire group of CCDFs may shift to the left. The uncertainties calculated in Factor 2 relate to 1) the uncertainty in the mean MREs and 2) the degree to which the set of CCDFs may become less spread out. Because the largest improvement in assurance that adequate containment will be achieved derives from reducing the spread of large releases (which are closest to the EPA limit), the second measure calculates an MRE based on the factor by which the 95th percentiles of value of radionuclide transport are reduced by each EA.

3.2.2 Methodology Used to Evaluate Factor 2

A given EA might have an impact on one or more parameters that are important to repository performance. Because the physical processes expected to operate in the repository are nonlinear and interrelated, the impacts on uncertainty in the overall estimate of performance cannot be determined analytically by examining changes in the uncertainty assigned to any one input parameter. Therefore, the EACBS evaluation of uncertainty generates a series of input parameter sets using Monte Carlo techniques that randomly sample the parameters' probability distributions. The DAM then uses each set of input parameters to estimate the quantity of radioactive materials that will be transported across the immediate boundary of the WIPP repository, given each of the intrusion scenarios occur. The uncertainty results are then correlated to those for the baseline design so that comparisons can be made of the proposed EAs.

3.2.2.1 Uncertainty of Key Repository Performance Parameters

The analysis proceeds by first characterizing the uncertainty of important parameters of the waste and the disposal system that influence the long term performance of the repository. It then

estimates how each EA's estimated physical characteristics treat uncertainty through impacting these parameters.

The quantity and rate of radionuclide movement will depend on the conditions produced by the intrusion event, the driving forces available at or near the repository, and the mobility of the waste in response to the driving forces. Input parameter uncertainty that impacts these processes includes the natural variability of materials used in the disposal system and uncertainty produced by the lack of sufficient data used to determine parameter ranges. Uncertainty is expressed by establishing distributions of the possible values for each of the parameters. Once a value is randomly selected from the distribution for a given sample calculation, it is assumed to remain at that value for the 10,000-year period of repository performance as calculated by the DAM.

First, the uncertainty in the state-of-knowledge regarding these parameters is assessed and represented by probability distributions in the STADIC Code, which is described in Appendix J. The definition of the probability distributions is done within a FORTRAN subroutine of STADIC. By further programming the subroutine, the analyst can explicitly account for physical correlations between the parameters by establishing dependencies in the sampling of their associated uncertainty distributions. STADIC generates random numbers using Monte Carlo subroutines and samples each of the probability distributions in accordance with the dependency rules established by the user-defined subroutine to produce a set of input values to the DAM code.

Given a set of input parameter values, the DAM calculates the evolution of conditions within the repository and the resultant transport of radioactive materials outside the immediate boundary of the repository for each of the three intrusion scenarios. The output of the DAM calculation is then stored with its associated input set as one trial of the Monte Carlo simulation. When a reasonable number of trials are accomplished (1,000 for this analysis), uncertainties in repository performance resulting from the uncertainties in the input parameters can be observed and analyzed. For this evaluation, 1,000 trials was judged to be reasonable. This produced a spectrum of results that clearly indicated trends and produced no discontinuous gaps in output.

3.2.2.2 Changes in Uncertainties Produced by an Engineered Alternative

Distribution of Overall MRE

As discussed in Section 3.1.2.2, the increased confidence in compliance assessment that would be achieved through implementing an EA is estimated by calculating two MREs for each intrusion scenario. These ratios are calculated individually for the two major mechanisms of radionuclide transport:

- MRE_{cut} Measure of Relative Effectiveness for cuttings releases on the surface
- MRE_{wat} Measure of Relative Effectiveness for reducing waterborne transport to the Culebra at the point of borehole intrusion.

An MRE is obtained by calculating the ratio of the cumulative release of radionuclides using the EA divided by the cumulative release of radionuclides with the baseline design. Values of an MRE that are less than one indicate that an EA will improve the long term performance of the disposal system. The net impact on a graph of the CCDF of the PA will be to move the

consequences associated with intrusion scenarios to the left, thus reducing the impact of uncertainties in the assessment.

Using the Monte Carlo process, the physical parameters describing the baseline design and each of the EA's are each subjected to 1,000 performance calculations using the DAM computer code. To ensure that the comparisons will be based on the uncertainties in the anticipated changes in performance parameters and not differences in the random samples, the same random number seed is used to initialize the sampling of the input parameters of the baseline design and each of the EAs. The order in which random samples are taken remains constant across the baseline design and all EAs. The two MREs previously described are then calculated based on samples that used the same random numbers set in both the baseline and the EA. These calculations produce 1,000 values for each MRE. The distribution of these MRE values represents the uncertainties regarding the potential for performance improvement produced by each EA.

MRE for Reducing Larger Releases of Radioactive Materials

An MRE that relates an EA's effectiveness in addressing conditions that could produce larger releases from the repository is determined by comparing the 95th percentiles of the cumulative distributions results of the 1,000 random sample calculations for quantities of radioactive materials transported in reference to the EA and the baseline. In this case, the individual sample calculations are not directly correlated. The objective is to gain confidence that an EA may reduce the quantities of radioactive materials that could potentially be released under combinations of physical conditions particularly favorable for transport.

3.2.3 Assumptions and Input for Factor 2

3.2.3.1 Assumptions

The calculations conducted for evaluation of an EA assume that an intrusion event corresponding to the E1, E2, or E1E2 scenarios has occurred. The calculations do not address the frequency at which these intrusion events occur. They calculate only the consequences of a breach of repository containment as produced by the intrusion event.

Numerical model uncertainty is related to the inability to incorporate the actual physical complexity of the process into the model analysis. Factor 2 analysis assumes that no uncertainty is attributable to the computer models used. This assures that any uncertainty in modeling would impact both the performance of the baseline design and the EA in a similar manner, and thus not have a significant impact on the calculation of MREs.

3.2.3.2 Input Parameter Distributions

The distributions used for the uncertainty analysis were derived by interpretation of the evidence used to establish the point estimates for Factor 1. Only a limited amount of information was available regarding the uncertainty, mostly in the form of upper and lower bounds. Consequently, the uncertainty distributions were formulated using the combined judgement of both the Factor 1 and Factor 2 teams to best reflect the available evidence. Table 3-4 identifies the baseline physical parameters whose uncertainty has been judged to have a potential significant influence

TABLE 3-4

DEFINITION OF UNCERTAIN PARAMETERS IN THE DESIGN ANALYSIS MODEL

Parameters Having Uncertainty	Variable Description (units)	Is this Variable Changed by an Engineered Alternative?															
		1	6	10	33	35a,b	77a	77b	77c	77d	83	94a	94b	94c,d	94e	94f	111
BHUMRATE	Microbial gas generation rate under humid facility conditions (moles/kg cellulosics-yr)	No Change From Baseline															
BINURATE	Microbial gas generation rate from anoxic corrosion under inundated facility conditions (moles/kg cellulosics-yr)	No Change From Baseline															
BIOSTOIC	Ratio of moles of biogas generated to moles of cellulosics consumed (dimensionless)	No Change From Baseline															
CB	Brine inflow rate at a pressure difference of lithostatic minus atmospheric (m3/yr-panel)	No Change From Baseline															
H2MAX	Maximum hydrogen gas generation potential from anoxic corrosion (mol/panel)	Yes	Yes	Yes	No Change		Yes	Yes	Yes	Yes	No Change From Baseline						
HHUMRATE	Hydrogen gas generation rate from anoxic corrosion under humid facility conditions (moles/drum-yr)	No Change From Baseline															
HINURATE	Hydrogen gas generation rate from anoxic corrosion under inundated facility conditions (moles/drum-yr)	No Change From Baseline															
KPANH	Negative log of the permeability of the anhydrite beds (dimensionless)	No Change from Baseline															
RADFAC	Factor used to estimate the effective borehole radius during intrusion (dimensionless)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No
RADSOL (1)	Pu-240 solubility in brine (mol/l)	No Change from Baseline								Yes	Yes	No Change from BL				Yes	No
RADSOL (2)	U-236 solubility in brine (mol/l)	No Change from Baseline								Yes	Yes	No Change from BL				Yes	No
RADSOL (3)	Am-241 solubility in brine (mol/l)	No Change from Baseline								Yes	Yes	No Change from BL				Yes	No
RADSOL (4)	Np-237 solubility in brine (mol/l)	No Change from Baseline								Yes	Yes	No Change from BL				Yes	No
RADSOL (5)	U-233 solubility in brine (mol/l)	Completely Correlated With RADSOL(2)															
RADSOL (6)	Th-229 solubility in brine (mol/l)	No Change from Baseline								Yes	Yes	No Change from BL				Yes	No
RADSOL (7)	Pu-238 solubility in brine (mol/l)	Completely Correlated With RADSOL(1)															
RADSOL (8)	U-234 solubility in brine (mol/l)	Completely Correlated With RADSOL(2)															
RADSOL (9)	Th-230 solubility in brine (mol/l)	Completely Correlated With RADSOL(6)															
RADSOL (12)	Pu-239 solubility in brine (mol/l)	Completely Correlated With RADSOL(1)															
RBOR	Radius of borehole for intrusion scenarios (m)	No Change From Baseline															
RHTORW	Ratio of hydrogen gas generation rate to water consumption rate during anoxic corrosion (dimensionless)	No Change From Baseline															

on the assurance of compliance. Detailed documentation of the input parameter distributions can be found in Appendix J.

Dependencies and correlations among input parameters are modeled using the STADIC sampling subroutine by allowing the same random number to be used to generate the values for two or more physical parameters. Details of the specific variables for which dependencies are established are given in Appendix J. For example, they include dependencies between the inundated and humid gas generation rates for both anoxic and biodegradation conditions. The dependency reflects the similarity of the chemical conversion involved, with the differences in brine availability producing a different model for the rate of the process and reflects the judgement that the humid gas generation rate should never exceed the inundated gas generation rate, since the cumulative distribution of the humid process has lower values at all percentiles of the distribution.

3.2.4 Results of Analysis of Factor 2

The results of the uncertainty analysis are presented in a series of four tables that match the MREs for releases to both the surface and the Culebra assuming the three human intrusion scenarios, as defined in Section 3.2.2. The description of the variability within the 1,000 case-by-case calculations of the overall MRE is broken into three parts:

- The first column shows the percentage of cases that produced no transport of radioactive material from the repository. These cases reflect the combination of parameters values that produce conditions favorable for complete containment.

- The next four columns present the 5th, 50th (median) and 95th percentile distribution parameters and the mean value of the distribution of MRE for those cases that do not include zero transport in either the baseline design or the engineered alternatives. The percentage of cases that produce no transport can be read directly from the first column. Of this percentage, the cases that were zero for the baseline are indeterminate, with the remaining having an MRE of zero.

- The sixth column presents the percentage of cases that produced the same upper bound value of release. These cases reflect the combination of parameter values that produce conditions favorable for transport.

The last column of the table presents the MRE comparing the 95th percentiles of the CCDF of predicted cumulative release of radioactive materials released for each engineered alternative. This MRE is a single point value.

3.2.4.1 Release of Cuttings, All Scenarios

By definition, all baseline and EA calculations for the drill cuttings release scenario resulted in the release of radioactive material to the surface in the cuttings, since the material intersected by the borehole must be deposited on the surface. None of the EAs that passed the screening process change the horizontal footprint of waste that the drilling operation could intersect. Therefore, the major impact of an EA with respect to radionuclide releases is the reduction in the effective radius of the borehole due to the increased effective resistance of the waste material to erosion during the drilling process.

Table 3-5 shows the results of the uncertainty calculations for cuttings release by all scenarios. First, it can be seen that radioactive materials removed from the repository horizon with drill cuttings is not subject to lower or upper bounds. This is reasonable, since the drilling operation must pass through only a few meters of waste at most, with compaction making the layer thinner. Given even conservatively slow drilling rates, the borehole walls should not be subject to slurry erosion from the drilling process for more than a few hours. Thus, the enlargement of the borehole radius due to erosion of waste is expected to be between a Factor 1 and 3, as indicated in Table J-4 of Appendix J. Thus, the MRE predicted by the DAM for reduction in cuttings removal can vary at most by a factor of 9 across all alternatives, with each MRE being well defined.

Figures 3-2 and 3-3 illustrate the results given in Table 3-5 for ease of comparison. It can be seen from these figures that plasma processing produces the best MRE for reducing cuttings releases. In fact, the waste composite produced by plasma processing produces an approximate maximum possible improvement, because it is estimated that waste treated by plasma processing could make the effective radius of the eroded borehole very close to that of the drill bit. There are no other significant trends among the other alternatives.

3.2.4.2 Waterborne Transport, Scenario E1

Table 3-6 gives the results for waterborne transport of radioactive materials from the repository to the Culebra (Scenario E1). For all 1,000 trials the transported quantities of radionuclides fell in a narrow band of values, indicating that the processes modeled in the DAM may not be sensitive to the input parameters that were modeled with uncertainty. This result can be explained by the boundary conditions imposed upon the repository by the assumptions made about the Castile. In Scenario E1, a borehole completely penetrates the Salado salt formation and punctures the Castile approximately 656 feet (200 meters) below the level of the repository. The Castile is assumed to contain a brine reservoir that is an infinite source of salt-saturated fluid at high pressure, resulting in a continuous flow of brine up the borehole to the Culebra.

As the brine flows through the repository level via the borehole, it may also spread into a limited volume of the waste composite, termed the wash-through volume. As it passes through the waste composite, it dissolves radionuclides to the limit of their solubilities in brine. As indicated in Appendix E, the quantities of radionuclides transported to the Culebra as a result of E1 is a function of the quantity of water flowing from the Castile and the volume of the repository it washes through. If a sufficient quantity of this brine flows through some volume of the repository, radioactive material will be carried to the Culebra until the available inventory of radionuclides in the wash-through volume is completely depleted. The calculated results of the 1,000 uncertainty cases are insensitive to the solubility of radionuclides in brine, indicating that the 5,000 years available after the intrusion event is sufficient to produce this result. Consequently, transport of radioactive material to the Culebra in this scenario is primarily dependent on the magnitude of the wash-through volume and the radionuclide inventory within that volume.

An important parameter for determining both the rate of brine flow through the repository and the size of the wash-through volume is the hydraulic conductivity of the backfill/waste composite. Hydraulic conductivity of the backfill/waste composite is not derived by the DAM and is currently expressed as a ninth order polynomial of the effective stress level of waste compaction (Appendix F). Since specifying the uncertainty of the hydraulic conductivity correlation would require establishing a weighted set of polynomial expressions, each with its own set of nine

TABLE 3-5

UNCERTAINTY ANALYSIS OF MEASURE OF RELATIVE EFFECTIVENESS FOR RELEASE OF CUTTINGS TO THE SURFACE (ALL SCENARIOS)

TRU Disposal System Scenario					Variability in Case by Case Calculations of MRE						
						Distribution of MREs for Cases With No Zero Transport					
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Percent Runs Producing Zero Transport	5th Percentile (most benefit)	Median	Mean	95th Percentile (least benefit)	Percent Runs at Maximum Limit of Transport	MRE for 95th %-tiles of EA & Baseline Transport CCDFs
	None	None	1	Baseline	0%					0%	N/A
		Sand+Clay	2	33	0%	0.91	0.92	0.92	0.92	0%	0.92
		SAG	3	35a	0%	0.40	0.40	0.40	0.40	0%	0.40
		CG	4	35b	0%	0.40	0.40	0.40	0.40	0%	0.40
		Clay	5	111	0%	0.93	0.94	0.94	0.94	0%	0.94
		CaO + Salt	6	83	0%	0.94	0.94	0.94	0.94	0%	0.94
	Super C	None	7	1	0%	0.25	0.26	0.26	0.26	0%	0.25
		SAG	8	77a	0%	0.21	0.21	0.21	0.21	0%	0.21
		Clay	9	77b	0%	0.21	0.21	0.21	0.22	0%	0.21
		Sand+Clay	10	77c	0%	0.21	0.21	0.21	0.21	0%	0.21
		CaO + Salt	11	77d	0%	0.21	0.21	0.21	0.22	0%	0.22
	S&C	None	12	6	0%	0.75	0.79	0.78	0.80	0%	0.77
	SCC	None	13	94a	0%	0.56	0.57	0.57	0.57	0%	0.57
		Sand+Clay	14	94b	0%	0.52	0.52	0.52	0.52	0%	0.52
		CG	15	94c	0%	0.29	0.30	0.30	0.30	0%	0.30
		SAG	16	94d	0%	0.29	0.30	0.30	0.30	0%	0.30
		Clay	17	94e	0%	0.53	0.53	0.53	0.53	0%	0.53
		CaO + Salt	18	94f	0%	0.53	0.54	0.53	0.54	0%	0.54
	Plasma	None	19	10	0%	0.11	0.12	0.13	0.18	0%	0.12

LEGEND:
Super C: Supercompaction of all waste, except sludges
S&C: Shredding and compaction of all waste, except sludges
EC/SC: Enhanced cementation of sludges. Shred and add clay based materials to organics and inorganics
SAG: Salt aggregate grout
CG: Cementitious grout

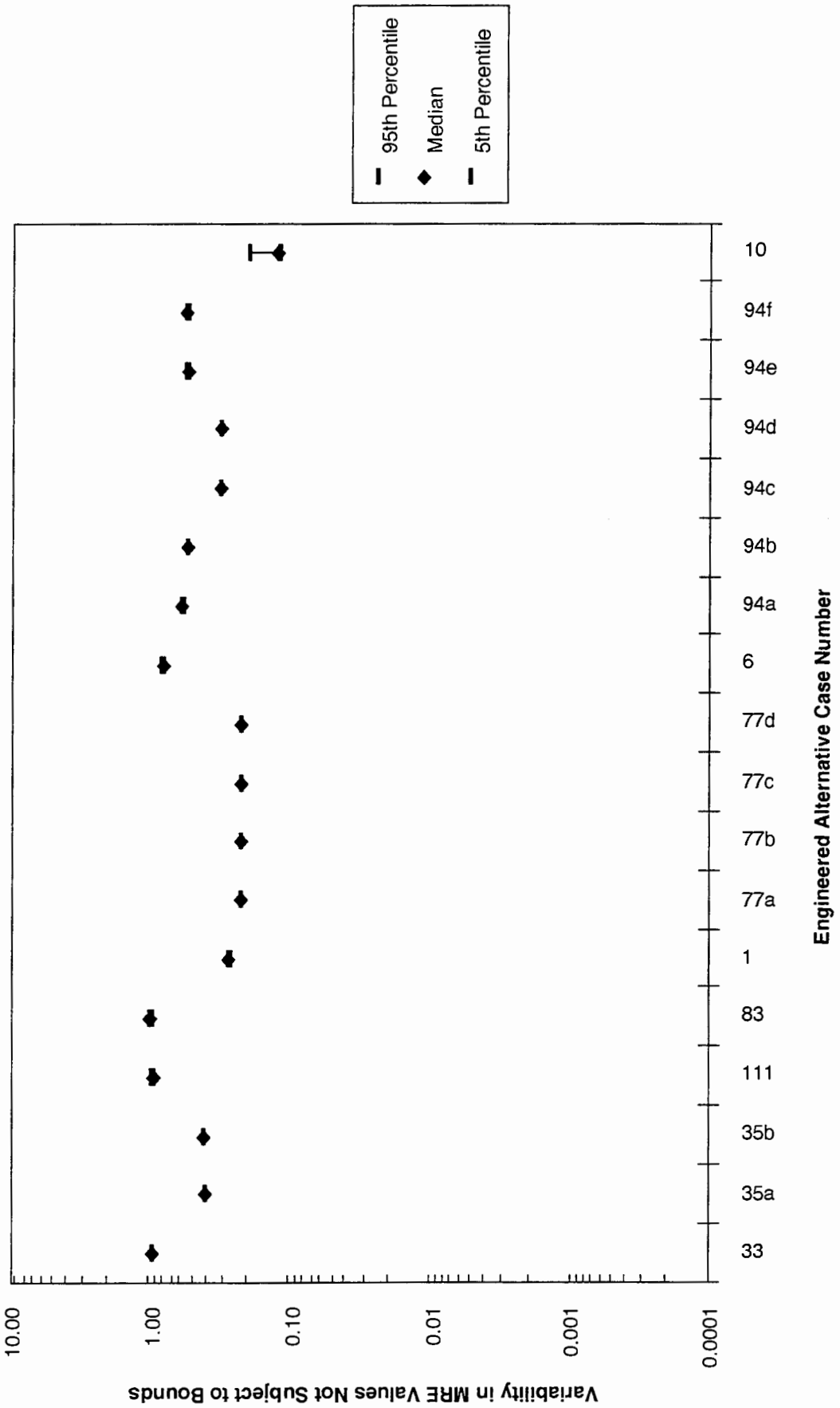

Figure 3-2
Uncertainty Analysis of Case-by Case Measure of Relative Effectiveness for Release of Cuttings to the Surface (all scenarios)

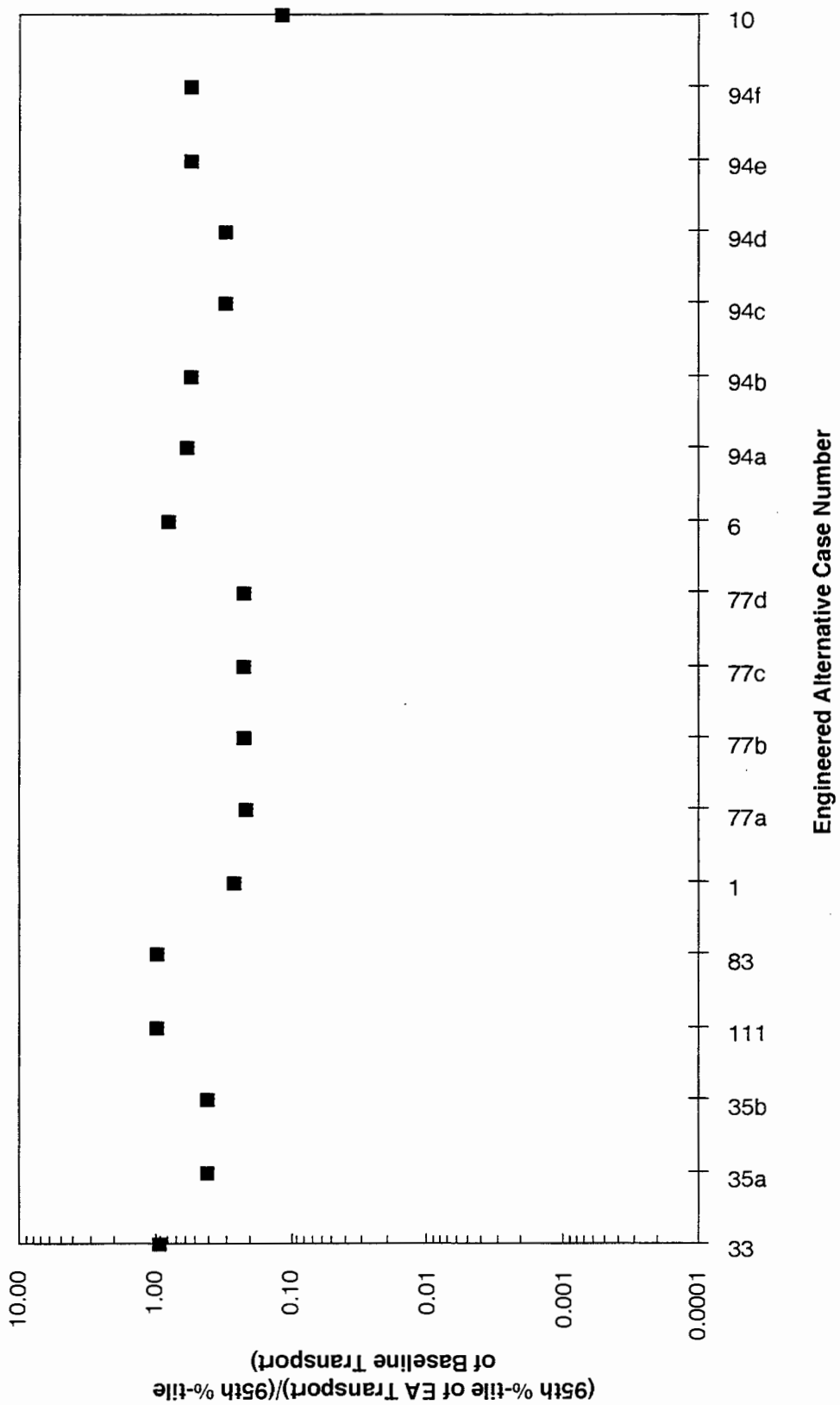

Figure 3-3
Measure of Relative Effectiveness for Reducing 95th Percentile of All Uncertainty Case Runs for Release of Cuttings to the Surface (all scenarios)

TABLE 3-6

UNCERTAINTY ANALYSIS OF MEASURE OF RELATIVE EFFECTIVENESS FOR WATERBORNE TRANSPORT TO CULEBRA DOLOMITE (SCENARIO E1)

TRU Disposal System Scenario					Variability in Case by Case Calculations of MRE						
						Distribution of MREs for Cases With No Zero Transport					
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Percent Runs Producing Zero Transport	5th Percentile (most benefit)	Median	Mean	95th Percentile (least benefit)	Percent Runs at Maximum Limit of Transport	MRE for 95th %-tiles of EA & Baseline Transport CCDFs
	None	None	1	Baseline	0%					0%	N/A
		Sand+Clay	2	33	0%	0.73	0.75	0.75	0.78	0%	0.73
		SAG	3	35a	0%	0.40	0.41	0.41	0.42	0%	0.40
		CG	4	35b	0%	0.40	0.41	0.41	0.42	0%	0.40
		Clay	5	111	0%	0.53	0.54	0.54	0.55	0%	0.53
		CaO + Salt	6	83	0%	0.83	0.83	0.81	0.84	0%	0.83
	Super C	None	7	1	0%	0.92	0.93	0.93	0.94	0%	0.94
		SAG	8	77a	0%	0.43	0.45	0.45	0.47	0%	0.43
		Clay	9	77b	0%	0.55	0.56	0.57	0.59	0%	0.55
		Sand+Clay	10	77c	0%	0.72	0.74	0.74	0.78	0%	0.72
		CaO + Salt	11	77d	0%	0.60	0.80	0.77	0.81	0%	0.78
	S&C	None	12	6	0%	0.92	0.94	0.94	0.96	0%	0.96
	SCC	None	13	94a	0%	0.68	0.69	0.70	0.72	0%	0.68
		Sand+Clay	14	94b	0%	0.64	0.66	0.66	0.69	0%	0.64
		CG	15	94c	0%	0.44	0.45	0.45	0.47	0%	0.44
		SAG	16	94d	0%	0.44	0.45	0.45	0.47	0%	0.44
		Clay	17	94e	0%	0.52	0.54	0.54	0.56	0%	0.52
		CaO + Salt	18	94f	0%	0.26	0.67	0.63	0.68	0%	0.66
	Plasma	None	19	10	0%	0.0004	0.0007	0.0008	0.0012	0%	0.0011

LEGEND:
Super C: Supercompaction of all waste, except sludges
S&C: Shredding and compaction of all waste, except sludges
EC/SC: Enhanced cementation of sludges. Shred and add clay based materials to organics and inorganics
SAG: Salt aggregate grout
CG: Cementitious grout

coefficients, to express the range of potential relations, only a best estimate was used for EA comparison purposes. This explains the very narrow range of actinide activity transported and also the resultant overall MRE.

Figures 3-4a and 3-4b plot the results given in Table 3-6 for ease of comparison. It can be seen from this figure that plasma processing reduces transport following an E1 scenario by a factor of over 1,000, whereas all the other alternatives produce reductions of less than a factor of 10. This significant difference is attributed to the resulting very low hydraulic conductivity within the waste horizon for a vitrified waste/salt composite. This very low permeability greatly restricts the radius to which the wash-through volume extends into the waste horizon, compared to the baseline design and all other alternatives.

Of those involving backfill, the engineered alternatives that use either SAG or SG backfill provide the best performance for the E1 Scenario. These backfill options would tend to provide a consistently tough waste composite across the entire cross section penetrated by the borehole.

3.2.4.3 Waterborne Transport, Scenario E2

Of all the scenarios and mechanisms for transport investigated in this study, waterborne transport as a result of the E2 Scenario is the most dependent on the inflow of brine and the buildup of fluid pressure within the undisturbed repository. It does not have the assumed pressure and infinite source of brine available from the Castile as a driving force to move radionuclides to the Culebra, as is the case with the E1 scenario.

Because of the wide variation in the physical input parameters, there are random sample calculations in which the baseline design for the EA may produce waterborne radioactive transport to the Culebra of zero. For example, a combination of conditions that produce a low repository pressure may result in a hydraulic head too low for water to rise to the Culebra. In addition, low brine inflow and/or a high brine consumption rate from anoxic corrosion may simply not provide sufficient brine for any release. Conversely, there are a group of random sample calculations in which the baseline design or the EA produce waterborne radioactive transport to the Culebra at a bounding limit corresponding to the entire inventory of radioactive material available in a panel.

Table 3-7 shows that about 1 percent of cases for the baseline design produce zero releases, while 7% of the cases transport essentially all available radionuclides in a panel. Many of the EAs increase the percentage of cases that produce zero transport, but some also increase the number of cases that produce releases at the upper limit of waste that is available for hydraulic communication with the borehole. It should be noted that plasma processing produces the most improvement by far and also produces the least spread of MRE values. This indicates that the vitrified waste/salt composite has performance properties that are insensitive to the quantities that were modeled with uncertainty for this analysis.

Figures 3-5a and b plot the results given in Table 3-7 for ease of comparison. As with Scenario E1, plasma processing produces the most improvement of performance against E2 scenarios, for the same reason as stated in Section 3.2.4.3 for E1 scenarios. The backfill EAs that use lime (CaO) to reduce the actinide solubility also produces a very significant benefit because the limited availability of brine enhances the importance of actinide solubility. The SAG and CG backfill also add some benefit, although not as significant as lime. The waste processing options have little to no significant impact on performance. In Figure 3-5b, the large number of

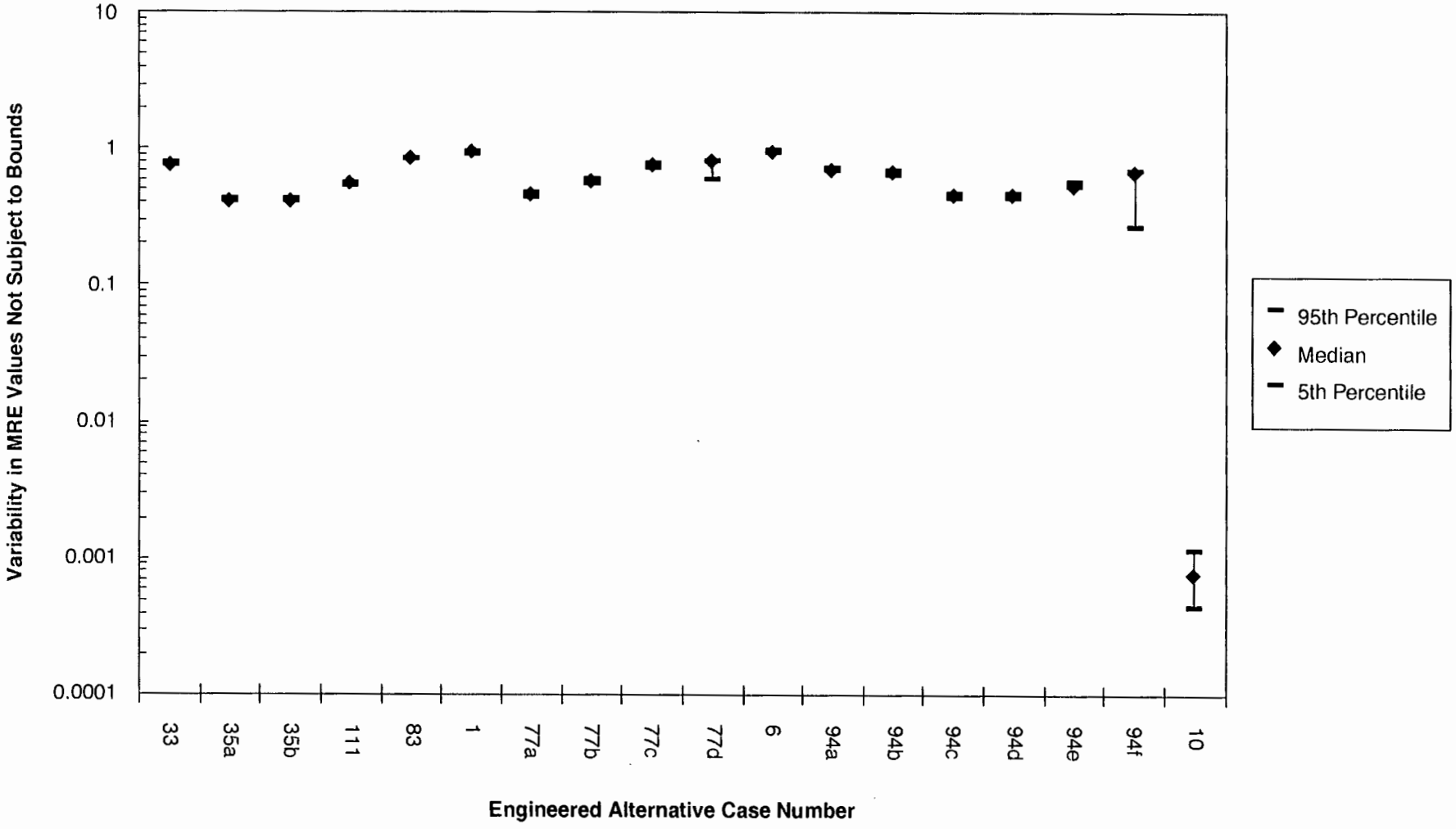

Figure 3-4a

Uncertainty Analysis of Case-by Case Measure of Relative Effectiveness for Waterborne Transport to Culebra Dolomite (Scenario E1)

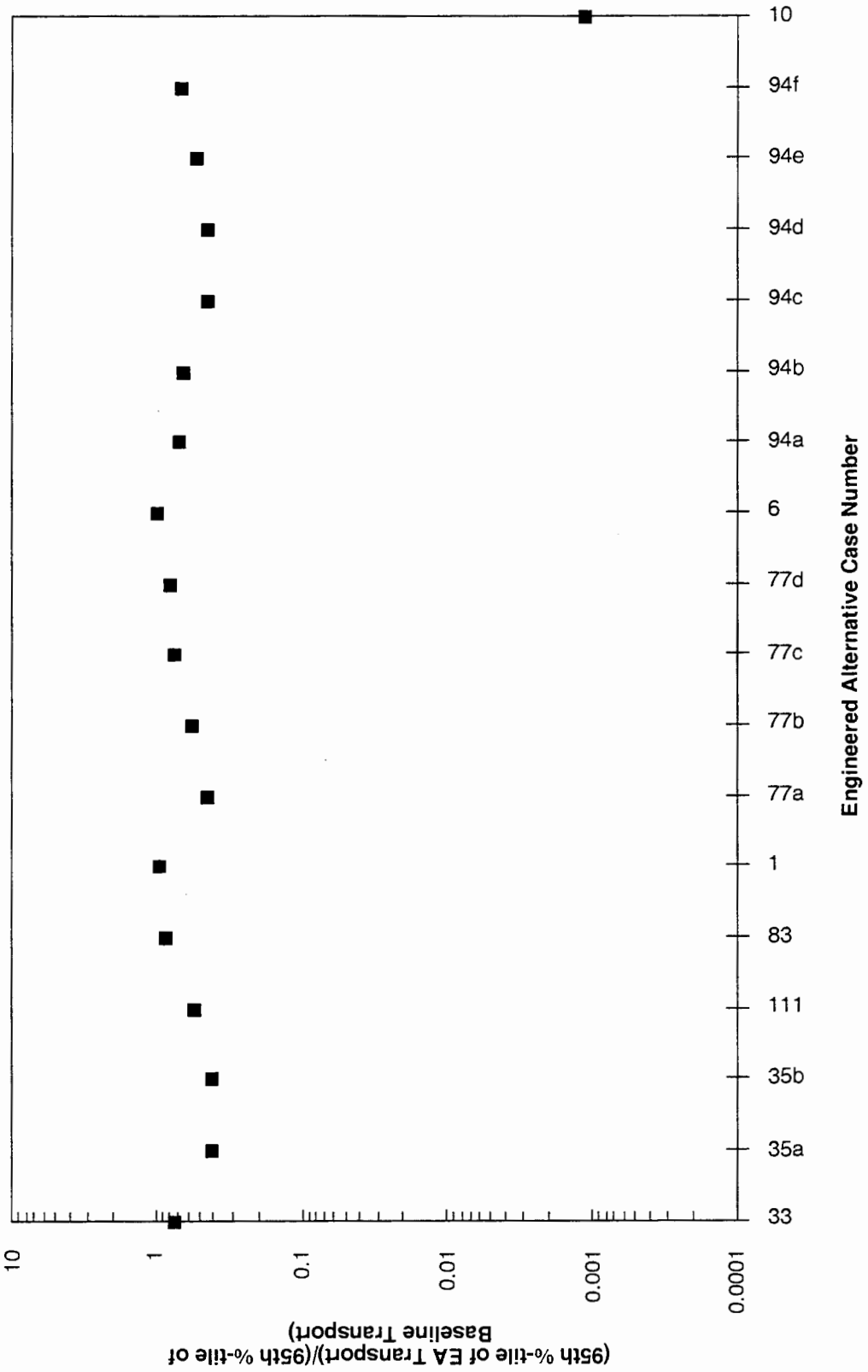

Figure 3-4b
Measure fo Relative Effectiveness for Reducing 95th Percentile of All Uncertainty Case Runs for Waterborne Transport to Culebra Dolomite (Scenario E1)

TABLE 3-7

UNCERTAINTY ANALYSIS OF MEASURE OF RELATIVE EFFECTIVENESS FOR WATERBORNE TRANSPORT TO CULEBRA DOLOMITE (SCENARIO E2)

TRU Disposal Scenario					Variability in Case by Case Calculations of MRE						
						Distribution of MREs for Cases With No Zero Transport					
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Percent Runs Producing Zero Transport	5th Percentile (most benefit)	Median	Mean	95th Percentile (least benefit	Percent Runs at Maximum Limit of Transport	MRE for 95th %-tiles of EA & Baseline Transport CCDFs
	None	None	1	Baseline	1%					7%	N/A
		Sand+Clay	2	33	21%	0.31	1.07	1.11	1.99	7%	1.00
		SAG	3	35a	24%	0.18	0.71	0.68	1.09	3%	0.54
		CG	4	35b	24%	0.18	0.71	0.68	1.09	3%	0.54
		Clay	5	111	21%	0.33	1.14	1.20	2.18	7%	1.00
		CaO + Salt	6	83	7%	0.009	0.12	0.24	0.84	0%	0.009
	Super C	None	7	1	0%	0.61	1.08	1.28	2.08	8%	1.00
		SAG	8	77a	19%	0.091	0.31	0.37	0.87	1%	0.19
		Clay	9	77b	18%	0.45	1.11	1.23	2.35	8%	1.00
		Sand+Clay	10	77c	18%	0.37	1.06	1.15	2.06	8%	1.00
		CaO + Salt	11	77d	4%	0.009	0.119	0.235	0.83	0%	0.009
	S&C	None	12	6	0%	0.75	1.01	1.17	1.75	8%	1.00
	SCC	None	13	94a	24%	0.19	0.72	0.69	1.08	3%	0.57
		Sand+Clay	14	94b	56%	0.14	0.74	0.77	1.61	2%	0.25
		CG	15	94c	59%	0.03	0.37	0.41	0.88	1%	0.08
		SAG	16	94d	59%	0.03	0.37	0.41	0.88	1%	0.08
		Clay	17	94e	55%	0.16	0.75	0.78	1.62	2%	0.26
		CaO + Salt	18	94f	31%	0.005	0.09	0.19	0.75	0%	0.009
	Plasma	None	19	10	0%	0.0009	0.0088	0.0194	0.0549	0%	0.0018

LEGEND:
Super C: Supercompaction of all waste, except sludges
S&C: Shredding and compaction of all waste, except sludges
EC/SC: Enhanced cementation of sludges. Shred and add clay based materials to organics and inorganics
SAG: Salt aggregate grout
CG: Cementitious grout

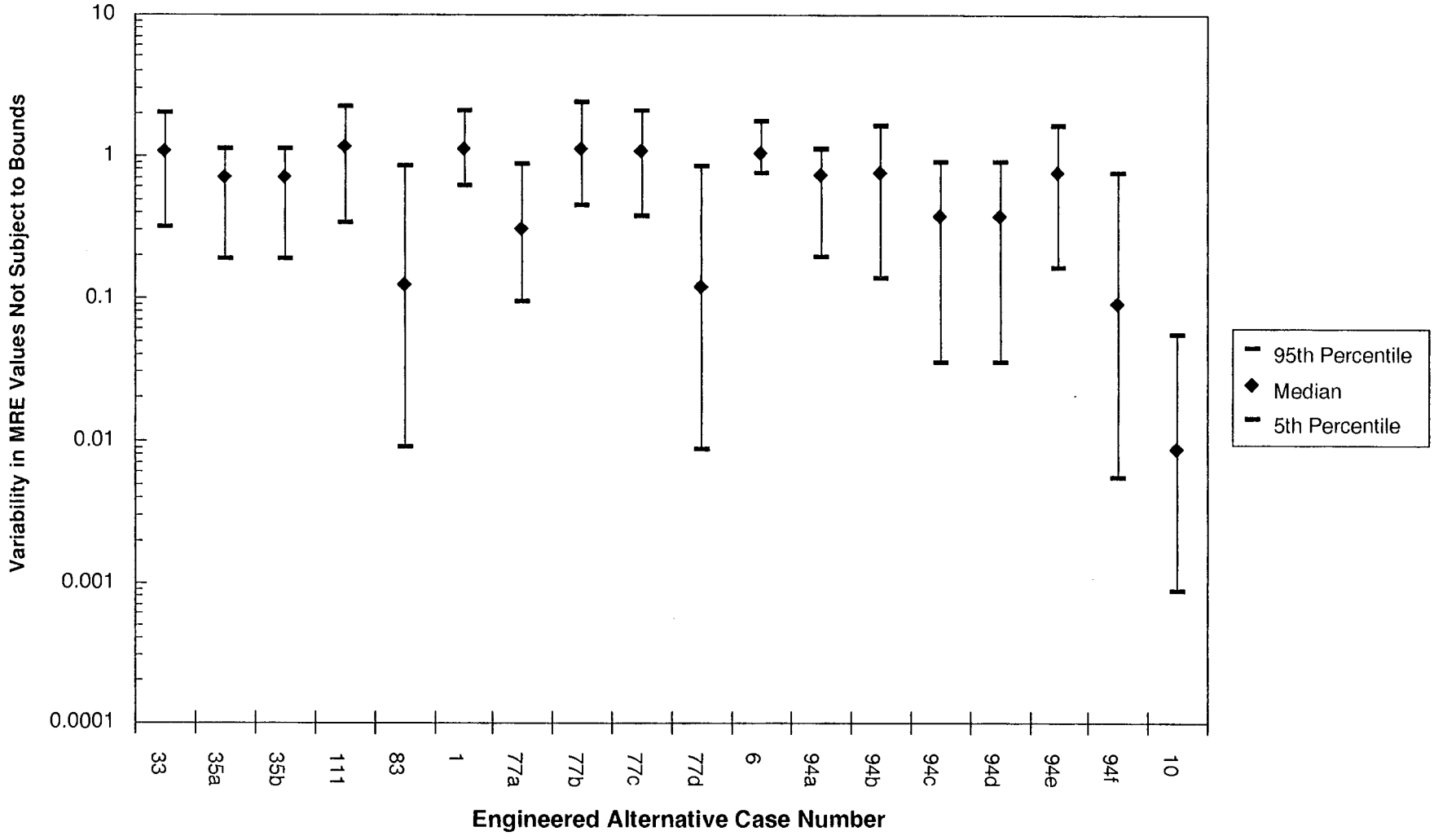

Figure 3-5a

Uncertainty Analysis of Case-by Case Measure of Relative Effectiveness for Waterborne Transport to Culebra Dolomite (Scenario E2)

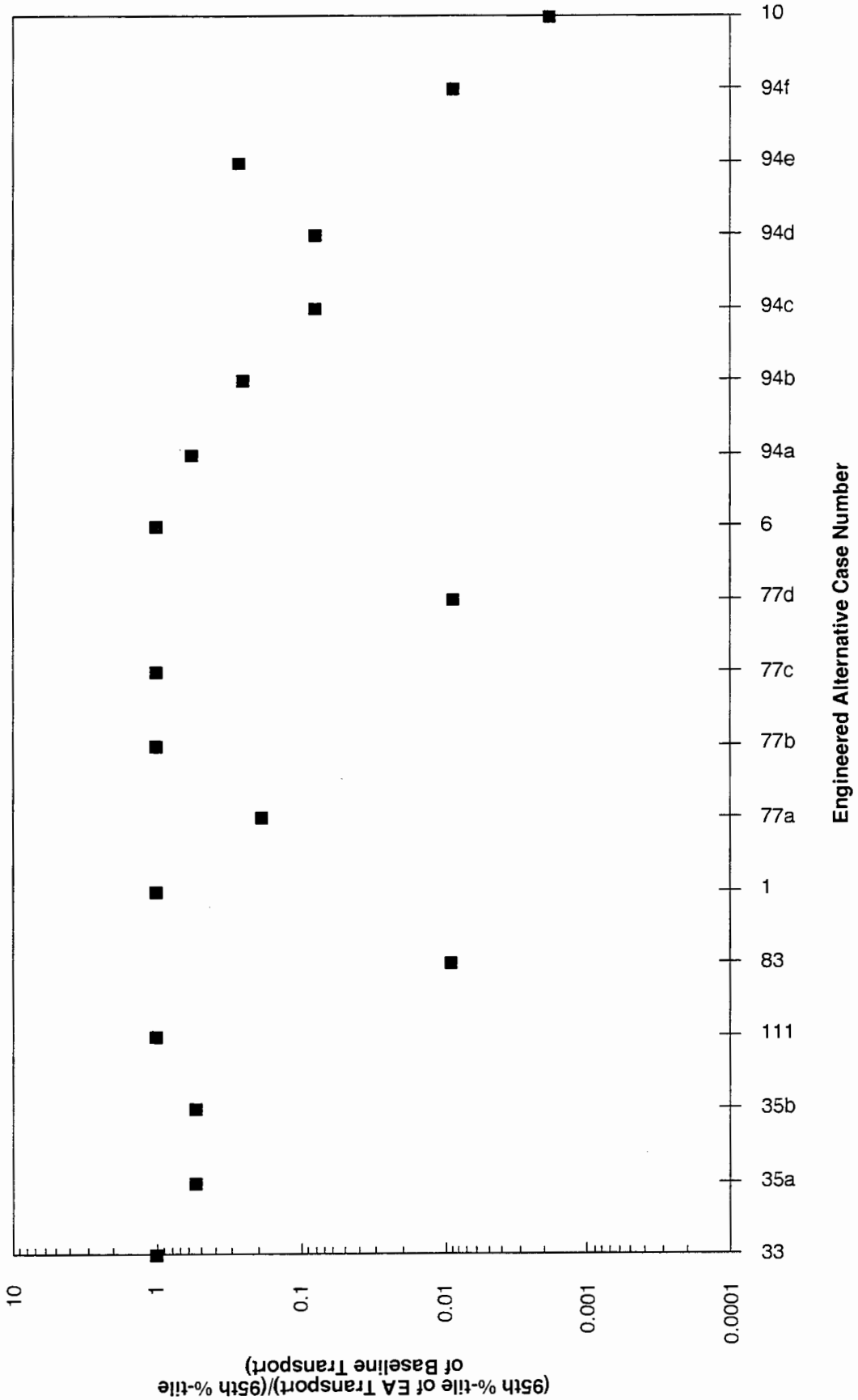

Figure 3-5b
Measure of Relative Effectiveness for Reducing 95th Percentile of All Uncertainty Waterborne Transport to Culebra Dolomite (Scenario E2)

values at 1.0 indicate that at least 5% of the cases are producing releases at the limit of available radionuclide inventory for both the baseline design and the EA. In these cases, the EA has no impact on the potential for the larger releases for this scenario.

3.2.4.4 Waterborne Transport, Scenario E1E2

The physical process of interest for the E1E2 Scenario involves saturated brine flowing through the repository horizon between two boreholes. One borehole permits Castile brine at high pressure to flow into the repository, but blocks the brine's path to the surface via that borehole. A second borehole then forms a path for flow in response to the pressure head to the Culebra. For comparison of EA performance, the two boreholes are assumed to be at opposite ends of a room, resulting in the wash-through volume being equal to the volume of one room at the time of the human intrusion event.

As with the E1 Scenario, the quantity of brine that flows through the room is dependent on the backfill/waste composite hydraulic conductivity; but if enough brine flows through the room, the radionuclide inventory in the room can be completely dissolved. Because of the hydraulic conductivity of the baseline design, high pressure, and unlimited supply of brine assumed to be available from the Castile, all the baseline calculations resulted in complete dissolution of the waste inventory of the room. The 1,000 random sample calculations for the E1E2 scenario for the baseline design all result in the same quantity of radionuclide transport.

Table 3-8 and Figure 3-6a and 3-6b show the results for waterborne transport due to the E1E2 Scenario. The EAs that are effective against Scenario E1E2 either alter the backfill/waste composite hydraulic conductivity or the actinide solubility along that path, which is assumed to consist of an entire room. Consistent with E1 and E2, plasma processing, which produces the greatest reductions in permeability, results in the best improvement. However, other EAs also produced good results. Those EAs that use either SAG or CG backfill significantly reduce permeability, which in turn reduces the backfill/waste composite hydraulic conductivity. This lowers the rate of brine flow, thus reducing the quantity of brine available to dissolve and transport actinides. The EAs that employ lime reduce solubility, thus lowering the quantity of actinides that a given amount of brine can dissolve.

TABLE 3-8

UNCERTAINTY ANALYSIS OF MEASURE OF RELATIVE EFFECTIVENESS FOR WATERBORNE TRANSPORT TO CULEBRA DOLOMITE (SCENARIO E1E2)

TRU Disposal System Scenario					Variability in Case by Case Calculations of MRE						
						Distribution of MREs for Cases With No Zero Transport					
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Percent Runs Producing Zero Transport	5th Percentile	Median	Mean	95th Percentile	Percent Runs at Maximum Limit of Transport	MRE for 95th %-tiles of EA & Baseline Transport CCDFs
	None	None	1	Baseline	0%					100%	N/A
		Sand+Clay	2	33	0%	0.99	0.99	0.97	0.99	96%	0.99
		SAG	3	35a	0%	0.009	0.036	0.129	0.75	4%	0.75
		CG	4	35b	0%	0.009	0.036	0.129	0.75	4%	0.75
		Clay	5	111	0%	0.024	0.476	0.53	0.99	35%	0.99
		CaO	6	83	0%	0.012	0.041	0.14	0.76	4%	0.76
	Super C	None	7	1	0%	1.00	1.00	1.00	1.00	100%	1.00
		SAG	8	77a	0%	0.011	0.075	0.224	0.98	10%	0.98
		Clay	9	77b	0%	0.037	0.825	0.63	0.98	48%	0.98
		Sand+Clay	10	77c	0%	0.98	0.98	0.96	0.98	96%	0.98
		CaO	11	77d	0%	0.012	0.027	0.094	0.438	2%	0.437
	S&C	None	12	6	0%	1.00	1.00	1.00	1.00	100%	1.00
	SCC	None	13	94a	0%	0.37	1.00	0.93	1.00	88%	1.00
		Sand+Clay	14	94b	0%	0.22	0.99	0.89	0.99	82%	0.99
		CG	15	94c	0%	0.01	0.08	0.23	0.98	11%	0.98
		SAG	16	94d	0%	0.01	0.08	0.23	0.98	11%	0.98
		Clay	17	94e	0%	0.024	0.44	0.52	0.99	34%	0.98
		CaO	18	94f	0%	0.009	0.012	0.020	0.045	1%	0.045
	Plasma	None	19	10	0%	0.0003	0.0009	0.0018	0.0066	0%	0.01

LEGEND:
Super C: Shredding and compaction of all waste, except sludges
S&C: Shredding and compaction of all waste, except sludges
SCC: All wastes other than sludges are shredded and repackaged with clay. Sludges are cemented.
SAG: Salt Aggregate Grout
CG: Cementitious Grout

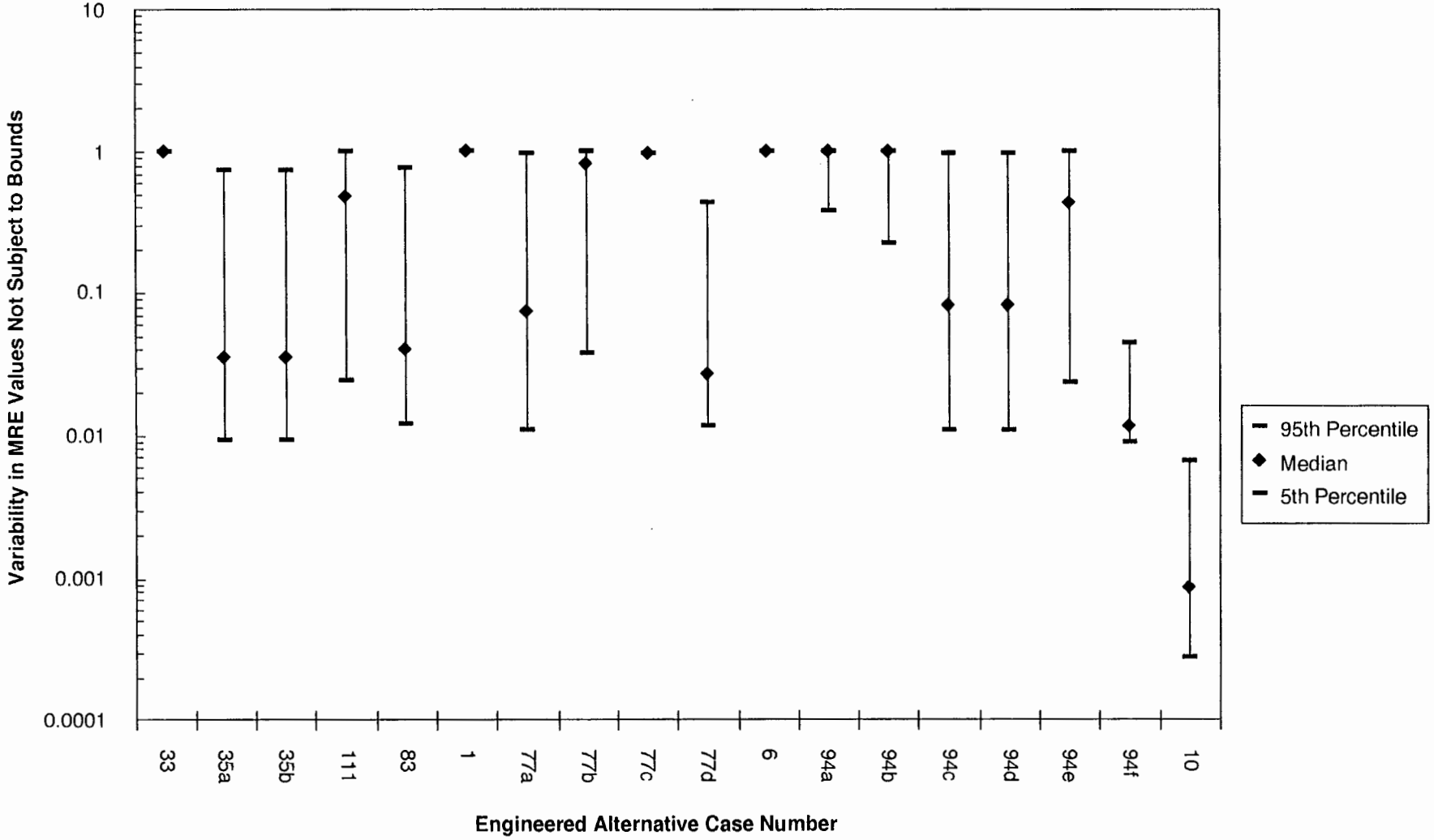

Figure 3-6a

Uncertainty Analysis of Case-by-Case Measure of Relative Effectiveness for Waterbourne Transport to Culebra Dolomite (Scenario E1E2)

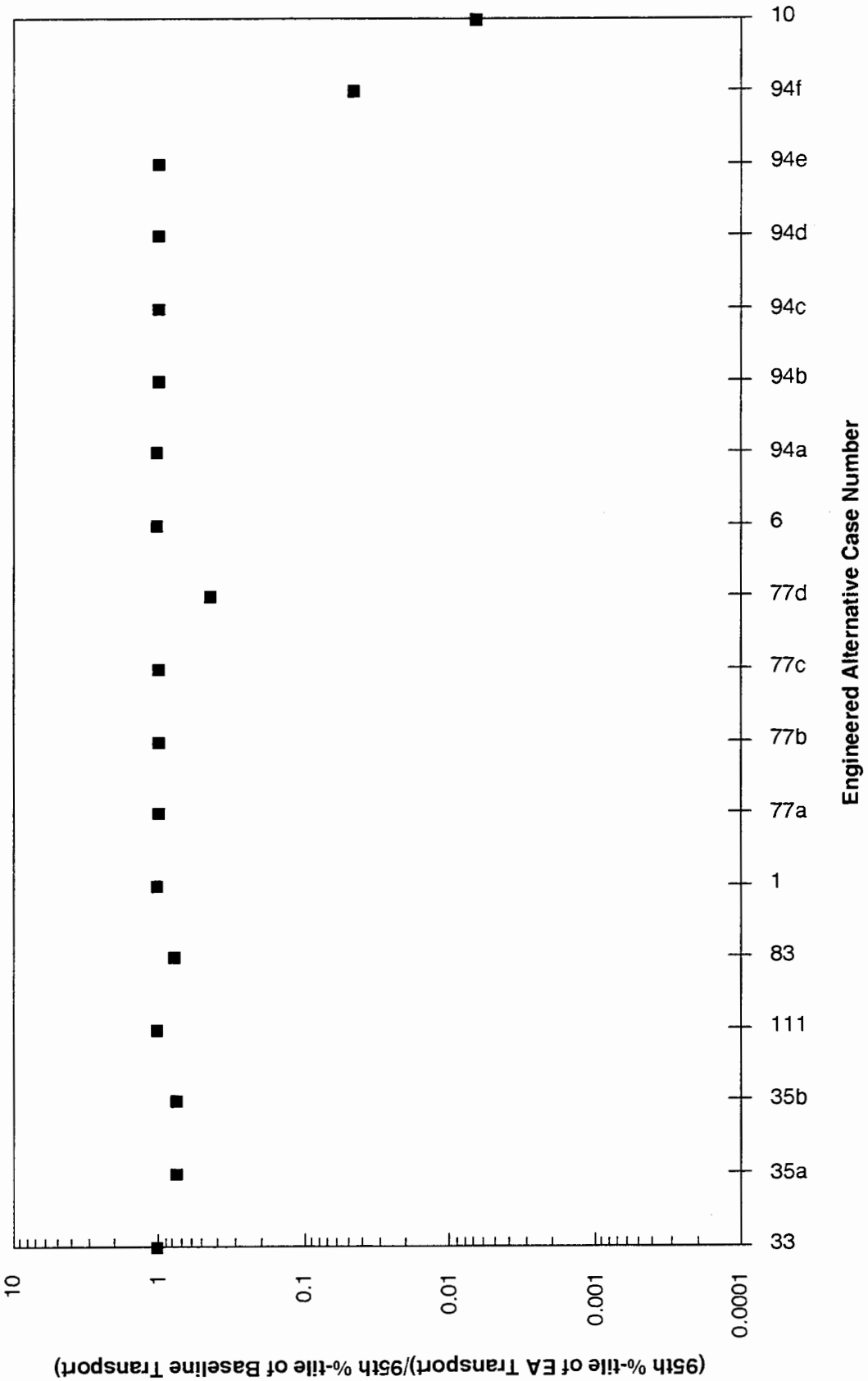

Figure 3-6b
Measure of Relative Effectiveness for Reducing 95th Percentile of All Uncertainty Waterborne Transport to Culebra Dolomite (Scenario E1E2)

3.3 FACTOR 3: IMPACT ON WORKER AND PUBLIC RISK

3.3.1 Definition of Factor 3

Discussion of the human health risks associated with adopting an EA includes impacts that may be realized at the WIPP site and generator or disposal facilities that are involved with TRU or TRU-mixed waste. Consideration of potential impacts includes radiation effects (both radiation emanating from waste or processing equipment and the release of radioactive material), effects from the release of hazardous material, and, in the case of individuals within the facilities, ordinary industrial hazards. Impacts are considered for the following five groups of individuals at the WIPP and at the generator/disposal sites:

- Workers directly involved with handling, processing, or storing TRU waste (generally referred to as "workers")
- Other workers in the facility who are not directly involved with the TRU waste (also referred to as "co-located workers")
- The co-located worker who receives the highest exposure to radiation or hazardous material from TRU waste activities
- All members of the public who live within 50 miles (80.5 km) of the facility where the TRU waste is being handled, processed, or stored (generally referred to as "public")
- The member of the public located off-site who receives the highest exposure from activities associated with TRU handling, processing, or disposal (often called the Maximum Off-Site Individual or MOI).

Radiation emanating from waste or processing equipment primarily affects workers. Because co-located workers and members of the public are much further from the source of radiation, the human health impacts on these groups are small and can be ignored in this analysis. Hazardous and toxic chemicals do not have human health impacts on any of the groups as long as the chemicals remain contained.

If radioactive material, hazardous material, or toxic chemicals do not remain contained within packaging, they may pose a hazard to workers, co-located workers, or the public, primarily by being taken into the body via numerous exposure processes. Such releases may result from faulty packaging, violation of the integrity of the packaging, or opening of the packaging during processing. To constitute a risk, however, the released materials must come in contact with an individual. To do that, the material must move through some pathway between the source of material and the exposed individual. The most frequent pathway involves some portion of the material becoming airborne, moving in air to the exposed individual, and being inhaled. Other pathways include contamination of water that is subsequently consumed by the exposed individual or used to water food crops or provide drinking water for animals; deposition from the air to food crops; and deposition on the ground where it may be taken up by plants, become a source for contaminating water, or be resuspended in the air. Exposure may also come from contact with or ingestion of soil or other materials contaminated by the waste.

Human health impacts are not generally measured the same way for radiation, toxic chemicals, carcinogenic chemicals, or industrial accidents. To facilitate comparison with other reported data, this document reports impacts in the units most commonly used in other studies. In addition, to the extent possible, the report also displays results in units that will facilitate comparing the impacts from the different types of hazards, recognizing that the endpoints are not identical. The following paragraphs describe significant differences between the endpoints reported.

Standard health and safety control practices include administrative control of exposures to radiation or hazardous material for workers as individuals and as groups. Workers are often rotated through hazardous and nonhazardous work to limit individual exposures. For this reason, the concept of the full-time equivalent (FTE) is used in relation to worker doses. An FTE is assumed to be commensurate to one individual working full time in a waste management facility even though it may actually represent a number of individuals, none of whom work full time in the facility. Rather than reporting maximum individual or average worker doses, the report uses collective dose for all workers. These doses will be expressed in FTE-rem rather than person-rem to emphasize that they are worker and not public doses.

The impacts of exposure to radiation and to carcinogenic chemicals may be reported as excess cancers. Unfortunately, most of the data reported in the literature relating radiation exposure and cancer are given in terms of cancer fatalities, and cancer incidence is usually reported for exposure to carcinogenic chemicals. Because cancer incidence is not synonymous with cancer fatalities, the units for radiation risk will be excess fatalities, and the units for carcinogenic compounds will be excess cancers.

Unlike carcinogenic hazardous chemicals, toxic chemicals do not have an apparent impact when present in less than a threshold concentration. Exposure to these types of chemicals is reported as a fraction of the applicable limit. For members of the public, the estimated long-term air concentration for each chemical is divided by the maximum level to which an individual may be exposed 24 hours a day for 70 years without developing adverse effects. The resulting fraction, called a hazard quotient, is totaled for all reported chemicals and the sum reported as a hazard index. The amount the hazard index exceeds 1.0 can serve as an indicator of relative potential for causing harm.

For workers, the exposure to toxic chemicals is reported as an exposure index. The exposure ratio is calculated similarly to the hazard quotient except that it is based on the maximum concentration that might be observed for each chemical which is divided by a threshold limit value based on safe exposure for a shorter time, typically an 8-hour day or 40-hour week. The sum of the exposure ratios for all chemicals of concern is called the exposure index. An exposure index of greater than 1.0 indicates an increased likelihood of adverse health effects in the workers.

Table 3-9 summarizes the types of human health risk analyses and the units in which the results are reported.

3.3.2 Methodology Used to Evaluate Worker and Public Risk

This section of the report describes the methodology used to produce estimates of worker and public risk. Details of the models and the way they were applied may be found in Appendix K.

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TABLE 3-9

REPORTING UNITS FOR HUMAN HEALTH RISK ANALYSIS

Exposure Group	Radiation Impacts	Carcinogenic Chemicals	Toxic Chemicals	Industrial Accidents
Workers (Collective)	FTE-rem Excess Fatalities	Excess Cancers	Exposure Index	Injuries Fatalities
Most Exposed Co-Located Worker	Rem Excess Risk	Excess Cancers	Hazard Index	Not Applicable
Co-Located Workers (Collective)	Person-rem Excess Fatalities	Excess Cancers	Not Applicable	Not Applicable
Most Exposed Off-site Individual	Rem Excess Risk	Excess Cancers	Hazard Index	Not Applicable
Collective Off-site (Public)	Person-rem Excess Fatalities	Excess Cancers	Not Applicable	Not Applicable

Many of the alternatives consist of a combination of a method of waste processing with a method of emplacement of the waste at the WIPP. For the sake of simplicity of presentation and flexibility in considering the impacts of the alternatives, the analysis of the treatment options has been performed separately from the analysis of the impacts of emplacement at the WIPP. With the exception of the data for the maximally exposed individuals, all the human health impacts may be considered additive, and thus, may be considered in multiple combinations.

All alternatives, including the baseline, have some activities in common. Those include retrieval, packaging, and certification of the waste to WIPP WAC standards. All of the alternatives may be considered as various combinations of four waste processes and five emplacement options. The four processing options follow:

- Compact (supercompact) all waste except sludges. This process is included in Alternatives 1 and 77(a–d).
- Shred and compact all waste except sludges, Alternative 6.
- Plasma processing, Alternative 10.
- Shred and add clay-based materials to organics and inorganics used in Alternatives 94(a–f).

The baseline involves no backfill during emplacement. The five emplacement options involve various types of backfill:

- Sand plus clay backfill, Alternatives 33, 77c, and 94b.
- Salt aggregate grout backfill, Alternatives 35a, 77a, and 94d.
- Cementitious grout backfill, Alternatives 35b and 94c.
- Clay-based backfill, Alternatives 77b, 94e, and 111.
- CaO backfill, Alternatives 83, 77d, and 94f.

Table 3-10 displays the processing and emplacement options used in each EA. The total impact of each alternative is the sum of the processing and emplacement impacts.

Because the WIPP is not now active for emplacement of TRU waste, and most of the facilities throughout the DOE system are not operating the types of waste processing specified in the alternatives, all analysis of EA performance must be performed using modeling techniques.

3.3.2.1 Methodology Used to Evaluate Waste Process Impacts

The impacts from each alternative are compared to the impacts from a baseline, which consists of the emplacement of waste certified to meet the WIPP WAC without any backfill of the rooms after emplacement. The baseline includes waste that is already packaged and complies with the WAC, waste that is not yet generated but will be packaged and certified to meet WAC, and waste that is not yet packaged or needs to be repackaged to meet the WAC or that requires some

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TABLE 3-10

HUMAN HEALTH ANALYTICAL COMPONENTS OF EACH ENGINEERED ALTERNATIVE

Engineered Alternative	Processing Analysis	Emplacement Analysis
1	Supercompaction	Same as Baseline
6	Shred and Compact	Same as Baseline
10	Plasma Processing	Same as Baseline
33	Same as Baseline	Sand plus Clay Backfill
35a	Same as Baseline	Salt Aggregate Grout Backfill
35b	Same as Baseline	Cementitious Grout Backfill
111	Same as Baseline	Clay-based Backfill
77a	Supercompaction	Salt Aggregate Grout Backfill
77b	Supercompaction	Clay-based Backfill
77c	Supercompaction	Sand plus Clay Backfill
77d	Supercompaction	CaO Backfill
83	Same as Baseline	CaO Backfill
94a	Shred and Add Clay	Same as Baseline
94b	Shred and Add Clay	Sand plus Clay Backfill
94c	Shred and Add Clay	Cementitious Grout Backfill
94d	Shred and Add Clay	Salt Aggregate Grout Backfill
94e	Shred and Add Clay	Clay-based Backfill
94f	Shred and Add Clay	CaO Backfill

processing to allow certification that it meets the WAC. The latter two situations will require operation of facilities that are considered part of the baseline. These activities are expected to take place at 10 major DOE facilities (see Table 2-4)[1]:

In considering waste processing, where the required waste handling facilities do not currently exist, worker exposures and airborne releases are estimated by assuming a generic facility located at the site. The analysis of these generic facilities is based on individual modules, each of which is designed to perform one specific and necessary part of the task. For example, most generic facilities require a module in which waste is received and inspected and another from which the final product is shipped or sent to a disposal location. Other modules might include repackaging or specific waste processing. Isotopic concentrations of the waste and physical configuration of each module (size and placement of tanks, etc.) are used to estimate worker dose rates. The operations performed in each module are analyzed and estimates of exposure rates, potential air concentrations in the workplace, releases from the vent system, and personnel requirements for operation and maintenance are made and reported on a normalized basis. For example, data on personnel doses are calculated on a per unit throughput basis. Multiplying by the projected annual throughput for a particular site yields an estimate of the annual dose to all the workers for that module. These types of data are then combined for all the necessary modules for a given facility to estimate the annual worker dose for the appropriate waste processing at that particular site. Finally, the data for operations at all waste processing facilities is combined to give a total for the DOE system for that particular alternative.

The impacts of material released to the environment are analyzed independently for each facility. The primary pathway for exposure involves air transport of the material. The impacts associated with the air releases are dependent on local meteorology, air dispersion, and the location of the individual(s) exposed relative to the release point. Thus details of local meteorology and population density and distribution are all inputs to the models for each individual storage or processing facility. In other words, an identical quantity and type of waste going through the same waste processing method may have different human health impacts at each facility.

Performing the analyses as described above involves the application of many very complex models and large data sets. Because performing this type of analysis for all possible combinations of each alternative and each configuration[2] is beyond the scope of this report, a method was developed that simplifies the modeling requirements while retaining adequate information to allow comparison of the many alternatives and configurations. This procedure consists of applying scaling factors to the results of a limited number of the complex analyses described above. The scaling factors are developed independently for each facility and combined to form a weighted scaling factor applied to the systemwide results of the selected fullscale analyses.

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[1]Almost all the waste is located at these 10 sites. Minor additional amounts of waste stored at other small DOE sites may be transported to one or more of these sites. These additional amounts of waste are insignificant and do not impact the human health analysis. DOE sites other than these 10 are currently generating small quantities of TRU waste.

[2]Configuration refers to the arrangement of location(s) at which waste processing is assumed to occur. In the 'Distributed' configuration, waste treatment occurs at the ten sites identified previously. In the 'Regional' configuration, waste is transported to five sites for treatment. In the 'Centralized' configuration, all waste is transported to the WIPP and is treated at a facility built for that purpose.

For a selected EA process, there are two primary considerations that would require scaling of human health impacts. One would be whether or not the selected process was performed at the particular facility. The other is the variation in waste throughput at each facility. The difference in throughput at any given facility may result from either changes to meet the WIPP design capacity or modifications in the system-wide configuration. Consider, for example, the Lawrence Livermore National Laboratory (LLNL), which would perform plasma processing of waste in the decentralized configuration but would only be involved in shipping waste to other facilities for the regional and centralized configurations. In addition to these considerations, the amount of waste assumed to be processed and/or shipped from LLNL must be adjusted, along with all other facilities, to match the design capacity of the WIPP.

Changes in process and throughput alter the human health impacts in two primary ways. Human health impacts are primarily due to materials released to the air to which individuals are subsequently exposed and radiation emitted from the waste exposing those in close proximity either to the waste processing equipment or to the waste in disposal. Exposure to radiation or hazardous materials released during transportation activities is considered in Section 3.5, Risk of Transportation. Changes in waste handling during processing and changes in the amount of waste processed change the amount of radioactive and/or hazardous material released to the air. These releases impact co-located workers and the public. Air releases for different waste processes are process-dependent rather than throughput-dependent. For a given waste process, however, the modeled amount of material released is a linear function of the amount of waste processed or the total throughput. Thus, at each facility, modeling must consider each process separately but may apply linear scaling factors to account for variations in waste throughput.

Impacts on workers are primarily time and process dependent for both exposure to radiation and to airborne contaminants in the workplace. The working time is dependent on the processes involved and the amount of waste processed. The variation between processes requires individual analyses for each process or combination of processes. The amount of time workers spend performing a particular waste process, expressed in full-time equivalents or FTEs, is a function of the amount of waste processed or the waste throughput but that function is not a linear function. Efficiencies of scale dictate that, as facility capacities increase, the number of FTEs required to process a given amount of waste decrease, often eventually reaching a point where increases in waste capacity do not increase FTE requirements to perform the activity. These effects may be plotted on graphs showing the number of FTEs required to process a given input capacity. The shape of these graphs depends on not only the process but also the activities within the process and the range of input capacities considered. To facilitate incorporating these data into the modeling, polynomial equations were generated to match the curves for each process considered which included FTE requirements for pre-operational, construction, operation and maintenance (O&M), and decontamination and decommissioning (D&D) activities. Scaling factors for worker impacts were then generated based on the change in the number of FTEs required at each facility for changes in process and throughput. Construction activities and O&M were considered individually since exposure to radiation and air contaminants would not be expected during construction activities.

3.3.2.2 Methodology Used to Evaluate Waste Emplacement and Backfill Impacts

The amount of waste assumed as the input to all treatment processes was based on the amount of waste that would meet the WIPP design limit for the baseline. The output volume for different alternatives varies depending on the processes used to treat the waste. With the exception of

alternatives involving plasma processing, scaling factors for the off-site impacts of changing emplacement options are based on the changes in total volume of waste emplaced. The releases of hazardous material from waste treated with the plasma process reflects the expectation that all volatile hazardous material is either destroyed in the plasma process or immobilized in the final waste form.

Although different treatments would produce waste forms that vary in both radioactivity concentration levels and total volume, the potential increase in surface radiation levels is offset by both increased self-shielding and decreased volume of waste handled. The modeling reflects this by retaining a scaling factor of one for worker exposure to all waste forms. Scaling factors for worker impacts, based on changes in the numbers of FTEs for emplacement, are applied only for those alternatives that vary the amount of underground work because of changes in the placement or backfill options. These scaling factors are modeled as linear functions of the number of FTEs because the size of the WIPP facility does not vary in a manner that would affect efficiencies of scale.

The analyses for worker injuries and fatalities are performed by applying statistical data from industry operational experience to the number of affected workers for a particular operation. The operation data that most closely approximates the underground mining activities involved in emplacement and backfilling are those gathered for underground salt mining. Accident statistics are typically represented in terms of incident rates (IR). The incident rate is calculated as the number of occurrences divided by a multiple of the numbers of employee hours worked such as injuries per million person-hours worked. The impacts of accidents are modeled by multiplying the IR by the number of person-hours for the particular activity and alternative. The impacts for above ground waste handling, underground emplacement, and backfill activities are summed to represent the total impact for each alternative.

3.3.3 Assumptions and Input for Factor 3

The DOE Office of Environmental Management is developing extensive analyses of waste processing options at fixed locations for the EMPEIS (DOE, 1994b) consistent with the analytical techniques described in Section 3.3.2. The following alternatives were analyzed for CH-TRU waste:

- No Action (Case 1). CH-TRU waste removal, packaging, certification to WIPP acceptance criteria, and indefinite interim storage at all generator sites.

- Decentralized Alternative (Case 4). CH-TRU waste removal, packaging, certification to WIPP acceptance criteria, and stored at ten installations. CH-TRU waste from smaller sites shipped to one of the ten identified sites for processing and storage.

- Regionalized Alternative (Case 5). CH-TRU waste is consolidated, treated to minimize gas generation, and stored at five installations. Treatment involves shredding of appropriate waste and grouting of all waste.

- Regionalized Alternative 2 (Case 6). CH-TRU waste is consolidated, treated to meet RCRA land disposal restrictions, and stored at five installations. Treatment involves incineration and grouting of ash.

- Regionalized Alternative 3 (Case 8). CH-TRU waste is consolidated, treated to meet RCRA land disposal restrictions, and stored at three installations. Treatment involves incineration and grouting of ash.

- Centralized Alternative (Case 9). CH-TRU waste is consolidated, treated to meet RCRA land disposal restrictions, and disposed of at one installation, the WIPP site. Treatment involves incineration and grouting of ash.

The alternatives analyzed in the EMPEIS are not identical to those selected for analysis by the EACBS, but the similarities are sufficiently close to allow selective use of the EMPEIS results as the basis of the analysis for the four processing options for the alternatives. A discussion of some general observations common to the processing options and a description of the basis for the analysis of each of the processing options follows.

3.3.3.1 General Observations on Processing Options

With the exception of the high temperature treatment of the waste, the processing step with the highest potential for contamination release to the work area and through the facility ventilation and discharge filtration system occurs during opening of waste containers and handling of the waste. This opening and handling of waste is a necessary part of sorting the waste prior to shredding or compacting or grouting organics and inorganics. This tends to make releases from all waste processes that incorporate such activities similar in magnitude for the same throughput of waste. Only those processes that involve high temperatures or other actions that would drive off contaminants in the waste would be expected to show a very significant difference in air releases.

Similarly, except for processes that strongly concentrate the contaminants, the highest dose rates to which workers would be exposed would normally occur when they are handling the waste or waste containers. Manual activities such as emptying and sorting waste from waste containers or waste streams tend to be labor-intensive, leading to increased worker exposures for a given quantity of waste processed.

3.3.3.2 Baseline

The alternative baseline is modeled using the results from the EMPEIS Case 4. Both operations consist of retrieval, packaging, and certification to the WIPP WAC at 10 selected facilities. The modeling accounts for the small amounts of waste shipped from smaller generators to one of the ten processor facilities as well as the increase in throughput required to fill the WIPP to design capacity.

3.3.3.3 Shred and Compact

The alternatives that involve shred and compact of everything but sludges are modeled using the results from the EMPEIS shred and grout process, EMPEIS Case 5. Both waste processing methods involve opening, sorting, and shredding the waste. The compacting and grouting are performed remotely and have similar potential for airborne releases and worker exposures. The releases and exposures for either compacting or grouting are expected to be small compared to opening, sorting, and shredding the waste.

3.3.3.4 Shred and Add Clay-based Materials to Organics and Inorganics

The differences between the addition of grout material to drums of waste, as is done in EMPEIS Case 5, and the addition of clay-based material in the alternatives are negligible both for worker exposures and airborne releases. The shred and add clay EA is modeled after the EMPEIS Case 5 scenario.

3.3.3.5 Supercompaction

The processes used in supercompaction of wastes other than sludges is very similar to shred and compact with the addition of a step following the initial compaction in which the normally compacted drum is compressed in a high pressure hydraulic press. The initial steps do not require shredding but do require opening the waste drums and sorting to assure noncompressible materials are not included in the initial drum loading. Supercompaction is modeled using the results of the EMPEIS shred and grout combined with data on the supercompaction module taken from the environmental assessment of the supercompactor at the RFETS (DOE, 1990a).

3.3.3.6 Plasma Process

Plasma Processing is significantly different from EMPEIS Cases 6 and 9, incineration and grouting of the ash. However, from the standpoint of potential airborne releases, the two are similar in that both are high temperature processes which would drive off and/or destroy organic hazardous contaminants. The results from EMPEIS Cases 6 and 9 were used as the basis for impacts involving airborne releases. Worker exposure rates would be expected to be similar, and process modeling was performed to account for differences in total operational FTEs.

3.3.3.7 Emplacement Activities

The basis numbers for impact estimates of emplacement activities were taken from the WIPP FSEIS (DOE, 1990b). Industrial accident estimates, which were not available in the FSEIS, were calculated from estimates of FTEs required to perform waste handling, emplacement, and backfill activities and incident rates for salt mine operation from nationwide reported industry experience from 1978 through 1993 (U.S. Department of Labor, 1978-1993). Some types of accidents that contribute heavily to the incident rates for ordinary salt mining would not be involved in WIPP operations. Data on the contribution of types of accidents to the numbers of incidents (D'Appolonia Consulting Engineers, Inc., 1976) were used to refine the estimate of the number of incidents at the WIPP. The following assumptions were made in the analysis of the impacts of accidents involved in waste handling at the WIPP, emplacement, and backfill activities:

- The WIPP operational life is assumed to be 35 years, and emplacement operations will continue over the entire lifetime.

- Waste receipt and emplacement is based on 2 shifts per day, 5 days per week, 20 days per month for the 35 years of operational life of the WIPP.

- Based on industry experience (Hartman, 1992) backfill operations are expected to be performed as a batch operation functioning an average of 4 hours per day, 5 days per week, 20 days per month for the 35 years of operational life.

- Because of the differences between salt mining and WIPP emplacement and backfill activities, the following types of accidents are assumed not to be significant sources of accidental injuries or fatalities: falls of the roof, face, or sides of panels; explosives handling, fires, and explosions.

- Worker risk at the WIPP analyzed in this section does not include mining of panels or associated activities.

- Above-ground support activities not associated with waste handling are not included in this impact analysis.

3.3.3.8 Other Data

The polynomial equations used to estimate FTEs as a function of process throughput were created from manpower curves developed for the EMPEIS facility cost estimates (Feizollahi and Shropshire, 1994).

The estimates for waste process throughput volumes were taken from data developed for Section 3.8.

3.3.3.9 Sources of Uncertainty

Most of the estimates for human health impacts are based on numbers reported in the EMPEIS. These are based on generic designs for hypothetical facilities, not on measured dose or release rates of currently constructed and operating facilities. The use of those results includes uncertainty associated with those estimates, including uncertainties from definition of the physical setting; model applicability and assumptions; fate, transport, and exposure parameters; and toxicity and risk characterization. Other data used in the analysis, such as the waste quantities and FTE estimates, have uncertainties associated with them.

While the modeling process in the EMPEIS was refined as much as possible for individual facilities, the estimates were not intended to indicate absolute risks for any alternative or facility. The intent of the analysis in the EMPEIS and also in this document was to provide estimates of relative risks between alternatives. Because of that, any systematic errors in the modeling would tend to be diminished in the final analysis since the same errors would be applied to each case.

The largest single source of uncertainty in this analysis arises from applying the EMPEIS models to the alternatives. Two extensions have been made, which are potential sources of error. There are no adequate data available to allow the estimation of how much error may be involved in applying results from the analysis of processes selected in the EMPEIS to those selected in this report. Because this report also considers a complete set of configurations for each waste handling process, there are additional uncertainties involved in the extension of EMPEIS alternative data to additional configurations.

Other potential sources of uncertainty are listed below. These, however, are considered of minor consequence compared to those mentioned above. It is unlikely that any of these uncertainties have any measurable impact on the final results but are listed primarily for thoroughness.

- The EMPEIS calculations include adjustments for the isotopic mixtures expected at each facility based on available radionuclide inventories. As wastes from different sites were combined to allow analysis of configurations not analyzed in the EMPEIS, no adjustment was made to account for changes in the resulting radionuclide inventories.

- The EMPEIS analysis addressed how much of the waste from each site was readily retrievable, how much would require potentially difficult retrieval (such as retrieval of buried waste for which container integrity may have been compromised), and how much was newly generated. Each of these sources of waste yields different values for airborne releases and potential worker exposures. Individual site scaling factors were developed using the differences between the waste inventory used in the EMPEIS and the more current inventory figures used by the EACBS in this report. Thus the scaling factors use an inherent assumption that the ratio of retrieved waste to newly generated waste does not change. Actual increases in waste throughput at each facility would result from changes in the quantity of newly generated waste rather than changes in the quantity of retrieved waste.

- Model adjustments were performed for changes in total waste volumes on a site-by-site basis. Although changes in the organic:inorganic:sludge ratios would affect both worker doses and airborne releases, available data were insufficient to allow accounting for those differences.

- The EMPEIS does not assume any storage at the WIPP. All EMPEIS alternatives for TRU waste include storage at the location where the waste is processed. Storage does not increase airborne releases but does increase worker doses from required inspections and maintenance. However, these doses would be expected to be directly proportional to waste volume and relatively unaffected by waste form. In-storage inspection does not benefit from efficiencies of scale. Although different waste forms may be expected to have different dose rates, any increases in dose rates are offset by decreases in the total volume requiring inspection and emplacement. Thus, while the EMPEIS worker doses on which the alternatives are based include doses from long-term waste storage, the effect is applied to all processes and configurations and does not change the relative assessment of those alternatives.

3.3.4 Results of Analysis

Tables 3-11 through 3-28 contain the results of the human health impact analysis for processing and emplacing CH-TRU waste. RH-TRU waste was not evaluated for human health impacts as part of the EACBS. All impacts are expressed as impacts accumulated over a 20-year operating lifetime of the waste processing facilities.

System-wide human health impacts for the baseline and four processing options described in Section 3.3.2 and the three processing configurations are shown in Tables 3-11 through 3-23. Each table displays the impacts as detailed in Table 3-9 for a single processing option and configuration. The injuries and fatalities from industrial accidents are further divided into impacts associated with construction and operations activities. Each table also lists the waste processing facility associated with the most exposed individual impacts reported in the body of the table.

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TABLE 3-11

SYSTEM-WIDE HUMAN HEALTH IMPACTS PREPARE AND CERTIFY WASTE TO WIPP ACCEPTANCE CRITERIA AT 10 LOCATIONS BASELINE

			Hazardous Chemicals		Physical
Receptor	Endpoint	Radionuclides	Carcinogens	Noncarcinogens	Hazards
Co-located Workers	Dose (person-rem)	3.73×10^{-02}			
	Excess Fatalities	1.78×10^{-05}			
	Excess Cancers		5.51×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	1.54×10^{-05}			
	Excess Risk	7.78×10^{-09}			
	Excess Cancers		1.44×10^{-11}		
	Hazard Index			2.27×10^{-09}	
Off-site Population	Dose (Person-rem)	3.89×10^{-01}			
	Excess Fatalities	1.94×10^{-04}			
	Excess Cancers		2.11×10^{-07}		
Most Exposed Off-site Individual	Dose (Rem)	2.14×10^{-05}			
	Excess Risk	1.11×10^{-08}			
	Excess Cancers		5.44×10^{-12}		
	Hazard Index			2.92×10^{-10}	
Workers	Dose (FTE-rem)	$1.94 \times 10^{+03}$			
	Excess Fatalities	7.78×10^{-01}			
	Excess Cancers		1.30×10^{-05}		
	Exposure Index			4.02×10^{-05}	
	Construction Fatalities				9.92×10^{-01}
	Construction Injuries				$8.52 \times 10^{+02}$
	Operations Fatalities				$1.81 \times 10^{+00}$
	Operations Injuries				$7.65 \times 10^{+02}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-12

SYSTEM-WIDE HUMAN HEALTH IMPACTS SUPERCOMPACTION OF WASTE AT 10 LOCATIONS ALTERNATIVE CASES 1 AND 77(a–d)

			Hazardous Chemicals		Physical
Receptor	Endpoint	Radionuclides	Carcinogens	Noncarcinogens	Hazards
Co-located Workers	Dose (person-rem)	5.00×10^{-01}			
	Excess Fatalities	2.50×10^{-05}			
	Excess Cancers		9.06×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.34×10^{-05}			
	Excess Risk	1.20×10^{-08}			
	Excess Cancers		2.34×10^{-11}		
	Hazard Index			3.90×10^{-09}	
Off-site Population	Dose (person-rem)	5.31×10^{-01}			
	Excess Fatalities	2.65×10^{-04}			
	Excess Cancers		3.59×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	5.29×10^{-05}			
	Excess Risk	2.61×10^{-08}			
	Excess Cancers		1.82×10^{-11}		
	Hazard Index			8.32×10^{-10}	
Workers	Dose (FTE-rem)	$2.42 \times 10^{+03}$			
	Excess Fatalities	9.54×10^{-01}			
	Excess Cancers		3.03×10^{-05}		
	Exposure Index			4.69×10^{-05}	
	Construction Fatalities				$1.47 \times 10^{+00}$
	Construction Injuries				$1.28 \times 10^{+03}$
	Operations Fatalities				$2.57 \times 10^{+00}$
	Operations Injuries				$1.14 \times 10^{+03}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-13

SYSTEM-WIDE HUMAN HEALTH IMPACTS SUPERCOMPACTION OF WASTE AT FIVE LOCATIONS ALTERNATIVE CASES 1 AND 77(a–d)

			Hazardous Chemicals		Physical
Receptor	Endpoint	Radionuclides	Carcinogens	Noncarcinogens	Hazards
Co-located Workers	Dose (person-rem)	5.13×10^{-01}			
	Excess Fatalities	2.57×10^{-05}			
	Excess Cancers		9.30×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.41×10^{-05}			
	Excess Risk	1.24×10^{-08}			
	Excess Cancers		2.41×10^{-11}		
	Hazard Index			4.01×10^{-09}	
Off-site Population	Dose (person-rem)	5.45×10^{-01}			
	Excess Fatalities	2.73×10^{-04}			
	Excess Cancers		3.69×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	2.72×10^{-05}			
	Excess Risk	1.34×10^{-08}			
	Excess Cancers		9.33×10^{-12}		
	Hazard Index			4.28×10^{-10}	
Workers	Dose (FTE-rem)	$2.52 \times 10^{+03}$			
	Excess Fatalities	9.92×10^{-01}			
	Excess Cancers		3.15×10^{-05}		
	Exposure Index			4.88×10^{-05}	
	Construction Fatalities				$1.16 \times 10^{+00}$
	Construction Injuries				$1.00 \times 10^{+03}$
	Operations Fatalities				$2.68 \times 10^{+00}$
	Operations Injuries				$1.18 \times 10^{+03}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-14

SYSTEM-WIDE HUMAN HEALTH IMPACTS SUPERCOMPACTION OF WASTE AT ONE LOCATION ALTERNATIVE CASES 1 AND 77(a–d)

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	7.99×10^{-01}			
	Excess Fatalities	3.99×10^{-05}			
	Excess Cancers		1.45×10^{-07}		
Most Exposed Co-located Individual	Dose (rem)	3.74×10^{-05}			
	Excess Risk	1.92×10^{-08}			
	Excess Cancers		3.74×10^{-11}		
	Hazard Index			6.24×10^{-09}	
Off-site Population	Dose (person-rem)	8.49×10^{-01}			
	Excess Fatalities	4.24×10^{-04}			
	Excess Cancers		5.74×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	3.17×10^{-04}			
	Excess Risk	1.56×10^{-07}			
	Excess Cancers		1.09×10^{-10}		
	Hazard Index			4.98×10^{-09}	
Workers	Dose (FTE-rem)	$2.79 \times 10^{+03}$			
	Excess Fatalities	$1.10 \times 10^{+00}$			
	Excess Cancers		3.49×10^{-05}		
	Exposure Index			5.41×10^{-05}	
	Construction Fatalities				8.18×10^{-01}
	Construction Injuries				$7.11 \times 10^{+02}$
	Operations Fatalities				$2.97 \times 10^{+00}$
	Operations Injuries				$1.31 \times 10^{+03}$

The most exposed off-site individual is associated with WIPP

1

TABLE 3-15

SYSTEM-WIDE HUMAN HEALTH IMPACTS SHRED AND COMPACT WASTE AT 10 LOCATIONS ALTERNATIVE CASE 6

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	5.00×10^{-01}			
	Excess Fatalities	2.50×10^{-05}			
	Excess Cancers		9.06×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.34×10^{-05}			
	Excess Risk	1.20×10^{-08}			
	Excess Cancers		2.34×10^{-11}		
	Hazard Index			3.90×10^{-09}	
Off-site Population	Dose (person-rem)	5.31×10^{-01}			
	Excess Fatalities	2.65×10^{-04}			
	Excess Cancers		3.59×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	5.29×10^{-05}			
	Excess Risk	2.61×10^{-08}			
	Excess Cancers		1.82×10^{-11}		
	Hazard Index			8.32×10^{-10}	
Workers	Dose (FTE-rem)	$2.01 \times 10^{+03}$			
	Excess Fatalities	7.91×10^{-01}			
	Excess Cancers		2.51×10^{-05}		
	Exposure Index			3.89×10^{-05}	
	Construction Fatalities				$1.65 \times 10^{+00}$
	Construction Injuries				$1.43 \times 10^{+03}$
	Operations Fatalities				$2.13 \times 10^{+00}$
	Operations Injuries				$9.41 \times 10^{+02}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-16

SYSTEM-WIDE HUMAN HEALTH IMPACTS SHRED AND COMPACT WASTE AT FIVE LOCATIONS ALTERNATIVE CASE 6

			Hazardous Chemicals		Physical
Receptor	Endpoint	Radionuclides	Carcinogens	Noncarcinogens	Hazards
Co-located Workers	Dose (person-rem)	5.13×10^{-01}			
	Excess Fatalities	2.57×10^{-05}			
	Excess Cancers		9.30×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.41×10^{-05}			
	Excess Risk	1.24×10^{-08}			
	Excess Cancers		2.41×10^{-11}		
	Hazard Index			4.01×10^{-09}	
Off-site Population	Dose (person-rem)	5.45×10^{-01}			
	Excess Fatalities	2.73×10^{-04}			
	Excess Cancers		3.69×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	2.72×10^{-05}			
	Excess Risk	1.34×10^{-08}			
	Excess Cancers		9.33×10^{-12}		
	Hazard Index			4.28×10^{-10}	
Workers	Dose (FTE-rem)	$2.06 \times 10^{+03}$			
	Excess Fatalities	8.12×10^{-01}			
	Excess Cancers		2.58×10^{-05}		
	Exposure Index			4.00×10^{-05}	
	Construction Fatalities				$1.26 \times 10^{+00}$
	Construction Injuries				$1.09 \times 10^{+03}$
	Operations Fatalities				$2.19 \times 10^{+00}$
	Operations Injuries				$9.67 \times 10^{+02}$

The most exposed off-site individual is associated with Los Alamos National Lab

1

TABLE 3-17

SYSTEM-WIDE HUMAN HEALTH IMPACTS SHRED AND COMPACT WASTE AT ONE LOCATION ALTERNATIVE CASE 6

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	7.99×10^{-01}			
	Excess Fatalities	3.99×10^{-05}			
	Excess Cancers		1.45×10^{-07}		
Most Exposed Co-located Individual	Dose (rem)	3.74×10^{-05}			
	Excess Risk	1.92×10^{-08}			
	Excess Cancers		3.74×10^{-11}		
	Hazard Index			6.24×10^{-09}	
Off-site Population	Dose (person-rem)	8.49×10^{-01}			
	Excess Fatalities	4.24×10^{-04}			
	Excess Cancers		5.74×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	9.29×10^{-05}			
	Excess Risk	4.58×10^{-08}			
	Excess Cancers		3.18×10^{-11}		
	Hazard Index			1.46×10^{-09}	
Workers	Dose (FTE-rem)	$3.04 \times 10^{+03}$			
	Excess Fatalities	$1.20 \times 10^{+00}$			
	Excess Cancers		3.80×10^{-05}		
	Exposure Index			5.90×10^{-05}	
	Construction Fatalities				8.44×10^{-01}
	Construction Injuries				$7.35 \times 10^{+02}$
	Operations Fatalities				$3.23 \times 10^{+00}$
	Operations Injuries				$1.43 \times 10^{+03}$

The most exposed off-site individual is associated with WIPP

1

TABLE 3-18

SYSTEM-WIDE HUMAN HEALTH IMPACTS
PLASMA PROCESSING OF WASTE AT 10 LOCATIONS
ALTERNATIVE CASE 10

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	$9.61 \times 10^{+02}$			
	Excess Fatalities	4.73×10^{-01}			
	Excess Cancers		7.80×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	6.82×10^{-01}			
	Excess Risk	3.34×10^{-04}			
	Excess Cancers		2.09×10^{-11}		
	Hazard Index			1.81×10^{-07}	
Off-site Population	Dose (person-rem)	$9.33 \times 10^{+03}$			
	Excess Fatalities	$4.60 \times 10^{+00}$			
	Excess Cancers		3.06×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	4.92×10^{-01}			
	Excess Risk	2.54×10^{-04}			
	Excess Cancers		1.82×10^{-11}		
	Hazard Index			4.17×10^{-08}	
Workers	Dose (FTE-rem)	$2.88 \times 10^{+03}$			
	Excess Fatalities	$1.17 \times 10^{+00}$			
	Excess Cancers		4.81×10^{-05}		
	Exposure Index			1.65×10^{-03}	
	Construction Fatalities				$4.73 \times 10^{+00}$
	Construction Injuries				$3.94 \times 10^{+03}$
	Operations Fatalities				$5.00 \times 10^{+00}$
	Operations Injuries				$2.12 \times 10^{+03}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-19

SYSTEM-WIDE HUMAN HEALTH IMPACTS
PLASMA PROCESSING OF WASTE AT FIVE LOCATIONS
ALTERNATIVE CASE 10

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	$1.00 \times 10^{+03}$			
	Excess Fatalities	4.93×10^{-01}			
	Excess Cancers		8.13×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	7.11×10^{-01}			
	Excess Risk	3.48×10^{-04}			
	Excess Cancers		2.18×10^{-11}		
	Hazard Index			1.89×10^{-07}	
Off-site Population	Dose (person-rem)	$9.72 \times 10^{+03}$			
	Excess Fatalities	$4.79 \times 10^{+00}$			
	Excess Cancers		3.19×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	2.53×10^{-01}			
	Excess Risk	1.30×10^{-04}			
	Excess Cancers		9.34×10^{-12}		
	Hazard Index			2.14×10^{-08}	
Workers	Dose (FTE-rem)	$2.24 \times 10^{+03}$			
	Excess Fatalities	9.10×10^{-01}			
	Excess Cancers		3.73×10^{-05}		
	Exposure Index			1.28×10^{-03}	
	Construction Fatalities				$3.31 \times 10^{+00}$
	Construction Injuries				$2.75 \times 10^{+03}$
	Operations Fatalities				$3.88 \times 10^{+00}$
	Operations Injuries				$1.64 \times 10^{+03}$

The most exposed off-site individual is associated with Los Alamos National Lab

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TABLE 3-20

SYSTEM-WIDE HUMAN HEALTH IMPACTS
PLASMA PROCESSING OF WASTE AT ONE LOCATION
ALTERNATIVE CASE 10

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	$1.46 \times 10^{+02}$			
	Excess Fatalities	7.37×10^{-02}			
	Excess Cancers		9.73×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	5.60×10^{-01}			
	Excess Risk	2.80×10^{-04}			
	Excess Cancers		2.21×10^{-11}		
	Hazard Index			6.78×10^{-07}	
Off-site Population	Dose (person-rem)	$1.77 \times 10^{+03}$			
	Excess Fatalities	8.99×10^{-01}			
	Excess Cancers		3.39×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	4.72×10^{-01}			
	Excess Risk	2.36×10^{-04}			
	Excess Cancers		7.07×10^{-12}		
	Hazard Index			1.12×10^{-07}	
Workers	Dose (FTE-rem)	$3.34 \times 10^{+03}$			
	Excess Fatalities	$1.34 \times 10^{+00}$			
	Excess Cancers		1.69×10^{-04}		
	Exposure Index			2.16×10^{-03}	
	Construction Fatalities				$1.75 \times 10^{+00}$
	Construction Injuries				$1.61 \times 10^{+03}$
	Operations Fatalities				$3.54 \times 10^{+00}$
	Operations Injuries				$1.55 \times 10^{+03}$

The most exposed off-site individual is associated with WIPP

1

TABLE 3-21

SYSTEM-WIDE HUMAN HEALTH IMPACTS
SHRED AND ADD CLAY TO WASTE AT 10 LOCATIONS
ALTERNATIVE CASES 94(a–f)

			Hazardous Chemicals		Physical
Receptor	Endpoint	Radionuclides	Carcinogens	Noncarcinogens	Hazards
Co-located Workers	Dose (person-rem)	5.00×10^{-01}			
	Excess Fatalities	2.50×10^{-05}			
	Excess Cancers		9.06×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.34×10^{-05}			
	Excess Risk	1.20×10^{-08}			
	Excess Cancers		2.34×10^{-11}		
	Hazard Index			3.90×10^{-09}	
Off-site Population	Dose (person-rem)	5.31×10^{-01}			
	Excess Fatalities	2.65×10^{-04}			
	Excess Cancers		3.59×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	5.29×10^{-05}			
	Excess Risk	2.61×10^{-08}			
	Excess Cancers		1.82×10^{-11}		
	Hazard Index			8.32×10^{-10}	
Workers	Dose (FTE-rem)	$2.01 \times 10^{+03}$			
	Excess Fatalities	7.91×10^{-01}			
	Excess Cancers		2.51×10^{-05}		
	Exposure Index			3.89×10^{-05}	
	Construction Fatalities				$1.65 \times 10^{+00}$
	Construction Injuries				$1.43 \times 10^{+03}$
	Operations Fatalities				$2.13 \times 10^{+00}$
	Operations Injuries				$9.41 \times 10^{+02}$

The most exposed off-site individual is associated with Los Alamos National Lab

1

TABLE 3-22

SYSTEM-WIDE HUMAN HEALTH IMPACTS SHRED AND ADD CLAY TO WASTE AT FIVE LOCATIONS ALTERNATIVE CASES 94(a–f)

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	5.13×10^{-01}			
	Excess Fatalities	2.57×10^{-05}			
	Excess Cancers		9.30×10^{-08}		
Most Exposed Co-located Individual	Dose (rem)	2.41×10^{-05}			
	Excess Risk	1.24×10^{-08}			
	Excess Cancers		2.41×10^{-11}		
	Hazard Index			4.01×10^{-09}	
Off-site Population	Dose (person-rem)	5.45×10^{-01}			
	Excess Fatalities	2.73×10^{-04}			
	Excess Cancers		3.69×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	2.72×10^{-05}			
	Excess Risk	1.34×10^{-08}			
	Excess Cancers		9.33×10^{-12}		
	Hazard Index			4.28×10^{-10}	
Workers	Dose (FTE-rem)	$2.06 \times 10^{+03}$			
	Excess Fatalities	8.12×10^{-01}			
	Excess Cancers		2.58×10^{-05}		
	Exposure Index			4.00×10^{-05}	
	Construction Fatalities				$1.26 \times 10^{+00}$
	Construction Injuries				$1.09 \times 10^{+03}$
	Operations Fatalities				$2.19 \times 10^{+00}$
	Operations Injuries				$9.67 \times 10^{+02}$

The most exposed off-site individual is associated with Los Alamos National Lab

1

TABLE 3-23

SYSTEM-WIDE HUMAN HEALTH IMPACTS
SHRED AND ADD CLAY TO WASTE AT ONE LOCATION
ALTERNATIVE CASES 94(a–f)

Receptor	Endpoint	Radionuclides	Hazardous Chemicals: Carcinogens	Hazardous Chemicals: Noncarcinogens	Physical Hazards
Co-located Workers	Dose (person-rem)	7.99×10^{-01}			
	Excess Fatalities	3.99×10^{-05}			
	Excess Cancers		1.45×10^{-07}		
Most Exposed Co-located Individual	Dose (rem)	3.74×10^{-05}			
	Excess Risk	1.92×10^{-08}			
	Excess Cancers		3.74×10^{-11}		
	Hazard Index			6.24×10^{-09}	
Off-site Population	Dose (person-rem)	8.49×10^{-01}			
	Excess Fatalities	4.24×10^{-04}			
	Excess Cancers		5.74×10^{-07}		
Most Exposed Off-site Individual	Dose (rem)	9.29×10^{-05}			
	Excess Risk	4.58×10^{-08}			
	Excess Cancers		3.18×10^{-11}		
	Hazard Index			1.46×10^{-09}	
Workers	Dose (FTE-rem)	$3.04 \times 10^{+03}$			
	Excess Fatalities	$1.20 \times 10^{+00}$			
	Excess Cancers		3.80×10^{-05}		
	Exposure Index			5.90×10^{-05}	
	Construction Fatalities				8.44×10^{-01}
	Construction Injuries				$7.35 \times 10^{+02}$
	Operations Fatalities				$3.23 \times 10^{+00}$
	Operations Injuries				$1.43 \times 10^{+03}$

The most exposed off-site individual is associated with WIPP

TABLE 3-24

SUMMARY OF ENGINEERED ALTERNATIVES HUMAN HEALTH IMPACTS CONTACT-HANDLED TRU WASTE RISKS TO TOTAL POPULATIONS BY WASTE TREATMENT AND CONFIGURATION

EA Number	Treatment Process	Configuration	Off-site Population		Co-located Workers		Workers		C&OF[3]
			CF[1]	CI[2]	CF	CI	CF	CI	
0	Baseline	Ten sites	1.94×10^{-04}	5.51×10^{-08}	1.78×10^{-05}	1.44×10^{-11}	7.78×10^{-01}	1.30×10^{-05}	2.81
1	Supercompaction	Ten sites	2.65×10^{-04}	3.59×10^{-07}	2.50×10^{-05}	9.06×10^{-08}	9.54×10^{-01}	3.03×10^{-05}	4.05
1	Supercompaction	Five sites	2.73×10^{-04}	3.69×10^{-07}	2.57×10^{-05}	9.30×10^{-08}	9.92×10^{-01}	3.15×10^{-05}	3.83
1	Supercompaction	One site	4.24×10^{-04}	5.74×10^{-07}	3.99×10^{-05}	1.45×10^{-07}	$1.10 \times 10^{+00}$	3.49×10^{-05}	3.79
6	Shred and Compact	Ten sites	2.65×10^{-04}	3.59×10^{-07}	2.50×10^{-05}	9.06×10^{-08}	7.91×10^{-01}	2.51×10^{-05}	3.78
6	Shred and Compact	Five sites	2.73×10^{-04}	3.69×10^{-07}	2.57×10^{-05}	9.30×10^{-08}	8.12×10^{-01}	2.58×10^{-05}	3.45
6	Shred and Compact	One site	4.24×10^{-04}	5.74×10^{-07}	3.99×10^{-05}	1.45×10^{-07}	$1.20 \times 10^{+00}$	3.80×10^{-05}	4.08
10	Plasma Processing	Ten sites	$4.60 \times 10^{+00}$	3.06×10^{-07}	4.73×10^{-01}	7.80×10^{-08}	$1.17 \times 10^{+00}$	4.81×10^{-05}	9.73
10	Plasma Processing	Five sites	$4.79 \times 10^{+00}$	3.19×10^{-07}	4.93×10^{-01}	8.13×10^{-08}	9.10×10^{-01}	3.73×10^{-05}	7.18
10	Plasma Processing	One site	8.99×10^{-01}	3.39×10^{-07}	7.37×10^{-02}	9.73×10^{-08}	$1.34 \times 10^{+00}$	1.69×10^{-04}	5.29
94	Shred and Add Clay	Ten sites	2.65×10^{-04}	3.59×10^{-07}	2.50×10^{-05}	9.06×10^{-08}	7.91×10^{-01}	2.51×10^{-05}	3.78
94	Shred and Add Clay	Five sites	2.73×10^{-04}	3.69×10^{-07}	2.57×10^{-05}	9.30×10^{-08}	8.12×10^{-01}	2.58×10^{-05}	3.45
94	Shred and Add Clay	One site	4.24×10^{-04}	5.74×10^{-07}	3.99×10^{-05}	1.45×10^{-07}	$1.20 \times 10^{+00}$	3.80×10^{-05}	4.08

[1]CF—cancer fatality.
[2]CI—cancer incidence.
[3]C&OF—fatalities from physical hazards during construction and operating activities.

TABLE 3-25

SUMMARY OF ENGINEERED ALTERNATIVES HUMAN HEALTH IMPACTS CONTACT-HANDLED TRU WASTE RISKS TO OFF-SITE AND CO-LOCATED WORKERS BY WASTE TREATMENT AND CONFIGURATION

EA Number	Treatment Process	Configuration	Most Exposed Off-site Individual			Most Exposed Co-located Worker			Associated Site
			CF[2]	CI[2]	HI[3]	CF	CI	HI	
0	Baseline	Ten sites	1.11×10^{-08}	5.44×10^{-12}	2.92×10^{-10}	7.78×10^{-09}	1.44×10^{-11}	2.27×10^{-09}	Los Alamos National Lab
1	Supercompaction	Ten sites	2.61×10^{-08}	1.82×10^{-11}	8.32×10^{-10}	1.20×10^{-08}	2.34×10^{-11}	3.90×10^{-09}	Los Alamos National Lab
1	Supercompaction	Five sites	1.34×10^{-08}	9.33×10^{-12}	4.28×10^{-10}	1.24×10^{-08}	2.41×10^{-11}	4.01×10^{-09}	Los Alamos National Lab
1	Supercompaction	One site	1.56×10^{-07}	1.09×10^{-10}	4.98×10^{-09}	3.99×10^{-05}	3.74×10^{-11}	6.24×10^{-09}	WIPP
6	Shred and Compact	Ten sites	2.61×10^{-08}	1.82×10^{-11}	8.32×10^{-10}	1.20×10^{-08}	2.34×10^{-11}	3.90×10^{-09}	Los Alamos National Lab
6	Shred and Compact	Five sites	1.34×10^{-08}	9.33×10^{-12}	4.28×10^{-10}	1.24×10^{-08}	2.41×10^{-11}	4.01×10^{-09}	Los Alamos National Lab
6	Shred and Compact	One site	4.58×10^{-08}	3.18×10^{-11}	1.46×10^{-09}	1.92×10^{-08}	3.74×10^{-11}	6.24×10^{-09}	WIPP
10	Plasma Processing	Ten sites	2.54×10^{-04}	1.82×10^{-11}	4.17×10^{-08}	3.34×10^{-04}	2.09×10^{-11}	1.81×10^{-07}	Los Alamos National Lab
10	Plasma Processing	Five sites	1.30×10^{-04}	9.34×10^{-12}	2.14×10^{-08}	3.48×10^{-04}	2.18×10^{-11}	1.89×10^{-07}	Los Alamos National Lab
10	Plasma Processing	One site	2.36×10^{-04}	7.07×10^{-12}	1.12×10^{-07}	2.80×10^{-04}	2.21×10^{-11}	6.78×10^{-07}	WIPP
94	Shred and Add Clay	Ten sites	2.61×10^{-08}	1.82×10^{-11}	8.32×10^{-10}	1.20×10^{-08}	2.34×10^{-11}	3.90×10^{-09}	Los Alamos National Lab
94	Shred and Add Clay	Five sites	1.34×10^{-08}	9.33×10^{-12}	4.28×10^{-10}	1.24×10^{-08}	2.41×10^{-11}	4.01×10^{-09}	Los Alamos National Lab
94	Shred and Add Clay	One site	4.58×10^{-08}	3.18×10^{-11}	1.46×10^{-09}	1.92×10^{-08}	3.74×10^{-11}	6.24×10^{-09}	WIPP

[1]CF—cancer fatality.
[2]CI—cancer incidence.
[3]HI—hazard index.

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TABLE 3-26

SUMMARY OF HUMAN HEALTH IMPACTS ASSOCIATED WITH CH-TRU WASTE EMPLACEMENT AT THE WIPP RADIATION IMPACTS

		Workers		Most Exposed Off-site		Collective Off-site	
EA Number	Case Description	Doses (FTE-rem)	Excess Fatalities	Doses (rem)	Excess Risk	Doses (person-rem)	Excess Fatalities
0	Baseline	322.85	0.13	6.65×10^{-05}	3.32×10^{-08}	2.09×10^{-02}	1.04×10^{-05}
1	Supercompaction	322.85	0.13	6.65×10^{-05}	3.32×10^{-08}	1.17×10^{-02}	5.87×10^{-06}
6	Shred and Compact	322.85	0.13	3.73×10^{-05}	1.87×10^{-08}	1.75×10^{-02}	8.75×10^{-06}
10	Plasma Processing	322.85	0.13	5.57×10^{-05}	2.79×10^{-08}	6.00×10^{-03}	3.00×10^{-06}
33	Sand plus Clay Backfill	345.27	0.14	1.91×10^{-05}	9.54×10^{-09}	2.09×10^{-02}	1.04×10^{-05}
35a	Salt Aggregate Grout Backfill	357.23	0.14	6.65×10^{-05}	3.32×10^{-08}	2.09×10^{-02}	1.04×10^{-05}
35b	Cementitious Grout Backfill	357.23	0.14	6.65×10^{-05}	3.32×10^{-08}	2.09×10^{-02}	1.04×10^{-05}
111	Clay Based Backfill	342.28	0.14	6.65×10^{-05}	3.32×10^{-08}	2.09×10^{-02}	1.04×10^{-05}
77a	Supercompact with Salt Aggregate Grout	342.07	0.14	6.65×10^{-05}	3.32×10^{-08}	1.17×10^{-02}	5.87×10^{-06}
77b	Supercompact with Clay Based Backfill	340.15	0.14	3.73×10^{-05}	1.87×10^{-08}	1.17×10^{-02}	5.87×10^{-06}
77c	Supercompact with Sand and Clay Backfill	343.99	0.14	3.73×10^{-05}	1.87×10^{-08}	1.17×10^{-02}	5.87×10^{-06}
77d	Supercompact with Cao Backfill	338.23	0.14	3.73×10^{-05}	1.87×10^{-08}	1.17×10^{-02}	5.87×10^{-06}
83	Cao Backfill	339.29	0.14	3.73×10^{-05}	1.87×10^{-08}	2.09×10^{-02}	1.04×10^{-05}
94a	Shred and Add Clay to Waste	322.85	0.13	6.65×10^{-05}	3.32×10^{-08}	2.43×10^{-02}	1.21×10^{-05}
94b	Shred and Add Clay, Clay/sand Backfill	346.77	0.14	7.73×10^{-05}	3.86×10^{-08}	2.43×10^{-02}	1.21×10^{-05}
94c	Shred and Add Clay, Cementitious Grout	366.20	0.15	7.73×10^{-05}	3.86×10^{-08}	2.43×10^{-02}	1.21×10^{-05}
94d	Shred and Add Clay, Salt Aggregate Grout	343.78	0.14	7.73×10^{-05}	3.86×10^{-08}	2.43×10^{-02}	1.21×10^{-05}
94e	Shred and Add Clay to Waste, Clay Backfill	342.28	0.14	7.73×10^{-05}	3.86×10^{-08}	2.43×10^{-02}	1.21×10^{-05}
94f	Shred and Add Clay to Waste Cao Backfill	339.29	0.14	7.73×10^{-05}	3.86×10^{-08}	2.43×10^{-02}	1.21×10^{-05}

TABLE 3-27

SUMMARY OF HUMAN HEALTH IMPACTS ASSOCIATED WITH CH-TRU WASTE EMPLACEMENT AT THE WIPP HAZARDOUS AND TOXIC CHEMICAL IMPACTS

EA Number	Case Description	Carcinogenic Chemicals (Excess Cancers)			Toxic Chemicals (Hazard Index)		
		Workers	Most Exposed Co-located	Most Exposed Off-site	Workers	Most Exposed Co-located	Most Exposed Off-site
0	Baseline	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
1	Supercompaction	6.93×10^{-06}	1.71×10^{-10}	1.44×10^{-10}	9.60×10^{-04}	2.40×10^{-08}	4.43×10^{-09}
6	Shred and Compact	1.03×10^{-05}	2.55×10^{-10}	2.15×10^{-10}	1.43×10^{-03}	3.58×10^{-08}	6.61×10^{-09}
10	Plasma Processing	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
33	Sand plus Clay Backfill	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
35a	Salt Aggregate Grout	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
35b	Cementitious Grout	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
111	Clay Based Backfill	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
77a	Supercompact with	6.93×10^{-06}	1.71×10^{-10}	1.44×10^{-10}	9.60×10^{-04}	2.40×10^{-08}	4.43×10^{-09}
77b	Supercompact with	6.93×10^{-06}	1.71×10^{-10}	1.44×10^{-10}	9.60×10^{-04}	2.40×10^{-08}	4.43×10^{-09}
77c	Supercompact with	6.93×10^{-06}	1.71×10^{-10}	1.44×10^{-10}	9.60×10^{-04}	2.40×10^{-08}	4.43×10^{-09}
77d	Supercompact with	6.93×10^{-06}	1.71×10^{-10}	1.44×10^{-10}	9.60×10^{-04}	2.40×10^{-08}	4.43×10^{-09}
83	Cao Backfill	1.23×10^{-05}	3.04×10^{-10}	2.56×10^{-10}	1.71×10^{-03}	4.27×10^{-08}	7.88×10^{-09}
94a	Shred and Add Clay to	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}
94b	Shred and Add Clay,	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}
94c	Shred and Add Clay,	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}
94d	Shred and Add Clay,	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}
94e	Shred and Add Clay to	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}
94f	Shred and Add Clay to	1.44×10^{-05}	3.53×10^{-10}	2.98×10^{-10}	1.99×10^{-03}	4.97×10^{-08}	9.16×10^{-09}

1

TABLE 3-28

SUMMARY OF HUMAN HEALTH IMPACTS ASSOCIATED CH-TRU WASTE EMPLACEMENT AT THE WIPP WORKER INDUSTRIAL ACCIDENTS

EA Number	Case Description	Injuries	Fatalities
0	Baseline	53.63	0.16
1	Supercompaction	44.05	0.13
6	Shred and Compact	44.05	0.13
10	Plasma Processing	33.20	0.10
33	Sand plus Clay Backfill	64.50	0.29
35a	Salt Aggregate Grout Backfill	70.81	0.30
35b	Cementitious Grout Backfill	70.81	0.30
111	Clay Based Backfill	62.53	0.18
77a	Supercompact with Salt Aggregate Grout	55.53	0.15
77b	Supercompact with Clay Based Backfill	49.80	0.15
77c	Supercompact with Sand and Clay Backfill	51.77	0.15
77d	Supercompact with Cao Backfill	51.06	0.25
83	CaO Backfill	66.45	0.28
94a	Shred and Add Clay to Waste	53.63	0.16
94b	Shred and Add Clay to Waste Clay and Sand Backfill	67.04	0.39
94c	Shred and Add Clay to Waste Cementitious Grout Backfill	69.14	0.21
94d	Shred and Add Clay to Waste Salt Aggregate Grout Backfill	69.56	0.49
94e	Shred and Add Clay to Waste Clay Based Backfill	61.83	0.18
94f	Shred and Add Clay to Waste Cao Backfill	63.25	0.28

Table 3-24 shows a summary of the system-wide cumulative impacts on workers, co-located workers, and the off-site population for all combinations of waste processes and configurations. The impacts included in this table are the excess cancer fatalities from radiation exposure, excess cancer incidence from hazardous chemical exposure, and worker fatalities from industrial accidents. Table 3-25 contains similar data for the most exposed off-site individual and most exposed co-located worker. The impacts of industrial accidents from handling CH-TRU waste are not applicable to co-located workers and off-site individuals and are not included on Table 3-25. The table does add the Hazard Index for the most exposed individuals as well as the facility at which the highest individual impact was determined.

Tables 3-26 through 3-28 show summaries of the impacts on workers, co-located workers, and the off-site population from emplacement activities at the WIPP. Each combination of waste processing and emplacement backfill are represented because the waste processes generate different waste forms and quantities for equivalent inputs. Differing backfill options affect the amount of time and effort required to complete the emplacement of the waste. Table 3-26 shows the impacts, in terms of both dose and excess fatalities, from collective doses to workers and the off-site population and the total dose to the most exposed off-site individual. Table 3-27 shows the impacts of both carcinogenic and toxic chemicals on workers, the most exposed co-located worker, and the most exposed off-site individual. Table 3-28 shows the injuries and fatal accidents at the WIPP estimated to involve workers over the period analyzed for waste emplacement at the WIPP.

As discussed in Section 3.3.3.9, there are a number of sources of uncertainty, but the largest single source of uncertainty arises from applying EMPEIS models to the alternatives. The equivalence of the scenarios in the EMPEIS and the alternatives vary from very close, such as using the shred and grout from the EMPEIS to simulate shred and add clay in the alternatives, to much more tenuous, such as simulating the plasma processing in the alternatives by the EMPEIS incinerate-and-grout process. The information available is insufficient to allow a numerical estimate of how much uncertainty is introduced by these assumptions, but it is expected that nonsystemic uncertainties should not exceed plus or minus 100 percent of the risk estimates.

The conclusions in the following bullet list may be inferred from the data in Tables 3-11 through 3-28.

- The differences in cancer incidence for workers, co-located workers, and off-site populations are within a factor of two for all processes and configurations. The cancer incidence for the alternatives are the same as for the baseline for workers but four orders of magnitude higher than the baseline for co-located workers and about one order of magnitude for off-site populations. This probably results from adequate control of worker exposure to volatile chemicals in the waste by ventilation controls during waste processing, but vent releases increase with any processing. The baseline does not require opening the waste drums, but all the analyzed waste processes do require some opening of the waste, thus releasing volatile chemicals to be exhausted from the facility vents.

- Cancer fatalities for workers are also within a factor of two for all processes and configurations and for the baseline. The same is true for co-located workers and

off-site populations except that cancer fatalities are about four orders of magnitude higher for plasma processing than for the baseline or any other process.

- Cancer fatalities show a general increase with increased consolidation, although differences are less than a factor of two. Only plasma processing does not follow the trend, with centralized impacts showing a slight decrease for off-site populations and co-located workers but an increase for workers.

- Physical hazards show very little difference between process or configurations, including the baseline, except for plasma processing where distributed and regional processing show an increase of two to three times other processes and configurations.

- Somewhat greater differences between configurations might have been expected than were observed for those impacts most affected by the change in FTEs (cancer fatalities and physical hazard fatalities). However, the improvements expected to be provided by the efficiencies of scale are offset by the double handling required to prepare waste at nonprocessing facilities followed by additional handling to receive that waste at the processing site.

- For individuals, risk values of less than 10^{-6} for cancer fatalities or incidence or hazard index values less than one are not considered significant. With the exception of cancer fatalities for plasma processing, none of the impacts to most exposed individuals are considered significant. The variations between processes and configurations do not show variations greater than a factor of two to five except for plasma processing which shows the same four orders of magnitude increase observed in cancer fatalities in groups. Even for cancer fatalities for plasma processing, the annualized risks are between 7×10^{-6} and 2×10^{-5}, just slightly greater than the level of insignificance.

- Impacts for emplacement of the waste at WIPP show only about a factor of two or three between the various alternatives for either radiation or chemical hazard exposure. Plasma processing shows a decrease of approximately five for off-site population risks from radiation, primarily because most of the radioactive material is retained in the waste form. No risks are shown for chemical impacts of emplacement of plasma-processed waste because all the volatile chemicals have either been removed from the waste during processing or are tightly bound within the waste form.

- Fatalities from physical accidents are no more than 1 for the 35-year operational period for any of the alternatives. Both injuries and fatalities for each alternative are within 25 percent of the baseline.

3.4 WASTE REMOVAL IMPACT

3.4.1 Definition of Factor 4

Waste removal is defined as the activity involving recovery of the waste after repository closure. In assessing the waste removal activities, the waste inventory and physical properties for each engineered alternative determine the underground panel geometry that would in turn determine the time required for underground removal. Underground removal considers the compressive strength and density of the waste form as well as the consolidation of the backfill expected to occur after a specified period of time. The occupational hazards for industrial accidents include the conventional hazards due to underground mining accidents, hazardous waste exposure, and radioactive waste exposure.

After waste emplacement, the surrounding salt will be subject to creep with encroachment of the waste occurring after a period of 10 to 20 years. As encroachment occurs, the waste and backfill (if present) consolidate with a reduction of void space. This reduction affects the physical characteristics of the waste with time. The degree of difficulty in removing waste depends on the degree of consolidation at the time of removal, and the physical properties that in turn affect underground waste removal operations. The room geometry and repository layout also affect underground waste removal operations. The evaluation of this factor considers these waste and backfill (if present) properties for the baseline and each alternative at some future point in time when waste removal would be accomplished. This factor determines the impact on the ability to remove waste. No provisions are made with any of the EAs that specifically facilitate removal. Such provisions are not required by the disposal standard.

3.4.2 Methodology Used to Evaluate the Mine Waste Removal Factor (Factor 4)

The main objective of mine waste removal evaluation is to assess the degree of difficulty in extracting waste and backfill and how each of the alternatives influences the associated risk and detriments for each alternative. The factor components include (1) the waste volume and repository layout for each alternative that would determine the number of panels for waste disposal; and (2) the unconfined compressive strength of the waste/backfill that affect the mining advance rate. If a waste form/backfill were selected that would have desirable characteristics for long term isolation (such as a high compressive strength that reduces the release of drill cuttings), it might be undesirable from the mine waste removal in that there would be increased hazards regarding removal.

The baseline for waste removal is evaluated by defining the physical layout for underground waste removal activities. The analysis of industrial hazards suggests that the number of accidents is related to the time required for underground waste removal, and that in turn relates to the underground continuous mining time. Each of the alternatives can be ranked with regard to waste removal subjecting workers to risk. For waste forms exhibiting higher compressive strength (grouted waste, etc.), more time is required for mining and removal with the occurrence of a larger number of nonradiological and radiological accidents and doses.

The unconfined compressive strengths of various waste forms are evaluated using the relationships of compressive strength to porosity. For crushed salt backfill, cementitious materials, and earthen materials, test data were compiled and relationships developed as illustrated in Figure 3-7 (Nelson et al., 1981; Mindess and Young, 1981; U.S. Bureau of

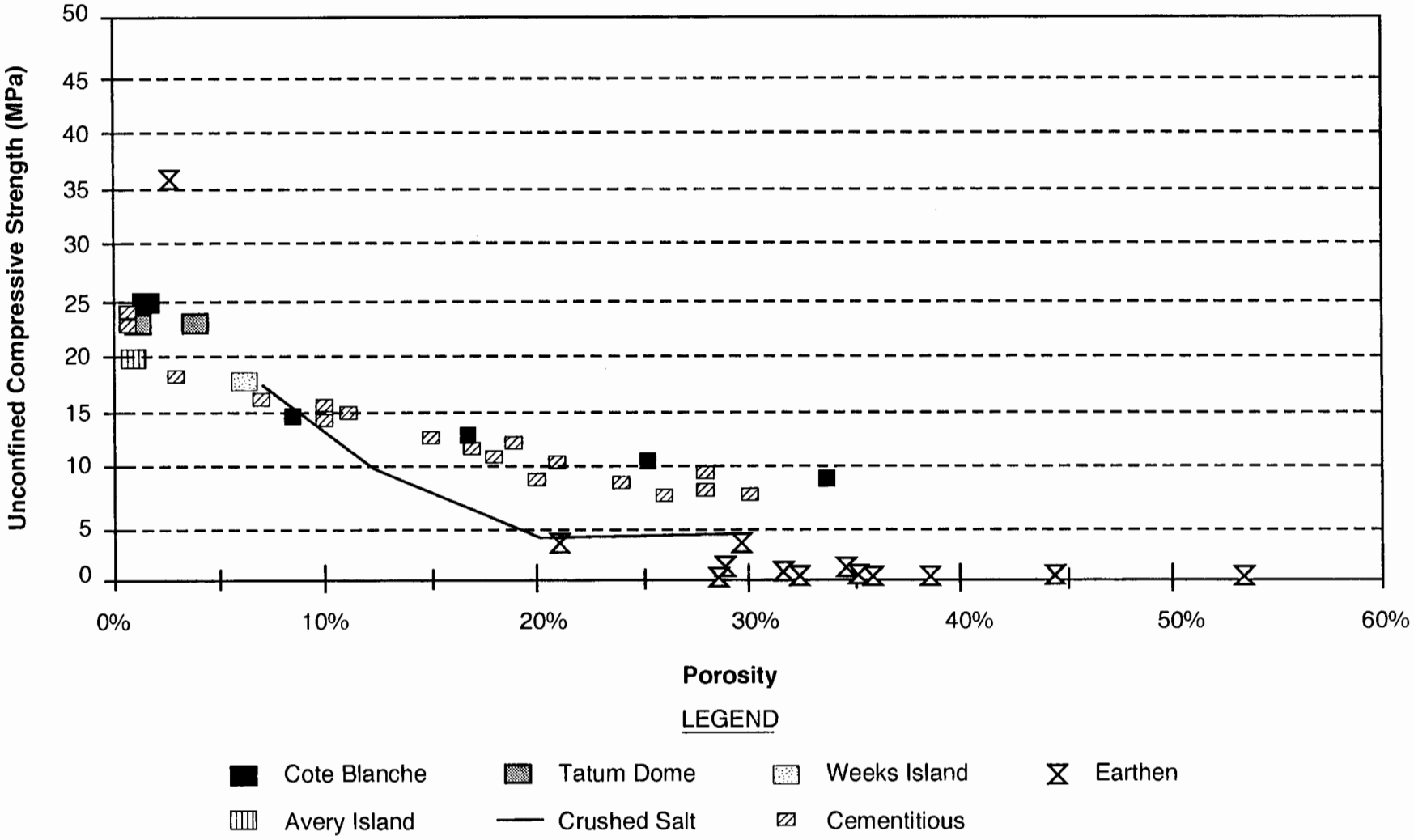

Figure 3-7
Relationship of Unrestricted Compressive Strength to Porosity

Reclamation, 1974; and Winterkorn and Fang, 1977). The test data from these sources show that cementitious materials exhibit a range of low to high porosities with higher compressive strengths, earthen materials (clay, sand) exhibit higher porosities with lower compressive strengths, and that crushed salt exhibits compressive strengths intermediate to these materials. The inorganic or metallic waste would exhibit a much higher compressive strength; yet the effective porosity would be much higher. As discussed subsequently, the mining advance rate was selected to be about one-half of the rate for other waste forms and backfill.

After approximately 100 years, the waste and backfill (if present) would consolidate to a value near lithostatic stress. As stresses buildup on the waste form and backfill, the secondary creep rate would reduce. If waste removal is assumed to occur when the waste compressive stress has reached 90 percent of lithostatic stress (14 MPa), the porosity can be determined for the various materials. The porosity of the various materials at this stress level is presented in Table 3-29. Note that the same relationships for porosity with stress level as used for Factor 1 were considered here. From the unconfined compressive strength vs. porosity relationship presented in Figure 3-7, the approximate compressive strengths can be determined, and then averaged on the basis of volume for each of the materials.

The mining advance rate as a function of compressive strength is determined by relating the specific energy to compressive strength from laboratory disc cutting studies for rocks of various compressive strengths from 50 to 350 MPa (Temporal et al., 1983), and then relating the specific energy to excavation rate (McFeat-Smith and Powell, 1979). In laboratory disc cutting studies, the specific energy in cutting is determined, and then correlated to compressive strength as presented in Figure 3-8. The laboratory procedure was to make a series of cuts on a rock surface to simulate an excavated face, make cuts with the disc cutter on the simulated rock surface while recording the tool force, and length of cut, measure the cut volume, and then determine the specific energy as the tool force times the length of cut divided by the excavation volume. The relationship in Figure 3-8 can then be related to other combined laboratory and field studies where specific energy is determined, and then related to field cutting rates for a typical medium weight roadheader as shown in Figure 3-9. Although other operational parameters such as depth of cut, cutting geometry, line spacing and the degree of wear of the cutting tool, the use of a standard cutting test ensures that variation in specific energy can be directly attributed to the cutting characteristics tested. If consideration is given to a 13 ft by 33 ft (3.96 by 10.06 m) or a 6 ft by 33 ft (1.83 by 10.06 m) room size, the mining advance rate as a function of unconfined compressive strength can be determined as shown in Figure 3-10.

For metallic waste, steel exhibits a high average compressive strength of approximately 30,000 psi (206 MPa).

From the above discussion, the mining advance rate would be smaller than normal mining advance rates. From Temporal, et al., 1983, the specific energy is about 30 MJ/m^3. From McFeat-Smith and Powell, 1979, the mining rate is about 177 ft^3 (5 m^3) per hour. This results in a mining advance rate of 3.3 ft (1 m) per shift, which is about one-half the mining advance rate for other materials.

TABLE 3-29
SUMMARY OF POROSITIES AND COMPRESSIVE STRENGTHS

Identifier	Alternative	Porosity at Lithostatic Pressure				Unconfined Compressive Strength					Average Waste/ Backfill Composite (MPa)
		Sludges[1]	Solid Organic	Solid Inorganic Metals	Backfill	Sludges (MPa)	Solid Organic (MPa)	Solid Inorganic (MPa)	Backfill (MPa)	Host Salt (MPa)	
0	Baseline	12.21%	15.42%	41.72%	—	16	7	75	—	25	25.2
1	Compact Waste	12.21%	15.42%	41.72%	—	16	9	75	—	25	24.5
6	Shred and Compact	12.21%	13.15%	39.16%	—	16	9	75	—	25	25.1
10	Plasma Processing of All Waste	12.21%	12.21%	12.21%	—	16	16	16	—	25	24.1
33	Sand Plus Clay Backfill	12.21%	15.42%	41.72%	33.60%	16	7	75	3	25	15.2
35.a	Salt Aggregate Grout Backfill	12.21%	15.42%	41.72%	31.30%	16	7	75	16	25	21.1
35.b	Cementitious Grout Backfill	12.21%	15.42%	41.72%	31.30%	16	7	75	16	25	21.1
77.a	Supercompact organics and inorganics, salt-aggregate grout backfill, monolayer of 2,000 drums, in 6X33X300	12.21%	24.00%	39.16%	31.30%	16	9	75	16	25	19.4
77.b	Supercompact organics and inorganics, clay based backfill, monolayer of 2000 drums, in 6X33X300	12.21%	13.15%	39.16%	40.50%	16	9	75	3	25	12.2
77.c	Supercompact organics and inorganics, sand plus clay based backfill, monolayer of 2,000 drums, in 6X33X300	12.21%	13.15%	39.16%	33.60%	16	9	75	3	25	12.2
77.d	Supercompact organics and inorganics, CaO based backfill, monolayer of 2,000 drums, in 6X33X300	12.21%	13.15%	39.16%	10.10%	16	9	75	14	25	18.3
83	Salt Backfill with CaO	12.21%	15.42%	41.72%	10.10%	16	7	75	14	25	20.2

TABLE 3-29 (Continued)
SUMMARY OF POROSITIES AND COMPRESSIVE STRENGTHS

Identifier	Alternative	Porosity at Lithostatic Pressure				Unconfined Compressive Strength					Average Composite Waste/ Backfill (MPa)
		Sludges[1]	Solid Organic	Solid Inorganic Metals	Backfill	Sludges (MPa)	Solid Organic (MPa)	Solid Inorganic (MPa)	Backfill (MPa)	Host Salt (MPa)	
94.a	SPM IT-4 Enhanced cement sludges, shred and add clay organics and inorganics, no backfill	20.0%	24.00%	41.30%	—	16	7	75	0	25	24.7
94.b	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, sand plus clay backfill.	20.0%	24.00%	41.30%	33.60%	16	7	75	3	25	14.7
94.c	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, cementitious grout backfill.	20.0%	24.00%	41.30%	31.30%	16	7	75	16	25	20.6
94.d	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.	20.0%	24.00%	41.30%	31.30%	16	7	75	16	25	20.6
94.e	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, clay backfill.	20.0%	24.00%	41.30%	40.50%	16	7	75	3	25	14.7
94.f	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, CaO backfill.	20.0%	24.00%	41.30%	10.10%	16	7	75	14	25	19.7
111	Clay Based Backfill	12.21%	15.42%	41.72%	40.50%	16	7	75	3	25	15.2

[1]Porosity for enhanced cementation is estimated at 20% at 2000 psi stress. The enhanced cemented sludge is assumed to have a compressive strength of greater than 2000 psi. The 20% pore space is assumed to be from entrained air during mixing and does not change with increased pressure up to 2000 psi.

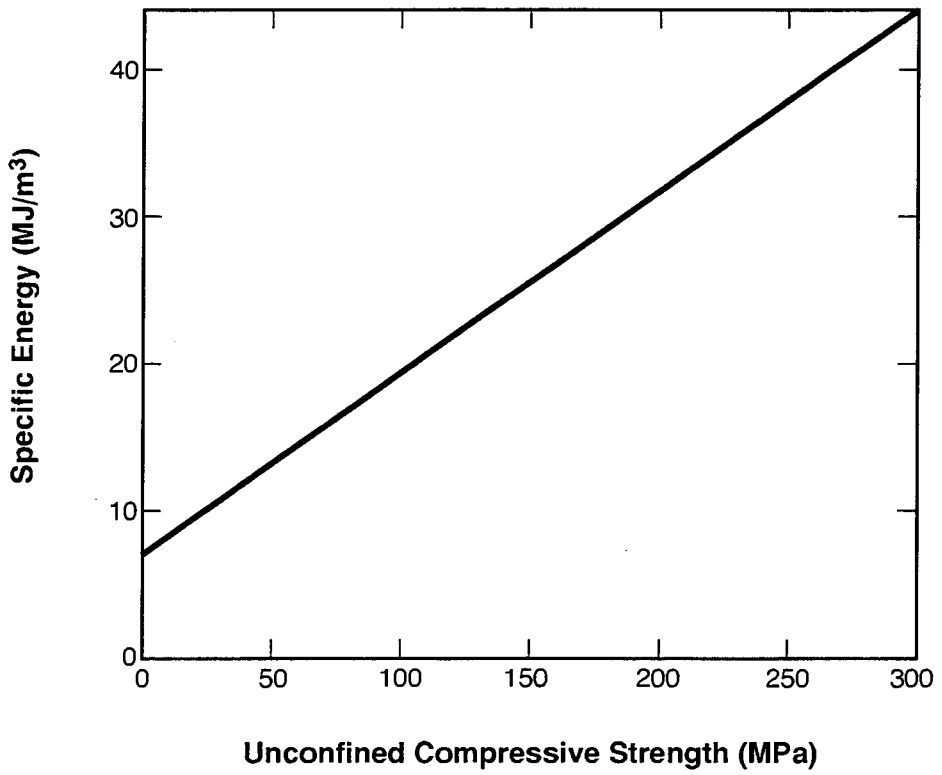

Figure 3-8
Mining Advance Rate Mine Waste Removal Evaluation

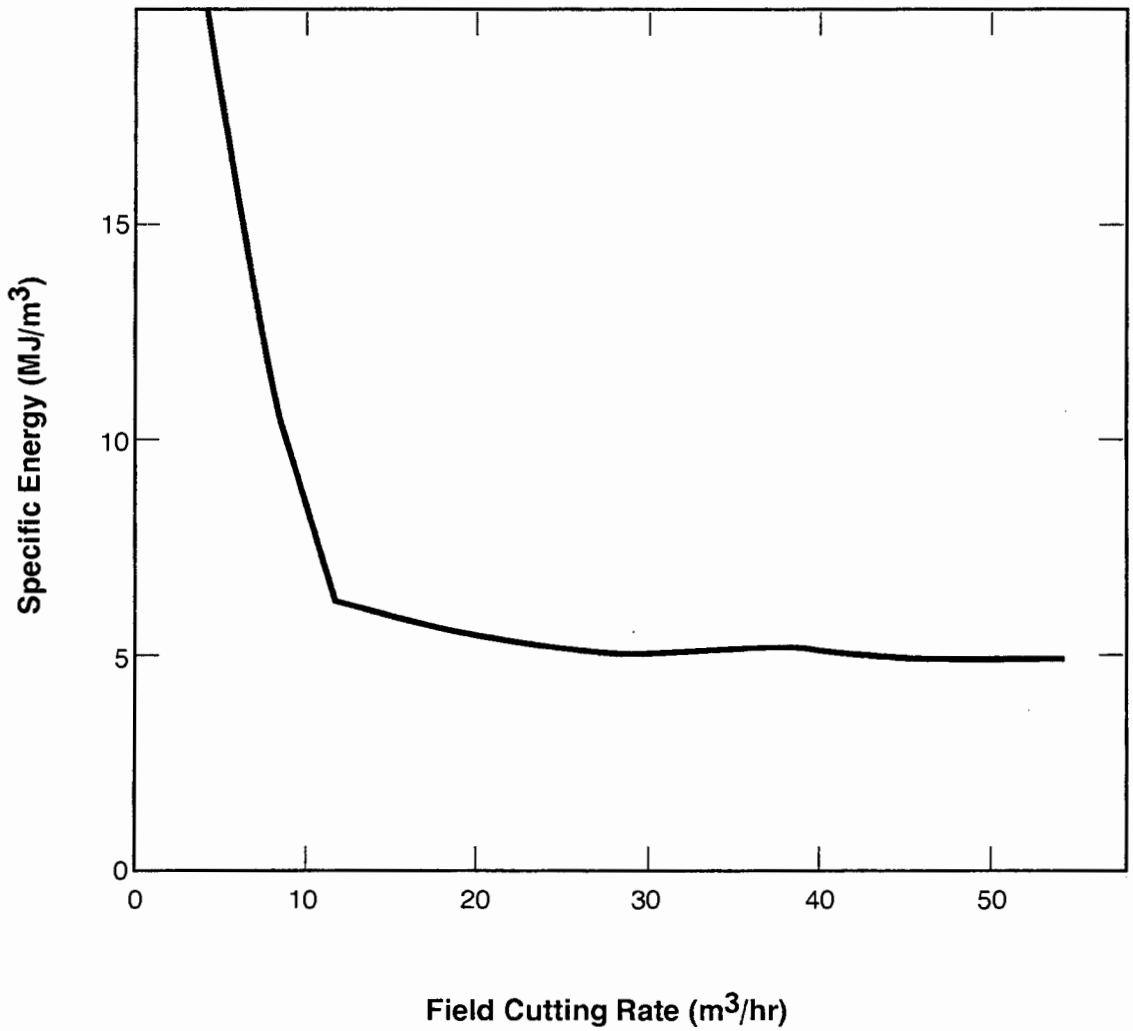

Figure 3-9
Relationship of Specific Energy to the Field Cutting Rate

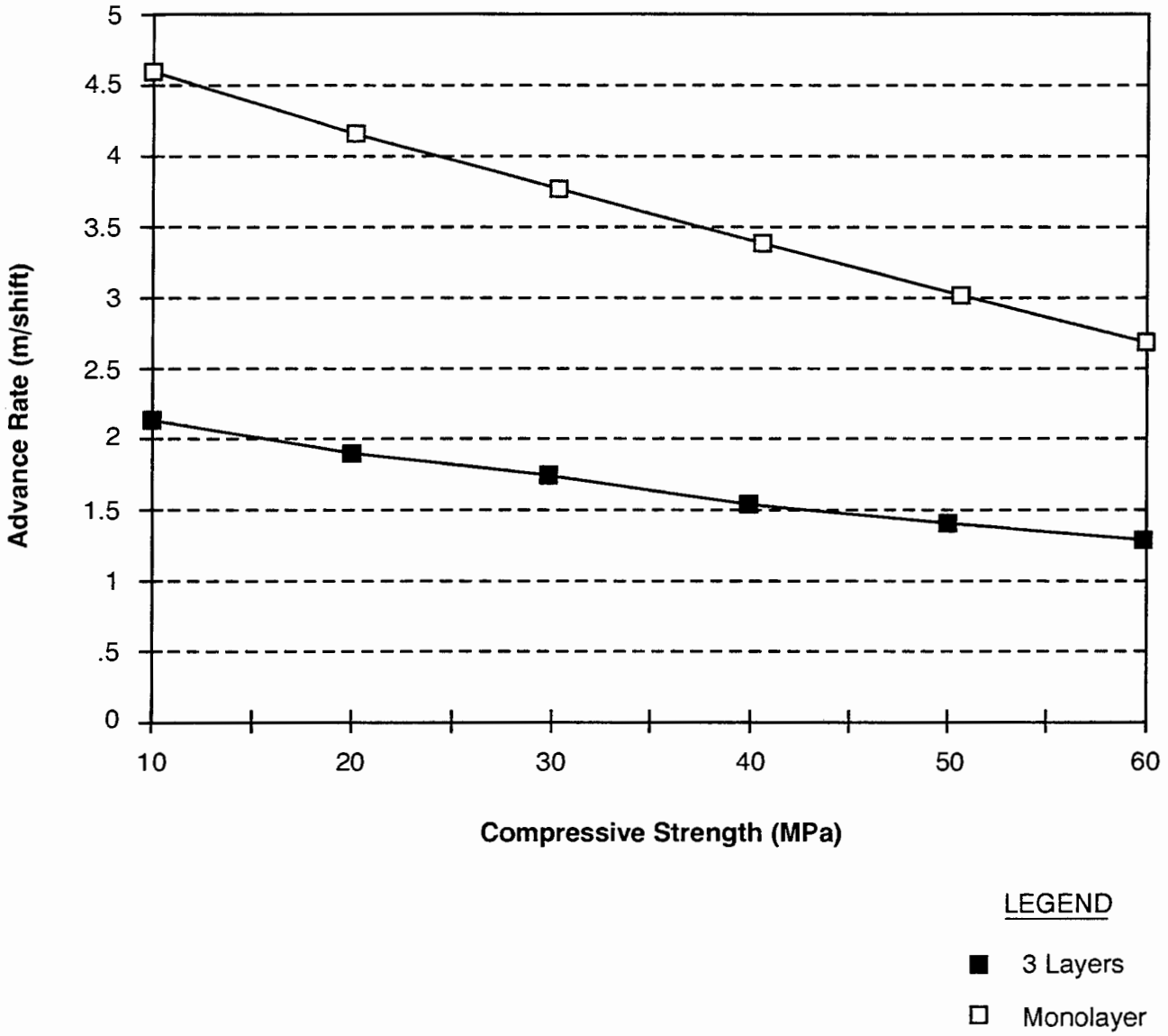

Figure 3-10
Relationship of Mining Advance Rate to Compressive Strength

3.4.3 Assumptions and Data for Factor 4

Data sources for assessing the unconfined compressive strength and the mining advance rate have been described previously. The baseline operational parameters for waste removal is defined by the following assumptions:

- Waste will be placed in the eight panels plus their associated access drifts giving the waste disposal volume of 10 panel equivalents.

- Underground excavation and waste removal occurs at some future time when the waste consolidate to near lithostatic stress after decommissioning and sealing of the facility. Waste recovery is by continuous mining using available technology.

- The underground waste removal activities require continuous mining and re-excavation of the ten equivalent panels. Each panel equivalent will hold approximately 80,000 drums of contact handled waste for a total waste inventory of approximately 800,000 drums. The waste inventory for the baseline consists of sludges, solid organic waste and solid inorganic waste. No backfill is considered, but overexcavation of the waste stack would be necessary to assure complete removal of the waste stack. For purposes of analysis, it is assumed that the dimensions of the rooms excavated equals the initial dimensions. The dimensions of the rooms for the baseline analysis are 13 ft by 33 ft by 300 ft (3.96 by 10.06 by 91.43 m) (Case et al., 1991). There are 12.54 room equivalents per panel, and 10 equivalent panels for all EAs. The WIPP design includes eight panels, with the associated panel access drifts providing an additional two panel equivalents.

- RH TRU waste is not considered in this analysis. The comparison of RH waste baseline with the EAs shows no difference. The analysis of baseline conditions with respect to EA related cost, time, and risk values shows no variability in results.

- Mining advance rates will be developed from the estimated strength and density of the waste forms after consolidation to near lithostatic stress. At this point in time, each waste form will have a certain density and porosity. The porosity is estimated from porosity versus stress relationships developed, and then related to the compressive strength for each waste form. The mining advance rate is inversely proportional to the compressive strength and density of the waste form.

- Performance studies have been performed by the mining industry for mining advance rates using continuous mining equipment relative to various rock types and rock strengths (e.g., McFeat-Smith and Powell, 1979). Mining advance rates at the WIPP will be estimated from these performance studies. Mined waste handling is scheduled at the same rate as excavation. The amount of time required for mining is determined from the panel entry lengths divided by the mining advance rate.

- Following excavation, the CH-TRU waste will be emplaced in waste containers similar to the standard waste boxes used by the project by a Load-Haul-Dump operation. Waste transporters move the material to the ground surface. The material disposition of the waste after this point in time is beyond the scope the EACBS.

- After completion of waste removal activities in a panel, the panel will be closed and isolated from the other panel by the construction of panel ventilation barriers. Underground ventilation will then be established to the next panel for waste removal activities.

- Based upon the above assumptions for underground mining and removal operations, a schedule is developed for waste removal, the number of man hours determined, and the occupational hazards assessed for the removal period. The occupational hazards for industrial accidents include the conventional hazards due to underground mining accidents, hazardous waste exposure during an accident, and radiation exposure during an accident.

For each of the alternatives, additional operational parameters are defined regarding repository geometry, and backfill emplacement. These include:

- For plasma processing with a single layer of drums per room, an initial void space 8.2 ft (2.5 meters) high above the waste stack would exist. This results in the excavation of salt that affects the mining time.

- For the 77 series of EAs involving the monolayer of waste containers, the initial room dimensions are 6 ft X 33 ft X 300 ft (1.83 X 10.06 X 91.44 m).

- The radionuclide inventory per panel remains the same for each of the alternatives. For alternatives involving the 77 and 94 series, less waste is placed per room under this assumption and the WIPP cannot accommodate the total waste inventory.

- The thickness of the backfill layer around the drums is 0.5 m between the room sidewall and the waste stack, and about 2 ft (0.6 m) above the waste stack. The void space between the waste drums is 80 percent for the "wet" backfill alternatives involving grout, and 50 percent for the "dry" backfill alternatives.

The volumes of backfill have been calculated and are presented in Table 3-30. The salt volume excavated to the initial room dimensions considers the total volume for 10 panel equivalents that are mined out equal to 16,138,593 ft^3 (456,938 m^3) for a 13 ft (3.96 m) high drift and 7,448,565 ft^3 (210,894 m^3) for a 6 ft (1.83 m) high drift minus the volume for the waste and the emplaced backfill. The total backfill volume is based on the geometry of the backfill, and the void space.

The average mining advance rate is determined from the average compressive strength in Table 3-29 and the relationships in Figure 3-10 for either the 6 ft (1.83 m) high or the 13 ft (3.96 m) high entry. The number of shifts is determined by the entry length divided by the average mining advance rate (Table 3-31). The subtotal manning table for mining excavation during waste removal is determined by multiplying the number of shifts by 24 with 8 persons working at any given time. The subtotal manning for materials handling during waste removal is determined by the number of workers per shift (assumed to be 30 with 10 working at any given time). The total man hours available for accidents to occur is equal to 18 workers per shift times 8 hours per shift times the number of shifts. The industrial accident estimates are taken from (D'Appolonia Consulting Engineers, Inc., 1976) for salt. The rates are 39.7 injuries per 3.04 million man-hours worked for nonfatal accidents, and 1.97 fatalities per 3.04 million man-hours worked for fatal

TABLE 3-30
SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Backfill Material Volume (m^3)	Backfill Emplaced Volume (m^3)	Salt Volume (m^3)	No. of Panels
0	Baseline	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	0	—	289,814	10
1	Compact Waste	54,389	26,019	13,438	93,846	9,385	45,097	93,846	0	0	—	363,092	10
6	Shred and Compact	54,389	56,498	29,181	140,068	14,007	67,308	140,068	0	0	—	316,870	10
10	Plasma Processing of All Waste	10,767	24,532	12,671	47,970	4,797	23,051	47,970	0	0	—	408,968	10
33	Sand Plus Clay Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	154,500	207,370	82,444	10
35.a	Salt Aggregate Grout Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	186,220	207,370	82,444	10
35.b	Cementitious Grout Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	186,220	207,370	82,444	10
77.a	Supercompact organics and inorganics, salt-aggregate grout backfill, monolayer of 2,000 drums, in 6X33X300	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	109,220	117,000	41,703	10
77.b	Supercompact organics and inorganics, clay based backfill, monolayer of 2,000 drums, in 6X33X300	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	97,540	117,000	41,703	10
77.c	Supercompact organics and inorganics, sand plus clay based backfill, monolayer of 2,000 drums, in 6X33X300	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	97,540	117,000	41,703	10

Refer to footnotes at end of table.

TABLE 3-30 (Continued)
SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Backfill Material Volume (m^3)	Backfill Emplaced Volume (m^3)	Salt Volume (m^3)	No. of Panels
77.d	Supercompact organics and inorganics, CaO based backfill, monolayer of 2,000 drums, in 6X33X300	54,389	26,019	13,438	93,846	5,219	25,080	52,191	41,655	97,540	117,000	41,703	10
83	Salt Backfill with CaO	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	154,500	207,370	82,444	10
94.a	SPM IT-4 Enhanced cement sludges, shred and add clay organics and inorganics, no backfill	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	0	0	289,814	10
94.b	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, sand plus clay backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	154,500	207,370	82,444	10
94.c	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, cementitious grout backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	186,220	207,370	82,444	10

Refer to footnotes at end of table.

TABLE 3-30 (Continued)
SUMMARY OF WASTE INVENTORIES

Identifier	Alternative	Sludges Volume (m^3)	Solid Organic Volume (m^3)	Solid Inorganic Volume (m^3)	Total Waste Volume (m^3)	Total Waste per Panel (m^3)	Total Drums per Panel	Total Allowable Waste Volume (m^3)	Unaccepted Waste Volume* (m^3)	Backfill Material Volume (m^3)	Backfill Emplaced Volume (m^3)	Salt Volume (m^3)	No. of Panels
94.d	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	186,220	207,370	82,444	10
94.e	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, clay backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	154,500	207,370	82,444	10
94.f	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, CaO backfill.	81,566	74,339	38,396	194,301	16,712	80,309	167,124	27,177	154,500	207,370	82,444	10
111	Clay Based Backfill	54,389	74,339	38,396	167,124	16,712	80,309	167,124	0	154,500	207,370	82,444	10

*Unaccepted Waste Volume is the volume of waste generated by a treatment process that is in excess of the WIPP design volume.

Source: DOE, 1995e, Baseline Inventory Report, See Appendix O for Waste Inventory Details.

TABLE 3-31
MINING ADVANCE RATE AND TIME

Identifier	Alternative	Average Advance Rate m/shift	No. of Shifts	Mining Excavation Man-Shifts	Materials Handling Man-Shifts	Total Man-Shifts	Man Hours	Fatal Accidents	Nonfatal Accidents
0	Baseline	1.8	6,243	149,835	187,294	337,129	899,010	0.58	11.74
1	Compact Waste	1.8	6,202	148,842	186,052	334,894	893,051	0.58	11.66
6	Shred and Compact	1.8	6,240	149,753	187,192	336,945	898,521	0.58	11.73
10	Plasma Processing of All Waste	1.9	6,177	148,246	185,307	333,553	889,474	0.58	11.62
33	Sand Plus Clay Backfill	2.0	5,710	137,042	171,303	308,345	822,254	0.53	10.74
35.a	Salt Aggregate Grout Backfill	1.9	6,013	144,324	180,404	324,728	865,941	0.56	11.31
35.b	Cementitious Grout Backfill	1.9	6,013	144,324	180,404	324,728	865,941	0.56	11.31
77.a	Supercompact organics and inorganics, salt-aggregate grout backfill, monolayer of 2,000 drums, in 6X33X300	4.2	2,733	65,591	81,988	147,579	393,544	0.26	5.14
77.b	Supercompact organics and inorganics, clay based backfill, monolayer of 2000 drums, in 6X33X300	4.5	2,569	61,648	77,060	138,708	369,887	0.24	4.83
77.c	Supercompact organics and inorganics, sand plus clay based backfill, monolayer of 2,000 drums, in 6X33X300	4.5	2,569	61,648	77,060	138,708	369,887	0.24	4.83
77.d	Supercompact organics and inorganics, CaO based backfill, monolayer of 2,000 drums, in 6X33X300	4.2	2,706	64,952	81,189	146,141	389,709	0.25	5.09
83	Salt Backfill with CaO	1.9	5,965	143,153	178,942	322,095	858,921	0.56	11.22

TABLE 3-31 (Continued)
MINING ADVANCE RATE AND TIME

Identifier	Alternative	Average Advance Rate m/shift	No. of Shifts	Mining Excavation Man-Shifts	Materials Handling Man-Shifts	Total Man-Shifts	Man Hours	Fatal Accidents	Nonfatal Accidents
94.a	Enhanced cement sludges, shred and add clay organics and inorganics, no backfill	1.8	6,215	149,154	186,442	335,596	894,921	0.58	11.69
94.b	Enhanced cement sludges, shred and add clay based material to organics and inorganics, sand plus clay backfill.	2.0	5,686	136,472	170,590	307,062	818,832	0.53	10.69
94.c	Enhanced cement sludges, shred and add clay based material to organics and inorganics, cementitious grout backfill.	1.9	5,987	143,691	179,614	323,305	862,147	0.56	11.26
94.d	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.	1.9	5,987	143,691	179,614	323,305	862,147	0.56	11.26
94.e	Enhanced cement sludges, shred and add clay based material to organics and inorganics, clay backfill.	2.0	5,686	136,472	170,590	307,062	818,832	0.53	10.69
94.f	Enhanced cement sludges, shred and add clay based material to organics and inorganics, CaO backfill.	1.9	5,939	142,531	178,164	320,695	855,188	0.55	11.17
111	Clay Based Backfill	2.0	5,710	137,042	171,303	308,345	822,254	0.53	10.74

accidents. The radiation exposure would be no different between alternatives based upon the assumption that the radionuclide inventory per panel remains the same for each of the alternatives. For hazardous organic materials, plasma processing would eliminate hazardous waste exposure.

3.4.4 Results of Analysis for Factor 4

The results show that among the alternatives, the placement of the waste in a single monolayer in a 6 ft by 33 ft (1.83 by 10.06 m) room would reduce mining excavation substantially, and would reduce the number of underground mining accidents substantially. The results show little difference among the other alternatives since the mining advance rate is nearly the same at 6.56 ft (2 m) per shift for nonmetallic waste, and 3.28 ft (1 m) per shift for metallic waste. The use of clay or sand backfill would exhibit a slightly lower strength, and result in a reduced waste removal time. Yet, these effects are secondary since the waste stack would need to be overexcavated to assure removal of the waste.

3.5 IMPACT ON TRANSPORTATION RISK

Transportation risks are evaluated based on the number of CH- and RH-TRU waste shipments required to dispose of the WIPP authorized waste volume of 6.2 million cubic feet. This provides a reasonably conservative analysis which is consistent with prior waste shipment studies for the WIPP. In general, this volume basis analysis approach involves more shipments than would be required to ship the EA final waste form quantities identified in Table 2-6. Based on estimated final waste form densities, some shipments may be weight limited and may not be able to fully utilize the volume capacity of a TRUPACT-II. With the current level of available information and to meet the objectives of the current study as discussed in Section 1.1, this study retains the use of WIPP's authorized waste volume and the volume capacity of a TRUPACT-II to estimate the number of waste shipments.

Four transportation configurations are considered in the analysis: the baseline and decentralized, regionalized, and centralized configurations. The baseline is defined as shipment of WIPP WAC-certified TRU waste from all generator/storage sites to WIPP (Figure 3-11). In the decentralized case (also shown on Figure 3-11), most waste processing required to enhance repository performance would occur at the generator/storage sites, but some of the small-quantity generators would ship waste to one of the large-quantity generators for processing. In the regionalized case, waste would be shipped to Hanford Site, Idaho National Engineering Laboratory, Savannah River Site, or Los Alamos National Laboratory for processing (Figure 3-12). The centralized case would consist of shipment of all waste from the generator/storage sites to a processing facility located at WIPP (Figure 3-13).

Approximately 98 percent of the CH- and RH-TRU waste shipments will originate from six major generator/storage facilities. The remaining shipments originate from approximately 14 minor facilities. The major/minor facilities, shown on Figures 3-11 through 3-13, are as follows:

Facilities	CH-TRU	RH-TRU
Hanford	Major site	Major site
INEL	Major site	Minor site
LANL	Major site	Minor site
RFETS	Major site	Minor site
SRS	Major site	Minor site
ORNL	Minor site	Major site
AMES	Minor site	Not generated or stored
ANL/E	Minor site	Not generated or stored
Battelle	Not generated or stored	Minor site
Bettis	Minor site	Minor site
ETEC	Minor site	Not generated or stored
KAPL	Minor site	Minor site
LBL	Minor site	Not generated or stored
LLNL	Minor site	Not generated or stored
Mound	Minor site	Not generated or stored
MU	Minor site	Not generated or stored

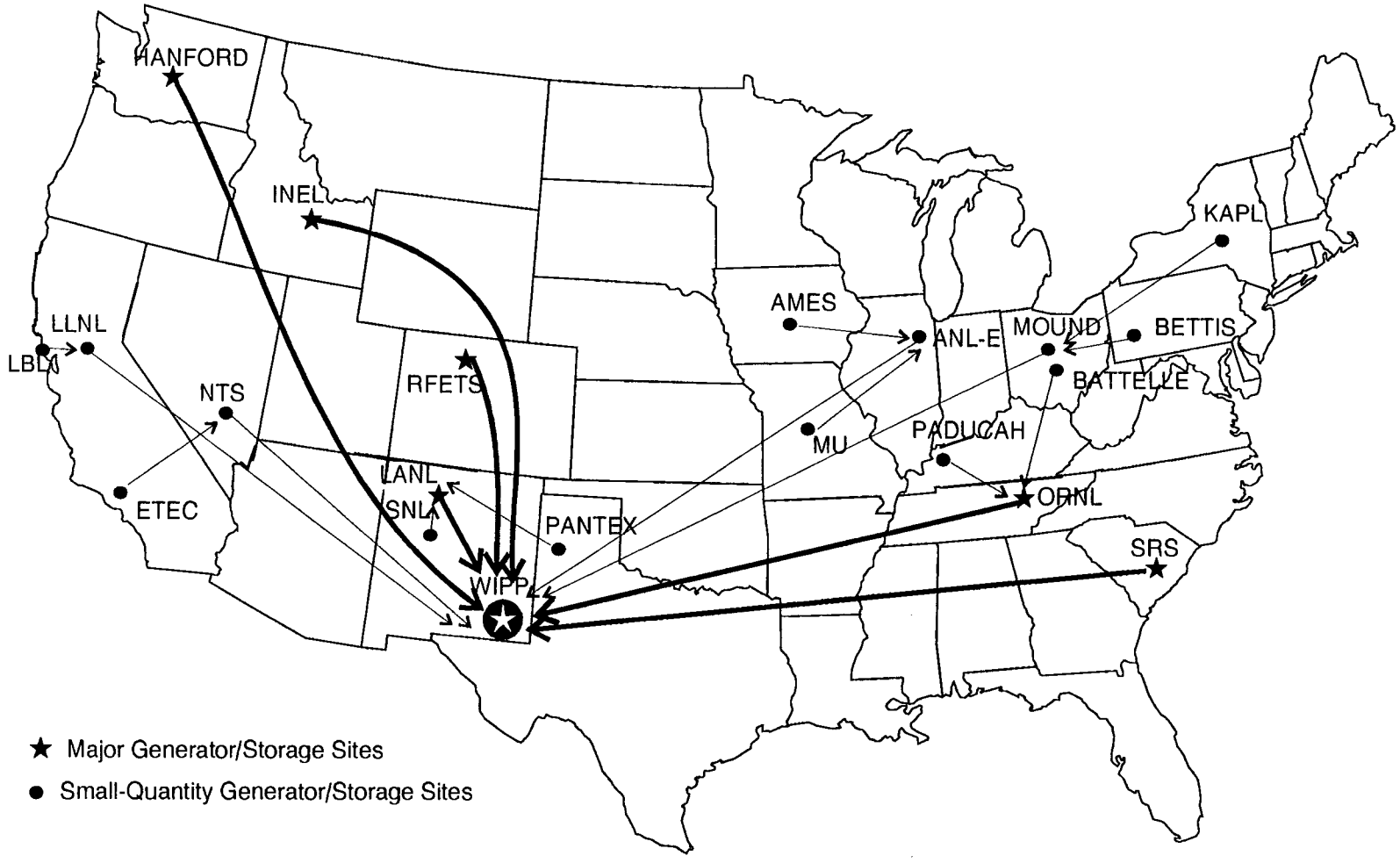

Figure 3-11
Transportation Configuration for Generator/Storage Site Base Case & Decentralized Configuration

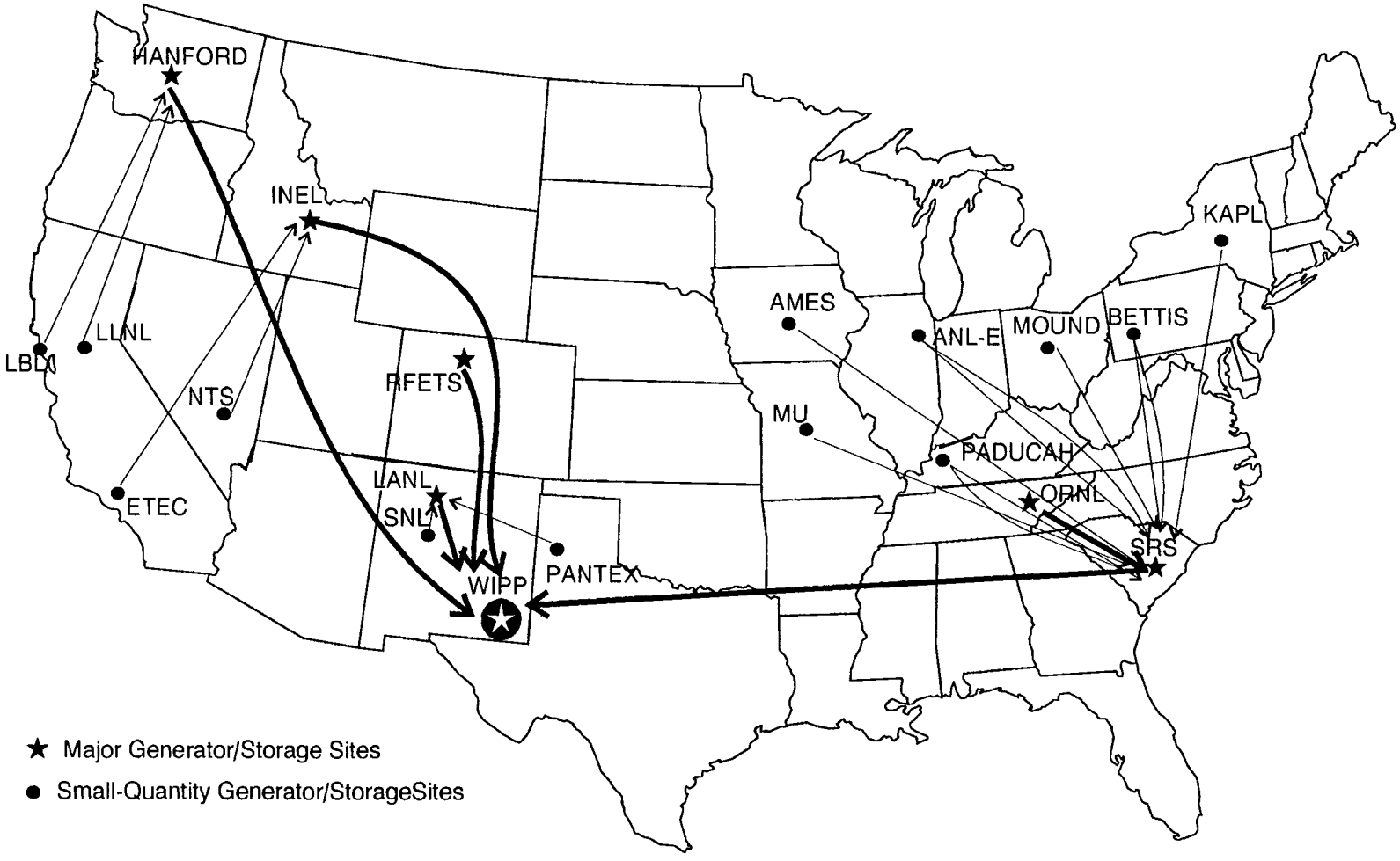

Figure 3-12
Transportation Configuration for Generator/Storage Site Regionalized Configuration

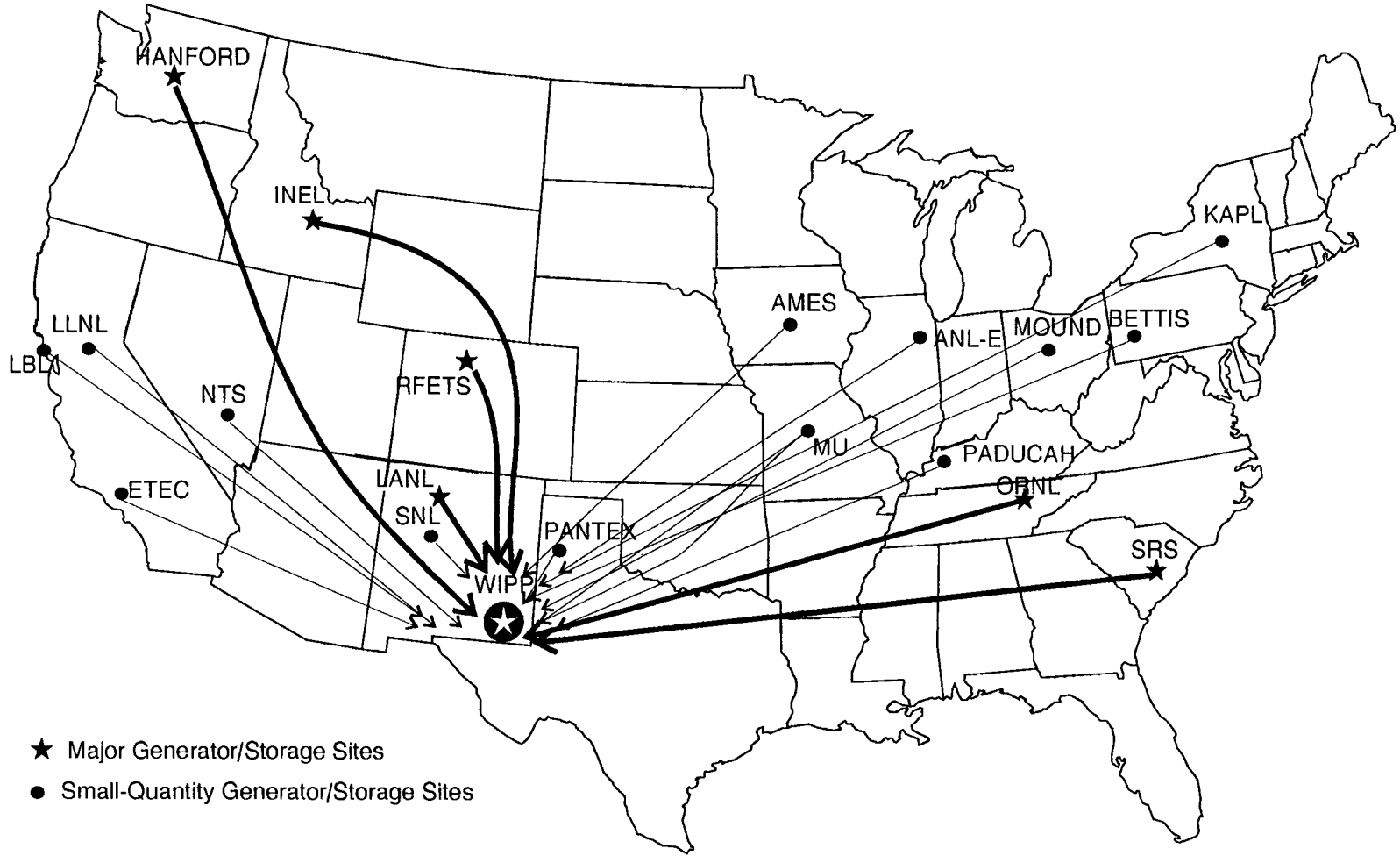

Figure 3-13
Transportation Configuration for Generator/Storage Site Centralized Configuration

NTS	Minor site	Not generated or stored
Paducah	Minor site	Not generated or stored
Pantex	Minor site	Not generated or stored
SNL	Minor site	Not generated or stored

The engineered alternatives that are being analyzed for their impact on transportation risk are:

No. 1: Compact waste

No. 6: Shred and compact

No. 10: Plasma processing

No. 77: Supercompact organics and inorganics (solid waste)

No. 94: Enhanced cementation of sludges, shred and add clay based materials to organics and inorganics.

All CH- and RH-TRU waste that is transported either for processing or disposal will be shipped in Type B transportation packages. CH-TRU waste will be placed either in 55-gallon (208-liter) drums or standard waste boxes (SWBs) and transported in a Transuranic Package Transporter-II (TRUPACT-II) (Figure 3-14). RH-TRU waste will be in either 30-gallon (113.6-liter) or 55-gallon (208-liter) drums placed in a RH-TRU waste canister and transported in an RH-72B cask. The TRUPACT-II has been certified by the U.S. Nuclear Regulatory Commission (NRC) and has been used by the DOE for intrasite CH-TRU waste transportation. The RH-72B cask (Figure 3-15) has yet to be NRC certified, but is scheduled to be available for RH-TRU waste transportation when WIPP is ready for waste emplacement.

3.5.1 Definition of the TRU Waste Transportation Risk Factor

The transportation risk factor consists of the human health impacts that could potentially result from transporting CH- or RH-TRU waste. The risk factor is defined in terms of the radiological, chemical, and non-radiological/non-chemical impacts of either normal, incident-free transportation or transportation accidents.

3.5.2 Methodology Used to Evaluate the Transportation Risk Factor

The transportation analysis presented in this chapter was conducted similarly to assessments such as NUREG-0170 (NRC, 1977), the WIPP FEIS (DOE, 1980), the WIPP FSEIS (DOE, 1990b), and the Comparative Study of Waste Isolation Pilot Plant (WIPP) Transportation Alternatives (DOE, 1994a). Since 1980, computer models and basic assumptions have been refined, but the approach to estimating the consequences and risks has remained the same. This methodology has proven to be accurate, reliable, and technically acceptable. The analytical codes or models used for this analysis have been extensively documented in the WIPP FSEIS (DOE, 1990b). Methods and assumptions used are provided in the following subsections.

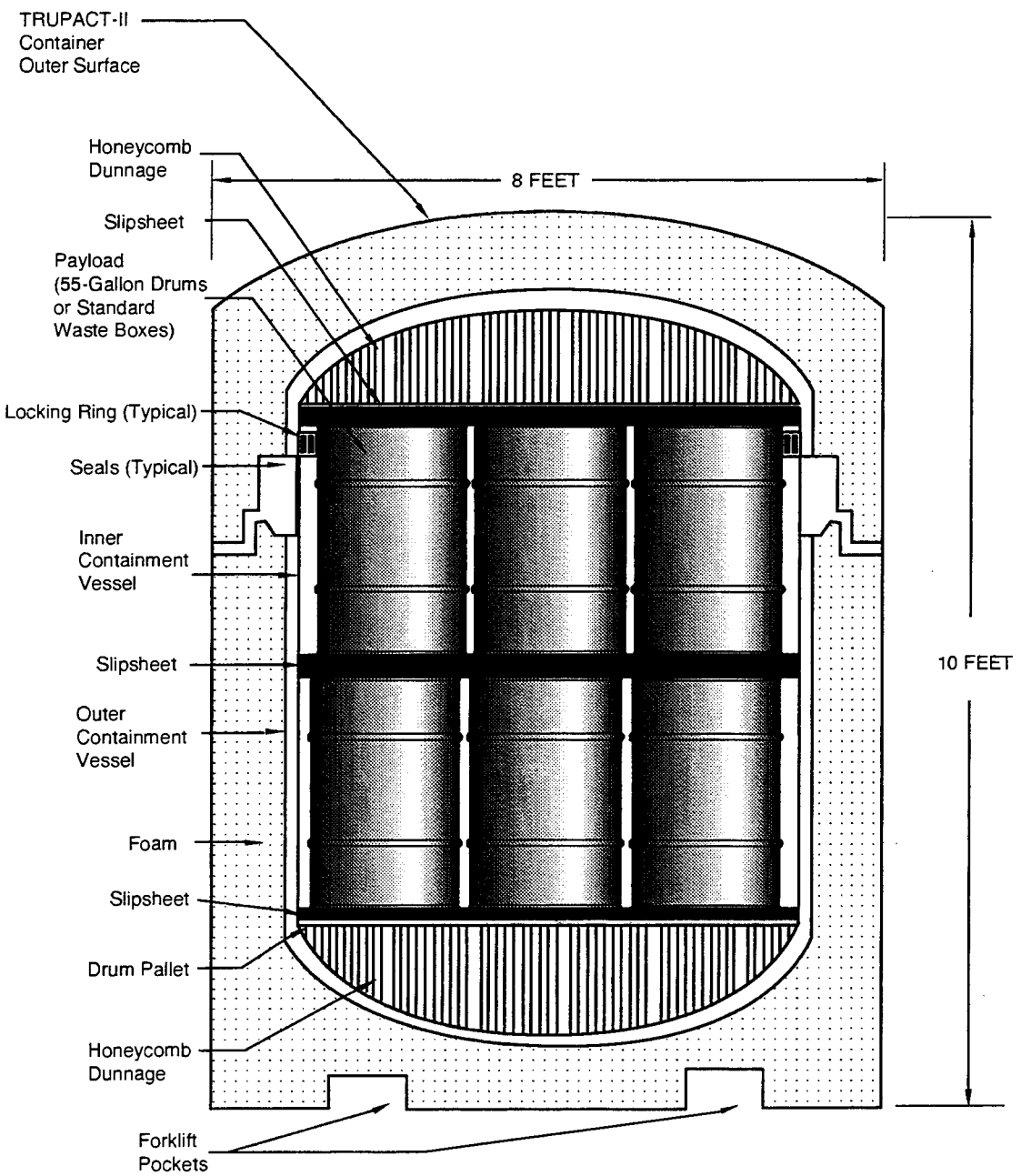

Figure 3-14
TRUPACT-II Shipping Container For CH-TRU Waste (Schematic)

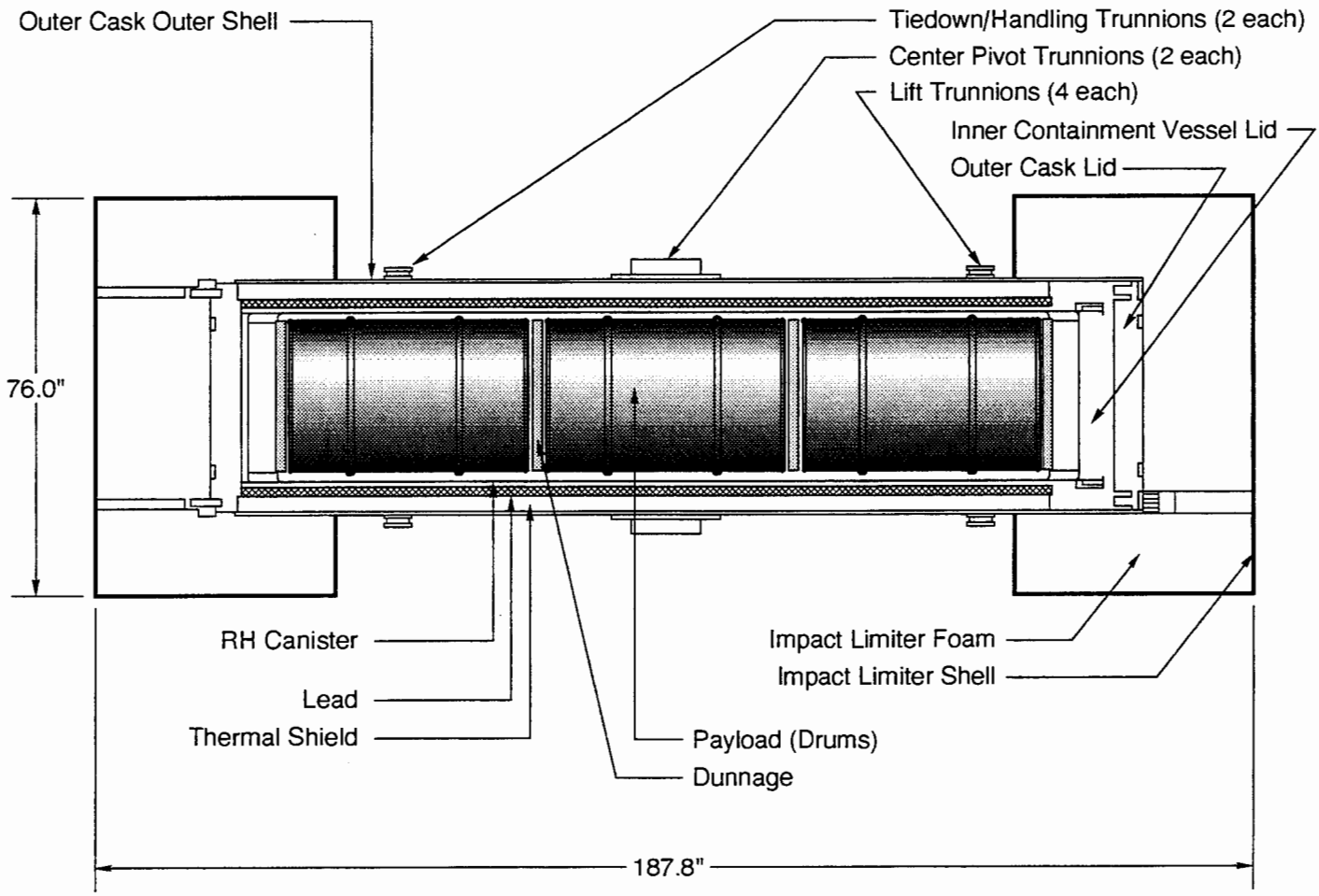

Figure 3-15
RH-72B Shipping Cask for RH-TRU Waste (Schematic)

3.5.2.1 Evaluation Methods Used

3.5.2.1.1 Transportation Routes

The CH- and RH-TRU waste shipments will travel routes as specified in 49 CFR 177.825, which regulates highway and state-approved non-interstate segments between shipment origin sites and the WIPP. Tables 3-32 through 3-35 present origin/destination, total one-way mileage, and fraction of travel in various population zones. These tables also summarize the number of shipments for the transportation configurations for each engineered alternative considered.

3.5.2.1.2 Radiological Exposures

The RADTRAN computer code was used to calculate radiological risks. RADTRAN was originally developed by Sandia National Laboratories to support preparation of NUREG-0170, Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (NRC, 1977). This code has undergone over 18 years of development and is continuing to be refined. RADTRAN 4 (version 4.0.17) (Neuhauser and Kanipe, 1992) was used for the current analyses and was accessed using TRANSNET, an SNL/NM centralized MICRO VAX II computer system. The TRANSNET system incorporates transportation models and data bases that may be accessed via a modem-equipped personal computer.

RADTRAN calculates doses for various population subgroups (e.g., workers, the public) for normal transportation conditions. For the public, it calculates doses to people

- In the vicinity of the transportation vehicle while it is stopped
- Surrounding the transportation route
- Sharing the transportation route with the vehicle.

The dose assessment incorporates a point-source approximation for distances between the receptor and the source of more than twice the largest physical dimension of the source. A line-source approximation is applied for exposure distances less than twice the largest package dimension. The RADTRAN code incorporates features to take credit for shielding for typical structures in urban and suburban settings. RADTRAN also calculates a hypothetical maximum exposure to an individual who resides along the surface transportation route. The model assumes that the individual lives approximately 100 feet (30 meters) from the surface transportation link and that the vehicle passes by at approximately 40 miles per hour (64 kilometers per hour). RADTRAN incorporates algorithms to predict radiological impacts from accidents exceeding transportation package performance conditions. The code evaluates both internal exposure pathways (i.e., inhalation, resuspension, and ingestion) and external exposure pathways (i.e., cloudshine, groundshine) to project potential accident consequences and risks (probability x consequence) to the general public.

Low levels of penetrating radiation from radioactive material shipments pose an external exposure pathway to transportation workers and the public during normal (incident-free) transportation conditions. Shipment external radiation levels are regulated by the U.S. Department of Transportation (DOT) and the NRC on the basis of the Transport Index (TI). The TI represents

1

TABLE 3-32

NUMBER OF SHIPMENTS AND MILEAGE FOR CH-TRU WASTE BASELINE

Waste Origin Site	To Route Destination	Total[1] Shipments	Rural	Suburban	Urban	Total One-Way Mileage
Major CH-TRU Waste Sites						
HANFORD	WIPP	5,712	1,645.3	144.4	18.1	1,808.0
INEL	WIPP	4,974	1,262.5	114.1	15.4	1,392.0
LANL	WIPP	2,839[2]	318.4	21.4	2.1	342.0
RFETS	WIPP	931	618.6	71.1	14.1	704.0
SRS	WIPP	2,827	1,184.2	304.8	19.8	1,509.0
Small CH-TRU Waste Sites						
AMES	ANL-E	1	300.7	50.2	2.1	353.0
ANL-E	WIPP	7[3]	1,237.7	203.0	13.8	1,455.0
BETTIS	MOUND	17	155.0	113.8	20.0	289.0
ETEC	NTS	2	269.1	61.3	44.6	375.0
KAPL	MOUND	1	381.8	291.2	20.6	694.0
LBL	LLNL	1	19.9	31.8	23.2	75.0
LLNL	WIPP	137[4]	1,303.6	100.4	47.9	1,452.0
MOUND	WIPP	47[5]	1,301.3	234.3	20.8	1,557.0
MU	ANL-E	1	294.8	89.0	9.2	393.0
NTS	WIPP	68[6]	1,136.7	63.8	13.4	1,214.0
ORNL	WIPP	120[7]	1,317.6	182.1	21.1	1,521.0
PADUCAH	ORNL	1	251.0	61.7	4.4	317.0
PANTEX	LANL	1	314.2	16.9	3.8	335.0
SNL	LANL	3	82.1	16.7	5.2	104.0
	TOTAL SHIPMENTS	17,690				

[1]The total number of shipments is based on 60% of the waste being shipped in 55-gallon (208-liter) drums and 40% of the waste being shipped in standard waste boxes. It is also assumed that any site with three or less shipments will make all shipments in 55-gallon (208-liter) drums.
[2]This total includes one shipment from PANTEX to LANL and three shipments from SNL to LANL.
[3]This total includes one shipment from AMES to ANL-E and one shipment from MU to ANL-E.
[4]This includes one shipment from LBL.
[5]This total includes 17 shipments from BETTIS to MOUND and one shipment from KAPL to MOUND.
[6]This total includes two shipments from ETEC.
[7]This total includes one shipment from PADUCAH.

Source: Waste Quantity Throughput and Shipments from Wagner, 1995; mileage data from the Highway Computer Code, Johnson et al., 1993.

1

TABLE 3-33

NUMBER OF SHIPMENTS AND MILEAGE FOR RH-TRU WASTE BASELINE AND DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Destination	Total Shipments	Rural	Suburban	Urban	Total One-Way Mileage
Major RH-TRU Waste Sites						
HANFORD	WIPP	5,176	1,645.3	144.4	18.1	1,808.0
ORNL	WIPP	2,185[1]	1,317.6	182.1	21.1	1,521.0
Small RH-TRU Waste Sites						
BATTELLE	ORNL	123	242.6	151.4	14.9	409.0
BETTIS	ORNL	3	414.2	180.1	12.6	607.0
INEL	WIPP	109	1,262.5	114.1	15.4	1,392.0
KAPL	ORNL	57	588.6	285.5	9.8	884.0
LANL	WIPP	249	318.4	21.4	2.1	342.0
SRS	WIPP	56	1,184.2	304.8	19.8	1,509.0
TOTAL SHIPMENTS		7,958				

[1]Total includes 123 shipments from Battelle to ORNL, 3 shipments from Bettis to ORNL, and 57 shipments from KAPL to ORNL.

Source: Waste Quantity Throughput and Shipments from Wagner, 1995; mileage data from the Highway Computer Code, Johnson et al., 1993.

1

TABLE 3-34

NUMBER OF SHIPMENTS AND MILEAGE FOR CH-TRU WASTE REGIONAL CONFIGURATION

Waste Origin Site	Route Destination	Total[1] Shipments	Rural	Suburban	Urban	Total One-Way Mileage
Major CH-TRU Waste Sites						
HANFORD	WIPP	5,849[2]	1,645.3	144.4	18.1	1,808
INEL	WIPP	5,042[3]	1,262.5	114.1	15.4	1,392
LANL	WIPP	2,839[4]	318.4	21.4	2.1	342
RFETS	WIPP	931	618.6	71.1	14.1	704
SRS	WIPP	3,001[5]	1,184.2	304.8	19.8	1,509
Small CH-TRU Waste Sites						
AMES	SRS	1	881.9	292.3	15.7	1,190
ANL-E	SRS	5	587.3	265.9	23.7	877
BETTIS	SRS	17	485	188.4	12.4	686
ETEC	INEL	2	754.7	141.5	61.7	958
KAPL	SRS	1	641.3	295.2	11.7	949
LBL	HANFORD	1	667.7	167.1	35.2	870
LLNL	HANFORD	136	675.1	183.9	30.8	890
MOUND	SRS	29	424.2	206.4	10.4	641
MU	SRS	1	604.3	231.3	27.2	863
NTS	INEL	66	600.3	92.3	20.3	713
ORNL	SRS	119	244.6	110.4	3	358
PADUCAH	SRS	1	380.1	171.1	17.6	569
PANTEX	LANL	1	314.2	16.9	3.8	335
SNL	LANL	3	82.1	16.7	5.2	104
TOTAL SHIPMENTS		18,045				

[1]The total number of shipments is based on 60% of the waste being shipped in 55-gallon (208-liter) drums and 40% of the waste being shipped in Standard Waste Boxes. It is also assumed that any site with three or less shipments will make all shipments in 55-gallon (208-liter) drums.
[2]This total includes 136 shipments from LLNL to HANFORD and one shipment from LBL to HANFORD.
[3]This total includes 66 shipments from NTS to INEL and two shipments from ETEC to INEL.
[4]This total includes one shipment from PANTEX to LANL and three shipments from SNL to LANL.
[5]This total includes five shipments from ANL-E to SRS; one shipment from AMES to SRS; 17 shipments from BETTIS to SRS; one shipment from KAPL to SRS; 20 shipments from MOUND to SRS; one shipment from MU to SRS; 119 shipments from ORNL to SRS; one shipment from PADUCH to SRS.

Source: Waste Quantity Throughput and Shipments from Wagner, 1995; mileage data from the Highway Computer Code, Johnson et al., 1993.

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TABLE 3-35

NUMBER OF SHIPMENTS AND MILEAGE FOR CH-TRU WASTE CENTRALIZED CONFIGURATION

Waste Origin Site	Route Destination	Total[1] Shipments	Rural	Suburban	Urban	Total One-Way Mileage
Major CH-TRU Waste Sites						
HANFORD	WIPP	5,712	1,645.3	144.4	18.1	1,808.0
INEL	WIPP	4,974	1,262.5	114.1	15.4	1,392.0
LANL	WIPP	2,835	318.4	21.4	2.1	342.0
RFETS	WIPP	931	618.6	71.1	14.1	704.0
SRS	WIPP	2,827	1,184.2	304.8	19.8	1,509.0
Small CH-TRU Waste Sites						
AMES	WIPP	1	1,121.4	117.8	15.7	1,255.0
ANL-E	WIPP	5	1,237.7	203.0	13.8	1,455.0
BETTIS	WIPP	17	1,452.7	318.3	31.4	1,803.0
ETEC	WIPP	2	754.7	141.5	61.7	958
KAPL	WIPP	1	1,679.6	495.7	31.9	2,208.0
LBL	WIPP	1	1,320.2	130.5	71.0	1,522.0
LLNL	WIPP	136	1,303.6	100.4	47.9	1,452.0
MOUND	WIPP	29	1,301.3	234.3	20.8	1,557.0
MU	WIPP	1	1,017.5	109.5	17.9	1,145.0
NTS	WIPP	66	1,136.7	63.8	13.4	1,214.0
ORNL	WIPP	119	1,317.6	182.1	21.1	1,521.0
PADUCAH	WIPP	1	1,174.1	171.4	13.9	1,360.0
PANTEX	WIPP	1	412.6	26.7	3.6	443.0
SNL	WIPP	3	288.3	18.7	3.9	311.0
	TOTAL SHIPMENTS	17,662				

[1]The total number of shipments is based on 60% of the waste being shipped in 55-gallon (208-liter) drums and 40% of the waste being shipped in Standard Waste Boxes. It is also assumed that any site with three or less shipments will make all shipments in 55-gallon (208-liter) drums.

Source: Wagner, 1995, mileage data from the Highway Computer Code, Johnson et al., 1993.

the radiation dose rate (in mrem/hr) at 3.3 feet (1 meter) from the surface of the shipping package. Calculated TI values are dependent on:

- Distribution and quantity of radionuclides per shipment
- Self-shielding characteristics of the waste
  - Waste configuration
  - Bulk density
  - Whole-atom ratios of chemical composition
- Configuration and shielding characteristics of the shipment packages.

Calculated TI values are key inputs to the RADTRAN code to evaluate normal transportation impacts.

Shipment TI values were determined using the Microshield Code (Version 3.13, Groves Engineering Inc.) Microshield incorporates libraries of radionuclide kinetics and energies, material absorption coefficients, buildup factors, and dose integration options. TI values were calculated using a cylindrical source/shield model. The calculations took credit for the shelf-shielding characteristics of the waste and for the packaging design. While the TRUPACT-II is not designed specifically to provide shielding, its materials of construction provide some shielding benefits. Pacific Nuclear Systems Dwg No. 2077-500SNP (Rev. K) was used to establish the packaging configuration and material thickness (NRC, 1994). The RH-72B cask is designed to provide shielding and was modeled using Pacific Nuclear Systems Dwg No. X-106-500SNP (Rev. none).

Other key inputs to assess normal transportation impacts are the shipment route length and the fraction of travel in urban, suburban, and rural zones. These zones were determined using the HIGHWAY model (Johnson et al., 1993). Routes were selected for analysis based on 49 CFR 177.825, for truck, which regulates highways and state-approved, non-interstate segments between the shipment origin sites and the WIPP. Exposures to individuals residing or working in buildings along the route were determined using RADTRAN Shielding Option 2. This option estimates exposures to individuals in buildings at reduced rates and takes representative credit for shielding benefits afforded by typical building structures found in the three population areas.

Primary RADTRAN input parameters are summarized in Table 3-36 and are representative of CH-TRU and RH-TRU waste truck shipment modes analyzed in this study. Route-specific population densities were used as determined by the HIGHWAY model. Calculated TRU waste truck shipment TI values are presented in Table 3-37 and were estimated using the Microshield code as discussed above. For engineered alternatives and system configurations requiring waste processing at another location, the TI for the origin/treatment location route segment differs from the TI for the treatment location/WIPP route segment, as determined by how the treatment process affects the final waste form mass (kg/m^3) and radionuclide (Ci/m^3) densities. Radionuclides evaluated and their associated RADTRAN input parameters are summarized in Table 3-38.

A screening analysis was performed to select the radionuclides for evaluation, as summarized in Table 3-38. The BIR identifies approximately 139 radionuclides in the WIPP disposal inventory

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TABLE 3-36

RADTRAN INPUT DATA

Parameter	CH-TRU Waste	RH-TRU Waste
Configuration Data		
Transport Mode	Truck	Truck
Package Type	TRUPACT-II	72B Cask
Packages/Shipment	3[1]	1
Package Characteristic Dimension, m	7.39	3.6
Movement Data		
Shipment distance, km	(site/alternative-specific)	
Population density, people/km	(route/alternative-specific per Highway Routing Model)	
Shipment speed, km/hr		
- Urban population zone	24.16	24.16
- Suburban population zone	40.32	40.32
- Rural population zone	88.56	88.56
Stop time per kilometer, hr/km	0.011	0.011
Other normal input	(RADTRAN 4 default values)	
Normal Exposure Data		
Transport Index (TI), mrem/hr	(site/alternative-specific, see Table 3-37)	
Number of crew members	2	2
Effective distance from source to crew,[2]	10	19
Number of people per public vehicle	2	2
Number of people exposed while stopped	50	50
Exposure distance while stopped, m	20	20
Accident Exposure Data		
Number of accident severity categories[3]	8	8
Accident severity category frequency	(NUREG-0170 values)	
Radioactive contents/parameters	(see Table 3-38)	
Release fractions	(See Table 3-39)	
Other accident inputs	(RADTRAN 4 and default values)	
Accident rates,[4] accidents/km		
- Urban population zone	1.60×10^{-05}	1.60×10^{-05}
- Suburban population zone	3.00×10^{-06}	3.00×10^{-06}
- Rural population zone	1.37×10^{-07}	1.37×10^{-07}

[1]Treated in RADTRAN model as one effective package.
[2]Accounts for RADTRAN simplified exposure model.
[3]Based on NUREG-0170, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes" (NRC, 1977).
[4]Based on *Comparative Study of Waste Isolation Pilot Plant (WIPP) Transportation Alternatives* (DOE, 1994a).

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TABLE 3-37

CALCULATED TRU WASTE TRUCK SHIPMENT TI VALUES[1,2,3,4]

		CH-TRU					RH-TRU
Waste Origin Site	To Route Segment Destination	Baseline	Alternative No. 1 & 77	Alternative No. 6	Alternative No. 10	Alternative No. 94	Baseline
AMES	ANL-E	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	SRS		$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	WIPP	$1.0x10^{+00}$	$9.0x10^{-01}$	$8.7x10^{-01}$	$1.2x10^{+00}$	$5.1x10^{-01}$	
ANL-E	SRS		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
BATTELLE	ORNL						$3.8x10^{-01}$
	WIPP						$3.8x10^{-01}$
BETTIS	MOUND	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	ORNL						$3.2x10^{-01}$
	SRS		$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	WIPP	$1.0x10^{+00}$	$9.0x10^{-01}$	$8.7x10^{-01}$	$1.2x10^{+00}$	$5.1x10^{-01}$	$3.2x10^{-01}$
ETEC	INEL		$5.6x10^{+00}$	$5.6x10^{+00}$	$5.6x10^{+00}$	$5.6x10^{+00}$	
	NTS	$5.6x10^{+00}$	$5.6x10^{+00}$	$5.6x10^{+00}$	$5.6x10^{+00}$	$5.6x10^{+00}$	
	WIPP	$5.6x10^{+00}$	$1.3x10^{+01}$	$7.4x10^{+00}$	$1.4x10^{+01}$	$1.0x10^{+01}$	
HANFORD	WIPP	$9.3x10^{+00}$	$8.0x10^{+00}$	$7.5x10^{+00}$	$9.8x10^{+00}$	$5.9x10^{+00}$	$6.9x10^{+01}$
INEL	WIPP	$1.0x10^{+00}$	$9.0x10^{-01}$	$8.7x10^{-01}$	$1.2x10^{+00}$	$5.1x10^{-01}$	$2.4x10^{+00}$
KAPL	MOUND	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	ORNL						$7.1x10^{-01}$
	SRS		$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	WIPP	$1.0x10^{+00}$	$9.0x10^{-01}$	$8.7x10^{-01}$	$1.2x10^{+00}$	$5.1x10^{-01}$	$7.1x10^{-01}$
LANL	WIPP	$4.8x10^{-01}$	$6.8x10^{-01}$	$6.6x10^{-01}$	$1.0x10^{+00}$	$4.3x10^{-01}$	$1.3x10^{+00}$
LBL	HANFORD		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	LLNL	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	

Refer to footnotes at end of table.

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TABLE 3-37 (Continued)

CALCULATED TRU WASTE TRUCK SHIPMENT TI VALUES[1,2,3,4]

		CH-TRU					RH-TRU
Waste Origin Site	To Route Segment Destination	Baseline	Alternative No. 1 & 77	Alternative No. 6	Alternative No. 10	Alternative No. 94	Baseline
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
LLNL	HANFORD		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
MOUND	SRS		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
MU	ANL-E	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	SRS		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
NTS	INEL		$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	$1.0x10^{+00}$	
	WIPP	$1.0x10^{+00}$	$9.0x10^{-01}$	$8.7x10^{-01}$	$1.2x10^{+00}$	$5.1x10^{-01}$	
ORNL	SRS		$2.2x10^{+02}$	$2.2x10^{+02}$	$2.2x10^{+02}$	$2.2x10^{+02}$	
	WIPP	$2.2x10^{+02}$	$1.1x10^{+02}$	$1.3x10^{+02}$	$1.2x10^{+02}$	$6.9x10^{+01}$	$2.0x10^{+01}$
PA	ORNL	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	SRS		$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
PANTEX	LANL	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
RFETS	WIPP	$1.3x10^{-02}$	$9.3x10^{-03}$	$9.2x10^{-03}$	$1.8x10^{-02}$	$7.8x10^{-03}$	
SNL	LANL	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	$1.0x10^{-02}$	
	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	
SRS	WIPP	$1.0x10^{-02}$	$1.1x10^{-02}$	$1.0x10^{-02}$	$1.2x10^{-02}$	$7.7x10^{-03}$	$1.6x10^{+01}$

[1]Tabulated TI values have units of mrem/hr.
[2]Tablulated shipment TI values for route segments to treatment/storage considered under the decentralized and regional treatment configuration are the same as the baseline values.
[3]Tablulated shipment TI values for the WIPP route segments are for the treated waste forms considered under the respective engineered alternatives.
[4]Shipment TI values to WIPP under the centralized treatment configuration are the same as the baseline values for all engineered alternatives.

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TABLE 3-38

SELECTED RADIONUCLIDES FOR TRANSPORTATION ANALYSIS AND ASSOCIATED RADTRAN INPUTS

Radionuclide	Half-life (days)	Photon Energy (MeV)	Cloudshine Dose Factor (rem-m^3/Ci-sec)	Inhalation Dose Factor (rem CEDE/Ci)	Lung Type	1-yr Lung Dose for Inhalation (rem/Ci)	1-yr Marrow Dose for Inh (rem/Ci)
AC-227	$7.29\times10^{+03}$	2.31×10^{-04}	1.99×10^{-05}	$7.70\times10^{+09}$	3	$2.30\times10^{+09}$	$4.30\times10^{+08}$
AM-241	$1.58\times10^{+05}$	3.24×10^{-02}	3.01×10^{-03}	$5.90\times10^{+08}$	3	$1.20\times10^{+08}$	$1.70\times10^{+07}$
AM-243	$2.70\times10^{+06}$	5.59×10^{-02}	8.11×10^{-03}	$5.90\times10^{+08}$	3	$1.10\times10^{+08}$	$1.60\times10^{+07}$
BA-137m	Accounted for by RADTRAN with parent nuclide (CS-137)						
CE-144	$2.84\times10^{+02}$	5.25×10^{-02}	2.88×10^{-03}	$6.30\times10^{+05}$	1	$3.60\times10^{+06}$	$4.20\times10^{+03}$
CF-252	$9.64\times10^{+02}$	1.20×10^{-03}	1.19×10^{-05}	$2.40\times10^{+08}$	3	$8.60\times10^{+08}$	$2.30\times10^{+06}$
CM-243	$1.04\times10^{+04}$	1.34×10^{-01}	2.02×10^{-02}	$4.00\times10^{+08}$	3	$1.20\times10^{+08}$	$1.70\times10^{+07}$
CM-244	$6.62\times10^{+03}$	1.70×10^{-03}	1.33×10^{-05}	$3.10\times10^{+08}$	3	$1.20\times10^{+08}$	$1.70\times10^{+07}$
CM-245	$3.10\times10^{+06}$	9.55×10^{-02}	1.13×10^{-02}	$6.20\times10^{+08}$	3	$1.10\times10^{+08}$	$1.60\times10^{+07}$
CO-60	$1.93\times10^{+03}$	$2.50\times10^{+00}$	4.12×10^{-01}	$2.80\times10^{+05}$	2	$7.90\times10^{+05}$	$3.80\times10^{+04}$
CS-134	$7.53\times10^{+02}$	$1.55\times10^{+00}$	2.54×10^{-01}	$4.60\times10^{+04}$	2	$4.10\times10^{+04}$	$3.90\times10^{+04}$
CS-137	$1.10\times10^{+04}$	5.96×10^{-01}	$0.00\times10^{+00}$	$3.20\times10^{+04}$	2	$3.10\times10^{+04}$	$2.60\times10^{+04}$
EU-152	$4.87\times10^{+03}$	$1.14\times10^{+00}$	1.87×10^{-01}	$2.60\times10^{+05}$	2	$0.00\times10^{+00}$	$0.00\times10^{+00}$
EU-154	$3.21\times10^{+03}$	$1.22\times10^{+00}$	2.06×10^{-01}	$3.10\times10^{+05}$	2	$0.00\times10^{+00}$	$0.00\times10^{+00}$
EU-155	$1.81\times10^{+03}$	6.05×10^{-02}	9.10×10^{-03}	$4.80\times10^{+04}$	2	$0.00\times10^{+00}$	$0.00\times10^{+00}$
NB-95	$3.52\times10^{+01}$	7.66×10^{-01}	1.26×10^{-01}	$7.30\times10^{+03}$	1	$5.30\times10^{+04}$	$2.40\times10^{+03}$
NP-237	$7.82\times10^{+08}$	3.43×10^{-02}	3.64×10^{-03}	$5.60\times10^{+08}$	3	$1.00\times10^{+08}$	$1.50\times10^{+07}$
PR-144	Accounted for by RADTRAN with parent nuclide (CE-144)						
PU-238	$3.21\times10^{+04}$	1.81×10^{-03}	1.40×10^{-05}	$5.30\times10^{+08}$	3	$4.50\times10^{+08}$	$1.10\times10^{+06}$
PU-239	$8.79\times10^{+06}$	7.96×10^{-04}	1.30×10^{-05}	$5.70\times10^{+08}$	3	$4.20\times10^{+08}$	$1.10\times10^{+06}$
PU-240	$2.39\times10^{+06}$	1.73×10^{-03}	1.37×10^{-05}	$5.70\times10^{+08}$	3	$4.20\times10^{+08}$	$1.10\times10^{+06}$
PU-241	$5.26\times10^{+03}$	2.54×10^{-06}	0.00×10^{-00}	$9.90\times10^{+06}$	3	$3.60\times10^{+05}$	$1.30\times10^{+03}$
PU-242	$1.37\times10^{+08}$	1.44×10^{-03}	1.16×10^{-05}	$5.30\times10^{+08}$	3	$4.00\times10^{+08}$	$1.00\times10^{+06}$
RH-106	3.46×10^{-04}	2.01×10^{-01}	3.33×10^{-02}	$2.20\times10^{+00}$	1	$4.30\times10^{+06}$	$4.00\times10^{+04}$
SB-125	$1.01\times10^{+03}$	4.30×10^{-01}	6.75×10^{-02}	$1.70\times10^{+04}$	2	$4.40\times10^{+04}$	$5.50\times10^{+02}$

1 **TABLE 3-38 (Continued)**

SELECTED RADIONUCLIDES FOR TRANSPORTATION ANALYSIS AND ASSOCIATED RADTRAN INPUTS

Radionuclide	Half-life (days)	Photon Energy (MeV)	Cloudshine Dose Factor (rem-m^3/Ci-sec)	Inhalation Dose Factor (rem CEDE/Ci)	Lung Type	1-yr Lung Dose for Inhalation (rem/Ci)	1-yr Marrow Dose for Inh (rem/Ci)
SR-90	$1.06x10^{+04}$	$0.00x10^{+00}$	$0.00x10^{+00}$	$2.40x10^{+06}$	2	$4.50x10^{+06}$	$3.80x10^{+03}$
TE-125m	$5.80x10^{+01}$	$3.55x10^{-02}$	$1.53x10^{-03}$	$1.00x10^{+04}$	1	$0.00x10^{+00}$	$0.00x10^{+00}$
TH-228	$6.98x10^{+02}$	$3.03x10^{-03}$	$3.14x10^{-04}$	$5.80x10^{+08}$	3	$2.20x10^{+09}$	$1.20x10^{+08}$
TH-229	$2.68x10^{+06}$	$9.54x10^{-02}$	$1.37x10^{-02}$	$2.90x10^{+09}$	3	$2.40x10^{+09}$	$1.40x10^{+08}$
TH-231	$1.06x10^{+00}$	$2.55x10^{-02}$	$1.85x10^{-03}$	$1.00x10^{+03}$	1	$5.10x10^{+03}$	$6.70x10^{+01}$
TL-208	$2.13x10^{-03}$	$3.36x10^{+00}$	$6.28x10^{-01}$	$8.00x10^{+00}$	1	$5.70x10^{+01}$	$1.10x10^{+00}$
U-232	$2.63x10^{+04}$	$2.19x10^{-03}$	$4.22x10^{-05}$	$1.10x10^{+09}$	3	$8.30x10^{+08}$	$5.20x10^{+05}$
U-233	$5.79x10^{+07}$	$1.31x10^{-03}$	$3.80x10^{-05}$	$2.40x10^{+08}$	3	$4.00x10^{+08}$	$6.10x10^{+03}$
U-234	$8.90x10^{+07}$	$1.73x10^{-03}$	$2.43x10^{-05}$	$2.30x10^{+08}$	3	$3.90x10^{+08}$	$3.10x10^{+05}$
U-238	$1.63x10^{+12}$	$1.36x10^{-03}$	$1.65x10^{-05}$	$2.20x10^{-08}$	3	$3.50x10^{+08}$	$6.30x10^{+03}$
Y-90	$2.67x10^{+00}$	$1.69x10^{-06}$	$0.00x10^{+00}$	$9.90x10^{+03}$	1	$5.90x10^{+04}$	$7.40x10^{+02}$

for CH-TRU and RH-TRU waste. Radionuclides were ranked as to their potential significance in determining the Transportation Risk Factor using a relative hazard value. The relative hazard value for each radionuclide was calculated by multiplying the anticipated inventory activity fraction of each radionuclide by a dose factor index and a photon energy index and summing the products. The dose factor index for each radionuclide was determined by summing its ingestion and inhalation dose factors (rem/Ci) and dividing by the Pu-239 dose factor sum. Similarly, the photon energy index for each radionuclide was determined by dividing its average photon energy by the maximum photon energy of the radionuclides in the inventory. In this manner, a relative measure of internal and external exposure hazards for each radionuclide could be assessed. Those radionuclides having relative hazard values within four orders of magnitude of the highest value were selected for analysis.

To predict potential radiological impacts from accidents, this analysis uses an accident severity classification scheme and associated probabilities of occurrence derived from NUREG-0170 (NRC, 1977) and the WIPP FSEIS (DOE, 1990b). Accident severity categories define the seriousness of an accident in terms of mechanical and thermal (fire) loads and influence the potential amount of radioactive material released during an accident. Most accidents are unlikely to cause any release, but very severe accidents (much more severe than represented by NRC certification standards for Type B containers) may cause some of the radioactive material to escape. NUREG-0170 defined eight accident severity categories. The first two accident categories were defined to be less serious than the hypothetical accident conditions specified in 10 CFR Part 71 for testing Type B packaging and were retained in this analysis. Thus, use of the TRUPACT-II container and RH-72B cask would be very unlikely to result in any releases to the environment for severity category I or II accidents. NUREG-0170 defined the remaining six categories to postulate increasingly severe, but less likely, accidents resulting in a release of radioactive materials from Type B packages.

A key parameter for analyzing postulated accidents is the estimated release fraction of radioactive material escaping to the environment. Particulates can result from impacts that fracture or suspend the radioactive material or from fires that can entrain impact-generated particulates, cause off-gassing of volatile fission products, or thermally degrade and then entrain particulates from previously intact material. Inhalation is a primary internal exposure pathway for people that results from breathing respirable (<10 microns), aerosolized particulates. As the particulates move downwind, some settle out onto the ground where they can expose people to penetrating radiation. This constitutes the "groundshine" exposure pathway. After settling, some fraction of the particles can also be resuspended into the air due to wind or other surface disturbances. These particulates can then be inhaled by people as were those in the initial plume and constitute the source term for the resuspension dose pathway. Finally, particles in the air can also expose people to penetrating radiation; this constitutes the "cloudshine" exposure pathway. For this analysis, the ingestion pathway (through which particles settle on crops and are subsequently consumed by the public) was not assessed. Reasons for not incorporating the ingestion pathway were that (1) any accident resulting in contamination of crops would result in interdiction of those crops prior to any significant consumption by the public, (2) based on dose conversion factors for the radionuclides of interest, inhalation exposures result in doses typically one to two orders of magnitude greater than those from ingestion for equal uptakes of radioactive material, and (3) the RADTRAN model has not formally adopted radionuclide ingestion parameters (i.e., soil or food transfer factors).

This analysis uses the release fractions developed in Appendix D of the WIPP FSEIS (DOE,

1990b) for postulated accidents involving baseline CH-TRU and RH-TRU waste shipments. The release fraction analysis determined how much radioactive material could be potentially released to the environment in a respirable, airborne form for accident severity categories III through VIII. Larger particle sizes (greater than 10 microns) were not analyzed, as they tend to be eliminated by the body and consequently are not as significant in estimating health effects.

Calculation of respirable release fractions for engineered alternatives No. 1 and No. 77 (supercompacted waste) followed the WIPP FSEIS methodology. The fraction of material released from failed containers was reduced by one third for severity categories III through VII, reflecting greater crush resistance of the drums (less void space) and that there will typically be four supercompacted pucks in each drum. Additionally, the fraction of material aerosolized from impact was reduced by an order of magnitude to reflect reduced aerosolization of the supercompacted waste form by impact forces. Similarly, the fraction of material entrained to the environment was reduced by an order of magnitude to represent the supercompacted waste form. Finally, the fraction of material aerosolized by the postulated thermal event was also reduced by an order of magnitude to account for the reduced surface area of the supercompacted waste form.

Calculation of respirable release fractions for engineered alternative No. 6 (compacted/shredded waste) also followed the WIPP FSEIS methodology. The fraction of material released from failed containers was reduced by one third (assumed same as supercompacted waste) for the lower accident severity categories (III, IV, and V). This accounts for the increased crush resistance of the drums due to compaction but recognizes that it is not as great as with supercompaction. The fraction of material aerosolized by the thermal event was increased by an order of magnitude to reflect the increased surface area of the shredded material. It was assumed that engineered alternative No. 94 waste forms would have similar release fractions because they have essentially the same treated waste matrices, except that clay is added to enhance repository performance.

Calculation of release fractions for engineered alternative No. 10 waste forms required the use of alternative analysis methodologies. The products of plasma processing are vitrified glasses and solid metals and are anticipated to be able to withstand severe temperatures. Respirable impact releases were determined using impact test data for vitrified materials (Pacific Northwest Laboratories, 1975). The amount of material fractured at an impact velocity of 66 feet per second ranged from 0.013 to 0.15 percent. The upper value of this range was used as the amount of material released for accident severity category VIII. RADTRAN default values for an immobile material for the aerosol fraction and the respirable fraction were applied to the estimated material released to quantify the respirable impact release. This value was conservatively applied to accident severity categories III through VIII. Under thermal accident conditions, vitrified materials are anticipated to behave like refractory brick. The primary release mechanism is expected to be the aerosolization of material from contaminated surfaces. Any such releases are anticipated to occur only at the more severe accident categories involving a prolonged fire (category IV through VIII). The Nuclear Fuel Cycle Facility Accident Analysis Handbook (Ayer et al., 1988) recommends a thermal suspension factor of 2.5×10^{-5}/s. This analysis assumed that there is an effective thermal suspension duration of one hour and that 10 percent of the material fractured is available for release under severity category VIII accident conditions. Additionally, a decontamination factor of 5×10^{-2} was used for releases from the package cavity to the environment. This is consistent with values used in Transportation—Accident Scenarios for Commercial Spent Fuel (Wilmot, 1981) and takes credit for mitigation processes reducing radioactive material releases such as particulate settlement, plateout, and filtration effects along

the leak path. The resulting respirable thermal release fraction was conservatively applied to accident severity categories IV through VIII. The total respirable release fraction was determined by summing the impact and thermal release components.

Table 3-39 summarizes the resulting radioactive material release fractions for postulated accidents for the baseline and engineered alternatives evaluated in this study. Radiological exposures to internal and external doses of radiation are reported in units of rem (individual dose) or person-rem (collective dose to a group of individuals). The average annual dose of ionizing radiation to a member of the U.S. population is estimated to be 0.36 rem (National Council on Radiation Protection and Measurements, 1987). This includes both natural sources (e.g., radon) and artificial sources (e.g., diagnostic x-rays). Principal adverse effects from human exposure to low-level ionizing radiation are carcinogenicity (ability to cause cancer), mutagenicity (ability to cause inheritable defects), and teratogenicity (ability to cause noninheritable birth defects). For low-level exposures, the most significant risk is that of latent (delayed) cancers. The summation of radiation doses (collective dose) to a group of individuals may be multiplied by a dose-to-risk conversion factor to estimate the number of incremental latent cancer fatalities (LCFs) associated with the postulated exposure. Use of a dose-to-risk conversion factor of 500 LCFs per million person-rem (5.0×10^{-4} LCFs/person-rem) for the general population and of 400 latent cancer fatalities per million person-rem (4.0×10^{-4} LCFs/person-rem) for workers are currently accepted values (NRC, 1991). This difference in dose-to-risk conversion factors for the two population groups is attributable to the presence of children in the general population.

3.5.2.1.3 Hazardous Chemical Exposures

The hazardous chemical analysis is based on the methodology presented in the Transportation Alternatives report (DOE, 1994a). As the scope of the current chapter and above-mentioned report is limited to the analysis of transportation impacts from the gate of the shipment origin site to the gate of the treatment or disposal site, no handling of waste containers is considered. Additionally, the hazardous chemical constituents of the waste are completely contained within the shipment package (i.e., TRUPACT-II or RH-72B cask). Because of the integrity and leak tightness of these Type B packages, it can be concluded that the shipment of hazardous chemical waste constituents presents an insignificant hazard to workers and the public under incident-free transportation conditions.

While it is very unlikely that an accident will breach a Type B package, such an accident is credible and constitutes a potential chemical exposure source to the public. Comparison of resulting airborne chemical concentrations to an accepted level of protection is used as the basis for determining the chemical component of the Transportation Risk Factor. Because predicted airborne chemical concentrations are determined by the waste form (i.e., untreated, supercompacted, vitrified) and associated release mechanisms, the chemical component of the Transportation Risk Factor is affected by the engineered alternative considered and not by the decentralized, regionalized, or centralized configurations to be evaluated. Thus, each engineered alternative considered will have one chemical risk factor, which will be the same for all configurations.

The chemical assessment was performed based on a very severe shipment accident. Maximum impacts were evaluated by assuming a severity VIII category accident and associated releases. The risk factor was evaluated by comparing maximum airborne chemical concentrations for a member of the public with concentrations based on Emergency Response Planning Guideline 2

1

TABLE 3-39

TRU WASTE TRUCK SHIPMENT RELEASE FRACTIONS FOR POSTULATED ACCIDENTS[1]

	Accident Severity Category							
Scenario	I	II	III	IV	V	VI	VII	VIII
Baseline[2]								
CH-TRU Waste	$0x10^{-00}$	$0x10^{-00}$	$8x10^{-09}$	$2x10^{-07}$	$8x10^{-05}$	$2x10^{-04}$	$2x10^{-04}$	$2x10^{-04}$
RH-TRU Waste	$0x10^{-00}$	$0x10^{-00}$	$6x10^{-09}$	$2x10^{-07}$	$1x10^{-04}$	$1x10^{-04}$	$2x10^{-04}$	$2x10^{-04}$
CH-TRU Waste Engineered Alternatives[3]								
Alternative No. 1 & 77	$0x10^{-00}$	$0x10^{-00}$	$8x10^{-09}$	$2x10^{-08}$	$2x10^{-06}$	$5x10^{-06}$	$7x10^{-06}$	$2x10^{-05}$
Alternative No. 6	$0x10^{-00}$	$0x10^{-00}$	$1x10^{-08}$	$2x10^{-06}$	$3x10^{-05}$	$2x10^{-04}$	$2x10^{-04}$	$2x10^{-04}$
Alternative No. 10	$0x10^{-00}$	$0x10^{-00}$	$8x10^{-11}$	$7x10^{-08}$	$7x10^{-08}$	$7x10^{-08}$	$7x10^{-08}$	$7x10^{-08}$
Alternative No. 94	$0x10^{-00}$	$0x10^{-00}$	$1x10^{-08}$	$2x10^{-06}$	$3x10^{-05}$	$2x10^{-04}$	$2x10^{-04}$	$2x10^{-04}$

[1]Tabulated release fractions are for the final waste form.
[2]Baseline release fractions based on the WIPP FSEIS (Appendix D, TABLES D.3.21 and D.3.22) (DOE, 1990b).
[3]See Section 3.5.2.1.2 text for basis of engineered alternative release fractions.

(ERPG-2). An ERPG-2 is defined as the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action (AIHA, 1989). This is an appropriate exposure level for the public and is consistent with the recommendations in the DOT 1990 Emergency Response Guidebook (DOT, 1990).

ERPG-2 values are developed based on an anticipated one-hour exposure. To address a postulated two-hour exposure, the ERPG-2 value was halved to provide an adjusted ERPG-2 value. This is a more stringent exposure level for comparing two-hour release concentration values with calculated chemical airborne concentrations. This comparison was accomplished by dividing the maximum calculated receptor concentrations for each chemical by the adjusted ERPG-2 value. Ratios smaller than unity indicate that exposures fall within health-based reference levels. Additionally, the individual chemical ratios were summed and compared to unity. This provides an indication of potential cumulative effects for exposure to multiple chemicals even though it does not take into consideration possible synergistic effects among the chemicals.

Based on the relative shipment capacity of the TRUPACT-II (308.7 cubic feet per drum shipment and 389.1 cubic feet (11.02 cubic meters) per SWB shipment) versus the relative shipment capacity of the RH-72B (31.4 cubic feet [0.89 cubic meters]) and the chemical characterization data presented in the Interim Mixed Waste Inventory Report (DOE, 1993a), it is concluded that hazardous constituent accident analyses for CH-TRU waste baseline shipments are bounding for RH-TRU waste baseline shipments.

An initial screening analysis was performed to identify potential chemicals for analysis under accident conditions. Table C-1 of the WIPP RCRA Part B Permit Application (DOE, 1993b) and the TRUPACT-II List of Chemical Compounds in Each Content Code in TRUCON (DOE, 1994g) were reviewed to identify chemicals found in CH-TRU waste streams for INEL, Hanford Site, RFETS, and Savannah River Site. Waste streams from these sites are currently projected to constitute 82 percent of the CH-TRU waste to be emplaced at the WIPP. Chemicals were retained as candidates for analysis if an airborne concentration limit could be found for the chemical of interest. Concentration limits considered included:

- The EPA list of acutely hazardous substances having levels of concern (LOCs)
- Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) values
- American Industrial Hygiene Association Emergency Response Planning Guideline (ERPG) values
- American Conference of Governmental Industrial Hygienists Threshold Limit Values (TLVs)

Following the initial screening analysis, chemicals were further ranked as to their potential health significance using a relative hazard value. The relative hazard value for each chemical was determined by dividing the hazard value for a given chemical by the maximum hazard value for all the chemicals in the respective table. The hazard value was calculated as the fraction (concentration) of the chemical in the waste matrix divided by the airborne concentration limit of

the subject chemical. Thus, the higher a chemical concentration in a waste matrix or the lower its airborne concentration limit, the greater its potential hazard. All substances having a relative hazard value within 1 percent of the maximum relative risk value were retained for final analysis. The 20 chemicals that fell within 1 percent of the maximum hazard value and that were selected for further analysis are presented in Table 3-40.

Chemical concentrations in the waste matrix were estimated using Table C-1 of the WIPP RCRA Part B Permit Application (DOE, 1993b) and the TRUPACT-II list of chemical compounds in each content code in TRUCON (DOE, 1994g). These documents provide concentration values for chemicals in the various waste matrices. Chemicals were typically reported as either dominant (>10 weight percent), minor (1-10 weight percent), trace (<1 weight percent), trace 1 (< 0.1 weight percent), trace 2 (low parts per million [ppm] range), or trace 3 (<1 ppm by weight). The following concentration values were assigned for each category (fraction by weight):

Dominant	(D)	–	0.3
Minor	(M)	–	0.10
Trace	(T)	–	0.01
Trace 1	(T1)	–	0.001
Trace 2	(T2)	–	0.0001
Trace 3	(T3)	–	no chemicals passing the initial screening were in this category.

The analysis used the highest reported nominal concentration for a given chemical, with the exception of cadmium, due to the variability of its concentration in the waste forms considered (maximum reported value is "D," value utilized is "M").

Airborne chemical concentrations for the maximally exposed member of the public were determined using the Gaussian Dispersion Plume equation of Pasquill as modified by Gifford (1961) for ground-level concentrations at the centerline of the plume:

$$\chi = [Q/(\pi\ \sigma_y \sigma_z\ \mu)]\ \exp\ [-.5\ (H/\sigma_z)^2], \qquad 3.8$$

where

χ = contaminant airborne concentration at x meters downwind, mg/m^3
Q = contaminant release rate, mg/s
μ = mean wind speed, m/s
σ_y = horizontal dispersion coefficient, m
σ_z = vertical dispersion coefficient, m
H = effective release height, m.

The above equation does not incorporate plume depletion effects from particulate settlement (by gravitational or chemical effects) and thus will overstate air concentrations and resulting inhalation exposures. Additionally, each accident was postulated to occur during a period having very stable atmospheric meteorological conditions (Pasquill Stability Class F, wind speed of 1 m/s). Use of these unfavorable meteorological conditions introduces additional conservatism into the analysis.

The following short-term dispersion coefficients (Slade, 1968) were incorporated in the Gaussian Plume Dispersion equation:

1

TABLE 3-40

SELECTION OF CHEMICAL CONSTITUENTS IN CH-TRU WASTE FOR FURTHER ANALYSIS

Chemical Name	CAS Number	Quantity Code[1]	Fraction in Waste Matrix[2]	ERPG-2 (ppm)	ERPG-2 Source[3]	Hazard Value	Relative Hazard Value
Beryllium	7740-41-7	T	0.01	0.01	c	$1.00x10^{+00}$	$2.33x10^{-01}$
Bromine	7726-95-6	T	0.01	1.00	c	$1.00x10^{-02}$	$3.33x10^{-02}$
Cadmium (fume)	7440-43-9	D	0.3	0.07	b	$4.29x10^{+00}$	$9.99x10^{-01}$
Carbon tetrachloride	56-23-5	D	0.3	25.00	b	$1.20x10^{-02}$	$4.00x10^{-02}$
Cellulose	9004-34-6	D	0.3	25.00	a	$1.2x10^{-02}$	$4.00x10^{-02}$
Chloroform	67-66-3	D	0.3	100.00	d	$3.00x10^{-03}$	$1.00x10^{-02}$
Chlorosulfonic acid	7790-94-5	T	0.01	2.10	c	$4.76x10^{-03}$	$1.59x10^{-02}$
Chromium VI compounds,as Cr		T	0.01	0.10	a	$1.00x10^{-01}$	$2.33x10^{-02}$
Copper (fume)	7440-50-8	M	0.1	0.40	a	$2.50x10^{-01}$	$5.83x10^{-02}$
Hydrazine	302-01-2	T	0.01	0.80	c	$1.25x10^{-02}$	$4.17x10^{-02}$
Lead	7439-92-1	D	0.3	0.09	a	$3.33x10^{+00}$	$7.77x10^{-01}$
Mercury (inorganic)	7439-97-6	T	0.01	0.01	b	$1.00x10^{+00}$	$2.33x10^{-01}$
Oxalic acid	144-62-7	T	0.01	1.50	a	$6.67x10^{-03}$	$2.22x10^{-02}$
Platinum	7440-06-4	M	0.1	0.50	a	$2.00x10^{-01}$	$4.66x10^{-02}$
Phosphoric acid	7664-38-2	T	0.01	1.50	a	$6.67x10^{-03}$	$2.22x10^{-02}$
Silver	7440-22-4	T	0.01	0.10	a	$1.00x10^{-01}$	$2.33x10^{-02}$
Sodium hydroxide	1310-73-2	T	0.01	1.20	b	$8.33x10^{-03}$	$2.78x10^{-02}$
Tributyl phosphate	126-73-8	D	0.3	1.00	a	$3.00x10^{-01}$	$1.00x10^{+00}$
Tungsten (sol. Compounds as W)	7440-33-7	M	0.1	0.50	a	$2.00x10^{-01}$	$4.66x10^{-02}$
Uranium	7440-61-1	T	0.01	0.10	a	$1.00x10^{-01}$	$2.33x10^{-02}$

[1]D = Dominant; M = Minor; T = Trace
[2]Chemical concentrations in the waste matrix are conservatively estimated based on the assigned quantity codes for use in the risk analysis and are not representative of average TRU waste characteristics.
[3]a. TLV-TWA X5; b. PEL-C; c. ERPG-2; d. LOC

$\sigma_y = 0.02\ (x)^{.89}$
$\sigma_z = 0.05\ (x)^{.61}$
x = downwind distance, m

The effective height (H) of the accident plume was estimated as approximately 69 feet (21 meters). This takes into consideration the buoyancy rise associated with the thermal effects from the accident. Thermal effects (e.g., hydrocarbon fuel fire) are expected to play a major role in any loss-of-containment scenario. The buoyancy rise was determined using a heat emission of $8.3 \times 10^{+4}$ watts/m^2, based on hydrocarbon fuel fire tests (Gregory et al., 1987).

The resulting maximum receptor concentration for a member of the public was calculated as:

$$\text{Receptor concentration (maximum individual)} = \chi/Q\ \text{(maximum individual)} \times \text{Release Rate (mg/s)} \qquad 3.9$$

where:	χ/Q (maximum individual)	=	1.13×10^{-04} s/m^3
	Release Rate	=	Release Quantity (mg)/7200 (s) (assumes a two-hour release)
	Release Quantity	=	Release fraction x fraction of waste chemical is present x chemical fraction in waste x weight of waste/shipment.

Thus, receptor chemical concentrations for postulated accidents will vary by engineered alternative as determined by how the final waste form affects the release fraction, the chemical fraction in the waste, and the density of the waste matrix.

Quantities of hazardous constituents released during the maximum accident were determined using the following bases:

- A severity category VIII accident occurs, resulting in a breach of all three TRUPACT-II packages, and involves both impact and thermal release mechanisms.
- The CH-TRU waste matrix form and density vary by engineered alternative.
- Chemicals released as respirable particulate matter will have a release fraction as determined for the radiological analysis.
- Chemicals released as vapors will have a release fraction dependent on their vapor pressure at the elevated temperature conditions of the TRUPACT-II under accident conditions.
- The fraction of a TRU waste shipment containing the hazardous chemicals of interest was determined on a systemwide-average basis.

- The Interim Mixed Waste Inventory Report (DOE, 1993a) (Chapter 4.0, Table 4-1, and site waste profile sheets) was used to estimate the fraction of CH-TRU waste volume (or shipment) for which each hazardous constituent of interest is present.

3.5.2.1.4 Nonradiological/Non-chemical Risks

The methodology presented in the WIPP FSEIS (DOE, 1990b) was used to estimate the range of non-radiological and non-chemical risks, which involve traumatic injuries and fatalities that are independent of the characteristics of the cargo (Table 3-41).

The HIGHWAY model (Johnson et al., 1993) was used to determine truck travel mileages and travel distance in rural, suburban, and urban population zones. The model incorporates updated 1990 census data.

Estimates of per-shipment risk include accident-related injuries and fatalities of a single TRU waste shipment (round trip) to the WIPP. Cumulative risk estimates were determined by multiplying per-shipment risks by the total number of shipments.

3.5.3 Assumptions and Data Used

3.5.3.1 Number of Waste Shipments

Number of waste shipments is dependent on a site-by-site volume. The analysis in this chapter assumes that a total volume of 6.2 million cubic feet (0.17 million cubic meters) of TRU waste will be emplaced at WIPP. This total includes 5.95 million cubic feet (0.16 million cubic meters) of CH-TRU waste and 250,000 cubic feet (7078.3 cubic meters) of RH-TRU waste. Tables R-20 and R-21 in Appendix R ("Waste Volumes and Inventories") present the CH-TRU and RH-TRU waste volumes for each site. The volumes have been scaled up to reach repository emplacement limits.

The following assumptions were used to estimate the site-by-site shipment volume for TRU waste (Wagner, March 1995):

CH-TRU waste
- 7.35 cubic feet (0.208 cubic meters) per drum
- 64.85 cubic feet (1.836 cubic meters) per SWB
- 14 drums per TRUPACT-II
- 2 SWBs per TRUPACT-II
- 3 TRUPACT-IIs per shipment
- 308.7 cubic feet (8.74 cubic meters) per drum shipment
- 389.1 cubic feet (11.02 cubic meters) per SWB shipment

RH-TRU waste
- 31.4 cubic feet (0.89 cubic meters) per RH-72B cask
- one RH-72B cask per shipment
- 31.4 cubic feet (0.89 cubic meters) per shipment

1

TABLE 3-41

NONRADIOLOGICAL AND NONCHEMICAL UNIT RISK FACTORS

Mode	Zone	Injuries/Mile	Fatalities/Mile
Truck	Rural	1.33×10^{-06}	1.09×10^{-07}
	Suburban	6.32×10^{-07}	2.69×10^{-08}
	Urban	6.16×10^{-07}	1.54×10^{-08}

3.5.3.2 Waste Characteristics

Baseline waste characteristics were primarily established using two information resources: (1) the Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (DOE, 1995e) and (2) the Comparative Study of Waste Isolation Pilot Plant (WIPP) Transportation Alternatives (DOE, 1994a), which was prepared to meet requirements of the LWA. In subsequent discussions, these reports are referred to as the BIR and the Transportation Alternatives report, respectively. The BIR was used to establish waste forms and densities and their corresponding radionuclide content and distribution. Average sitewide information was incorporated into the analysis. The Transportation Alternatives report was used to quantify hazardous chemical concentrations in the TRU waste matrices. The information presented in the Transportation Alternatives report was derived from (1) the U.S. Department of Energy Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capabilities and Technologies (DOE, 1993a); (2) Table C-1 of the Waste Isolation Pilot Plant Resource Conservation and Recovery Act (RCRA) Part B Permit Application (DOE, 1993b); and (3) the Waste Isolation Pilot Plant, TRUPACT-II List of Chemical Compounds in Each Content Code in TRUCON (DOE, 1994g).

Final waste forms and associated characteristics for the engineered alternatives were determined using the program information presented in Section 2.3 and supporting appendices. As with the baseline analysis, waste form characteristics were evaluated on an average sitewide basis.

As previously discussed in Section 3.5.2.1.2, a screening analysis was performed to identify the radionuclides of primary concern for the transportation risk assessment. The disposal radionuclide inventory presented in Chapter 4.0 of the BIR identifies approximately 139 radionuclides in the CH-TRU and RH-TRU waste. These radionuclides result from the varied waste operations throughout the DOE complex and the ingrowth of daughter products during the radioactive decay process. Based on the screening analysis, a manageable and representative evaluation was possible with the inclusion of 36 of the radionuclides.

3.5.4 Results of the Analysis of the Transportation Risk Factors

3.5.4.1 Radiological Exposures

Appendix L, "Transportation Risk," provides tables of data that are the outcome of the analysis of transportation risk factors. The following subsections discuss key aspects of these data as they apply to risks of radiological and hazardous chemical exposures and to nonradiological/ nonchemical risks.

3.5.4.1.1 Baseline

The detailed results of the radiological Transportation Risk Factor analysis for baseline CH-TRU and RH-TRU waste shipments are presented in Tables L-1 through L-4 in Appendix L. Risk factor values are provided on a per-shipment basis and for cumulative/lifetime shipments for each applicable route segment. As discussed in the methodology section, incident-free risk factor doses are determined for the truck crew, the public, and the maximum member of the public residing or working along the transportation route corridor. The accident risk dose factor provides a probabilistic measure of doses to the public resulting from a spectrum of postulated accidents ranging from minor incidents (no radiological material released) to very severe accidents (incident exceeds Type B packaging test conditions).

Major CH-TRU sites (Hanford, INEL, LANL, RFETS, and SRS) involve almost 98 percent of all CH-TRU waste shipments and account for a comparable percentage of total radiological doses (incident-free and accident risks) to the public. Similarly, major RH-TRU sites (Hanford and ORNL) comprise 90 percent of all RH-TRU waste shipments and account for almost 99 percent of incident-free public doses and 96 percent of accident risk doses to the public for RH-TRU waste shipments. It is noted that while the number of RH-TRU waste shipments equals approximately 45 percent of the number of CH-TRU waste shipments, total RH-TRU incident-free public doses are projected to equal almost 83 percent of the total CH-TRU value. Also, calculated maximum individual doses are anticipated to be greater for RH-TRU waste shipments. This results from the higher TI values for RH-TRU waste shipments. The hypothetical maximum individual exposed to every TRU waste shipment is predicted to receive a cumulative dose of 1.7×10^{-2} rem over the lifetime of WIPP operations.

It is observed that Hanford RH-TRU waste constitutes the large majority of RH-TRU shipment radiological risks. Additionally, this site was estimated to have a shipment TI value (69 mrem/hr; Table 3-37) exceeding regulatory limits for exclusive-use vehicles. RADTRAN dose calculations were performed using regulatory limit values; however, the analysis suggests that proper load management, additional waste shielding, or reduced payload capacity options may need to be addressed.

3.5.4.1.2 Engineered Alternatives Nos. 1 and 77

As discussed in Section 3.5.2, engineered alternatives No. 1 and No. 77 have similar final waste forms and, as such, have similar Transportation Risk Factors. Both incident-free risk factor doses and accident risk doses were determined. Predicted values are summarized in Appendix L Tables L-5 through L-10 for the decentralized, regionalized, and centralized configurations. Per-shipment and cumulative WIPP lifetime risk factors are tabulated for each configuration.

As with the baseline analysis, major CH-TRU sites comprise the large majority of waste shipments and account for a comparable percentage of total radiological risks. Population risks (i.e., crew, public) are greatest for the centralized configuration and lowest for the decentralized configuration; however, all configuration values are within 16 percent of each other. Maximum hypothetical individual doses are highest for the regionalized configuration and lowest for the decentralized configuration. This is largely due to the increased number of shipments associated with the regionalized configuration (approximately 355 more shipments than the decentralized configuration). With this difference, maximum hypothetical individual doses vary by 38 percent.

Comparing baseline with engineered alternative No. 1 and No. 77 radiological risk factors, it can be concluded that:

- There are no significant differences in the extent of radiological risks.
- The decentralized and regionalized configurations for the engineered alternatives result in nominal reductions in population radiological risks.
- The centralized configuration for the engineered alternatives has essentially the same level of risk as the baseline, as expected, because shipment waste forms and movements are comparable.

3.5.4.1.3 Engineered Alternative No. 6

Predicted radiological Transportation Risk Factors for engineered alternative No. 6 are presented in Appendix L Tables L-11 through L-14 for the decentralized and regionalized configurations. Risk factors are provided on a per-shipment and cumulative WIPP lifetime basis for each configuration. As with the foregoing analyses, both incident-free doses and accident risk doses are tabulated. Radiological risk factors for the centralized configuration are identical to those presented in Table L-9 (per shipment) and Table L-10 (cumulative WIPP lifetime). In fact, all engineered alternatives will have the same radiological risk factors for the centralized configuration because all have identical shipment waste forms and movements.

As with the other engineered alternatives, major CH-TRU waste shipment sites account for the large majority of radiological risks. All three configurations for the engineered alternative result in comparable levels of risk. Incident-free population doses are projected to be the highest for the centralized configuration and comparable for the decentralized and regionalized configurations. Maximum hypothetical individual doses are highest for the regionalized configuration and lowest for the decentralized configuration. This will tend to be true for all engineered alternatives due to the previously noted increase in the number of shipments associated with the regionalized configuration. Accident risk doses for the centralized configuration are predicted to be nominally higher (approximately 5 percent) than the decentralized and regionalized configurations.

Comparison of engineered alternative No. 6 radiological risk factors with those for the baseline results in conclusions similar to those derived for alternative No. 1 and No. 77; namely, there are no significant differences in the extent of radiological risks.

3.5.4.1.4 Engineered Alternative No. 10

The results of the radiological Transportation Risk Factor analysis for engineered alternative No. 10 are summarized in Appendix L Tables L-15 through L-18. Risk factor values for the decentralized and regionalized configurations are tabulated. As discussed in Section 3.5.4.1.3, all engineered alternatives will have identical radiological risk factors for the centralized configuration as listed in Tables L-9 and L-10.

All three configurations for the engineered alternative result in comparable incident-free population doses to the crew members and the public. All values are within approximately 7 percent of each other. As previously observed, the regionalized configuration results in the highest dose for the hypothetical maximum individual and is approximately 32 percent higher than the decentralized value (lowest maximum individual dose). The accident risk doses for the decentralized and regionalized configurations are over an order of magnitude lower than the centralized configuration value. These reduced accident risks result from the reduced release fraction estimates for the engineered alternative vitrified waste form.

There are no significant differences between engineered alternative No. 10 and the baseline for incident-free doses. However, the subject alternative does provide significantly reduced accident risk doses (by over an order of magnitude) due to the reduced released fractions associated with the immobilized waste form for postulated accidents.

3.5.4.1.5 Engineered Alternative No. 94

Appendix L Tables L-19 through L-22 present calculated radiological risk factors for engineered alternative No. 94. Risk factors are provided on a per-shipment and cumulative WIPP lifetime basis for the decentralized and regionalized configurations. Centralized configuration risk factors are summarized in Tables L-9 and L-10.

Radiological Transportation Risk Factors are comparable for all three configurations. The treated waste form for this alternative is similar to that for engineered alternative No. 6, with the exception that clay is added to the shredded waste matrix. This has the effect of reducing the average radionuclide density and increasing the mass density of the treated waste matrix. Both effects tend to reduce the shipment TI value for the treated waste form. Consequently, incident-free doses for engineered alternative No. 94 are approximately 32 percent less than those for engineered alternative No. 6.

Radiological risk factors for the three configurations are comparable with those for the baseline, although it can be concluded that the decentralized and regionalized configurations provide risk reductions ranging from 28 percent to 46 percent, depending on the specific risk parameter considered (i.e., crew, public, or maximum individual doses or accident risks).

3.5.4.2 Hazardous Chemical Exposures

3.5.4.2.1 Baseline

The results of the baseline chemical exposure analysis are presented in Table L-23 of Appendix L. As described in Section 3.5.2.1.3, the analysis postulates that a very severe accident occurs and compares the predicted receptor (maximum member of the public) airborne concentrations with adjusted ERPG-2 values. This was done by dividing the calculated receptor concentration by the adjusted ERPG-2 value for each hazardous chemical. Ratios smaller than one indicate that exposures fall within health-based reference levels.

Table L-23 of Appendix L shows that all individual chemical concentration/ERPG-2 ratios for the postulated maximum exposed individual are acceptable. The combined chemical exposure ratio exceeds a value of one (1.2). This suggests that irreversible or other serious health effects cannot be excluded from occurring; however, the conservatisms incorporated into the analysis (as discussed in Section 3.5.2.2) make it highly likely that the occurrence of any such postulated event would fall within health-based reference levels and would be acceptable.

Based on the relative shipment capacity of the TRUPACT-II and the RH-72B cask and on current chemical characterization data, it can be concluded that hazardous chemical accident analyses for CH-TRU waste shipments bound RH-TRU waste shipments.

3.5.4.2.2 Engineered Alternatives

Chemical airborne releases for engineered alternatives No. 1, 6, 10, 77, and 94 are summarized in Table L-24 of Appendix L for a postulated very severe accident. The release form, release fraction, and receptor concentration/ERPG-2 ratios are tabulated for each engineered alternative.

Engineered alternatives No. 1 and 77 have the highest combined chemical exposure hazard,

followed by engineered alternative No. 6. Engineered alternatives No. 10 and 94 have combined chemical exposure ratios that fall within health-based reference levels and for which it can be concluded that no irreversible or other serious health effects are expected to occur. For all engineered alternatives, individual chemical exposure ratios for engineered alternatives No. 1, 6, and 77 exceed one, indicating that irreversible health effects cannot be excluded from occurring. As noted in Section 3.5.3.2.1, the analysis incorporates several conservatisms. It can be concluded that the levels of exposure would not result in any fatalities.

3.5.4.3 Non-radiological/Non-chemical Risks

The non-radiological and non-chemical impacts of transporting TRU waste to the WIPP are the same as those resulting from transporting non-nuclear and non-hazardous materials. The risks involve traumatic injuries and fatalities from transportation accidents. Non-radiological and non-chemical impacts are independent of the characteristics of the cargo and therefore totally unrelated to radiological and hazardous chemical risks resulting from projected accidents. The non-radiological/non-chemical risks are also therefore independent of impacts from waste processing engineered alternatives.

Calculated per-shipment non-radiological and non-chemical risks for CH-TRU and RH-TRU shipments to the WIPP are summarized in Appendix L Table L-25. These risks include the impact of the return trip by truck from the WIPP to the generator or storage facility.

Total cumulative non-radiological and non-chemical CH-TRU and RH-TRU transportation risks are summarized in Appendix L Tables L-26 through L-29 for the entire life of the disposal phase.

3.5.4.4 Uncertainties

The transportation risks estimated in this chapter are affected by a number of uncertainties. For example:

- Waste Volume vs. Waste Mass—Waste volume limited shipments were analyzed to provide an upper bound for the transportation risks. The risks associated with waste mass limited shipments would fall below this upper bound.

- Waste volumes and locations—The risks will either increase or decrease depending on the volume of waste shipped and the distance to WIPP.

- Waste form—The risks in an accident will decrease if the waste is solidified, incinerated, vitrified, etc., because less material would be released. The non-radiological/non-chemical risks will increase if more shipments occur.

- Waste mass—The TRUPACT-IIs and RH-72B casks are weight limited. The waste mass could be such that many shipments could consist of just a few drums, thus increasing the number of shipments.

- TRU waste from environmental restoration activities—To date, the TRU waste volumes for environmental restoration activities have not been factored into WIPP operations.

- Mode of shipment—The analysis presented here is based on all shipments being made by truck. All previous transportation risk assessments for WIPP have analyzed rail shipments as well.

3.5.4.5 Summary of Results

As defined in Section 3.5.1, the Transportation Risk Factor is comprised of three risk components: radiological, chemical, and non-radiological/non-chemical. The radiological risk component is expressed in both doses (person-rem for collective exposures or rem for individual exposures) and health effects (incremental LCFs). These risks result from both incident-free transportation activities and postulated accidents. The chemical risk component provides a measure of the level of hazard for the maximally exposed member of the public for a postulated very severe accident. It is expressed as a unitless number and is calculated as the sum of each airborne chemical concentration divided by its respective ERPG-2 value. Chemical risk component values below 1.0 suggest that nearly all individuals could be exposed without experiencing or developing irreversible or serious health effects which could impair an individual's ability to take protective action. The non-radiological/non-chemical risk component results from non-cargo-related accident impacts and is expressed as traumatic injuries and fatalities.

A summary of the results of the transportation risk analysis is presented in Tables 3-42, 3-43, and 3-44. Table 3-42 summarizes the Transportation Risk Factor for baseline CH-TRU and RH-TRU waste shipments and for CH-TRU waste shipments for the centralized configuration. Tables 3-43 and 3-44 summarize the Transportation Risk Factor for CH-TRU waste shipments for the decentralized and regionalized configurations, respectively. As previously discussed, only five engineered alternatives affect the Transportation Risk Factor (Nos. 1, 6, 10, 77, and 94). Of these, two (Nos. 1 and 77) have the same risk factor values. The remaining engineered alternatives have the same Transportation Risk Factor as the baseline. To quantify the total Transportation Risk Factor for all TRU waste shipments, the baseline RH-TRU waste Transportation Risk Factor must be added to the risk factor for the CH-TRU engineered alternative of interest.

The chemical risk component is not affected by transportation movements and thus varies by engineered alternative but not by transportation configuration. The non-radiological/non-chemical risk component is affected by transportation movements but not by the nature of the waste cargo, and thus varies by transportation configuration but not by engineered alternative. The radiological risk component is affected by both transportation movements and the nature of the cargo and thus varies by both the engineered alternative and the transportation configuration evaluated.

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TABLE 3-42

SUMMARY OF CUMULATIVE/LIFETIME TRANSPORTATION RISK FACTOR BASELINE AND CENTRALIZED CONFIGURATION

	Baseline		Centralized Configuration
	CH-TRU Waste	RH-TRU Waste	All Engineered Alternatives for CH-TRU Waste
Radiological Risk Component			
Crew[1] - person-rem (LCFs)	$6.69 \times 10^{+02}$ (2.68×10^{-01})	$6.38 \times 10^{+02}$ (2.55×10^{-01})	$6.69 \times 10^{+02}$ (2.68×10^{-01})
Public[1] - person-rem (LCFs)	$4.00 \times 10^{+03}$ ($2.00 \times 10^{+00}$)	$3.32 \times 10^{+03}$ ($1.66 \times 10^{+00}$)	$4.00 \times 10^{+03}$ ($2.00 \times 10^{+00}$)
Max Individual[1,2,3] - rem (LCFs)	4.99×10^{-03} (2.50×10^{-06})	1.20×10^{-02} (6.00×10^{-06})	4.99×10^{-03} (2.50×10^{-06})
Accident Risk - person-rem (LCFs)	$8.01 \times 10^{+01}$ (4.01×10^{-02})	6.52×10^{-01} (3.26×10^{-04})	$8.01 \times 10^{+01}$ (4.01×10^{-02})
Chemical Risk Component			
Max Individual[4] - Total Airborne Concentration/ Adj'd ERPG-2	$1.2 \times 10^{+00}$	$1.2 \times 10^{+00}$[5]	Varies by alternative; same as shown on Table 3-42 or 3-43
Non-radiological/Non-chemical Risk Component			
Injuries	$6.61 \times 10^{+01}$	$3.35 \times 10^{+01}$	$7.06 \times 10^{+01}$
Fatalities	$4.87 \times 10^{+00}$	$2.63 \times 10^{+00}$	$4.71 \times 10^{+00}$

[1]Results from incident-free transportation activities.
[2]RADTRAN calculated maximum individual who is exposed to every shipment.
[3]LCF for the maximum individual estimated using the collective dose risk factor for a population exposure.
[4]Assumes a severity category VIII accident occurs.
[5]Bounding CH-TRU waste value used.

1

TABLE 3-43

SUMMARY OF CUMULATIVE/LIFETIME CH-TRU WASTE TRANSPORTATION RISK FACTOR DECENTRALIZED CONFIGURATION

	Engineered Alternative			
	No. 1 & 77	No. 6	No. 10	No. 94
Radiological Risk Component				
Crew[1] - person-rem (LCFs)	$5.81 \times 10^{+02}$ (2.32×10^{-01})	$5.47 \times 10^{+02}$ (2.19×10^{-01})	$7.16 \times 10^{+02}$ (2.86×10^{-01})	$4.25 \times 10^{+02}$ (1.70×10^{-01})
Public[1] - person-rem (LCFs)	$3.47 \times 10^{+03}$ ($1.74 \times 10^{+00}$)	$3.27 \times 10^{+03}$ ($1.64 \times 10^{+00}$)	$4.27 \times 10^{+03}$ ($2.14 \times 10^{+00}$)	$2.55 \times 10^{+03}$ ($1.28 \times 10^{+00}$)
Max Individual[1,2,3] - rem (LCFs)	3.80×10^{-03} (1.90×10^{-06})	3.81×10^{-03} (1.91×10^{-06})	4.61×10^{-03} (2.31×10^{-06})	2.68×10^{-03} (1.35×10^{-06})
Accident Risk - person-rem (LCFs)	$5.92 \times 10^{+00}$ (2.96×10^{-03})	$7.59 \times 10^{+01}$ (3.80×10^{-02})	$1.21 \times 10^{+00}$ (6.05×10^{-04})	$5.76 \times 10^{+01}$ (2.88×10^{-02})
Chemical Risk Component				
Max Individual[4] - Total Airborne Concentration/ Adj'd ERPG-2	$1.80 \times 10^{+00}$	$1.20 \times 10^{+00}$	2.10×10^{-05}	8.10×10^{-01}
Non-radiological/Non-chemical Risk Component				
Injuries	$6.61 \times 10^{+01}$	$6.61 \times 10^{+01}$	$6.61 \times 10^{+01}$	$6.61 \times 10^{+01}$
Fatalities	$4.87 \times 10^{+00}$	$4.87 \times 10^{+00}$	$4.87 \times 10^{+00}$	$4.87 \times 10^{+00}$

[1]Results from incident-free transportation activities.
[2]RADTRAN model calculated maximum individual who is exposed to every shipment.
[3]LCF for the maximum individual estimated using the collective dose risk factor for a population exposure.
[4]Assumes a severity category VIII accident occurs.

1

TABLE 3-44

SUMMARY OF CUMULATIVE/LIFETIME CH-TRU WASTE TRANSPORTATION RISK FACTOR REGIONALIZED CONFIGURATION

	Engineered Alternative			
	No. 1 & 77	No. 6	No. 10	No. 94
Radiological Risk Component				
Crew[1] - person-rem (LCFs)	$5.87 \times 10^{+02}$ (2.35×10^{-01})	$5.53 \times 10^{+02}$ (2.21×10^{-01})	$7.22 \times 10^{+02}$ (2.88×10^{-01})	$4.31 \times 10^{+02}$ (1.72×10^{-01})
Public[1] - person-rem (LCFs)	$3.50 \times 10^{+03}$ ($1.75 \times 10^{+00}$)	$3.28 \times 10^{+03}$ ($1.64 \times 10^{+00}$)	$4.30 \times 10^{+03}$ ($2.16 \times 10^{+00}$)	$2.58 \times 10^{+03}$ ($1.29 \times 10^{+00}$)
Max Individual[1,2,3] - rem (LCFs)	5.30×10^{-03} (2.65×10^{-06})	5.32×10^{-03} (2.66×10^{-06})	6.11×10^{-03} (3.06×10^{-06})	4.19×10^{-03} (2.10×10^{-06})
Accident Risk - person-rem (LCFs)	$6.71 \times 10^{+00}$ (3.36×10^{-03})	$7.65 \times 10^{+01}$ (3.83×10^{-02})	$1.96 \times 10^{+00}$ (9.80×10^{-04})	$5.86 \times 10^{+01}$ (2.93×10^{-02})
Chemical Risk Component				
Max Individual[4] - Total Airborne Concentration/ Adj'd ERPG-2	$1.80 \times 10^{+00}$	$1.20 \times 10^{+00}$	2.10×10^{-05}	8.10×10^{-01}
Non-radiological/Non-chemical Risk Component				
Injuries	$5.98 \times 10^{+01}$	$5.98 \times 10^{+01}$	$5.98 \times 10^{+01}$	$5.98 \times 10^{+01}$
Fatalities	$4.76 \times 10^{+00}$	$4.76 \times 10^{+00}$	$4.76 \times 10^{+00}$	$4.76 \times 10^{+00}$

[1]Results from incident-free transportation activities.
[2]RADTRAN calculated maximum individual who is exposed to every shipment.
[3]LCF for the maximum individual estimated using the collective dose risk factor for a population exposure.
[4]Assumes a severity category VIII accident occurs.

3.6 IMPACT ON PUBLIC CONFIDENCE IN THE PERFORMANCE OF THE DISPOSAL SYSTEM

3.6.1 Definition of Factor 6

Identifying and understanding public concern about real or perceived risks associated with WIPP in its postclosure state provide important information that can assist the DOE in:

- Planning and executing sound engineered alternatives to eliminate potential postclosure risks and address public concerns.
- Providing credible scientific bases and data to assist the public in understanding risk probabilities as related to posed concerns and comments.
- Actively involving the general public in the WIPP development process to ensure a two-way flow of information that fosters openness and credibility.

This study was conducted in two phases to identify both historic and current public concerns about WIPP's postclosure performance. During Phase 1, some significant existing public commentary was examined to identify concerns about postclosure WIPP. These comments and concerns were further analyzed to determine the relative frequency of the concerns, the persistence of concerns over time, and the geographic source of concerns. Data sources included:

- The WIPP FSEIS (DOE, 1990b).
- Response to Comments for Amendments to 40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (EPA, 1993)
- Public Hearings on EPA's Proposed Rule 40 CFR Part 194, Criteria for the Certification and Determination of the WIPP's Compliance with Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes, March 21-24, 1995 (EPA, 1995).

During Phase 2, comments were collected during a series of focus group discussions and interviews held in Carlsbad, Albuquerque, and Santa Fe, New Mexico, in which participants were invited to share their concerns about postclosure WIPP. These cities were selected as sites for the meetings because they were communities which have major population centers with residents that have shown interest in WIPP. Focus group discussions were held in Carlsbad on June 26, 1995; Albuquerque, on June 27, 1995; and Santa Fe on June 28, 1995. Additionally, interviews were held with three individuals who were invited but unable to participate in the focus group discussions. The Carlsbad interviews were held on July 6 and July 10, 1995, and the Santa Fe interview was conducted on June 28, 1995.

The combined findings from Phase 1 and Phase 2 analyses serve as considerations for selecting EAs that would address expressed public concern.

3.6.2 Methodology Used to Evaluate the Public Confidence Factor (Factor 6)

The data sources used as a source of public comments for the Phase I portion of this study were selected for several reasons:

- There are well-organized and published records of extensive public comments in the WIPP FSEIS. The FSEIS provided a wealth of commentary for developing a taxonomy of public postclosure concerns.

- The series of public hearings held in Carlsbad, Albuquerque, and Santa Fe during the period March 22-24, 1995, regarding EPA's Proposed Rule 40 CFR Part 194, provided an excellent opportunity for collection of contemporary public concerns about postclosure WIPP.

- The six years of elapsed time between the comments documented in the WIPP SEIS and those collected in March 1995 provide an opportunity to examine public concerns over a period of time. A comparison between the two, allowed analysts to identify possible shifts in public concerns since the oral and written comments were made as contained in the FSEIS.

The focus group discussions held in Carlsbad, Albuquerque, and Santa Fe, New Mexico were composed of community and business leaders, public opinion leaders, and advocacy group leaders. A proposed list of stakeholders to be asked to participate in the focus group discussions was developed for each location and was presented to Westinghouse Waste Isolation Division (WID) and the DOE-CAO for review and approval. This list was developed (1) by reviewing the EA stakeholder list, (2) through discussions with WIPP personnel, (3) from team knowledge of local communities and stakeholders, and (4) by reviewing the lists of attendees at the EPA 40 CFR Part 194 public hearings. Criteria for selection of focus group discussion participants included the following:

- Demonstrated long-term and abiding interest in the WIPP

- Business and community leaders who represent more than just a singular point of view

- Interest in the WIPP demonstrated by providing oral and/or written comments at public hearings on WIPP.

These selection criteria were developed to ensure that a diverse group, representative of New Mexico, was selected and that focus group participants had some knowledge about WIPP before the meeting. The final list of proposed participants for each location was presented to WID and DOE-CAO for review and approval. No participant attended more than one focus group discussion.

3.6.2.1 Data Collection and Formatting

Development of a Comment Taxonomy for Phase 1

The WIPP FSEIS represents the most comprehensive collection of formally organized public commentary about the WIPP Project. Published in 1990, the FSEIS records 1591 oral and 4948 written comments that express a wide range of public concerns. For example, there are comments related to potential economic and social impacts, comments on the geologic characteristics of the underground site, and comments on the possible risks to endangered species. In short, the comments are wide-ranging in content and depth.

For purposes of this study, a comment classification scheme was developed by identifying within the FSEIS those comments relating to issues about postclosure WIPP. This classification system was refined into the taxonomy of public concerns shown on Figure 3-16, WIPP Postclosure Concerns Phase 1 Taxonomy, which presents the relative frequency of public comments by category and are described below.

Phase 1 Comment Taxonomy

1.0 Conditions—Conditions seen as potential causes for undesirable outcomes. This category of comment is broken down further into three subcategories.

1.1 Waste Characteristics—Attributes (e.g., origin, volume, quantity) of the waste proposed for disposal at the WIPP facility.

1.1.1 Characterization/identification—Radioactivity level of waste (e.g., curie level), commercial waste, hazardous wastes, hazardous chemical constituents, etc.

1.1.2 In-storage reactions—Gas generation, heat generation.

1.1.3 Treatment—Vitrification, cementation, etc.

1.2 Waste Repository Technology Applied—Aspects, appropriateness, and nature of technologies to be used at the WIPP.

1.2.1 Siting—Geological, hydrological aspects of the WIPP site itself.

1.2.2 Design—Plugs and seals, backfill, etc.

1.3 Disposal Period Events—Outcomes regardless of cause that could introduce adverse risk to the environment.

1.3.1 Human-caused intrusion—Mining, drilling, sabotage, terrorism

1.3.2 Intrusion due to natural causes—Seismic, climatic changes (e.g., substantially increased precipitation), tornadoes.

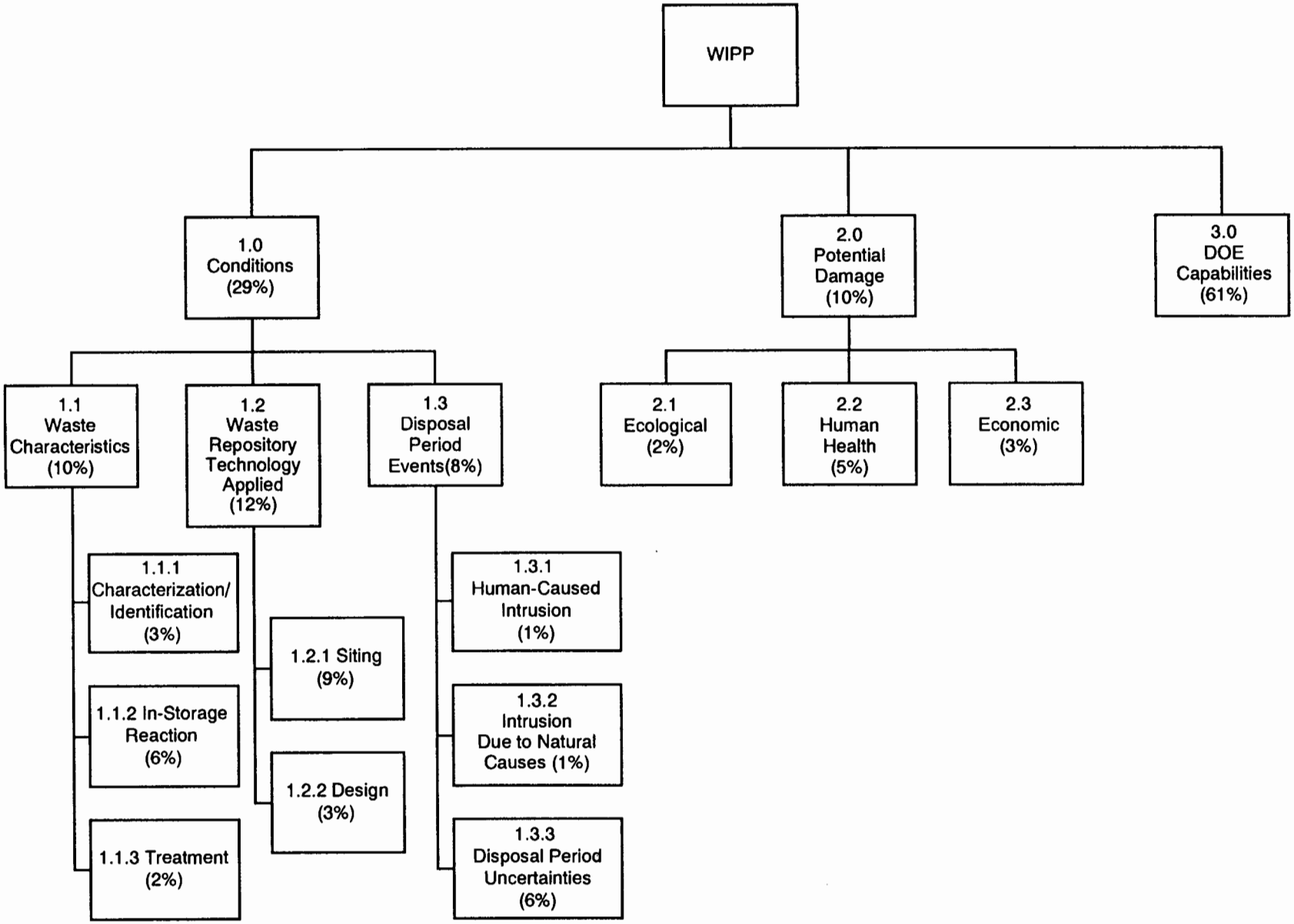


Figure 3-16
WIPP Postclosure Concerns Phase 1 Taxonomy

1.3.3 Disposal period uncertainties (10,000 years)—Standards, technology obsolescence, changes in cultural/social norms and practices, shifts in language use and meaning, unpredictable events

2.0 Potential Damage—Issues and conditions pertaining to environmental and human health and safety.

2.1 Ecological—Indigenous flora and fauna, groundwater contamination, effects on the Pecos and Rio Grande Rivers.

2.2 Human Health—Psychological impacts, medical services, radiation dose limits, radiation protection standards, exposure to plutonium.

2.3 Economy—Business development, tourism, property values, financial responsibility in event of accidental release.

3.0 DOE Capabilities—Public perceptions of DOE and its ability to manage the WIPP (e.g., credibility, impartial scientific review, needs for review and oversight).

Modifying the Comment Taxonomy for Phase 2

Focus group results indicated a need for extending and modifying the Phase 1 taxonomy so that suggested contemporary stakeholder concerns could be more adequately categorized. The original taxonomy was extended into seven major categories as shown on Figure 3-17, WIPP Postclosure Concerns Phase 2 Taxonomy, and discussed below. All Phase 1 categories are represented in the Phase 2 taxonomy. Percentages reflect relative frequency of comment by category.

Phase 2 Comment Taxonomy

1.0 Waste Conditions—Conditions seen as potential causes for undesirable outcomes.

1.1 Characterization/Identification -Radioactivity level of waste (e.g., curie level), commercial waste, hazardous wastes, hazardous chemical constituents.

1.2 In-Storage Reaction—Gas generation, heat generation.

1.3 Treatment—Vitrification, cementation.

1.4 Characteristics—Attributes (e.g., origin, volume, quantity) of the waste proposed for disposal at the WIPP facility.

2.0 Technology Applied—Aspects, appropriateness, and nature of technologies to be used at the WIPP.

2.1 Siting—Geological, hydrological aspects of the WIPP site itself.

2.2 Site Design—Plugs and seals, backfill.

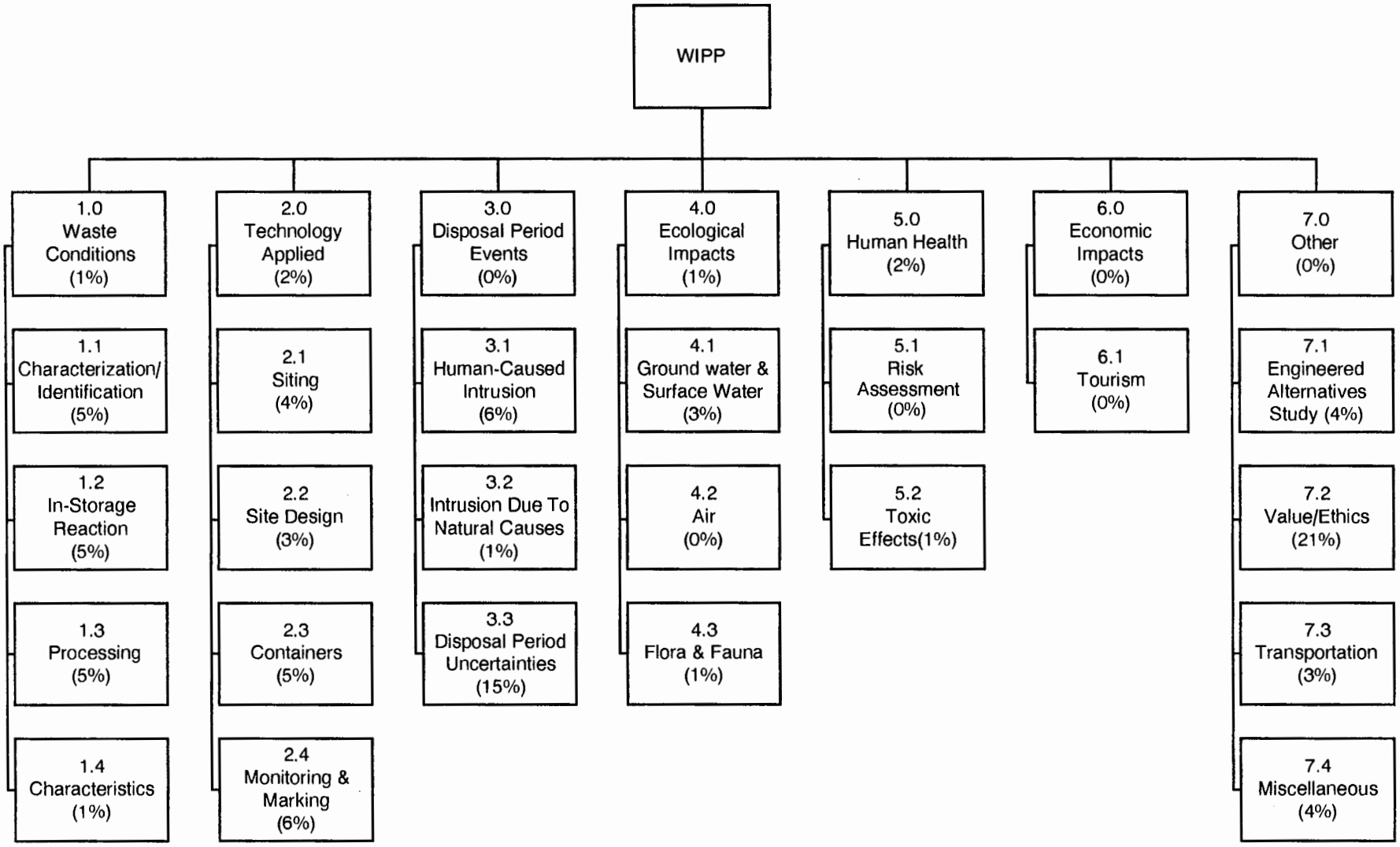


Figure 3-17
WIPP Postclosure Concerns Phase 2 Taxonomy

2.3 Containers—Permanent and temporary waste storage devices, e.g., drums, TRUPACT.

2.4 Monitoring and Marking—Matters pertaining to the short and long-term monitoring of the WIPP and/or its contents. Concerns about how WIPP can be marked such that future generations comprehend its location and purpose.

3.0 Disposal Period Events—Outcomes, regardless of cause, that could introduce adverse risk to the environment.

3.1 Human-Caused Intrusion—Planned and unplanned mining, drilling, sabotage, terrorism events.

3.2 Intrusion Due to Natural Causes—Seismic, climatic changes (e.g., substantially increased precipitation, tornadoes).

3.3 Disposal Period Uncertainties—Standards, technology obsolescence, changes in cultural/social norms and practices, shifts in language use and meaning, unpredictable events.

4.0 Ecological Impacts—Events which could result in damage to the environment, including groundwater, surface water, and plant and animal life.

5.0 Human Health—Psychological impacts, medical services, radiation dose limits, risk assessments, radiation protection standards, exposure to nuclear materials, and toxic effects.

6.0 Economic Impacts—Business development, tourism, property values, financial responsibility in event of accidental release.

7.0 Other

7.1 EA Study—Matters relating directly to this study, e.g., concerns about whether the regulations require the use of engineered alternatives.

7.2 Value/Ethics—Public perceptions of, individuals, society, and its institutions as they relate to motives, values, and actions pertaining to the public good. (e.g., credibility, impartial scientific review, need for review and oversight).

7.3 Transportation—Topics concerning the movement of waste materials via public roadways and/or other routes by motorized conveyance prior to WIPP closure.

7.4 Miscellaneous—Comments not readily associated with any other taxonomic category.

Formatting Comment Data in Phase 1

Each comment was tagged with a unique identifier. For example, "roll-up" comments from the WIPP FSEIS were already numbered. If a particular comment published in the FSEIS was identified as pertaining to postclosure WIPP, then the number of that comment was placed into one of the comment categories as defined by the taxonomy discussed above. Other comment sources were handled similarly by using either existing comment identification codes or by creating new ones when necessary. This system allows traceability from data back to the original comment as published or collected from oral presentation.

In some instances, a single recorded comment may have been made many times by different individuals. In such cases, the frequency of comment occurrence has been recorded as ***the total number of times the comment was made.*** This allows the same comment to be examined against time and frequency of occurrence. All raw data have been retained on file and may be accessed as required.

Additionally, comments have been coded by location source. For example, comment category 5.1-2 (a roll-up comment from the FSEIS) pertains to waste characterization and identification. There are 19 individual comments that form the basis for this roll-up. Fifteen of these comments were from New Mexico sources and four from outside the state. Further, data have been collected for this study that documents that fourteen of the fifteen New Mexico comments were from Santa Fe sources and one from an Albuquerque source. Geographic source data are on file.

Formatting Comment Data in Phase 2

Verbatim transcripts of the meetings were not prepared. Instead, notes were recorded on flip charts. As completed, individual sheets of notes were posted around the room. Additionally, notetakers were provided to record information to supplement that recorded on the charts. After the meeting, the meeting notes were finalized and sent to each participant for review and comment. Focus group comments are included as Appendix M.

Written comments for each meeting were analyzed and were sorted into specific taxonomic categories. In many instances, a "single" comment made by an individual at the focus group meeting consisted of comments on several subjects. For example, a participant might begin commentary by talking about perceived risks associated with groundwater intrusion into the repository, transition to a remark about how future generations might know about WIPP, and close with a statement concluding that, in the speaker's opinion, WIPP was well engineered, scientifically thorough, and ready to be put to use. Comments such as this are related to several taxonomic categories and were so recorded. When all comments had been categorized, they were then examined to determine whether they reflected a concern about postclosure WIPP or a more general concern not directly pertinent to postclosure WIPP (e.g., transportation of waste via TRUPACT-II).

3.6.2.2 Data Reduction

The number of comments occurring in each taxonomic category was converted to a percent of the total number of comments from a single source. Data in tabular form are provided in

Appendix N. Phase 1 data were combined to yield a composite of all original data sources. Phase 2 data were similarly combined for a composite view.

Phase 1 data include only comments pertaining to postclosure WIPP. Phase 2 data include more general comments about WIPP that extend beyond concerns about the postclosure period. These additional data are included to give a more accurate impression of actual focus group commentary. While the purpose of the focus group meeting was clearly stated by group leaders at the beginning of each session, discussion quite naturally extended beyond concerns about postclosure WIPP to other topics. The ratio of postclosure-specific to WIPP-general comments is perhaps a useful index of the intensity of public concern with postclosure WIPP in relation to concern about more current WIPP-related issues.

All data are presented in the body of this report as exploded pie charts. This format allows easy comparison of one data set to another. Changes were made to all sections of the Phase 1 taxonomy to accommodate specific concerns presented at the focus group discussions. Additionally, the focus group discussions concentrated on WIPP postclosure concerns. Therefore, Phase 1 and Phase 2 data are not directly comparable on a category-to-category basis. Nonetheless, trend comparisons can be made easily. Data presented in chart form have been intentionally limited in level of detail (this allows easier interpretation); a detailed accounting of frequency counts and percentages by category and subcategories is available in Appendix N.

3.6.2.3 Data Analysis

Raw data have been arrayed in similar formats such that major comparisons and trends may be identified. For example, much data reduction has been in terms of "percent." This practice allows rapid comparison of data sets of unequal size. There has been no attempt to apply formal analytic tools for the purpose of testing the statistical significance of this study's preliminary findings. Nonetheless, it is useful to note highly visible trends as a means for further thought and investigation.

Data were examined systematically to determine:

1. Which area is the most frequent comment category?

2. What are the sources of comments? (By state, city, etc.)

3. Have the relative frequency of comments changed over time?

4. How are public concerns about postclosure WIPP proportional to more general, contemporary WIPP issues?

5. Are there differences in comment frequencies related to geographic origin of comments?

3.6.2.4 Matching EAs to Noted Public Concerns About Postclosure WIPP

An interdisciplinary Working Group (the EASWG) of technical professionals who participated in the development of the EACBS was assembled to examine each EA and assess whether the alternative could address noted postclosure concerns. The Phase 2 taxonomy was used for this assessment as all concerns categorized in the Phase 1 taxonomy are addressed in the Phase 2

taxonomy. To ensure the Working Group understood the postclosure concerns present by the focus groups, a review was made of all notes for the focus group discussions and interviews. The Working Group did not assess the importance of the concerns, only whether the EAs could address or mitigate the noted postclosure concerns. Several assumptions were used by the Working Group in this assessment. The assumptions that were used are presented below.

- All waste processing EAs will require some level of postprocessing waste characterization.
- All waste will be assayed prior to disposal or shipment to WIPP.
- EAs were only matched to postclosure concerns.
- Sampling and analysis of headspace gas will be performed for all drums to determine the quantities of hydrogen, methane, and listed volatile organic compounds.
- All drums will undergo real-time-radiography which is a nondestructive test used to X-ray and inspect waste containers to determine the physical form of the waste and identify the presence or absence of free liquids.
- Using a statistically valid sample, a visual inspection will be performed of waste containers to ensure the level of quality for the real-time radiography inspections.

The results of this assessment are presented below. For each EA evaluated in the Cost/Benefit Study, a brief description of the alternative is presented, along with a statement of how the alternative would augment current baseline conditions/or programs for the WIPP. Many of the EAs in the Cost/Benefit Study are different combinations of waste processing techniques and/or backfill measures. For the purposes of this assessment, the waste processing techniques and types of backfills are addressed separately. The public postclosure concerns that could be addressed by the alternative are then presented by category and the total percentage of the comments that pertain to that concern are noted.

3.6.2.4.1 Supercompact Waste [Alternatives #1 and #77(a-d)]

Solid organic and inorganic wastes are sorted to remove items that cannot be compacted. The sorted waste is precompacted into 35-gallon drums and the supercompacted sludges are not processed.

Public Concerns Which May Be Addressed by this Alternative

This EA cannot be used for all waste streams. Some sorting and visual inspection of the waste is performed for this alternative which will augment the waste characterization process that is used to ensure that waste meets the WIPP WAC. Therefore, concerns regarding waste characterization/identification (5%), could be addressed by this alternative. Additionally, as the alternative would increase the density and strength of the waste form that would be emplaced in the repository, the potential release of hazardous and radioactive materials that could result from human-caused intrusions would be mitigated. Public concerns regarding human-caused

intrusions (6%), disposal period uncertainties (15%), ecological impacts (1%), engineered alternatives (4%), and human health (2%) could therefore be mitigated by this alternative.

3.6.2.4.2 Shred and Compact Solid Organic and Solid Inorganic Waste (Alternative #6)

Solid organic and inorganic wastes are shredded and compacted into 55-gallon (208-liter) drums using a lower pressure compactor than in supercompaction. Sludges are not processed.

Public Concerns Which May Be Addressed by this Alternative

This EA cannot be used for all waste streams. Some sorting and visual inspection of the waste is performed for this alternative which will augment the waste characterization process that is used to ensure that waste meets the WIPP Waste Acceptance Criteria. Therefore, concerns regarding waste characterization/identification (5%) could be addressed by this alternative. Additionally, as the alternative would increase the density and strength of the waste form that would be emplaced in the repository, the potential release of hazardous and radioactive materials that could result from human-caused intrusions would be mitigated. Public concerns regarding human-caused intrusions (6%), disposal period uncertainties (15%), ecological impacts (1%), engineered alternatives (4%), and human health (2%) could therefore be mitigated by this alternative.

3.6.2.4.3 Treat All Waste in a Plasma Melter (Alternative #10)

All wastes are processed through a shredder and the input waste stream is regulated to ensure a suitable metal to waste ratio. The waste is processed through a Plasma Arc Centrifugal Treatment system and poured into 55-gallon (208-liter) drums.

Public Concerns Which May Be Addressed by this Alternative

This EA can be used for all waste streams. In addition to the waste characterization that will be performed for all WIPP waste, some sorting and visual inspection of the waste is performed for this alternative. Therefore, concerns regarding waste characterization/identification (5%), could be addressed by this alternative. Additionally, as the alternative would destroy the hazardous organic constituents in the waste, concerns pertaining to the release or migration of hazardous constituents would be addressed. The alternative would also increase the density and strength of the waste form that would be emplaced in the repository, thus the potential release of hazardous and radioactive materials that could result from human-caused intrusions would be reduced. Thus, public concerns regarding waste processing (6%), waste characteristics (1%), human-caused intrusions (6%), disposal period uncertainties (15%), ecological impacts (1%), engineered alternatives (4%), and human health (2%) could be mitigated by this alternative.

3.6.2.4.4 Sand Plus Clay Backfill (Alternative #33)

A mixture of medium grained sand and granulated clay is used as a backfill for this alternative. The mixture is placed around the waste stack and between the drums filling the void space in the rooms within the repository.

Public Concerns Which May Be Addressed by this Alternative

This sand/clay backfill will lower the permeability and porosity of the waste, thus reducing the potential for release of contaminated brine through a drilling event. It will also limit brine inflow, thus reducing gas generation. Therefore, this alternative addresses concerns regarding in-storage reactions (5%), human-caused intrusions (6%), site design (3%), disposal period uncertainties (15%), engineered alternatives (4%), ecological impacts (1%), and human health (2%).

3.6.2.4.5 Salt Aggregate Grout Backfill (Alternative #35a)

This EA uses a salt aggregated grout mixture as backfill to fill the void spaces within a room in the repository after the waste is emplaced. This backfill consisting of a cementitious-based grout (which uses crushed salt as the aggregate and simulated WIPP brine as the added water), is pumped around the waste stack and between the drums filling the void space within the rooms.

Public Concerns Which May Be Addressed by this Alternative

Salt aggregate grout backfill increase the pH of any brine that may come in contact with the waste, thereby reducing gas generation and radionuclide solubility and mobility. This backfill also lowers the permeability and porosity of the waste, which minimizes brine inflow. Public concerns which may be mitigated by this alternative include those regarding in-storage reactions (5%), human-caused intrusions (6%), site design, (3%), disposal period uncertainties (15%), engineered alternatives (4%), ecological impacts (1%), and human health (2%).

3.6.2.4.6 Cementitious Grout Backfill (Alternative #35b)

A cementitious based grout backfill consisting of ordinary Portland cement, sand aggregate, and fresh waster is used for this alternative. The backfill is pumped around the waste stack and between the drums filling the void space within the room.

Public Concerns Which May Be Addressed by this Alternative

This backfill will increase the pH of any brine that may come in contact with the waste, thereby reducing gas generation and radionuclide solubility. This backfill also lowers the permeability and porosity of the waste, which minimizes brine inflow. Public concerns which may be mitigated or addressed by this alternative include those regarding in-storage reactions (5%), human-caused intrusions (6%), site design (3%), disposal period uncertainties (15%), engineered alternatives (4%), ecological impacts (1%), and human health (2%).

3.6.2.4.7 Lime (CaO) and Crushed Salt Backfill (Alternative #83)

This backfill consists of a commercially available granulated lime (quick lime) and crushed salt aggregate which is pneumatically placed around the waste stack and between the drums, filling the void space in the rooms. The mixture consists of less than 10% lime and 90% crushed salt aggregate.

Public Concerns Which May Be Addressed by this Alternative

The introduction of lime to the backfill increases the pH of any brine that may come in contact with the waste in the repository, thereby reducing radionuclide solubility and mobility. Lime backfill also lowers the permeability and porosity of the waste, which minimizes brine inflow. Public concerns which may be mitigated or addressed by this alternative include those regarding in-storage reactions (5%), human-caused intrusions (6%), site design, (3%), engineered alternatives (4%), disposal period uncertainties (15%), ecological impacts (1%), and human health (2%).

3.6.2.4.8 Enhanced Cementation of Sludges, Shred and Add Clay to Solid Organic and Solid Inorganic Wastes [Alternatives #94(a-f)]

This alternative includes two processes to treat the waste: (1) enhanced cementation of previously solidified and as generated sludges and (2) shredding solid organic and inorganic waste and adding clay to the shredded waste. Existing sludges are fed into a crusher/shredder. The crushed waste is mixed with an enhanced cement and is poured into 55-gallon (208-liter) drums. Newly generated sludges that are not dried will be solidified with the enhanced cement.

Solid organics and inorganics are shred and clay is added to the waste. This waste is packaged in 55-gallon (208-liter) drums.

Public Concerns Which May Be Addressed by this Alternative

This EA can treat both sludges and solid inorganic and organic waste. In addition to the waste characterization that is performed to meet the WIPP Waste Acceptance Criteria, some sorting and visual inspection of the waste is performed prior to shredding. Therefore, noted public concerns regarding waste characterization/identification (5%) could be mitigated by this alternative. This alternative will also reduce the generation of gas by increasing the pH of brine that may come into contact with the waste form. Thus, concerns about in-storage reactions (5%) would be mitigated by this alternative. Additionally, the alternative will reduce brine inflow through the addition of clay-based materials to the waste, therefore, the potential release of hazardous and radioactive materials that could result from human-caused intrusions would be reduced. Thus, public concerns regarding waste processing (5%), waste characteristics (1%), human-caused intrusions (6%), disposal period uncertainties (13%), ecological impacts (1%), engineered alternatives (4%), and human health (2%) could be addressed or mitigated by this alternative.

3.6.2.4.9 Clay-based Backfill (Alternative #111)

A backfill consisting of commercially available pelletized clay will be used for this alternative. The clay backfill will be placed around the waste stack and between the drums filling the void pace within the rooms.

Public Concerns Which May Be Addressed by this Alternative

The clay backfill will reduce the hydraulic conductivity of the backfill and impede the flow of brine and the mobility of radionuclides. This alternative may therefore address or mitigate public concerns regarding in-storage reactions (5%), human-caused intrusions (6%), site design (3%),

disposal period uncertainties (15%), ecological impacts (1%), engineered alternatives (4%), and human health (2%).

3.6.2.4.10 Public Concerns That Could Not be Addressed by an EA

The EAs that are assessed in this Cost/Benefit Study could not address all postclosure concerns that were noted during this study. The categories of public concerns that could not be addressed or reduced by an EA include siting (4%), containers (5%), monitoring and marking (6%), intrusion due to natural causes (1%), economic impacts (0%), values and ethics (21%), and miscellaneous (4%).

3.6.3 Results of Analysis

3.6.3.1 Comments on the WIPP FSEIS, 1990

Figure 3-18, Relative Frequency of Comments by Category for the WIPP FSEIS, is a graphical representation of the comments by category.

1. *Most comments fell into the "DOE Capabilities" category.*

   Sixty-three percent (4,154 out of 6,539) of all postclosure WIPP comments pertained to perceptions of DOE as they related to DOE's ability to manage the WIPP (Figure 3-18). Comments included concerns about credibility, scientific impartiality, and need for proper review and oversight. The percentage of comments falling into this category decreases in other comment sources made at later dates.

2. *The majority of comments were from New Mexico residents.*

   Of the 1,591 total postclosure oral comments on the WIPP FSEIS, 1,417 (89%) were comments made by New Mexicans. Total written comments on the WIPP SEIS numbered 4,948 with 4,412 (89%) being from New Mexicans.

3. *The rank ordering of comment categories and subcategories by number of comments recorded reveals that New Mexican and non-New Mexican commenters alike tended to place importance on the same issues.*

   A comparison of total comment frequency to comment frequency attributed to New Mexicans showed no rank order position differing by more than one.

4. *Public concerns are approximately equally balanced among the categories within "Conditions."*

   Concerns about "Waste Characteristics" total 10% while concerns about "Waste Repository Technology Applied" total 12% and concerns expressed about "Disposal Period Events" total 8%.

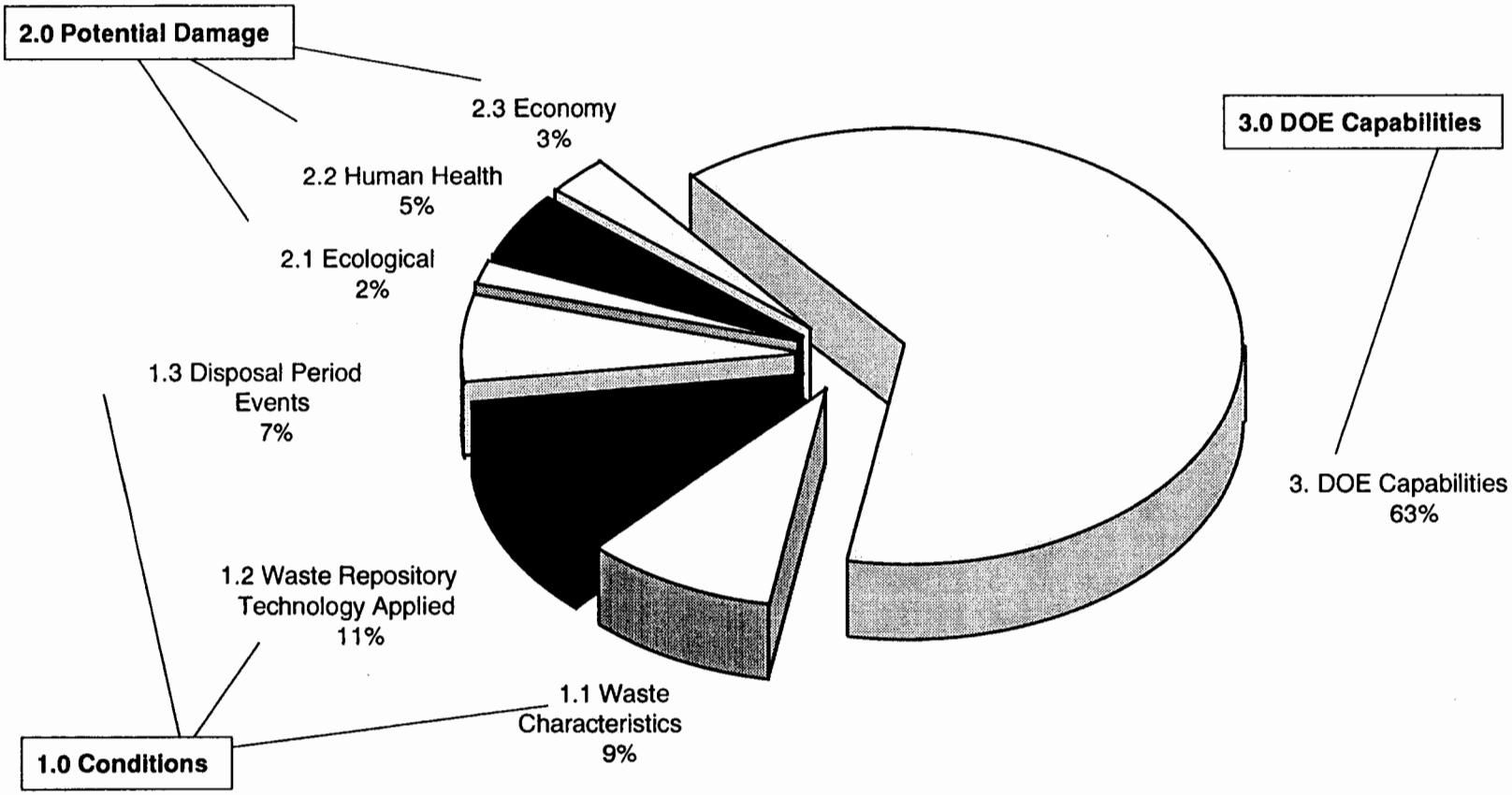


Figure 3-18
Relative Frequency of Comments by Category
WIPP Supplement Environmental Impact Statement
n = 6,539

3.6.3.2 Comments on 40 CFR Part 191, December 1993

Figure 3-19 illustrates relative frequency of comments by category for the December 1993 responses to the Amendments for 40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Wastes.

1. *Comments directly related to DOE capabilities were 2% of the total.*

2. *The comment category of more frequent concern was "Conditions" (85%).*

3. *The most frequent comment category within "Potential Damage" pertained to potential human health effects of the repository (10% of a total 13%).*

3.6.3.3 Comments on Proposed Rule 40 CFR Part 194, March 21-24, 1995

Figure 3-20 shows the relative frequency of comments by category for the March 21-24, 1995, public hearing on the EPA's Proposed Rule 40 CFR Part 194.

1. *The majority of comments pertained to "Conditions" (81%).*

2. *Within the category "Conditions," most comments were directed toward applied waste repository technology and disposal period events (38% and 26% respectively). The third subcategory, "Waste Characteristics," accounted for 17% of the total.*

3. *Comments regarding potential damage (human health, ecological, and economic) accounted for a total of 13% of all comments.*

3.6.3.4 Comments from Carlsbad Focus Group Discussion and Interviews

Figure 3-21 provides the relative frequency of comments for the focus group discussions held in Carlsbad, New Mexico.

1. *The largest percentage of comments fell under "Other." By reference to Appendix N, the single largest subcategory of comments is "Value/Ethics."*

2. *"Economic Impacts" had the least number of total comments (2%).*

3. *Comments pertaining to "Disposal Period Events" constitute 12% of all comments.*

3.6.3.5 Comments from Albuquerque Focus Group

Figure 3-22 illustrates the relative frequency of comments for the Albuquerque focus group.

1. *As with the Carlsbad focus group, Albuquerque results show the majority of comments (34%) falling into the category "Other." Again, the data in Appendix N help clarify this finding. Within this category, comments concerning "Value/Ethics" dominate (19%), with the remaining portion mostly concerning the EA Study (10%).*

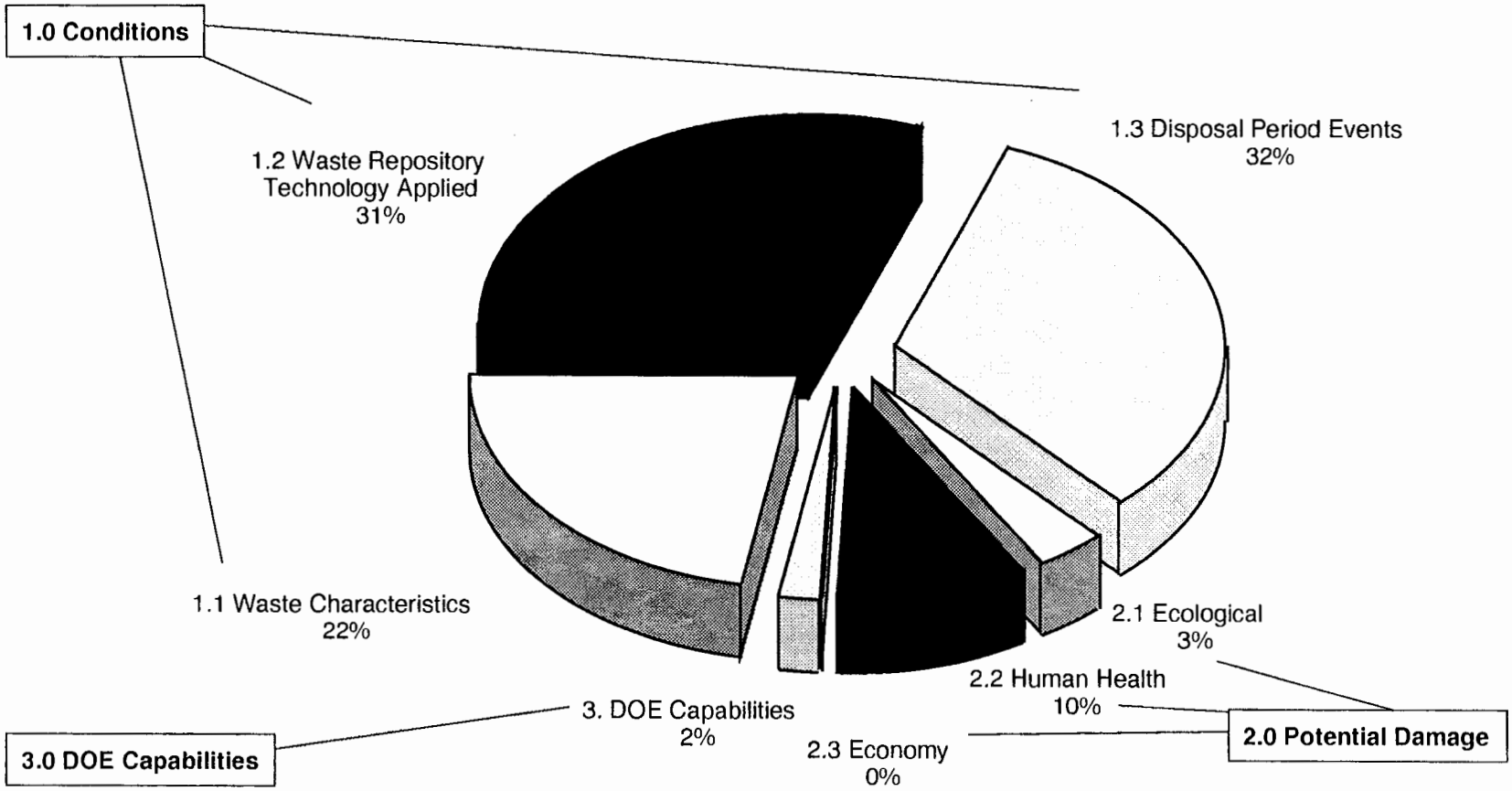


Figure 3-19
Relative Frequency of Comments by Category
Response to Amendments for 40 CFR Part 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, December 1993
n = 157

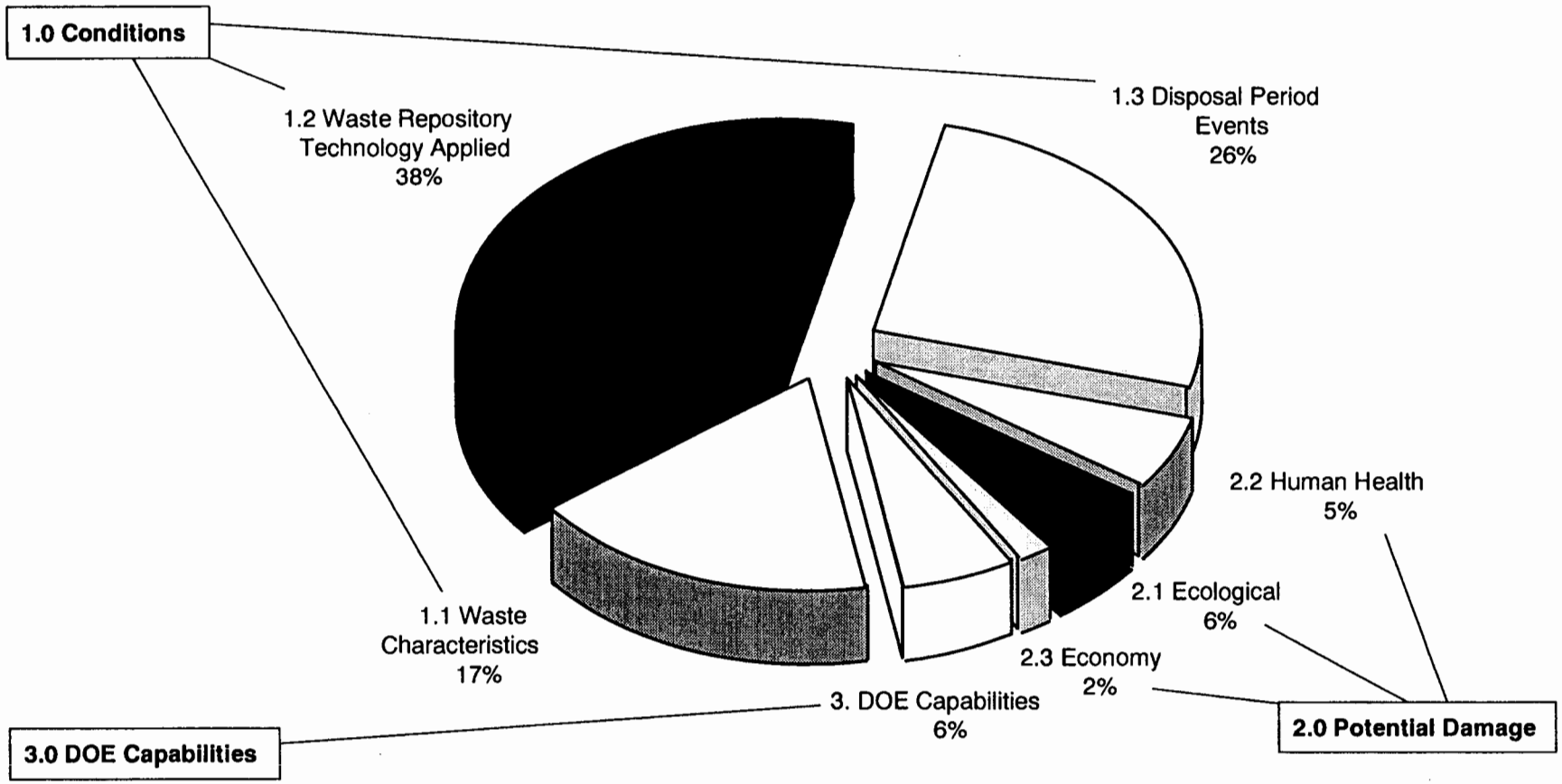


Figure 3-20
Relative Frequency of Comments by Category
Public Hearings on EPA's Proposed Rule 40 CFR Part 194, March 21-24, 1995
n = 181

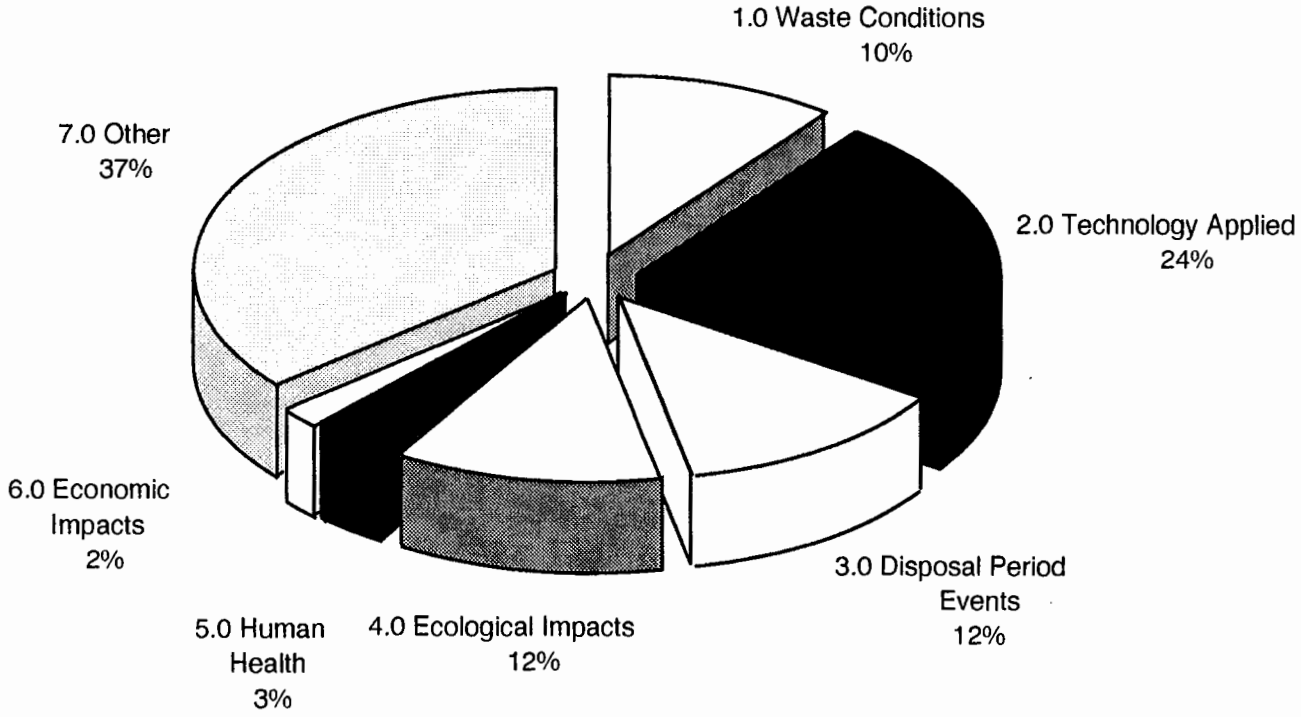


Figure 3-21
Relative Frequency of Comments by Category
Focus Group Meetings – June 1995
Carlsbad
n = 58

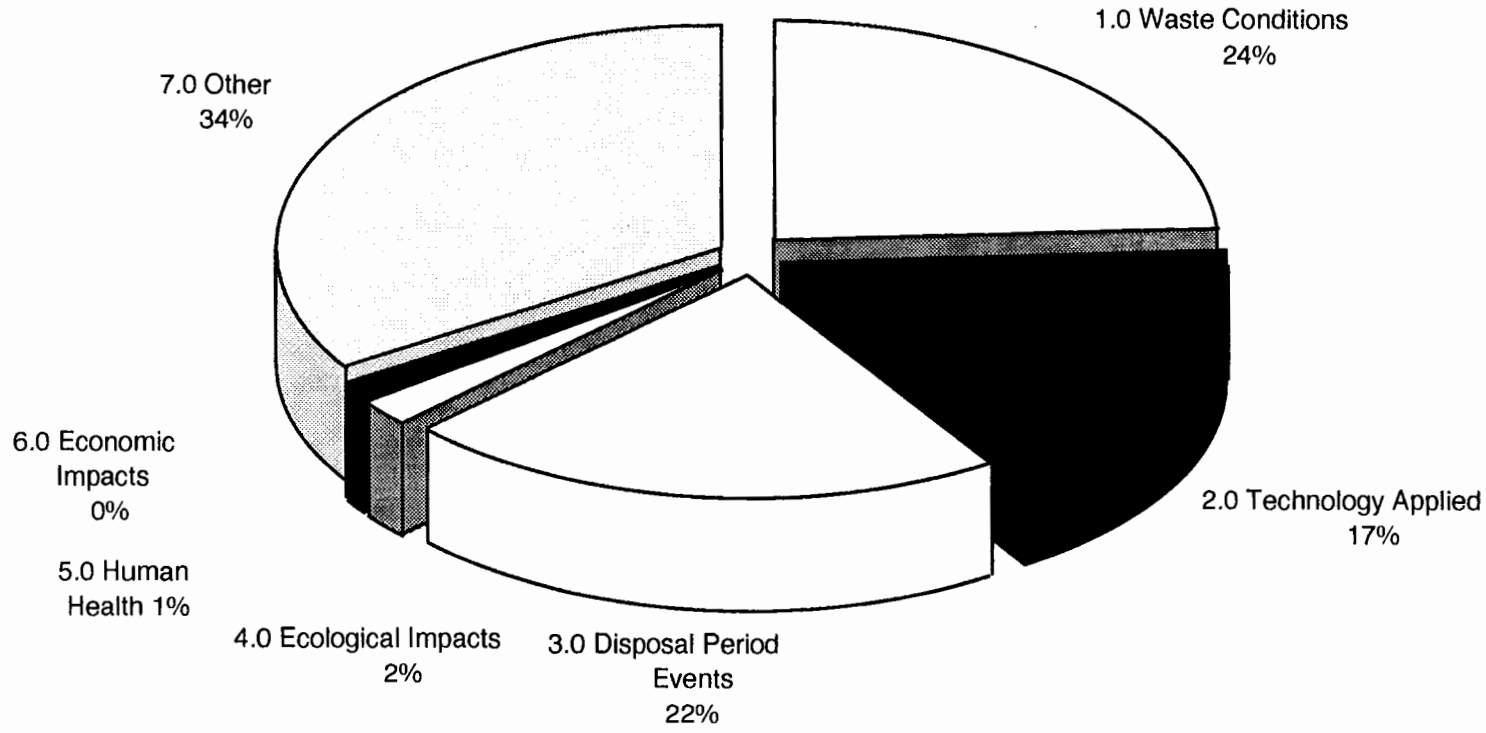


Figure 3-22
Relative Frequency of Comments by Category
Focus Group Meetings – June 1995
Albuquerque
n = 105

2. *Twenty-two percent of all comments were related to issues surrounding disposal period events, with 11% relating to "Disposal Period Uncertainties" and 11% concerned with "Human-Caused Intrusion."*

3.6.3.6 Comments from Santa Fe Focus Group Discussion and Interview

Figure 3-23 illustrates the relative frequency of comments for the focus group discussions held in Santa Fe, New Mexico.

1. *The majority of comments are again in the category of "Other" (28%). Examination of detail data in Appendix N reveals that 22% of the comments pertained to "Value/Ethics" with the remaining 5% fairly evenly distributed over the remaining three subset categories, "Engineered Alternatives Study," "Transportation," and "Miscellaneous.".*

2. *Comments pertaining to "Waste Conditions," "Technology Applied," and "Disposal Period Events" constitute 60% of all comments made during the focus group discussion. A review of actual comments in Appendix M helps to further explain the concerns.*

3.6.3.7 Data Comparison for Phase 1 Data

Figure 3-24, Relative Frequency of Comments by Category, Total All Comments, graphically represents the combined Phase 1 public concerns.

1. *Comment frequencies tend to follow the same pattern from one comment source to another.*

   The highest percentage of comments fell into the "Conditions" category (e.g., comments concerning "Waste Characteristics, Waste Repository Technology, and Disposal Period Events"). The range for this category was 58 percentage points (with a maximum value of 83% and a minimum of 25%), and the mean was 58%. A visual examination of the charts makes this observation more apparent. Other categories also tend to conform to this observation.

2. *The percentage of comments pertaining to Category 3 ("DOE Capabilities") has dropped markedly over time.*

   The 1990 SEIS recorded 4,154 comments pertaining to issues related to DOE capabilities. This represented 64% of the total 6539 comments recorded in the SEIS. The percentage of comments from other, more recent, Phase 1 sources ranged from 2% to 6%. Even though the number of comments from the other two sources totaled only 338 in comparison to the 6,539 comments from the SEIS, there seems to be a definite downward trend in this category.

3.6.3.8 Data Comparison for Phase 2 Data

Figure 3-25, Relative Frequency of Comments by Category, Focus Group Discussions and Interviews, is a composite pie chart illustrating the combined results for the focus group discussions and interviews held at Carlsbad, Santa Fe, and Albuquerque.

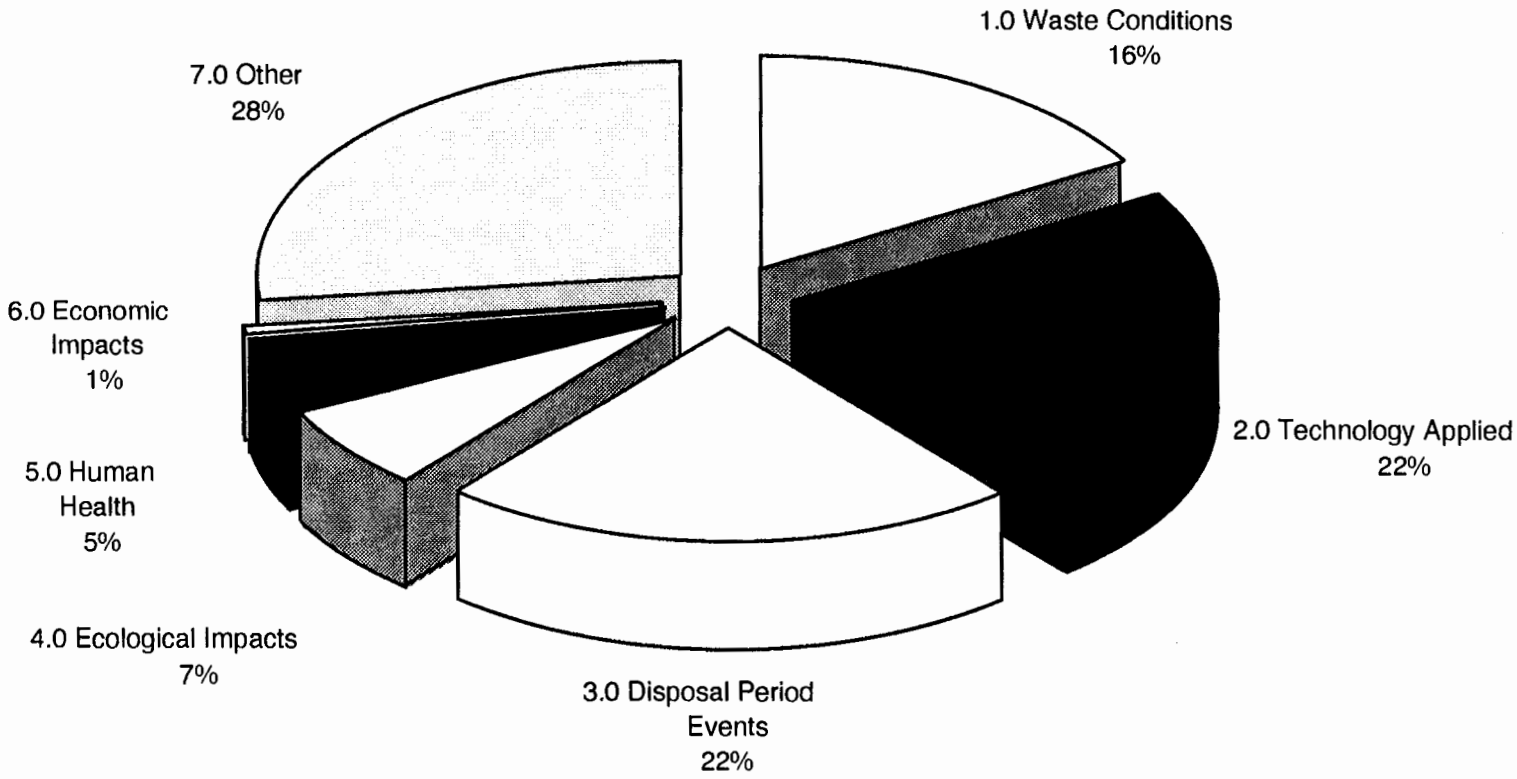


Figure 3-23
Relative Frequency of Comments by Category
Focus Group Meetings – June 1995
Santa Fe
n = 178

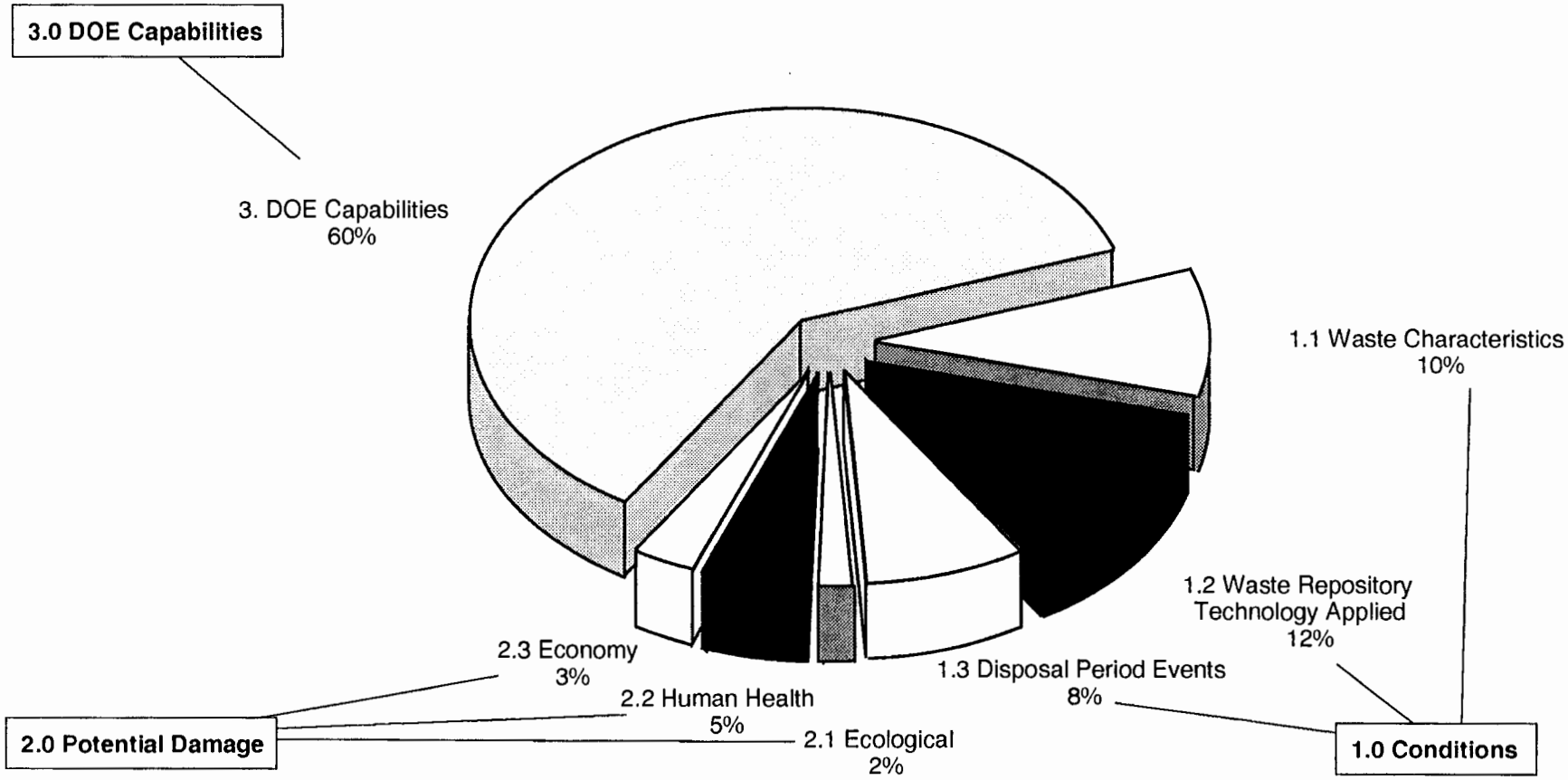


Figure 3-24
Relative Frequency of Comments by Category
Total All Comments
n = 6,877

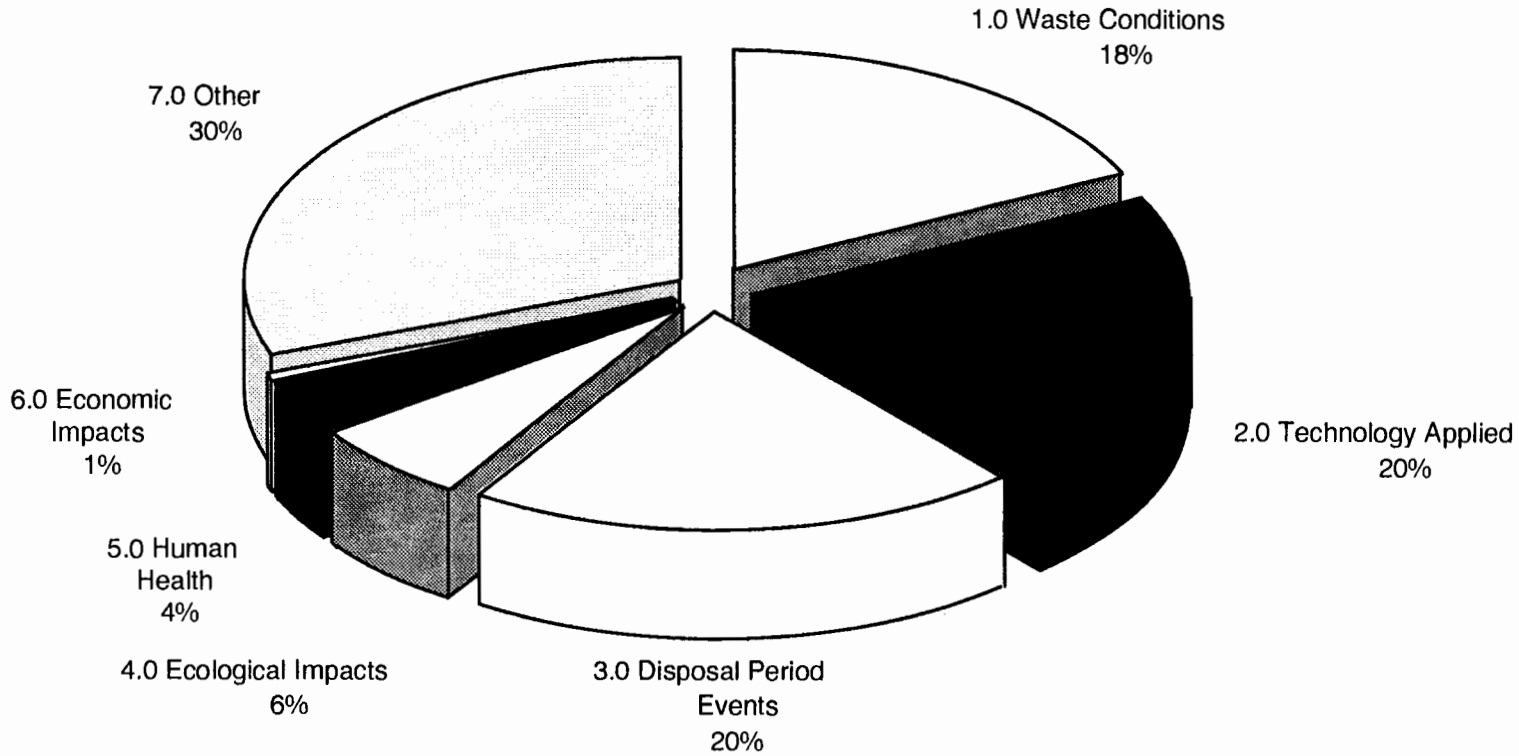


Figure 3-25
Relative Frequency of Comments by Category
Focus Group Discussions and Interviews
Composite: Carlsbad + Santa Fe + Albuquerque
n = 341

1. *Every comment made during a focus group discussion was categorized as either pertinent or not pertinent to postclosure WIPP. Interestingly, most comments made were pertinent to postclosure WIPP (ranging from 83% of all comments made on human health to 95% of all comments concerning disposal period events). The two taxonomic categories having the least percentage of comments that related directly to postclosure WIPP were "Economic Impacts" (0%) and "Other" (48%). The low percentage of postclosure-related comments in the "Economic Impact" category has little or no significance because there were only two comments made during the entire series of focus group sessions. The lower percentage of comments relevant to postclosure WIPP in the category "Other" is attributable to a host of comments made about values and ethics directed at matters of trust (see "DOE Capabilities" in the Phase 1 taxonomy). In any case, almost half of the comments included in the "Other" category cannot be regarded as comments directed specifically at postclosure WIPP. See Appendix N for detailed information on how comments were classified as pertinent or not pertinent.*

2. *"Disposal Period Events" received 20% of total comments. The very long safekeeping period required for wastes emplaced at the WIPP is a time period well beyond the predictive range commonly used by most people.*

3. *A total of only 11% of comments were classified into the categories "Economic Impacts," "Human Health," and "Ecological Impacts."*

4. *Next to concerns about "Disposal Period Uncertainties," "Technology Applied" (20% of all focus group comments) and "Waste Conditions" (18% of all comments) gathered the most comments. These comments included concerns about waste containers, the types of waste to be accepted at WIPP, waste characterization, and the technologies appropriate for long-term isolation of the waste.*

3.6.3.9 Concluding Remarks

While not a statistically pure undertaking, results of this study are several:

- The majority (78%) of the concerns presented during the focus group discussions pertained to postclosure WIPP.

- The majority of the categories of concerns can be addressed or mitigated by an EA. Only seven of the eighteen categories of concern cannot be addressed or mitigated by an EA.

- The largest single category of concern for all focus group discussions was value/ethics. Comments in this category include concerns about how decisions are made and whose values are used by the government in its decision-making practices.

- Tabular frequency analysis allows traceability of study results back to the original source of comment.

- The raw data offer expanded opportunity for more detailed examination as interest and need dictate (e.g., geographic source of comments).

Anecdotal results include the fact that each focus group discussion varied in the expressed concerns. Most of the stakeholders who participated in the Carlsbad discussions expressed their confidence in the long-term ability of the WIPP to isolate hazardous wastes from the environment. Several of the Carlsbad participants stated that they didn't really have any serious postclosure concerns about WIPP but were mildly concerned about issues such as long-term record keeping and permanent site markers. Many of the Albuquerque participants commented on the regulatory requirements for EAs, human-caused intrusion, and disposal period uncertainties. The Santa Fe participants commented on waste processing, disposal period uncertainties, monitoring and marking of the site, and how and whose values are used by the government in its decision-making practices.

There were also several comments presented during each focus group discussion which expressed concern about the adequacy of 55-gallon (208-liter) drums as waste containers, and the ecological impacts of water breaching the site, becoming contaminated, and migrating to the surface or to the overlying water-bearing strata.

3.7 FACTOR 7: DOE TOTAL SYSTEMS COST AND SCHEDULE ESTIMATES

3.7.1 Definition of Factor 7

The impact of cost and schedule for each alternative will be an important tool for planning the implementation of an alternative. Cost and schedule will typically determine the level of funding that must be appropriated, the required manpower for the activities, and a schedule that provides conceptual start and stop dates.

The total cost will be composed of waste processing, transportation, repository backfill, and emplacement handling costs for the selected alternatives in different configurations. Processing cost are estimated by first developing process flow diagrams that segment the alternative into functional elements. The costs for the alternatives are developed on the basis of waste quantities and throughput rates required to meet schedule constraints. The throughputs for each element are used to determine costs for each element, and total processing costs consist of a summation of each appropriate element cost. Other cost elements (transportation, backfill, and emplacement handling) will be estimated using accepted departmental methods. The presentation of total costs will include a comparative analysis of the incremental change of the screened alternatives relative to the repository baseline cost.

The schedule for each alternative will provide a measure of the alternative's desirability. An alternative with an excessive implementation schedule may be deemed undesirable. The schedule analysis provides a measure of time required to implement an EA relative to the baseline. The schedule will include a baseline and the incremental change of an alternative to the baseline.

Both cost and schedule impacts will be based on an approach consistent with current departmental methodologies and assumptions. The results of the analysis are presented according to key elements and summarized according to each alternative.

3.7.2 Methodology Used to Evaluate Factor 7

Costs estimates for implementing the individual EAs in the different facility configurations were composed of four major elements:

- Waste processing costs (Section 3.7.2.1)
- Transportation costs (Section 3.7.2.2)
- Backfill emplacement costs (Section 3.7.2.3)
- Waste emplacement handling costs (Section 3.7.2.4).

Each of these elements was summed to arrive at a total system cost.

3.7.2.1 Process Costing Methodology

The waste processing costs were estimated using information contained in "Interim Report: Waste Management Facilities Cost Information for Transuranic Waste" (WMFCITRUW) (Feizollahi and Shropshire, 1994). The cost estimating method used by Feizollahi and Shropshire involves segmenting waste management facilities into discrete modules which are used to estimate the costs for building and operating facilities to perform various waste management functions. Cost

estimates for different types of integrated TRU waste facilities are created by linking modules for different functions together in such a way that they closely approximate an actual waste management facility. This methodology provides the flexibility to estimate the costs many different sized facilities with many different functions without having to perform a rigorous conceptual design and cost estimate for each facility configuration.

Figure 3-26 shows the information flow diagram used to develop waste processing cost estimates. Information from process flow diagrams and mass flow rates are required as input to the cost modules. A combination of data sources were used to develop this information, including existing waste inventories and waste generation projections (Appendix O), processing schedules (Appendix Q), a listing of EAs that require waste processing (Section 2), and the system configuration for the waste processing facilities (i.e., centralized, regionalized, or decentralized) (Section 2).

Process flow diagrams were developed for each alternative in each configuration (see Figures 3-27 to 3-37). These flow schemes were based on the DOE "Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force" (DOE, 1991a), the Draft EM-PEIS report, and the WMFCITRUW report (Feizollahi and Shropshire, 1994). Information from these sources were used to connect each of the modules and to construct a visual description of mass and volume flow through each treatment process.

The modules are described below:

- Front End: Front-end support facilities consist of all administrative and laboratory buildings required for the waste management support functions. Front-end support functions include security, personnel decontamination (radioactive and hazardous), maintenance of noncontaminated areas and equipment, health physics, radiation badges, facility access control, sanitary facilities, work control and personnel support, internal and external communications, spill or emergency response provisions (hazardous and radioactive), analytical laboratory, environmental field sampling, environmental regulatory reporting, and records management.

- Retrieval: This module consists of all-weather excavation, inspection, and repackaging of bermed waste. The module includes three principal unit operations: earthen-cover extraction and decontamination, waste-container retrieval and inspection, and packaging and staging for shipment.

- Waste Characterization: This module is a self-contained facility in which waste characterization is performed. Activities include extracting physical samples of waste; conducting chemical, physical, and radiological analysis of waste samples; and repackaging drums and boxes to remove and stabilize noncompliant waste.

- Maintenance: A maintenance facility is used in conjunction with treatment facilities. It consists of a failed-equipment receiving and repair building housing machinery and tools.

- Treatment: The treatment module varies based on the alternative being considered. Treatment options include grouting, supercompacting, shredding and

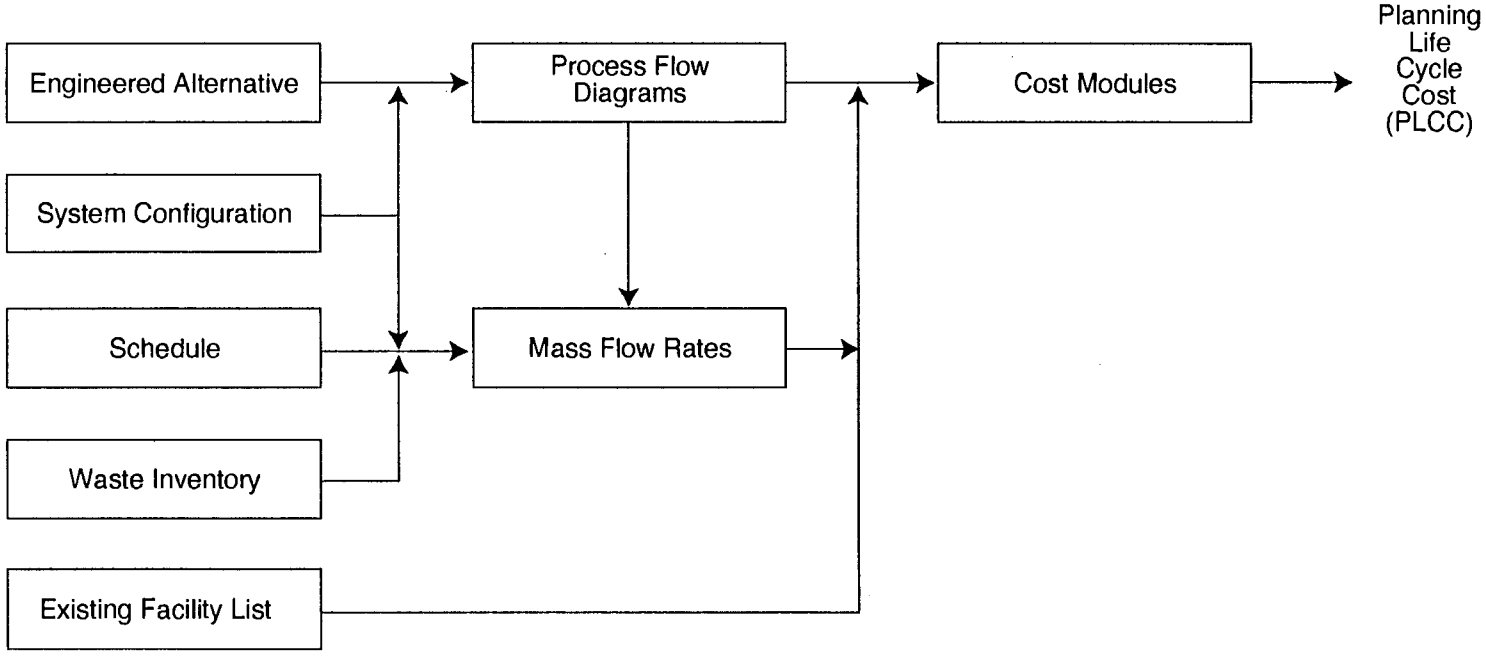


Figure 3-26
Process Costing Methodology Flow Diagram

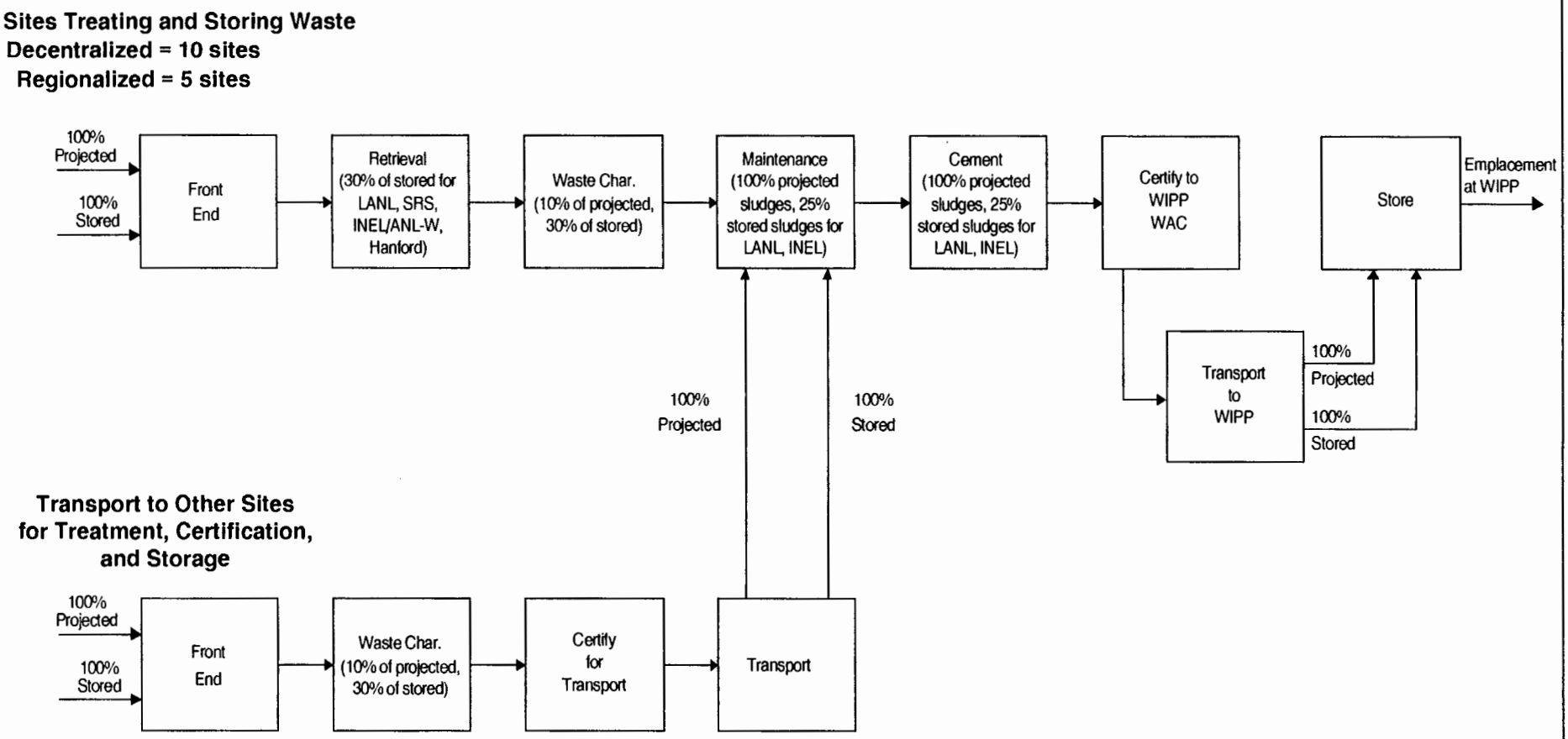
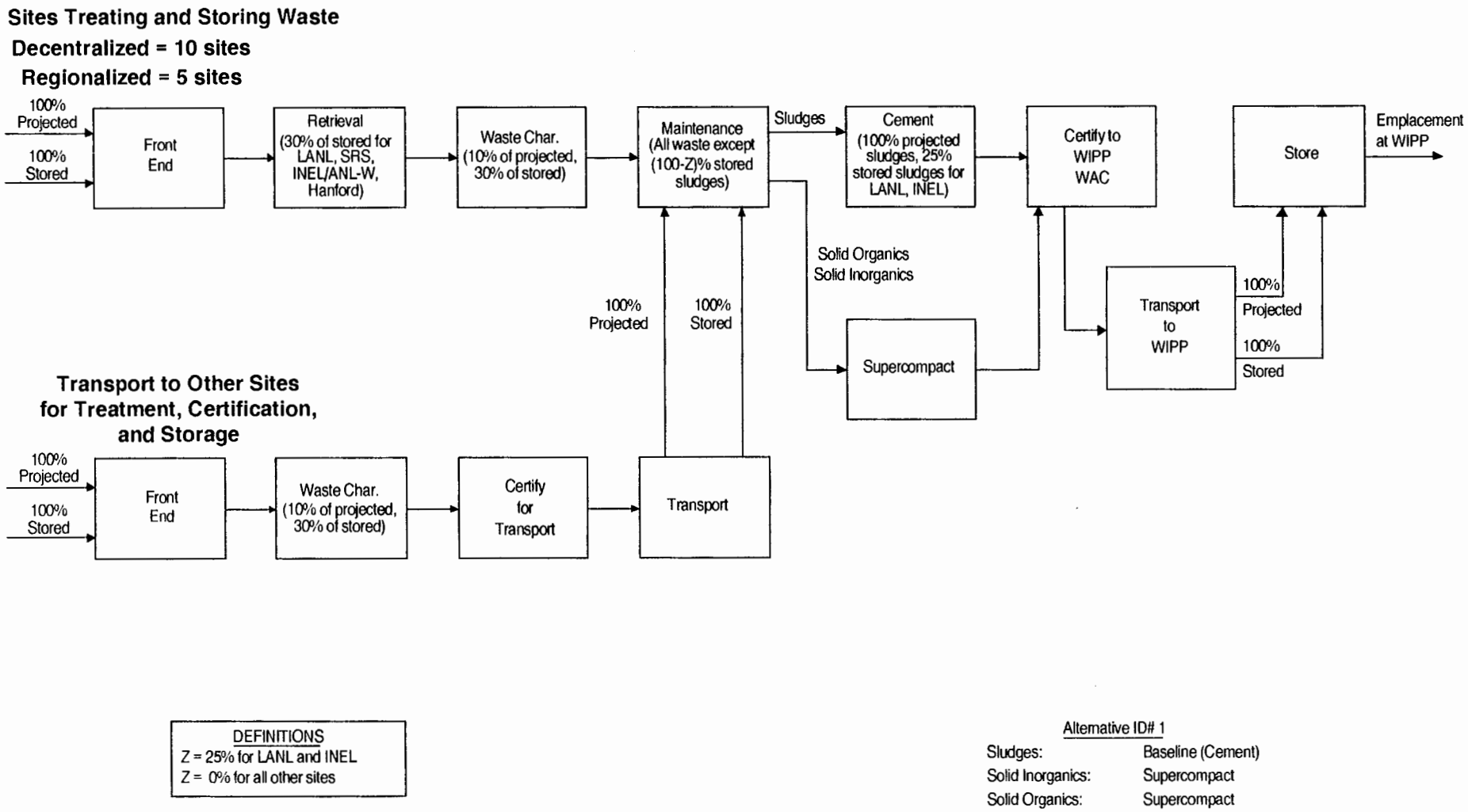


Figure 3-27

Decentralized and Regionalized Base Cases and Alternative ID #s 33, 35(a&b), 83, and 111 Contact Handled Process Flow Diagram A



DEFINITIONS
Z = 25% for LANL and INEL
Z = 0% for all other sites

Alternative ID# 1

Sludges:	Baseline (Cement)
Solid Inorganics:	Supercompact
Solid Organics:	Supercompact

Figure 3-28

Decentralized and Regionalized Alternative ID #s 1 and 77(a-d) Contact Handled Process Flow Diagram B

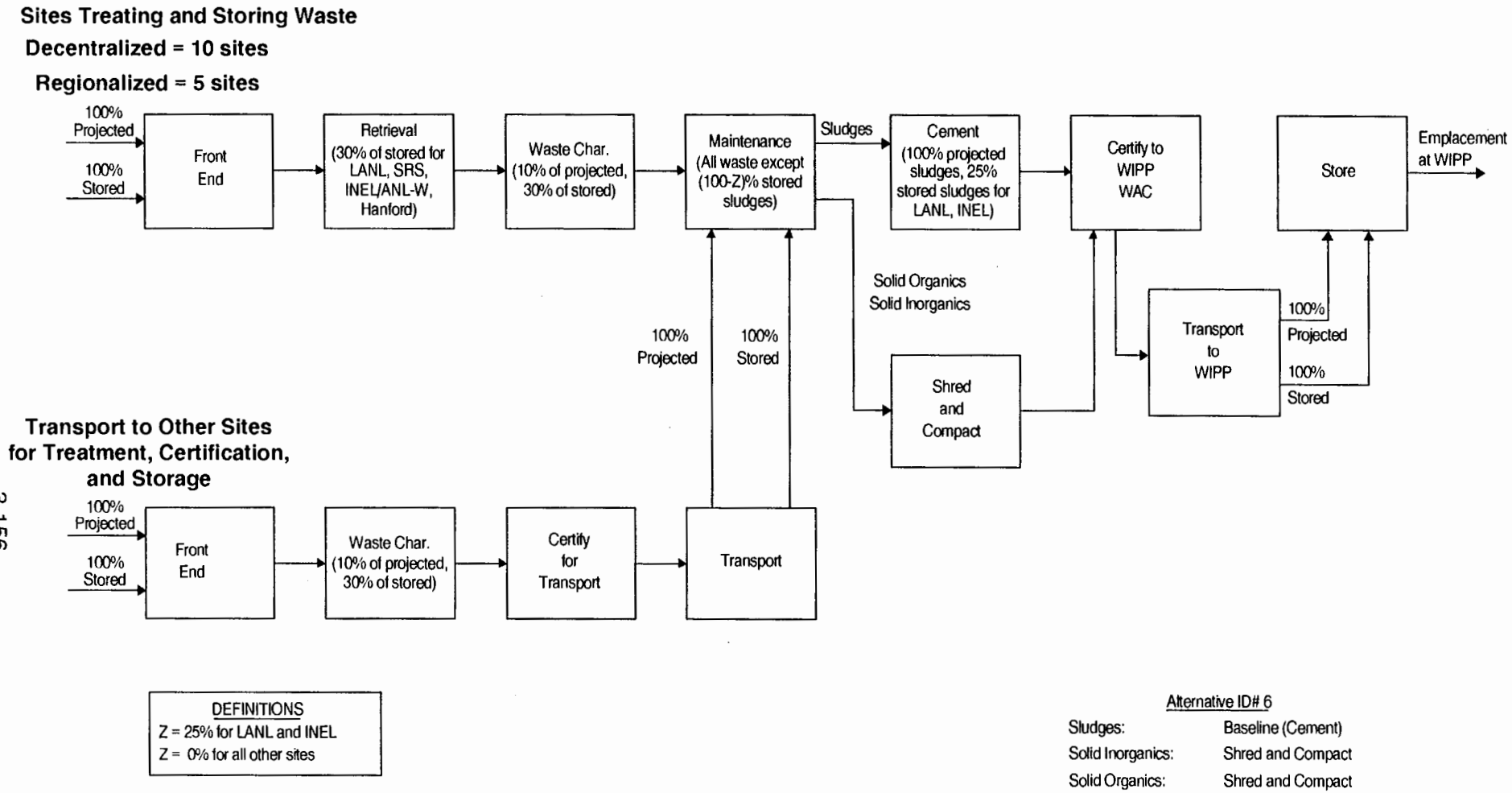
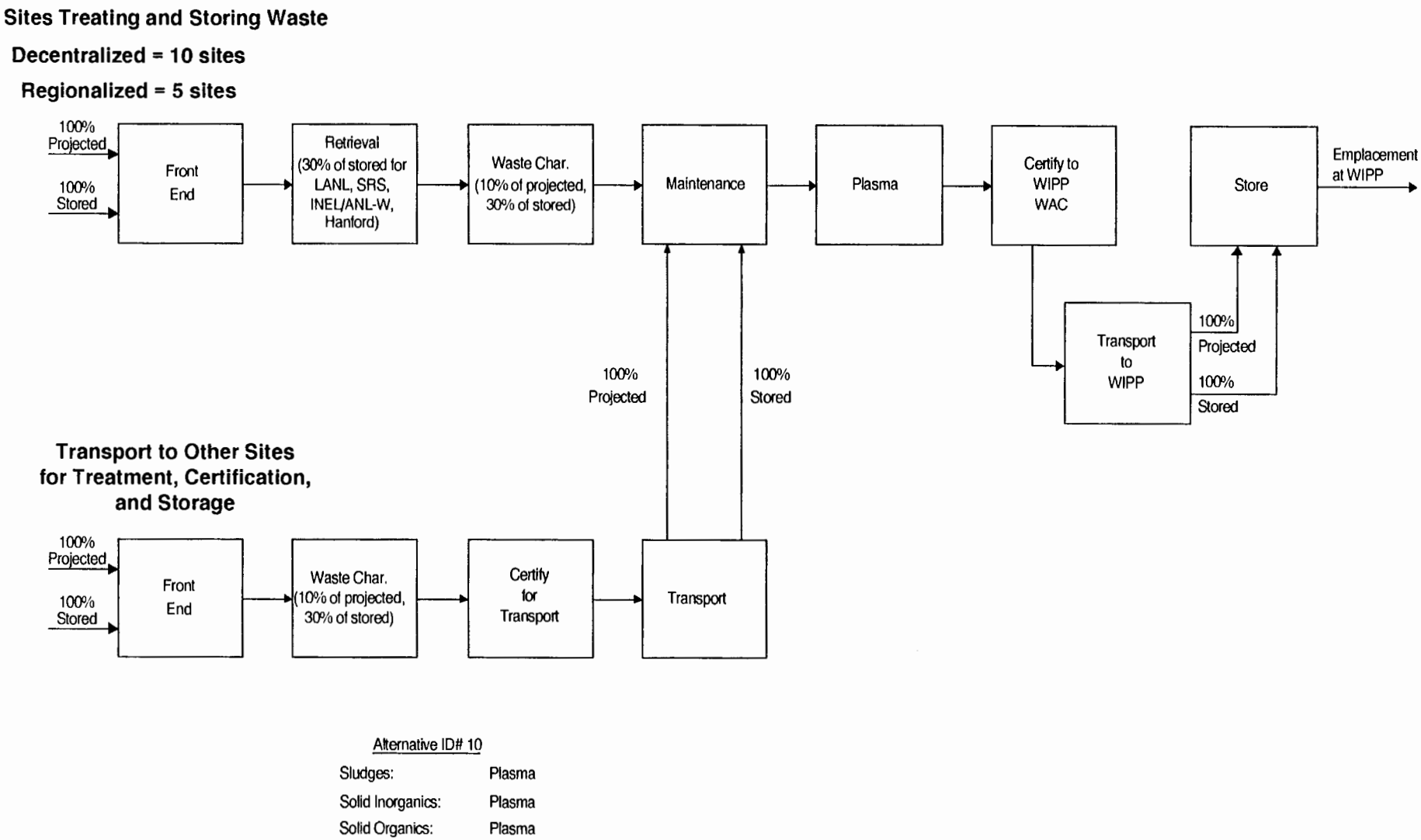


Figure 3-29

Decentralized and Regionalized Alternative ID# 6 Contact Handled Process Flow Diagram C

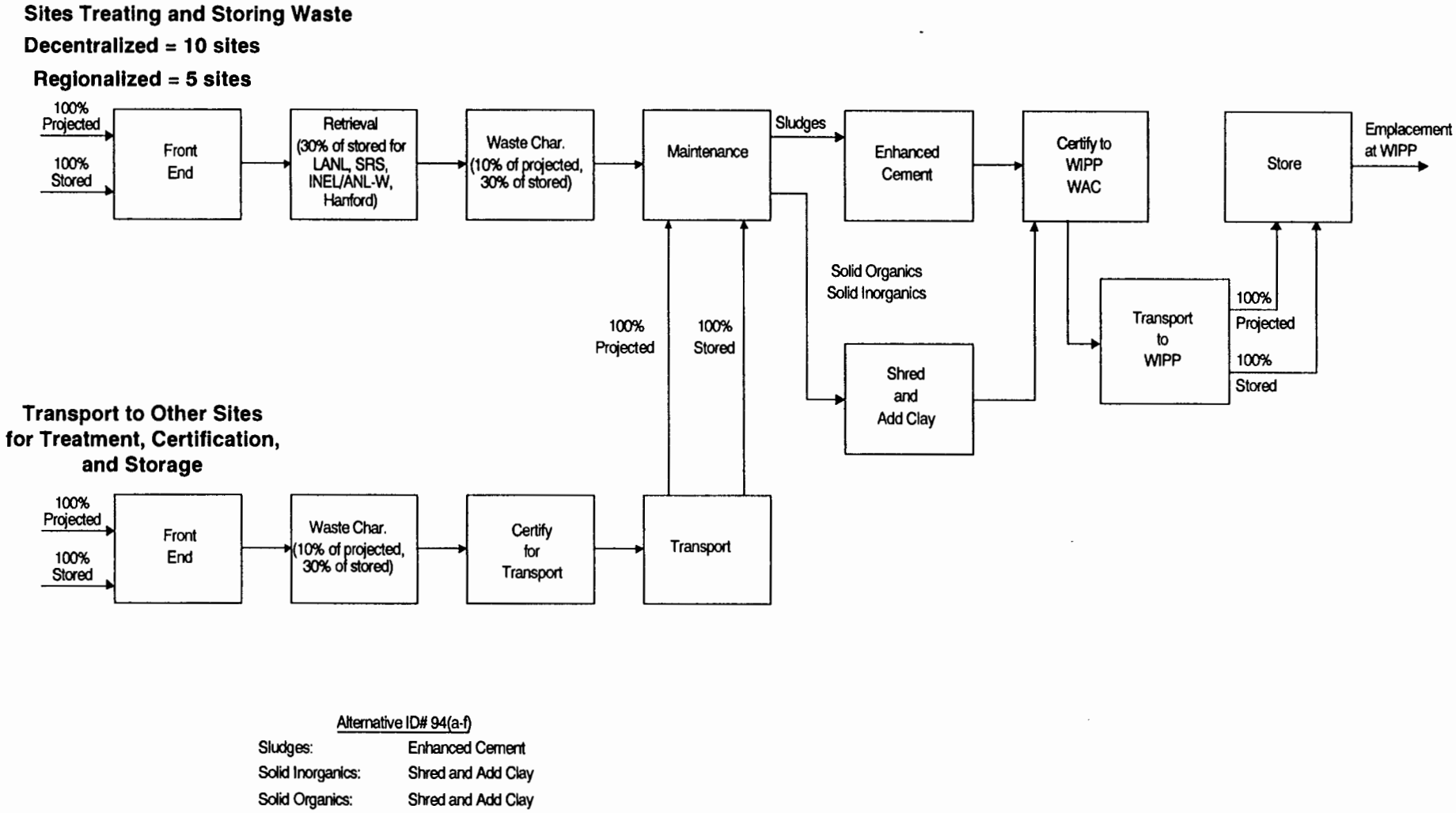


Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure 3-30

Decentralized and Regionalized Alternative ID# 10 Contact Handled Process Flow Diagram D



Alternative ID# 94(a-f)	
Sludges:	Enhanced Cement
Solid Inorganics:	Shred and Add Clay
Solid Organics:	Shred and Add Clay

Figure 3-31

Decentralized and Regionalized Alternative ID# 94(a-f) Contact Handled Process Flow Diagram E

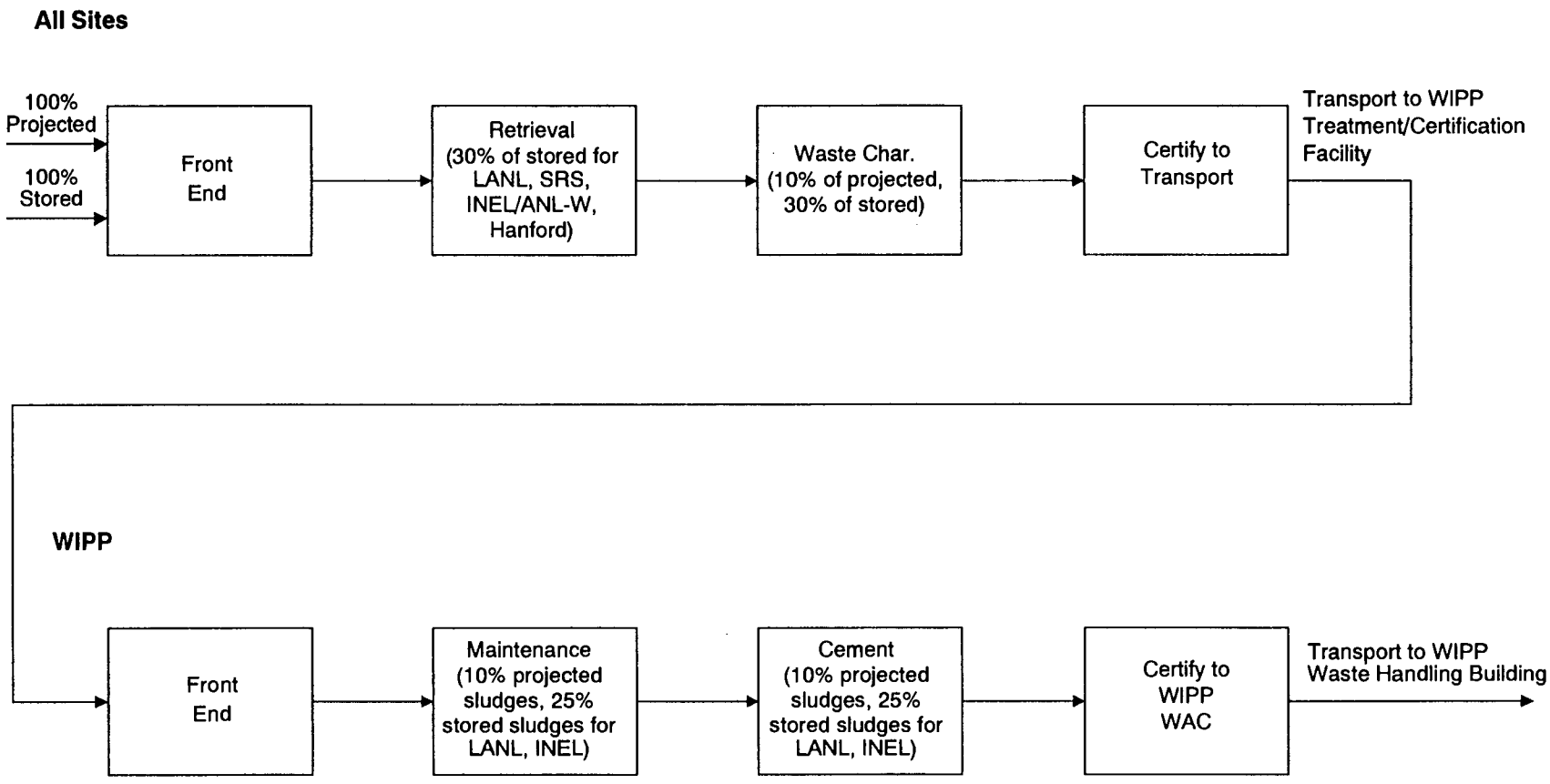


Figure 3-32

Centralized Base Case and Alternative ID #s 33, 35(a&b), 83, and 111 Contact Handled Process Flow Diagram F

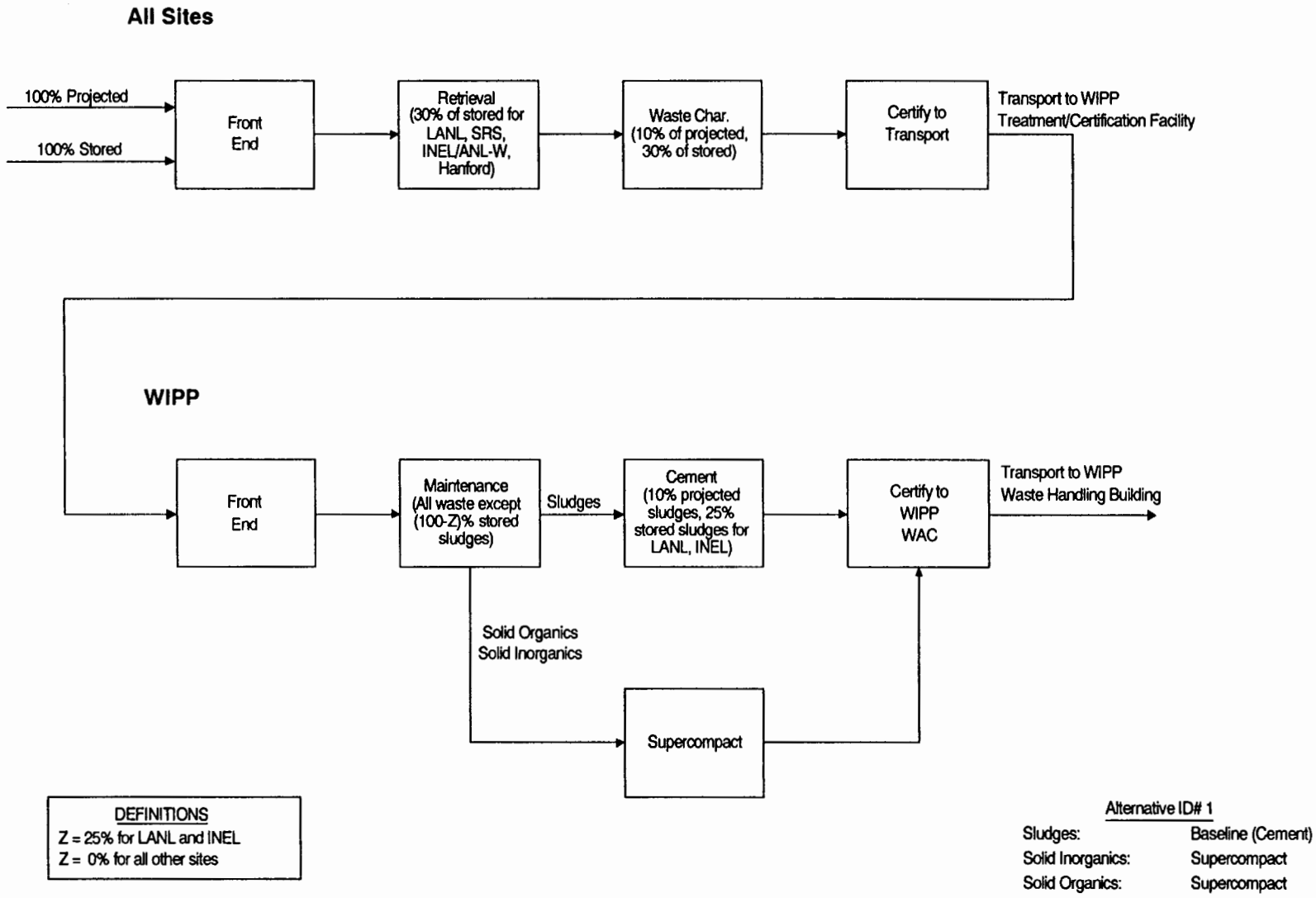


Figure 3-33
Centralized Alternative ID#s 1 and 77(a-d) Contact Handled Process Flow Diagram G

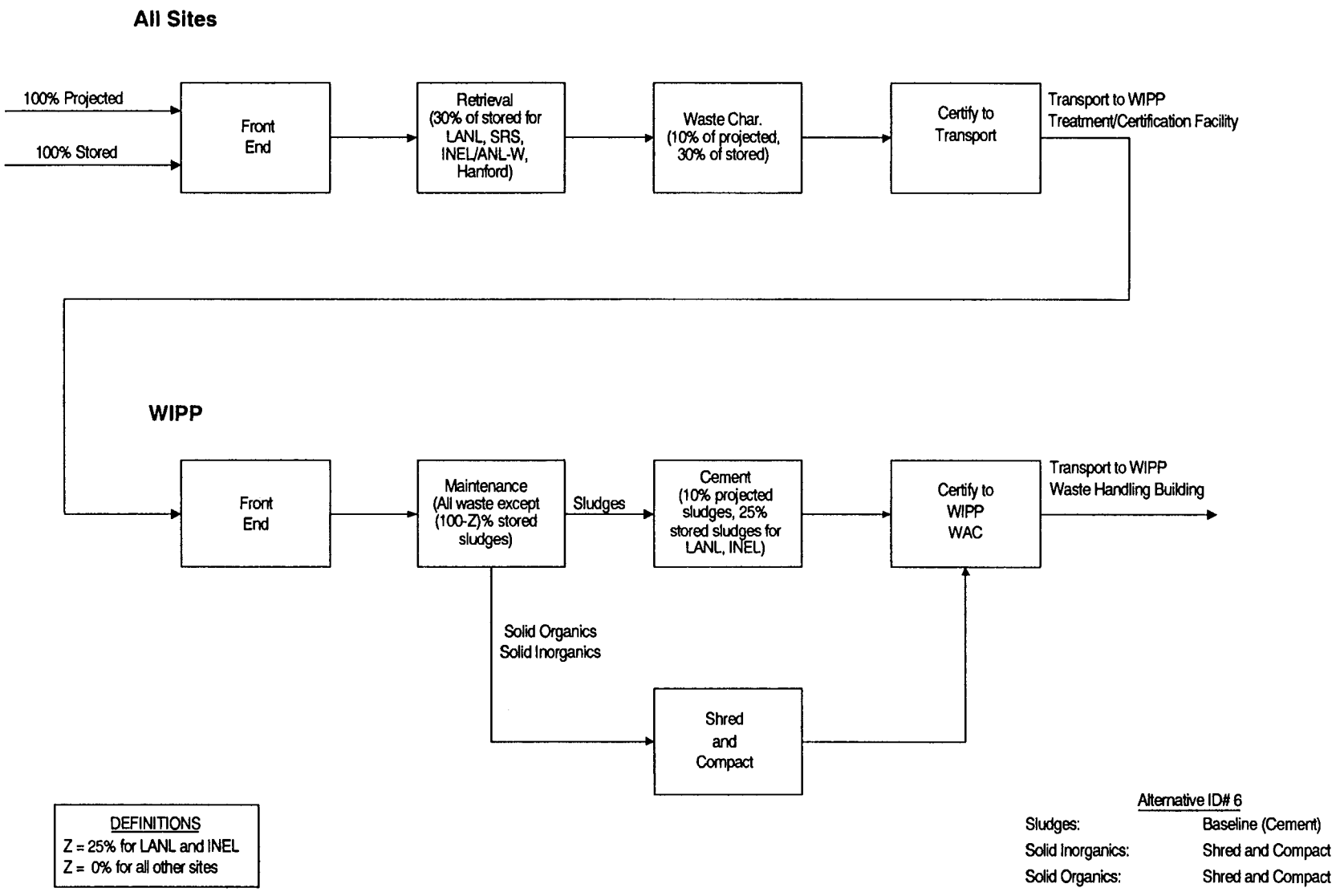
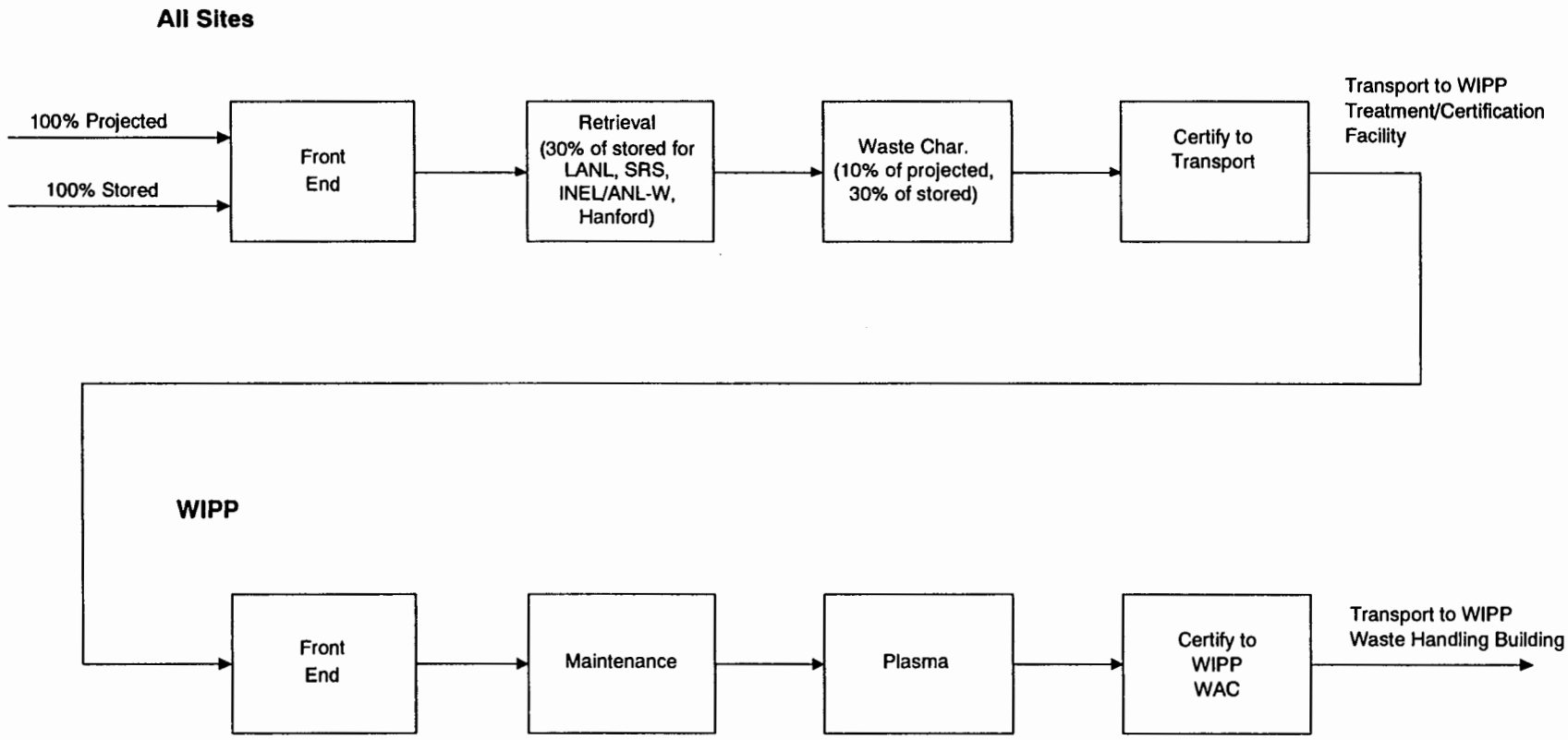


Figure 3-34
Centralized Alternative ID# 6 Contact Handled Process Flow Diagram H



Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure 3-35
Centralized Alternative ID# 10 Contact Handled Process Flow Diagram I

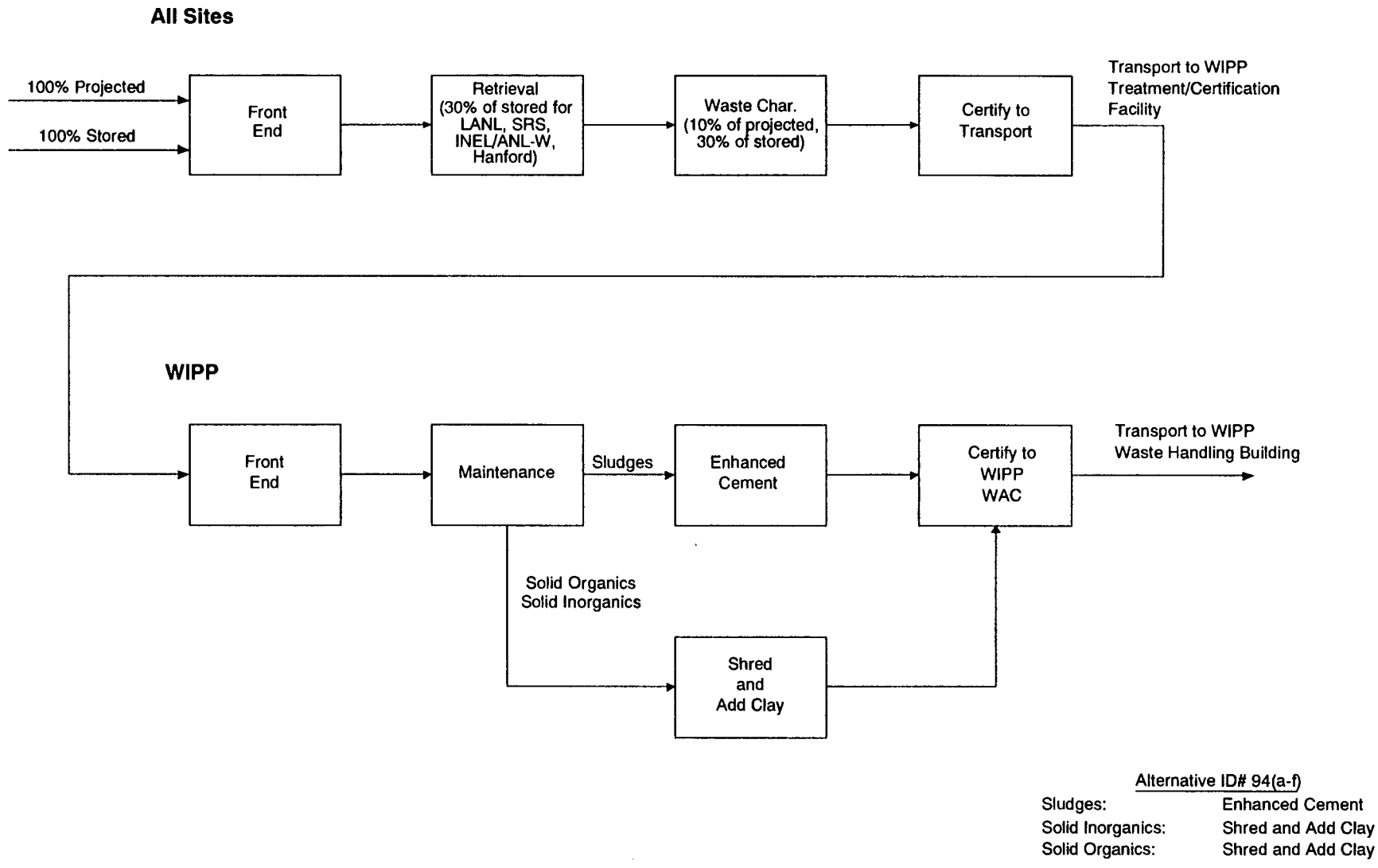


Figure 3-36
Centralized Alternative ID# 94(a-f)
Process Flow Diagram J

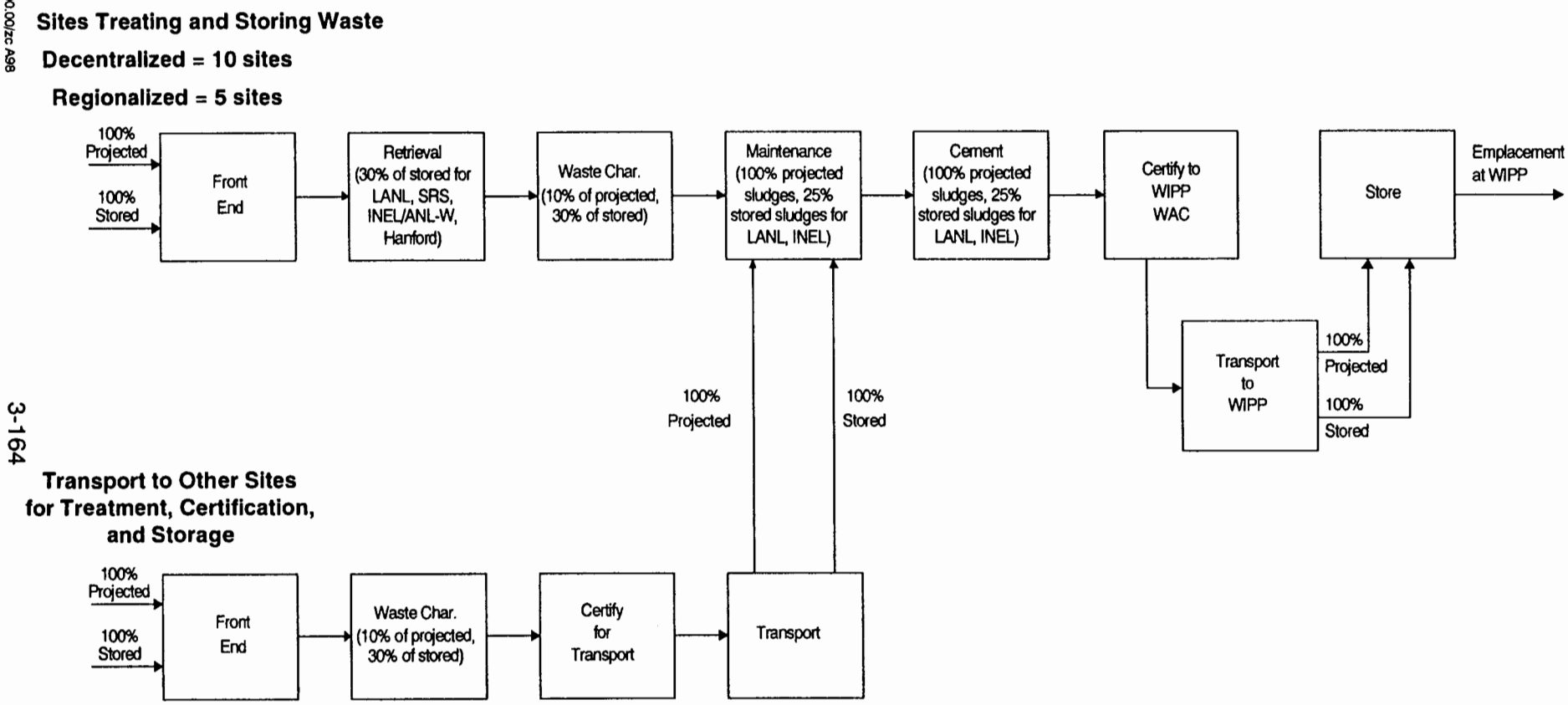


Figure 3-37

Decentralized Base Case Remote Handled Process Flow Diagram K

compacting, plasma melting, enhanced-cement processing, and shredding and adding clay.

- Storage: This module consists of a RCRA-compliant storage building sized to accommodate an accumulation of up to 20 years' volume of waste input from treatment modules. Storage area features include spill collection, sloping floors, sumps, and concrete berms. Monitoring is included for both gamma and alpha radiation control.

- Certification: Certification consists of storage of incoming material, assay and certification, and truck loading. The facility is equipped with a bridge crane and a forklift. It is assumed that certification operations will take place indoors.

- Transportation: Transportation consists of truck shipments. Equipment includes a tractor and trailer transporting three TRUPACT-IIs for CH waste or one RH cask (RH-72B) (a cylinder consisting of a separate inner canister within an outer cask protected by impact limiters at each end) for RH waste.

The process flow diagrams are developed from multiple data sources, and TRU waste processing knowledge from various sources; therefore, the uncertainty of the process flow diagrams cannot be quantified, but should be in the same order of magnitude as the documents used as guidelines for this study. The process flow diagrams developed for this study were designed mostly in accordance with the EM-PEIS and the WMFCITRUW report, however, not every module recommended in the WMFCITRUW report was included in this study. The reasons for deviating from the recommended WMFCITRUW guidance include 1) minimizing the costs of duplicate equipment contained in more than one module, and 2) more accurately representing the functions in existing and planned TRU waste facilities.

Mass and volume throughput are calculated using data from the WIPP BIR (DOE, 1995e). These rates are calculated using a 20-year processing period and a 4,032-hour working year. The mass or volume input to each of the individual modules is shown in Appendix O and is used as the basis for the module throughput which is the primary data used to estimate the cost of the module.

"The TRU waste disposal inventory in the BIR is derived from existing information on waste, which has been provided by DOE TRU waste generator/storage sites and is predominately based on process knowledge" (DOE, 1995e). Any uncertainty within the BIR is carried into this EA study. Calculated processing rates using a 20-year period and 4,032-hour working year may also introduce a level of uncertainty in estimating the costs. Many of the calculated processing rates were below or beyond the range of processing rates listed in the WMFCITRUW report and may cause the calculated costs to be skewed.

Numerical data values for cost versus flow rate information were obtained from the authors of the WMFCITRUW and used to construct approximate relations or curve fits for cost versus mass or volume throughput for a specific processing module. Cost data are available in the WMFCITRUW report according to specific project activities including pre-operations (pre-ops), planning life cycle cost (PLCC), construction, O&M, and D&D. Appendix P provides additional information on the method for establishing the modules. The PLCC is the summation of pre-ops, construction, O&M and D&D cost.

The WMFCITRUW was developed specifically to calculate facility costs in the EM-PEIS. Neither the WMFCITRUW nor the EM-PEIS provide a quantitative uncertainty of the costing data. From the costing categories listed in Plant Design and Economics for Chemical Engineers (Peters et al., 1991), the WMFCITRUW study cost estimates fall into the Study Estimate cost category where the probable accuracy of the estimate is plus or minus 30 percent.

To ensure that the waste processing cost estimates presented in this study account for those facilities that currently exist, a list of existing facilities was assembled from information gathered from several sources, including personal communications (Bjotued, 1995; George, 1995) and preliminary information being developed by the DOE National TRU Program Office (NTPO). Data from these sources were consolidated into a single list used to describe existing TRU waste processing facilities for this study, as shown in Table 3-45. All of the information sources have not been subject to extensive review, thus uncertainty of the data arises from the uncertainties associated with the sources themselves, and any changes that have occurred between the current time and the time these sources were compiled.

The existing facility list was used to adjust process cost estimates. O&M and D&D costs were added and applied to facilities that had current existing TRU waste processing facilities for a specific module, while the PLCC was applied to facilities that did not have existing processing capabilities for a specific module.

Combining all of the information gathered, computer cost-model programs have been developed using Visual Basic computer programming language and cost equations were applied based on a calculated mass or volume throughput for a specific module. These programs were implemented using a computer spreadsheet with mass and volume throughput data. The computer cost model programs calculate the cost for each processing module for each alternative in each configuration. Summary results for process costs are presented in Section 3.7.4.1 of this report.

3.7.2.2 TRU Waste Transportation Cost Estimation Methodology

This section presents the information sources and assumptions used to complete transportation cost estimations for the various alternatives.

The guidance chosen for development of transportation cost estimates comes from "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials," (Feizollahi et al., 1994). This report was also used as guidance for development of transportation cost estimation in the Draft EM-PEIS. The report also covers the procedure for estimating the costs of various types of wastes, including an entire section on RH and CH TRU waste transportation. The report includes only guidance for estimating the cost of transportation of waste; loading and unloading operations are included in the facility operating and maintenance costs.

It is assumed that all CH TRU waste will be shipped by truck in TRUPACT-II containers, which have mass, volume, and radionuclide restrictions that limit the amount of waste transported in one shipment. Using volume and mass data for waste at each of the sites, both mass-limited and volume-limited cases were developed (Appendix P), but radionuclide content was not considered a limiting factor for CH-TRU waste. For RH-TRU waste, however, radionuclide limitations were important, and the volumes had to be further reduced to meet container and shipping

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TABLE 3-45

EXISTING TRU FACILITIES

	Waste Processing Functions								
								Treatment[b]	
Site	Retrieve	Waste Char	Front End	Certify/ Ship	Maint	Storage	Grout	Super Cmpct	Plasma
Major Generator/Storage Sites									
ANL-E	–		X		X	X			
Hanf		X	X	X	X	X			
INEL/ ANL-W		X	X	X	X	X			X[c]
LANL		X	X		X	X	X		
LLNL	–	X	X	X	X	X			
Mound	–		X		X				
NTS	–		X		X	X			
ORNL	–	X	X	X	X	X			
RFETS	–	X	X	X	X	X	X	X	
SRS			X		X	X			
Small Quantity Sites									
Ames	–	P	[a]	P	–	–	–	–	–
BCLDP	–	P	[a]	P	–	–	–	–	–
BT	–	P	[a]	P	–	–	–	–	–
ETEC	–	P	[a]	P	–	–	–	–	–
KAPL	–	P	[a]	P	–	–	–	–	–
LBL	–	P	[a]	P	–	–	–	–	–
Pad	–	P	[a]	P	–	–	–	–	–
Pantex	–	P	[a]	P	–	–	–	–	–
SNL	–	P	[a]	P	–	–	–	–	–
U Mo	–	P	[a]	P	–	–	–	–	–
WVDP	–	P	[a]	P	–	–	–	–	–

Notes:
X = Site has existing facilities to perform this function. No credit was given for planned facilities. Costs only include 20 years of O&M and D&D.
– = Site will not require this function.
P = This function will be accomplished utilizing portable equipment.
[a]For sites which will use portable equipment for waste characterization and certification and shipment, it is assumed that existing facilities will be sufficient for administrative purposes.
[b]No facilities exist to treat TRU waste using shred/compact, shred/add clay, or enhanced cement.
[c]It is assumed that the INEL Pit 9 treatment facility will be available to treat stored waste.

specifications. Appendix P shows how the number of shipments was derived for each EA and each configuration. The number is drums allowable in a TRUPACT II shipment is dependent on the density of the waste. Shipments may include as many as 42 drums of low density waste or as little as 14 drums of high density waste. It should be noted that the number of shipments used to calculate transportation costs differs from the number of shipments used to estimate transportation risks. Transportation risk methodology (Section 3.5.2) adjusts the number of shipments so that they represent a conservative bounding case. Transportation costs were based on less conservative estimates as shown in Appendix P.

The planned route and total mileage traveled for each of the shipments was determined by the HIGHWAY 3.3 Routing Model. The model is an extensive computerized atlas that determines the optimum route for a given origin and destination. The DOE sites that produce and treat TRU waste are all included, as is the WIPP repository. The program allows the user to place constraints on route choices, and several were invoked in order to choose the most preferred route for TRU waste transportation. Route constraints include the barred use of roads that prohibit truck use, the preferred use of routes already designated for hazardous waste transportation, and the use of roads in New Mexico designated as preferred shipment routes to the WIPP. The model is described in Section 3.5.2, Methodology Used to Evaluate Factor 5 (Risk of Transportation).

There are three types of costs associated with transportation. Carrier costs and hardware costs are functions of a moving vehicle and are combined to make up the "costs per loaded mile" (CPLM). Carrier costs include tractor, fuel, labor, insurance, security escort, taxes, tools, permit fees, and related costs incurred during waste transportation. Hardware costs are associated with maintenance of the specialized trailers and railroad cars used to transport waste. Fixed costs are independent of the distance traveled and considered separately. Fixed costs include demurrage costs of the carrier and the hardware used in the shipment. The total cost for a single shipment can be determined by adding the fixed costs to the product of the CPLM and the number of miles traveled. It should be noted that the CPLM unit rate is based on one-way mileage from origin to destination, but that the total cost for one shipment includes the return trip (see Section 3.5.3.5).

Finally, the process of estimating the costs is a straightforward analysis (Appendix P). The costs are derived from the number of shipments, taking into consideration the volume of drums or standard waste boxes, waste density, and the radionuclide inventory of the waste. The number of shipments are applied to the CPLM and the round-trip mileage, and the fixed costs are added to determine the total transportation costs for each individual site. Transportation cost estimations were performed for the decentralized and regionalized cases and each alternative therein. An estimation was also made for the centralized baseline. Since the centralized transportation configuration requires that all waste be treated at the WIPP, all the centralized alternatives are similar from a transportation point of view. Results are discussed in Section 3.7.4.2.

There are relatively few sources of uncertainty in the development of the transportation cost estimations. Included in these are the uncertainty of the waste inventory requiring transportation and the uncertainty in the numbers provided in the report used as guidance for estimate development. The level of uncertainty is discussed in Section 3.7.4.2.

3.7.2.3 Backfill Emplacement Cost Estimation Methodology

Backfill emplacement costs were developed by analyzing a logical approach to emplacing material into a panel. The approach was generic in nature to accommodate the fact that an exact method of emplacement has not been developed. The approach for estimating the costs of emplacement are generated by applying mine development data sources to an activity that is not characteristic to the mining industry (Appendix P). The backfilling of waste emplaced in a mine has not been an activity that is common practice for the DOE or mining industry.

The cost estimation of a backfill operation had to be developed based on the rate at which backfill would be emplaced. The assumptions for this estimation are listed in section 3.7.3. Once the capacity of the equipment requirement is determined a cost model determines the cost requirement for backfill.

The primary source of costing information is the SME Mining Engineering Handbook (Hartman, 1992) which provides a logical approach to the activities that would be performed. Assumptions had to be made in order to provide some logical data points for performing a backfill activity. An estimation of this type would be categorized as a Study Estimate where the uncertainty of the estimate is plus or minus 30 percent.

Data for the estimate is dependent on the mass and volume of backfill material. The backfill is emplaced daily as a batch and would not interrupt the waste emplacement activities. The working rate for backfill emplacement is assumed to be 960 hours per year for 35 years.

Calculation of the cost estimation is developed utilizing a spreadsheet format that applied the cost equations to the rate at which the backfill would be emplaced. The spreadsheet calculated the cost for each alternative that had a backfill associated with it.

3.7.2.4 WIPP Waste Operations Emplacement Cost Estimation Methodology

The cost estimation for the impacts associated with the WIPP operations only analyzed the incremental costs to the actual activities associated with waste handling and emplacement. These impacts provide a measure of the planning necessary to implementing an alternative.

For each of the alternatives and configuration (decentralized, regionalized, centralized) the throughput of the waste is determined in order to handle and emplace the waste at WIPP. The throughput rate is based on the number of transported waste shipments to be handled at WIPP (see Appendix P). The waste work-off and repository configuration is analyzed against the baseline to determine additional equipment requirements or modifications. The next parameter is to determine the manpower necessary to handle the waste was also determined. Guidance was provided in order to determine the size of a crew and the waste handling capacity.

The number of waste shipments to the WIPP is determined based on the methodology for transportation (see section 3.7.2.2). The throughput rate is calculated by applying the number of shipments to the operational period of the WIPP. The manpower requirements for the waste handling operations are given as three possible crews based on the throughput rate. The capital equipment requirement is estimated and totaled for the applicable alternative.

Calculation of the WIPP handling cost estimation was developed utilizing a spreadsheet format that applied the capital requirements and the throughput rate of the waste to the manpower requirement. The cost was calculated for each alternative and case. A comparative analysis was performed to the baseline decentralized alternative.

3.7.2.5 Schedule Methodology

The EA analysis included developing a permitting, construction, and operating schedule for each alternative and the baseline. Schedules are developed for each treatment option and then combined as appropriate to determine a schedule for each alternative. For example, the schedule for Alternative 94 incorporates the schedules for treatment scenarios of Enhanced Cement and Shred and Add Clay. The schedules will not be affected by the different site configurations, so these are not included.

For each treatment option, several steps are followed in order to arrive at a schedule. It was assumed that these treatment units would be capital projects, so a generic "Capital Project Logic Flow Diagram," developed for RFETS capital projects, was modeled to determine the major activities and their logical relationship to the other major activities (Appendix Q). To arrive at meaningful time estimates, it was necessary to develop some schedule detail, which was based on previous experience at RFETS, INEL, and Hanford. For some of the tasks, a deterministic approach was used, also referred to as Critical Path Method (CPM) scheduling, based on similar or identical work performed previously. For other tasks, a Program Evaluation and Review Techniques (PERT) analysis was applied to arrive at a probable duration estimate. PERT uses three time estimates for each activity: an optimistic or minimum time T_o, a most likely or modal time T_m, and a pessimistic or maximum time T_p. This probabilistic approach lends itself well to activities for which there is little historical record. PERT analysis was applied to the Plasma alternative, whereas a CPM analysis was applied to the Shred and Compact alternative. Once the task durations were determined, the activities were loaded into PRIMAVERA with the appropriate logic ties, and the system was allowed to perform the schedule calculations. Table 3-46 presents the results of a PERT analysis that was used as a starting point for estimating activity durations for several of the major activities.

The operational life for the WIPP site was constrained to be 35 years. This provides the basis for the operational and backfill activities to be performed within the limitation of time. Therefore, the backfill and waste emplacement operations do not have any significant schedule impact.

Schedule scenarios for each treatment option are developed relative to the baseline and Shred and Compact to have a reference point for subsequent schedule development. The primary differences between the schedules for each treatment option are the durations estimated for the design, construction, and D&D activities. The more complex the treatment process, the longer the durations for each of these activities. The baseline and Shred and Compact scenarios are assumed to have the shortest schedules because they employ the simplest technologies, followed in order of complexity by Shred and Compact, Enhanced Cement, Supercompact, and Plasma. For the Plasma Melter scenario, the RCRA permitting and National Environmental Policy Act (NEPA) documentation durations are also increased because of the likelihood of significant public and agency comments.

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TABLE 3-46

PERT ANALYSIS TIME ESTIMATES

Major Activities[a]	To	Tm	Tp	Te	Te in Days
Preliminary Safety Analysis	.890	1.000	2.250	1.190	298
Final Safety Analysis Report	1.420	2.000	4.440	2.310	578
Title I Design	.375	.500	1.250	.604	151
Title II Design	.738	.860	2.810	.998	250
Construction	1.910	2.000	3.160	2.178	545
NEPA	1.781	2.120	7.632	2.982	746
Prevention of Significant Deterioration Preparation	.840	1.000	2.250	1.182	295
Prevention of Significant Deterioration Approval	.335	.830	2.330	.998	249
NESHAPS	.750	1.000	2.500	1.208	302
Resource Conservation & Recovery Act Permit Preparation	.269	.320	.720	.378	95
Operations Readiness Review	1.840	1.840	4.287	2.248	562
Te=New Estimated Duration in Years	$Te=\frac{To+Tm(4)+TP}{6}$				

[a]Some major activities may be performed in parallel.
*Values are approximate.

3.7.3 Assumptions and Data for Factor 7

Two major sources of data are used for the analysis of cost and schedule:

- The initial retrievable and projected waste volumes are obtained from the WIPP BIR (DOE, 1995e) (see Appendix O).
- Guidance for process flow diagrams and costing and cost curves are obtained from the WMFCITRUW report.

The major assumptions follow:

- Mass and volume changes occur during certain processing activities. A summary of the mass and volume changes is presented in Table 3-47.
- The volume of waste categorized as "unknown" is processed the same as solid organics and inorganics. However, the mass of unknown waste is assumed to be zero because no information is available regarding the density of the unknown waste and the volume of this waste is small compared to the total volume of waste destined for WIPP.
- Thirty percent of the stored waste at Los Alamos National Laboratory (LANL), Savannah River Site (SRS), INEL/Argonne National Laboratory-West (ANL-W), and Hanford requires retrieval.
- Twenty-five percent of stored sludges at LANL and INEL requires re-grouting, and all of the stored sludges at ORNL require grouting.
- Waste is treated and or stored according to the site configurations denoted in Table 3-48.
- Waste is processed 4,032 hours per year over a 20-year waste processing facility operating life.
- All waste within a major waste form category (i.e., sludges, solid organic, solid inorganic) can be treated using a specified technology.
- The supercompaction module does not include shredding.
- Costs for a vitrification unit are considered adequate for the costs for a plasma melter.
- Costs for enhanced cement processing are identical to costs for grouting except for material costs.
- Costs for shredding and adding clay are identical to costs for grouting except for material costs.

1

TABLE 3-47

MASS AND VOLUME CHANGES FOR WASTE TREATMENT/PROCESSING MODULES

Module	Mass Ratio (Output/Input)	Volume Ratio (Output/Input)
Front End	1.0[a]	1.0[b]
Retrieval	1.1[a]	1.1[b]
Waste Characterization	1.0[b]	1.0[b]
Maintenance	1.0[b]	1.1[b]
Grout	3.15[a]	2.5[b]
Supercompact	1.1[a]	0.35[b]
Shred and Compact	1.1[a]	0.76[b]
Shred and Add Clay	2.35[b]	1.0[b]
Plasma	1.0[a]	0.33[b]
Certification	1.0[b]	1.0[b]
Storage	1.0[b]	1.0[b]

[a]Source (Feizollahi and Shropshire, 1994)
[b]Values derived from engineered calculations.

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TABLE 3-48

SITE TRANSFERS FOR THE DECENTRALIZED, REGIONALIZED, AND CENTRALIZED CONFIGURATIONS

Decentralized			Regionalized			Centralized		
Site	**CH**	**RH**	**Site**	**CH**	**RH**	**Site**	**CH**	**RH**
ANL-E*	WIPP	ORNL+	ANL-E	SRS	ORNL	ANL-E	WIPP	WIPP
Ames	ANL-E#		Ames	SRS		Ames	WIPP	
BCLDP		ORNL+	BCLDP		ORNL	BCLDP		WIPP
BT	Mound	ORNL+	BT	SRS	ORNL	BT	WIPP	WIPP
ETEC	NTS		ETEC	INEL/ ANL-W		ETEC	WIPP	
INEL/ ANL-W*	WIPP	WIPP	INEL/ ANL-W*	WIPP	Hanford	INEL/ ANL-W	WIPP	WIPP
KAPL	Mound	ORNL+	KAPL	SRS	ORNL	KAPL	WIPP	WIPP
LANL*	WIPP	WIPP	LANL*	WIPP	Hanford	LANL	WIPP	WIPP
LBL	(LLNL)		LBL	Hanford		LBL	WIPP	
LLNL*	WIPP		LLNL	Hanford		LLNL	WIPP	
Mound*	WIPP		Mound	SRS		Mound	WIPP	
MU	ANL-E#		MU	SRS		MU	WIPP	
NTS*	WIPP	WIPP	NTS	INEL/ ANL-W	Hanford	NTS	WIPP	WIPP
ORNL*	WIPP	WIPP	ORNL* (rh)	SRS	WIPP	ORNL	WIPP	WIPP
PA	ORNL		PA	SRS		PA	WIPP	
Pantex	LANL		Pantex	LANL		Pantex	WIPP	
RFETS*	WIPP		RFETS*	WIPP		RFETS	WIPP	
Hanford*	WIPP	WIPP	Hanford*	WIPP	WIPP	Hanford	WIPP	WIPP
SNL/NM	LANL		SNL/NM	LANL		SNL/NM	WIPP	
SRS*	WIPP	WIPP	SRS*	WIPP	ORNL	SRS	WIPP	WIPP

Notes:

* Denotes a processing site.

ORNL+ Remote handled wastes from BCLDP, BT, KAPL, (these are not discussed in the EM-PEIS) and ANL-E should be processed at ORNL instead of Mound because Mound currently does not process or store RH waste.

ANL-E# The EM-PEIS discusses that ANL-E will process and ship their own CH waste, but does not cover Ames and MU, which are closer to ANL-E than ORNL.

(LLNL) EM-PEIS indicates LBL waste will be shipped to Hanford. LBL waste should be shipped to LLNL because it is much closer.

- Costs for shredding and compacting are analyzed as a modified cost module for supercompaction.
- Funding is unconstrained for the purposes of developing schedules.
- Costs are in 1994 dollars and do not take into account escalation or the time value of dollars.
- The operations at WIPP are 35 years.
- The waste emplacement operations at WIPP consists of two eight hour shift operations five days a week.
- Both waste handling and backfill are completed in the 35 year operational period.
- Waste emplacement is dependent upon the number of TRUPACT-IIs per day.
- Backfill costs are based on a batch per day (tons) of material that would be emplaced each day.
- Backfill of the rooms does not impact operations.

3.7.4 Results of Analysis for Factor 7

3.7.4.1 Process Costing Results

As described in Section 3.7.2.1, process costs are calculated using computer program cost models developed for this study (Appendix P). Costs are calculated for each alternative in each configuration for CH waste and for decentralized baseline for RH waste. Cost values are based on 1994 cost data and do not take into consideration time value of money or escalation for expenditures occurring during the planning life cycle (Feizollahi and Shropshire, 1994). Summaries of these costs are presented in Tables 3-49 and 3-50. These tables present the summary of process costs for the baseline and each of the different alternatives in each of the configurations for CH waste and for the decentralized baseline for RH waste. Processing schemes for Alternatives 33, 35(a&b), 83, and 111 are identical to the processing schemes for the baseline for each of the configurations, therefore their processing costs are assumed to be identical to the processing costs for the baseline. The processing scheme for Alternative 77 (a-d) is the same as the processing scheme for Alternative 1 for each of the configurations; therefore, its processing costs are identical to the process costs for Alternative 1. Alternative 33, 35(a-b), 77(a-d), 83, and 111 will be omitted from further discussion in this section because they are not unique with respect to processing cost.

The range of processing costs for CH waste varies between $3.2 billion for the centralized baseline and $6.3 billion for decentralized Alternatives 94(a-f). The process costs for the decentralized alternatives are the highest for a specific alternative; the process costs for the centralized configuration are the lowest. This was expected due to process costs for treatment

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TABLE 3-49

CH WASTE PROCESSING COST GRAND TOTALS ($K)

Alternative ID #	Decentralized	Regionalized	Centralized
Baseline	3,576,954	3,418,650	3,202,376
1	4,379,357	3,974.696	3,411,991
6	4,117,678	3,757,294	3,329,333
10	5,966,427	4,992,885	3,960,139
33	3,576,954	3,418,650	3,202,376
35 (a&b)	3,576,954	3,418,650	3,202,376
77(a-d)	4,379,357	3,974,696	3,411,991
83	3,576,954	3,418,650	3,202,376
94 (a-f)	6,301,672	5,502,932	4,217,091
111	3,576,954	3,418,650	3,202,376

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TABLE 3-50

RH CENTRALIZED BASELINE COST PER SITE ($K)

Site	Cost
BCLDP	0
BT	0
HANFORD	173,279
INEL/ANL-W	170,849
KAPL	0
LANL	206,932
ORNL	339,190
SRS	121,730
GRAND TOTAL	1,011,980

(maintenance and specific alternative treatments) being applied to a larger number of sites in the decentralized (10 sites) and regionalized (5 sites) configuration as compared to the centralized (1 site) configuration.

The processing costs for the baseline are least expensive when compared to the alternatives; processing costs for Alternative 94 are most expensive. This results from a combination of effects. One explanation for this is that the treatment module throughput values for the baseline are lowest; treatment module throughput values for Alternative 94 (a-f) are highest. The baseline consists of treating to the WIPP-WAC (DOE, 1991c). Treatment to WAC entailed shredding and grouting a portion of the existing sludges and all of the projected sludges, along with repackaging waste as necessary to meet transportation and WIPP requirements. In Alternative 94(a-f) all of the waste is treated in some way by either repackaging, enhanced-cement processing, or shredding and adding clay. Thus, the "waste treatment" processing throughput for Alternative 94 (a-f) is higher than the baseline.

The second explanation is that for the shred-and-add-clay and, enhanced-cement cost modules, it is assumed that there are currently no facilities that had these processing capabilities. The result is that the PLCC is applied to all appropriate sites (decentralized, regionalized and centralized configurations) making Alternative 94 (a-f) more costly than other alternatives (e.g Alternative 1, etc.) where some facilities currently do have a specific processing capability.

Another observation from the information presented in Table 3-49 is that after taking the level of uncertainty of the cost estimations plus or minus 30 percent (Section 3.7.2.1), that the centralized alternative processing costs are approximately the same as compared to the decentralized baseline. The decentralized baseline represents the current strategy for managing CH waste.

The RH process costs for the baseline decentralized configuration is $1.0 billion.

3.7.4.2 TRU Waste Transportation Cost Estimation Results

This section provides information on the results of the transportation cost estimations for the various alternatives. For information regarding the sources and assumptions used to complete transportation cost estimations, refer to Section 3.7.2.2 and Appendix P.

Transportation cost estimations are performed for each configuration and alternative. Within the centralized, regionalized, and decentralized configurations, some of the alternatives are identical from a transportation standpoint, making the transportation costs for these alternatives the same. For example, the centralized configuration provides only one set of transportation requirements because all treatment occurs at the WIPP, making the transportation costs for all centralized alternatives the same. Similarly, the regionalized and decentralized alternatives that vary backfill options do not provide unique situations to transportation, so these cases have transportation costs equal to those of other alternatives. Alternatives that present transportation with a unique scheme include the baseline and Alternatives 1, 6, 10, and 94(a-f).

Shipments being limited by both mass and volume has a significant effect on the transportation costs for alternatives that result in a more dense waste form, especially supercompaction (alternatives 1 and 77), plasma melting (alternative 10), and shred/add clay (alternatives 94 a-f). In the case of supercompaction and plasma melting, the final waste volumes were significantly reduced, but the transportation costs for the decentralized configurations only reduced by less

than 1 percent and less than 13 percent, respectively. In the case of alternative 94, the final waste volume was not decreased and the waste density was significantly increased, causing many of the shipments to become mass-limited. In the decentralized configuration, this had the effect of increasing the transportation costs by more than 66 percent. It is clear increasing waste density plays a key role in reducing the benefits derived from waste treatments that result in a volume reduction.

The transportation costs range from a minimum of $603.4 million for decentralized Alternative 10, which has the largest degree of waste volume reduction at the most number of sites, to a maximum of $1.2 billion for regionalized Alternative 94(a-f), which not only increases the original volume of waste by the largest percentage, but also increased the density of the final waste, thus causing mass-limited shipment, and also has the highest percentage of "double handled" waste. An estimate to handle RH waste for the decentralized baseline is also prepared. In addition to the $690.9 million estimated to transport CH waste for this alternative, $318.3 million is estimated to transport RH waste. Even though the volume of RH waste is significantly smaller than CH waste, to avoid exceeding radionuclide content limitations during transportation, a much smaller volume is carried by each shipment. The Transportation Cost Estimation Summary, Table 3-51 presents the estimated transportation costs for each alternative. The level of uncertainty in the cost estimates comes from two sources. One, the level of uncertainty in the stored and projected waste volumes in the BIR (DOE, 1995e) and two, the level of uncertainty in the studies used as guidance to develop the transportation cost estimates. For guidance in estimating transportation costs, a report titled "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials" (Feizollahi et al., 1994), was contracted by the DOE, and Revision 1 was completed in September 1994. A report of this nature would be classified as a "study estimate" (Peters and Timmerhaus, 1991), and would have a probable accuracy only within plus or minus 30 percent.

3.7.4.2.1 Backfill Emplacement Cost Results

Backfill emplacement costs are determined for each of the alternatives that specified backfill. The cost for emplacement activities is independent to the case of the alternative (decentralized, regionalized, centralized) and is only affected by the mass and volume of the backfill. Thus, costs for the alternatives are dependent only upon the amount and type of backfill that is to be utilized. Table 3-52 provides a summary of the estimated cost total for each alternative. The lowest cost for backfill are alternatives 77(b-d) which consists of the least amount of backfill material due to the reduced room height for waste. The highest cost for backfill are alternatives 35(a-b) and 94d, respectively. This is due to the increased complexity of emplacing a wet (grout) backfill.

Cost of backfill is categorized as a planning cost estimate and has an uncertainty of plus or minus 30 percent. In addition the estimation does not include the cost of the material to be utilized for backfill. It is assumed that backfill materials consisting of salt would utilize the existing mined materials.

3.7.4.2.2 WIPP Waste Operations Emplacement Cost Results

Cost information for the emplacement activities associated with the waste handling at the WIPP are discussed in this section. The discussion includes the assumptions and limitations of the results. The comparative analysis of the WIPP waste handling and emplacement activities is discussed is shown in Table 3-53. The cost of WIPP handling and emplacing the waste is

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TABLE 3-51

TRANSPORTATION COST GRAND TOTAL SUMMARY

	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
CH Centralized Baseline	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 1	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 6	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 10	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 33	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 35	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 77	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 83	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 94	17,401	47,883,104	161,133	449,956	611,089
CH Centralized Alternative 111	17,401	47,883,104	161,133	449,956	611,089
CH Regionalized Baseline	20356	54,395,038	188,497	512,795	701,291
CH Regionalized Alternative 1	19948	54,214,868	184,718	510,549	695,268
CH Regionalized Alternative 6	19253	51,234,016	178,283	483,104	661,387
CH Regionalized Alternative 10	17627	47,954,934	163,226	451,451	614,677
CH Regionalized Alternative 33	20356	54,395,038	188,497	512,795	701,291
CH Regionalized Alternative 35	20356	54,395,038	188,497	512,795	701,291
CH Regionalized Alternative 77	19948	54,214,868	184,718	510,549	695,268
CH Regionalized Alternative 83	20356	54,395,038	188,497	512,795	701,291
CH Regionalized Alternative 94	33598	89,825,730	311,117	845,163	1,156,280
CH Regionalized Alternative 111	20356	54,395,038	188,497	512,795	701,291
CH Decentralized Baseline	19974	53,744,480	184,959	505,929	690,888
RH Decentralized Baseline	7958	26,210,998	73,691	244,610	318,301
CH Decentralized Alternative 1	19602	53,672,290	181,515	504,689	686,204
CH Decentralized Alternative 6	18831	50,447,700	174,375	474,981	649,356
CH Decentralized Alternative 10	17203	47,259,152	159,300	444,134	603,433
CH Decentralized Alternative 33	19974	53,744,480	184,959	505,929	690,888
CH Decentralized Alternative 35	19974	53,744,480	184,959	505,929	690,888
CH Decentralized Alternative 77	19602	53,672,290	181,515	504,689	686,204
CH Decentralized Alternative 83	19974	53,744,480	184,959	505,929	690,888
CH Decentralized Alternative 94	33290	89,202,790	308,265	838,670	1,146,935
CH Decentralized Alternative 111	19974	53,744,480	184,959	505,929	690,888

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TABLE 3-52

BACKFILL EMPLACEMENT COST TOTALS SUMMARY

Alternative ID#	Total Cost ($K)
33	55,527
35a	86,139
35b	86,141
77a	60,394
77b	31,299
77c	37,487
77d	35,894
83	53,146
94b	50,707
94c	78,536
94d	79,057
94e	42,262
94f	48,533
111	46,272

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TABLE 3-53

WIPP WASTE HANDLING COSTS

Alternative	Configuration	Cost ($K)
Baseline[a]	Decentralized	215,040
	Regionalized	215,040
	Centralized	215,040
1[b]	Decentralized	153,600
	Regionalized	153,600
	Centralized	153,600
6[b]	Decentralized	188,160
	Regionalized	188,160
	Centralized	188,160
10[b]	Decentralized	134,400
	Regionalized	134,400
	Centralized	153,600
33[a]	Decentralized	215,040
	Regionalized	215,040
	Centralized	215,040
35 (a,b)[a]	Decentralized	215,040
	Regionalized	215,040
	Centralized	215,040
77 (a-d)[b]	Decentralized	153,600
	Regionalized	153,600
	Centralized	153,600
83[a]	Decentralized	215,040
	Regionalized	215,040
	Centralized	215,040
94 (a-f)[c]	Decentralized	175,718
	Regionalized	175,718
	Centralized	153,600
111[a]	Decentralized	215,040
	Regionalized	215,040
	Centralized	215,040

Notes
[a]These alternatives involve only treating waste to WIPP WAC. WIPP emplaces waste for 35 years.
[b]These alternatives involve building new treatment facilities. WIPP emplaces waste for 25 years.
[c]This alternative involves building new treatment facilities. WIPP emplaces waste for 28.6 years for the decentralized and regionalized configurations, 3.6 years longer than the assumed operating life.

primarily independent of the cases (decentralized, regionalized, centralized) for this cost estimate study. For this estimate there were three waste handling/emplacement crew configuration that are utilized as input for the alternatives. The crew sized was dependent upon the number of TRUPACT-IIs that are processed per day. The number of TRUPACT-IIs that are processed based on the number of waste shipment and the limiting factor of a 35 year operational life for WIPP.

Baseline cost is established based on the required labor to handle and emplace the waste. The alternatives 33, 35(a-b), and 111 have the same comparable cost as the baseline. The alternative with the highest handling savings are number 10 and 94(a-f). This is due to a decrease in emplacement activities for 25 years rather than 35 years. Alternatives 1 and 6 have the same handling savings. Alternative 77(a-d) has a reduced savings as compared to alternative 1. This is due to the reduced room height but does not accommodate the current remote handled underground handling equipment or emplacement configuration. The limitation of this estimate is that the total WIPP budget is not included in this estimate. The only costs included are labor and anticipated capital equipment or modifications. Additional cost not included in this comparative analysis is the required budget that would be needed to manage and operate the WIPP, departmental management, and any additional research and development. This estimate is only intended to provide a measure of the relative cost savings or burden for an alternative.

3.7.4.3 Total Cost Summary

The total costs for implementing various alternatives are shown in Table 3-54. Total costs range from $4.0 billion for centralized treatment to WIPP WAC, to $7.7 billion for alternative 94c. Waste processing is by far the largest cost element, accounting for approximately 80 percent of the total cost.

3.7.4.4 Schedule Results

The results of the schedule development for the baseline and each of the different alternatives are presented in Figures 3-38 through 3-42. These schedules represent a "worst case" scenario where facilities needed to implement the baseline or alternatives are not currently available. It is assumed that where facilities currently exist, waste would be available for emplacement at WIPP in 1998. These figures present summary level schedules that include major activities and durations. Detailed schedules that list intermediate steps for each major activity and include all assumptions are included in Appendix Q, the schedule appendix.

Table 3-55 presents a summary comparison of the major activities and their associated start and finish dates for the baseline and each alternative. There is only a two year increase in total project duration between the baseline and the alternative with the longest duration (plasma). Operations are projected to begin in 11 to 12 years for alternatives that require new treatment facilities. Those facilities already available could begin treating waste immediately. For all alternatives, the treatment operations are projected to be completed within the anticipated operational lifetime of the WIPP facility. Based on schedules alone, no alternative presents significant benefits or detriments relative to the baseline.

Three major uncertainties associated with the schedules include:

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TABLE 3-54

TOTAL COST SUMMARY

Alternative	Configuration	Costs ($K) Process[a]	Transportation	Backfill	Handling	Total
Baseline	Decentralized	3,576,954	690,888	0	215,040	4,482,882
	Regionalized	3,418,650	701,291	0	215,040	4,334,981
	Centralized	3,202,376	611,089	0	215,040	4,028,505
1	Decentralized	4,379,357	686,204	0	153,600	5,219,161
	Regionalized	3,974,696	695,268	0	153,600	4,823,564
	Centralized	3,411,991	611,089	0	153,600	4,176,680
6	Decentralized	4,117,678	649,356	0	188,160	4,955,194
	Regionalized	3,757,294	661,387	0	188,160	4,606,841
	Centralized	3,329,333	611,089	0	188,160	4,128,582
10	Decentralized	5,966,427	603,433	0	134,400	6,704,260
	Regionalized	4,992,885	614,677	0	134,400	5,741,962
	Centralized	3,960,139	611,089	0	153,600	4,724,828
33	Decentralized	3,576,954	690,888	55,527	215,040	4,538,409
	Regionalized	3,418,650	701,291	55,527	215,040	4,390,508
	Centralized	3,202,376	611,089	55,527	215,040	4,084,032
35a	Decentralized	3,576,954	690,888	86,139	215,040	4,569,021
	Regionalized	3,418,650	701,291	86,139	215,040	4,421,120
	Centralized	3,202,376	611,089	86,139	215,040	4,114,644
35b	Decentralized	3,576,954	690,888	86,141	215,040	4,569,023
	Regionalized	3,418,650	701,291	86,141	215,040	4,421,122
	Centralized	3,202,376	611,089	86,141	215,040	4,114,646
77a	Decentralized	4,379,357	686,204	60,394	153,600	5,279,555
	Regionalized	3,974,696	695,268	60,394	153,600	4,883,958
	Centralized	3,411,991	611,089	60,394	153,600	4,237,074
77b	Decentralized	4,379,357	686,204	31,299	153,600	5,250,460
	Regionalized	3,974,696	695,268	31,299	153,600	4,854,863
	Centralized	3,411,991	611,089	31,299	153,600	4,207,979
77c	Decentralized	4,379,357	686,204	37,487	153,600	5,256,648
	Regionalized	3,974,696	695,268	37,487	153,600	4,861,051
	Centralized	3,411,991	611,089	37,487	153,600	4,214,167
77d	Decentralized	4,379,357	686,204	35,894	153,600	5,255,055
	Regionalized	3,974,696	695,268	35,894	153,600	4,859,458
	Centralized	3,411,991	611,089	35,894	153,600	4,212,574
83	Decentralized	3,576,954	690,888	53,146	215,040	4,536,028
	Regionalized	3,418,650	701,291	53,146	215,040	4,388,127
	Centralized	3,202,376	611,089	53,146	215,040	4,081,651
94a	Decentralized	6,301,672	1,146,935	0	175,718	7,624,325
	Regionalized	5,502,932	1,156,280	0	175,718	6,834,930
	Centralized	4,217,091	611,089	0	153,600	4,981,780
94b	Decentralized	6,301,672	1,146,935	50,707	175,718	7,675,032
	Regionalized	5,502,932	1,156,280	50,707	175,718	6,885,637
	Centralized	4,217,091	611,089	50,707	153,600	5,032,487
94c	Decentralized	6,301,672	1,146,935	78,536	175,718	7,702,861
	Regionalized	5,502,932	1,156,280	78,536	175,718	6,913,466
	Centralized	4,217,091	611,089	78,536	153,600	5,060,316

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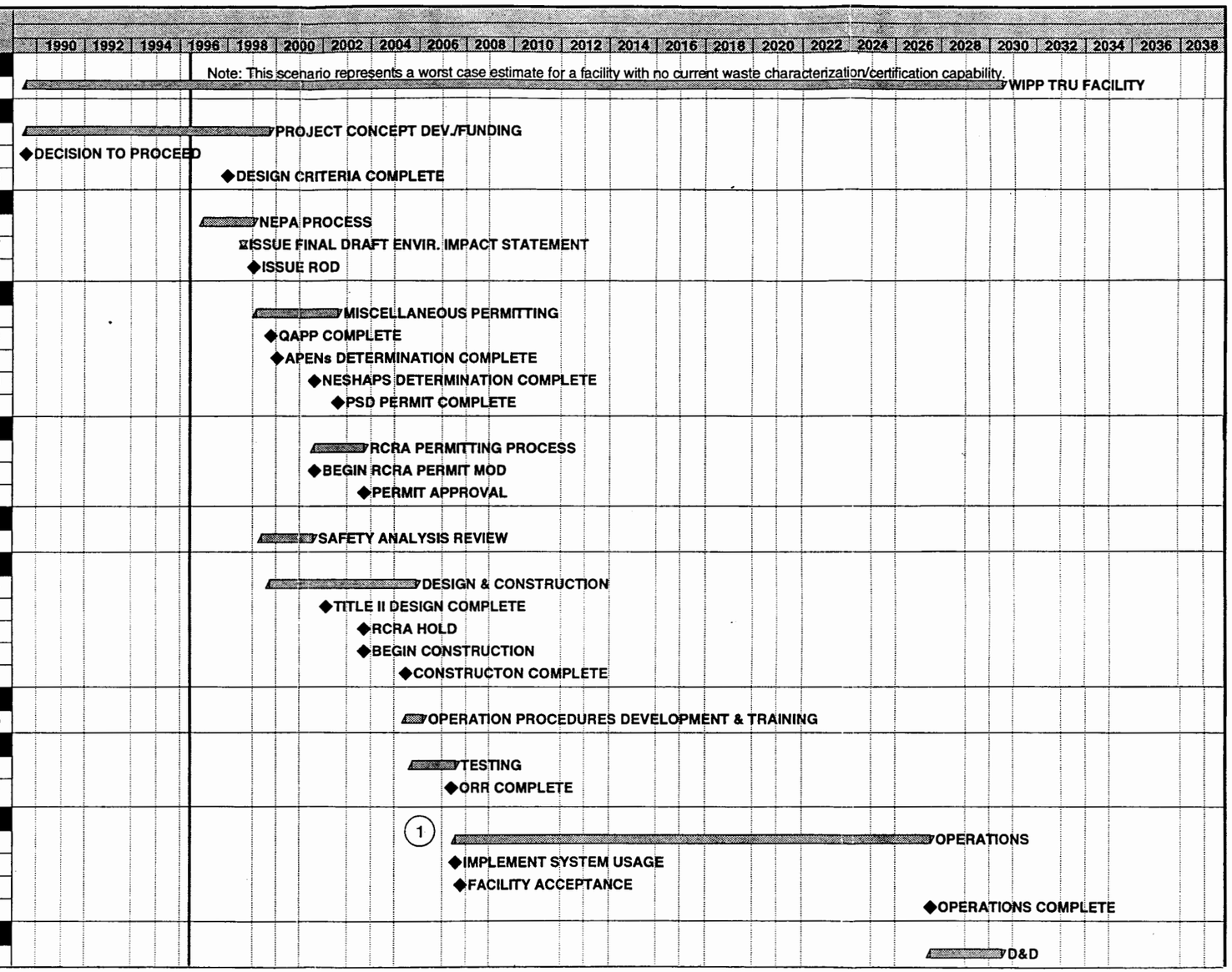
TABLE 3-54 (Continued)

TOTAL COST SUMMARY

		Costs ($K)				
Alternative	Configuration	Process[a]	Transportation	Backfill	Handling	Total
94d	Decentralized	6,301,672	1,146,935	79,057	175,718	7,703,382
	Regionalized	5,502,932	1,156,280	79,057	175,718	6,913,987
	Centralized	4,217,091	611,089	79,057	153,600	5,060,837
94e	Decentralized	6,301,672	1,146,935	42,262	175,718	7,666,587
	Regionalized	5,502,932	1,156,280	42,262	175,718	6,877,192
	Centralized	4,217,091	611,089	42,262	153,600	5,024,042
94f	Decentralized	6,301,672	1,146,935	48,533	175,718	7,672,858
	Regionalized	5,502,932	1,156,280	48,533	175,718	6,883,463
	Centralized	4,217,091	611,089	48,533	153,600	5,030,313
111	Decentralized	3,576,954	690,888	46,272	215,040	4,529,154
	Regionalized	3,418,650	701,291	46,272	215,040	4,381,253
	Centralized	3,202,376	611,089	46,272	215,040	4,074,777

[a]Process costs only represent those costs to process CH waste. Decentralized processing of RH waste costs approximately $1.0 billion.

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,451*	14JUL88A	13JUL29
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
15	DECISION TO PROCEED	0	14JUL88A	
51	DESIGN CRITERIA COMPLETE	0		20DEC96
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
190	ISSUE FINAL DRAFT ENVIR. IMPACT STATEMENT	0	12AUG97	11AUG97
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	881*	10MAR98	21AUG01
486	QAPP COMPLETE	0		08OCT98
451	APENs DETERMINATION COMPLETE	0		19JAN99
501	NESHAPS DETERMINATION COMPLETE	0		28AUG00
504	PSD PERMIT COMPLETE	0		21AUG01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	29AUG00	26SEP02
339	BEGIN RCRA PERMIT MOD	0	29AUG00	
430	PERMIT APPROVAL	0		26SEP02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,571*	25SEP98	22NOV04
266	TITLE II DESIGN COMPLETE	0		23FEB01
285	RCRA HOLD	0		26SEP02
289	BEGIN CONSTRUCTION	0	27SEP02	
291	CONSTRUCTON COMPLETE	0		01JUL04
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	02JUL04	17MAR05
TESTING				
507	TESTING	460*	28SEP04	18JUL06
530	ORR COMPLETE	0		19MAY06
OPERATIONS				
539	OPERATIONS	5,100*	19JUL06	21JUL26
560	IMPLEMENT SYSTEM USAGE	0	19JUL06	
565	FACILITY ACCEPTANCE	0	12OCT06	
567	OPERATIONS COMPLETE	0		21JUL26
D&D				
574	D&D	760*	22JUL26	13JUL29



* *Represents a calculated time duration based on estimated scheduling values*

(1) *Baseline waste emplacement starts after WIPP is declared operational, the start date shown here represents the point in time when all WIPP WAC*

Figure 3-38

Baseline Scenario Summary

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,681*	14JUL88A	07JUN30
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
15	DECISION TO PROCEED	0	14JUL88A	
51	DESIGN CRITERIA COMPLETE	0		20DEC96
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	899*	10MAR98	17SEP01
486	QAPP COMPLETE	0		08OCT98
451	APENs DETERMINATION COMPLETE	0		19JAN99
501	NESHAPS DETERMINATION COMPLETE	0		22SEP00
504	PSD PERMIT COMPLETE	0		17SEP01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	28NOV00	26DEC02
339	BEGIN RCRA PERMIT MOD	0	28NOV00	
430	PERMIT APPROVAL	0		26DEC02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,744*	25SEP98	28JUL05
266	TITLE II DESIGN COMPLETE	0		23MAY01
285	RCRA HOLD	0		26DEC02
289	BEGIN CONSTRUCTION	0	27DEC02	
291	CONSTRUCTION COMPLETE	0		08MAR05
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	09MAR05	18NOV05
TESTING				
507	TESTING	460*	02JUN05	22MAR07
530	ORR COMPLETE	0		25JAN07
OPERATIONS				
539	OPERATIONS	5,100*	23MAR07	25MAR27
560	IMPLEMENT SYSTEM USAGE	0	23MAR07	
565	FACILITY ACCEPTANCE	0	18JUN07	
567	OPERATIONS COMPLETE	0		25MAR27
D&D				
574	D&D	817*	26MAR27	07JUN30

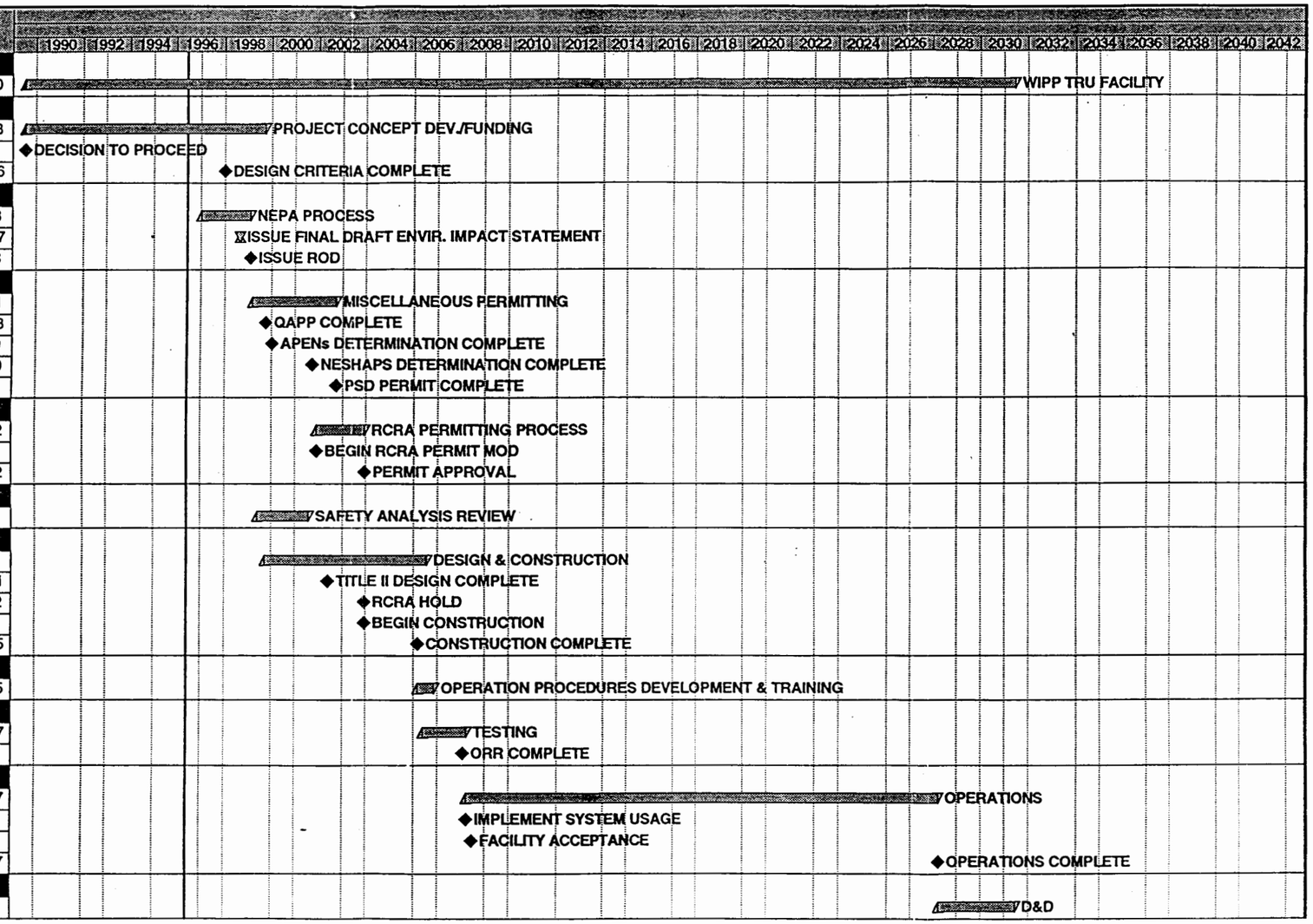


Figure 3-33

Supercompaction Scenario Summary

* *Represents a calculated time duration based on estimated scheduling values*

7634 00.00.00/ac B2

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,529*	14JUL88A	01NOV29
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
15	DECISION TO PROCEED	0	14JUL88A	
51	DESIGN CRITERIA COMPLETE	0		20DEC96
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	881*	10MAR98	21AUG01
486	QAPP COMPLETE	0		08OCT98
451	APENs DETERMINATION COMPLETE	0		19JAN99
501	NESHAPS DETERMINATION COMPLETE	0		28AUG00
504	PSD PERMIT COMPLETE	0		21AUG01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	29AUG00	26SEP02
339	BEGIN RCRA PERMIT MOD	0	29AUG00	
430	PERMIT APPROVAL	0		26SEP02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,621*	25SEP98	03FEB05
266	TITLE II DESIGN COMPLETE	0		23FEB01
285	RCRA HOLD	0		26SEP02
289	BEGIN CONSTRUCTION	0	27SEP02	
291	CONSTRUCTION COMPLETE	0		13SEP04
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	14SEP04	26MAY05
TESTING				
507	TESTING	460*	08DEC04	27SEP06
530	ORR COMPLETE	0		01AUG06
OPERATIONS				
539	OPERATIONS	5,100*	28SEP06	30SEP26
560	IMPLEMENT SYSTEM USAGE	0	28SEP06	
565	FACILITY ACCEPTANCE	0	22DEC06	
567	OPERATIONS COMPLETE	0		30SEP26
D&D				
574	D&D	788*	01OCT26	01NOV29

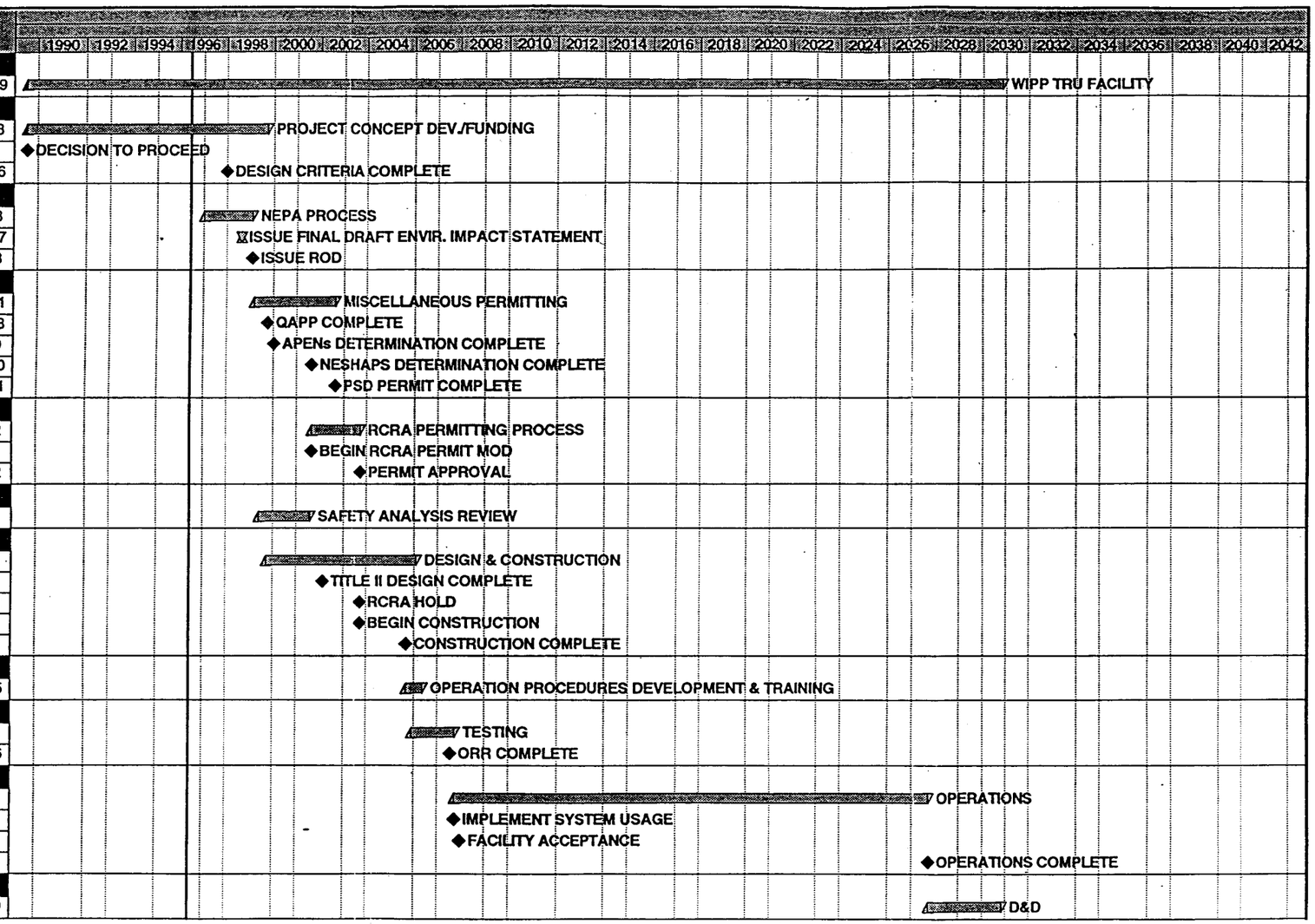


Figure 3-40

Shred & Compact Scenario Summary

* *Represents a calculated time duration based on estimated scheduling values*

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,903*	14JUL88A	22APR31
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
15	DECISION TO PROCEED	0	14JUL88A	
51	DESIGN CRITERIA COMPLETE	0		20DEC96
NEPA PROCESS				
74	NEPA PROCESS	680*	04JAN96	01SEP98
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	16MAR98	13MAR98
205	ISSUE ROD	0		01SEP98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	1,138*	10MAR98	23AUG02
486	QAPP COMPLETE	0		08OCT98
451	APENs DETERMINATION COMPLETE	0		15OCT99
501	NESHAPS DETERMINATION COMPLETE	0		30AUG01
504	PSD PERMIT COMPLETE	0		23AUG02
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	700*	22SEP00	20JUN03
339	BEGIN RCRA PERMIT MOD	0	22SEP00	
430	PERMIT APPROVAL	0		20JUN03
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,933*	25SEP98	25APR06
266	TITLE II DESIGN COMPLETE	0		28AUG01
285	RCRA HOLD	0		20JUN03
289	BEGIN CONSTRUCTION	0	23JUN03	
291	CONSTRUCTION COMPLETE	0		02DEC05
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	05DEC05	17AUG06
TESTING				
507	TESTING	460*	01MAR06	18DEC07
530	ORR COMPLETE	0		22OCT07
OPERATIONS				
539	OPERATIONS	5,100*	19DEC07	21DEC27
560	IMPLEMENT SYSTEM USAGE	0	19DEC07	
565	FACILITY ACCEPTANCE	0	14MAR08	
567	OPERATIONS COMPLETE	0		21DEC27
D&D				
574	D&D	850*	22DEC27	22APR31

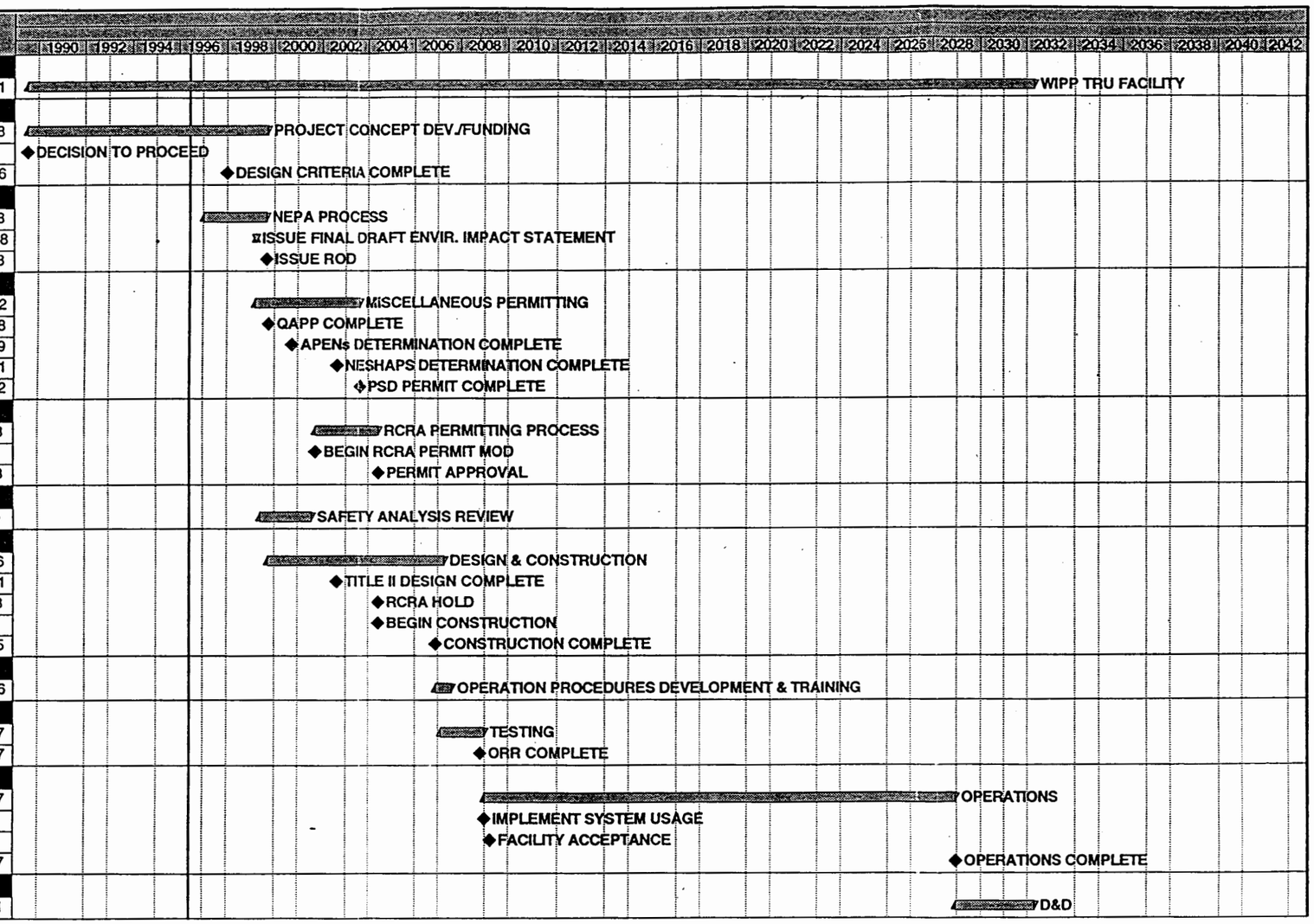


Figure 3-11
Plasma Scenario Summary

* *Represents a calculated time duration based on estimated scheduling values*

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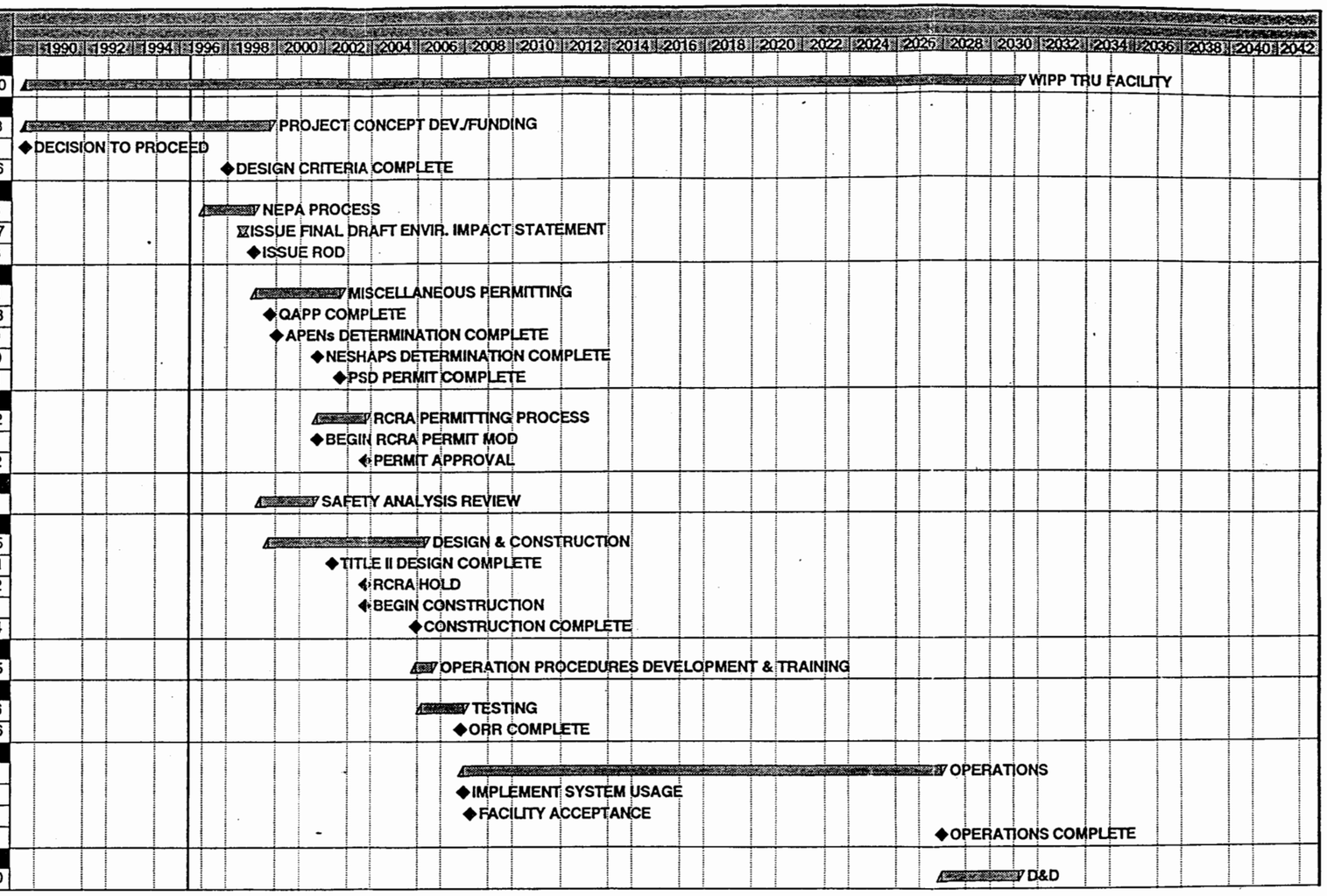
Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,618*	14JUL88A	11MAR30
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
15	DECISION TO PROCEED	0	14JUL88A	
51	DESIGN CRITERIA COMPLETE	0		20DEC96
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	896*	10MAR98	12SEP01
486	QAPP COMPLETE	0		08OCT98
451	APENs DETERMINATION COMPLETE	0		19JAN99
501	NESHAPS DETERMINATION COMPLETE	0		19SEP00
504	PSD PERMIT COMPLETE	0		12SEP01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	20SEP00	17OCT02
339	BEGIN RCRA PERMIT MOD	0	20SEP00	
430	PERMIT APPROVAL	0		17OCT02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,686*	25SEP98	05MAY05
266	TITLE II DESIGN COMPLETE	0		08MAY01
285	RCRA HOLD	0		17OCT02
289	BEGIN CONSTRUCTION	0	18OCT02	
291	CONSTRUCTION COMPLETE	0		14DEC04
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	15DEC04	29AUG05
TESTING				
507	TESTING	460*	11MAR05	29DEC06
530	ORR COMPLETE	0		01NOV06
OPERATIONS				
539	OPERATIONS	5,100*	02JAN07	04JAN27
560	IMPLEMENT SYSTEM USAGE	0	02JAN07	
565	FACILITY ACCEPTANCE	0	27MAR07	
567	OPERATIONS COMPLETE	0		04JAN27
D&D				
574	D&D	812*	05JAN27	11MAR30



* *Represents a calculated time duration based on estimated scheduling values*

Figure 3-12
Cementation/Shred/ Add Clay Scenario

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TABLE 3-55

PROCESSING SCHEDULE SUMMARY

Alternative	Description	Start	Finish	Years
6	Shred and Compact	1/4/96	11/1/2029	34
94	Cementation/Shred and Add Clay	1/4/96	3/11/2030	35
1	Supercompact	1/4/96	6/7/2030	35.5
10	Plasma	1/4/96	4/22/2031	36
N/A	Baseline	1/4/96	7/13/2029	33.5

- Availability of funding. Lack of funding could result in schedule delays.

- Ability of sites to obtain RCRA permits and other approvals and permits. For instance, it is anticipated that obtaining a RCRA permit for a plasma melter may be more difficult than obtaining one for some of the other processes. Additionally, there may be resistance at a given location to accepting waste from off-site, making it difficult to permit alternatives associated with the regionalized or centralized alternatives.

- Political climate, which could vary on a state-by-state basis.

These uncertainties are not quantified.

3.8 IMPACT ON OTHER WASTE DISPOSAL PROGRAMS

3.8.1 Definition of Factor 8

This factor includes an assessment of the impacts that the EAs will have on other waste processing and disposal programs, including programs for LLW and low-level mixed waste (LLMW). Major impacts are assessed based on additional volumes of waste that are projected to be generated by the TRU waste processing as analyzed for each waste processing based EA. EAs that do not process waste, such as backfill only EAs, are not considered in this analysis.

3.8.2 Methodology Used to Evaluate Factor 8

Data from four TRU waste cementation treatment processes at RFETS were analyzed, and the low-level secondary waste stream volumes were summed for each treatment process. The four waste generation rates, calculated as volume of low-level secondary waste generated per volume of cemented (output) waste, were then averaged (Appendix R). This average is 0.3 drums of secondary waste generated per drum of output cemented waste. The percents of the total secondary waste generated as LLW and LLMW are also averaged for the four treatment processes, and the average was approximately fifty percent LLW and fifty percent LLMW.

Because data are not available for other treatment processes, it is assumed that the other waste processes being evaluated (with the exception of plasma melting) generate similar volumes of secondary LLW as the cementation process, on a waste input basis. To convert the cementation data from an output basis to an input basis, the volume increase factor for cementation of 1:2.5 was used (see Table 3-47). This waste input basis factor, calculated to be 0.75 drums of secondary waste per drum of input waste, is then applied to each treatment process to calculate the volume of secondary LLW generated. The scaled volumes of sludges, solid organics, and solid inorganics that are used as inputs in the EA cost analysis were also used in this analysis (Section 2.3).

For the plasma melting process, the secondary low-level waste generation is assumed to be zero because the treatment process is designed such that secondary waste feeds back through the plasma melter. The volume reduction achieved in the plasma process for typical secondary wastes such as personal protective equipment (PPE), filters, and combustibles, is very high, so the volume of secondary wastes generated from the treatment process will be negligible. However, secondary waste will still be generated in the waste characterization step.

The waste characterization step is shown in the process flow diagrams in Section 3.7.2.1. The waste characterization module, as defined in the EM-PEIS, includes opening and sorting drum contents, collecting waste samples, and repackaging, if necessary, to remove and stabilize noncompliant waste. This operation, which occurs in a glovebox, is assumed to generate secondary low-level waste at the same rate (input basis) as the treatment processes. The secondary waste generated is calculated only for the portion of the waste inventory that passes through the waste characterization step (assumed to be 30 percent of stored waste and 10 percent of projected waste, as shown on the process flow diagrams in Section 3.7.2.1. Secondary waste generated from waste characterization is the same for the baseline and all EAs.

The calculated generation rates of LLW and LLMW for each EA were then compared to current and projected total DOE inventories of LLW and LLMW to determine impact in terms of percentage increase over current levels for each EA (Appendix R).

3.8.3 Assumptions and Data for Factor 8

The data analyzed for this factor comes from the RFETS Waste Stream and Residue Identification and Characterization report (WSRIC) (EG&G Rocky Flats, Inc., 1995), version 5.0. Four treatment processes are reviewed:

Building 774: Organic and Sludge Immobilization System (OASIS)
Building 774: Miscellaneous Waste Handling
Building 774: Precipitation/Filtration
Building 374: Sludge Solidification

All of these processes involve cementation of TRU waste and occur in gloveboxes. It is assumed that the RFETS data would generally be representative of TRU waste cementation processes at any DOE facility. Several other assumptions were made in assembling and compiling the data:

- All secondary waste characterized as "TRU or LL" is assumed to be LL, to estimate conservatively the potential impacts on the LL waste program. Likewise, waste characterized as "TRUM or LLM" is assumed to be LLM, and waste characterized as "LLM or HAZ" is assumed to be LLM.

- Several waste streams listed generation rates as "variable" or "insufficient data." Generation rates for these waste streams are estimated based on other similar processes and wastes.

- Most generation rates are provided on a volume basis. Those that are presented on a mass basis were converted to volume basis using assumed densities based on other RFETS data and the Baseline Inventory Report.

Other TRU waste processes at RFETS that parallel treatment options being evaluated in this study, such as the supercompactor, did not have secondary waste estimates provided in the WSRIC report. Because other data were not readily available, it is assumed that the other waste processes being evaluated (with the exception of plasma melting) generate similar volumes of secondary LLW as the cementation process, on a waste input basis.

Data for total DOE waste inventories and projections for LLW and LLMW are obtained from the 1993 Integrated Data Base Report (IDB) (DOE, 1994c) and the 1994 Mixed Waste Inventory Report (MWIR) (DOE, 1994d), respectively.

3.8.4 Results of Analysis of Factor 8

Table 3-56 presents the estimated volumes of secondary waste that are projected for each EA, including the amount calculated from the waste characterization and treatment steps. The annual waste generation shown is based on a 20-year treatment operation period for EA treatments. As explained in the methodology section, the secondary waste is assumed to be comprised of 50 percent LLW and 50 percent LLMW. Alternative 94 is projected to generate the most secondary

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TABLE 3-56

SECONDARY WASTE VOLUMES
(cubic meters)

	Secondary Waste		LLW/LLMW (Each)	
Alternative	**Total**	**Annual[1]**	**Total**	**Annual[1]**
Baseline	32,729	1,636	16,365	818
1 and 77 (Supercompact)	118,040	5,902	59,020	2,951
6 (Shred and compact)	118,040	5,902	59,020	2,951
10 (Plasma)	21,848	1,092	10,924	546
94 (Enhanced cement/ shred and add clay)	131,625	6,581	65,813	3,291

[1]Based on a 20-year treatment operation period.

waste (three times more than the baseline), with Alternative 10 generating the least (one-third less than the baseline). Alternatives 1 and 6 generate 2.6 times more secondary waste than the baseline.

Table 3-57 shows a summary of LLMW impacts from each waste processing EA, expressed as percentages of total DOE LLMW (stored-plus-projected) and annual DOE LLMW generation. The annual DOE rate is taken as an average of projected generation rates for 1993 through 1997 from the MWIR. Projected generation rates beyond 1997 are not consistently provided in the MWIR. Alternative 10 (plasma) will generate less LLMW than the baseline, making this an attractive alternative in terms of impacts on other waste disposal programs. Compared to total DOE stored-plus-projected LLMW, the other alternatives will generate 14 to 16 percent more LLMW. The range for the annual generation basis is 10 to 12 percent more LLMW. This could have an impact on available permitted RCRA storage and treatment capacity at some sites.

Table 3-58 presents a summary of LLW impacts from each EA, expressed as percentages of total DOE LLW (buried-plus-projected) and annual DOE LLW generation. The annual DOE rate is taken as an average of projected generation rates for 1993 and 1994 from the IDB (the only years with annual generation rates projected). Again, Alternative 10 (plasma) generates less LLW than the baseline, making it an attractive alternative in terms of impacts on other waste disposal programs. Compared to total DOE LLW (buried-plus-projected), the other alternatives generate about one percent more LLW. The range for the annual generation basis is eight to nine percent more LLW. Because LLW can generally be shipped for disposal as it is generated, this increase is not expected to have as significant an impact on DOE's LLW program as the LLMW increase.

Uncertainties associated with this analysis of impacts on LLW and LLMW programs result from uncertainties in the source documents (WSRIC, MWIR, and IDB) as well as uncertainties introduced in this analysis. The IDB states that waste characterization is underway at many DOE sites, which may cause the classification of the waste to change in the future. In addition, the MWIR includes some waste from environmental restoration and D&D programs, while the IDB does not appear to. In this analysis, all EA treatments were assumed to generate secondary waste at the same rate (on an input basis) as four cementation processes at RFETS, which is felt to be a reasonable estimate for purposes of this analysis but which may require further study to reduce uncertainties.

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TABLE 3-57
LOW-LEVEL MIXED WASTE IMPACTS

Alternative	% of Total DOE LLMW (Stored + Projected)[1]	% of Annual LLMW Generation[2]
Baseline	3.8	2.9
1 (Supercompact)	13.9	10.4
6 (Shred and compact)	13.9	10.4
10 (Plasma)	2.6	1.9
94 (Enhanced cement/shred and add clay)	15.5	11.6

[1]Based on stored and projected volumes from MWIR through 2022 (total = 425,932 m^3).

[2]Based on average of annual projected volumes from MWIR for 1993 to 1997 (average = 28,420 m^3/yr).

TABLE 3-58

LOW-LEVEL WASTE IMPACTS

Alternative	% of Total DOE LLW (Buried + Projected)[1]	% of Annual LLW Generation[2]
Baseline	0.29	2.2
1 (Supercompact)	1.03	7.8
6 (Shred and compact)	1.03	7.8
10 (Plasma)	0.19	1.4
94 (Enhanced cement/shred and add clay)	1.15	8.7

[1]Based on historical and projected buried waste volumes from IDB through 2022 (total = 5,722,000 m^3).

[2]Based on average of annual projected volumes from IDB for 1993 to 1994 (average = 37,895 m^3/yr).

4.0 QUALITY ASSURANCE

4.1 QUALITY ASSURANCE APPROACH

The DOE-CAO has developed a quality assurance (QA) program in the CAO Quality Assurance Program Description (CAO-QAPD; CAO-94-1012). The program meets the applicable requirements of the American Society of Mechanical Engineer's (ASME) "Quality Assurance Program Requirements for Nuclear Facilities" (NQA-1-1989 Edition), ASME's "Quality Assurance Requirements of Computer Software for Nuclear Facility Applications" (NQA-2a-1990 addenda, part 2.7 to ASME NQA-2-1989 edition), and ASME's "Quality Assurance Program Requirements for the Collection of Scientific and Technical Information on Site Characterization of High-Level Nuclear Waste Repositories" (NQA-3-1989 edition).

The ASME NQA-1-1989 edition sets forth requirements for the "establishment and execution of quality assurance programs for the siting, design, construction, operation, and decommissioning of nuclear facilities." For the purpose of this project, the NQA-2a-1990 addenda to ASME NQA-2-1989 edition standard applies to computer software "used to produce or manipulate data which are used directly in the design, analysis, and operation of structures, systems, and components." The NQA-3-1989 edition standard sets forth quality assurance requirements which apply to "activities which could affect the quality of scientific and technical information collected as part of the site characterization phase of high-level nuclear waste repositories."

The QA program implemented in support of the EACBS address elements such as calculations, models, and data collection used to perform the EA analysis. Documentation that details quality indicators such as data accuracy, precision, representativeness, completeness, comparability, and reproducibility has been compiled for the record, as appropriate. Appendix S details specific QA procedures used in most of the factors.

Computer models developed in support of the analyses in this study are based upon appropriate conceptual, mathematical, and numerical models. Program verification and validation methods were applied to ensure the desired performance of these models. Verification is the process by which the output (e.g., numerical results) of a computer program are determined to be "correct". Verification implies that the program solves the numerical problem as intended by the program author. Validation implies that the theory and assumptions used in constructing the program logic constitute a correct representation of the process or system being simulated by the program. Verification was performed by one, or more of the following methods, depending on the intended use of the program:

- Independent manual calculations are performed to verify the program algorithms.
- The results produced by the program are compared to the results from an "independently developed" program (e.g., a program developed outside the company or by an independent working group).
- The program results are compared to analyses published in textbooks and journals or, to the results of applicable experiments.

- Previous Validation. Models that have been previously used and approved in other DOE program will not be revalidated unless the model is modified or used for other purposes than their intended design.

Validation documentation, as necessary, consist of published conclusions comparing model predictions with data from laboratory experiments, field experiments, natural analogues, and published conclusions made by external review groups.

Many aspects of the EACBS are qualitative in nature. The methods used to analyze the EAs within the factors used many quantitative tools such as computer models and spreadsheet calculations (see appendices for details). However the results from these quantitative tools are qualitative since the input parameters and assumptions are based on qualitative estimates and judgements. The quality assurance program used in this report mostly centers around hand checking calculations from spreadsheets, computer models and validating changes made to these models.

5.0 INTEGRATION AND SUMMARY OF ANALYSIS RESULTS

5.1 OVERVIEW OF THE INTEGRATION PROCESS

The EAs proposed in this study are intended to reduce the estimated risks to future populations from waste disposal at WIPP and to provide additional confidence in the performance of the disposal system. EA evaluation factors 1 and 2 address these issues. The additional handling and processing of wastes required to implement the EAs may, however, impose additional near-term costs and health risks beyond those involved in the WIPP baseline design. These potential concerns are addressed by evaluation factors 3 through 8. This section integrates the results from all the evaluation factors into a form that will assist decisionmakers and other stakeholders in assessing the costs and benefits of EA adoption for both short and long-term impacts.

The next subsection reviews the TRU waste disposal program scenarios evaluated in detail for this study. Next, the quantitative performance measures used to document waste system performance against the evaluation factors found in Chapter 3 are described and organized for integrated results presentation. Finally, integrated results are presented in a form that allows the overall performance of the EAs to be compared to the baseline WIPP design.

5.2 SUMMARY OF EAs EVALUATED

The identification and screening of EAs is documented in Chapter 2. Out of 111 EA concepts screened for this analysis, 18 specific alternatives were selected for further evaluation. The 18 EAs represent a complete spectrum of EAs ranging from those believed to be narrowly effective in one impact area to those with broad effectiveness plus EAs judged to have high feasibility. Summary descriptions of the EAs selected for evaluation are presented in Section 2.2.1.

EAs involving additional waste processing were further evaluated under three separate configurations:

- Waste processing is decentralized at 10 generator sites.
- Waste is processed at 5 regional generator sites.
- Waste is centrally processed at WIPP.

This consideration of waste processing location expanded the number of EA scenarios to be evaluated to 44 plus the baseline case.

The EAs can be uniquely defined by the following three parameters:

- Combination alternatives
- Waste processing alternatives
- Waste backfill provisions

Figure 5-1 presents a scenario tree constructed using these parameters to organize the baseline and 44 evaluated EAs in a logical order . The scenario tree organization starts at the top with the baseline TRU disposal system. Next follows those EAs that involve only backfill external to the waste drums. EAs that use increasingly aggressive processing technologies are found by descending down the scenario tree.

TRU Disposal System	Additional Waste Processing?	Processing Facilities Location?	Waste Backfill?	Seq. No.	Engineered Alternative Case #
	None*	N/A	None	1	Baseline
			Sand+Clay	2	33
			SAG	3	35a
			CG	4	35b
			Clay	5	111
			CaO	6	83
	Super C	WIPP	None	7	1-1
			SAG	8	77a-1
			Clay	9	77b-1
			Sand+Clay	10	77c-1
			CaO	11	77d-1
		5 Sites	None	12	1-5
			SAG	13	77a-5
			Clay	14	77b-5
			Sand+Clay	15	77c-5
			CaO	16	77d-5
		10 Sites	None	17	1-10
			SAG	18	77a-10
			Clay	19	77b-10
			Sand+Clay	20	77c-10
			CaO	21	77d-10
	S&C	WIPP	None	22	6-1
		5 Sites	None	23	6-5
		10 Sites	None	24	6-10
	SCC	WIPP	None	25	94a-1
			Sand+Clay	26	94b-1
			CG	27	94c-1
			SAG	28	94d-1
			Clay	29	94e-1
			CaO	30	94f-1
		5 Sites	None	31	94a-5
			Sand+Clay	32	94b-5
			CG	33	94c-5
			SAG	34	94d-5
			Clay	35	94e-5
			CaO	36	94f-5
		10 Sites	None	37	94a-10
			Sand+Clay	38	94b-10
			CG	39	94c-10
			SAG	40	94d-10
			Clay	41	94e-10
			CaO	42	94f-10
	Plasma	WIPP	None	43	10-1
		5 Sites	None	44	10-5
		10 Sites	None	45	10-10

LEGEND:

Super C: Supercompaction of all waste, except sludges
S&C: Shredding and compaction of all waste, except sludges
SCC: All wastes other than sludges are shredded and repackaged with clay. Sludges are cemented.
SAG: Salt Aggregate Grout
CG: Cemenitious Grout
* Baseline assumes processing to meet WIPP WAC is performed.

Figure 5-1
Engineered Alternatives Scenario Tree

5.3 PERFORMANCE MEASURES FOR RESULTS INTEGRATION

The baseline TRU waste disposal system and the 18 EAs defined in Chapter 2 were evaluated against each of the eight factors discussed in Chapter 3. In Chapter 3, analysis results were presented for each factor using quantifiable performance measures identified for each factor. While some factors were characterized by a single performance measure, others required several different performance measures to adequately describe the results. Table 5-1 summarizes the performance measures reported for each factor.

To facilitate the integration of results, the performance measures reported in Chapter 3 were organized and condensed to define a multi-element "impact vector" describing the complete analysis results for each EA for all factors. Special attention was given in constructing the impact vector to communicate the phase of the TRU disposal program being impacted by an EA and the location (at WIPP, at generator sites) of the risk or cost impact. The relationships between the eight assessment factors and the elements of the impact vector are shown in Figure 5-2.

5.4 SUMMARY OF ANALYSIS RESULTS FOR EVALUATED ALTERNATIVES

5.4.1 Approach to Results Integration

Figure 5-3 combines the EA scenario tree from Figure 5-1 and the impact vector from Figure 5-2 to form a matrix for integrating and summarizing the results of the EA analyses. To facilitate comparison of the EAs to the baseline WIPP design, the quantitative results from each factor analysis, expressed in the different units of measure as summarized in Table 5-1, are translated into a common qualitative scale that compares the EA to the baseline in general terms. Table 5-2 below shows the five categories that are used to represent the results of each impact vector element.

The term "significant" refers to the overlap in the range of performance predicted for the EA verses the baseline. Interpretation of these categories varies with the relative magnitude and uncertainty of the performance measures. For example, a factor of two difference between the predicted point estimates for total cost of alternatives may be very significant with essentially no overlap in the distributions of the two predictions. A factor of two difference in predicted point estimates for latent cancer fatalities may, by comparison, be less significant with a considerable overlap in the distributions of the two predictions. This concept is similar to the idea of statistical significance, however, it is assigned judgmentally in this report since we are addressing a state of knowledge rather than the results of controlled experiments.

Figure 5-4 presents the same qualitative ratings shown in Figure 5-3, only condensed down to the eight top level elements of the impact vector.

A summary of selected analysis results from each of the eight factors are presented in Table 5-3. Table 5-3 contains an overview of the analysis results for each EA and the baseline case. Supportive data for the results are also included.

The remainder of this chapter discusses how the quantitative evaluation results from Chapter 3 were interpreted for each of the major impact categories for presentation in Figure 5-3.

1

TABLE 5-1
PERFORMANCE MEASURES REPORTED

EA FACTOR	PERFORMANCE MEASURE	UNITS
1) Long term Repository Performance	Measure of relative effectiveness (MRE) of repository performance compared to the baseline.	Ratio of the mean value EA performance to the baseline
2) Uncertainty in Compliance Assessment	Measure of the relative uncertainty (MRU) of repository performance compared to the baseline.	Ratio of the range factor for EA performance to the baseline
3) Worker & Public Risk[a]	Facility worker risk	FTE-REM excess fatalities, construction and operation injuries and fatalities
	Maximum co-located worker risk	REM, excess cancer fatalities
	Co-located worker collective risk	Person-REM excess fatalities[b]
	Maximum off-site individual risk	REM, excess cancer fatalities
	Collective off-site public risk	Person-REM excess fatalities[b]
4) Impact on Waste Removal	Measure of relative difficulty of waste removal compared to the baseline.	Qualitative ranking.
5) Transportation Risk[a]	Transport crew collective radiological, nonaccident risk	Person-REM, latent cancer fatalities
	Public collective radiological, nonaccident risk	Person-REM, latent cancer fatalities
	Public maximum individual radiological, nonaccident risk	REM, latent cancer fatalities
	Public and crew collective radiological, accident risk	Person-REM, latent cancer fatalities
	Public and crew collective chemical risk	EPRG-2 ratio
	Public and crew collective non-rad, non-chemical risk	injuries, fatalities
6) Public Confidence	Listing of citizen concerns about repository performance	Not applicable
7) System Cost & Schedule[a]	Waste storage costs	1994 dollars
	Waste treatment costs	1994 dollars
	Waste transportation costs	1994 dollars
	WIPP waste placement and backfill costs	1994 dollars
	Start of WIPP operations	Date of first waste placement
	Completion of WIPP operations	Date of closure
8) Impact on Other Disposal Systems	Secondary waste volumes	Percentage change in estimated secondary waste volumes relative to the DOE low level and low level mixed waste

[a]For EAs that involve waste treatment, results are reported separately for decentralized, regionalized and centralized locations.
[b]Other units of measure are also used for non-radiological risk.

EA FACTORS	WIPP ENGINEERED ALTERNATIVES IMPACT VECTOR ELEMENTS																
	LONG TERM COMPLIANCE CONFIDENCE		PUBLIC HEALTH RISK				WORKER HEALTH		DISPOSAL SYSTEM COSTS					WIPP SCHEDULE			
									TRU WASTE								
					At WIPP						At WIPP						
	Cutings Scenarios	Water Scenarios	At Generator	In Transport	*Before Closure*	*After Closure*	At Generator	At WIPP	At Generator	In Transport	Storage & Treatment	Placement & Backfill	OTHER WASTE	First Waste to WIPP	Closure	WASTE REMOVAL CAPABILITY	PUBLIC ACCEPTANCE
1) Long Term Repository Performance						X											
2) Uncertainty in Compliance	X	X															
3) Worker & Public Risk			X		X		X	X									
4) Waste Removal Capability																X	
5) Transportation Risk				X													
6) Public Confidence																	X
7) System Cost & Schedule									X	X	X	X		X	X		
8) Other Disposal Systems													X				

Figure 5-2
Relationship of EA Factors and Impact Vector

WIPP ENGINEERED ALTERNATIVES IMPACT VECTOR ELEMENTS

TRU WASTE DISPOSAL SCENARIO					LONG TERM COMPLIANCE CONFIDENCE		PUBLIC HEALTH RISK				WORKER HEALTH		DISPOSAL SYSTEM COSTS					WIPP SCHEDULE			
									At WIPP				TRU WASTE		At WIPP						
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Cutings Scenarios	Water Scenarios	At Generator	In Transport	*Before Closure*	*After Closure*	At Generator	At WIPP	At Generator	In Transport	Storage & Treatment	Placement & Backfill	OTHER WASTE	First Waste	Closure	WASTE REMOVAL CAPABILITY	PUBLIC ACCEPTANCE
	None	None	1	Baseline-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Sand+Clay	2	33-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	□	▲	▲	▲	▲	▲
		SAG	3	35a-1	◐	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	□	▲	▲	▲	▲	▲
		CG	4	35b-1	◐	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	□	▲	▲	▲	▲	▲
		Clay	5	111-1	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	□	▲	▲	▲	▲	▲
		CaO	6	83-1	▲	◐	▲	▲	▲	▲	▲	▲	▲	▲	▲	□	▲	▲	▲	▲	▲
	Super C	None	7	1-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	□	▲	□	■	▲	◐	▲
		SAG	8	77a-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	□	□	□	■	▲	◐	▲
		Clay	9	77b-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	□	□	□	■	▲	◐	▲
		Sand+Clay	10	77c-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	□	□	□	■	▲	◐	▲
		CaO	11	77d-1	◐	◐	▲	▲	□	▲	▲	■	▲	▲	□	□	□	■	▲	◐	▲
	S&C	None	12	6-1	▲	▲	▲	▲	□	▲	▲	■	▲	▲	□	▲	□	■	▲	▲	▲
	SCC	None	13	94a-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	■	▲	□	■	▲	▲	▲
		Sand+Clay	14	94b-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	■	□	□	■	▲	▲	▲
		CG	15	94c-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	■	□	□	■	▲	▲	▲
		SAG	16	94d-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	■	□	□	■	▲	▲	▲
		Clay	17	94e-1	◐	▲	▲	▲	□	▲	▲	■	▲	▲	■	□	□	■	▲	▲	▲
		CaO	18	94f-1	◐	◐	▲	▲	□	▲	▲	■	▲	▲	■	□	□	■	▲	▲	▲
	Plasma	None	19	10-1	●	●	▲	▲	■	▲	▲	■	▲	▲	■	▲	◐	■	▲	▲	▲

SCENARIO TREE LEGEND:

Super C: Supercompaction of all waste, except sludges
S&C: Shreding and compaction of all waste, except sludges
SCC: All wastes other than sludges are shredded and repackaged with clay. Sludges are cemented.
SAG: Salt Aggregate Grout
CG: Cementitious Grout

IMPACT VECTOR RANKING:

● Performance is significantly better than the corresponding baseline performance.
◐ Performance is marginally better than the corresponding baseline performance.
▲ Performance is approximately the same as the corresponding baseline performance.
□ Performance is marginally worse than the corresponding baseline performance.
■ Performance is significantly worse than the corresponding baseline performance.

[a] The Centralized Processing Scenario was selected because it generally produces the lowest increase in cost, schedule impacts, and health risks with respect to the baseline case–results for the regionalized and decentralized scenarios are found in Section 3.0.

Figure 5-3
Summary of WIPP Engineered Alternative Evaluation Results for Centralized Processing Scenario[a]

1

TABLE 5-2

QUALITATIVE IMPACT VECTOR RESULT CATEGORIES

SYMBOL	DESCRIPTION
●	Performance is significantly better than the corresponding baseline performance.
○	Performance is marginally better than the corresponding baseline performance.
▲	Performance is approximately the same as the corresponding baseline performance.
□	Performance is marginally worse than the corresponding baseline performance.
■	Performance is significantly worse than the corresponding baseline performance.

TRU DISPOSAL SYSTEM SCENARIO					WIPP ENGINEERED ALTERNATIVES IMPACT VECTOR ELEMENTS								
TRU Disposal System	Additional Waste Processing?	Waste Backfill?	Seq. No.	Engineered Alternative Case #	Cutings Scenarios Confidence	Water Scenarios Confidence	PUBLIC HEALTH RISK	WORKER HEALTH RISK	DISPOSAL SYSTEM COSTS	OTHER DISPOSAL SYSTEM IMPACTS	WIPP SCHEDULE	WASTE REMOVAL CAPABILITY	PUBLIC ACCEPTANCE
	None	None	1	Baseline-1	▲	▲	▲	▲	▲	▲	▲	▲	▲
		Sand+Clay	2	33-1	▲	▲	▲	▲	▲	▲	▲	▲	▲
		SAG	3	35a-1	◐	▲	▲	▲	▲	▲	▲	▲	▲
		CG	4	35b-1	◐	▲	▲	▲	▲	▲	▲	▲	▲
		Clay	5	111-1	▲	▲	▲	▲	▲	▲	▲	▲	▲
		CaO	6	83-1	▲	◐	▲	▲	▲	▲	▲	▲	▲
	Super C	None	7	1-1	◐	▲	▲	❒	❒	❒	■	◐	▲
		SAG	8	77a-1	◐	▲	▲	❒	❒	❒	■	◐	▲
		Clay	9	77b-1	◐	▲	▲	❒	❒	❒	■	◐	▲
		Sand+Clay	10	77c-1	◐	▲	▲	❒	❒	❒	■	◐	▲
		CaO	11	77d-1	◐	◐	▲	❒	❒	❒	■	◐	▲
	S&C	None	12	6-1	▲	▲	▲	❒	❒	❒	■	▲	▲
	SCC	None	13	94a-1	◐	▲	▲	❒	■	❒	■	▲	▲
		Sand+Clay	14	94b-1	◐	▲	▲	❒	■	❒	■	▲	▲
		CG	15	94c-1	◐	▲	▲	❒	■	❒	■	▲	▲
		SAG	16	94d-1	◐	▲	▲	❒	■	❒	■	▲	▲
		Clay	17	94e-1	◐	▲	▲	❒	■	❒	■	▲	▲
		CaO	18	94f-1	◐	◐	▲	❒	■	❒	■	▲	▲
	Plasma	None	19	10-1	●	●	■	❒	■	◐	■	▲	▲

SCENARIO TREE LEGEND:

Super C: Supercompaction of all waste, except sludges
S&C: Shreding and compaction of all waste, except sludges
SCC: All wastes other than sludges are shredded and repackaged with clay. Sludges are cemented.
SAG: Salt Aggregate Grout
CG: Cemenitious Grout

IMPACT VECTOR RANKING:

● Performance is significantly better than the corresponding baseline performance.
◐ Performance is marginally better than the corresponding baseline performance.
▲ Performance is approximately the same as the corresponding baseline performance.
❒ Performance is marginally worse than the corresponding baseline performance.
■ Performance is significantly worse than the corresponding baseline performance.

[a] The Centralized Processing Scenario was selected because it generally produces the lowest increase in cost, schedule impacts, and health risks with respect to the baseline case–results for the regionalized and decentralized scenarios are found in Section 3.0.

Figure 5-4
Condensed Summary of WIPP Engineered Alternative Evaluation Results for Centralized Processing Scenario[a]

Factor Output	Factor Number	Baseline	EA 94c Sup-a + cement out BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Waste Backfill Compressive Strength (MPa)	NA	25.2	24.5.6	20.6	14.7	19.7	15.2
Emplacement Volume Impact (% Emplaced or Amount not Emplaced m^3)	NA	100% emplaced	100%,177 emp	27,177	27,177	27,177	100% emplaced
Backfill Properties -							
Initial Density (Kg/m^3)	NA	NA	NA 384	1,884	1,000	1,193	1,000
Initial Porosity (%)			.3	31.3	62.5	44.8	62.5
Solid Density (Kg/m^3)			741	2,741	2,670	2,162	2,670
MRE (unitless)	1						
E1		1.0	0.9345	0.45	0.53	0.67	0.54
E2		1.0	1.4 46	0.46	0.88	0.30	2.1
E1E2		1.0	1.0 089	0.089	0.49	0.012	0.56
Cuttings		1.0	.26 30	0.30	0.53	0.54	0.94
Uncertainty E1	2						
5th Percentile		NA	0.9244	0.44	0.52	0.26	0.53
95th Percentile			0.9447	0.47	0.56	0.68	0.55
Uncertainty E2	2						
5th Percentile		NA	0.6103	0.03	0.16	0.005	0.33
95th Percentile			2.0888	0.88	1.62	0.75	2.18
Uncertainty E1E2	2						
5th Percentile		NA	1.0 01	0.01	0.024	0.009	0.024
95th Percentile			1.0 98	0.98	0.99	0.045	0.99
Uncertainty Cuttings	2						
5th Percentile		NA	0.2599	0.29	0.53	0.53	0.93
95th Percentile			0.2600	0.30	0.53	0.54	0.94
WIPP Worker Rad Risk	3						
FTE-Rem		322.85	322.20	343.78	342.28	339.29	342.28
Excess Fatalities		0.13	0.135	0.14	0.14	0.14	0.14
WIPP Indust. Accidents	3						
Injuries		53.63	44.014	69.56	61.83	63.25	62.53
Fatalities		0.16	0.131	0.49	0.18	0.28	0.18

Factor Output	Factor Number	Baseline	EA 1]4c Suppe+ compaent ıt BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Waste Processing Risk	3						
Centralized Scenario							
Off-site Population							
Cancer Fatalities		$1.94x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	$4..24x10^{-4}$	NA
Cancer Incidence		$5.51x10^{-8}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	$5.74x10^{-7}$	
Workers							
Cancer Fatalities		$7.78x10^{-1}$	$1.10x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	$1.20x10^{+0}$	
Cancer Incidence		$1.30x10^{-5}$	$3.49x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	$3.80x10^{-5}$	
Construct/Op Fatalities		2.81	3.79	4.08	4.08	4.08	
Waste Processing Risk	3						
Regionalized Scenario							
Off-site Population		$1.94x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	$2.73x10^{-4}$	NA
Cancer Fatalities		$5.51x10^{-8}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	$3.69x10^{-7}$	
Cancer Incidence							
Workers		$7.78x10^{-1}$	$9.92x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	$8.12x10^{-1}$	
Cancer Fatalities		$1.30x10^{-5}$	$3.15x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	$2.58x10^{-5}$	
Cancer Incidence		2.81	3.83	3.45	3.45	3.45	
Construct/Op Fatalities							
Waste Processing Risk	3						
Decentralized Scenario							
Off-site Population		$1.94x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	$2.65x10^{-4}$	NA
Cancer Fatalities		$5.51x10^{-8}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	$3.59x10^{-7}$	
Cancer Incidence							
Workers		$7.78x10^{-1}$	$9.54x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	$7.91x10^{-1}$	
Cancer Fatalities		$1.30x10^{-5}$	$3.03x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	$2.51x10^{-5}$	
Cancer Incidence		2.81	4.05	3.78	3.78	3.78	
Construct/Op Fatalities							
Mining Advance Rate (m/Shift)	4	1.8	1.8	1.9	2.0	1.9	2.0
Removal Risk	4						
Fatal Accidents		0.58	0.58	0.56	0.53	0.55	0.53
Non- Fatal Accidents		11.74	11.66	11.26	10.69	11.17	10.74

Factor Output	Factor Number	Baseline	EA 1 Suppe[illegible] comp[illegible]	[illegible]94c [illegible]ent [illegible]t BF	EA 94d 94a + Salt Agg. BF	EA 94e 94a + Clay Base BF	EA 94f 94a + CaO BF	EA 111 Clay Based BF
Trans Rad Risk[1] **Decentralized** (CH only)	5							
Worker		$6.69 \times 10^{+2}$	5.81x[illegible]$\times 10^{+2}$		$4.25 \times 10^{+2}$	$4.25 \times 10^{+2}$	$4.25 \times 10^{+2}$	$6.69 \times 10^{+2}$
Person-Rem		2.68×10^{-1}	2.32x[illegible]$\times 10^{-1}$		1.70×10^{-1}	1.70×10^{-1}	1.70×10^{-1}	$2.68 10^{-1}$
LCF								
Public		$4.00 \times 10^{+3}$	3.47x[illegible]$\times 10^{+3}$		$2.55 \times 10^{+3}$	$2.55 \times 10^{+3}$	$2.55 \times 10^{+3}$	$4.00 \times 10^{+3}$
Person-Rem		$2.00 \times 10^{+0}$	1.74x[illegible]$\times 10^{+0}$		$1.28 \times 10^{+0}$	$1.28 \times 10^{+0}$	$1.28 \times 10^{+0}$	$2.00 \times 10^{+0}$
LCF								
Accident		$8.01 \times 10^{+1}$	5.92x[illegible]$\times 10^{+1}$		$5.76 \times 10^{+1}$	$5.76 \times 10^{+1}$	$5.76 \times 10^{+1}$	$8.01 \times 10^{+1}$
Person-Rem		4.01×10^{-2}	2.96x[illegible]$\times 10^{-2}$		2.88×10^{-2}	2.88×10^{-2}	2.88×10^{-2}	4.01×10^{-2}
LCF								
Trans Chemical Risk **Decentralized**	5							
Max. Individual		$1.21 \times 10^{+0}$	1.80x[illegible]$\times 10^{-1}$		8.10×10^{-1}	8.10×10^{-1}	8.10×10^{-1}	$1.21 \times 10^{+0}$
Trans Non-Rad/Chem Risk **Decentralized**	5							
Injuries		$6.61 \times 10^{+1}$	6.61x[illegible]$\times 10^{+1}$		$6.61 \times 10^{+1}$	$6.61 \times 10^{+1}$	$6.61 \times 10^{+1}$	$6.61 \times 10^{+1}$
Fatalities		$4.87 \times 10^{+0}$	4.87x[illegible]$\times 10^{+0}$		$4.87 \times 10^{+0}$	$4.87 \times 10^{+0}$	$4.87 \times 10^{+0}$	$4.87 \times 10^{+0}$
Percent of Comments Addressed by EA	6	NA	33%		42%	42%	42%	36%
Total System Cost	7							
Decentralized ($\times 10^6$)		4,483	5,219[illegible]3		7,703	7,667	7,673	4,529
Regionalized ($\times 10^6$)		4,335	4,824[illegible]3		6,914	6,877	6,883	4,381
Centralized ($\times 10^6$)		4,029	4,177[illegible]0		5,061	5,024	5,030	4,075
Schedule Impact - Delayed Emplacement Relative to Baseline Startup	7	No Delay	9yrs.		9yrs.	9yrs.	9yrs.	No Delay
Other Waste Generation	8							
Secondary (m^3)		32,729	118,0[illegible]625		131,625	131,625	131,625	32,729
LLW/LLMW (m^3)		16,365	59,02[illegible]13		65,813	65,813	65,813	16,365

[1]Only the Decentralized scenario is shown here. The Central

In order to simplify the summary, only results for centralized processing scenarios from the Figure 5-1 EA scenario tree are included in Figure 5-3. This was done because, among the three processing facility schemes studied, centralized processing at WIPP generally produced the lowest increases in cost and schedule along with approximately comparable health risks. The impacts of regionalized and decentralized processing on cost are discussed in section 5.4.5.

5.4.2 Long-term Compliance Confidence

Chapters 3.1 and 3.2 report the evaluation of potential material releases from WIPP, given human intrusion into the repository in the distant future. These chapters discuss the impact of the EAs on the best estimate of WIPP performance and our confidence in the best estimate predictions, respectively.

The evaluations in chapters 3.1 and 3.2 focus on the possible transport of waste material from WIPP via direct removal by drilling and indirect removal via the transport of contaminated brine. Because the drilled material is removed from the bore hole directly into the above ground environment, while contaminated brine is subject to dilution and retention in the water bearing strata between the repository and the surface, evaluation results for these two release mechanisms are reported separately. Ongoing performance assessment work is now in progress that may produce conclusions on the relative importance of these release mechanisms.

Figures 5-5a and 5-5b show the predicted performance for all EAs relative to the baseline for direct material releases and the three brine transport scenarios. Figure 5-5a compares the median value results and Figure 5-5b compares the 95th percentile results.

Since no EA alters the footprint of the disposal area of the repository, EAs that reduce the effective diameter of the borehole through the waste should show the best improvement in predicted performance for direct drilling releases. The effective diameter of the borehole can, in theory, be reduced from the baseline conditions by increasing the shear strength of the waste bearing material, thereby causing the drill to cut a "cleaner" hole through the waste. Following this line of reasoning, EAs involving cement backfills and the supercompacting or plasma processing of waste should be expected to produce improved performance. This prediction was confirmed by the analysis results in Section 3.2. The reduction shown for plasma processing (approximately a factor of 9) was near the maximum achievable, considering the assumed increase in the effective borehole radius for unprocessed waste was a factor of 3. As stated in Section 3.1.1, it was not feasible to consider the impacts of actinide sorption on clays, EAs that employ clay based materials may exhibit better performance than the results presented in this report.

Repository performance with respect to brine transport is a much more complex question than direct material removal and was found to be dependent on the particular release scenario modeled. For the case where drilling passes through the repository and into the Castile brine reservoir below WIPP, plasma processing (EA#10) and EAs using cementitious backfills (EAs 35a, 35b, 77a, 94c, and 94d) produced a notable improvement over the baseline case.

For release scenarios where brine was modeled to pass through the waste horizontally before exiting (scenarios E2 and E1E2), the solubility of radionuclides and permeability of the waste were shown to be important. For release scenario E2, EAs using CaO backfill (EA#77d, 83 and 94f) produced marginally improved performance over the baseline. For release scenario E1E2, both

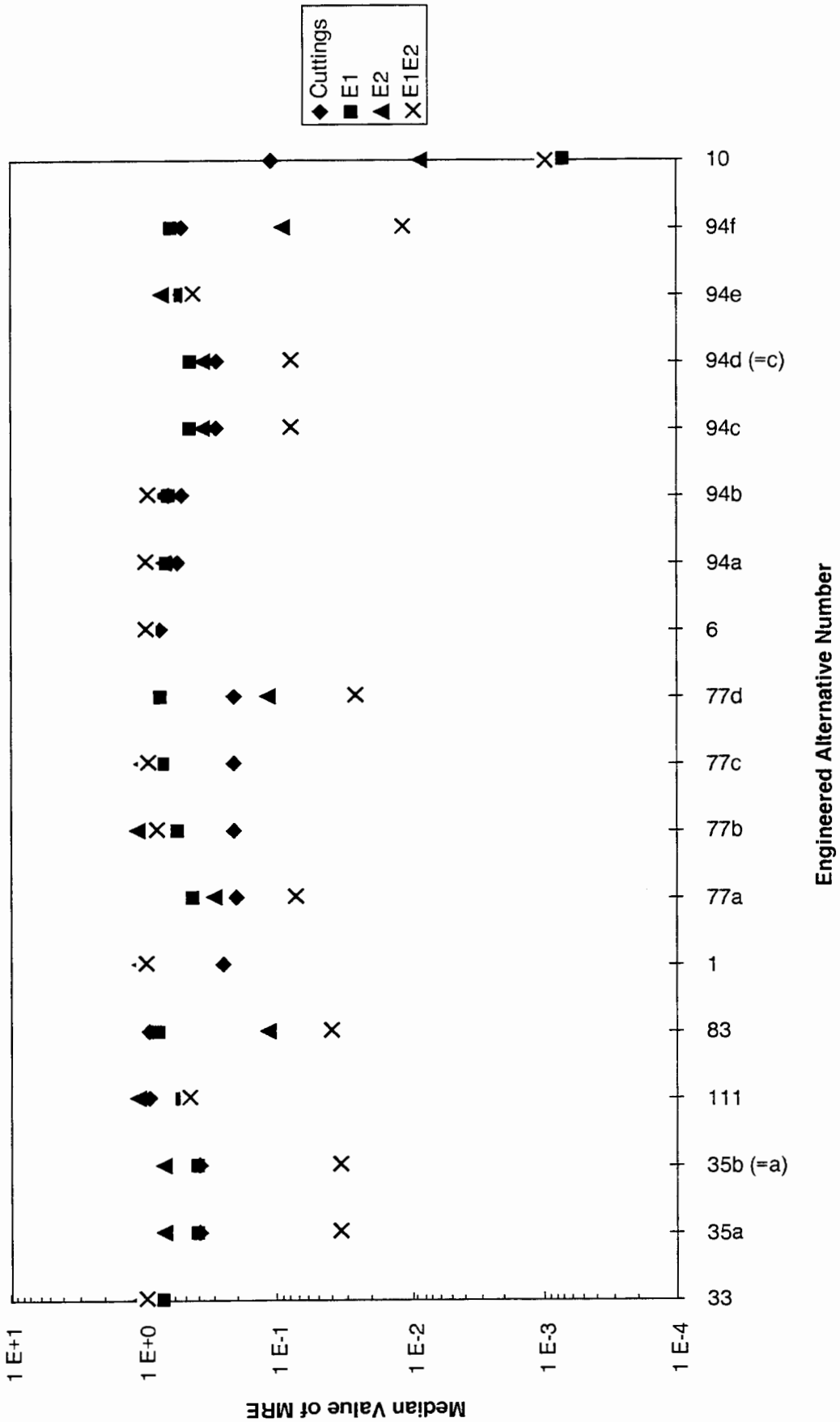

Figure 5-5a
Comparison of Medians of Case-by-Case MREs Across All Scenarios

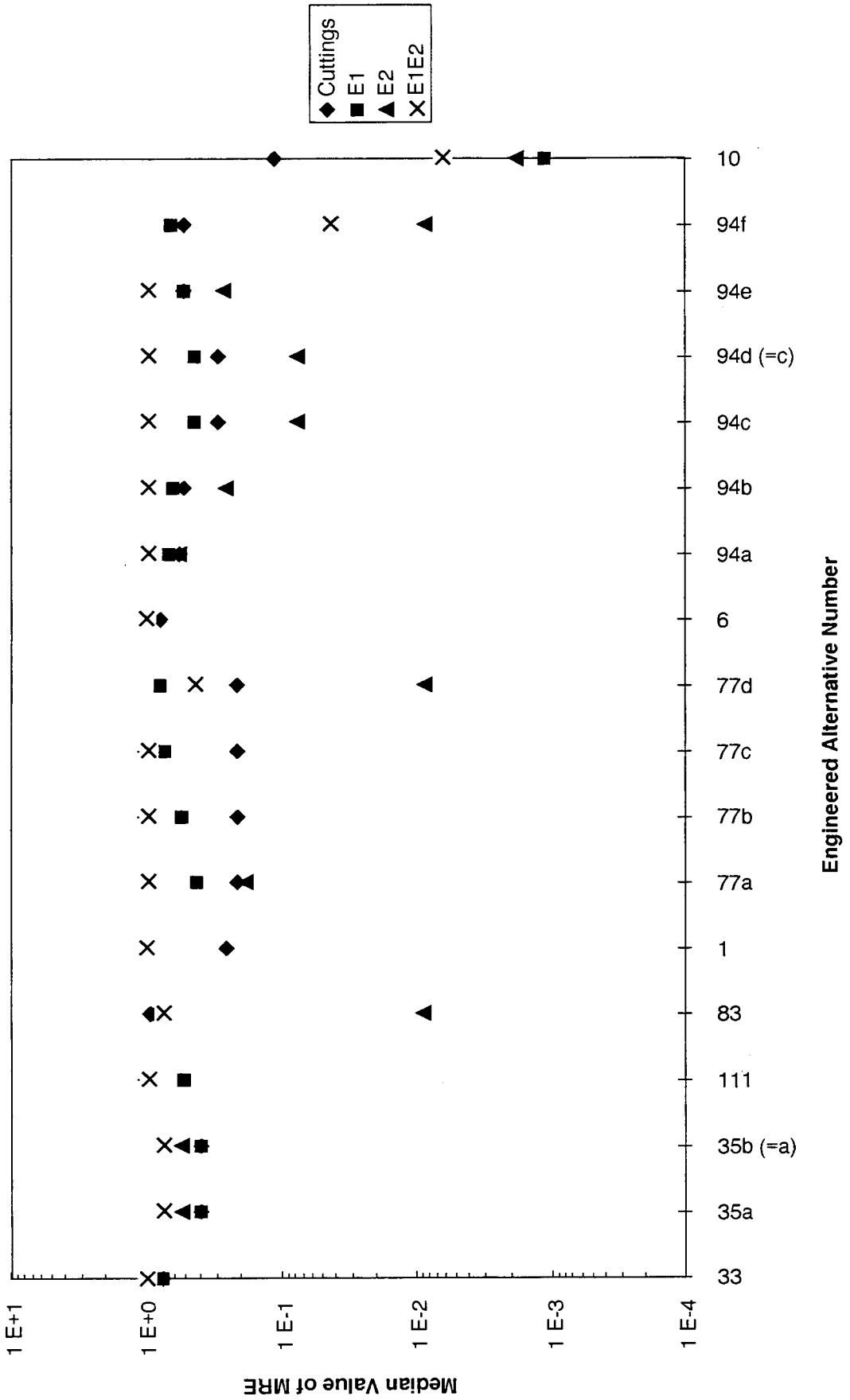

Figure 5-5b
Comparison of 95th Percentiles of the CDFs Across All Scenarios

CaO and cementitious backfills (EA#35a 35b, 77a, 77d, 83, 94c, and 94f) produced significant performance improvements. Plasma processing showed increased performance for both the E2 and E1E2 scenarios.

The qualitative performance rankings for brine transport scenarios in Figure 5-3 were assigned based on a combination of the results across the three brine transport scenarios. Based on the above discussion, Plasma Processing (EA#10) was given a "significant" rating because of its improvement in performance for all three brine transport scenarios. CaO backfill options (EA#77d, 83, and 94f) were given a "marginal" rating based on their improvements in both E2 and E1E2 release scenarios. All other EAs were rated generally unchanged from the baseline.

5.4.3 Public Health Risk

5.4.3.1 Public Health Risk Before Closure

Off-site public health risk from potential exposure to radionuclides and hazardous chemicals before WIPP closure was estimated for the baseline WIPP design and each EA. Calculations were performed to estimate added risks for both a hypothetical maximum exposed individual (MEI) and the collective off-site population. Relative risk indications among the EAs were consistent using either of these measures.

Total public health risk results for all EAs except those involving plasma waste processing were found to be quite close to the baseline predictions. Plasma waste processing (EA#10) public risk was found to be approximately four orders of magnitude greater than that for the other TRU processing options.

Public health risks at the generator sites were found to be relatively consistent across all scenarios (except plasma processing) due to the fact that processing risks added only marginally to the risk involved in waste handling and packaging found in the baseline alternative.

Public health risks at WIPP were higher, compared to the baseline, for scenarios requiring centralized waste processing at WIPP. This would be expected because the baseline has very minimal above ground waste handling at WIPP, while centralized processing will require extensive new treatment and disposal facilities at WIPP. This increased health risk at WIPP is partially offset, however, by lower risk at the generator sites, because the handling and packaging requirements for pre-treatment waste transfer are less than for direct placement at WIPP. The resulting total public risk across all sites for the centralized processing scenarios was generally found to be higher than for regionalized or 10-site processing. Based on the above findings, the results reported in Figure 5-3 show public health risk at the generator sites to be essentially unchanged for all EAs. Public health risks at WIPP are unchanged for the backfill only scenarios and marginally higher for all processing options, except plasma, which is significantly higher. These indicated increases in risk at WIPP are for the centralized processing options shown. For regionalized and decentralized cases, overall public health risks are marginally higher than that for the baseline.

Public health risk results are presented graphically in Figure 5-6 for all waste processing EAs. Backfill EAs (EA Nos. 33, 35a, 35b, 83, and 111) have the same risk as the baseline case. In this display, the total additional point estimate fatality risks from Tables 3-9 to 3-21 are summed

to form the midpoints shown and the high and low values estimated by assigning a range factor of 2 to the distribution of possible outcomes around the point estimate values.

5.4.3.2 Transportation Risk

Transportation risks reported in Chapter 3.5 included the potential consequences to both the transport crew and the public from both radiological and nonradiological sources. Differences among the EAs were found for radiological and hazardous chemical exposure risks. However, these risks were dominated by nonradiological/nonchemical risks and the results for total excess fatalities showed only minor variations from the baseline (less than 8%) across all EA scenarios. Thus, transportation risks prior to WIPP closure are indicated as unchanged from the baseline for all EAs in Figure 5-3.

Transportation risk results are presented graphically in Figure 5-7. In this display, the total additional point estimate fatality risks from Tables 3-42, 3-43, and 3-43 are summed to form the best estimate values shown.

5.4.3.3 Public Health Risk After Closure

Estimates of the impact of the EAs on predicted long-term public heath risk, presented in Chapter 3.1, mirror the compliance results discussed in section 5.4.2. However, the magnitude of long-term health risks predicted for the baseline and all EAs are exceedingly small. Therefore, long-term public health risks for all EAs are classified as essentially the same as the baseline.

5.4.4 Worker Health Risk

Worker risks were estimated for both facility workers directly involved in handling and processing TRU wastes and for co-located workers not directly involved with the wastes.

Health risks to both facility and on-site co-located workers from potential exposure to radionuclides and hazardous chemicals was estimated for the baseline WIPP design and each EA. Calculations were performed to estimate added risks for both a hypothetical MEI and the collective on-site population. Relative risk indications among the EAs were consistent using either of these risk measures. Risks to facility workers from standard industrial hazards involved in facility construction and operation were also calculated. For all scenarios, standard industrial risks outweighed risks from exposure to radionuclides or hazardous chemicals.

Total worker health risk results for all EAs involving all types of waste processing were found to be higher than for nonprocessing scenarios. These higher risks were incurred at the processing sites, that is the generators for distributed or regionalized processing and at WIPP for centralized processing. As a result, the centralized processing cases reported in Figure 5-3 show unchanged risks for the generator sites and significantly higher risks at WIPP for all processing options.

Worker health risk results are presented graphically in Figure 5-8. In this display, the total additional point estimate fatality risks from Tables 3-9 to 3-21 are summed to form the midpoints shown and the high and low values are estimated by assigning a range factor of 2 to the distribution of possible outcomes around the point estimate values.

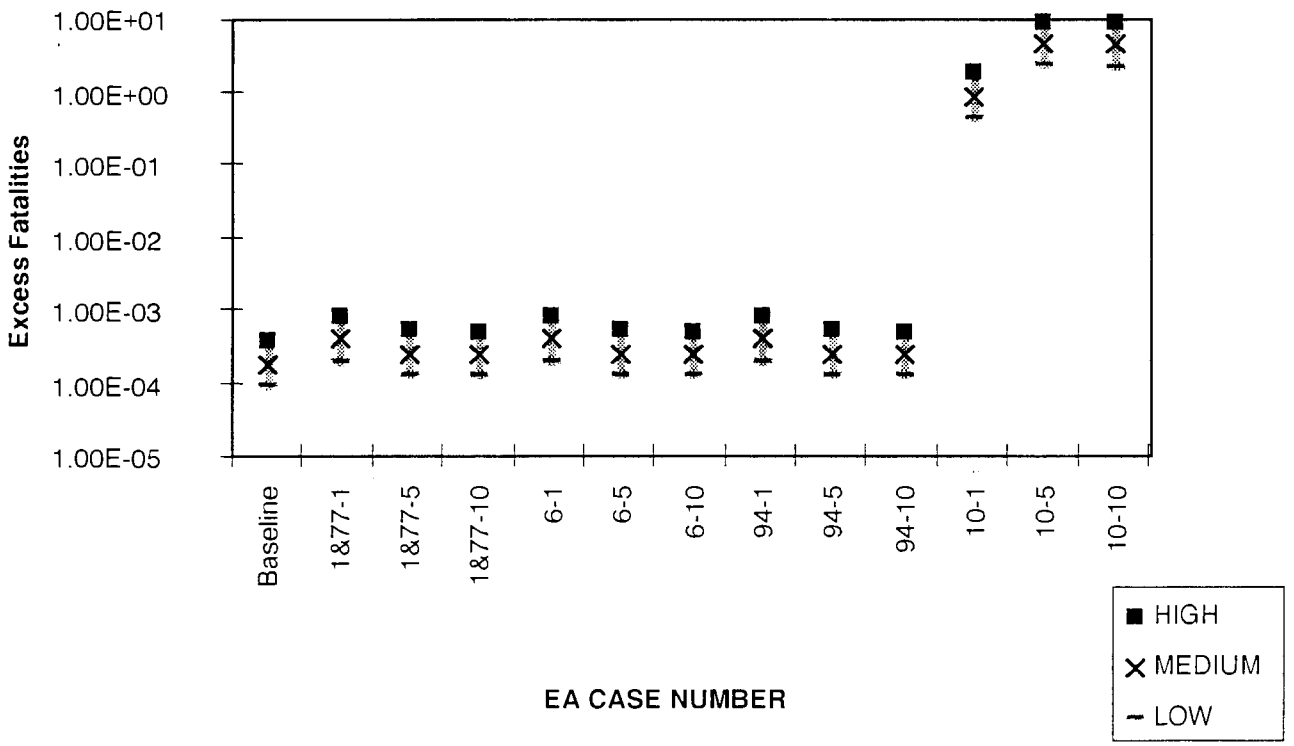

Figure 5-6
Offsite Public Risk

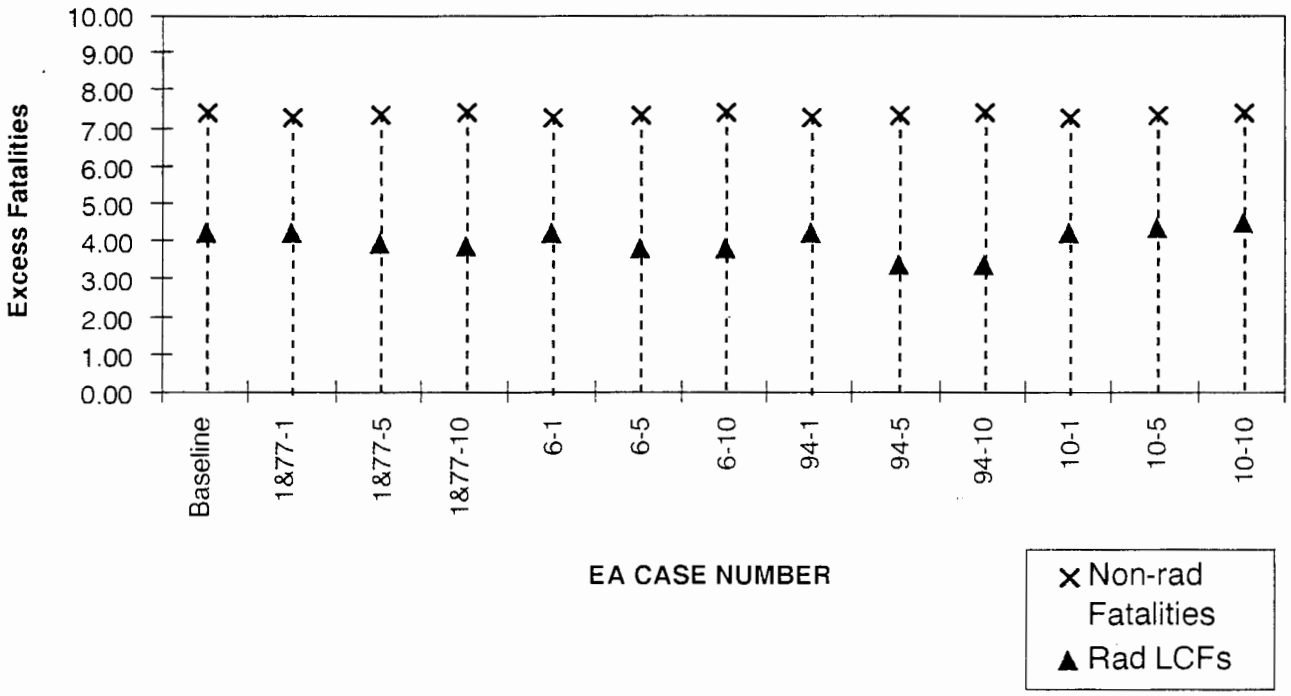

Figure 5-7
Transportation Risk

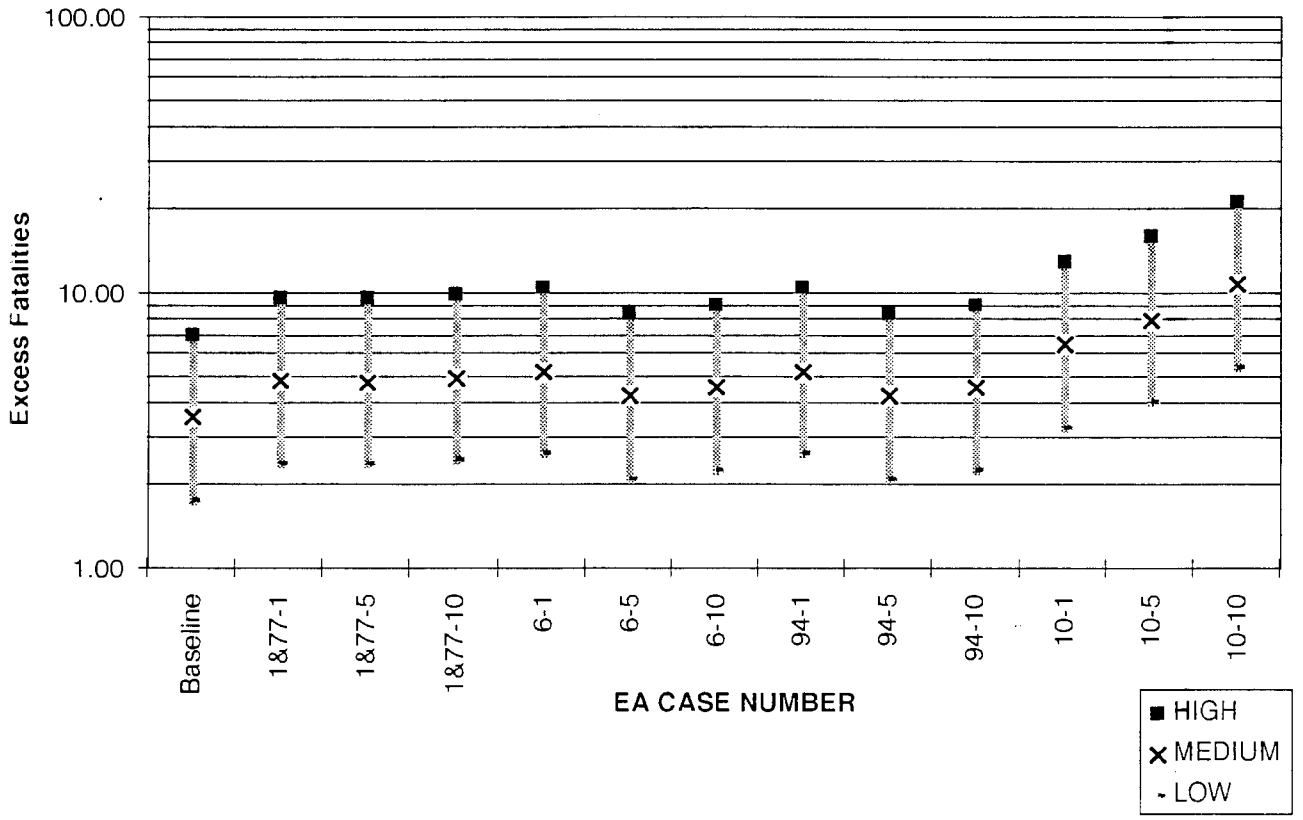

Figure 5-8
Worker Risk

5.4.5 Disposal System Cost

5.4.5.1 Waste Processing Cost

Estimated costs for waste processing summarized in Chapter 3.7.4.1.1 were found to increase substantially over the baseline for the more extensive processing methods. Overlaid on this trend, powerful economies of scale are predicted for accomplishing the processing centrally at WIPP rather than regionally or at each waste generation site. Centralized processing at WIPP, while potentially reducing overall costs, would result in significantly increased expenditures at WIPP. This shift is estimated to total between 15% and 34% of total processing costs or $500 million to $1.5 billion.

5.4.5.2 Transportation Cost

Waste transportation costs were found to be essentially the same for all centralized and backfill only EAs. These costs were estimated to be the same as the baseline centralized transportation costs. The decentralized and regionalized baseline costs were the same for the corresponding EAs except for the 94 series which had a significantly higher cost.

5.4.5.3 Waste Placement and Backfill Cost

Cost impacts for waste placement and backfill are estimated to total between $30 and $80 million or less than 1.5% of the total disposal system costs. The cost additions indicated on Figure 5-3 are incurred for the placement of wet cement backfills, while potential savings are shown for EA Nos. 1, 6, 10, 77 all, and 94 all processing options.

5.4.5.4 Total TRU Disposal System Cost

By combining the costs from the previous subsections, the combined influences of processing method and processing location on the total TRU waste disposal system costs can be seen. The impact of processing costs on the total TRU system is seen in Figure 5-9. This Figure shows the total TRU system costs, with uncertainty for all processing options performed centrally at WIPP. Supercompaction with backfill EAs (EA#77 all) and the shred and add clay alternatives (EA#94) show significant cost increases over the baseline. This conclusion is valid, however, only for the centralized processing results shown. Figure 5-10 shows that economies of scale are much stronger for the more aggressive processing methods than for the baseline. Thus, while centralized shred and add clay (EA#94) and plasma processing (EA#10) appear competitive with lesser processing alternatives, a decentralized approach for the same processes is significantly more costly.

5.4.6 Impact on Other Waste Programs

In general, only the additional waste processing activities associated with the WIPP EAs have the potential to impact other waste systems. The assessment of other waste system impacts reported in Chapter 3.8 found that all processing techniques evaluated, except plasma processing, significantly increased the LLW and LLMW volumes generated from the TRU waste disposal system. Plasma processing (EA#10) actually reduces somewhat the volumes of other waste from the base since all contaminated materials are recycled into the final product.

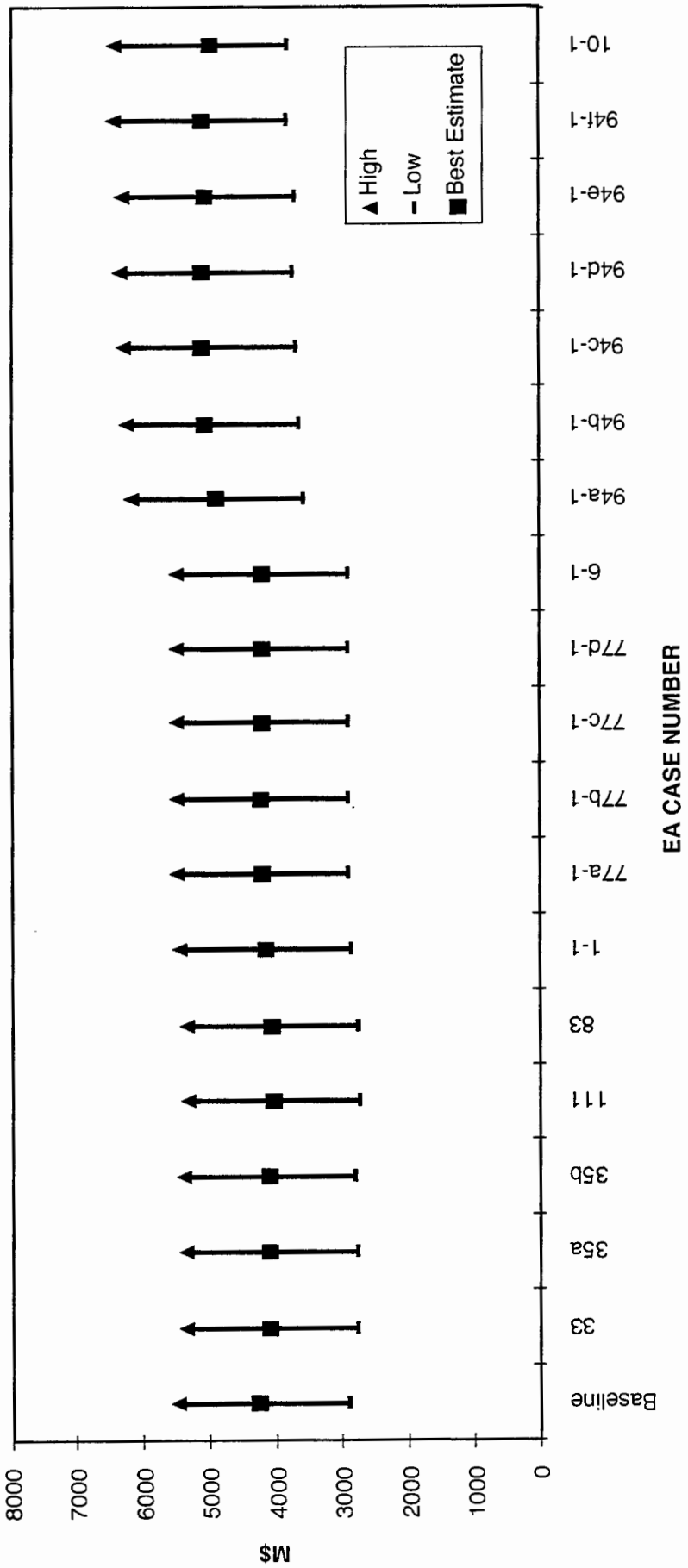

Figure 5-9

Impact of Processing Method on Total TRU Waste System Cost (for Centralized Processing Cases)

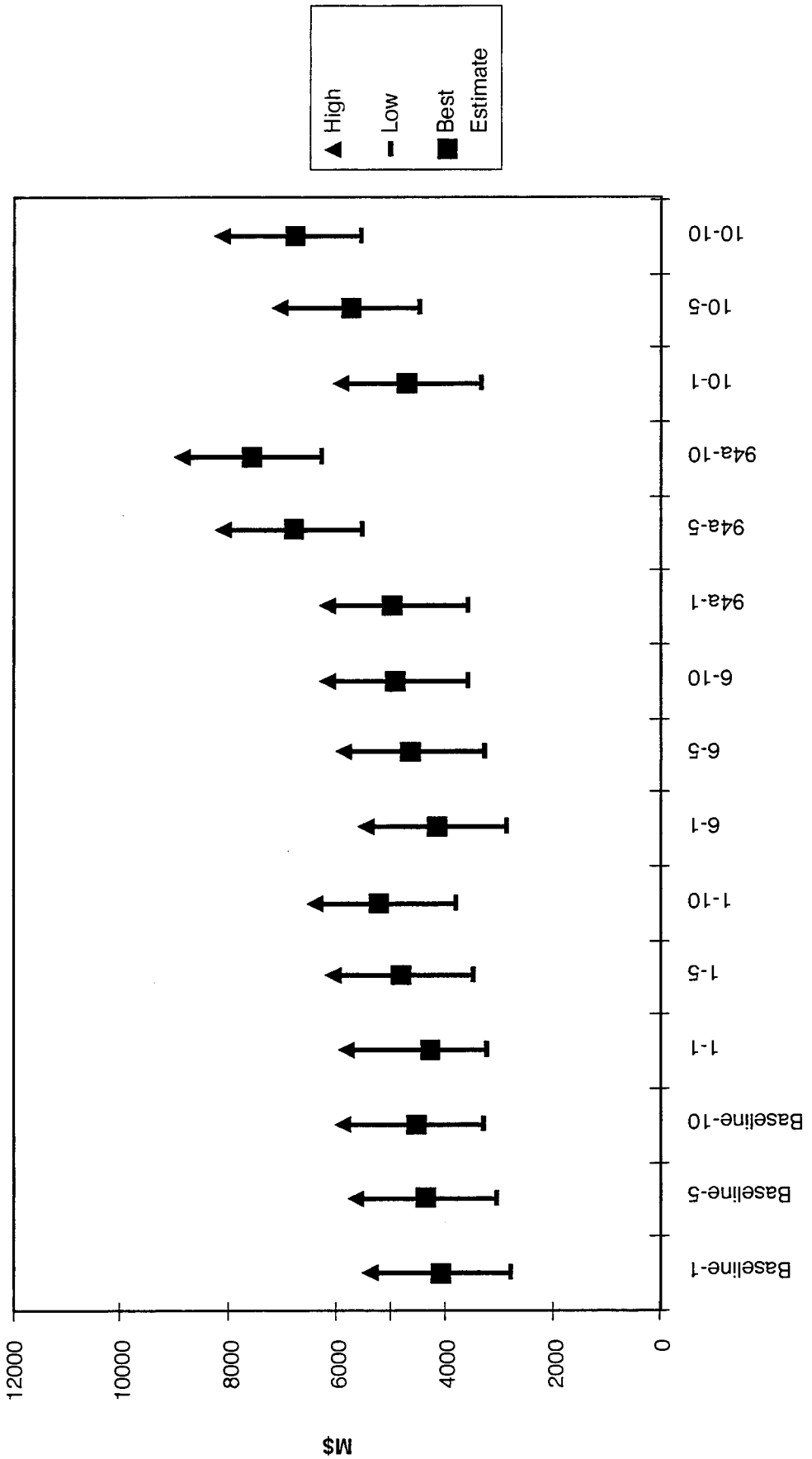

Figure 5-10
Impact Of Processing Location On Total TRU Waste System Cost

Even though the volumes of other waste produced from the TRU program would be increased by processing, the volumes generated were found to be small compared to those coming from other sources. Therefore, the impact on the overall volumes of LLW and LLMW requiring disposal is minor. Thus, the impacts on other waste disposal systems for processing alternatives #1, 6, 77 and 94 are indicated as marginal in Figure 5-3.

5.4.7 WIPP Schedule

Analyses of the potential impacts of EAs on the WIPP operating schedule presented in Chapter 3.7.2 show that the waste processing, placement and backfill activities included in any of the evaluated EAs can be accomplished within a 35 year operational life for WIPP. Underlying this broad conclusion, however, it is also acknowledged that the placement of wastes requiring additional processing may be delayed 12 years or more while the facilities needed to perform the processing are licensed and built. Because of this, the WIPP schedule impacts shown on Figure 5-3 for the first placement of wastes requiring additional processing are indicated to be significantly later than the baseline.

5.4.8 Waste Removal Capability

Table 3-31 summarizes the person-hour effort and associated risks for the hypothetical removal of wastes from WIPP for the baseline and all EAs. This evaluation shows that all EAs except those involving supercompaction of wastes, would require essentially the same effort to remove. EAs that limit the total emplacement volumes below the baseline case (EA#1 and 77 all), reduce the waste removal effort by approximately 50 percent. Thus, EAs 1 and 77a-d are shown as marginally better than the baseline in Figure 5-3.

5.4.9 Public Confidence

Chapter 3.6 documents the potential for selected waste processing and backfill actions to address public concerns expressed about long-term WIPP performance. The evaluated processing and backfill actions were found to have a possible impact on 31% to 42% of the public concerns registered to date. Potential concerns about additional public health risks or TRU disposal system costs prior to WIPP closure have not yet been investigated.

Because of the nature of public opinion and the qualitative analysis used to assess public confidence, measurement of public confidence in the performance of the disposal system was taken as the percentage of comments that could be addressed by an EA. The overall spread of the results were such that they do not lend to differentiation. Therefore, all EAs are indicated as unchanged from the baseline for this impact vector element (Figure 5-3).

5.5 Summary of Observations and Conclusions

Each EA was analyzed in the EACBS and the results are presented in Chapter 3. These results were integrated into a summary presented in Sections 5.1 through 5.4. comparing the results to the baseline. The following sections provide an overview of the limitations of the study and present some observations that were apparent from the evaluation of the results.

Engineered Alternatives analyzed in the EACBS can be categorized into the following three groups.

- Processing Alternatives—Processing alternatives (EA# 1,6 & 10) were analyzed for three processing scenarios, centralized, regionalized and decentralized. The three scenarios have inherent benefits and detriments independent of the EAs. In general, processing alternatives impact the entire waste disposal system, involving the generator/storage sites, waste transportation, other waste disposal systems, and the WIPP waste handling system. Processing alternatives have higher cost, risks and schedule delays than the baseline and backfill only EAs. Processing EAs have a marginal performance impact on the repository excluding plasma processing (EA# 10) which showed a significant increase in repository impact at the expense of having the highest potential risk of all EAs analyzed.

- Backfill Alternatives—Backfill alternatives (EA# 33, 35a, 35b, 83 & 111) have the least impact on the entire waste disposal system. The WIPP waste handling system is impacted; waste transportation, generator/storage sites, and other waste disposal systems are not affected. Cost, schedule radiation and chemical exposure are all similar to the baseline estimates. All backfill alternatives improve long-term disposal system performance.

- Combination Alternatives—Combination alternatives contain both multiple processing and/or backfill alternatives.[1] These alternatives (EA# 77a through 77d and 94a through 94f) have benefits and detriments associated with each alternative type. The overall costs and schedule impacts on the EAs are the highest of all and the transportation, worker and public risks (radiological, chemical accidental and incidental) are also the highest of the alternatives. The overall impact on long-term disposal system performance for combination EAs is comparable to the performance associated with the single backfill and processing alternatives.

5.5.1 Limitations of the Study

- The EAs considered in this study were restricted to waste treatment, backfill, and minor facility design modification such as changes in room dimensions to accommodate treated waste forms. The definition of an EA used in this study does not include processes that would reduce the probability of an intrusive event.

- Assessment of the frequency of human intrusion and any active or passive features that might impact the intrusion frequency were outside the scope of this evaluation. Since any changes affecting the frequency of intrusion would impact both the baseline and each EA equally, those effects cancel when the measures of relative effectiveness are calculated.

- No releases to the accessible environment of radionuclides are predicted to occur under undisturbed performance. Therefore, this analysis focused on EAs that could mitigate the consequences of human intrusion events.

- This study calculated releases to the Culebra; transport processes in the Culebra were not simulated as part of the long-term performance modeling. Since none of

[1]One combination EA contains "Enhanced Cementation of Sludges," a processing EA, that was not one of the individual processing EAs but will be detailed in the Combination EA section.

the EAs evaluated in this study affect those transport processes, the effects of those processes cancel when the measures of relative effectiveness are calculated.

- The actinide sorption properties of clays were not included in the EACBS analysis, impacting the results for EAs that included clay materials. The performance of these EAs may be higher all for radionuclide transport scenarios.

- The cost models used in the EACBS analysis originated in the EMPEIS. The accuracy of the results presented here are a function of the accuracy of the models.

5.5.2 Benefits and Detriments of Processing Alternatives

All EAs involving waste processing were analyzed for three separate scenarios related to where the waste would be processed and how many facilities are to be used. These scenarios have inherent benefits and determents that are independent of the EA. These benefits and determents are discussed below.

5.5.2.1 Centralized Cases

Detriment

The centralized case processes all waste at one processing facility, the WIPP. All generators retrieve, package and certify the waste prior to shipment to the one processing facility. The risks and costs for these operations are the same as baseline, however the overall worker and public risks are higher since all the waste is handled twice, once at the generator and again at the processing facility. Since a majority of the off-site risks are associated with opening of the drums, and the generators and processing facility both perform this operation, the off-site and on-site radiological and health risks are highest for the centralized scenario.

The centralized scenario has the highest potential to impact system wide disposal operations. Since one facility is used to process the waste, it must be fully operational on schedule and must operate as designed without failures. The processing facility is the bottleneck of the disposal system since delays impact the total disposal operation. Success or failure of the centralized processing scenario is dependent on the functional design, siting, permitting, construction, schedule, and functionality of one facility.

WIPP currently has no facilities or capabilities to process the waste. All centralized EAs will require the construction of new facilities to process the waste at WIPP.

Benefit

The centralized scenario has the lowest implementation cost to of the three scenarios (baseline not included). The cost of building one facility will be lower than building five or ten smaller facilities (Figure 5-10). With respect to the baseline, the generator/storage sites incur the same general costs as the baseline, and may be slightly lower. The EACBS assumed that less certification will be required to ship the waste to the processing facility since the shipped waste is not the final waste form emplaced in WIPP. The waste would not need to meet the WIPP WAC, only DOT transportation requirements.

The operational/construction incidental/fatalities are lower than the decentralized scenario and are either better or worse than the regionalized scenario, depending on the particular EA (baseline not included).

All transportation risks are unchanged from the baseline configuration; the transportation scenario for the centralized case is identical to the baseline.

5.5.2.2 Regionalized

Detriments

The regionalized scenario processes waste at five generator sites. The sites are selected such that a majority of the waste is presently stored at those sites, requiring only a small amount of waste to be transported from the other five generator/storage sites. The waste must be retrieved, packaged and certified prior to shipment to the five processing facilities. The five processing sites must also retrieve and handle their waste. Therefore, the total off-site and on-site risks are similar to but slightly higher than the baseline (Table 3-24). This is because the small quantities of waste from the sites shipped to the five processing facilities are handled twice.

For most of the EAs, the cost for the regionalized scenario is significantly higher than the centralized scenario and lower than the decentralized scenario (Figure 5-10). The cost differences between the EAs are due to the current capabilities of the generator storage sites; some sites will require minor modifications to process the waste for the minor processing EAs such as Shred and Compact (#77EAs).

Benefits

The regionalized processing scenario is more flexible than the centralized case. Since five facilities are required, the impact of failure at one facility will not severely impact the total disposal system operations. Failures at sites prior to completion operation of that facility may be overcome by the success of the other facilities; contingencies could include designs that are capable of processing more than would be required for five sites. Schedule impacts and processing rates can be adjusted to compensate for deficiencies at other facilities.

The operational/construction indecent/fatalities are lower than the decentralized scenario and are better or worse than the centralized scenario depending on the particular EA (baseline not included).

Since most of the waste is processed at the five sites, and most processing modifies the waste into a safer form for transportation, a reduction in transportation chemical risk is gained. The radiation risks are assumed to be the same as the baseline except for EAs that reduce the overall waste volume shipped to WIPP.

5.5.2.3 Decentralized

Detriments

The decentralized scenario builds and operates ten processing facilities at the major sites. The cost of this scenario is the highest of all three. The EACBS takes into account the current capabilities of the sites and factors in cost reductions where site capabilities and existing

structures for the processing facilities can be utilized. However, not all EAs can utilize current site facilities or capabilities.

The operational/construction indecent/fatalities are generally higher than both the centralized and regionalized scenarios (baseline included).

Benefits

A reduction in the transportation radiation and chemical risks for accident scenarios occurs for most processing EAs because the waste form has been modified. Since all waste is processed prior to shipment to WIPP, all accident scenarios occur with the improved waste form. This reduction is related to the EAs final waste characteristics and is dependent on the particular EA.

5.5.3 Conclusion

The conclusions of this report do not recommend, select or reject EAs based on the results of the EACBS analysis. The results and observations are intended to be used by a DOE decision maker for consideration regarding the potential use of EAs at WIPP for additional assurance. If a decision is made to select an EA for WIPP, it will be made with full system wide knowledge and best available information for which the EACBS provides only a part. The risk cost benefits and overall disposal system impacts must be considered along with the potential benefits if an EA is selected. The EACBS was conceived to provide information regarding these impacts and benefits.

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APPENDIX A
INITIAL ENGINEERED ALTERNATIVES SCREENING CANDIDATES

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TABLE A-1
INITIAL ENGINEERED ALTERNATIVES SCREENING CANDIDATES

The individual Engineered Alternatives (EA) found in the 1991 Engineered Alternatives Task Force (EATF) Final Report (DOE, 1991), #1 through #64, are as follows:

1	Compact Waste
2	Incinerate and Cement
3	Incinerate and Vitrify
4	Wet Oxidation
5	Shred and Bituminize
6	Shred and Compact
7	Shred and Cement
8	Shred and Polymer Encapsulation
9	Shred add Salt and Compact
10	Plasma Processing
11	Melt Metals
12	Add Salt Backfill
13	Add other Sorbents
14	Add Gas Suppressant
15	Shred and Add Bentonite
16	Acid Digestion
17	Sterilization
18	Add Copper Sulfate
19	Add Gas Getters
20	Add Fillers
21	Segregate Waste Forms
22	Decontaminate Metals
23	Change Waste Generation Process
24	Add Anti-Bacterial Material
25	Accelerate Waste Digestion Process
26	Alter Corrosion Environment
27	Alter Bacterial Environment in WIPP
28	Transmutation of Radionuclides
29	Vitrify Sludges
30	Salt Backfill Only
31	Salt Backfill Plus Gas Getters
32	Compact Backfill
33	Salt Plus Brine Sorbents
34	Preformed Compacted Backfill
35	Grout Backfill
36	Bitumen Backfill
37	Add Gas Suppressant
38	Minimize Space Around Waste Stack
39	Segregate Waste in WIPP
40	Decrease Amount of Waste per Room
41	Emplace Waste and Backfill Simultaneously
42	Selected Vegetive Uptake

TABLE A-1 (CONTINUED)
INITIAL ENGINEERED ALTERNATIVES SCREENING CANDIDATES

43 Brine Isolating Dikes
44 Raise Waste Above the Floor
45 Brine Sump and Drains
46 Gas Expansion Volume
47 Seal Repository Room Walls
48 Vent Facility
49 Ventilate Facility
50 Add floor of Brine Sorbents
51 Change Mine Extraction Ratio
52 Change Room Configurations
53 Seal Individual Rooms
54 Two Level Repository
55 Monument Forest Over Repository
56 Monument Covering the Entire Repository
57 Buried Steel Plate Over the Repository
58 Artificial Surface layer Over the Repository
59 Add Marker Dye to Strata
60 Drain Castile Reservoir
61 Grout Culebra Foundation
62 Increase Land Withdrawal Area
63 Change Waste Container Shape
64 Change Waste Container Material

The EATF Combination EAs, #65 through #79

65 EATF Baseline—As received with salt backfill.
66 EATF Alternative 1—Shred and cement organics and inorganics only, salt backfill.
67 EATF Alternative 2—Cement sludges, shred and cement organics and inorganics, salt backfill.
68 EATF Alternative 3—Cement sludges, shred and cement organics and inorganics, grout backfill.
69 EATF Alternative 4—Cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.
70 EATF Alternative 5—Cement sludges, incinerate and cement organics, shred and cement inorganics, grout backfill.
71 EATF Alternative 6—Vitrify sludges, incinerate and vitrify organics, melt metals into TRU waste ingots, salt backfill.
72 EATF Alternative 7—Vitrify sludges, incinerate and vitrify organics, melt metals into TRU waste ingots, grout backfill.
73 EATF Alternative 8—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, salt backfill, non-ferrous container.

TABLE A-1 (CONTINUED)
INITIAL ENGINEERED ALTERNATIVES SCREENING CANDIDATES

74 EATF Alternative 9—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, grout backfill, non-ferrous container.

75 EATF Alternative 10—Remove metals and decontaminate by vibratory finishing and eliminate from the WIPP inventory, no backfill, nickel alloy rectangular container, 10x31x188 rooms.

76 EATF Alternative 11—Supercompact organics and inorganics, grout backfill, monolayer of 2000 drums in a 6x33x300 room.

77 EATF Alternative 12—Supercompact organics and inorganics, grout backfill, monolayer of 2000 drums, in a 6x33x300 room.

78 EATF Alternative 13—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag, and metals are eliminated from the WIPP, no backfill, non-ferrous rectangular containers, minimize space around waste stack in a 10x31x188 room.

79 EATF Alternative 14—Supercompact organics, and inorganics, salt aggregate backfill, compartmentalize waste, 2000 drums per room, salt dikes and waste separation.

The Systems Prioritization Methodology-II (SPM-2) original EAs (SNL/NM, 1995), #80 through #99, are as follows:

80 SPM-Baseline

81 SPM-A Salt backfill 50% filling efficiency

82 SPM-B Salt/Bentonite backfill 50-50 mix, 50% filling efficiency

83 SPM-C Salt/pH buffer backfill some amount of CaO

84 SPM-D Cement grout backfill 100% filling efficiency

85 SPM-E Salt/Grout backfill 100% efficiency

86 SPM IT-1 Shred and cement organics and inorganics, salt backfill 50% filling efficiency

87 SPM IT-2 Cement sludges, shred and cement organics and inorganics, salt backfill 50% filling efficiency, nickel alloy container.

88 SPM IT-3 Cement sludges, shred and cement organics and inorganics, cement grout 100% filling efficiency.

89 SPM IT-4 Cement sludges, shred and cement organics and inorganics, salt/pH buffer backfill with some amount of CaO.

90 SPM IT-5 Cement sludges, shred and compact organics and inorganics, salt backfill with 50% filling efficiency, 200 drum monolayer, 6x33x300 room.

91 SPM IT-6 Cement sludges, shred and compact organics and inorganics, cement grout backfill 100% filling efficiency, 2000 drum monolayer, 6x33x300 room.

92 SPM IT-7 Cement sludges, compact organics and inorganics, salt/pH buffer backfill with some amount of CaO, 2000 drums monolayer, 6x33x300 room.

93 SPM IT-8 Cement sludges, shred and add bentonite to organics and inorganics, salt backfill 50% filling efficiency.

94 SPM IT-9 Cement sludges, shred and add bentonite to organics and inorganics, cement grout backfill 100% efficiency.

95 SPM IT-10 Decontaminate metals, nickel alloy container, cement grout backfill 100% filling efficiency.

TABLE A-1 (CONTINUED)
INITIAL ENGINEERED ALTERNATIVES SCREENING CANDIDATES

96 SPM EATF-8 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, salt backfill, non-ferrous container.

97 SPM EATF-9 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, grout backfill, non-ferrous container.

98 SPM DOE-1 Passive markers—no specific scenario given reduce human intrusion probability parameters.

99 SPM DOE-2 Compartmentalization of waste—various unspecified scenarios.

The individual EAs found in Title 40, Code of Federal Regulations (CFR), Part 194 (40 CFR 194) (EPA, 1995), #100 through #109, are as follows:

100 194—Cementation
101 194—Shredding
102 194—Supercompaction
103 194—Incineration
104 194—Vitrification
105 194—Improved waste containers
106 194—Grout and bentonite backfill
107 194—Metal Melting
108 194—Alternative configuration of waste emplacement
109 194—Alternative disposal system dimensions

The individual EAs added by the EA Screening Working Group during the screening process are as follows:

110 Enhanced solidification of sludges
111 Clay based backfill

TABLE A-2

INITIAL ENGINEERED ALTERNATIVE CANDIDATE LIST

EAs considered in the 1991 EATF
EA #1 – #79

Alternative Number	Title
1	Compact Waste
2	Incinerate and Cement
3	Incinerate and Vitrify
4	Wet Oxidation
5	Shred and Bituminize
6	Shred and Compact
7	Shred and Cement
8	Shred and Polymer Encapsulation
9	Shred add Salt and Compact
10	Plasma Processing
11	Melt Metals
12	Add Salt Backfill
13	Add other Sorbents
14	Add Gas Suppressant
15	Shred and Add Bentonite
16	Acid Digestion
17	Sterilization
18	Add Copper Sulfate
19	Add Gas Getters
20	Add Fillers
21	Segregate Waste Forms
22	Decontaminate Metals
23	Change Waste Generation Process
24	Add Anti-Bacterial Material
25	Accelerate Waste Digestion Process
26	Alter Corrosion Environment
27	Alter Bacterial Environment in WIPP
28	Transmutation of Radionuclides
29	Vitrify Sludges
30	Salt Backfill Only
31	Salt Backfill Plus Gas Getters
32	Compact Backfill
33	Salt Plus Brine Sorbents
34	Preformed Compacted Backfill
35	Grout Backfill
36	Bitumen Backfill
37	Add Gas Suppressant
38	Minimize Space Around Waste Stack
39	Segregate Waste in WIPP
40	Decrease Amount of Waste per Room
41	Emplace Waste and Backfill Simultaneously
42	Selected Vegetive Uptake
43	Brine Isolating Dikes

TABLE A-2 (CONTINUED)

INITIAL ENGINEERED ALTERNATIVE CANDIDATE LIST

EAs considered in the 1991 EATF
EA #1 – #79 (Continued)

Alternative Number	Title
44	Raise Waste Above the Floor
45	Brine Sump and Drains
46	Gas Expansion Volumes
47	Seal Repository Room Walls
48	Vent Facility
49	Ventilate Facility
50	Add floor of Brine Sorbents
51	Change Mine Extraction Ratio
52	Change Room Configurations
53	Seal Individual Rooms
54	Two Level Repository
55	Monument Forest Over Repository
56	Monument Covering the Entire Repository
57	Buried Steel Plate Over the Repository
58	Artificial Surface layer Over the Repository
59	Add Marker Dye to Strata
60	Drain Castile Reservoir
61	Grout Culebra Foundation
62	Increase Land Withdrawal Area
63	Change Waste Container Shape
64	Change Waste Container Material
65	EATF Baseline—As Received with Salt Backfill
66	EATF Alternative 1—Shred and cement organics and inorganics only, salt Backfill.
67	EATF Alternative 2—Cement Sludges, shred and cement organics and inorganics, salt Backfill.
68	EATF Alternative 3—Cement sludges, shred and cement organics and inorganics, grout backfill.
69	EATF Alternative 4—Cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.
70	EATF Alternative 5—Cement sludges, incinerate and cement organics, shred and cement inorganics, grout backfill.
71	EATF Alternative 6—Vitrify sludges, incinerate and vitrify organics, melt metals into TRU waste ingots, salt backfill.
72	EATF Alternative 7—Vitrify sludges, incinerate and vitrify organics, melt metals into TRU waste ingots, grout backfill.
73	EATF Alternative 8—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, salt backfill, non-ferrous container.
74	EATF Alternative 9—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, grout backfill, non-ferrous container.

TABLE A-2 (CONTINUED)

INITIAL ENGINEERED ALTERNATIVE CANDIDATE LIST

EAs considered in the 1991 EATF
EA #1 – #79 (Continued)

Alternative Number	Title
75	EATF Alternative 10—Remove metals and decontaminate by vibratory finishing and eliminate from the WIPP inventory, no backfill, nickel alloy rectangular container, 10X31X188 rooms.
76	EATF Alternative 11—Supercompact organics and inorganics, grout backfill, monolayer of 2000 drums in a 6X33X300 room.
77	EATF Alternative 12—Supercompact organics and inorganics, grout backfill, monolayer of 2000 drums, in a 6X33X300 room.
78	EATF Alternative 13—Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag, and metals are eliminated from the WIPP, no backfill, non-ferrous rectangular containers, minimize space around waste stack in a 10X31X188 room.
79	EATF Alternative 14—Supercompact organics, and inorganics, salt aggregate backfill, compartmentalize waste, 2000 drums per room, salt dikes and waste separation.

EAs initially considered in the SPM
EA #80 - #99

Alternative Number	Title
80	SPM-Baseline
81	SPM-A Salt backfill 50% filling efficiency
82	SPM-B Salt/Bentonite backfill 50-50 mix, 50% filling efficiency
83	SPM-C Salt/pH buffer backfill some amount of CaO
84	SPM-D Cement grout backfill 100% filling efficiency
85	SPM-E Salt/Grout backfill 100% efficiency
86	SPM IT-1 Shred and cement organics and inorganics, salt backfill 50% filling efficiency
87	SPM IT-2 Cement sludges, shred and cement organics and inorganics, salt backfill 50% filling efficiency, nickel alloy container.
88	SPM IT-3 Cement sludges, shred and cement organics and inorganics, cement grout 100% filling efficiency.
89	SPM IT-4 Cement sludges, shred and cement organics and inorganics, salt/pH buffer backfill with some amount of CaO.
90	SPM IT-5 Cement sludges, shred and compact organics and inorganics, salt backfill with 50% filling efficiency, 200 drum monolayer, 6X33X300 room.
91	SPM IT-6 Cement sludges, shred and compact organics and inorganics, cement grout backfill 100% filling efficiency, 2000 drum monolayer, 6X33X300 room.
92	SPM IT-7 Cement sludges, compact organics and inorganics, salt/pH buffer backfill with some amount of CaO, 2000 drums monolayer, 6X33X300 room.

TABLE A-2 (CONTINUED)

INITIAL ENGINEERED ALTERNATIVE CANDIDATE LIST

EAs initially considered in the SPM
EA #80 – #99 (Continued)

Alternative Number	Title
93	SPM IT-8 Cement sludges, shred and add bentonite to organics and inorganics, salt backfill 50% filling efficiency.
94	SPM IT-9 Cement sludges, shred and add bentonite to organics and inorganics, cement grout backfill 100% efficiency.
95	SPM IT-10 Decontaminate metals, nickel alloy container, cement grout backfill 100% filling efficiency.
96	SPM EATF-8 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, salt backfill, non-ferrous container.
97	SPM EATF-9 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, grout backfill, non-ferrous container.
98	SPM DOE-1 Passive markers- no specific scenario given reduce human intrusion probability parameters.
99	SPM DOE-2 Compartmentalization of waste - various unspecified scenarios.

EAs Listed in 40 CFR 194
EA #100 – #109

Alternative Number	Title
100	194—Cementation
101	194—Shredding
102	194—Supercompaction
103	194—Incineration
104	194—Vitrification
105	194—Improved Waste Containers
106	194—Grout and Bentonite Backfill
107	194—Metal Melting
108	194—Alternative Configuration of Waste Emplacement
109	194—Alternative Disposal System Dimensions

TABLE A-3

FIRST PRIORITIZED EA LIST

ID Number	Description
# 10	Plasma Processing of All Waste
# 12	Salt Backfill Around Drums and Waste Stack
# 33	Salt Plus Clay Backfill
# 35	Salt Aggregate Grout Backfill Around Drums
# 53	Seal Individual Rooms
# 60	Depressurize Castile Reservoir
# 63	Change Waste Container Shape
# 74	Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt aggregate grout backfill, change container material.
# 75	Decontaminate surface of metallic wastes for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
# 83	Salt backfill with CaO
# 89	Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.
# 94	Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.
# 95	Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.
# 111	Clay Based Backfill

TABLE A-4

INITIAL PRIORITIZED LIST CHANGE JUSTIFICATIONS

EA#	Added, Removed, or Not Changed from Initial List	Description and Modifications	Basis for Modification, Addition, or Removal
1	Added	Supercompact Organics and Inorganics	High Feasibility, Lower Permeability, Increases shear strength
6	Added	Shred and Compact Organics and Inorganics	High Feasibility, Lower Permeability, Increases shear strength
10	No Change	Plasma Processing of all Waste	
12	Removed	Salt Backfill	No Benefit to Disposal System
33	No Change	Salt plus Clay backfill. *Examine using sand as the filler material instead*	Information to-date suggests that sand interacts more effectively with clay that does salt.
35	No Change	Salt Aggregate Grout Backfill Around Drums. *Perform an additional assessment with a cementitious grout.*	Allows the CAO to assess any additional benefits from using a cementitious grout.
53	Removed	Seal individual Rooms	Contrary to No Migration Determination
60	Removed	Depressurize the Castile Formation	Extra Holes and Assurance system is depressurized to 10K years not Justified (may enhance lateral flow from the repository)
63	Removed	Change Waste Container Shape	With Respect to Solubility and Shear Strength, adds No Benefit
74	Removed	Vitrify Sludges, shred and vitrify organics, melt metals and remove actinides, Salt/Agg Grout BF, Change Container Mat'l	Gas Generation Reduction EA

TABLE A-4 (CONTINUED)

INITIAL PRIORITIZED LIST CHANGE JUSTIFICATIONS

EA#	Added, Removed, or Not Changed from Initial List	Description and Modifications	Basis for Modification, Addition, or Removal
75	Removed	Decon Metals for LLW, no BF, change Container Mat'l and shape, 10x31x188 room	Gas Generation Reduction EA
77	Added	Supercompact Organics and inorganics, Salt Aggregate Grout Backfill, Monolayer of 2000 Drums in a 6x33x300 foot room. *Add assessments with clay-based backfill, sand/clay backfill, and high percentage CaO Backfill.*	Allows the CAO to assess increases in benefit for several types of backfill.
83	No Change	Salt Backfill with CaO.	CaO acts as a pH Buffer to decrease actinide solubility. The salt acts as a filler. the more CaO is emplaced the more effective the EA is at affecting solubility.
89	Removed	Enhance cement sludges, S&C orgs and inorgs, CaO BF	Very Similar to 94 which is a Final EA
94	No Change	Enhanced Cementation of Sludges, Shred and add Clay-Based Material to Organics and Inorganics. *Examine this alternative alone and with all combinations of backfills.*	Enables CAO to assess any additional benefit from adding backfill to the rooms when used in conjunction with the waste treatment activities.

TABLE A-4 (CONTINUED)

INITIAL PRIORITIZED LIST CHANGE JUSTIFICATIONS

EA#	Added, Removed or Not Changed from Initial List	Description and Modifications	Basis for Modification, Addition, or Removal
95	Removed	Decon Metals for LLW, Salt/Agg Grout BF, change Container shape	Gas Generation Reduction EA
111	No Change	Clay-Based Backfill	

APPENDIX B
ENGINEERED ALTERNATIVE PASS LIST

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ENGINEERED ALTERNATIVE PASS LIST

The following is a listing of Engineered Alternatives (EA) that passed the screening process. The listing includes the definition of the individual EA and the Engineered Alternatives Screening Working Group (EASWG) comments justifying assignment of the EA to the Pass List.

1 Supercompact Everything Except Sludges

All wastes except sludges are processed by first pre-compacting the waste into 35-gallon drums; the "pucks" are then supercompacted at forces in excess of 2,200 tons and packed for disposal in 55-gallon drums. The volume reduction is approximately 3:1.

The EASWG concluded that this EA met the definition and would be considered further. Off-the-shelf technology is available. Widely used for low-level waste (LLW). Transuranic (TRU) waste supercompacted at Rocky Flats Plant (RFP). Resource Conservation and Recovery Act (RCRA) Part B permitting in interim status at RFP.

2 Incinerate and Cement Solid Organic Waste

Solid organics are incinerated, and the resulting ash is cemented into an ash/cement matrix.

The EASWG concluded that this EA met the definition and would be considered further. Technology mature for hazardous constituents some engineering is still required for TRU waste. Commonly used for LLW—Japan, France, United States. No TRU waste incinerator operating. Permitted incinerators at Los Alamos National Laboratories for hazardous materials; moratorium on new hazardous materials incinerators; major effort required to permit future incinerators.

3 Shred and Vitrify Solid Organic Waste

Solid organics are incinerated and fused into a glass matrix by vitrifying. Vitrification melts/fuses the waste; silica may be added prior to melting.

The EASWG changed the title from "Incinerate and Vitrify" to "Shred and Vitrify" because the current vitrification technology does not require incineration, only shredding. The EASWG also concluded that this EA met the EA definition and would be considered further. Various vitrification technologies have been demonstrated related to plasma melting. France's (Marcoule Facility) is currently making radioactive glass logs. Not yet permitted for TRU waste.

4a Wet Oxidation and Cement Solid Organic Waste

Solid organics are oxidized into an ash residue. Wet oxidation involves the accelerated oxidation of waste in the presence of heated water, vapor, or steam, with the intent to chemically degraded the waste. The ash residue is cemented into an ash/cement matrix.

The EASWG concluded that wet oxidation alone did not meet the definition, because the resulting waste must be solidified to meet the Waste Acceptance Criteria (WAC). Two common solidification techniques were added to this EA to meet the definition. Wet oxidation technology demonstrated at bench scale, questions exist regarding ability to

handle all organic wastes. Currently used to treat non-radioactive organics in water. Technology never permitted but believed possible.

4b Wet Oxidation and Vitrify Solid Organic Waste

Solid organics are oxidized into an ash residue. Wet oxidation involves the accelerated oxidation of waste in the presence of heated water, vapor, or steam, with the intent to chemically degrade the waste. The ash residue is vitrified into a fused glass. Silica may be added to the residue prior to melting/fusing.

The EASWG concluded that wet oxidation alone did not meet the definition, because the resulting waste must be solidified to meet the WAC. Two common solidification techniques were added to this EA to meet the definition. Same technical and regulatory feasibility comments as EA #4a.

5 Shred and Bituminize Everything Except Sludges

All waste except sludges are mechanically shredded. A volume reduction ratio of 1.2:1 is assumed for shredding only. Bitumen is mixed into the waste, filling the void space in the waste drum.

The EASWG concluded that this EA met the definition and would be considered further. Technology is mature but not applied to TRU waste; development work required. Used in Japan for radioactive resins and sludges. This technology has not been permitted; however, the EASWG believes obtaining a permit is possible.

6 Shred and Compact Everything Except Sludges

All waste except sludges are mechanically shredded. A volume reduction ratio of 1.2:1 is assumed for shredding only. The shredded waste is compacted in the drum. Supercompaction is not used.

The EASWG concluded that this EA met the definition and would be considered further. (Not supercompaction—low pressure compaction.) Commercial nuclear plants routinely use compaction technology for LLW. Not currently being done for TRU nor demonstrated. Off-the-shelf equipment available. Permitted for LLW but not TRU, highly probable permit obtainable.

7 Shred and Cement Everything Except Sludges

All waste except sludges are mechanically shredded. A volume reduction ratio of 1.2:1 is assumed for shredding only. "Wet" cement is added to the waste creating a solid homogeneous waste/cement matrix.

The EASWG concluded that this EA met the definition and would be considered further. Grouting technology demonstrated at Hanford, believed used in German application for TRU type waste. Permitting of cementation of TRU sludges under interim status at U.S. Department of Energy (DOE) facilities. Permitting problems not expected by EASWG.

8 Shred and Cold Polymer Encapsulate Everything Except Sludges

All waste except sludges are mechanically shredded. A volume reduction ratio of 1.2:1 is assumed for shredding only. The shredded waste is encapsulated with a polymer.

The EASWG concluded that this EA met the definition and would be considered further. Commercial technology in use that polymerizes LLW. Not demonstrated for TRU waste. Technology is available off the shelf. Permitting problems are not expected by the EASWG.

9 Shred, add Salt and Compact Everything Except Sludges

All waste except sludges are mechanically shredded. A volume reduction ratio of 1.2:1 is assumed for shredding only. Shredded waste is mixed with crushed salt and compacted in the drum. Supercompaction is not used.

The EASWG concluded that this EA met the definition and would be considered further. Technology is available off the shelf; however, process not in use for TRU waste. Compaction of LLW currently permitted and performed. Permitting problems not expected by the EASWG.

10 Plasma Processing of All Waste

All waste is subjected to a high temperature plasma arc eliminating organics and melting metals and sludges into a solid form. The products of this process are vitrified glasses and solid metals.

The EASWG concluded that this EA met the definition and would be considered further. Centrifugal and fixed hearth technologies demonstrated with non-TRU materials, Centrifugal technology used to extract exotic metals in industrial applications. Pilot test completed for the Idaho National Engineering Laboratory (INEL) Pit 9 application with simulated waste. Design of a full-scale unit is approximately 90% complete at INEL (Lockheed) Research and development permitted. Not permitted for TRU waste. EASWG expects permit obtainable.

11a Melt Metals into TRU waste ingots

All metals are melted (sludges and combustibles are excluded) into an ingot and disposed of at the Waste Isolation Pilot Plant (WIPP). The size and weight of the final product are within transportation limits.

The EASWG decided to separate this EA into two categories: a) melt metals and emplace all at WIPP, and b) melt metals, partition radionuclides in slag and remove, cast metal, and dispose of as LLW. The EASWG determined that this separation allows for greater flexibilities in the analysis. The EASWG concluded that both EAs met the definition and would be considered further. Technology is mature but not applied to TRU wastes, development work required. EASWG believes technology is transferable to TRU waste uses. Technology not permitted for TRU waste, EASWG expects permits are obtainable.

11b Melt Metals with Frit to Partition Actinides

All metals are melted (sludges and combustibles are excluded). Glass Frit is added to the molten metal partitioning the radionuclides within the slag. The slag is removed, solidified, and disposed of at the WIPP. The metal is cast into ingots and disposed of as LLW at a LLW facility. The size and weight of the ingot are within transportation limits.

The EASWG decided to separate this EA into two categories: a) melt metals and emplace all at WIPP, and b) melt metals, partition radionuclides in slag and remove, cast metal, and dispose of as LLW. The EASWG determined that this separation allows for greater flexibilities in the analysis. The EASWG concluded that both EAs met the definition and would be considered further. Technology is mature but not applied to TRU wastes, development work required. EASWG believes technology is transferable to TRU waste uses. Potential to recycle waste containers/container materials. Technology not permitted for TRU waste; impacts LLW disposal facilities.

12 Salt Backfill Around Drums and Waste Stack

A crushed salt backfill is placed around and between the waste containers, filling the void space within the rooms. A 50% filling efficiency is assumed.

The EASWG concluded that this EA met the definition and would be considered further. The technology of pneumatic backfilling was demonstrated at WIPP. Can also be as simple as a pile of salt and a shovel. No regulatory concerns were noted. EASWG believes no permit is required for this technology.

15 Shred, Add Clay Based Material to Everything Except Sludges

All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. Engineered clay grout is added to the shredded waste removing the void space within the waste drum. Two forms of clays are considered, swelling (smectites) and non-swelling (illite/kaolinite).

The EASWG decided to change the title of this EA to allow for various types of clays to be considered in the analysis. The EASWG concluded that this EA met the definition and would be considered further. Process is not being done for TRU waste. Equipment is available off-the-shelf. EASWG believes permits are obtainable.

16a Acid Digestion and Cementation of Solid Organics

Solid organics are dissolved in a strong acidic solution that is subsequently neutralized and precipitated, resulting in a reduced volume sludge waste form, which is solidified into a cement/precipitate matrix.

The EASWG concluded that acid digestion alone was not an EA; acid digestion must be followed by a stabilization process. Acid digestion was deleted and acid digestion with solidification was added. The EASWG determined that this EA meet the definition and should be considered further. This technology was used to process approximately 5,000 kg TRU waste between 1972 and 1980 at Hanford using sulfuric acid. Current bench-scale technology at Savanna River Site uses an acid process at 180°C and 15 psig. Belgium recovers Pu with sulfuric acid. Development of processes waste and residue stabilization systems, spent acid treatment, off-gas systems, is required. Cementation of resulting sludge has not been demonstrated. Technology not permitted. Permit issues associated with disposition of hazardous constituents. EASWG believed the technology may be permitted; however, not enough information is available to justify rejection.

16b Acid Digestion and Vitrification of Solid Organics

Solid organics are dissolved in a strongly acidic solution that is subsequently neutralized and precipitated, resulting in a reduced volume sludge waste form, which is vitrified into a fused glass. Silica may be added prior to vitrification.

The EASWG concluded that Acid Digestion alone was not an EA; acid digestion must be followed by a stabilization process. Acid digestion was deleted and acid digestion with solidification was added. The EASWG determined that this EA met the definition and should be considered further. The Technology and regulatory feasibility is identical to #16a with vitrification consideration #3.

19 Add Lime to Solid Organic Waste

Lime (CaO) is added to solid organics within a drum.

The EASWG changed the title of this EA from "Add Gas Getters" to "Add Lime to Solid Organic Waste". The new title was changed to better describe the EA. The EASWG concluded that this EA met the definition and would be considered further. This EA is a material handling process, no treatment technology is involved. Aluminum would have to be removed from the waste prior to the addition of lime. The EASWG concluded that a permit may not be required for this EA but potential WAC and U.S. Nuclear Regulatory Commission (NRC) Transuranic Package Transporter-II (TRUPACT-II) certification issues may be involved in implementing this EA.

22 Decontaminate Surface of Metallic Wastes for LLW Disposal.

Metals are sorted and decontaminated using freon or carbon dioxide. Filters are used to collect the radionuclides and are disposed of as TRU waste. Decontaminated metals are recycled or disposed of as LLW.

The EASWG concluded that this EA met the definition and would be considered further. The EASWG concluded that this technology was mature, and off-the-shelf technology is available. This technology was commonly used for alpha contaminated materials. The EASWG expects that a permit is obtainable if required.

29 Microwave Melt Sludges

Sludge waste is melted/fused into a fused glass. Silica may be added prior to vitrification.

The EASWG changed the title from "Vitrify Sludges" to "Microwave Melt Sludges" to better define the EA. The EASWG concluded that this EA met the definition and would be considered further. The microwave technology has been demonstrated for radioactive waste; however, the entire waste handling process has not been demonstrated. Completed systems with feed and off-gas processes must still be designed. Problems are expected with obtaining a permit because this is a thermal process however the EASWG believes a permit is obtainable.

33 Salt Plus Clay Backfill

Crushed salt is mixed with approximately 30% clay. The salt/clay backfill is placed around the drums filling the void space within the rooms. A 50% filling efficiency is assumed.

The EASWG determined that this EA met the definition of an EA and that it would be kept for further consideration. The EASWG changed the title to "Salt plus Clay Backfill" and described the alternative as a crushed salt backfill containing 30% clay. The technical and regulatory feasibility is identical to #12.

35 Salt Aggregate Grout Backfill Around Drums

Crushed salt is sifted and used as an aggregate in a brine based grout backfill (properties of Type 10 grout are assumed). The grout is pumped into the rooms, filling the void spaces within the rooms. A high filling efficiency is assumed.

The EASWG changed the title to specify a salt aggregate grout. The EASWG concluded that this EA met the definition and would be considered further. The technology is mature. Brine saturated grouts are commonly used in the petroleum and mining industries. Questions on gas generation potential may limit the effectiveness of this alternatives. The EASWG believed a permit would not be required—only DOE requirements need to be satisfied.

36 Bitumen Backfill

Bitumen is placed around the waste drums filling the void space within the disposal rooms.

The EASWG concluded that this EA met the definition and would be considered further. Material handling technology is mature. Bitumen backfill used in Germany. Off-the-shelf technology is available. May impact the no-migration permit; possible large increase in hazardous materials. Uncertainty in safety requirements due to combustible nature. The EASWG concluded that there is a large uncertainty in regulatory feasibility; however, not enough information is available to justify rejection.

38 Reduce Room Dimensions to Minimize Space Around Waste Stack

This alternative reduces the room dimensions to minimize space around the waste containers. Only minimal space around the waste containers is assumed after emplacement.

The EASWG concluded that this EA met the definition and would be considered further. The technology used to initially mine the rooms and panels can be used; the technology is mature. Equipment is available at the site, and the operation required to implement the EA is understood. Regulatory issues include site design validation process considerations with the State of New Mexico, the Consultation and Cooperation Agreement, and other coordination concerns with the state.

51 Change Mined Extraction Ratio

The mined extraction ratio is increased to increase the closure rate or the disposal rooms (i.e., leaving less supportive salt around the mined waste disposal rooms).

The EASWG concluded that this EA met the definition and would be considered further. The EASWG concluded that this technology is mature and understood. Equipment is available. Major analysis would be required to determine the design and the overall impact on the disposal system. Regulatory concerns include major considerations with respect to the site design validation process, State of New Mexico agreements, and Mine

Safety and Health Administration requirements. The EASWG concluded that no permit is required to implement this EA.

53 Seal Individual Rooms

Individual rooms are sealed instead of only sealing the panels. Communication between the rooms during an intrusion scenario is significantly reduced (gas, brine, and radionuclides).

The EASWG concluded that this EA met the definition and would be considered further. Technology is available off the shelf. Major analysis is required to determine seal design and performance parameters. No permitting problems were envisioned.

60 Depressurize Castile Reservoir

This alternative removes brine from the Castile Formation in sufficient quantities to remove the motive force that transports waste from the repository to the accessible environment in an intrusion event involving the Castile Formation.

The EASWG determined this EA met the definition of an EA and should be considered further. The EASWG changed the title from "Drain" to "Depressurize" stating that drain was not technically correct and was misleading. Technology is a standard oil industry practice (per Nelson Munsey of Yates Petroleum). Must dispose of brine—many options for disposal available. Technology has been permitted, minimal permitting problems anticipated. State permit required.

63 Change Waste Container Shape

Square waste or hexagonal packages are used to decrease the void space within the disposal room.

The EASWG concluded that this EA met the definition and would be considered further. Technology is mature and available. Off-the-shelf containers of different various shapes are available and may meet existing TRU waste container requirements. NRC TRUPACT-II certification modification required, and U.S. Department of Transportation certification required. These certifications have been obtained for TRU waste containers previously. Permits can be obtained.

64 Change Waste Container Material

Non-ferrous materials are used to construct the waste container. Nickel, stainless steel, copper and glass/ceramic are examples of materials that could be used.

The EASWG concluded that this EA met the definition and would be considered further. The technology is mature and available. Depending on the specific material, waste containers made of non-ferrous materials are available off-the-shelf that may meet the current TRU waste container requirements. Same regulatory feasibility comments as #63.

83 Salt backfill with CaO

Crushed salt and CaO (lime) are used to backfill around the drums and fill void space in the waste panel.

The EASWG concluded that this EA met the definition and would be considered further.

110 Enhanced Solidification of Sludges

Cementation of sludges is performed to provide a waste form with improved properties over sludges cemented with existing systems.

The EASWG determined that this EA met the definition and would be considered further. Technology of cementing sludges has been demonstrated. RFP has matured this technology. Some development work may be required. The regulatory issues include satisfying DOE requirements and RCRA permit or modification to permit.

111 Clay Based Backfill

Clay based backfill is placed around the drum, filling the void spaces within the room to hasten room closure and isolate the waste with a low permeability barrier. Two forms of clays are considered, swelling (smectites) and non-swelling (illite/kaolinite). Clay may be placed dry or water may be added and the material pumped into the rooms.

The EASWG determined that this EA met the definition and would be considered further. The Technology is mature for moist and dry clay emplacement. The EASWG believes that no permits are required and only DOE requirements must be met.

Note:

The combination EAs were derived from those used in the Engineered Alternatives Task Force (EATF) report and System Prioritization Methodology (SPM) program. The titles/descriptions have been changed to match the title of the discrete technologies. For example, the title "Nickel Alloy Container" was changed to "Change Waste Containers Material, #64" and "Rectangular Containers" was changed to "Change Waste Container Shape, #63". This was done to provide consistency throughout the analysis.

66 EATF Alternative 1—

Shred and cement organics and inorganics only, salt backfill.

The EASWG concluded that this EA met the definition and would be considered further.

67 EATF Alternative 2—

Enhanced cement sludges, shred and cement organics and inorganics, salt backfill.

The EASWG concluded that this EA met the definition and would be considered further.

68 EATF Alternative 3—

Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.

The EASWG concluded that this EA met the definition and would be considered further.

69 EATF Alternative 4—

Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.

The EASWG concluded that this EA met the definition and would be considered further.

70 EATF Alternative 5—

Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt aggregate grout backfill.

The EASWG concluded that this EA met the definition and would be considered further.

71 EATF Alternative 6—
Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

72 EATF Alternative 7—
Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

73 EATF Alternative 8—
Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt backfill, change waste container material.
The EASWG concluded that this EA met the definition and would be considered further.

74 EATF Alternative 9—
Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt aggregate grout backfill, change waste container material.

The EASWG concluded that this EA met the definition and would be considered further.

75 EATF Alternative 10—
Decontaminate surface of metallic waste for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
The EASWG concluded that this EA met the definition and would be considered further.

76 EATF Alternative 11—
Supercompact organics and inorganics, salt backfill, monolayer of 2,000 drums in a 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

77 EATF Alternative 12—
Supercompact organics and inorganics, salt aggregate grout backfill, monolayer of 2,000 drums, in a 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

78 EATF Alternative 13—
Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP), no backfill, change waste container material and shape, minimize space around waste stack in a 10x31x188 room.
The EAWG concluded that this EA met the definition and would be considered further.

79 EATF Alternative 14—
Supercompact organics, and inorganics, salt backfill, seal individual rooms, 2,000 drums per room.
The EASWG concluded that this EA met the definition and would be considered further.

87 SPM IT-2

Enhanced cement sludges, shred and cement organics and inorganics, salt backfill, change waste container material.

The EASWG concluded that this EA met the definition and would be considered further.

88 SPM IT-3

Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.

The EASWG concluded that this EA is a duplicate of #68, "EATF Alternative 3".

89 SPM IT-4

Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.

The EASWG concluded that this EA met the definition and would be considered further.

90 SPM IT-5

Enhanced cement sludges, shred and compact organics and inorganics, salt backfill, 2,000 drum monolayer, 6x33x300 room.

The EASWG concluded that this EA met the definition and would be considered further.

92 SPM IT-7

Enhanced cement sludges, compact organics and inorganics, salt backfill with CaO, 2,000 drums monolayer, 6x33x300 room.

The EASWG concluded that this EA met the definition and would be considered further.

93 SPM IT-8

Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt backfill.

The EASWG concluded that this EA met the definition and would be considered further.

94 SPM IT-9

Enhanced cement sludges, shred and add clay based materials to organics and inorganics, salt aggregate grout backfill.

The EASWG concluded that this EA met the definition and would be considered further.

95 SPM IT-10

Decontaminate surface of metallic waste for LLW disposal, change waste container material, salt aggregate grout backfill.

The EASWG concluded that this EA met the definition and would be considered further.

APPENDIX C
ENGINEERED ALTERNATIVES REJECTION LIST WITH JUSTIFICATIONS

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ENGINEERED ALTERNATIVES REJECTION LIST WITH JUSTIFICATIONS

The following is a listing of Engineered Alternatives (EA) that failed the screening process. A brief description of the Engineered Alternatives Screening Working Groups (EASWG) rejection justification is provided.

4 Wet Oxidation

Wet oxidation alone was not considered an EA and was deleted. The EASWG determined that wet oxidation must be followed by a stabilization process to be an EA so #4 (Wet Oxidation) was changed to wet oxidation plus two separate solidifiers, #4a and #4b.

11 Melt Metals

The EASWG decided to delete this EA and separate it into two categories: #11a (melt metals and emplace all at the Waste Isolation Pilot Plant [WIPP]) and #11b (melt metals, partition radionuclides in slag and remove, cast metal and dispose of as low-level waste). The EASWG determined that this separation allows for greater flexibility in the analysis.

13 Add Other Sorbents

The EASWG determined that this EA is a duplicate of #15.

14 Add Gas Suppressant

The EASWG concluded that this EA is a duplicate of #19.

16 Acid Digestion

The EASWG concluded that acid digestion alone was not considered an EA. Acid digestion must be followed by a stabilization process to be an EA so #16, Acid Digestion, was changed to include two separate solidifiers, #16a and #16b.

17 Sterilization

The EASWG determined that the original Engineered Alternatives Task Force (EATF) rejection justification was still valid and that this EA would be rejected. The EATF rejection justification states, "Not feasible to maintain long-term effectiveness."

18 Add Copper Sulfate

The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. The EATF rejection justification states, "Potential for hydrogen generation by galvanic coupling of deposited copper."

20 Add Fillers

The EASWG concluded that this EA was not specific enough to evaluate and is considered by other more specific alternatives (#7, 9, 13, 14, 15, 18, and 19).

21 Segregate Waste Forms

The EASWG concluded that this EA did not meet the definition of an EA and was inherent with most waste processing EAs. This EA was not considered for further evaluation.

23 Change Waste Generation Process

The EASWG could not define this alternative and rejected it from further consideration. The EASWG determined the original EATF rejection justification was still valid. The EATF rejection justification states, "Scope too broad to be evaluated."

24 Add Anti-Bacterial Material

The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. Adding mercury was discussed and rejected due to the health hazards. The EASWG stated that adding hazardous materials to increase the safety of the repository was self-defeating. The EATF rejection justification states, "Unable to identify a long-term, anti-bacterial material."

25 Accelerate Waste Digestion Process

The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. The EASWG discussed the experimental results for culturing digestive materials. The working group was not convinced that the WIPP environment could be controlled to the extent required by the digestion process. The EATF rejection justification states, "Technology for fast waste digestion not demonstrated."

26 Alter Corrosion Environment

The EASWG concluded that this EA was not specific enough to evaluate. The technology was less than bench scale and has not been demonstrated. This concept is considered under other alternatives.

27 Alter Bacterial Environment in WIPP

The EASWG concluded that this EA is a duplicate of #24, which was deleted.

28 Transmutation of Radionuclides

The EASWG concluded that transmutation technologies are not feasible for transuranic (TRU) wastes and that the process requires the segregation of the pure isotopes from the waste. If waste was placed directly in the reactor, activated (radioactive) materials would be generated. The EATF rejection justification states, "Technology not demonstrated for large amounts."

30 Salt Backfill Only

The EASWG concluded that this EA is a duplicate of #12.

31 Salt Backfill Plus Gas Getters

The EASWG concluded that this EA is a duplicate of #83.

32 Compact Backfill

The EASWG determined that this EA was considered under EA #12 and would not be evaluated further.

34 Preformed Compacted Backfill

The EASWG concluded that this alternative is considered under the salt backfill alternative and would not be evaluated further.

37 Add Gas Suppressant

The EASWG concluded that the original EATF rejection justification was still valid. The EATF rejection justification states, "This alternative was considered together with the 'Salt Plus Gas Getters' alternative, and therefore was not subject to separate evaluation."

39 Segregate Waste in WIPP

The EASWG concluded that this EA was part of the baseline repository design. Load management is considered in the compliance documentation. The EASWG concluded that this EA does not meet the definition of an EA.

40 Decrease Amount of Waste per Room

The EASWG concluded that the original EATF rejection justification was still valid. The EATF rejection justification states, "This alternative was considered together with some of the backfill alternatives, and hence not evaluated separately."

41 Emplace Waste and Backfill Simultaneously

The EASWG concluded that this alternative is a subset of other backfill alternatives and was not evaluated separately.

42 Selected Vegetative Uptake

The EASWG determined that the process for vegetative uptake would not allow for proper containment of the alpha emitters. This process would require the waste to be placed in soil with plants. The EASWG determined the original EATF rejection was still valid. The EATF rejection justification states, "Not been laboratory demonstrated for TRU waste."

43 Brine Isolating Dikes

The EASWG determined that the isolation dikes configuration must be maintained to be effective. Room consolidation would alter the configuration, and the EA would not be effective. The EA was not considered further.

44 Raise Waste Above the Floor

The EASWG determined that this is a short-term fix for a long-term problem. The EA would provide no benefit and therefore would not be considered further. The EASWG also concluded that the original EATF rejection justification was still valid.

45 Brine Sump and Drains

The EASWG concluded that this EA is not effective since the required configuration cannot be maintained due to creep closure and rock mechanics of the repository. The EASWG also concluded that the original EATF rejection was still valid. The EATF rejection justification states, "This alternative was deleted because the EAMP (Engineered Alternatives Multidisciplinary Panel) believed that the flow paths leading to the sumps would not remain open long enough to allow substantial amounts of brine to be isolated from the waste."

46 Gas Expansion Volume

The EASWG concluded that this EA was detrimental to repository performance because the extra void volume allows for more stored energy and greater consequences during human intrusion scenarios. The EA was not considered further.

47 Seal Repository Room Walls

The EASWG determined that the rock mechanics of the repository precluded sealing. The technology has not been proven. Creep closure and interaction with the waste would be detrimental to the seal. The EASWG determined the original EATF rejection was still valid. The EATF rejection justification states, "The technology has not been demonstrated."

48 Vent Facility

The EASWG reviewed past data from the EATF data and the Design Analysis Model and determined that higher peak pressures would result for a vented facility. The EASWG also determined the original EATF rejection justification was still valid. The EATF rejection justification states, "Not regulatory feasible after institutional control" (period).

49 Ventilate Facility

The EASWG reviewed data from the EATF and concluded that this alternative was not feasible due to both regulatory and technical concerns. Quoting the original EATF, "...regulatory concerns about maintaining active facility controls for such a long period (100 years), the difficulty of assuring continuous ventilation in all spaces, and the potential for rupturing the waste containers during the ventilation period. The difficulty of safely sealing the rooms and panels of the facility, after so many years of creep closure has taken place, was also considered. Also, ventilation might violate the RCRA 'no migration' variance proposed for the WIPP." The EASWG concluded that this EA would not be evaluated further.

50 Add Floor of Brine Sorbents

The EASWG determined that this EA is a duplicate of #44, which was deleted.

52 Change Room Configurations

The EASWG determined that this EA did not meet the definition of an EA and may be detrimental to the performance of the repository during a human intrusion scenario.

54 Two-Level Repository

The EASWG determined that this EA did not meet the definition of an EA and may be detrimental to the performance of the repository during a human intrusion scenario.

55 Monument Forest Over Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

56 Monument Covering the Entire Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

57 Buried Steel Plate Over the Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

58 Artificial Surface Layer Over the Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

59 Add Marker Dye to Strata

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

61 Grout Culebra Foundation

The EASWG concluded that grouting the Culebra could be detrimental to the performance of the repository. The technology was not considered feasible in part, because it has not been demonstrated for this application. Verification of the effectiveness is problematic; may create alternative pathways within the Culebra formation, and the long-term effectiveness is unknown.

62 Increase Land Withdrawal Area

The EASWG concluded that increasing the area does not reduce the consequences of releases or increase the performance of the repository. Regulatory restriction on resource recovery within the new area would be problematic (resource lease acquisition).

65 EATF Baseline—As Received with Salt Backfill

The EASWG determined that this EA is a duplicate of #12, "Add Salt Backfill".

80 SPM-Baseline

The EASWG determined that the SPM baseline is the current repository baseline. The baseline is not an alternative and is inherent in the analysis.

81 SPM-A Salt Backfill

The EASWG concluded that this EA is a duplicate of #12, "Add Salt Backfill".

82 SPM-B Salt/Bentonite Backfill 50-50 Mix, 50% Filling Efficiency

The EASWG concluded that this EA is a duplicate of #22, "Salt Plus Clay Backfill".

84 SPM-D Cement Grout Backfill

The EASWG concluded that this EA is a duplicate of #35, "Salt Aggregate Grout Backfill".

85 SPM-E Salt/Grout Backfill

The EASWG concluded that this EA is a duplicate of #35, "Salt Aggregate Grout Backfill".

86 SPM IT-1 Shred and Cement Organics and Inorganics, Salt Backfill

The EASWG concluded that this EA is a duplicate of #66, "EATF Alternative 1".

88 SPM IT-3 Enhanced Cement Sludges, Shred and Cement Organics and Inorganics, Salt Aggregate Grout Backfill.

The EASWG concluded that this EA is a duplicate of #68, "EATF Alternative 3".

91 SPM IT-6 Enhanced Cement Sludges, Shred and Compact Organics and Inorganics, Salt Aggregate Grout Backfill, 2,000 drum monolayer, 6x33x300 room.

The EASWG concluded that this EA is a duplicate of #77, "EATF Alternative 12".

96 SPM EATF-8 Vitrify Sludges, Shred and Vitrify Organics, Melt Metals with Frit to Partition Actinides (metals are eliminated from the WIPP inventory), Salt Backfill, Change Waste Container Material.

The EASWG concluded that this EA is a duplicate of #73, "EATF Alternative 8".

97 SPM EATF-9 Vitrify Sludges, Shred and Vitrify Organics, Melt Metals with Frit to Partition Actinides (metals are eliminated from the WIPP inventory), Salt Aggregate Grout Backfill, Change Waste Container Material.

The EASWG concluded that this EA is a duplicate of #74, "EATF Alternative 9".

98 SPM DOE-1 Passive Markers—No Specific Scenario Given to Reduce Human Intrusion Probability Parameters.

The EASWG concluded that this EA dos not meet the definition of an alternative. The proposed alternative is a marker and not a barrier. This alternative does not increase the performance nor reduce the uncertainty in performance assessment.

99 SPM DOE-2 Compartmentalization of Waste—Various Unspecified Scenarios.

The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

100 194—Cementation

The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

101 194—Shredding

The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

102 194—Supercompaction

The EASWG concluded that this EA is a duplicate of #1, "Compact Waste."

103 194—Incineration

The EASWG concluded that this EA is inherent in #2, "Incinerate and Cement," because incineration is not an EA alone. Incineration must be followed by a form of solidification to meet the particulate restriction in the waste acceptance criteria.

104 194—Vitrification

The EASWG concluded that this EA is a duplicate of #3, "Shred and Vitrify Waste."

105 194—Improved Waste Containers

The EASWG concluded that this EA is a duplicate of #63, "Change Waste Container Shape," and #64, "Change Waste Container Material."

106 194—Grout and Bentonite Backfill

The EASWG determined that this EA is inherent in other EAs (#33 and #35) and does not require further consideration in the analysis.

107 194—Metal Melting

The EASWG concluded that this EA is a duplicate of #11a and 11b, "Melt Metals."

108 194—Alternative Configuration of Waste Emplacement

The EASWG concluded that this EA is inherent in several other EAs and does not require further consideration in the analysis.

109 194—Alternative Disposal System Dimensions

The EASWG concluded that this EA is inherent to several other EAs and does not require further consideration in the analysis.

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APPENDIX D
ENGINEERED ALTERNATIVES COST/BENEFIT STUDY REPORT ON PRIORITIZED ENGINEERED ALTERNATIVES FOR FURTHER ANALYSIS

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ENGINEERED ALTERNATIVES COST/BENEFIT STUDY REPORT ON PRIORITIZED ENGINEERED ALTERNATIVES FOR FURTHER ANALYSIS

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1.0 INTRODUCTION

This report documents the approach used to recommend a prioritized list of previously screened engineered alternatives (EA) for further analysis in the Engineered Alternatives Cost/Benefit Study (EACBS); this recommendation does not preclude further analysis of other screened engineered alternatives. The purpose and scope of the EACBS is outlined in the Engineered Alternatives Cost/Benefit Study Scoping Report (WID, 1995b). The specific approach used in screening engineered alternatives from an initial engineered alternatives candidate list is presented in the draft Engineered Alternatives Cost/Benefit Study Screening Report (WID, 1995a).

The EACBS Scoping Report outlines a general approach to screen alternatives. The approach consisted of a multi-disciplinary panel, a specified list of initial EA candidates, and a screening method to perform the screen. A multi-disciplinary panel of technical professionals facilitated the EA candidates for screening. This panel was designated as the Engineered Alternatives Screening Working Group (EASWG).

2.0 BACKGROUND

Fifty three EAs successfully passed the screening process. Analysis of EAs is a lengthy and costly process. Given limited resources, a management tool was needed to prioritize EAs for further analysis. A tool was developed and is presented in this report.

3.0 PRIORITIZATION PROCESS

Engineered Alternatives were prioritized to allow for the generation of detailed information of selected EAs through a focused analysis. This prioritization was done without eliminating any of the aspects of the engineered barrier study prescribed in proposed rule Title 40, Code of Federal Regulations (CFR), Part 194 (40 CFR 194) (EPA, 1995).

This was achieved by assessing each of the screened EAs for technological and regulatory feasibility, as well as effectiveness along four general categories of performance; gas generation, actinide solubility, permeability, and shear strength. Once the qualitative assessments were complete, a prioritization objective statement was developed. From this statement, the screening criteria were developed. Based on the criteria, a suite of EAs were retained for further analysis.

3.1 Qualitative Assessment of the Feasibility of Screened Alternatives

During the initial screening process (WID, 1995), the EASWG determined which EAs passed the definition and screening criteria for an EA. The results comprise 53 individual and combination EAs. In order to provide management guidance regarding the prioritization of EAs for analysis, further discrimination among the successfully screened EAs was required.

The discriminating criteria chosen for the prioritization process were regulatory feasibility and technological feasibility. An approach similar to that used in the 1991 Engineered Alternatives

Task Force (EATF) Final Report (DOE, 1991) was developed for the scoring process. The goal was to provide a relative feasibility score, independent of effectiveness, for each EA. The relative scores provided the input for a management to determine the prioritization of EAs for further analysis. The process assigned a score for technological feasibility, and a score for regulatory feasibility for each of the EAs under consideration by the same multi-disciplinary working group that performed the EA screening. Additionally, an independent facilitator ensured the scoring process had objectivity, help develop consensus within the working group, and maintained the process in accordance with the approach and scoring criteria.

Methodology

The methodology that was developed to score the EAs is described in Attachment D2. Attachment D2 provides the process description, basis for scoring, and example evidence that supports a given score. To assure that all EASWG members understood the meaning of "Regulatory and Technological Feasibility," definitions were provided, considered by the group, and agreed upon. The group evaluated the EAs on the basis of the current status of technology. The group concluded that, for the purpose of scoring, the relative importance or weighting of the regulatory and technology feasibility criteria was equal, and therefore gave each a relative weight of one-half of the total score.

A range of zero to five was used for both feasibility scores. A zero score is defined as not feasible, and the EA is then excluded from further analysis in the EACBS. The score of five is defined as an EA that requires no permitting to be implemented, or that the supporting technology is mature. A score of one is defined as one with a low expectation that the EA could be permitted, or that the technology is at bench or laboratory scale and not in use.

The calculation that provide the total feasibility score is:

$$F = (S_r)\cdot(W_r) + (S_t)\cdot(W_t)$$

Where F = Total weighted feasibility score or Feasibility Index

S_r = Regulatory feasibility score

W_r = Regulatory feasibility weighting (equal to .5)

S_t = Technology feasibility score

W_t = Technology feasibility weighting (equal to .5)

Each EA's score was deliberated until a consensus was formed. In some cases consensus could only be reached by allowing scores that were not whole numbers. This happened in a limited number of cases.

After all the relative scores had been developed, the EASWG went through a final review of the EA scores to determine whether the scores were realistic relative to each other. This resulted in a final list of individual EAs and their relative scores. Combinations of EAs were scored using the individual scores as a basis. Since a combination's feasibility is limited by the lowest scoring

EAs in the grouping, the lowest individual score for each feasibility criterion determined the score for the combination.

Results of the Scoring Process

Feasibility scores, rationale, and specific evidence for each EA score are shown in Attachment D3.

Results of the individual EA scoring process are shown in Attachment D4, and are sorted in a descending order of index feasibility score. The results show that EAs requiring the least amount of development, such as backfilling a waste room, have the highest feasibility, while EAs that require considerable development, such as acid digestion or wet oxidation, have the lowest feasibility.

3.2 Preliminary Assessment of the Effectiveness of Screened Alternatives

A preliminary qualitative assessment of effectiveness was determined for each of the 53 screened EAs shown in Attachment D1; this assessment provides a separate and independent process of the feasibility scoring process. This qualitative approach was efficient in that it provided an adequate level of information for consideration of each EA along several areas of effectiveness for the purpose of prioritizing analyses.

A qualified individual, with direct knowledge and involvement in the 1991 EATF, as well as knowledge of disposal system sensitive parameters, provided the assessments.

The assessment of effectiveness was combined with feasibility scores in an Effectiveness and Feasibility Matrix shown in Attachment D5. This matrix shows the results of a preliminary assessment of the effectiveness of screened engineered alternatives in terms of the following parameters:

- Gas generation
- Actinide solubility
- Waste stack permeability
- Human intrusion.

The significance of these parameters are discussed below.

Gas Generation

Gas may be generated by anoxic corrosion of metals (metallic waste and steel containers) and by microbial degradation of organic waste (paper, plastic, wood, etc.). The generation of low to moderate amounts of gas by the waste can improve performance by repressurizing the repository faster, thus minimizing the total amount of brine inflow. However, if gases are generated at rates that are greater that the rates at which gas can flow away from the repository, then the pressures that are significantly greater than lithostatic are predicted to occur. The physical response of a disposal room to excess pressure is highly uncertain. The room may respond by inflation, fracturing, or some combination of the two. Fracturing may manifest itself as generation of new fractures, or expansion of pre-existing fractures within clay and anhydrite layers. The main concern regarding high gas generation rates is that it introduces an uncertainty with respect to

the long-term performance of the disposal system. Alternatives that reduce the rate of gas generation, or eliminate any potential of the particular gas generation mechanism entirely are noted in the matrix.

Actinide Solubility

One pathway considered for the release of radionuclides to the accessible environment is the dissolution of the radionuclides in brine that may come in contact with the waste, followed by transport of the contaminated brine to the accessible environment. Brine can be transported via fractures caused by excessive pressurization of the repository by gas generation, or by pathways created by human intrusions. A key factor controlling release of radionuclides by these mechanisms is the solubility of the radionuclides in brine. Solubility is defined in this case as the maximum mass of a given actinide element that can dissolve in a unit volume of brine of a specified composition. The solubilities of the actinide elements of concern are complex functions of several parameters, however, they all show similar behavior with respect to pH, showing a solubility minimum over a pH range of 8.5 to 10.

The ability of brine to transport radionuclides could be greatly reduced if the pH of any brine that accumulates in the repository is raised from the ambient value of around 6.1 to a value corresponding to the solubility minimum range. Alternatives that buffer the pH to a more favorable range by the addition of lime (calcium oxide, or CaO) or portland-type cement (which contains a major percentage of lime) to either the drum contents of backfill are noted as decrease in actinide solubilities.

Waste Stack Permeability

The permeability of the waste stack is a major factor in controlling the flow of contaminated brine in a waste disposal room toward a human intrusion drill hole that penetrates the room. Alternatives that reduce the permeability of the waste or backfill are noted in the matrix. Supercompaction provides only a slight decrease in permeability, whereas cementation or vitrification provides a large decrease in permeability.

Human Intrusion

One significant pathway for the release of radionuclides in response to human intrusion events is the direct removal of drill cuttings to the surface. The total volume of waste that is brought to the surface in response to a drilling event is equal to the volume of waste that is physically intercepted by the drill bit. This includes the value removed by the bit ($V=\pi r^2 h$), plus any waste surrounding the hole that spalls or erodes into the hole in response to the action of the bit or circulation of drilling mud. The first volume term is directly controlled by the radius of the bit, which is an assumed value. The second volume term is controlled in part by the shear strength of the waste. Alternatives that increase the shear strength of the waste or backfill are noted in the matrix.

3.3 Prioritization Goal and Objective Statements

To prioritize EAs while satisfying the intent of the engineered barrier study prescribed in proposed rule 40 CFR 194, and allowing for the generation of valuable information through a focused

analysis of select EAs, the Waste Isolation Division (WID) of Westinghouse Electric Corporation developed a goal and objective statement as follows:

Goal

To ensure a broad spectrum of EAs have been identified for analysis in order to focus resources and efforts on pragmatic solutions to meeting the expected requirements of proposed rule 40 CFR 194.

Objective

To identify a list of engineered alternatives, either as discreet technologies or combinations of technologies, in which further analysis may be performed within the resources available.

3.4 Prioritization Criteria

Based on the goal and objective statements developed for the prioritization process, the WID developed the following steps for selecting specific EAs as recommended candidates for further analysis in the EACBS. The Effectiveness and Feasibility Matrix was the tool used for this selection.

1. At least one of the most effective EAs for each of the four impact areas (gas generation, solubility, permeability, and human intrusion) should be selected.

2. At least one of the most effective EAs from a broad spectrum effectiveness should be selected.

3. At least one high feasibility index EA for each of the four impact areas (gas generation, solubility, permeability, and human intrusion).

A given EA may be identified as potentially optimal for one or more of the criteria steps above. After accounting for the EAs identified in more than one of the criteria above, the final steps are as follows:

4. Identify and consider EAs that have technical merit but currently have no assessment along each of the four impact areas of gas generation, solubility, permeability, and human intrusion.

5. The balance of EAs shall be prioritized based on the feasibility index and broad spectrum effectiveness.

3.5 Developing the Recommended List of EAs

The criteria were applied to the list of screened and scored EAs shown in Attachment D5. The process was designed to maximize objectivity while minimizing subjectivity in the prioritization process. The selection of EAs for each of the criteria are shown in the following Tables D-1 through D-5.

TABLE D-1

SPECIFIC—MOST EFFECTIVE FOR EACH OF THE FOUR IMPACT AREAS (STEP 1)

Gas	Solubility	Permeability	Human Intrusion
#74 EATF Alternative 9—Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt aggregate grout backfill, change container material.	#94 SPM IT-9—Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.	#10 Plasma Processing of All Waste	#10 Plasma Processing of All Waste

1

TABLE D-2

BROAD SPECTRUM—MOST EFFECTIVE (STEP 2)

10 Plasma Processing of All Waste
89 SPM IT-4 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.

1

TABLE D-3

SPECIFIC—HIGH FEASIBILITY (STEP 3)

Gas	Solubility	Permeability	Human Intrusion
# 95 SPM IT-10 Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.	# 111 Clay Based Backfill	# 63 Change Waste Container Shape	# 12 Salt Backfill Around Drums and Waste Stack
# 111 Clay Based Backfill	# 83 Salt backfill with CaO	# 111 Clay Based Backfill # 33 Salt Plus Clay Backfill	

1

TABLE D-4

TECHNOLOGICAL MERIT (STEP 4)

# 53	Seal Individual Rooms
# 60	Depressurize Castile Reservoir

1

TABLE D-5

BROAD SPECTRUM—HIGH FEASIBILITY (STEP 5)

12 Salt Backfill Around Drums and Waste Stack

63 Change Waste Container Shape

83 Salt backfill with CaO

95 SPM IT-10 Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.

35 Salt Aggregate Grout Backfill Around Drums

75 EATF Alternative 10 - Decontaminate surface of metallic wastes for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.

After accounting for duplicates in the above tables, Table D-6 shows the recommended EAs for further analysis in the EACBS. A list of these recommended prioritized EAs with feasibility and effectiveness ratings is shown in Attachment D6.

4.0 SUMMARY

As part of the EACBS, 54 EAs successfully passed the screening process. Analysis of EAs is a lengthy and costly process. Given limited resources, a management tool was developed to prioritize EAs for further analysis. The objective of the management tool was to prioritize EAs while satisfying the intent of the engineered barrier study prescribed in proposed rule 40 CFR 194, and allowing for the generation of valuable information through a focused analysis of select EAs. Qualitative assessments of feasibility and effectiveness were made for each screened EA. A criteria, consistent with the goals and objectives of this prioritization, were developed and applied to the list of screened and scored EAs shown in Attachment D5. The results of this systematic process is a recommended list of EAs (Attachment D6) for further analysis in the EACBS.

TABLE D-6

RECOMMENDED PRIORITIZED EAs

ID Number	Description
# 10	Plasma Processing of All Waste
# 12	Salt Backfill Around Drums and Waste Stack
# 33	Salt Plus Clay Backfill
# 35	Salt Aggregate Grout Backfill Around Drums
# 53	Seal Individual Rooms
# 60	Depressurize Castile Reservoir
# 63	Change Waste Container Shape
# 74	**EATF Alternative 9** - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt aggregate grout backfill, change container material.
# 75	**EATF Alternative 10** - Decontaminate surface of metallic wastes for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
# 83	Salt backfill with CaO
# 89	**SPM IT-4** Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.
# 94	**SPM IT-9** Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.
# 95	**SPM IT-10** Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.
# 111	Clay Based Backfill

APPENDIX D
ATTACHMENT D1

SCREENED ENGINEERED ALTERNATIVES—DESCRIPTION

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SCREENED ENGINEERED ALTERNATIVES—DESCRIPTION

The following is a listing of Engineered Alternatives that passed the screening process.

1	Supercompact Everything Except Sludges
2	Incinerate and Cement Solid Organic Waste
3	Shred and Vitrify Solid Organic Waste
4a	Wet Oxidation and Cement Solid Organic Waste
4b	Wet Oxidation and Vitrify Solid Organic Waste
5	Shred and Bituminize Everything Except Sludges
6	Shred and Compact Everything Except Sludges
7	Shred and Cement Everything Except Sludges
8	Shred and Cold Polymer Encapsulate Everything Except Sludges
9	Shred, add Salt and Compact Everything Except Sludges
10	Plasma Processing of All Waste
11a	Melt Metals into transuranic (TRU) waste ingots
11b	Melt Metals with Frit to Partition Actinides
12	Salt Backfill Around Drums and Waste Stack
15	Shred, Add Clay Based Material to Everything Except Sludges
16a	Acid Digestion and Cementation of Solid Organics
16b	Acid Digestion and Vitrification of Solid Organics
19	Add Lime to Solid Organic Waste
22	Decontaminate Surface of Metallic Wastes for low level waste (LLW) Disposal.
29	Microwave Melt Sludges
33	Salt Plus Clay Backfill
35	Salt Aggregate Grout Backfill Around Drums
36	Bitumen Backfill
38	Reduce Room Dimensions to Minimize Space Around Waste Stack
51	Change Mined Extraction Ratio
53	Seal Individual Rooms
60	Depressurize Castile Reservoir
63	Change Waste Container Shape
64	Change Waste Container Material
66	The 1991 Engineered Alternatives Task Forces Final Report (EATF Alternative 1 - Shred and cement organics and inorganics only, salt backfill.
67	EATF Alternative 2—Enhanced cement sludges, shred and cement organics and inorganics, salt backfill.
68	EATF Alternative 3—Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.
69	EATF Alternative 4—Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.
70	EATF Alternative 5—Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt aggregate grout backfill.
71	EATF Alternative 6—Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt backfill.
72	EATF Alternative 7—Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt aggregate grout backfill.

73	EATF Alternative 8—Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt backfill, change container material.
74	EATF Alternative 9—Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt aggregate grout backfill, change container material.
75	EATF Alternative 10—Decontaminate surface of metallic wastes for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
76	EATF Alternative 11—Supercompact organics and inorganics, salt backfill, monolayer of 2,000 drums in a 6x33x300 room.
77	EATF Alternative 12—Supercompact organics and inorganics, salt aggregate grout backfill, monolayer of 2,000 drums, in a 6x33x300 room.
78	EATF Alternative 13—Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, no backfill, alternate container, 10x31x188.
79	EATF Alternative 14—Supercompact organics, and inorganics, salt backfill, seal individual rooms, 2,000 supercompacted drums per room.
83	Salt backfill with CaO
87	Systems Prioritization Methodology (SPM) IT-2 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill, change container material.
89	SPM IT-4 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.
90	SPM IT-5 Enhanced cement sludges, shred and compact organics and inorganics, salt backfill, 2,000 drum monolayer, 6x33x300 room.
92	SPM IT-7 Enhanced cement sludges, shred and compact organics and inorganics, salt backfill with CaO, 2,000 drums monolayer, 6x33x300 room.
93	SPM IT-8 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt backfill.
94	SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.
95	SPM IT-10 Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.
110	Enhanced Solidification of Sludges
111	Clay Based Backfill

APPENDIX D
ATTACHMENT D2

SCORING APPROACH

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ENGINEERED ALTERNATIVES SCREENING WORKING GROUP
SCORING APPROACH

Scoring Process Description

The working group is to assign feasibility scores for each EA. Feasibility is defined in terms of two attributes:

1) Regulatory Feasibility

Ease or difficulty of achieving federal and state regulatory compliance for implementation of an EA

The working group is to identify the activities required to obtain all necessary approvals and permits to implement and consider whether the EA technology has ever been permitted, the difficulties involved with obtaining permits, the time required to achieve regulatory compliance, and if significant, the cost of permitting.

2) Technological Feasibility

Technological feasibility of the EA

The working group is to consider the maturity of the technology that forms the basis for the EA, the level of difficulty required to reach technical maturity that would allow implementation of the EA.

Basis for Scoring

Scores resulting from this process provides a measure of relative feasibility for the EA with respect to each other, rather than assessing an absolute score. The guidelines below are intended to provide consistency during the scoring process

General Considerations

As you address each EA, the following considerations are provided to assist in structuring the thought process;

1) On a broad scale, what activities, processes, and facilities will be required to implement this EA, and/or to operate the waste disposal process with the EA incorporated.

2) Consider the evidence that exists that would give us confidence that we can successfully implement and/or operate the waste disposal process with this EA. Consider;

   a. Similar processes that have operated successfully

   b. Perceived complexities

   c. Magnitude of effort

d. Research and development status of technology

e Safety considerations.

APPENDIX D
ATTACHMENT D3

FEASIBILITY SCORES WITH RATIONALE

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FEASIBILITY SCORES WITH RATIONALE

EA #01 Description:
Supercompact everything except sludges

Regulatory Feasibility 4	Technical Feasibility 4.5
- Rocky Flats Plant (RFP) in interim status of Resource Conservation and Recovery Act (RCRA) Part B Permit - Not yet permitted	- Technology mature at RFP for transuranic (TRU) waste - RFP experience not necessarily transferrable - Not widely applied at other sites for TRU waste due to need - Widely used for low-level waste (LLW)

EA #02 Description:
Incinerate and cement solid organic waste

Regulatory Feasibility 2	Technical Feasibility 4
- Los Alamos National Laboratories (LANL) incinerator permitted (controlled air incinerator for hazardous) - Moratorium on new hazardous waste incinerators - Major effort required to permit future incinerator	- Technology mature for hazardous constituents—some engineering still required for TRU waste - SEG, Japan, and France commonly use for LLW - No TRU waste incinerator currently operating - Many examples of commercial incinerators used to destroy multiple waste streams

EA #03 Description:

Shred and vitrify solid organic waste

Regulatory Feasibility 2.5	Technical Feasibility 2
- Not yet permitted for TRU waste - Questions exist regarding ability to permit - U.S. Environmental Protection Agency (EPA) has favored vitrification as a waste form	- Vitrification of combustible solids a new technology - Bench Scale - Not applied to organics currently - France's (Marcoule Facility) currently making glass radioactive logs

EA #4a Description:

Wet oxidation and cement organic solid waste

Regulatory Feasibility 2	Technical Feasibility 1
- Technology never permitted - Safety considerations (high press. and high temp.) - Not enough information to score otherwise	- At bench-scale—questions exist regarding ability to handle all organic wastes - Safety issues - Currently used to treat organics in water

EA #4b Description:
Wet oxidation and vitrify organic solid waste

Regulatory Feasibility 2	Technical Feasibility 1
- Technology never permitted - Safety considerations (high press. and high temp.) - Not enough information to score otherwise	- At bench-scale—questions exist regarding ability to handle all organic wastes - Safety issues - Currently used to treat organics in water

EA #5 Description:
Shred and bituminize everything except sludges

Regulatory Feasibility 1	Technical Feasibility 3
- Low expectation that permit can be obtained—Safety has been questioned for commercial nuclear power plant applications - Never permitted	- Technology is mature but not applied to TRU waste - Development work required - Expect technology can be applied to TRU waste - Except for sludges, never been used for solid waste - Used in Japan for radioactive resins and sludges

EA #6 Description:
Shred and compact everything except sludges

Regulatory Feasibility 4	Technical Feasibility 4
- Never been permitted for TRU - It has been allowed for commercial LLW - Process will not require thermal/chemical treatment and attendant products - Permitting problems are not expected	- Commercial nuclear plants routinely use compaction of LLW - Shred and compact not being done for TRU waste—has not been demonstrated for TRU - Equipment readily available (off the shelf) from manufactures for commercial application

EA #7 Description:
Shred and cement everything except sludges

Regulatory Feasibility 4	Technical Feasibility 4
- Cementation of TRU sludges under interim status at U.S. Department of Energy (DOE) facilities - Not been done for solid TRU wastes - Process will not require thermal/chemical treatment and attendant products - Permitting problems are not expected	- Shred and cement not being done for TRU - LLW grouting being done at Hanford (J. Ward) - Possible German applications (J. Waters & N. Rempe) - Technology is off the shelf

EA #8 Description:

Shred and cold polymer encapsulation everything except sludges

May not be an effective treatment for RH

Regulatory Feasibility 4	Technical Feasibility 4
- Allowed for LLW under commercial power plant license - Not been done for solid TRU wastes - Process will not require thermal/chemical treatment of the waste and attendant products - Permitting problems are not expected	- LLW is being polymerized commercially - Not being done for TRU - Technology is off the shelf

EA #9 Description:

Shred, add salt and compact everything except sludges

Regulatory Feasibility 4	Technical Feasibility 4
- Compaction allowed for LLW - Not permitted for TRU - Permitting problems not expected	- Process is not being done for TRU - Equipment off the shelf - LLW compaction being done at power plants

EA #10 Description:
Plasma processing of all waste

Regulatory Feasibility 2.5	Technical Feasibility 2
- Not yet permitted for TRU waste - Questions exist regarding permitability - Current Western Governors Association (WGA) considers this a promising technology - Cleaner technology than incinerate—lower level of off gas	- Beyond bench scale but not yet approaching mature technology - Commonly used for exotic metals refining - Pilot test completed for Pit 9, Idaho National Engineering Laboratory (INEL) application (simulated waste) - Design of a full scale unit is approx. 90% complete at INEL (Lockheed)

EA #11a Description:
Melt Metals

Regulatory Feasibility 3	Technical Feasibility 3
- Not yet permitted for TRU waste - Expect that permits could be obtained	- Technology is mature but not applied to TRU waste - Development work required - Expectation that technology can be applied to TRU waste

EA #11b Description:

Melt Metals with frit to partition actinides

Regulatory Feasibility 3	Technical Feasibility 3
- Not yet permitted for TRU waste - Expect that permits could be obtained - Potential for recycle as low level waste containers; perceived as a good thing to do	- Technology is mature but not applied to TRU waste - Development work required - Expectation that technology can be applied to TRU waste

EA #12 Description:

Salt backfill around drums and waste stack

Regulatory Feasibility 5	Technical Feasibility 5
- No permitting required - Original Final Safety Analysis Report (FSAR) already considers this process	- Mature - Equipment available - Operation understood

EA #15 Description:

Shred, add clay based material to everything except sludges

Regulatory Feasibility 4	Technical Feasibility 4
- Not permitted for radioactive waste - Permitting problems not expected - Process will not require thermal/chemical treatment and attendant products	- Shred and add clay process is not being done for TRU waste - Equipment off the shelf

EA #16a Description:

Acid digestion and cementation of solid organics

Regulatory Feasibility 2	Technical Feasibility 2
- Technology not been permitted - Disposition of (RCRA) hazardous constituents may be an issue - Not enough information to score otherwise	- 1972–1980 5,000 kg TRU processed with sulfuric acid at Hanford (pilot scale) - Current technology 180°C and 15 psig at bench (Savannah River Site [SRS]) - Belgium (recovery of Pu with sulfuric acid) and SRS experience with phosphoric acid (bench scale) - Feed requires shredding - Acid handling a commercial process - Development required for stabilization of residue, off gas systems, and spent acid treatment and disposal - Disposition of (RCRA) hazardous constituents during and after process unknown - Cementation of the resultant sludges has not been demonstrated

EA #16b Description:

Acid digestion and vitrification of solid organics

Regulatory Feasibility 2	Technical Feasibility 2
- Technology not been permitted - Disposition of (RCRA) hazardous constituents may be an issue - Vitrification not yet permitted for TRU waste - Questions exist regarding ability to permit vitrification - EPA has favored vitrification as a waste form - Not enough information to score otherwise	- 1972–1980 5,000 kg TRU processed with sulfuric acid at Hanford (pilot scale) - Current technology 180°C and 15 psig at bench (SRS) - Belgium (recovery of Pu with sulfuric acid) and SRS experience with phosphoric acid (bench scale) - Feed requires shredding - Acid handling a commercial process - Development required for stabilization of residue, off gas systems, and spent acid treatment and disposal - Disposition of (RCRA) hazardous constituents during and after process unknown - Cementation of the resultant sludges has not been demonstrated - Vitrification of combustible solids a new technology - Vitrification of solid organics at bench scale - Vitrification not applied to organics currently - France's (Marcoule Facility) currently making glass radioactive logs

EA #19 Description:

Add lime to solid organic waste

Regulatory Feasibility 4	Technical Feasibility 5
- May require a permit - Potential waste acceptance criteria and TRUPACT-II certification impact Chemical reaction Particulate	- Assumed that no shredding is required - This is a material handling process—no treatment technology involved - Aluminum would have to be removed for existing waste

EA #22 Description:

Decontaminate surface of metallic wastes for LLW disposal

Regulatory Feasibility 4	Technical Feasibility 5
- May require a permit - Expect permit to be obtained, if required	- Mature technology - Commonly used for alpha decontamination - Off-the-shelf technology

EA #29 Description:

Microwave melting of sludges

Regulatory Feasibility 3	Technical Feasibility 2
- Problems expected but permit can be obtained - Microwave technology generally accepted by public - WGA considers microwave melting a promising technology	- Unit operations only have been developed—complete systems (feed systems, and off gas systems) have not been developed - Has been demonstrated for radioactive waste

EA #33 Description:
Salt plus clay backfill

Regulatory Feasibility 5	Technical Feasibility 5
- No permitting required - Original FSAR does not explicitly consider this process	- Mature - Equipment available - Operation understood

EA #35 Description:
Salt aggregate grout backfill around drums

Regulatory Feasibility 5	Technical Feasibility 5
- No permits required - Only DOE requirements need to be satisfied	- Technology is mature - Brine saturated grouts used in mining and petroleum industry

EA #36 Description:
Bitumen backfill

Regulatory Feasibility 2	Technical Feasibility 5
- Will impact RCRA no-migration; large increase in a hazardous constituent - Uncertainty in safety requirements due to combustible nature - Major regulatory uncertainty	- Material handling technology is mature - Bitumen backfill used in Germany (J. Myers) Asse or Gorleben - Off-the-shelf equipment

APPENDIX D
ATTACHMENT D4

FEASIBILITY SCORES TABLE

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TABLE D4-1

FEASIBILITY SCORES TABLE

Primary Key: Index Feasibility				
Secondary Keys	Human Intrusion	Permeability	Actinide Solubility	Gas Generation
Alternative Numbers	12	35	35	35
"	35	111	111	33
"	33	33	33	111
"	111	12	83	83
"	83	83	12	12
"	38	38	38	38
"	95	63	95	95
"	110	95	110	63
"	19	110	19	75
"	63	75	63	22
"	75	22	75	51
"	64	64	51	64
"	51	51	64	19
"	22	19	22	110
"	60	53	60	60
"	53	60	53	53
"	77	77	77	77
"	79	76	76	76
"	76	79	79	79
"	1	1	1	1
"	89	89	89	89
"	94	94	94	15
"	93	92	93	67
"	68	93	67	68
"	67	90	68	87
"	87	68	87	66
"	92	67	92	7
"	90	87	66	8
"	66	66	7	94
"	7	8	15	92
"	9	7	90	93
"	15	9	9	90
"	8	15	8	9
"	6	6	6	6
"	36	36	36	36
"	69	69	70	70
"	70	70	69	69
"	2	2	2	2
"	11.2	11.2	11.2	11.2
"	11.1	11.1	11.1	11.1
"	29	29	29	29
"	10	10	74	74
"	74	74	72	73
"	72	73	10	10
"	73	72	73	72
"	71	71	71	71
"	78	78	78	78
"	3	3	3	3
"	16.2	5	16.1	16.2
"	16.1	16.2	16.2	5
"	5	16.1	5	16.1
"	4.2	4.2	4.2	4.2
"	4.1	4.1	4.1	4.1

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ATTACHMENT D5

PRELIMINARY QUALITATIVE ASSESSMENT OF EFFECTIVENESS AND FEASIBILITY

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	Permeability			Human Initiated Events				External Drivers
	E1 Waste Stack		In Backfill	Shear Strength				
	Solid Inorganics	Sludges	All Materials	Solid Organics	Solid Inorganics	Sludges	Backfill	Anything
33 Salt Plus Clay Backfill	-	-	Decrease	-	-	-	Increase	-
12 Salt Backfill Around Drums	-	-	Small Decrease	Small Increase	Small Increase	Small Increase	Increase	-
35 Salt Aggregate Grout Backfi	-	-	Decrease	-	-	-	Increase	-
111 Clay Based Backfill	-	-	Small Decrease	-	-	-	Increase	-
83 Salt backfill with CaO	-	-	Decrease	-	-	-	Increase	-
95 SPM IT-10 Decontaminate t container material, salt aggrega	-	-	-	-	-	-	-	-
75 EATF Alternative 10 - Deco backfill, change container mater	Decrease	Decrease	-	-	-	-	-	-
63 Change Waste Container Si	-	-	-	-	-	-	-	Reduce Brine Volume in E1 and E1E2 Scenarios
60 Depressurize Castile Reser	-	-	-	-	-	-	-	-
53 Seal Individual Rooms	Decrease	Decrease	Decrease	Increase	Increase	Increase	Increase	-
94 SPM IT-9 Enhanced cement and inorganics, salt aggregate	Decrease	Decrease	Decrease	Increase	Increase	Increase	Increase	-
89 SPM IT-4 Enhanced cement backfill with CaO	Decrease	Decrease	Decrease	Increase	Increase	Increase	Increase	-
74 EATF Alternative 9 - Vitrify t partition actinides, salt aggrega	Large Decrease	Large Decrease	-	Large Increase	Large Increase	Large Increase	-	-
10 Plasma Processing of All W								

APPENDIX D
ATTACHMENT D6

PRIORITIZED EAs FOR FURTHER ANALYSIS

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	Engineering Alternati	ges	In Backfill All Materials	Human Induced Events Shear Strength Solid Organics	Solid Inorganics	Sludges	Backfill	External Drivers Anything
			Small Decrease	Small Increase	Small Increase	Small Increase	Increase	
12	12 Salt Backfill Around Drums		Decrease				Increase	
33	33 Salt Plus Clay Backfill		Small Decrease				Increase	
83	83 Salt backfill with CaO		Decrease				Increase	
35	35 Salt Aggregate Grout Back							
38	38 Reduce Room Dimensions Space Around Waste Stack		Decrease				Increase	
111	111 Clay Based Backfill							Enhances Closure
51	51 Change Mined Extraction F	rease						
63	63 Change Waste Container S							
19	19 Add Lime to Solid Organic							
53	53 Seal Individual Rooms							
64	64 Change Waste Container I							
75	75 EATF Alternative 10 - Decr of metallic wastes for LLW dis change container material and 10X31X188 rooms		Decrease				Increase	
95	95 SPM IT-10 Decontaminate waste for LLW disposal, chan material, salt aggregate grout	Decrease				Increase		
110	110 Enhanced Solidification o							
22	22 Decontaminate Surface of for LLW Disposal							Reduce Bins Volume in E1 and E1E2 Scenarios
60	60 Depressurize Castille Res							
				Increase	Increase			
1	1 Supercompact Everything		Decrease	Increase	Increase		Increase	
77	77 EATF Alternative 12 - Sup organics and inorganics, salt backfill, monolayer of 2000 dru room		Decrease	Increase	Increase		Increase	
76	76 EATF Alternative 11 - Sup organics and inorganics, salt of 2000 drums in a 6X3X3X3		Decrease	Increase	Increase		Increase	
79	79 EATF Alternative 14 - Sup organics, and inorganics, salt individual rooms, 2000 supers per room	crease	Decrease	Increase	Increase	Increase	Increase	
94	94 SPM IT-9 Enhanced com and add clay based material inorganics, salt aggregate gr	Decrease	Decrease	Increase	Increase	Increase	Increase	
67	67 EATF Alternative 2 - Enh sludges, shred and cement o inorganics, salt Backfill	Decrease	Decrease	Increase	Increase	Increase	Increase	
88	88 EATF Alternative 3 - Enh sludges, shred and cement o inorganics, salt aggregate gr	crease	Decrease	Increase	Increase	Increase	Increase	
90	90 SPM IT-5 Enhanced com and compact organics and in backfill, 2000 drum monolayer	crease	Decrease	Increase	Increase	Increase	Increase	
93	93 SPM IT-8 Enhanced com and add clay based material inorganics, salt backfill	crease	Decrease	Increase	Increase	Increase	Increase	
92	92 SPM IT-7 Enhanced com and compact organics and in backfill with CaO, 2000 drum 6X3X3X3 room	crease	Decrease	Increase	Increase	Increase	Increase	
89	89 SPM IT-4 Enhanced com and cement organics and in with CaO		Decrease	Increase	Increase		Increase	
66	66 EATF Alternative 1 - Shr organics and inorganics and			Smal Increase	Small Increase			
6	6 Shred and Compact Ever Sludges			Increase	Increase			
9	9 Shred, add Salt and Com Except Sludges	crease		Increase	Increase	Increase	Increase	
87	87 SPM IT-2 Enhanced co and cement organics and in backfill, change container m			Small Increase	Small Increase			
15	15 Shred, Add Clay Based Everything Except Sludges			Increase	Increase			
7	7 Shred and Cement Ever Sludges			Small Increase	Small Increase			
8	8 Shred and Cold Polyme Everything Except Sludges		Large Decrease				Increase	
36	36 Bitumen Backfill	Decrease	Decrease	Increase	Increase	Increase	Increase	
70	70 EATF Alternative 5 - En sludges, incinerate and co and cement inorganics, sal backfill	Decrease	Decrease	Increase	Increase	Increase	Increase	
69	69 EATF Alternative 4 - En sludges, incinerate and co and cement inorganics, sa			Increase				
2	2 Incinerate and Cement							
11 1	11a Melt Metals into TRU							
11 2	11b Melt Metals with Fid	Decrease				Large Increase		
29	29 Microwave Melt Sludge			Large Increase				
3	3 Shred and Vitrify Solid	crease	Decrease	Increase	Increase	Increase	Increase	
71	71 EATF Alternative 6 - V and vitrify organics, melt m ingots, salt backfill	crease	Decrease	Increase	Increase	Increase	Increase	
72	72 EATF Alternative 7 - V and vitrify organics, melt r ingots, salt aggregate gro	crease	Decrease	Increase	Increase	Increase	Increase	
73	73 EATF Alternative 8 - V and vitrify organics, melt r partition actinides, salt ba material	e Decrease		Large Increase	Large Increase	Large Increase		
10	10 Plasma Processing o	crease	Decrease	Increase	Increase	Increase	Increase	
74	74 EATF Alternative 9 - V and vitrify organics, melt partition actinides, salt a change container materi	crease		Increase	Increase	Increase		
78	78 EATF Alternative 13 - and vitrify organics, melt partition actinides, no ba container, 10X31X188			Large Increase				
16 2	16b Acid Digestion and V Organics			Increase				
16 1	16a Acid Digestion and C Organics			Small Increase	Small Increase			
5	5 Shred and Bitumenize Sludges			Increase				
4 1	4a Wet Oxidation and C Waste			Large Increase				
4 2	4b Wet Oxidation and V Waste							

APPENDIX D
ATTACHMENT D7

ENGINEERED ALTERNATIVE COST/BENEFIT STUDY SCREENING REPORT

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WIPP/WID-95-2104
Revision 0

Engineered Alternatives Cost/Benefit Study Screening Report

May 1995

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Area Office
Carlsbad, New Mexico

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PREFACE

This report documents the approach that was used to screen a list of engineered alternative (EA) candidates for the purpose of exclusion or retention in the Engineered Alternatives Cost/Benefit Study (EACBS). The EACBS is outlined in the Engineered Alternatives Cost/Benefit Study Scoping Report, WIPP/WID 95-2093.

The EACBS Scoping Report outlined a general approach to screen EAs. The approach includes use of a multi-disciplinary panel (working group), a list of initial EA candidates, and a screening method to ensure that the most viable alternatives are focused upon in .he cost/benefit study. This report documents the screening process used by the Engineered Alternatives Screening Working Group (EASWG) and presents the results of the screening process.

1.0 INTRODUCTION

The Engineered Alternatives Cost/Benefit Study (EACBS) Scoping Report (WIPP/WID 95-2093) was prepared to document the approach for gathering of technical data necessary for decision making regarding engineered alternatives (EA) to be used for meeting the Title 40 Code of Federal Regulations 191 (40 CFR 191)assurance requirements. The study will provide the technical basis for determining whether or not engineered alternatives should be included in the repository as assurance measures to either increase the performance of the disposal system beyond containment requirements or to reduce uncertainty associated with the performance prediction. The screening of initial EAs to be analyzed in the study is a key part of the study. Engineered Alternatives that pass the screen will be considered for further analysis in the EACBS.

The screening process is a non-ranking pass or fail type of screen which uses a panel of technical professionals. The process is such that any prospective alternative can be investigated to determine if it should be considered for further analysis in the EACBS.

The screening process is outlined in Sections 3.1 to 3.2.3 of the scoping report. This process compiles a list of EA candidates, compares these candidates to the definitions of an EA, and screens those that meet the definition against screening criteria. Those that meet the criteria will be used in the EACBS analysis and those that do not meet the definition and/or screening criteria are documented with a justification for rejection. This process is performed by a screening panel known as the Engineered Alternatives Screening Working Group (EASWG). The EASWG was allowed to refine and improve the process outlined in the scoping report.

The following sections detail the screening process used, the results, and describe any modifications made to the process outlined in the scoping report. Justification for these changes are also provided.

1.1 WIPP Mission Description

The Waste Isolation Pilot Plant (WIPP) is a research and development facility of the U.S. Department of Energy (DOE), designed to demonstrate the safe transportation, handling, and disposal of defense generated transuranic (TRU) radioactive waste. The facility is located 26 miles east of Carlsbad, New Mexico. The repository is located in a mined geologic salt deposit, 2,150 feet below ground. The waste will be shipped to the facility and placed in the

underground repository for disposal. After the WIPP repository is filled with waste, the access ways will be closed, shafts sealed, and the surface facilities removed.

1.2 EACBS Program Purpose

The DOE has initiated a cost benefit study to provide a technical basis for the selection and rejection of EAs for the WIPP beyond the engineered barriers required for compliance with containment requirements. The results of this study will be presented in the EACBS Final Report.

Engineered Alternatives included engineered barriers, waste modifications, facility modifications, process changes, or any other approach that after qualitative analysis with respect to performance assessment sensitivity and uncertainty analysis results, would reduce uncertainty in predictions of long-term performance.

1.3 EACBS Program Background

In accordance with Subparts B and C of 40 CFR 191, the WIPP Performance Assessment (PA) is used to predict the expected cumulative release of radionuclides to the accessible environment over the long-term repository performance period. The PA uses numerical modeling to predict whether the performance of the disposal system can reasonably be expected to meet the requirements of 40 CFR 191. The numerical modeling is supported by experimental programs and expert judgement. Results of the PA are quantitative in nature and indicate the WIPP design either does or does not meet the performance criteria and release limits imposed by the regulation. The WIPP disposal system performance assessment and the 40 CFR 191 standard are designed to ensure that a margin of safety is built into the evaluation process. The calculated results of PA can therefore only be used to conclude that the disposal system will or will not comply. Relative "degrees" of compliance cannot be deduced from a mean complementary cumulative distribution function (CCDF) resulting from the WIPP PA.

The regulation specifies that assurance requirements be used to provide additional confidence for long-term compliance. These assurance requirements introduce a "defense-in-depth" concept to the disposal system design by using engineered barriers, active and passive institutional controls, long-term monitoring, and permanent markers in addition to the natural and engineered systems to contain and isolate the waste. The assurance requirements in

40 CFR 191 are used to complement the disposal system containment requirements. As part of the assurance requirements, EAs may be used to provide additional confidence in the containment requirements which also has an added benefit of possibly enhancing disposal system performance and/or reduce uncertainty in the calculated performance results.

A distinction between containment and assurance must be maintained. Containment relates to the regulatory performance limits, whereas assurance relates to reducing the uncertainty associated with a compliance determination. The disposal system design meets the multiple barrier assurance requirements specified in 40 CFR § 191.14(d). This study will provide information about additional EAs which can be evaluated within the context of a compliant disposal system.

2.0 Engineered Alternatives Screening Process

The EACBS requires an input of EA to be used in the cost/benefit analysis. Since the analysis of EAs is a lengthy and costly process, the input EAs are examined prior to the analysis to determine if they are valid and viable alternatives with some expectation that they can improve the disposal system performance and/or reduce the uncertainty in the prediction of this performance. The screening process was designed to examine the prospective inputs to determine the validity of the alternatives.

The screening was performed by the EASWG. The EASWG is composed of a professional facilitator and technical professionals from the following fields:

Waste Management
Waste Processing
Probablistic Risk Assessment
Transportation Engineering
Environmental Engineering
Mine Engineering
Radiation Risk Assessment
Chemical Engineering
Cost/Schedule Assessment
Public Relations

Personnel that had technical experience from the listed fields and had direct knowledge of the WIPP project and/or other DOE waste programs were chosen. Members were chosen by the EACBS project managers. The members of the EASWG and their resumes are listed in Appendix B.

The EASWG met on April 24, 25, and 26, 1995, and again on May 1, 2, and 3, 1995. The working group initially broke the process down into the steps listed below which were derived from the scoping report.

1. Review the definition of an EA.
2. Review the screening criteria.
3. Review the EA candidates and their definitions.
4. Outline the screening process.
5. Compare the EA candidates to the EA definition. Document the results.
6. Determine if the EAs that met the definition also meet the screening criteria.
7. Document the results.

Each step is detailed in the following sections.

2.1 Review the Definition of an Engineered Alternative

The definition stated in Section 3.2.2 of the scoping report is:

> An EA is a process, technology, method, disposal system design, or waste form modification which makes a significant positive impact on the disposal system in terms of reducing uncertainty or improving long-term performance.
>
> In order for an EA concept to be considered as an engineered alternative, it must be technically feasible and must meet at least one of the following criteria.
>
> - Reduce permeability of the waste stack
> - Increase the shear strength of the waste form
> - Reduce the total gas produced from the waste form by:
>
> - Reducing corrosion rate - oxic, anoxic, or both
> - Reducing microbial activity

- Isolating or lowering available water/brine contact with the waste (Radiolysis gas generation is not a critical issue and is not a significant factor in gas generation)

- Reduce the transport rate of radionuclides
- Reduce the consequences of human initiated processes or events
- Reduce the solubility of the radionuclides

The working group concluded that the definition should also state that the final waste form must meet the Waste Acceptance Criteria (WAC). The working group decided that this change was required because all waste shipped to the WIPP for disposal must met the WAC and that any alternative that modifies the waste such that it could not meet the WAC would not be considered. No other changes were made.

2.2 Review the Screening Criteria

The EASWG reviewed the three screening criteria, Regulatory Compliance and Permitting, Availability of Technology, and Schedule of Implementation. These criteria are described in Section 3.2.3 of the scoping report. The EASWG concluded that these criteria are based on feasibility and abbreviated two of the titles to Regulatory Feasibility and Technical Feasibility. The definitions for these two criteria were considered adequate by the EASWG. The working group noted that schedule is inherent in these two criteria. There was therefore no reason to consider schedule as a separate measure for viability determinations made during screening.

2.3 Review Engineered Alternatives and their Definitions

The EA scoping report contains the initial listing of EA candidates that were used in the screening process. This list was compiled from the 64 individual and 14 EA combinations found in the 1991 Engineered Alternatives Task Force Final Report (EATF), the 20 EAs that were considered by Sandia National Laboratories (SNL) for the Systems Prioritization Methodology-II (SPM-2), and the 10 EAs listed in the proposed rule 40 CFR 194. This list is found in Appendix C of this report.

The EASWG reviewed the list of EAs and the definitions of the 64 individual technologies listed in the EATF. Definitions for the remaining EAs were not required because the remaining EAs are either combinations or duplicates of the 64. The working group

modified the 64 EATF definitions to clarify and expand the definitions or update advancements in the technologies since 1991. Some of the original titles were modified to expand on which waste types are used with the technologies. The definitions are listed in Appendix D of this report.

2.4 Outline the Screening Process

The EASWG developed a basic outline to screen the EAs. The outline is:

1. Compare EA to definition
2. Determine if the EA is detrimental to the disposal system
3. Identify duplicate EAs and delete
4. Compare remaining EAs to screening criteria
    a. Regulatory Feasibility
    b. Technology Feasibility

2.5 Compare the Engineered Alternative Candidates to Definition

The EASWG, after reviewing the modified definition of an EA in Section 3.2.2 of the scoping report, compared the initial list of EA candidates (Appendix C) to the definition. Those that met the definition were noted as such and those that did not were documented with a brief description why the working group concluded that it did not meet the definition. Duplicates were also deleted at this time. The initial EA list was divided into a Pass and Reject list. This list can be found in Appendix E.

In reviewing the EAs, the EASWG also considered any detrimental effects due to the implementation of an EA. Any EA that would have a detrimental impact on the performance of the disposal system was deleted.

2.6 Compare the Engineered Alternatives to the Screening Criteria

The remaining EAs that meet the definition were screened by assessing Regulatory and Technical Feasibility. The scoping report definitions for these criteria were used. After a thorough review, no EAs that met the definition were screened out due to regulatory or technical feasibility. Comments from the EASWG on regulatory and technical feasibility are listed in Appendix E.

2.7 Screening Results

After completing the screening process, a Pass and Reject list with justifications was compiled and finalized. The pass list by number and title only are shown in Table 2 - 1 and the rejection list by number and title only are shown in Table 2 - 2.

Table 2 - 1
Engineered Alternative Pass List

The following is a listing of Engineered Alternatives that passed the screening process.

1 Supercompact Everything Except Sludges
2 Incinerate and Cement Solid Organic Waste
3 Shred and Vitrify Solid Organic Waste
4a Wet Oxidation and Cement Solid Organic Waste
4b Wet Oxidation and Vitrify Solid Organic Waste
5 Shred and Bituminize Everything Except Sludges
6 Shred and Compact Everything Except Sludges
7 Shred and Cement Everything Except Sludges
8 Shred and Cold Polymer Encapsulate Everything Except Sludges
9 Shred, add Salt and Compact Everything Except Sludges
10 Plasma Processing of All Waste
11a Melt Metals into TRU waste ingots
11b Melt Metals with Frit to Partition Actinides
12 Salt Backfill Around Drums and Waste Stack
15 Shred, Add Clay Based Material to Everything Except Sludges
16a Acid Digestion and Cementation of Solid Organics
16b Acid Digestion and Vitrification of Solid Organics
19 Add Lime to Solid Organic Waste
22 Decontaminate Surface of Metallic Wastes for low level waste (LLW) Disposal.
29 Microwave Melt Sludges
33 Salt Plus Clay Backfill
35 Salt Aggregate Grout Backfill Around Drums
36 Bitumen Backfill
38 Reduce Room Dimensions to Minimize Space Around Waste Stack
51 Change Mined Extraction Ratio
53 Seal Individual Rooms
60 Depressurize Castile Reservoir
63 Change Waste Container Shape
64 Change Waste Container Material
66 The 1991 Engineered Alternatives Task Forces Final Report (EATF Alternative 1 - Shred and cement organics and inorganics only, salt backfill.
67 EATF Alternative 2 - Enhanced cement sludges, shred and cement organics and inorganics, salt backfill.

Table 2 - 1
Engineered Alternative Pass List

68 EATF Alternative 3 - Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.
69 EATF Alternative 4 - Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.
70 EATF Alternative 5 - Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt aggregate grout backfill.
71 EATF Alternative 6 - Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt backfill.
72 EATF Alternative 7 - Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt aggregate grout backfill.
73 EATF Alternative 8 - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt backfill, change container material.
74 EATF Alternative 9 - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, salt aggregate grout backfill, change container material.
75 EATF Alternative 10 - Decontaminate surface of metallic wastes for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
76 EATF Alternative 11 - Supercompact organics and inorganics, salt backfill, monolayer of 2,000 drums in a 6x33x300 room.
77 EATF Alternative 12 - Supercompact organics and inorganics, salt aggregate grout backfill, monolayer of 2,000 drums, in a 6x33x300 room.
78 EATF Alternative 13 - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides, no backfill, alternate container, 10x31x188.
79 EATF Alternative 14 - Supercompact organics, and inorganics, salt backfill, seal individual rooms, 2,000 supercompacted drums per room.
83 Salt backfill with CaO
87 Systems Prioritization Methodology (SPM) IT-2 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill, change container material.
89 SPM IT-4 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.
90 SPM IT-5 Enhanced cement sludges, shred and compact organics and inorganics, salt backfill, 2,000 drum monolayer, 6x33x300 room.
92 SPM IT-7 Enhanced cement sludges, shred and compact organics and inorganics, salt backfill with CaO, 2,000 drums monolayer, 6x33x300 room.
93 SPM IT-8 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt backfill.

Table 2 - 1
Engineered Alternative Pass List

94 SPM IT-9 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt aggregate grout backfill.
95 SPM IT-10 Decontaminate surface of metallic waste for LLW disposal, change container material, salt aggregate grout backfill.
110 Enhanced Solidification of Sludges
111 Clay Based Backfill

Table 2 - 2
Engineered Alternatives Rejection List

The following is a listing of Engineered Alternatives that failed the screening process.

4 Wet Oxidation
11 Melt Metals
13 Add other Sorbents
14 Add Gas Suppressant
16 Acid Digestion
17 Sterilization
18 Add Copper Sulfate
20 Add Fillers
21 Segregate Waste Forms
23 Change Waste Generation Process
24 Add Anti-Bacterial Material
25 Accelerate Waste Digestion Process
26 Alter Corrosion Environment
27 Alter Bacterial Environment in WIPP
28 Transmutation of Radionuclides
30 Salt Backfill Only
31 Salt Backfill Plus Gas Getters
32 Compact Backfill
34 Preformed Compacted Backfill
37 Add Gas Suppressant
39 Segregate Waste in WIPP
40 Decrease Amount of Waste per Room
41 Emplace Waste and Backfill Simultaneously
42 Selected Vegetative Uptake
43 Brine Isolating Dykes
44 Raise Waste Above the Floor
45 Brine Sump and Drains
46 Gas Expansion Volume
47 Seal Repository Room Walls
48 Vent Facility
49 Ventilate Facility
50 Add floor of Brine Sorbents

Table 2 - 2
Engineered Alternatives Rejection List

52 Change Room Configurations
54 Two Level Repository
55 Monument Forest Over Repository
56 Monument Covering the Entire Repository
57 Buried Steel Plate Over the Repository
58 Artificial Surface Layer Over the Repository
59 Add Marker Dye to Strata
61 Grout Culebra Foundation
62 Increase Land Withdrawal Area
65 EATF Baseline - As Received with Salt Backfill
80 SPM-Baseline
81 SPM-A Salt backfill
82 SPM-B Salt/Bentonite backfill 50-50 mix, 50% filling efficiency
84 SPM-D Cement grout backfill
85 SPM-E Salt/Grout backfill
86 SPM IT-1 Shred and cement organics and inorganics, salt backfill - Deleted
88 SPM IT-3 Enhanced cement sludges, shred and cement orginics and inorganics, salt aggregate grout backfill.
91 SPM IT-6 Enhanced cement sludges, shred and compact organics and inorganics, salt aggregate grout backfill, 2,000 drum monolayer, 6x33x300 room.
96 SPM EATF-8 Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt backfill, change waste container material.
97 SPM EATF-9 Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt aggregate grout backfill, change waste container material.
98 SPM DOE-1 Passive markers- no specific scenario given reduce human intrusion probability parameters.
99 SPM DOE-2 Compartmentalization of waste - various unspecified scenarios.
100 194- Cementation
101 194- Shredding
102 194- Supercompaction
103 194- Incineration
104 194- Vitrification
105 194- Improved Waste Containers

Table 2 - 2
Engineered Alternatives Rejection List

106 194- Grout and Bentonite Backfill
107 194- Metal Melting
108 194- Alternative Configuration of Waste Emplacement
109 194- Alternative Disposal System Dimensions

Engineered Alternative Working Group

Members (resumes attached)

Peter Carson
John Case
Sayan Chakraborti
Terry DeBiase
Andrew Dykes
Michael Emerson
Denise Gelston
Dave Lechel
John McFee
Jonathan Myers
Rod Palanca
David Palmer
James Ward
James Waters
Maggie Wood

Facilitator
Hans Kresney

Program Oversight
Jayne Davis
John Magyar
Steve Wagner

APPENDIX A

Engineered Alternatives Screening Working Group
Resumes

Peter H. Carson

Waste Management Engineer

8 Years of Relevant Experience

SUMMARY: Mr. Carson has more than eight years of experience in providing support to the U.S. Department of Energy (DOE) and its contractors in the area of radioactive and hazardous waste management. Mr. Carson's experience also includes performing work in waste stream characterization, waste certification, project management, RCRA permit applications, waste treatment technology development, waste management and environmental restoration planning and strategy development, and waste minimization cost/benefit analysis.

EDUCATION: B.S., Chemical and Petroleum Refining Engineering, Colorado School of Mines, 1984

RELEVANT EXPERIENCE:

Authoring chapters of the interim Preliminary Safety Analysis Report (PSAR) for the Lockheed Environmental Systems and Technologies (LESAT) Pit 9 waste retrieval and processing system as part of the INEL Pit 9 Interim Action. This effort includes contributing to the hazards analysis, preparing the facility description, and authoring chapters relating to radioactive waste management and quality assurance.

Provided regulatory compliance support to LESAT for INEL Pit 9 Interim Action Proof-of-Process (POP) Tests. These POP tests will demonstrate LESAT's ability to retrieve and process buried low-level, transuranic (TRU), hazardous, and mixed waste from a shallow land burial disposal pit at the Idaho National Engineering Laboratory (INEL). This project also addresses the handling and treatment of contaminated soils from the pit. Specific assignments include preparing the Quality Assurance Program Plan, assisting in the development of the Treatment/Storage/Disposal Plan, and identifying and resolving potential compliance issues.

Participated as a member of the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Group Audit Team. This team conducted an audit of EG&G Idaho, Inc. and Argonne National Laboratory-West (ANL-W) activities directed toward selecting, characterizing, and packaging TRU waste for experimental activities at WIPP. The audit was required to demonstrate compliance with the WIPP RCRA Part B Permit Application.

Supported the INEL Transuranic Waste Program by preparing and reviewing programmatic planning documents. This work was directed toward ensuring consistency between the Waste Management Division Strategic Plan, the TRU Waste Implementation Plan, and the INEL Roadmap. Specific tasks included

preparing sections of the test, resolving review comments, and suggesting improvements in the planning process.

Supported the Experimental-Waste Characterization Program (E-WCP) at the Rocky Flats Plant (RFP). This support included preparing a Project Management Plan, reviewing and revising operating procedures from various organizations at RFP that are participating in the E-WCP, assisting in the preparation of the Quality Assurance Project Plan, and participating in the development of a self-evaluation program. The E-WCP selected, characterized, repackaged, and shipped to WIPP various transuranic waste forms for experimental activities required to demonstrate that WIPP meets regulatory requirements.

Contributed to preparation of the WIPP Strategic Plan. This plan detailed at several levels the steps required to make WIPP an operating disposal facility. This work included conducting a requirements analysis and a stakeholder analysis, defining the goals and objectives of the WIPP program, creating activity logic diagrams, and analyzing alternate strategies for attaining programmatic goals.

Supported the WIPP Management Control Task Force. This support included preparing a Test Phase Management Plan, which establishes organizational roles and responsibilities for the DOE WIPP Project Office, Westinghouse Waste Isolation Division (WID), and Sandia National Laboratories, the three primary participants in the WIPP program.

Consulted for Rockwell International as part of the Joint Integration Office. Contributed to planning and systems integration efforts related to the Defense TRU Waste Program. Possesses in-depth knowledge of the TRU waste management systems at many DOE locations, including the Idaho National Engineering Laboratory, Oak Ridge National Laboratory, Savannah River Site, and Hanford Reservation. Responsible for preparing long-range plans, cost/schedule optimization studies, and system integration implementation plans.

Supported the Westinghouse Waste Isolation Division by assisting in revising the WIPP Waste Acceptance Criteria (WAC). Also preparing a Transportation System Management and Operating Plan utilizing detailed knowledge of TRU waste certification and transportation requirements.

PUBLICATIONS:

Carson, P.H., et al., 1990. *Sources of Waste*, Radioactive Waste Management and the Nuclear Fuel Cycle, Vol. 14 (1-2), pp. 27-44.

Kallas, J.A., Tipton, J.B., Carson, P.H., October 3, 1991. *Planning for Environmental Management Activities at the Rocky Flats Plant*, Proceedings from the 5th Annual Colorado Hazardous Waste Management Society Conference.

Ebra, M.A., Carson, P.H., Pierce, G.D., 1988. *Management of Remote-Handled Defense Transuranic Wastes*, Waste Management Eighty Eight, Volume 2 - High-Level Waste and General Interest, pg. 303.

John B. Case, PE

Professional Qualifications

Mr. Case is a Registered Professional Engineer with more than 16 years of experience in ground and surface water hydrology and geotechnical engineering. He is a specialist in sealing technology for nuclear waste and hazardous waste management. He has been involved in many hydrological, thermomechanical, and structural analyses conducted on nuclear waste repository projects including the Waste Isolation Pilot Plant (WIPP), the Basalt Waste Isolation Project (BWIP), the Office of Nuclear Waste Isolation (ONWI), the Yucca Mountain Project (YMP), and the Office of Waste Technology Development. His work for the BWIP, the YMP, the ONWI, and the OWTD has been primarily as a Principal Investigator, and has included analyzing hydrological, stress, and thermal effects using the boundary element, finite element, and finite difference methods; modeling heat conduction; analyzing the thermomechanical behavior of seals; analyzing room closure for salt creep; analyzing consolidation of crushed salt and other backfill materials; analyzing stress buildup on waste packages in salt; analyzing groundwater flow through seals and fractured rock; and evaluating the extent of the damage zone around boreholes, shafts, and tunnels. In addition, Mr. Case assisted in performing geotechnical, hydrologic, and structural analyses for certifying existing and new underground hazardous waste tank systems and developing spill prevention plans for surface and underground tank systems.

In support of IT-Albuquerque's Geotechnical Design specialty, Mr. Case is responsible for developing and implementing project plans using critical path methods, resource leveling, and cost-tracking methods. He is a member of IT's Senior Technical Associate program.

Education

M.S., Civil Engineering, University of Colorado, Boulder, Colorado; 1974
B.S., Civil Engineering, University of Colorado, Boulder, Colorado; 1972

Registrations/Certifications

Registered Professional Engineer, New Mexico, Colorado, Arizona

Experience and Background

1976 - 1980
1981 - Present

Project Manager, Geotechnical Design, International Technology Corporation (IT), Albuquerque, New Mexico. As a project manager, Mr. Case is responsible for projects involving nuclear waste and hazardous waste disposal, including evaluations of seal and rock behavior for repositories in basalt, tuff, and salt, and for deep-well injection.

- Evaluated the disturbed zone that resulted from drilling, blasting, or machine excavation around shafts and tunnels in salt, tuff, and basalt. Utilized the elasto-plastic theory to assess the mechanical properties of rock, stress distribution, and displacements around openings.

- Prepared field test plans for repository sealing in tuff.
- Developed a Borehole Sealing Strategy for exploratory boreholes at the YMP.
- Conducted performance assessment of repository seals for air and water flow above the groundwater table for the YMP.
- Developed field test plans for seals in terms of air flow and episodic water flow for the YMP.
- Graded quality assurance activities at the YMP for Sandia National Laboratories, Albuquerque (SNL).
- Performed selected analyses to evaluate the impact of the exploratory shaft test facility on the performance of the YMP repository.
- Designed the rock support systems at the BWIP using boundary element and rock-support interaction methods and developed the field test plans.
- Conducted performance assessment of a repository seal system in basalt at the BWIP using finite element and stochastic methods.
- Developed a numerical model to predict how cement hydration would affect the interface stress on a concrete plug at the Waste Isolation Pilot Plant (WIPP).
- Analyzed the flow of pressurized brine to and from the WIPP repository through boreholes. This represented the worst-case breach scenario for the WIPP.
- Developed a completed numerical model for evaluating brine inflow data for the WIPP.
- Provided peer review of field tests and made recommendations on test performance for the Stripa Project.
- Developed a spill prevention plan for surface and underground tanks at SNL.

1980 ***Senior Engineer, Rockwell Hanford Operations, Richland, Washington.*** Conducted thermal mechanical analyses in basalts and general rock mechanics analyses including:

- Numerical modeling and analysis of the full-scale heater tests simulating radioactive waste emplacement for the BWIP. Team Leader of the Numerical Modeling Group responsible for planning and reviewing laboratory and field tests in rock mechanics, and for selecting thermal and thermomechanical properties used in numerical analysis. Provided a preliminary analysis of temperature data recovered after 70 days of heater test operations.

- Planned, directed, and analyzed the results of rock mechanics characterization tests in basalt associated with the BWIP to provide thermal and thermomechanical data necessary for predicting the response of the host rock to waste-induced heating.

Professional Affiliations

American Institute of Mining Engineers
American Society of Civil Engineers
Kiwanis International
National Society of Professional Engineers
Tau Beta Pi, National Engineering Association

Publications

Fernandez, J. A., J. B. Case, and J. Tyburski, 1992, "Proposed Sealing Field Tests for a Potential High-Level Waste Repository in Unsaturated Tuff," Proceedings of the Third International Conference on High-Level Radioactive Waste Management, Las Vegas, Nevada, Vol. 2, pp. 2290-2297.

Case, J. B., J. A. Fernandez, and J. R. Tyburski, 1992, "Supporting Hydration Calculation for Small- to Large-Scale Seal Tests in Unsaturated Tuff," Proceedings of the Third International Conference on High-Level Radioactive Waste Management, Las Vegas, Nevada, Vol. 2, pp. 2298-2305.

Cook, R., and J. Case, 1991, "Design and Construction Issues Associated with Sealing of a Repository in Salt," *Waste Management '91, Proceedings of the Symposium in Waste Management*, Tucson, Arizona, Vol. 2, pp. 735-742.

Dietz, J. M., M. G. Wallace, B. A. Lauctes, J. B. Case, and D. E. Deal, 1985, "Coupled Fluid-Flow Modeling of Brines Flowing Through Salt Around the Excavations for the Waste Isolation Pilot Plant (WIPP) in the Permian Salado Formation," *Geological Society of America, Abstracts with Programs*, p. A347.

Wallace, M. G., J. M. Dietz, B. A. Lauctes, J. B. Case, and D. E. Deal, 1990, "Coupled Fluid-Flow Through Salt Around Excavations for the Waste Isolation Pilot Plant (WIPP) in the Permian Salado Formation" *Waste Management '90,*

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Fernandez, J. A., T. E. Hinkebein, and J. B. Case, 1988, "Selected Analyses to Evaluate the Effects of the Exploratory Shafts on Regulatory Performance at Yucca Mountain," *SAND0598*, Sandia National Laboratories, Albuquerque, New Mexico.

Case, J. B., and D. Deal, 1987, "Preliminary Hydrologic and Geomechanical Evaluations of Brine Inflow from Bedded Salt to a Nuclear Waste Repository," *Geological Society of America, Abstracts with Programs*, Vol. 19, No. 7, pp. 614-615.

Case, J. B., and P. C. Kelsall, 1987, "Modification of Rock Mass Permeability in the Zone Surrounding a Shaft in Fractured, Welded Tuff," *SAND86-7001*, Sandia National Laboratories, Albuquerque, New Mexico.

Case, J. B., P. C. Kelsall, and J. L. Withiam, 1987, "Laboratory Investigation of Crushed Salt Consolidation," *Proceedings of the 28th U.S. Symposium on Rock Mechanics*, A. A. Balkema, Rotterdam, pp. 189-196.

Case, J. B., S. Niou, J. Pietz, M. Wallace, and J. Zurkoff, 1987, "Coupled Fluid Flow and Salt Creep Analysis: Summary of Technical Work," *Waste Management '87, Proceedings of the Symposium on Waste Management*, University of Arizona, Tuscon, Arizona.

Deal, D. E., and J. B. Case, 1987, "Brine Sampling and Evaluation Program - Phase I Report," *DOE-WIPP-87-008*, U.S. Department of Energy, Carlsbad, New Mexico.

Fernandez, J. A., P. C. Kelsall, J. B. Case, and D. Meyer, 1987, "Technical Basis for Performance Goals, Design Requirements, and Material Recommendations for the NNWSI Repository Sealing Program," *SAND84-1895*, Sandia National Laboratories, Albuquerque, New Mexico.

Kelsall, P. C., J. B. Case, D. Meyer, J. G. Franzone, and W. E. Coons, 1986, "Schematic Designs for Penetration Seals for a Repository in the Richton Dome," *ONWI-565*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

Kelsall, P. C., J. B. Case, W. E. Coons, J. G. Franzone, and D. Meyer, 1986, "Schematic Designs for Penetration Seals for a Repository in the Permian Basin", *ONWI-564*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

Case, J. B., and P. C. Kelsall, 1985, "Coupled Processes in Repository Sealing," *Proceedings of the International Symposium on Coupled Processes Affecting the Performance of a Nuclear Repository*, Academic Press, Orlando, Florida, pp. 531-604.

Lundstrom, R. A., J. B. Case, and P. C. Kelsall, 1985, "The Influence of the Damaged Zone, Interface, and Various Sealing Components on Seal Performance for a Repository in Basalt," *Proceedings of the Topical Meeting on High-Level Nuclear Waste Disposal*, Battelle Press, Columbus, Ohio, pp. 727-738.

Case, J. B., P. C. Kelsall, and J. W. Holland, 1984, "The Development of Interface Stress in a Concrete Plug During Cement Hydration," presented at the Symposium on Concrete and Cementitious Materials for Radioactive Waste Management, American Concrete Institute, New York, New York.

Kelsall, P. C., J. B. Case, and C. R. Chabannes, 1984, "Evaluation of Excavation-Induced Changes in Permeability," *International Journal of Rock Mechanics and Mining Sciences*, Vol. 21, No. 3, pp. 123-125.

Kelsall, P. C., J. B. Case, J. W. Nelson, and J. G. Franzone, 1984, "Assessment of Crushed Salt Consolidation and Fracture Healing in a Nuclear Waste Respository in Salt," *Waste Management '84, Proceedings of the Symposium on Waste Management*, University of Arizona, Tuscon, Arizona.

Kelsall, P. C., J. B. Case, C. R. Chabannes, W. E. Coons, R. D. Ellison, D. Meyer, D. K. Shukla, and D. E. Stephenson, 1982, "Schematic Designs for Penetration Seals for a Reference Repository in Bedded Salt," *ONWI-405*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio.

Kuhn, A. K., J. B. Case, S. M. Dass, J. G. Franzone, and J. K. Register, 1982, "Analysis of Potential Impacts of Brine Flow Through Boreholes Penetrating the WIPP Storage Facility," prepared by D'Appolonia (predecessor to International Technology Corporation), Albuquerque, New Mexico.

Chabannes, C. R., J. B. Case, D. K. Shukla, and R. D. Ellison, 1981, "Thermomechanical Considerations in Designing Tests at the Asse Mine," *Proceedings of the 1st Conference on the Mechanical Behavior of Salt*, Pennsylvania State University, University Park, Pennsylvania.

Baca, R. G., J. B. Case, and J. G. Patricio, 1980, "Coupled Geomechanical/ Hydrological Modeling; An Overview of Basalt Waste Isolation Studies," *Proceedings of the Workshop on Thermomechanical-Hydrochemical Modeling for a Hard Rock Waste Repository*, LBL-11204, Lawrence Berkeley Laboratories, Berkeley, California.

Case, J. B., 1980, "A Technical Approach to Resolving Issues on Rock Mechanics as Applied to Development of a Nuclear Waste Repository in a Crystalline Rock Formation," *RHO-BWI-SA51*, Rockwell Hanford Operations, Richland, Washington.

Case, J. B., A. D. Krug, and J. Williams, 1980, "Full Scale Heater Results," *RHO-BWI-LD34*, Rockwell Hanford Operations, Richland, Washington.

Case, J. B., J. W. Nelson, and D. E. Shaw, 1980, "Thermal Expansion Effects in Oil Storage Caverns," presented at the American Society of Mechanical Engineers, Energy Technology Conference and Exhibition, New Orleans, Louisiana.

Case, J. B., J. G. Gusek, and D. E. Shaw, 1979, "Explosive Casting Technology in Surface Mining," *Proceedings of the 20th U.S. Symposium on Rock Mechanics*, University of Texas, Austin, Texas.

Case, J. B., 1974, "The Constitutive Relations of Pittsburgh Coal Subjected to a Multiaxial State of Stress," Master's Thesis, University of Colorado, Boulder, Colorado.

Sayan Chakraborti

Professional Qualifications

Mr. Chakraborti is a Chemical Engineer with more than five years of experience in radioactive waste management. This includes a wide variety of projects completed in support of both the U.S. Department of Energy-Headquarters (DOE-HQ) and the DOE sites in the areas of mixed transuranic (TRU) waste, mixed low-level waste (MLLW), low-level waste (LLW), and spent fuel management. As a staff member of the Transuranic and Mixed Waste Assessment Group at IT-Albuquerque, Mr. Chakraborti was the project coordinator and one of the primary contributors to the report of the Engineered Alternatives Task Force (EATF) that was prepared for DOE in support of the Waste Isolation Pilot Plant (WIPP) project. Subsequently he was also involved in the Engineered Alternatives Program (EAP) that was the follow-on effort to the EATF. He also provided support to the WIPP project in preparation of the Waste Characterization Program Plan and the RCRA Part B permit application. More recently he supported the Hanford Site in the evaluation of impacts of WIPP uncertainties on its Solid Waste Operations Complex and the technical review of the Waste Receiving and Processing (WRAP) 1 Title I design with respect to the WIPP Waste Acceptance Criteria (WAC). His recent accomplishments include the preparation of a report on the cost and schedule of selected engineered alternatives in support of the WIPP System Prioritization Initiative. His other accomplishments during the past two years include support to DOE-HQ in the development of the MLLW Systems Analysis Methodology, preparation of the Interim Mixed Waste Inventory Report in response to the Federal Facility Compliance Act (FFCA), and support to the Idaho National Engineering Laboratory in the preparation of background reports for LLW and spent fuel in the DOE system.

Education

M.B.A., Marketing Management, University of New Mexico, Albuquerque, New Mexico; 1989

M.S., Chemical Engineering, University of New Mexico, Albuquerque, New Mexico; 1985

Bachelor of Technology, Chemical Engineering, Indian Institute of Technology, Kharagpur, India; 1983

Experience and Background

1990–Present ***Chemical Engineer and Technical Associate, IT Corporation, Albuquerque, New Mexico.*** Mr. Chakraborti has developed diverse and comprehensive expertise in both the technical and programmatic aspects of DOE radioactive waste management through his active involvement in a variety of projects for DOE-HQ and the DOE sites that addressed many different types of radioactive waste. He is currently involved in the development of an automated cost and schedule estimation model that will be used for evaluation of DOE's site treatment plans for mixed waste. During the past two years he has co-authored several publications with DOE-HQ staff on various topics of radioactive waste management.

TRU Waste

- Task Manager for preparation of a report that estimated the life cycle cost and schedule of implementing engineered alternatives (EAs) for the WIPP in response to the draft version of 40 CFR 194. Report compared the cost of processing the waste to the WIPP-WAC versus alternative immobilization technologies.

- Primary contributor to a variety of tasks completed for the EATF project, including cost/benefit analyses of various engineered alternatives to the current TRU waste forms and the repository design; preparation of DOE reports on behalf of two expert panels that were organized for the project; preparation of all weekly, biweekly, and monthly project status reports; and coordination of all technical groups working on the project within IT.

- Primary contributor to many tasks for the EAP, which was the follow-on effort to the EATF project. Developed a program plan for the use of alternate containers for TRU waste and also prepared the technical requirements document for an alternate container for TRU waste.

- Investigated the impact of potential changes in the WIPP-WAC on the design of different facilities in the Hanford Site Solid Waste Operations Complex (SWOC) and determined if any major design modifications would be required as a result of these changes. Also estimated the impact of these potential design changes on the capital cost and implementation schedule for the Hanford SWOC.

- Analyzed the effects of supercompacting TRU waste on both the potential performance of the WIPP repository and the transportation costs. The analysis, which was conducted for Westinghouse-WIPP, evaluated the incremental effects on WIPP performance from supercompacting only Rocky Flats' waste as well the effect of supercompacting different percentages of the entire WIPP inventory.

- Involved in the development and preparation of Revision 2.0 of the WIPP TRU Waste Characterization Program Plan, which described TRU waste characterization requirements for the originally planned WIPP Test Phase, and also served as a DOE planning document for developing and implementing site-specific TRU waste characterization programs.

- Revised the TRUPACT-II Content Codes (TRUCON) document with the objective of simplifying it in order to reduce the time and effort required for review of future payload amendments by the U.S. Nuclear Regulatory Commission (NRC). The revised document is ready for presentation to the NRC for final approval.

- Contributed to the development and finalization of the waste analysis plan in support of the WIPP RCRA Part B permit application to ensure RCRA compliance for TRU waste to be accepted at the WIPP facility.

- Evaluated the Title I design of Module 1 of the proposed WRAP facility at the Hanford Site with respect to Revision 4 the WIPP-WAC and provided recommendations to ensure that the final TRU waste forms generated by the facility will satisfy the WIPP-WAC.

- Primary author of a memorandum to the EPA that helped DOE to successfully negotiate the exclusion of certain compounds from EPA-imposed flammability testing requirements for TRU waste in the Conditional No-Migration Determination granted by the EPA in 1990.

- Prepared a report for DOE that evaluated potential flammability concerns associated with TRU waste destined for disposal at the WIPP and concluded that adequate safety regulations currently exist for minimization of flammability concerns. The report helped DOE to address flammability concerns expressed by external agencies.

- Developed complete engineering design specifications for volatile organic compound monitoring systems for five locations at the WIPP facility. Specifications included sampling method and frequency, selection of sampler and accessories, instrumentation and control requirements, fabrication and assembly drawings of the entire monitoring system, equipment layout, and field execution and quality control procedures.

Mixed Low-Level Waste

- Deputy Project Manager for IT for the development of a Systems Analysis Methodology for evaluation of "cradle-to-grave" options for management of DOE MLLW that include all major components of MLLW management, such as waste characterization, treatment, storage, transportation, and disposal. The methodology, which was developed for EG&G Idaho in support to DOE-HQ, is an analytical tool for evaluation of MLLW options in terms of the performance of final waste forms in a disposal facility, life-cycle cost and schedule for implementing options, health and safety risks associated with the options, and also the regulatory impact of each option. Apart from routine responsibilities as Deputy Project Manager for the 18-month duration of this $2.4 million project was also the leader for the development of the life-cycle cost and schedule estimation methodology.

- Provided direct support to DOE-HQ in the preparation of the Interim Mixed Waste Inventory Report that was submitted to the EPA in May 1993 in response to the FFCA. Interfaced with DOE site representatives and completed technical review of waste profile sheets for a number of waste streams from these sites to verify the correctness and consistency of the data provided by the sites.

Low-Level Waste

- Primary author of many sections of the draft "Low-Level Waste Background Report," which was prepared for EG&G Idaho in support of the waste type-specific strategic planning process for DOE-HQ. The report presented an overview of LLW management in the DOE complex, with an emphasis on current challenges requiring attention and potential future courses of action.

- Contributed to the development of a macroengineering design for remediation of the 100 Area at the Hanford Site. Responsible for the development of a conceptual design of an efficient on-site system for transportation of excavated waste between different areas and facilities at the Hanford Site. Also prepared cost estimates and equipment specifications for this system.

Spent Fuel

- Primary author of many sections of the draft "Spent Fuel Background Report," which was prepared for EG&G Idaho in support of the waste type-specific strategic planning process for DOE-HQ. The report summarized the DOE spent fuel inventory and applicable regulations for management of spent fuel in the DOE complex and also discussed historical spent fuel management practices at each DOE site

- Primary author of many sections of a report titled, "Issues Related to DOE Management of Spent Nuclear Fuel," which was prepared for EG&G Idaho in support of DOE-HQ. This report summarized current spent fuel management issues (both site-specific and DOE complexwide) and discussed their potential implications on the DOE system.

1987–1989 ***Graduate Assistant, Anderson School of Management, University of New Mexico, Albuquerque, New Mexico.*** Responsible for assisting professors in research and course work. Tutored undergraduates in financial management courses and graded graduate-level financial management course work. Collected and summarized data from the Wall Street Journal in different areas of investment analysis.

1988 ***Marketing Intern, Southwest Airlines, Albuquerque, New Mexico.*** Assisted Area Marketing Manager in marketing activities, analyzed market share data, initiated sales calls, and prepared monthly airline market analysis reports.

1984–1986 ***Research Assistant, Department of Chemical Engineering, University of New Mexico, Albuquerque, New Mexico.*** Assisted professors with research in the areas of heterogeneous catalysis and solar engineering.

- Developed a comprehensive computer model for the design, performance analysis, and optimization of a gel solar pond for domestic heating purposes. Included

detailed modeling and simulation of heat collection, temperature profiles as a function of depth, and process heat exchange from any given size pond. The model was subsequently used to design and construct a pond 5 meters deep and 400 square meters in area for a local business center in Albuquerque.

- Designed and fabricated an automatic fine particle generator to prepare nonporous spherical TiO_2 particles to be used as supports for Rh catalysts. Investigated the metal-support interactions of Rh catalysts using nonporous oxide supports of model shapes (silica and titania spheres, magnesia cubes).

1983–1984 ***Teaching Assistant, Department of Chemical Engineering, University of New Mexico, Albuquerque, New Mexico.*** Assisted professors with undergraduate courses and grading and supervised undergraduates in Unit Operations Lab. Guided undergraduates through start-up and shut-down procedures of various units. Tutored undergraduate courses in chemical engineering.

Professional Affiliations

American Institute of Chemical Engineers

Publications

Chakraborti, S., M. Abashian, J. Rhoderick, and L. Harmon, 1993, "Transportation of DOE Mixed Waste in the U.S.," *Proceedings of the Second International Mixed Waste Symposium*, August 17–20, Baltimore, Maryland, p. 12.4.1.

Chakraborti, S., and T. DeBiase, 1993, "Transportation of Liquid Mixed Waste in the U.S.: Is It Really a Problem?" *Proceedings of the Second International Mixed Waste Symposium*, August 17–20, Baltimore, Maryland, p. 12.3.1.

Chakraborti, S., T. DeBiase, M. Devarakonda, M. Abashian, and J. Bassi, 1993, "Estimation of Initial Costs of DOE Mixed Low-Level Waste Management Options," *Proceedings of the 1993 Incineration Conference*, May 3–7, Knoxville, Tennessee, p. 125.

Caregeorges, M., S. Chakraborti, M. Abashian, and J. Bassi, 1993, "Evaluation of the Regulatory Compliance Impact on DOE Mixed Low-Level Waste Management Options," *Waste Management '93, Proceedings of the Symposium on Waste Management*, Tucson, Arizona, February 28–March 4, p. 1809.

Melvin, J., S. Chakraborti, M. Abashian, and D. Abbott, 1993, "Spent Fuel Storage in the DOE Complex: A Discussion of the Current Status and Unresolved Issues," *Waste Management '93, Proceedings of the Symposium on Waste Management at Tucson, Arizona*, February 28–March 4, p. 877.

Chakraborti, S., T. DeBiase, M. Devarakonda, M. Abashian, and J. Bassi, 1993, "Estimation of Initial Costs of DOE Mixed Low-Level Waste Management Options," *Waste Management '93, Proceedings of the Symposium on Waste Management at Tucson, Arizona*, February 28–March 4, p. 1803.

Chakraborti, S., T. DeBiase, M. Devarakonda, M. Abashian, and J. Bassi, 1992, "Development of a Methodology for Estimation of Initial Costs of DOE Mixed Low-Level Waste Management Options," *Proceedings of the Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference*, November 18–20, Phoenix, Arizona.

Abashian, M., Chakraborti, S., M. Devarakonda, S. Djordjevic, and J. Bassi, 1992, "A Decision Methodology for the Evaluation of Mixed Low-Level Radioactive Waste Management Options for DOE Sites," *Proceedings of the Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference*, November 18–20, Phoenix, Arizona, p. 428.

Chakraborti, S., M. Abashian, J. C. Lopez, and R. Batra, 1992, "Review of Alternate Container Materials for TRU Waste: An Expert Panel Evaluation," *Proceedings of the 1992 Incineration Conference*, May 11–15, Albuquerque, New Mexico, p. 657.

Datye, A. K., S. Chakraborti, and E. J. Braunschweig, 1988, "Structure and Reactivity of Small Metal Particles," *Proceedings of the 9th International Congress on Catalysis*, p. 1122.

Chakraborti, S., N. J. Long, and A. K. Datye, 1987, "Oxidation-Reduction Treatment of Rhodium Supported on Nonporous Silica Spheres," *Journal of Catalysis*, Vol. 108, pp. 444–451.

Holt, T., S. Chakraborti, A. D. Logan, and A. K. Datye, 1987, "The Effect of Catalyst Preparation Conditions on the Morphology of MgO Catalyst Supports," *Applied Catalysis*, Vol. 34, p. 199.

Wilkins, E., T. K. Lee, and S. Chakraborti, 1986, "Optimization of the Gel Solar Pond Parameters: Comparison of Analytical Models," *Energy Conversion and Management*, Vol. 26, No. 1, pp. 123–134.

Terry A. DeBiase

Professional Qualifications

Mr. DeBiase is a chemical engineer with more than five years of experience in the environmental field. His technical specialties include design, costing, and construction management for remediation systems, development and application of predictive models for engineering design, as well as issues regarding transportation of radioactive mixed waste. Since joining IT, he has provided engineering support to the Los Alamos National Laboratory (LANL) Radioactive Liquid Waste Treatment Facility, U.S. Department of Energy (DOE) mixed low-level waste System Analysis Methodology, New Mexico Environment Department remediation projects, the Hanford site transuranic (TRU) waste management efforts, the Waste Isolation Pilot Plant (WIPP) project dealing with the cost and feasibility of transporting supercompacted TRU waste from the Rocky Flats Plant, and the EG&G Idaho project addressing disposal facility performance assessment for various final wasteforms. He has a strong background in field operations management, technical report preparation, permitting issues, and project and engineering support.

Education

B.S., Chemical Engineering, University of California at Berkeley, California; 1987
Groundwater Pollution and Hydrology, Princeton Short Course, Omni Environmental Corporation; 1990
OSHA Hazardous Waste Operations Training (29 CFR 1910.120, 40 hours); 1989
Management and Supervisor Training (29 CFR 1910.120, 40 hours); 1991
Hazards and Protection (annual refresher) IT Corporation; 1994

Registrations/Certifications

OSHA Engineer in Training, California

Honors and Awards

California State Finalist, Rhodes Scholarship; 1987
Male Scholar-Athlete Award; 1987
Robert Gordon and Ida Sproul Award, Outstanding Junior at University of California at Berkeley
Edmund Kraft Scholarship, Top 100 Freshmen
NCAA Swimming All-American (four-time), NCAA Academic All-American (three-time)

Experience and Background

1992-Present **Chemical Engineer, IT Corporation, Albuquerque, New Mexico.** Provides project and task management and engineering and regulatory support for DOE projects.

- Served as project manager for the technical support to the Radioactive Liquid Waste Section (CST-13) at Los Alamos National Laboratory. Project Work included the 75,000 gallon retrofit study, a tank decontamination plan, and an industrial ventilation standards study.

- Served as project engineer and task manager for the Lawrence Livermore National Laboratory (LLNL) project addressing proper use of the TRUPACT-II shipping package and associated equipment. Work performed included compilation of site-specific information, field survey for selection of a staging area for TRUPACT-II operations, and preparation of reports and procedures to enable LLNL personnel to use the TRUPACT-II.

- Supervised construction and installation of the remediation system at a site in Albuquerque, New Mexico. Permitted the thermal oxidation unit in Albuquerque. New Mexico, in compliance with Albuquerque-Bernalillo County Air Quality Control Board Regulations.

- Evaluated the effect of engineered soils and other site modifications as on the performance of waste disposal facilities for the National Low-Level Waste Management Program at the Idaho National Engineering Laboratory.

- Provided technical support for the environmental assessment document prepared to satisfy NEPA requirements for the environmental restoration activities planned for Sandia National Laboratories/New Mexico.

- Evaluated the effectiveness of various final waste forms and disposal sites with respect to compliance with the performance objectives in applicable DOE orders for EG&G Idaho.

- Performed an analysis of potential impacts on the Hanford Site TRU waste management efforts from uncertainties associated with the current WIPP Waste Acceptance Criteria. Work performed included compilation and analysis of site-specific information, client interface for the interpretation of relevant information and identification of additional data needs, and report preparation documenting the findings of the study.

- Analyzed U.S. Department of Transportation (DOT) and DOE requirements for transportation of radioactive mixed waste for the development of the DOE mixed low-level waste Systems Analysis Methodology, Published papers in support of this DOE effort, including the development of a cost estimation methodology for mixed low-level waste management options.

- Performed analysis of regulatory and transportation cost issues regarding the disposal of supercompacted Rocky Flats Plant TRU waste forms at the WIPP.

- Provided technical review and database support for the Mixed Waste Inventory Report prepared by DOE in response to the Federal Facility Compliance Act of 1992.

1989-1991 **Assistant Engineer, McLaren/Hart, Alameda, California.** Responsible for field operation management, technical report preparation, engineering support.

- Designed and supervised construction of groundwater extraction trench and hydrocarbon reclamation system at a site in Richmond, California, which was subject to the regulations established by the Resource Conservation and Recovery Act (RCRA).

- Provided database programming and maintenance as well as final quality assurance inspection in support of the final feasibility study for a site in Palo Alto, California, which was subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

- Wrote Bay Area Air Quality Management District air emission reports and National Pollutant Discharge Elimination System sewer discharge reports for groundwater extraction and treatment systems at RCRA and CERCLA sites.

- Performed operation and maintenance of groundwater extraction and treatment systems at RCRA and CERCLA sites in the San Francisco Bay area.

- Supervised soil sampling to provide final closure for a chemical dilution pit at a CERCLA site in Palo Alto, California.

- Coordinated wastewater discharge permit modifications and sampling plan preparation for a semiconductor manufacturer in Fremont, California.

- Analyzed emission control technologies for various petroleum refinery operations and processes to establish best available control technologies and maximum achievable control technologies for the American Petroleum Institute.

- Wrote a site closure plan in accordance with 40 CFR 265 for a hazardous waste generation facility.

- Coordinated and performed utility clearances for soil borings and well drilling operations.

- Provided engineering support for various projects, such as cost estimation, engineering calculations, and treatment system conceptualization, design, and permitting.

1989 **Staff Chemical Engineer, Aqua Resources, Inc., Berkeley, California.** Responsible for field investigations and report preparation.

- Performed model development to assess groundwater flow at a CERCLA site in Mountain View, California. Coordinated and conducted water and soil sampling at the site.
- Conducted field surveys and wrote subsequent spill prevention, control, and countermeasure (SPCC) plans to comply with 40 CFR 112 for various United States Naval Bases in San Diego, California.
- Assisted in supervision of the removal of 11 underground storage tanks and subsequent soil and groundwater sampling at an Emeryville, California, site.

Publications/Presentation

Smith, T. H., J. Myers, S. M. Djordjevic, T. A. DeBiase, M. T. Goodrich, D. DeWitt, 1994, "Preliminary Parametric Performance Assessment of Potential Final Waste Forms for Alpha Low-Level Waste at the Idaho National Engineering Laboratory," EEG-WM-11415, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho.

Myers, J., S. M. Djordjevic, T. A. DeBiase, M. R. Goodrich, 1994 "Use of Engineered Soils and Other Site Modifications for Low-Level Radioactive Waste Disposal," DOE/LLW-207, National Low-Level Waste Management Program, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

Chakraborti, S., and T. DeBiase, 1993, "Transportation of Liquid Mixed Waste in the U.S.: Is it Really a Problem?" Proceedings of the 2nd International Mixed Waste Symposium, at Baltimore, Maryland.

Chakraborti, S., and T. DeBiase, M. Devarakonda, and M. Abashian, 1993, "Estimation of Initial Costs of Mixed Low-Level Waste Management Option," Proceedings of the Symposium on Waste Management, Tucson, Arizona.

Bassi, J., Chakraborti, S., and T. DeBiase, M. Devarakonda, and M. Abashian, 1992, "Development of a Methodology for Estimation of Initial Costs of DOE Mixed Low-Level Waste Management Options," Proceedings of the 14th Annual U.S. DOE Low-Level Radioactive Waste Management Conference, Phoenix, Arizona.

Andrew A. Dykes

Professional Qualifications

Mr. Dykes is a senior consultant, for PLG, Inc., and has 29 years of relevant experience. He has experience in the application of probabilistic risk assessment (PRA) to nuclear facilities, including waste, spent fuel, and reactor facilities. Skilled at the integration of a variety of analyses into coherent products that address the client's needs. Well versed in a wide variety of analytical techniques, such as Bayesian treatment of evidence, accident analysis, decision analysis, reliability and availability assessment, and human reliability assessment. An expert in the integration of human actions into PRAs and the establishment of risk-based technical specifications.

Ph.D., Nuclear Engineering, Massachusetts Institute of Technology; 1982
M.S., Nuclear Engineering, Massachusetts Institute of Technology; 1971
B.S., United States Military Academy; 1964
Nuclear Plant Engineer Certificate, U.S. Army Power Group; 1971

Registrations/Certifications

Registered Professional Engineer, California and Virginia

Honors and Awards

Treasurer, International Association for Probabilistic Safety Assessment and Management
Chair, Conference Organizing Committee, PSAM-II
Active member of Subcommittee SC-7, Human Factors and Control Facilities, Nuclear Power Engineering Committee, of the IEEE Power Engineering Society
Alpha Nu Sigma
Phi Kappa Phi
Sigma Xi
Member, American Nuclear Society
Member, Institute of Electrical and Electronics Engineers Reliability and Power Engineering Societies
Member, Society for Risk Analysis

Recent Experience and Background

Project Manager, PLG, Inc. Handled a variety of projects for the utility industry, and conducted programmatic risk assessments of the options for the removal and interim storage of spent nuclear fuel at Hanford. Project manager and key technical contributor to safety analysis at the Rocky Flats Plant involving criticality safety analysis of plutonium waste drum storage and plutonium holdup material in exhaust ducts of processing lines to support the Safety Analysis Report for Building 707. Conducted the criticality hazards assessment for the preliminary hazards analysis of TA-55, the plutonium processing facility at Los Alamos National Laboratory, to

support its FSAR upgrade. The evaluation of administrative controls to minimize human error played an important role in this assessment. Member of the independent safety assessment group for the SP-100 space nuclear reactor.

Completed human factors evaluation for the Final Safety Analysis Report (FSAR) upgrade to DOE Order 5480.23 criteria at the DOE's WIPP. Task leader for human reliability analysis on four full-scope PRAs. Developed a practical approach for eliciting judgment from operations personnel regarding human performance using the success likelihood index methodology. Guided operating crews through an elicitation process to both quantify the likelihood of error and identify potential improvements to operating procedures. This process produced a number of suggestions that were implemented to improve both operations and training. Participating in revisions of IEEE standards in human factors.

Experienced in the analysis of diverse operational and test data to support programmatic planning. As consultant to a U.S. Air Force System Program Office, established a Bayesian-based system for the assessing the flight reliability of the Advanced Cruise Missile. The system consisted of a structured reliability database to organize testing, failure, root cause evaluations, and corrective action effectiveness that provided an efficient communication tool that assisted the organizational decision process. Performed a variety of analyses ranging from the cost of modifications of a nuclear plant to reduce impact on marine life to the risk of cancellation of future projects. Task leader for performance assessment of coal-fired fueled power plants, resulting in a heat rate standard that was accepted by both the utility and the Public Utilities Commission as a fair measure for a rate incentive program.

Principal investigator on an Electric Power Research Institute project to apply risk-based technologies to reduce O&M costs and nuclear power plants. Accomplished studies supporting Technical Specification submissions for a number of utilities. Benefits included consolidation of surveillance procedures, reductions in test-caused failures, and extension of test intervals. Currently, formulating a framework for Technical Specification submissions to build on lessons learned and to speed up the review and approval cycle.

Extensive experience in a wide variety of engineering positions in the U.S. Army Corps of Engineers, including military nuclear power and nuclear weapons effects research and development. As an associate professor at the United States Military Academy, taught courses in nuclear physics, nuclear reactor physics, nuclear systems design, and computer-aided design.

Professional Affiliations

Active DOE "Q" Security Clearance
Active DoD "Secret" Security Clearance

Publications

Dykes, A. A., 1994, "Waste Isolation Pilot Plant Human Factors Evaluation," PLG, Inc., prepared for Merrick & Company and The S. M. Stoller Corporation, PLG-1004.

Dykes, R. A., A. A. Dykes, and J. Blodgett, 1994, "Risk Management and Corrective Actions," presented at the PSAM-II Conference, San Diego, California.

Dykes, R. A., A. A. Dykes, and J. Blodgett, 1994, "An Application of Bayes' Theorem to Management Decision Making," presented at the 1994 Annual Reliability and Maintainability Symposium, Anaheim, California.

Ho, V. S., W. T. Loh, A. A. Dykes, G. A. Tinsley, and H. F. Perla, 1994, "Fire and Flooding PSAs Requantification Project," PLG, Inc., prepared for IEA of Japan Co., Ltd., and Institute of Nuclear Safety, Nuclear Power Engineering Corporation, PLG-0967.

Kindinger, J. P., A. A. Dykes, W. G. He, and J. W. Read, 1993, "Decision Analysis to Support TVA Nuclear Generation Planning — Phase 2 Report," PLG, Inc., prepared for Tennessee Valley Authority, PLG-0922.

Dykes, A. A., C. R. Grantom, K. N. Fleming, J. M. Oddo, F. J. Rahn, and D. H. Johnson, "U.S. Nuclear Industry Efforts in Utilizing PSA for Technical Specifications Changes," 1993, presented at IAEA Technical Committee Meeting on Procedures for Use of PSA for Optimizing NPP Operational Limits and Conditions, Barcelona, Spain, September 20-23.

Dykes, A. A., 1993, "Derivation of Routine Human Error Rates Used as Screening Values for the TVA IPE," PLG, Inc., prepared for Tennessee Valley Authority, PLG-0931.

PLG, Inc., 1993, "Short Course — Safety and Risk Assessment of Nuclear and Nonnuclear Facilities," PLG-0927, Newport Beach, California.

PLG, Inc., 1993, "Short Course — Risk Assessment and Risk Management of Nuclear Facilities," PLG-0926, Newport Beach, California.

Dykes, A. A., and T. J. McIntyre, 1993, "Probabilistic Safety Assessment Applications in the U.S. and Canada," PLG, Inc., prepared for Mitsubishi Atomic Power Industries, Inc.

Dykes, A. A., and J. P. Kindinger, 1993, "Rocky Flats Drum Criticality Probabilistic Risk Assessment," PLG, Inc., prepared for EG&G Rocky Flats, Inc., PLG-0838, Rev. 1.

PLG, Inc., 1992, "Browns Ferry Nuclear Plant Unit 2 Probabilistic Risk Assessment Individual Plant Examination," prepared for Tennessee Valley Authority.

PLG, Inc., 1992, "Sequoyah Nuclear Plant Unit 1 Probabilistic Risk Assessment Individual Plant Examination," prepared for Tennessee Valley Authority.

PLG, Inc., 1992, "Watts Bar Nuclear Plant Unit 1 Probabilistic Risk Assessment Individual Plant Examination," prepared for Tennessee Valley Authority.

Dykes, A. A., and E. L. Quinn, 1992, "Methodology for Developing Risk-Based Surveillance Programs for Safety-Related Equipment at San Onofre Nuclear Generating Station Units 2 and 3," PLG, Inc., prepared for Southern California Edison Company, PLG-0575.

PLG, Inc., 1991, "Criticality Risk Assessment of Ductwork Material Holdup in Building 707," prepared for EG&G Rocky Flats, Inc., PLG-0818.

Dykes, A. A., J. A. Mundis, and D. A. Bidwell, 1991, "Application of a Bayesian Aging Model to Predict Steam Generator Plugging Rates," *Proceedings of the International Conference on Probabilistic Safety Assessment and Management*, Beverly Hills, California.

Dykes, A. A., J. W. Read, K. Woodard, and D. R. Buttemer, 1990, "Assessment of Marine Review Committee Recommendations for SONGS Units 2 and 3," PLG, Inc., prepared for Southern California Edison Company, PLG-0805.

MICHAEL A. EMERSON

Consultant, PLG, Inc.

8 Years of Relevant Experience

SUMMARY: Consultant and Manager of PLG's Albuquerque office specializing in the application of risk assessments in the nuclear, chemical, and aerospace industries.

EDUCATION:

M.S., Nuclear Engineering, University of Washington, 1988
B.S., Mechanical Engineering with Distinction, University of New Mexico, 1986

RECENT EXPERIENCE: Extensive experience in assisting utilities to perform nuclear plant probabilistic risk assessments (PRA), including development of risk models using PLG's RISKMAN® software. Currently participating in the B-52H Nuclear Weapon System Safety Assessment and associated B-52H Electrical Systems Analysis to provide hazard scenario screening and quantification.

Served as manager of computer operations and software development and as project manager for RISKMAN, PLG's most important computer package that provides quantitative risk management capability. Recent RISKMAN development included the addition of new data, spatial, seismic analysis modules, and risk management facilities.

Project manager on the development of programmatic risk assessment software tools.

OTHER EXPERIENCE: Provided full-time support to Pacific Gas and Electric Company's probabilistic risk assessment (PRA) group in the development of its individual plant examination report for the Diablo Canyon Nuclear Power Plant. Was principal editor of Level 1 and Level 2 portions of the report and produced the executive summary. As part of this support, updated systems analyses, performed an update of the internal flooding analysis, and used the PRA to examine potential changes in plant and procedures. The latter use of the PRA included prioritizing masonry walls for reinforcement on the basis of their potential failure impact on adjacent equipment or mounted conduits carrying important power or control wiring, for justifying continued plant operation under certain degraded systems conditions, and for evaluating the risk of taking specific equipment out of service for maintenance.

Co-authored BARP, a program that provides Bayesian updating of reliability data. Served as a contributor to the development of COPILOT, an expert system that used Bayes' theorem to diagnose nuclear plant transient and accident events. Performed system analyses for boiling water reactor and space station systems.

HONORS AND AWARDS:

Institute of Nuclear Power Operations Fellowship
Tau Beta Pi, Engineering Honor Society
Member, American Society of Mechanical Engineers
Member, American Nuclear Society
Member, Society for Risk Analysis

SECURITY CLEARANCES:

Active DoD "Secret" Security Clearance

RECENT PUBLICATIONS (LAST 5 YEARS):

Kaplan, S., K. M. Naassan, M. A. Emerson, W. R. Fuller, "SBIR Phase 1 Report - Probabilistic Schedule and Cost Risk Analysis for KSC Shuttle Operations," PLG, Inc., prepared for the National Aeronautics and Space Administration, Kennedy Space Center, PLG-0934, July 1993.

Emerson, M. A., K. N. Fleming, D. J. Wakefield, S. A. Epstein, "RISKMAN® - A System for PSA," presented at Probabilistic Safety Assessment, PSA '93, Clearwater Beach, Florida, January 26-29, 1993.

Emerson, M. A., V. S. Ho, D. H. Johnson, C. M. Lankheim, and K. M. Naassan, "Risk Analysis of Environmental Hazards at the High Flux Beam Reactor," Phase 1 Interim Report, PLG, Inc., prepared for Brookhaven National Laboratory, PLG-0884, September 1992.

Contributing Author to:
"Browns Ferry Nuclear Plant Unit 2 Probabilistic Risk Assessment Individual Plant Examination," PLG, Inc., prepared for Tennessee Valley Authority, 1992.

Contributing Author to:
"Sequoyah Nuclear Plant Unit 1 Probabilistic Risk Assessment Individual Plant Examination," PLG, Inc., prepared for Tennessee Valley Authority, 1992.

Contributing Author to:
"Watts Bar Nuclear Plant Unit 1 Probabilistic Risk Assessment Individual Plant Examination, PLG, Inc., prepared for Tennessee Valley Authority, 1992.

Kaplan, S., S. A. Epstein, A. A. Dykes, and M. A. Emerson, "BARP - A PC-Based Bayesian Reliability Program Allowing Engineers to Think in the Language of Probability Curves," *Journal of Reliability Engineering and System Safety*, Vol. 30, pp. 399-408, PLG-0706, 1990.

Kaplan, S., A. Keter, S. A. Epstein, D. C. Bley, and M. A. Emerson, "COPILOT - A PC-Based Expert System for Reactor Operational Assistance Using a Bayesian Diagnostic Module,"

Journal of Reliability Engineering and System Safety, Vol. 30, No. 1-3, pp. 219-237, PLG-0705, 1990.

Fleming, K. N., G. A. Tinsley, M. A. Emerson, D. J. Wakefield, "Risk-Based Equipment Prioritization for Beaver Valley," prepared for Duquesne Light Company, PLG-0770, May 1990.

Kaplan, S., A. Keter, D. G. Lindsay, D. C. Bley, S. A. Epstein, and M. A. Emerson, "Expert Systems for Diagnosis and Decision under Substantial Uncertainty - A Classical (Bayesian) Approach," presented at Forum on Artificial Intelligence in Management, PLG-0761, Monterey, California, May 14-17, 1990.

Denise C. Gelston

Manager, Air Programs

AREAS OF EXPERTISE

RCRA Compliance and Permitting
Hazardous and Mixed Waste Management
Air Emission Inventories
SARA 312 Reporting
Environmental Auditing

SUMMARY OF QUALIFICATIONS

Ms. Gelston has eight years of experience in environmental compliance and permitting and hazardous and mixed waste management. She ensures regulatory compliance, prepares Air Pollutant Emission Notices (APENs), prepares and reviews RCRA permit applications and closure plans, assists in the preparation of SARA 312 chemical inventory reports, and conducts compliance audits. Ms. Gelston has also assisted in developing a course curriculum for a Clean Air Act Operating Permit course, and has participated in presenting the course.

EXPERIENCE

Manager of Air Programs — **The S.M. Stoller Corporation**
March 1990 - Present — **Boulder, Colorado**

Project manager for the preparation of a RCRA permit application for a hazardous waste landfill. Responsibilities include planning and scheduling for a completed application and overall coordination of various activities that must be completed prior to permit application submittal, including site characterization and facility design. Other responsibilities include interaction with regulators, regulatory interpretation, and preparation of several sections of the permit application.

Project manager of the development of an environmental, health, and safety management system. Ensured that activities were conducted within budget constraints, provided regulatory interpretation, ensured that system components complied with applicable regulations, and assisted in preparation of SARA 312 chemical inventory reporting.

Assisted in preparation of course curriculum for a Clean Air Act Operating Permit course. Designed a process, identified emission points, quantified emissions, determined the applicability of operating permit regulations, and identified pollution prevention and legal options that could be used to assist a facility in avoiding operating permit requirements. Prepared a course segment on enhanced monitoring provisions. Currently assisting in the presentation of the course to various clients.

Assisted in the preparation of a RCRA closure procedure for a hazardous waste container storage area for a private client. The procedure described activities in sequence for decontaminating secondary containment, equipment, piping, and vaults; disposing of waste generated as a result of closure activities; and sampling to ensure clean closure. Identified methods to minimize waste generated during closure. The procedure was reviewed against the approved RCRA closure plan to ensure that all closure activities are consistent with the closure plan.

Assisted in revising the Rocky Flats Volume Basis Waste Management Cost Analysis, which is an effort to quantify direct labor and material costs associated with managing the principal waste streams at the Rocky Flats Environmental Technology Site. Identified waste management operations and quantified costs associated with those operations.

Served as a member of a multidisciplinary team preparing RCRA permit modification requests for hazardous, low-level mixed, and transuranic-mixed waste storage and treatment units at Rocky Flats. Prepared process flow diagrams, piping and instrumentation diagrams, unit descriptions, and secondary containment calculations for various units in Building 374 at Rocky Flats.

Assisted in preparation of the Rocky Flats Mixed Residues Part B permit modification request. The modification request included hundreds of storage tanks and container storage areas. Interpreted regulations, prepared reports on applicability of RCRA to various units, collected an extensive amount of field information regarding residue characterization and process operations, and prepared process flow diagrams, container storage area layouts, piping and instrumentation diagrams, unit descriptions, and secondary containment calculations for containers and tanks.

Prepared APEN reports for support facilities, storage tanks, and miscellaneous emission sources at Rocky Flats. Estimated airborne emissions of hazardous criteria and toxic pollutants from facilities and storage tanks. The analysis entailed the evaluation of processes and application of engineering judgment to determine source pathways and potential release rates of pollutants.

Assisted in the identification of processes and equipment at Rocky Flats that are subject to RCRA organic air emission regulations and conducted monitoring of equipment subject to the regulations. Demonstrated use of monitoring equipment to facility employees.

Participated in field surveys for the Waste Stream and Residue Identification and Characterization Program for Rocky Flats. Analyzed production and process systems and operations. Characterized both inputs and outputs to processes. Identified RCRA hazardous constituents possibly present in waste streams. Determined chemical reactions occurring during processing. Identified transfer of waste streams to waste management units.

Assisted in the preparation of a RCRA Part B Permit modification for the Waste System Evaporator in Building 374 at the Rocky Flats Environmental Technology Site. Reviewed engineering drawings, developed process flow diagrams, and wrote sections of the permit modification.

Prepared a Waste Beer Reduction Report for a brewery. Interviewed personnel, reviewed existing data, identified projects and strategies for reducing waste beer generation, calculated VOC emissions, generated a spread sheet, and wrote the final report.

Served as a member of a team assessing the 1993 Operational Readiness Review (ORR) at the Waste Isolation Pilot Plant. Evaluated the performance criteria for the ORR and assessed the adequacy of the facility response to the performance criteria for environmental programs and the RCRA permit application.

Environmental Engineer — **U.S. Department of Energy**
August 1986 - March 1990 — **Albuquerque Operations Office**
Albuquerque, New Mexico

Provided professional assistance and technical advice to DOE-AL organizations and contractors. Active in nonradioactive hazardous waste and mixed-waste management programs established in support of manufacturing and production technology and national laboratory research activities.

Evaluated DOE treatment, storage, and disposal facilities for compliance with statutes, regulations, and guidelines. Interpreted statutes, regulations, and guidelines to determine applicability to specific situations.

Reviewed and advised on potential impacts from proposed standards, guides, procedures, and regulations in waste management and environmental protection. In particular, provided assistance in determining the impacts of the RCRA Land Disposal Restrictions to mixed wastes at DOE facilities.

Coordinated permit processing in accordance with RCRA. In addition, assisted in the development of RCRA 3008(h) Orders and the response to other compliance orders issued pursuant to RCRA.

EDUCATION

B.S., Chemical Engineering, Rensselaer Polytechnic Institute, 1986

TRAINING

OSHA 40-Hour Hazardous Waste Health and Safety Training and 8-Hour Refreshers (March 1990, April 1991, and May 1993 Urie Environmental) (May 1992 - Condor Environmental)
Fundamentals of Groundwater and Well Technology, National Water Well Association, 1990
Occupational Environmental Radiation Protection, Harvard School of Public Health, 1988
DOE Environmental Regulations course, Executive Enterprises, November 1989
Nuclear Weapons Orientation, Advanced, U.S. Air Force, June 1987

DAVID J. LECHEL

Fields of Competence

Project management; peer review; environmental impact analysis; NEPA, CERCLA/SARA, RCRA regulatory expertise; design and implementation of environmental sampling programs; regulatory analysis and permit acquisition; strategic planning; environmental audits.

Experience Summary

Twenty one years of experience in project management and preparation of multidisciplinary environmental studies, regulatory analysis, and monitoring in support of remedial actions and construction activities. Responsibilities have included:

- Design, conduct, management, and report preparation of extensive environmental impact documents of U.S. Department of Energy defense facilities, national laboratories, and radioactive/hazardous waste disposal sites; commercial hazardous/toxic waste sites; and proposed coal mines, power plants, and wastewater treatment facilities.

- Regulatory analysis and strategic planning for compliant disposal of transuranic and mixed transuranic waste and byproduct material at U.S. Department of Energy disposal sites.

- Regulatory analysis, and licensing planning and implementation for closure of U.S. Department of Energy byproduct material disposal sites.

Credentials

M.S., Fisheries Biology -- Michigan State University (1974)
B.S., Fisheries Biology -- Michigan State University (1972)

Employment History

1992-Present	LECHEL, Inc.
1982-1992	Roy F. Weston, Inc.
1978-1982	Wapora, Inc.
1975-1978	Ichthyological Associates
1973-1975	Michigan State University

Key Projects

Engineered Alternatives Benefit/Detriment Analysis, Waste Isolation Pilot Plant, Carlsbad, New Mexico, Westinghouse Waste Isolation Division, Technical Consultant (1994-Ongoing). Provides assessment and probabilities of occurrence of potential environmental impacts consequent to each engineered alternative. The benefit/detriment analysis focuses on identifying and quantifying relevant aspects of environmental risk that may be posed by the engineered alternatives considered. The overall analysis requires the evaluation of several waste form modifications and alternative configurations for the repository. The benefits and detriments for which each alternative will be assessed include: short- and long-term environmental consequences, ability of the barrier(s) to retard movement of water and radionuclides, risk to workers from the implementation of the barriers, affect on waste retrieval, risk from transportation, uncertainties in resultant compliance analyses, changes in public confidence in the performance of the disposal system, costs, impacts on other waste disposal systems in the DOE complex, and the effects of mitigating the consequences of human initiated processes and events. The results from the above analysis will be coupled with those of the previous engineered alternatives task force and the current Systems Prioritization Methodology for inclusion in compliance demonstrations.

Peer Review, Tank Waste Remediation System Environmental Impact Statement, Richland, Washington, U.S. Department of Energy, Technical Consultant (1994-Ongoing). Provides independent review of project documents in support of preparation of the tank waste remediation system environmental impact statement (TWRS EIS). The proposed action is subject to the National Environmental Policy Act and the Washington State Environmental Policy Act. The DOE and State of Washington propose to manage, retrieve, treat, immobilize, and dispose or store radioactive, chemical, and mixed waste from 177 underground storage tanks and 1,933 cesium and strontium capsules at the Hanford Site. Remediation of single-shell and double-shell tank wastes will be evaluated by four overall alternatives: Tri-Party Agreement Preferred Alternative, Minimal Pretreatment Alternative, Extensive Pretreatment Alternative, and In-place Stabilization and Disposal Alternative. Alternatives for the long-term disposition of the cesium and strontium capsules include Tri-Party Agreement Storage and Disposal, Tri-Party Agreement Vitrification, and Onsite Stabilization and Disposal. The No Action Alternative is also under consideration. To date, peer reviews of the preliminary Implementation Plan and Chapter 4, Affected Environment have been conducted.

National Environmental Policy Act (NEPA) Support, Office of Civilian Radioactive Waste Management, Washington, D.C., U.S. Department of Energy, Technical Consultant (1994-Ongoing). Provided independent review of DOE and contractor prepared position papers to ascertain whether a Programmatic Environmental Impact Statement (PEIS) should be prepared to address the development of the nuclear waste management system. The DOE had announced in early 1994 that it would prepare multiple environmental impact statements (EISs) for its Proposed Program Approach to dispose of high-level waste and commercial spent nuclear fuel at the Yucca Mountain, Nevada site. EISs are to be prepared for the multi-purpose canister, the

Key Projects (continued)

suitability of Yucca Mountain as a repository site, the proposed rail spur, and possibly the monitored retrievable storage facility. The State of Nevada requested that DOE prepare a Programmatic Environmental Impact Statement (PEIS) because: (1) the multiple EISs will evaluate connected actions, which depend upon a larger action; and (2) the Proposed Program Approach represents but one of many alternatives to the development of the nuclear waste management system. Assessed various topical position papers, and reviewed DOE and the Council of Environmental Quality regulations that implement NEPA and other relevant and related NEPA compliance approaches within DOE. Recommended that DOE prepare multiple and generally expansive EISs that: (1) clearly articulate the types and timing of DOE decisions; (2) ensure that the many actions assessed in the early EISs do not limit future alternatives of subsequent EISs; and (3) build upon the previously established NEPA record as new information becomes available.

Technical Support, Idaho National Engineering Laboratory, Idaho Falls, Idaho, U.S. Department of Energy, Technical Consultant (1993-Ongoing). Prepared Summary and Record of Decision for, and provided independent technical review of, DOE's Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Management Programs Environmental Impact Statement (EIS). This two volume EIS evaluates programmatic approaches to management of spent nuclear fuel across the DOE complex, and considers site-specific approaches to the future direction of environmental restoration and waste management programs at INEL. The programmatic EIS evaluated five alternatives to manage existing and projected quantities of spent nuclear fuel, until the year 2035. The analyses focused on impacts to worker safety, public health and the environment, and socioeconomic factors related to transportation, receipt, stabilization and storage of DOE and Naval reactor spent nuclear fuel, as well as special-case commercial fuel. Siting locations for fuel stabilization, and research and development were also assessed. The site-specific EIS addressed five alternatives for management of environmental restoration, waste management, and spent nuclear fuel activities, until the year 2005, at INEL. Potential impacts from facility operations and environmental restoration, including decontamination and decommissioning activities, that would contribute to waste streams and their storage, treatment and disposal were included in the evaluations.

Technical and Management Support, Waste Isolation Pilot Plant, Albuquerque, New Mexico, U.S. Department of Energy, Technical Consultant (1992-Ongoing). Provided broad support including planning for the disposal phase supplement EIS, preparation of the Remote Handled Transuranic Waste Disposal Strategy, management and preparation of the WIPP-specific Regulatory Compliance Strategy and Management Plan, peer review of plans to comply with provisions of the WIPP Land Withdrawal Act, and technical peer review of elements of the WIPP regulatory compliance and experimental programs. Authored internal planning recommendations for the scope of the next supplemental EIS, including technical and regulatory content, schedule, and cost reduction. Provided peer review of DOE's Compliance Status

Key Projects (continued)

Report and Project Technical Baseline, and EPA's working draft implementing criteria at 40 CFR 194. Managed the preparation of the Regulatory Compliance Strategy and Management Plan which provided the strategy by which WIPP Program elements are integrated to comply with selected regulations including 40 CFR 191, Environmental Radiation Protection Standards for Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Wastes, and RCRA including 40 CFR 264 Subparts G and X and 268 Subparts C and D. Peer-reviewed plans and documents resulting from provisions of the Land Withdrawal Act including the transportation assessment, and the test phase and waste retrieval plans. Provided independent technical review of performance assessment reports for compliance with 40 CFR 191, technical and regulatory reports prepared by Sandia National Laboratories, and other test plans and management plans for radioactive waste tests.

Technical Peer Review Support, Waste Isolation Pilot Plant, Albuquerque, New Mexico, U.S. Department of Energy, Project Manager (1992). Provided technical and regulatory peer review of a variety of test plans, policy and issues papers, decision plans, and technical and regulatory reports. Managed the preparation of a Regulatory Criteria Document that will form the basis of DOE's demonstrations of compliance with 40 CFR 191, Environmental Radiation Protection Standards for Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Wastes and RCRA including 40 CFR 264 Subparts G and X and 268 Subparts C and D.

EIS/EIR for Continued Operations of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore, Livermore, California, Lawrence Livermore National Laboratory, Project Manager (1991-1992). Managed the preparation of a combined environmental impact statement (EIS) and an environmental impact report (EIR) for the continued operations of the two national laboratories for the U.S. Department of Energy (DOE). The EIS complies with NEPA and the EIR complies with the comparable California law, CEQA. The EIS/EIR examined the current and future (5 to 10 years) operations of the laboratories. Emphasis was placed on waste generation and types, radionuclide/chemical/high explosive inventories, work force growth, occupational and public exposures to routine emissions of radionuclides and chemicals as well as potential exposures during various hypothetical accidents including seismic events. Other elements evaluated included environmental restoration activities, regulatory compliance, socioeconomics, land use, traffic and transportation. As part of this project, multiple libraries and reading rooms were established and maintained and an extensive community relations plan was implemented.

Supplemental EIS, Waste Isolation Pilot Plant, Albuquerque, New Mexico, U.S. DOE, Project Manager (1989-1990). Managed the preparation of the technical and regulatory aspects of a supplement to the EIS for the Waste Isolation Pilot Plant (WIPP). The WIPP is planned as the nation's first repository for disposal of defense-related transuranic waste. The supplement was prepared to report new geologic and hydrologic data (e.g., brine inflow, flow paths, and

Key Projects (continued)

velocity), changes in the waste inventory from ten DOE facilities nationwide, the consideration of hazardous chemical constituents, and changes in the routes and modes of transportation of waste. Responsibilities included the technical management and oversight of eight contractor organizations, preparation of the draft supplement, and response to nearly 20,000 comments in the final supplement.

Technical Support, Waste Isolation Pilot Plant, Albuquerque, New Mexico, U.S. Department of Energy, Project Manager (1990-1991). Provided broad-based technical, policy and regulatory compliance support to the WIPP. Required the development of various position papers regarding the proposed test phase, transuranic waste characterization, and bin-scale tests. Also involved analysis of cost schedule controls and performance monitoring tools, contractor integration, and recommendations for the continued compliance with various DOE orders and regulations.

Uranium Mill Tailings Remedial Action (UMTRA) Project, Albuquerque, New Mexico, Department of Energy (DOE), Manager, Environmental Services (1982-1987). Project Manager (1988-1989). Managed the UMTRA Project to ensure compliance with NEPA, other Federal, state, and local environmental regulations and Nuclear Regulatory Commission (NRC) licensing requirements. Managed a staff to produce EISs and Environmental Assessments (EAs). Prepared Findings of No Significant Impact (FONSI) and Records of Decision, as well as all necessary *Federal Register* notices such as notices of wetlands involvement, public hearings, and related documents. Lead the efforts and was responsible for identification of Federal, state, and local permits and approvals necessary for cleanup of radioactive mill wastes, as well as other ancillary NEPA compliance issues. Managed the preparation of DOE's guidance document for post-remedial action surveillance and maintenance. Also prepared site-specific surveillance and maintenance plans for several UMTRA Project sites, and implemented these activities at four sites. From 1988 through 1989, was Project Manager in support of DOE's UMTRA Project. Provided administrative oversight for technical issues, cost and schedule of remedial design, regulatory compliance, NEPA documentation, quality assurance and other aspects in support of remediation of 24 uranium mill tailings sites in 10 states and 2 tribal reservations.

Environmental Review, Los Angeles, California, Pacific Enterprises, Project Manager (1989). Prepared oral and written testimony for environmental aspects of proposed gas transmission lines. Three pipeline companies proposed the construction of gas pipelines from Wyoming to southern California, and Texas to southern California. Reviewed the environmental aspects of the proposal and prepared oral and written testimony. Testimony focused on cultural resources, flora and fauna, and cumulative impacts.

Environmental Audit, Pantex Plant, Amarillo, Texas, U.S. DOE, Environmental Scientist (1987). Served as member of an audit team at the DOE Pantex Plant. Audit was conducted under the guidance of the Los Alamos National Laboratory (LANL) Environmental Audit Plan

Key Projects (continued)

and the DOE headquarters survey team. Plant was surveyed using 15 different checklists in the major waste areas of radiological mixed wastes, organics, inorganics, asbestos, and polychlorinated biphenyl (PCB). Prepared the report for submittal to DOE and LANL.

Regulatory Analysis, Bear Creek Remedial Project, Oak Ridge, Tennessee, U.S. DOE, Environmental Scientist (1987). Project Scientist associated with a comparative review of the technical requirements of Resource Conservation and Recovery Act (RCRA), NEPA, and CERCLA for the Bear Creek Remedial Action Project. This effort involved a detailed listing of all discipline requirements integral to the remedial investigation/feasibility study (RI/FS) process. A document was prepared for DOE Oak Ridge Operations to serve as the basis for the implementation plan of the Bear Creek remedial program.

Public Health Evaluation, Grand Junction Facility, U.S. DOE, Grand Junction, CO., Project Manager (1986). Managed the preparation of a public health evaluation at DOE's Grand Junction Area office. Required identification of contaminants, pathways of concern, and assessment of effects with major emphasis on arsenic, barium, selenium, and PCBs.

Environmental Assessment and Design Services, SFMP Monticello Site, U.S. DOE, Project Manager (1985-1986). Lead the preparation of an EA and engineering consulting services for DOE's SFMP Monticello site. In addition to preparing the EA for remedial actions, the radon barrier and erosion protection were designed for the stabilized site. A public health evaluation was conducted. Required contaminant identification and migration pathways analysis with focus on arsenic, thorium, and uranium.

Environmental Assessment of Remedial Action at Bruin Lagoon, Philadelphia, Pennsylvania, EPA, Environmental Scientist (1982). Principal Investigator of an EA of cleanup actions at the Bruin Lagoon abandoned hazardous waste site in western Pennsylvania. Compilation and analysis of environmental and other factors led to a finding of no significant impact.

Environmental Review, Fourth Nuclear Power Plant, Taiwan, Washington, D.C., U.S. State Department, Project Manager (1980). Managed and prepared a concise environmental review of the proposed Fourth Nuclear Power Plant, Taiwan. Analyses indicated that initial plant design required additional modifications to prevent site flooding during the monsoon season. Except for an unavoidably high population density, all design features were within NRC standards and IAEA requirements.

Entrainment and Impingement Studies at Various Power Plants, Consumers Power Co., Jackson, Michigan, Detroit Edison, Detroit, Michigan, Project Manager (1979). Project Manager of 316(b) demonstrations for power plants on Western Lake Erie, the Detroit River, and the St. Clair River. The 316(b) demonstrations for the Lake Erie and St. Clair River plants

Key Projects (continued)

were the second required at the plants by the Michigan DNR because of incorrect initial assessments. All of the second demonstrations were promptly accepted by the DNR and EPA Region V.

Site Assessment, PCB Contamination, Philadelphia, Pennsylvania, SEPTA, Project Manager (1980). Project Director of a site assessment of railroad car shops contaminated with PCBs. Historical "housekeeping" practices and vertical/horizontal migrations of PCBs on and offsite were examined.

Areawide EA for New Source Coal Mines, Philadelphia, Pennsylvania, EPA, Peer Reviewer (1981). Technical administrator of area-wide assessments of new source coal mining in West Virginia and Kentucky. Extensive compilation and assessment of West Virginia and Kentucky human resources (socioeconomics, land use), natural resources (aquatic and terrestrial biota), and earth resources (coal, soils) information in support of NPDES permitting requirements.

EIS, New Source Coal Mine, Philadelphia, Pennsylvania, EPA, Project Manager (1981-1982). EIS of a new source coal mine in West Virginia. Factors of significance included the potential for the production of acid mine drainage and subsequent adverse impacts on sensitive receiving streams and the positive benefits derived from enhanced employment and induced socioeconomic effects.

Effluent Control Practices, Philadelphia, Pennsylvania, EPA, Peer Reviewer (1981). Project Director of an assessment of effluent control practices in the hard rock mining industry. Heavy metal effluent, acid mine drainage, and sediment control techniques were examined at 10 mines in the west and south. Developed a conceptual approach for further effluent abatement at one mine site in the arid southwest.

John N. McFee

Professional Qualifications

Mr. McFee is a Registered Professional Engineer with 28 years of experience in chemical syntheses, energy recovery, waste management process design research and development, regulatory permitting, and characterization of hazardous and radioactive wastes. His technical expertise includes DOE waste treatment activities and technologies; design of incineration systems for hazardous and radioactive wastes; and developing systems for mixed waste processing. As Director of Engineering and Assessment of the IT-Albuquerque office, he supervises a staff of more than 40 environmental scientists and engineers with technical specialties in fate and transport modeling, mixed waste treatment technologies, and risk assessment. Mr. McFee is a member of IT's Technical Associate program.

Education

Nuclear Power Engineering School, Idaho National Engineering Laboratory; Idaho Falls, Idaho; 1974

B.S., Chemical Engineering, Clarkson College of Technology, Potsdam, New York; 1965

Registrations/Certifications

DOE Q Clearance, Active
Registered Professional Engineer, Idaho

Experience and Background

1988–Present ***Manager, Engineering and Assessment, IT, Albuquerque, New Mexico.*** Provides overall technical direction to IT's Albuquerque sections in remedial engineering, waste management engineering, risk assessment, and pathways modeling.

- Senior technical leader, titled Technical Area Leader for waste destruction and stabilization, supporting the DOE Office of Technology Development Mixed Waste Integrated Program. Responsibilities include review of DOE waste destruction research initiatives, technical oversight of waste destruction development programs, and consultation on DOE innovative waste treatment activities.

- Project Manager for the identification and characterization of technology improvements to the Waste Isolation Pilot Plant (WIPP). Participated in the WIPP Engineered Alternatives Task Force (EATF) project which was formed to identify and evaluate alternatives to the WIPP repository design and/or waste forms to enhance compliance with long-term performance standards (EPA 40 CFR 191). Assisted in developing an alternatives analysis technique to reduce the large number of possible alternatives to a manageable number of feasible alternatives. The preliminary screening was accomplished using an ordered decision logic system

which quantified the decision criteria. Recommendations were developed for the number of treatment facilities and preferred locations.

- Participated in the DOE Mixed Waste Working Group as a WIPP representative. The Working Group assembled waste generation data and reviewed regulatory alternatives for compliance with the EPA's Land Disposal Restrictions. These efforts resulted in a two-year variance for radioactive mixed waste compliance.

- Member of the Technical Resource Team, supporting the DOE Mixed Waste Focus Area. Responsible for providing DOE with information and expert opinion on innovative and conventional technology application to treatment of mixed waste streams. Specific areas of expertise are thermal and nonthermal waste destruction technologies.

- Project Manager for a study of remediation technologies for removing soil contaminated with radioactive and mixed waste at the 100 Area of the DOE Hanford site. The study involved "macroengineering" technologies to determine available large-scale equipment remediation alternatives Developed a screening technique to reduce the large number of alternatives to a single feasible recommendation.

- Provided senior technical guidance and review of DOE site treatment plans for Nevada Test Site, Los Alamos National Laboratory, Sandia National Laboratories, Pantex Plant, and the Weldon Spring site.

- Senior technical contributor and project manager for a conceptual design study of alternatives addressing retrieval and processing of buried radioactive waste at the DOE's Idaho National Engineering Laboratory (INEL). Conceptual designs, cost estimates, and technology status information were developed on three incineration alternatives for waste processing.

- Project Manager for IT's contribution to the EG&G Idaho System Design Study. Numerous process flow schemes were developed to address the problem of retrieving and processing buried waste at the Idaho National Engineering Laboratory (INEL). Conceptual designs and cost estimates were prepared for the most promising schemes. Information prepared by IT staff included functional and operational requirements documents, mass balance diagrams, layout drawings, an assessment of the research necessary for successful application of the concept, and a system cost estimate.

- Participant in the DOE-Headquarters T/S/D Workshop considering treatment/storage/disposal capabilities in the overall DOE system. This expert panel was created to develop a waste generation/waste treatment data base for all DOE facilities. Mr. McFee is a contributor in the specialties of transuranic waste and waste treatment.

- Project Manager for the RCRA waste stream characterization project of all Los Alamos National Laboratory facilities and On-Site Surveyor for a TA-55, the CMR Building, and the Sigma Complex where special nuclear materials are processed. The information is being used to document the Laboratory's waste generation activities pursuant to the requirements of the Laboratory's hazardous waste operating permit, to design wastewater treatment systems, and in NPDES permit applications. In several instances, recommendations were made for solvent substitution or waste segregation to minimize mixed waste generation.

- Project Manager of the EG&G Idaho master subcontract for hazardous waste management support at INEL.

- Supervised development of an information base of the existing waste treatment technologies currently in use in DOE facilities in support of DOE's application for regulatory relief from EPA's waste treatment requirements for mixed wastes subject to the Land Disposal Restrictions.

1985–1988 ***Senior Program Specialist, EG&G Idaho, Inc., Idaho Falls, Idaho.*** Mr. McFee's three years of experience with EG&G Idaho provided a broad background and understanding of INEL's waste management system. Specific activities included:

- Managed the RCRA Trial Burn for the INEL's low level waste incinerator. This included responsibilities for development of the waste characterization, evaluation of the trial burn plan strategies, preparation of the trial burn plan documentation, negotiation with EPA Region X for trial burn plan acceptance, subcontracting the sampling and analysis firm, and management of the trial burn. The trial burn was successful in two of the three selected test burns. U.S. DOE management presented a citation for excellent performance in the trial burn.

- Developed the design and cost estimate for a mixed waste liquid feed system for the WERF controlled air incinerator. Supervised development and execution of the RCRA trial burn plan and participated in meetings with EPA Region X on the permit application. Provided the bases and calculational methodology for the environmental assessment and safety analysis of the incinerator in the modified configuration.

- At the PREPP rotary kiln incinerator for retrieved TRU waste, responsibilities included preparing start-up test plans to evaluate the incinerator and off-gas system performance, and then serving as the test engineer to supervise the tests. After data were reduced, recommendations were made for system modifications which would enhance performance and operations.

- Principal technical representative in the development of the RCRA trial burn and state compliance test for PREPP. Served as the lead technical representative in discussions of the permit application with EPA Region X.

- Supervised the process design and cost study of alternatives for disposal of spent scrub solution from the PREPP incinerator off-gas clean-up system.

- Reviewed the Title I and Title II design package for an enriched uranium incinerator scheduled for installation at a DOE facility.

1984–1985 ***Director, Engineering and Technology, Waste-Tech Services, Inc., Idaho Falls, Idaho.*** As a Director of this Energy Incorporated spin-off company, responsibilities included the design and development of mobile fluidized bed hazardous waste incineration systems to be provided by this new company. The major tasks included supervising the design effort and preparing test plans and EPA permit applications.

- Directed the initial design efforts for a packaged hazardous waste incinerator system for destruction of chlorinated materials using a fluidized bed incinerator.

- Developed numerous designs for fluidized bed destruction systems addressing client waste problems including waste films, chemical process wastes, animal wastes, and contaminated soils. Most designs were based on pilot plant tests carried out to develop the design data.

- Directed a test program to demonstrate chlorinated organic compound destruction in a fluidized bed pilot plant. The destruction efficiencies were in compliance with RCRA standards, but at temperatures less than normally used for incineration of these compounds.

- Designed, developed, and demonstrated a prototype radioactive waste volume reduction system for nuclear power plant applications. The system was based on use of a single fluidized bed for calcining aqueous wastes and the incineration of combustible materials.

1975–1984 ***Group Manager, Fluidized Bed Applications, Energy Incorporated, Idaho Falls, Idaho.*** Directed the Energy Incorporated fluidized bed development laboratory. Specific activities included:

- Directed the company's development program on hazardous waste incineration. The program was concluded successfully having demonstrated fluidized bed capabilities in meeting EPA requirements for destruction efficiency and provided design parameters for commercial systems. Following successful development, an extensive marketing program was carried out in conjunction with the corporate marketing division.

- Developed test plans and directed numerous fluidized bed pilot plant tests to demonstrate energy recovery from various materials including: rubber tires, anthracite culm, waste hydrocarbon films, and production plant wastes.

- As Project Engineer and, subsequently, as Program Manager on the development program for the RWR-1, a commercial radioactive waste fluidized bed volume reduction system, a concept was designed, tested, and ultimately licensed by the NRC. Engineering responsibilities included: developing the concept, designing the prototype to meet regulatory and market needs, supervising the test program to develop design data, preparing the Licensing Topical Report with the appropriate safety assessment, and designing the deliverable system.

- As Senior Chemical Engineer, performed numerous process design tasks and incineration tests on fluidized bed programs.

1974–1975 ***Engineer, Westinghouse Electric Corporation, Idaho National Engineering Laboratory, Idaho Falls, Idaho.*** Graduated from a six-month, full-time Nuclear Power Engineering School for Naval Nuclear Power.

1973–1974 ***Engineer, Westinghouse Electric Corporation, Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania.*** Participated in the hydraulic analysis and design of a Naval Nuclear Core.

1966–1972 ***Engineer, Hooker Chemical Corporation, Niagara Falls, New York.*** Process engineer in development, design, and startup at chemical production facilities.

Patents Granted

"Method of Recovering Hazardous Waste from the Phenolic Resin Filters," D. H. M. Krantz, G. L. Bourne, J. N. McFee, B. G. Burdge, J. W. McConnell, U.S. Patent No. 4,995,916.

Professional Acknowledgments

Invited Instructor for the 1988 and 1989 Incineration Conference Basics Short Course
Director 1990 through 1994. Incineration Conference Basics Short Course
Invited Instructor for the 1989 and 1990 ASME Radioactive Waste Management Course

Professional Affiliations

American Institute of Chemical Engineers

Publications

McFee, J. N., W. E. Schwinkendorf, and P. W. Hart, 1995, "Evaluation of Alternatives to Incineration for DOE Mixed Waste," Waste Management '95, *Proceedings of the Symposium on Waste Management*, Tucson, Arizona.

McFee, J. N., and J. Berry, 1995, "Mixed Waste Integrated Program: Waste Destruction/Stabilization Technical Area Program Highlights," Waste Management '95, *Proceedings of the Symposium on Waste Management*, Tucson, Arizona.

McFee, J. N., P. W. Hart, D. J. Kuchynka, and W. E. Schwinkendorf, 1994, "Innovative Low-Temperature Waste Destruction Processes for U.S. Department of Energy Mixed Waste Treatment," *Emerging Technologies in Hazardous Waste Management VI*, Vol. I, D. William Tedder, American Chemical Society, Atlanta, Georgia.

McFee, J. N., and L. G. Gale, 1988, "Testing of the PREPP Rotary Kiln for Waste Incineration," *Proceedings of International Conference on Incineration of Hazardous, Radioactive, and Mixed Wastes: 1987*, San Francisco, California.

McFee, J. N., H. Bohrer, and D. Dalton, 1987, "Status Report on the INEL RCRA Permit for Incineration of Hazardous Waste," *Proceedings of Incineration of Low-Level and Mixed Waste*, St. Charles, Illinois.

Steverson, E. M., and J. N. McFee, 1987, "The Incineration of Absorbed Liquid Wastes in the INEL's WERF Incinerator," *Waste Management '95, Proceedings of the Symposium on Waste Management*, Tucson, Arizona.

McFee, J. N., and R. L. Gillins, 1986, "Low-Level Radioactive Waste Incineration at the Idaho National Engineering Laboratory During 1986," *Waste Management '86, Proceedings of the Symposium on Waste Management*, Tucson, Arizona.

Steverson, E. M., D. P. Clark, and J. N. McFee, 1986, "Addition of Liquid Waste Incineration Capability to the INEL's Low-Level Waste Incinerator," *Waste Management '86, Proceedings of the Symposium on Waste Management*, Tucson, Arizona.

McFee, J. N., G. P. Rasmussen, and C. M. Young, 1985, "The Design and Demonstration of a Fluidized Bed for the Destruction of Hazardous Organic Materials in Soils," *Journal of Hazardous Waste*.

Rasmussen, G. P., and J. N. McFee, 1983, "Fluidized Bed Incineration Systems for the Ultimate Disposal of Toxic and Hazardous Materials," *Proceedings of the First Hazardous Materials Management Conference*, Philadelphia, Pennsylvania.

Rasmussen, G. P., and J. N. McFee, 1982, "Fluidized Bed Systems for Steam Generation from Scrap Tires," *Proceedings of the Seventh International Fluidized Bed Conference*, Philadelphia, Pennsylvania.

Vance, R. F., J. N. McFee, and J. W. McConnell, 1980, "Volume Reduction of Radioactive Waste Resulting from Decontamination of Surplus Facilities,"

Decontamination and Decommissioning of Nuclear Facilities, Marilyn M. Osterhout, ed., Plenum Press, New York.

Jonathan Myers

Professional Qualifications

Dr. Myers holds a Ph.D. in Geochemistry and has twelve years of professional experience. His specialty involves the application of computer modeling techniques for designing waste isolation systems; predicting interactions between contaminants, soil, rock, and groundwater; and predicting the fate of hazardous, transuranic (TRU), low-level (LLW), mixed, and high-level radioactive substances released into the environment. He has been actively involved in waste characterization, site characterization, and long-term performance modeling for several nuclear waste disposal projects including the Waste Isolation Pilot Plant (WIPP), the Yucca Mountain Project (YMP), the Basalt Waste Isolation Project (BWIP), the Salt Repository Project, and the Swedish and Canadian high-level nuclear waste disposal programs. He has provided extensive support to the WIPP project for over eight years. He has also been active in LLW performance assessment projects including an assessment of treatment and disposal option for mixed LLW at the INEL, and an assessment of the effectiveness of engineered barriers for isolating commercial LLW.

He has also been active in applying computer modeling techniques for developing contaminant source terms and sorption coefficients for several mixed LLW operable units as part of the Fernald, INEL, Nevada Test Site, and Los Alamos Environmental Restoration Programs. For these projects he has developed novel computer simulation techniques to predict the limits on contaminant concentrations in leachate that may migrate from the operable units.

Other related activities include the development and use of a cement degradation model to predict the long-term performance of various cement formulations proposed for use as engineered barriers in the Yucca Mountain and Swedish high-level nuclear waste disposal programs.

Dr. Myers has also pioneered the use of computer simulation techniques to design and evaluate waste treatment processes. He has used these techniques to predict the performance of proposed air stripper systems at Mather Air Force Base, optimized the design of a lime treatment system for heavy metal waste streams, and predicted the mass and composition of sludge resulting from heavy metal and radionuclide precipitation processes.

Dr. Myers is a member of IT's Senior Technical Associate program and has published over thirty technical papers in his field of expertise. He has made many presentations to the National Academy of Sciences, the most recent being "Recommendations of the Engineered Alternatives Task Force on Improving the Long-Term Performance of WIPP." He is currently manager of the IT-Albuquerque Hydrologic and Geochemical Assessment Group with technical oversight, cost and schedule, and technical staff supervision responsibilities.

Education

Ph.D., Geochemistry, University of Wyoming, Laramie, Wyoming; 1982
M.S., Geology, University of Wyoming, Laramie, Wyoming; 1978
B.S., Geology, City University of New York, New York, New York; 1974

Experience and Background

1991-Present

Manager, Hydrologic and Geochemical Assessment Group, International Technology Corporation (IT), Albuquerque, New Mexico. Dr. Myers manages a group of eight scientists and engineers who specialize in geochemistry, hydrology, and contaminant flow and transport. The group serves as a technical resource for clients and the company by performing computer simulations in support of site characterization, remedial investigations, feasibility and treatability studies, disposal system designs, risk assessments, and long-term performance predictions. The group has considerable experience in performing groundwater flow and contaminant transport modeling, calculation of radionuclide and heavy metal source terms, and estimation of adsorption coefficients for contaminants. His specific responsibilities have included:

- Contributing author of the WIPP Test Phase Plan. This work included the development of a methodology to address RCRA concerns for the mixed TRU waste inventory, and a definition of the testing required to provide the data necessary to evaluate compliance with the No-Migration provisions of RCRA.

- Project manager for a 1.1 million dollar contract to provide geotechnical support for the WIPP project. Tasks have included conducting computer simulations of creep closure to evaluate alternative repository configurations for extending the useful life of storage rooms and increasing the safety of underground operations.

- Project manager and technical director for a LLW performance assessment investigation for EG&G-Idaho in which the long-term performance of six waste forms proposed for the treatment of retrievably-stored mixed LLW at the INEL, and three sites proposed for disposal were evaluated. A total of thirty simulations were performed, each of which calculated a maximum annual effective dose equivalent for both undisturbed long-term performance and inadvertent human intruder scenarios. Work included the development of conceptual models, selection of numerical codes, defining site and wasteform properties, performing simulations, and interpreting results.

- Project manager and technical director for a commercial LLW performance assessment investigation for the DOE National Low-Level Waste Management Program. The work involved assessing the benefits of engineered barriers in improving the long-term performance of commercial LLW disposal facilities. Various facility designs incorporating combinations of barriers such as concrete overpacks, concrete vaults, sloped soil covers, sorptive backfill, and sorptive underlying layers were defined. Designs were evaluated by calculating a long-term dose reduction factor for each facility

design relative to a reference facility design that did not incorporate engineered barriers.

- Technical director for a project to develop and use numerical models to assess the long-term performance of various mixed low-level radioactive waste (LLW) waste forms and disposal sites with respect to the performance requirements of DOE Order 5820.2A and 10 CFR 61 in support of the DOE-Headquarters Mixed LLW Management Program. Work involved the development of conceptual models, selection and modification of source-term, flow, transport, and dose assessment modules, linkage of modules, verification, benchmarking, and performing simulations.

- Proposed and evaluated options for the pump-and-treat remediation of groundwater contaminated with hexavalent chromium at sites in West Texas and Northern California. The evaluations utilized computer modeling techniques to quantify the effects of redox and pH adjustment on chromium precipitation and effluent composition. Recommendations resulting from the simulations were successfully implemented.

- Performed simulations of the deep injection well disposal of hazardous waste to predict the mobility of hazardous constituents at a site in West Texas. Analyses included the mixing of waste fluid and formation fluid at elevated temperatures in the presence of host rock mineralogy.

- Developed americium and plutonium source-terms for use in a risk assessment at a disposal pit at INEL. Source-terms were developed by performing waste/groundwater interaction simulations.

- Contributing author of several work plans developed for the Nevada Test Site ER program. This work included defining analytical parameters and detection limits for deep groundwater samples to support groundwater flow, contaminant transport, and risk assessment studies.

- Performed computer simulations of waste/groundwater interactions to calculate radionuclide and heavy metal leachate compositions at the central Los Alamos radioactive waste disposal facility for use in risk assessments.

- Performed simulations of the interactions that will occur at elevated temperatures between groundwater and several cement formulations proposed for seal materials at Yucca Mountain. The simulations provided estimates of the long-term seal performance.

- Used computer simulation techniques to optimize the design of a lime treatment system for the removal of radionuclides and heavy metals from

aqueous waste streams. The simulations provided very cost-effective analyses of proposed designs.

- Evaluated the potential for mineral precipitation to reduce the effectiveness of air stripper systems proposed for use at Mather Air Force Base to remove VOCs from groundwater.

- Performed computer simulations to determine the factors affecting the pH of power plant fly-ash at a commercial generation facility in Northern California. Results of analyses are being used to control process parameters to avoid the generation of hazardous by-products.

1985 - 1991 ***Section Manager, Geochemical Analysis, International Technology Corporation, Albuquerque, New Mexico.*** Dr. Myers managed technical staff involved in projects for the Geochemical Analysis specialty in Albuquerque. His specific responsibilities have included:

- In support of the WIPP Engineered Alternatives Task Force (EATF), which was created by the DOE to identify and evaluate alternatives that could enhance the WIPP facility's compliance with long-term performance standards (EPA 40 CFR 191), Dr. Myers directed the development and use of a Design Analysis Model to predict the relative improvements that could be realized from both alternative repository designs and waste forms. The model predicts the 10,000-year cumulative releases of each radionuclide while considering the coupled interactions between brine inflow, creep closure, and gas generation.

- Chaired an expert panel for the WIPP EATF to evaluate potential applications of cementitious materials as waste forms, backfill, and container materials to immobilize TRU waste.

- Evaluated the long-term performance of the WIPP in terms of EPA 40 CFR 191 and the RCRA no-migration requirements contained in 40 CFR 268.6. Analyses included the effects of processing waste forms on migration rates of radioactive and RCRA-listed contaminants.

- Served as contributing author to the "Draft Final Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment," a five-year plan which defines all of the waste characterization, site characterization, and computer modeling activities necessary to evaluate compliance with EPA regulations (RCRA and 40 CFR 191).

- Served as principal author of the "Panel One Test Plan for the Waste Isolation Pilot Plant" which outlined the procedures for conducting

underground tests for measuring gas generation rates using actual waste in the WIPP repository.

- Provided input to the WIPP No-Migration Variance Petition under 40 CFR 268.6 by developing contaminant source terms for modeling releases of RCRA-listed hazardous components from the WIPP disposal system.

- For the WIPP Brine Sampling and Evaluation Program, performed geochemical characterization of the repository environment, including brine chemistry and brine/rock interactions, and a geochemical characterization of potential sources of intruding water, including Castile and Salado brines. This information was subsequently used to develop source terms for performance assessment activities in support of 40 CFR 191.

- Developed the Water Quality Sampling Plan for the WIPP site which involved the repeated sampling and analysis of groundwater from approximately 20 wells in the vicinity of the repository to determine groundwater characteristics. Data from the program were subsequently used to predict radionuclide migration rates through the overlying aquifers.

- Served as Project Manager during 1985 and 1986 for integrating hydrological and geochemical modeling tasks with the overall WIPP performance assessment program to determine regulatory compliance for the WIPP site. Activities included developing conceptual models and computer codes so that coupled processes could be realistically simulated. Conducted code verification and validation to ensure integrity of the results.

- Developed and used innovative geochemical modeling techniques to optimize the removal of uranium from contaminated groundwater by pH adjustment and anion exchange processes in support of the Fernald CERCLA feasibility study.

- Developed modeling techniques to estimate uranium, thorium, and heavy metal solubilities and sorption coefficients to provide input into the fate and transport modeling for CERCLA RI/FS at the Fernald site.

- For the Yucca Mountain Project and the Swedish repository high-level nuclear waste programs, modeled the long-term performance of cementitious seals using the EQ3/EQ6 computer code.

- For the YMP, analyzed geochemical interactions between cementitious seal materials and groundwater to evaluate the longevity of shaft sealing components. The results of these studies were subsequently published and

presented at Waste Management '89 and the Sixth International Water/Rock Interactions Conference.

- Served as contributing author to the "Field Sampling and Laboratory Procedure Plan for the Fernald Geochemical Program" which defined the number, location, and types of analyses to be performed on soil, rock, and groundwater samples at the Fernald site.

1982 - 1985 ***Senior Geochemist, Basalt Waste Isolation Project, Rockwell International, Richland, Washington***. While at Rockwell International, Dr. Myers was involved in the following activities in the field of high-level nuclear waste management and disposal:

- Served as Principal Technical Director for a large experimental test program designed to determine the interactions which occur between actual high-level nuclear waste, barrier materials, host rock, and groundwater at elevated temperatures and pressures. Duties included providing technical guidance for long-term experiments performed in a radiation environment.

- Evaluated the performance of the Basalt Waste Isolation Project repository design in terms of the regulatory requirements as defined in NRC 10 CFR 60 and EPA 40 CFR 191 governing the long-term performance of a high-level nuclear waste repository. Specific analyses included interactions between radionuclides, groundwater, and rock to predict contaminant migration rates.

- Directed a project to develop Eh and pH sensor systems which will operate at temperatures up to 300°C and pressures up to 300 Atmospheres.

- Planned and conducted an experimental test program to determine the effects of alpha and gamma radiation on water/rock interactions.

- Responsible for negotiating technical statements of work and contract terms on several subcontracts placed with organizations including Westinghouse, Battelle, University of Colorado, Arizona State University, and Temple University.

Professional Affiliations

American Geophysical Union
Geochemical Society
International Association of Geochemistry and Cosmochemistry
Mineralogical Society of America
American Institute of Physics

Publications

Smith, T. H., J. Myers, S. M. Djordjevic, T. A. DeBiase, M. T. Goodrich, D. DeWitt, 1994, "Preliminary Parametric Performance Assessment of Potential Final Waste Forms for Alpha Low-Level Waste at the Idaho National Engineering Laboratory," EGG-WM-11415, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho.

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Myers, J., S. Djordjevic, M. Adams, R. Spangler, J. Valdez, D. Vetter, and P. Drez, 1991, "Design Analysis of Engineered Alternatives for the Waste Isolation Pilot Plant", *Waste Management '91, Proceedings of the Symposium on Waste Management.*

Abitz, R., J. Myers, P. Drez, and D. Deal, 1990, "Geochemistry of Salado Formation Brines Recovered From the Waste Isolation Pilot Plant Repository," in *Waste Management '90, Proceedings of the Symposium on Waste Management.*

Ulmer, G. C., D. E. Grandstaff, and J. Myers, 1990, "A New Hydrothermal Technique for Redox Sensing Using Buffer Capsules," *Fluid-Mineral Interactions: A Tribute to H. P. Eugster*, R. J. Spencer and I-Ming Chou, eds., The Geochemical Society, Special Publication No. 2.

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Rodney A. Palanca

Mr. Palanca holds a B.S. in Chemical Engineering from the University of Washington. He served 20 years in the U.S. Nuclear Navy, retiring with the rank of Lieutenant Commander. Mr. Palanca began his Westinghouse career at the DOE's Fast Flux Test Facility, Hanford, Washington and trained as a Chief Operator. He transferred to the Waste Isolation Pilot Plant in 1986 to work on the WIPP waste acceptance criteria. Since then, he has worked in several areas of TRU waste management and waste handling operations including startup testing and writing operating procedures for the waste handling equipment, developing Operational Safety Requirements, and conducting operational readiness reviews. He has served as the WID representative on the TRU Waste Integrated Working Group (formerly the National TRU Waste Task Force) and contributed to the development of a national TRU waste strategy for the DOE. He was the WIPP waste handling representative on the Engineered Alternatives Task Force. He is currently assigned as the cognizant engineer for all waste handling systems and is preparing plans for restoring the RH TRU waste handling systems to a ready condition.

David C. Palmer

Manager, Health Physics

22 Years of Relevant Experience

SUMMARY: Mr. Palmer has more than 22 years of professional management experience in health physics and environmental monitoring and analysis. He has been involved in management of radioactive protection and environmental monitoring programs for both mixed radioactive waste sites and the nuclear power industry, National Environmental Policy Act (NEPA) documentation, and exposure pathway analysis, including personnel exposure and risk analysis, for both radioactive material and hazardous chemicals. He was in charge of the health physics programs at one nuclear power reactor plant where he directed the environmental monitoring program and was responsible for the plant health physics program during preparations for decommissioning the reactor. Included in this task was removal and shipment of all reactor fuel assemblies to Europe for reprocessing, removal, and disposal of all irradiated reactor control rods, and other general activities to prepare for the complete dismantling of the nuclear supply system.

EDUCATION:

M.S., Environmental Health Sciences (Radiological Health), University of Michigan, 1969

B.S., Engineering Physics, University of Michigan, 1967

RELEVANT EXPERIENCE:

Principal contributor for a study evaluating all onsite and offsite transportation risks associated with full production operations at the Rocky Flats Plant. The resulting document was designed to serve as a technical resource to evaluate transportation impacts in the proposed Site-Wide Environmental Impact Statement (SWEIS). The risk assessment involved pathway and exposure analysis and dispersion modeling of radiological and hazardous materials.

Provided the operational health physics portion of the pre-operational quality assurance audit of the health physics program at the Waste Isolation Pilot Plant (WIPP). This included audits of the operational plans and practices, as well as a general assessment of the health physics program to identify those elements of the program requiring supplementation or improvement when compared to program requirements, applicable standards, good health physics practices, and actions that might be taken to limit the potential for future legal challenges.

Project manager and principal contributor for preparation of the Action Description Memorandum (ADM) and EA to comply with NEPA requirements and risk assessment documentation to comply with CERCLA requirements for the Rocky Flats Plant remedial actions at the 903 Pad, Mound, and East Trenches areas. Environmental and public health analyses were provided for each selected alternative action to aid in the selection of the proposed remedial action.

Project manager for the analysis of injury and fatality frequency rates to be applied to the transportation of wastes from the U.S. EPA Denver Radium Superfund Site to the appropriate disposal site. Calculated estimates of the number of injuries and fatalities for various transportation modes and routes, including truck and rail transportation combinations.

Project manager and principal contributor for preparation of a comparison between the U.S. EPA "Interim Recommendations on Doses to Persons Exposed to Transuranium Elements in the General Environment" with the Colorado Department of Health plutonium in soil standard. The study included a multiple pathway analysis of the risk to persons living in a hypothetical residential development on soil contaminated to the levels proposed in the two standards.

Supported the assessment of radiological risks associated with transportation accidents included in the Supplemental Environmental Impact Statement (SEIS) for WIPP.

Principal contributor to the preparation of an EA of the Supercompactor and Repackaging Facility (SARF) and the TRU Waste Shredder (TWS) at the Rocky Flats Plant, with specific responsibilities including evaluation of radiological exposures to workers and the public from routine operations and potential accidents.

Wrote the procedure for operation and calibration of a field instrument to detect low energy radiation (FIDLER) for WIPP. The instrument is designed to detect low-level surface contamination by alpha emitters and uses a microcomputer-based, portable radiation survey instrument with digital readout and data logging capabilities. The procedure included set-up, operation, and both full geometry and single point calibrations aided by a special computer program incorporated into the procedure.

Project manager for the peer review of Section 8 (Alternatives to the Proposed Action) of the Engineering and Emissions Data Base (EEDB) for the Recovery Modification Project (RMP) for the recovery of plutonium from residues at Rocky Flats. The EEDB was to be written as a reference document to be used by the Oak Ridge National Laboratory (ORNL) to prepare an Environmental Impact Statement (EIS) for the RMP. The task involved reviewing the document to assure that all feasible alternatives had been addressed, suggesting possible alternatives, and reviewing the description and evaluation of eight alternatives included in the draft EEDB.

Principal contributor to the Safety Evaluation for the Supercompactor and Repackaging Facility (SARF) at the Rocky Flats Plant. Responsibilities included identification of potential radiological and toxicological hazards, development of methodologies for analysis of the hazards, including failure mode and effects analysis, and evaluation of the probability of occurrence and potential consequences of the hazards identified.

OTHER EXPERIENCE:

Served as the Radiation Protection Manager of the Indiana & Michigan Electric Company facility, beginning at the plant's very early stages of construction. Responsible for the design and implementation of the entire Health Physics program at the plant, including writing the original Radiation Protection Manual.

Designed and administered of the radiological assessment portion and control portions of the emergency response plan for the Indiana and Michigan Electric Company facility. Included were the writing and implementation of all radiation protection related emergency procedures, development of both manual and computerized decisional aids for use by plant operations personnel and health physics technical personnel, formation and direction of all onsite and offsite radiological assessment teams, and formulation and distribution of recommendations for offsite protective actions to the appropriate federal and state agencies during the course of an emergency. Served as the primary contact with all state and federal agency personnel for all matters of radiological or environmental matters during formation of the emergency plan and during numerous drills and exercises.

At Elk River, directed the environmental monitoring program and was responsible for the plant health physics program during preparations for decommissioning the reactor. Included in this task were removal and disposal of all irradiated reactor control rods and other general activities to prepare for the complete dismantling of the nuclear supply system.

JAMES E. WARD

SUMMARY OF QUALIFICATIONS

Mr. Ward has over four years of professional experience in engineering with an emphasis on nuclear facility operations, design, and project engineering. His experience associated with the nuclear operations has included a sealed source fabrication program, a remote facility restoration, various regulatory compliance, and hazardous chemical and waste transportation. This experience has included positions of research and development engineer and project engineer. Currently, Mr. Ward supports project engineering for an engineering and architecture company.

PROFESSIONAL EXPERIENCE

Merrick and Company, Carlsbad Area Office, Carlsbad, New Mexico

- **Project Engineer.** Project Technical Baseline document. Project engineer on the preparation and submittal of a document that provides the bases of the WIPP project, technical parameters, description, design, safety and operation to the project. Responsible for the timely preparation of the document that is technically correct within a limited time schedule.

- **Project Engineer.** HVAC load calculation for Waste Isolation Pilot Plant (WIPP) Support and Waste Handling Building. Project lead on the heating and cooling load calculations for two buildings at WIPP. The project included the load calculations, a cooling load assessment of the existing system, and a technical report. Responsible for the budget, manpower allocation, and schedule of the project.

- **Project Engineer.** Final Safety Analysis Report (WIPP) upgrade to meet DOE Order 5480.23. This project included development of revisions to be incorporated in the existing WIPP FSAR to meet the issuance of a new departmental order on nuclear safety analysis reports. Responsible for client interface, project controls, project reporting, and technical revisions concerning the principal health and safety criteria. The upgrade included five subtasks that specifically targeted: Hazard analysis and classification, Principal health and safety criteria, Human Factors analysis and evaluation, Analysis of abnormal, normal, and accident conditions, and Demonstrated compliance with DOE Order 4330.4A, "Maintenance Management Program".

Battelle, Pacific Northwest Laboratories, Richland, Washington

- **Development Engineer.** Waste Management Section. Responsible for characterization, packaging, and DOT, EPA, and DOE compliance for all hazardous material and waste transportation shipments Responsibilities included staff training, packaging certification and development, procedure development, and program development.

- **Research and Development Engineer.** Nuclear Engineering and Testing Section. Selected accomplishments include the following: Feasibility study for waste management of Greater-Than-Class-C (GTCC) radioactive sealed sources, remote system and component designs for conducting research operations, perform shielding calculations and data collection for remote system designs and for reducing occupational exposure during operations, supervise operations for a medical radio-isotope program and a remote radioactive research facility restoration program, develop and implement training, and capital equipment procurement. Responsibilities

included leading research, supervising staff, procedure development, and training.

Transportation Manufacturing Corporation, Roswell, New Mexico

- **Liaison Engineer.** Liaison for design engineering that facilitated the primary interface to procurement, manufacturing, quality, and test programs. Principle accomplishments included: heads-up design changes, engineering change orders, change control management, and company wide interface.

EDUCATION AND TRAINING

B.S. Mechanical Engineering, University of New Mexico 1989

Previously Radiation worker II trained, MSA and SCBA respirator, OSHA 40-hour Hazardous Waste Worker, previous DOE "Q" and "L" clearance, DOT HM-181 shippers training. Functional knowledge of radioisotopes (radiochemistry, radiophysics, material degradation, shielding, and containment).

Computer skills include: AUTOCAD release 12 with AME, MICROSHIELD (a radioactive shielding program), COSMOS/M (finite element modeling/analysis), WordPerfect 6.0, Microsoft (WINDOWS, EXCEL), LOTUS, MATHCAD, ELITE HVAC analysis.

PROFESSIONAL EXPERIENCE

12/93 to present **Project Engineer.** Merrick & Company, Carlsbad area office, Carlsbad, New Mexico. Engineering and Architecture firm that provides a full range of services.

1/91 - 12/93 **Research and Development Engineer.** Battelle Pacific Northwest Laboratory, Richland, Washington. Not for profit research and development institute.

5/90 - 12/90 **Liaison Engineer.** Design Engineering Group, Transportation Manufacturing Corporation, Roswell, New Mexico. Manufacturing facility for intercity mass transit buses.

1/89 - 8/89 **Manufacturing Engineering CO-OP.** Advanced Composites Group, GE Aircraft Engines, Albuquerque, New Mexico. Methods engineer for development of advanced graphite composites for aircraft components.

1/88 - 8/88 **Environmental Engineering CO-OP.** Human Resources Group, GE Aircraft Engines, Albuquerque, New Mexico. Environmental staff engineer to maintain local, state, and federal environmental compliance. Direct oversight in hazardous waste shipments, and effluent emission compliance.

James D. Waters

Project Manager

20 Years of Relevant Experience

SUMMARY:

Mr. Waters has a broad range of experience in the management and operation of complex mineral facilities including 17 years experience in the potash mining district. He has completed several different projects involving ore reserve studies, minerals recovery, and budget planning to meet market conditions. He has held high level engineering and management positions at 3 of the 5 area mines. Mr. Waters is familiar with BLM and New Mexico State Land Use rules and their resource recovery regulations.

Mr. Waters has been involved in a number of efforts to support WIPP operations. He was involved in the development of the Project Technical Baseline, the Final Safety Analysis Report Upgrade, and various other regulatory compliance projects.

Mr. Waters is an accomplished process engineer with over 25 years of experience in the design construction and start up of complex chemical and mineral flowsheets. Mr. Waters has been involved in worker safety in a variety of positions and has successfully installed employee oriented safety programs at two different mining operations.

EDUCATION:

M.B.A., Western New Mexico University, 1974
B.S., Metallurgical Engineering, University of Texas at El Paso, 1968

RELEVANT EXPERIENCE:

Performed a detailed investigation on the borehole penetrations into known mining areas in the Carlsbad area and identified those boreholes available for observation in the mines. This project was performed to develop background information for future WIPP compliance permitting applications.

Assisted with development of the WIPP Project Technical Baseline. Prepared facility description, site description, and post closure sections. Performed an updated geological survey of data on the Los Medanos area and the Gnome Project and developed a resource book on geology of Project Gnome. Team member on the FSAR Upgrade project. Performed several plant walk downs to inventory hazardous chemicals and also helped develop the Hazardous Assessment criteria for the FSAR Upgrade. Reviewed the WIPP Maintenance program and wrote a new maintenance section for the WIPP FSAR. Assisted the DOE technical assistance contractor in developing a National TRU Program Manager.

Assisted Mining Services group with the development of a comprehensive reclamation plan on the remediation of the Horizon Potash mine facility.

Performed a detailed analysis of Eddy and Horizon potash mine ore reserves. Evaluated best current process technology and developed production costs based upon current mine operating costs. This information was used to develop a plan to combine the two operations into one profitable unit. A detailed proposal was developed to accomplish this plan.

Performed a preliminary environmental site assessment of Eddy Potash Mine and submitted a report and draft reclamation plan to top management.

Managed all surface operations including production, maintenance, utilities, and engineering for the largest potash facility in the United States. Performed continuous evaluations of mine reserves and mineral recovery to meet production goals.

Served as the last Project Manager for two major expansion studies involving adjacent ore reserves. Study to acquire National Potash involved fairly detailed analysis of most potash reserves located in the northern section of the potash basin.

Administered the operation and maintenance programs of the large chemical potash refinery, loading dock (600,000 tons per year shipped, and a granulation plant located about 5 miles from the main surface facility. Planned and developed short-term and long-term operational cost budgets and capital expenditure programs. Directly supervised the process engineering group, maintenance engineering group, and environmental group.

Obtained an air quality permit for National Potash plant site.

OTHER EXPERIENCE:

As Refinery Superintendent, supervised operation of a 9,000-tons-per-day refinery including crushing, grinding, flotation, and chemical refinery. Scheduled major maintenance projects and directed refinery mechanics. Supervised 10 to 12 salaried and 66 hourly employees.

Evaluated new process technologies and their application to Kennecott Copper Corporation. Acted as a consultant to five major mining divisions in fields of mineral processing and copper smelting. Assisted exploration group with conceptual plant design and cost estimates of proposed projects. Worked in the field at several divisions on a wide variety of engineering projects, usually as project engineer.

Margaret S. Wood

Manager, Institutional Programs

18 Years of Relevant Experience

SUMMARY: Ms. Wood currently serves as Stoller's Manager for Institutional Programs. She has 18 years of experience working in intergovernmental and public affairs, safeguards and security, personnel, industrial relations, and emergency preparedness at DOE facilities throughout the United States. She has worked at the DOE's Albuquerque Field Office, Kansas City Plant, Pinellas Plant, and Los Alamos National Laboratory, and is specifically informed about the technical and public perception issues associated with the environmental restoration and waste management programs at the Weapons Complex facilities.

EDUCATION: B.A., Public Justice, St. Mary's University, 1974

RELEVANT EXPERIENCE:

Developed a Community Relations Plan for the General Electric Corporation in St. Petersburg, Florida in accordance with Resource Conservation and Recovery Act, State of Florida, and federal requirements. Work products included development and production of a work plan, a Public Involvement Meeting and Hearing Guide, a Community Interview Plan, and a Community Relations Plan. Significant work accomplishments include identifying and developing site-specific methods for improving internal and external communication programs and public involvement in the facility's waste management and environmental restoration programs.

Developed public outreach strategies, prepared public outreach materials, and developed hearing plans and procedures for an Environmental Impact Statement prepared by the U.S. Department of Energy's (DOE) Plutonium Recovery Modification Project, Project Office. Identified the potentially affected public, applicable public involvement regulatory issues and requirements, and technical project issues that could generate public concern. Developed and produced public outreach materials, press releases, display advertisements, briefing materials, and scoping meeting and information meeting plans (including opening statements and rules of conduct), and assisted in speaker preparation. Outreach materials included design and development of fact sheets on various technical and management aspects of the project.

Project manager for the development of briefing materials and speaker preparation for the proposed Special Nuclear Materials Laboratory at the Los Alamos National Laboratory.

Project manager for the review and assessment of public outreach fact sheets being developed for the Weapons Complex Reconfiguration Programmatic Environmental Impact Statement.

Developed and produced management charters, management plans, strategic plans, work plans, and management presentations for Westinghouse, Waste Isolation Division, at the Waste Isolation Pilot Plant. The management plan serves as the superior DOE Waste Isolation Pilot Plant (WIPP) Project Site Office document in the hierarchy of management documents.

Developed and produced a Management Information Handbook for the DOE WIPP Project Site Office. The handbook presented information on DOE organizations, procedures, and directives as well as information to assist DOE personnel with interagency, intergovernmental, and contractor interactions.

Identified methods used to treat, handle, and dispose specific waste streams and the associated cost of performing this work as a part of a Volume-Based Cost Analysis that was performed for all waste streams at the Rocky Flats Plant.

Principal contributor to a Safety Analysis Report that is being developed on Pondcrete Storage for the Rocky Flats Plant.

Developed strategies to improve communication with federal, state, and local agencies, Tribal Governments, special interest groups, media, and the general public and expand public participation in major projects such as the Waste Isolation Pilot Plant (WIPP) and Uranium Mill Tailing Remedial Action projects at locations such as Riverton, Grand Junction, Ambrosia Lake, Rifle, Gunnison, and Falls City.

Participated in the preparation of public outreach materials, congressional briefings, public meetings, and public hearings for the Draft Supplement to the Environmental Impact Statement for WIPP.

Developed and presented briefings to local, state, and federal officials on issues such as WIPP and federal employment issues.

OTHER EXPERIENCE:

As Chief of Safeguards and Security for the DOE Rocky Flats Office, directly supervised a staff of seven employees, including chemists, engineers, and security specialists. Monitored and inspected all aspects of the contractor's safeguards, security, and emergency preparedness programs to ensure adequacy and compliance with all applicable federal requirements. Developed and approved building and site security plans, approved security procedures and plans for anti-nuclear demonstrations, and conducted facility threat analyses.

PUBLICATIONS:

DOE/AL, *Security Planning Guide*, Co-author
DOE/AL, *Personnel Security Handbook*, Principal Author
DOE/AL, *Engineering Analysis - Material Surveillance Task Force*, Co-author

Initial Engineered Alternatives Screening Candidates

The individual Engineered Alternatives (EA) found in the 1991 Engineered Alternatives Task Force Final Report (EATF), #1 through #64

1 Compact Waste
2 Incinerate and Cement
3 Incinerate and Vitrify
4 Wet Oxidation
5 Shred and Bituminize
6 Shred and Compact
7 Shred and Cement
8 Shred and Polymer Encapsulation
9 Shred add Salt and Compact
10 Plasma Processing
11 Melt Metals
12 Add Salt Backfill
13 Add other Sorbents
14 Add Gas Suppressant
15 Shred and Add Bentonite
16 Acid Digestion
17 Sterilization
18 Add Copper Sulfate
19 Add Gas Getters
20 Add Fillers
21 Segregate Waste Forms
22 Decontaminate Metals
23 Change Waste Generation Process
24 Add Anti-Bacterial Material
25 Accelerate Waste Digestion Process
26 Alter Corrosion Environment
27 Alter Bacterial Environment in WIPP
28 Transmutation of Radionuclides
29 Vitrify Sludges
30 Salt Backfill Only
31 Salt Backfill Plus Gas Getters
32 Compact Backfill
33 Salt Plus Brine Sorbents

Initial Engineered Alternatives Screening Candidates

34 Preformed Compacted Backfill
35 Grout Backfill
36 Bitumen Backfill
37 Add Gas Suppressant
38 Minimize Space Around Waste Stack
39 Segregate Waste in WIPP
40 Decrease Amount of Waste per Room
41 Emplace Waste and Backfill Simultaneously
42 Selected Vegetive Uptake
43 Brine Isolating Dykes
44 Raise Waste Above the Floor
45 Brine Sump and Drains
46 Gas Expansion Volume
47 Seal Repository Room Walls
48 Vent Facility
49 Ventilate Facility
50 Add floor of Brine Sorbents
51 Change Mine Extraction Ratio
52 Change Room Configurations
53 Seal Individual Rooms
54 Two Level Repository
55 Monument Forest Over Repository
56 Monument Covering the Entire Repository
57 Buried Steel Plate Over the Repository
58 Artificial Surface layer Over the Repository
59 Add Marker Dye to Strata
60 Drain Castile Reservoir
61 Grout Culebra Foundation
62 Increase Land Withdrawal Area
63 Change Waste Container Shape
64 Change Waste Container Material

The EATF Combination EAs, #65 through #79

65 EATF Baseline - As received with salt backfill.
66 EATF Alternative 1 - Shred and cement organics and inorganics only, salt backfill.

Initial Engineered Alternatives Screening Candidates

The Systems Prioritization Methodology - 2 (SPM-2) original EAs, #80 through #99 (from 1/19/95 list)

80 SPM-Baseline
81 SPM-A Salt backfill 50% filling efficiency
82 SPM-B Salt/Bentonite backfill 50-50 mix, 50% filling efficiency
83 SPM-C Salt/pH buffer backfill some amount of CaO
84 SPM-D Cement grout backfill 100% filling efficiency
85 SPM-E Salt/Grout backfill 100% efficiency
86 SPM IT-1 Shred and cement organics and inorganics, salt backfill 50% filling efficiency
87 SPM IT-2 Cement sludges, shred and cement orgainics and inorganics, salt backfill 50% filling efficiency, nickel alloy container.
88 SPM IT-3 Cement sludges, shred and cement orginics and inorganics, cement grout 100% filling efficiency.
89 SPM IT-4 Cement sludges, shred and cement organics and inorganics, salt/pH buffer backfill with some amount of CaO.
90 SPM IT-5 Cement sludges, shred and compact orgainics and inorganics, salt backfill with 50% filling efficiency, 200 drum monolayer, 6x33x300 room.
91 SPM IT-6 Cement sludges, shred and compact organics and inorganics, cement grout backfill 100% filling efficiency, 2000 drum monolayer, 6x33x300 room.
92 SPM IT-7 Cement sludges, compact organics and inorganics, salt/pH buffer backfill with some amount of CaO, 2000 drums monolayer, 6x33x300 room.
93 SPM IT-8 Cement sludges, shred and add bentonite to orgainics and inorganics, salt backfill 50% filling efficiency.
94 SPM IT-9 Cement sludges, shred and add bentonite to organics and inorganics, cement grout backfill 100% efficiency.
95 SPM IT-10 Decontaminate metals, nickel alloy container, cement grout backfill 100% filling efficiency.
96 SPM EATF-8 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, salt backfill, non-ferrous container.
97 SPM EATF-9 Vitrify sludges, incinerate and vitrify organics, melt metals with glass/glass frit, radionuclides partitioned into slag and metals are eliminated from the WIPP inventory, grout backfill, non-ferrous container.

Initial Engineered Alternatives Screening Candidates

98 SPM DOE-1 Passive markers- no specific scenario given reduce human intrusion probability parameters.
99 SPM DOE-2 Compartmentalization of waste - various unspecified scenarios.

The individual EAs found in 40 CFR Part 194, #100 through #109

100 194- Cementation
101 194- Shredding
102 194- Supercompaction
103 194- Incineration
104 194- Vitrification
105 194- Improved waste containers
106 194- Grout and bentonite backfill
107 194- Metal Melting
108 194- Alternative configuration of waste emplacement
109 194- Alternative disposal system dimensions

Engineered Alternatives Definitions

The following is a list of definitions for the discrete technology EAs, # 1 through # 64. The Engineered Alternatives Screening Working Group (EASWG) reviewed the original 1991 Engineered alternatives Task Force (EATF) definitions and modified them where necessary. Those taken directly from the EATF are noted as such.

Title Description

1 Compact Waste
All wastes except sludges are processed by first pre-compacting the waste into 35 gallon drums, the "pucks" are then supercompacted at forces in excess of 2200 tons and packed for disposal in 55 gallon drums. The volume reduction is approximately 3:1.

2 Incinerate and Cement
Solid organics are incinerated and the resulting ash is cemented into an ash/cement matrix.

3 Incinerate and Vitrify
Solid organics are incinerated and fused into a glass matrix by vitrifying. Vitrification melts/fuses the waste; silica may be added prior to melting.

4a Wet Oxidation and Cement
Solid organics are oxidized into an ash residue. Wet oxidation involves the accelerated oxidation of waste in the presence of heated water vapor or steam, with the intent to chemically degraded the waste. The ash residue is cemented into an ash/cement matrix.

4b Wet Oxidation and Vitrify
Solid organics are oxidized into an ash residue. Wet oxidation involves the accelerated oxidation of waste in the presence of heated water vapor or steam, with the intent to chemically degrade the waste. The ash residue is vitrified into a fused glass. Silica may be added to the residue prior to melting/fusing.

5 Shred and Bituminize
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. Bitumen is mixed into the waste, filling the void space in the waste drum.

Engineered Alternatives
Definitions

6 Shred and Compact
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. The shredded waste is compacted in the drum. Supercompaction is not used.

7 Shred and Cement
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. "Wet" Cement is added to the waste creating a solid homogeneous waste/cement matrix.

8 Shred and Polymer Encapsulation
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. The shredded waste is encapsulated with a polymer.

9 Shred, add Salt, and Compact
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. Shredded waste is mixed with crushed salt and compacted in the drum. Supercompaction is not used.

10 Plasma Processing
All waste is subjected to a high temperature plasma eliminating organics and melting metals and sludges into a solid form. The products of this process are vitrified glasses and solid metals.

11a Melt Metals
All metals are melted (sludges and combustibles are excluded) into an ingot and disposed at WIPP. The size and weight of the final product are within transportation limits.

11b Melt Metals - Partition Actinides with Frit
All metals are melted (Sludges and combustibles are excluded). Glass Frit is added to the molten metal partitioning the radionuclides within the slag. The slag is removed, solidified, and disposed at the Waste Isolation Pilot Plant (WIPP). The metal is cast into ingots and disposed as Low Level Waste (LLW) at a LLW facility. The size and weight of the ingot are within transportation limits.

Engineered Alternatives Definitions

12 Add Salt Backfill
A crushed salt backfill is placed around and between the waste containers, filling the void space within the rooms. A 50% filling efficiency is assumed.

13 Add Other Sorbents (EATF definition)
Evaluation of sorbents in addition to or other than bentonite may lead to improved waste characteristics of permeability and porosity. These sorbents are intended to sorb brine and radionuclides.

14 Add Gas Suppressant (EATF definition)
Adding materials to the waste that could reduce gas generation rates, such as materials that raise the pH of the brine that comes in contact with the waste, could prove beneficial in reducing gas pressure buildup in the waste disposal rooms.

15 Shred and Add Clay
All waste except sludges are mechanically shred. A volume reduction ratio of 1.2:1 is assumed for shredding only. Engineered clay grout is added to the shredded waste removing the void space within the waste drum. Two forms of clays are considered, swelling (smectites) and non-swelling (illite/kaolinite).

16a Acid Digestion and Cement
Solid organics are dissolved in a strong acidic solution that is subsequently neutralized and precipitated, resulting in a reduced volume sludge waste form, which is solidified into a cement/precipitate matrix.

16b Acid Digestion and Vitrify
Solid organics are dissolved in a strongly acidic solution that is subsequently neutralized and precipitated, resulting in a reduced volume sludge waste form, which is vitrified into a fused glass. Silica may be added prior to vitrification.

17 Sterilization (EATF definition)
Prior to emplacement of the waste in WIPP, sterilize the contents of each waste package to eliminate or reduce microbial gas generation. To be sufficiently effective, this alternative would probably have to be used in conjunction with sterilization of the entire underground waste disposal area, which is not considered a credible alternative.

Engineered Alternatives
Definitions

18 Add Copper Sulfate (EATF definition)
The addition of copper sulfate to the waste is expected to reduce the generation of gasses resulting from anoxic corrosion of iron based metals. The copper sulfate reacts with iron, forming ferrous sulfate and preventing the production of free hydrogen gas.

19 Add Lime
Lime (CaO) is added to solid organics within a drum.

20 Add Fillers (EATF definition)
Adding filler materials to the waste in order to reduce the initial void volume will reduce the waste's permeability and can reduce brine inflow during room reconsolidation.

21 Segregate Waste Forms (EATF definition)
This alternative refers to isolating each major waste form (i.e., sludges, combustibles, etc.) from one another. By segregating the various waste forms that are now intermingled within the waste packages, several engineered alternatives could be applied to smaller waste quantities, thereby possibly reducing costs and overall schedule.

22 Decontaminate Metals
Metals are sorted and decontaminated using freon or carbon dioxide. Filters are used to collect the radionuclides and are disposed as TRU waste. Decontaminated metals are recycled or disposed of as LLW.

23 Change Waste Generation Process (EATF definition)
Since two-thirds of the waste that will ultimately be emplaced in WIPP has not been generated, an opportunity exists to change the processes that generate the remaining waste to minimize waste porosity, permeability, and gas generation. Some progress has already been made in reducing waste generation Volume, and compaction of waste at generator sites is an example of a process that reduces porosity and permeability.

Engineered Alternatives Definitions

24 Add Anti-Bacterial Material (EATF definition)
The addition of an anti-bacterial material to the waste could alleviate some gas production if such a material does not pose a greater challenge than the gas itself. The material must has an estimated effective lifetime sufficient to prevent those microbes already present in the repository from eventually overtaking its effectiveness.

25 Accelerate the Waste Digestion Process (EATF definition)
This alternative suggests that the gas generation process might be accelerated so that gas generation is minimized after decommissioning of the repository. This requires the addition of appropriate bacterial agents to hasten waste digestion, which would have to be essentially complete before decommissioning.

26 Alter Corrosion Environment in WIPP (EATF definition)
The use of copper sulfate has already been identified as an engineered alternative that might modify the corrosion process to generate less gas. Other alternatives may alter the chemical environment of the waste storage rooms, such as assuring dryness or maintaining a pH buffer, so that corrosion is minimized.

27 Alter Bacterial Environment in WIPP (EATF definition)
This alternative is analogous to "Alter Corrosion Environment in WIPP." By changing the chemistry of the waste, microbial gas generation rates may be reduced to acceptable levels.

28 Transmutation (EATF definition)
This alternative considers transmutation of long-lived radionuclides to short-lived nuclides, eliminating the need for long-term disposal.

29 Vitrify Sludges
Sludge waste is melted/fused into a fused glass. Silica may be added prior to vitrification.

Engineered Alternatives
Definitions

30 Salt Backfill Only (EATF definition)
This is the basic backfill material being considered to reduce void volume around the waste and to hasten room closure. The material results from mining the disposal rooms and drifts, and can be processed by crushing or pulverizing to enhance backfilling operations. Unless the salt is preformed into compact shape(s), it has significant initial porosity and permeability, but will rapidly reconsolidate as a result of creep closure.

31 Salt Backfill Plus Gas Getters (EATF definition)
The addition of gas getters with the salt backfill may be advantageous for preventing buildup of unacceptable gas Volume. A potential disadvantage of applying gas getters in this matter is that salt reconsolidation takes place fairly quickly. If reconsolidation prevents interaction of gases with the gas getters in the salt matrix, it could prove ineffective. An added advantage of certain gas getters (e.g. CaO) is they will act as pH buffers thereby minimizing corrosion and radionuclide solubility in brine.

32 Compact Backfill (EATF definition)
Compacting backfill in place could reduce its permeability sufficiently to prevent significant brine mobility. Such a procedure would probably require more storage space than currently planned to permit equipment access between and around the waste packages.

33 Salt Plus Clay Backfill
Crushed salt is mixed with approximately 30% clay. The salt/clay backfill is placed around the drums filling the void space within the rooms. A 50% filling efficiency is assumed.

34 Preformed Compacted Backfill (EATF definition)
Preforming backfill into dense compacted modules, such as bricks or blocks, or shapes that can be inserted between waste packages, may reduce the overall permeability of the waste disposal rooms, thereby reducing the potential for brine contact with the waste. Compacted backfill reduces the time required for room closure and the amount of brine that can migrate into the room from the surrounding salt.

Engineered Alternatives
Definitions

35 Salt Aggregate Grout Backfill
Crushed salt is sifted and used as an aggregate in a brine based grout backfill (properties of Type 10 grout are assumed). The grout is pumped into the rooms, filling the void spaces within the rooms. A high filling efficiency is assumed.

36 Bitumen Backfill
Bitumen is placed around the waste drums filling the void space within the disposal rooms.

37 Add gas Suppressants (EATF definition) [backfill alternative]
This alternative is analogous to that described for the waste form (same name) but the suppressing material would be mixed with the backfill.

38 Minimize Space Around Waste Stack
This alternative reduces the room dimensions to minimized space around the waste containers. Only minimal space around the waste containers is assumed after emplacement.

39 Segregate Waste in WIPP (EATF definition)
The segregation of different waste forms in or among waste disposal rooms could prove beneficial. For instance, the segregation of permeable metal waste in small amounts within more easily compacted or previously compacted waste could "encapsulate" the metals with other waste that is less permeable. The segregation of high gas-generation waste from more benign waste would focus the solution on a smaller area of WIPP. There may also be an advantage in segregating sludges that contain nitrates, from combustible wastes to prevent nitrate reducing bacteria from generating nitrogen gas.

40 Decrease the Amount of Waste per Room (EATF definition)
By leaving the room size the same as currently designed, but emplacing less waste volume per room, sufficient space may be gained around the waste stack to isolate the stack from the surrounding host salt. This would be accomplished by creating a waste stack that is as compacted as practicable, surrounded by relatively "plastic" backfill containing sorbents and gas getters that would act as a secondary encapsulation medium. The host salt would, of course, remain the primary barrier.

Engineered Alternatives Definitions

41 Emplace Waste and Backfill Simultaneously (EATF definition)
The intent of this alternative is to emplace backfill more efficiently so that its effect is maximized. This alternative would be used in conjunction with compacting in place or using precompacted (and preformed if necessary) backfill.

42 Selective Vegetative Uptake (EATF definition)
Using the vegetative uptake of certain plants to concentrate radionuclides has been proposed. Some work has been done demonstrating the vegetative concentration of heavy metals.

43 Brine Isolating Dikes (EATF definition)
Brine dikes can consist of partial or full-height walls of material that segregate waste quantities to reduce the amount of waste accessed by inflowing brine or a driller's circulating mud.

44 Raise Waste Above Floor (EATF definition)
If it can be postulated that Salado brine will collect on the waste disposal room floor, then isolating the waste from the floor may be beneficial. If it can be further postulated that humidity generated by brine can be isolated from the waste, than this alternative may reduce the amount of corrosion-induced gas generation.

45 Brine Sumps and Drains (EATF definition)
By properly sloping the floor of waste disposal rooms toward collection sumps, it may be possible to isolate inflowing brine from the waste. Isolating the brine during room closure and designing the sumps so that they become "encapsulated" after closure, may result in reduced corrosion-induced gas generation.

46 Gas Expansion Volume (EATF definition)
This alternative refers to the mining of recesses within the repository to allow free expansion of the gases generated and thus reduce gas pressure.

47 Seal Repository Room Walls (EATF definition)
This alternative refers to a flexible, impermeable seal applied to the walls of each room such that closure does not break the seal. The intent is to prevent contact between the waste stack and interstitial brine.

Engineered Alternatives
Definitions

48 Vent Facility (EATF definition)
If gas generation results in the potential for overpressurizing waste disposal rooms, providing small engineered vents could alleviate this condition.

49 Ventilate the Facility (EATF definition)
Continuous ventilation of the waste disposal rooms until complete closure has taken place would eliminate concerns about brine from the surrounding Salado Formation collecting in the repository.

50 Add Floor of Brine Sorbent (EATF definition)
The intent of this alternative is to prevent free brine from contacting the waste stack, thereby reducing the potential for corrosion induced gas generation.

51 Change Mined Extraction Ratio
The mined extraction ratio is increased to increase the closure rate or the disposal rooms (i.e., leaving less supportive salt around the mined waste disposal rooms).

52 Change Room Configuration (EATF definition)
This alternative involves several possibilities. Stacking the waste tightly against the walls would eliminate initial void volume and enhance closure time. Another option involves increasing room size, which would also increase the extraction ratio, making room for a buffer of sorbents and gas getters completely surrounding the waste stack. A third option involves increasing room height and stacking the waste higher to reduce the overall footprint of the repository.

53 Seal Individual Rooms
Individual rooms are sealed instead of only sealing the panels. Communication between the rooms during an intrusion scenario is significantly reduced (gas, brine, and radionuclides).

Engineered Alternatives Definitions

54 Two Level Repository (EATF definition)
A two level repository refers to decreasing the facility's surface footprint by placing half the waste disposal area above the other, creating a two level facility. Although reduction of the facility footprint will reduce the probability of human intrusion into the underground disposal area, the consequences could double of the intrusion event penetrates both levels of the repository.

55 Monument Forest over Repository (EATF definition)
The use of closely spaced surface markers, consisting of long-lasting materials, can be used to alert potential intruders about the existence of the repository. These monuments could be mass produced and include other designations describing the location and content of the disposal area. Each marker would be deeply anchored in bedrock.

56 Monument Covering the Entire Repository (EATF definition)
The waste disposal area of the WIPP consists of approximately 100 acres. A monument 2,100 feet on a side, consisting of natural and/or man-made materials, could provide adequate warning to potential intruders as well as adding to the difficulty of drilling into the repository. The alternative could consist of a single "pyramid" or multiple contiguous monuments.

57 Buried Steel Plate Over the Repository (EATF definition)
The action of a drill bit makes it difficult to penetrate non-friable materials. Burying a relatively thick steel or other metal plate at some distance below the surface over the repository could alert an intruder that this is an unusual site. The plate would probably have to be sandwiched between corrosion inhibitors to assure longevity. Additionally, site exploration and evaluation prior to drilling would alert geologists that further exploration is needed.

58 Artificial Surface Layer Over Repository (EATF definition)
Replacing the natural surface material over the repository with a layer of artificial or sterile material to a reasonable depth is another way of alerting potential intruders to explore further before taking any action.

Engineered Alternatives
Definitions

59 Add Marker Dye to Strata (EATF definition)
The use of marker dye that is sufficiently strong to discolor the driller's mud pond may alert the intruder that some further evaluation is necessary.

60 Depressurize Castile Reservoir
This alternative removes brine from the Castile Formation in sufficient quantities to remove the motive force that transports waste from the repository to the accessible environment in an intrusion event involving the Castile Formation.

61 Grout Culebra Formation (EATF definition)
The Culebra is a potential conduit for releasing radionuclides to the accessible environment. Grouting the Culebra above the repository may reduce the pathway.

62 Increase Land Withdrawal (EATF definition)
Currently planned land withdrawal boundaries do not extend to the boundaries of 40 CFR Part 191. Extending the land withdrawal boundaries to coincide with the permitted regulatory boundaries would provide longer radionuclide transit times before reaching the boundaries used to calculate repository performance.
EASWG note: This definition was not modified even though the LWA has been enacted since this definition was generated in the EATF. The EASWG used the intent of the definition to extend the boundaries in determining the validity of this alternative.

63 Change Waste Container Shape (EATF definition)
Square waste or hexagonal packages are used to decrease the void space within the disposal room.

64 Change Waste Container Material
Materials other than ferrous materials are used to construct the waste package.. Materials shall be selected after reviewing previous material studies (further refinement at a later date).

Engineered Alternatives
Definitions

110 Enhanced Solidification of Sludges
Cementation of Sludges is performed to provided a waste from with improved properties over non-cemented sludges.

111 Clay Based Backfill
Clay based backfill is placed around the drum, filling the void spaces within the room to hasten room closure and isolate the waste with a low permeability barrier. Two forms of clays are considered, swelling (smectites) and non-swelling (illite/kaolinite). Clay may be placed dry or water may be added and the material pumped into the rooms.

Engineered Alternatives Pass List with Comments

The following is a listing of Engineered Alternatives (EA) that passed the screening process, a brief description of the Engineered Alternatives Screening Working Groups (EASWG) conclusion is provided.

1 Supercompact Everything Except Sludges (formerly "Compact Waste")
The EASWG concluded that this EA met the definition and would be considered further. Off-The Shelf technology is available. Widely used for low level waste (LLW). Transuranic (TRU) waste supercompacted at Rocky Flats Project (RFP). Permitting in interim status at RFP - Resource Conservation and Recovery Act (RCRA) Part B.

2 Incinerate and Cement Solid Organics (formerly "Incinerate and Cement")
The EASWG concluded that this EA met the definition and would be considered further. Technology mature for hazardous constituents some engineering instill required for TRU. Commonly used for LLW - Japan, France, USA. No TRU waste incinerator operating. Permitted incinerators at Los Alamos National Laboratories (LANL) for hazardous materials, moratorium on new hazardous materials incinerators, major effort required to permit future incinerators.

3 Shred and Vitrify Solid Organic Waste (formerly "Incinerate and Vitrify")
The EASWG changed the title from "Incinerate and Vitrify" to "Shred and Vitrify" because the current vitrification technology does not require incineration, only shredding. The EASWG also concluded that this EA met the EA definition and would be considered further. Various vitrification technologies have been demonstrated; related to plasma melting. Frances (Marcoule Facility) currently making radioactive glass logs. Not yet permitted for TRU waste.

4a Wet Oxidation and Cement Solid Organics Waste (formerly "Wet Oxidation")
The EASWG concluded that wet oxidation alone did not meet the definition because the resulting waste must be solidified to meet the Waste Acceptance Criteria (WAC). The two common solidification techniques were added to this EA to meet the definition. Wet Oxidation technology demonstrated at bench scale, questions exist regarding ability to handle all organic wastes. Currently used to treat non-rad organics in water. Technology never permitted but believed possible.

Engineered Alternatives Pass List with Comments

4b Wet Oxidation and Vitrify Solid Organic Waste (formerly "Wet Oxidation")
The EASWG concluded that wet oxidation alone did not meet the definition because the resulting waste must be solidified to meet the WAC. The two common solidification techniques were added to this EA to meet the definition. Same Technical and Regulatory feasibility comments as 4a.

5 Shred and Bituminize Everything Except Sludges (formerly "Shred and Bituminize")
The EASWG concluded that this EA met the definition and would be considered further. Technology is mature but not applied to TRU waste, development work required. Used in Japan for radioactive resins and sludges. This technology has not been permitted however, the EASWG believes obtaining a permit is possible.

6 Shred and Compact Everything Except Sludges (formerly "Shred and Compact")
The EASWG concluded that this EA met the definition and would be considered further. (Not Supercompaction - low pressure compaction) Commercial nuclear plants routinely use compaction technology for LLW. Not currently being done for TRU nor demonstrated. Off-the-shelf equipment available. Permitted for LLW but not TRU, highly probable permit obtainable.

7 Shred and Cement Everything Except Sludges (formerly "Shred and Cement")
The EASWG concluded that this EA met the definition and would be considered further. Grouting technology demonstrated at Hanford, believed used in German application for TRU type waste. Permitting of cementation of TRU sludges under interim status at DOE facilities. Permitting problems not expected by EASWG.

8 Shred and Cold Polymer Encapsulate Everything Except Sludges (formerly "Shred and Polymer Encapsulation")
The EASWG concluded that this EA met the definition and would be considered further. Commercial technology in use that polymerizes LLW. Not demonstrated for TRU waste. Technology is available off-the-shelf. Permitting problems are not expected by the EASWG.

Engineered Alternatives Pass List with Comments

9 Shred, Add Salt, and Compact Everything Except Sludges (formerly "Shred add Salt and Compact")

The EASWG concluded that this EA met the definition and would be considered further. Technology is available off-the -shelf however process not in use for TRU waste. Compaction of LLW currently permitted and performed. Permitting problems not expected by the EASWG.

10 Plasma Processing of All Waste (formerly "Plasma Processing")

The EASWG concluded that this EA met the definition and would be considered further. Centrifical (molten maytag) and Fixed Hearth technologies demonstrated with non-TRU materials, Centrifical technology used to extract exotic metals in industrial applications. Pilot test completed for pit nine, INEL application with simulated waste. Design of a full-scale unit is approximately 90% complete at INEL (Lockheed) Research and Development (R&D) permitted. Not permitted for TRU waste. EASWG expects permit obtainable.

11a Melt Metals into TRU Waste Ingots (formerly "Melt Metals")

The EASWG decided to separate this EA into two categories: a) melt metals and emplace all at WIPP and b) melt metals, partition radionuclides in slag and remove, cast metal, and dispose as LLW. The EASWG determined that this separation allows for greater flexibilities in the analysis. The EASWG concluded that both EAs met the definition and would be considered further. Technology is mature but not applied to TRU wastes, development work required. EASWG believes technology is transferable to TRU waste uses. Technology not permitted for TRU waste, EASWG expects permits are obtainable.

11b Melt Metals with Frit to Partition Actinides (formerly "Melt Metals")

The EASWG decided to separate this EA into two categories: a) melt metals and emplace all at WIPP and b) melt metals, partition radionuclides in slag and remove, cast metal, and dispose as LLW. The EASWG determined that this separation allows for greater flexibilities in the analysis. The EASWG concluded that both EAs met the definition and would be considered further. Technology is mature but not applied to TRU wastes, development work required. EASWG believes technology is transferable to TRU waste uses. Potential to recycle waste containers/container materials. Technology not permitted for TRU waste, impacts LLW disposal. facilities.

Engineered Alternatives Pass List with Comments

12 Salt Backfill Around Drums and Waste Stack (formerly "Add Salt Backfill")
The EASWG concluded that this EA met the definition and would be considered further. The technology of pneumatic backfilling was demonstrated at WIPP. Can also be as simple as a pile of salt and a shovel. No regulatory concerns were noted. EASWG believes no permit is required for this technology.

15 Shred, Add Clay Based Material to Everything (formerly "Shred and Add Bentonite")
The EASWG decided to change the title of this EA to allow for various types of clays to be considered in the analysis. The EASWG concluded that this EA met the definition and would be considered further. Process is not being done for TRU waste. Equipment is available off-the-shelf. EASWG believes permits are obtainable.

16a Acid Digestion and Cementation of Solid Organics (formerly "Acid Digestion ")
The EASWG concluded that Acid Digestion alone was not an EA; acid digestion must be followed by a stabilization process. Acid digestion was deleted and acid digestion with solidification was added. The EASWG determined that this EA meet the definition and should be considered further. This Technology was used to process approximately 5,000 Kg TRU
waste between 1972 and 1980 at Handford using sulfuric acid. Current bench-scale technology at Savanna River Site uses an acid process at 180°C and 15 psig. Belgium recovers Pu with sulfuric acid. Development of processes waste and residue stabilization systems, spent acid treatment, off-gas systems, is required. Cementation of resulting sludge has not been demonstrated. Technology not permitted. Permit issues associated with disposition of hazardous constituents. EASWG believed the technology may be permitted however not enough information is available to justify rejection.

16b Acid Digestion and Vitrify of Solid Organics (formerly "Acid Digestion")
The EASWG concluded that Acid Digestion alone was not an EA; acid digestion must be followed by a stabilization process. Acid digestion was deleted and acid digestion with solidification was added. The EASWG determined that this EA met the definition and should be considered further. The Technology and regulatory feasibility is identical to #16a with vitrification consideration #3.

Engineered Alternatives Pass List with Comments

19 Add Lime to Solid Organic Waste (formerly "Add Gas Getters")
The EASWG changed the title of this EA from "Add Gas Getters" to "Add Lime to Solid Organic Waste". The new title was changed to better describe the EA. The EASWG concluded that this EA met the definition and would be considered further. This EA is a material handling process, no treatment technology is involved. Aluminum would have to be removed from the waste prior to the addition of lime. The EASWG concluded that a permit may not be required for this EA but potential WAC and TRUPACT II certification issues may be involved in implementing this EA.

22 Decontaminate Surface of Metallic Wastes for LLW Disposal (formerly "Decontaminate Metals")
The EASWG concluded that this EA met the definition and would be considered further. The EASWG concluded that this technology was mature and off-the-shelf technology is available. This technology was commonly used for alpha contaminated materials. The EASWG expects that a permit is obtainable if required.

29 Microwave Melt Sludges (formerly "Vitrify Sludges")
The EASWG changed the title from "Vitrify Sludges" to "Microwave Melt Sludges" to better define the EA. The EASWG concluded that this EA met the definition and would be considered further. The microwave technology has been demonstrated for radioactive waste, however the entire waste handling process has not been demonstrated. Completed systems with feed and off-gas processes must still be designed. Problems are expected with obtaining a permit because this is a thermal process however the EASWG believes a permit is obtainable.

33 Salt Plus Clay Backfill (formerly "Salt Plus Brine Sorbents")
The EASWG determined that this EA met the definition of an EA and that it would be kept for further consideration. The EASWG changed the title to "Salt plus Clay Backfill" and described the alternative as a crushed salt backfill containing 30% clay. The technical and regulatory feasibility is identical to #12.

Engineered Alternatives Pass List with Comments

35 Salt Aggregate Grout Backfill Around Drums (formerly "Grout Backfill"
The EASWG changed the title to specify a salt aggregate grout. The EASWG concluded that this EA met the definition and would be considered further. The technology is mature. Brine saturated grouts are commonly used in the petroleum and mining industries. Questions on gas generation potential may limit the effectiveness of this alternatives. The EASWG believed a permit would not be required, only DOE requirements need to be satisfied.

36 Bitumen Backfill
The EASWG concluded that this EA met the definition and would be considered further. Material handling technology is mature. Bitumen backfill used in Germany. Off-the-shelf technology is available. May impact the no-migration permit; possible large increase in hazardous materials. Uncertainty in safety requirements due to combustible nature. The EASWG concluded that there is a large uncertainty in regulatory feasibility, however not enough information is available to justify rejection.

38 Reduce Room Dimensions to Minimize Space Around the Waste Stack (formerly "Minimize Space Around Waste Stack")
The EASWG concluded that this EA met the definition and would be considered further. The technology used to initially mine the rooms and panels can be used, the technology is mature. Equipments is available at the site and the operations required to implement the EA is understood. Regulatory issues include, site design validation process considerations with the State of New Mexico, the Consultation and Cooperation Agreement and other coordination concerns with the state.

51 Change Mine Extraction Ratio
The EASWG concluded that this EA met the definition and would be considered further. The EASWG concluded that this technology is mature and understood. Equipment is available. Mayor analysis would be required to determine the design and the overall impact on the disposal system. Regulatory concerns include: mayor considerations with respect to the site design validation process, State of New Mexico agreements and MSHA requirements. The EASWG concluded that no permit is required to implement this EA.

Engineered Alternatives Pass List with Comments

53 Seal Individual Rooms
The EASWG concluded that this EA met the definition and would be considered further. Technology is available off-the-shelf. Major analysis is required to determine seal design and performance parameters. No permitting problems were envisioned by the working group.

60 Depressurize the Castile Reservoir (formerly "Drain the Castile Formation")
The EASWG determined this EA met the definition of an EA and should be considered further. The EASWG changed the title from "drain" to "Depressurize" stating that drain was not technically correct and was misleading. Technology is a standard oil industry practices (per Nelson Munsey of Yates Petroleum). Must dispose of brine - many options for disposal available. Technology has been permitted, minimal permitting problems anticipated. State permit required.

63 Change Waste Container Shape
The EASWG concluded that this EA met the definition and would be considered further. Technology is mature and available. Off-the-shelf containers of different various shapes are available and may meet existing TRU waste container requirements. NRC TRUPACT II certification modification required, DOT certification required. These certifications have been obtained for TRU waste containers previously. Permits can be obtained.

64 Change Waste Container Material
The EASWG concluded that this EA met the definition and would be considered further. The technology is mature and available. Depending on the specific material, waste containers made of non-ferrous materials are available off-the-shelf that may meet the current TRU waste container requirements. Same regulatory feasibility comments as #63.

83 SPM-C Salt backfill with CaO
The EASWG concluded that this EA met the definition and would be considered further.

Engineered Alternatives Pass List with Comments

110 Enhanced Solidification of Sludges
The EASWG determined that this EA met the definition and would be considered further. Technology of cementing sludges has been demonstrated. RFP has matured this technology. Some development work may be required. The regulatory issues include, satisfying DOE requirements and RCRA permit or modification to permit.

111 Clay Based Backfill
The EASWG determined that this EA met the definition and would be considered further. The Technology is mature for moist and dry clay emplacement. The EASWG believes that no permits are required and only DOE requirements must be met.

Note:
The Combination EAs were derived from those used in the EATF report and SPM program. The titles/descriptions have been changed to match the title of the discrete technologies. For example, the title "Nickel Alloy Container" was changed to "Change Waste Containers Material, #64" and "Rectangular Containers" was changed to "Change Waste Container Shape, #63". This was done to provide consistency throughout the analysis.

66 EATF Alternative 1 - Shred and cement organics and inorganics only, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

67 EATF Alternative 2 - Enhanced cement sludges, shred and cement organics and inorganics, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

68 EATF Alternative 3 - Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

Engineered Alternatives Pass List with Comments

69 EATF Alternative 4 - Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

70 EATF Alternative 5 - Enhanced cement sludges, incinerate and cement organics, shred and cement inorganics, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

71 EATF Alternative 6 - Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

72 EATF Alternative 7 - Vitrify sludges, shred and vitrify organics, melt metals into TRU waste ingots, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

73 EATF Alternative 8 - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt backfill, change waste container material.
The EASWG concluded that this EA met the definition and would be considered further.

74 EATF Alternative 9 - Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt aggregate grout backfill, change waste container material.
The EASWG concluded that this EA met the definition and would be considered further.

75 EATF Alternative 10 - Decontaminate surface of metallic waste for LLW disposal, no backfill, change container material and shape, 10x31x188 rooms.
The EASWG concluded that this EA met the definition and would be considered further.

Engineered Alternatives Pass List with Comments

76 EATF Alternative 11 - Supercompact organics and inorganics, salt backfill, monolayer of 2,000 drums in a 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

77 EATF Alternative 12 - Supercompact orgainics and inorganics, salt aggregate grout backfill, monolayer of 2,000 drums, in a 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

78 EATF Alternative 13 - Vitrify slugdes, shred and vitrify orgainics, melt metals with frit to partition actinides (metals are eliminated from the WIPP), no backfill, change waste container material and shape, minimize space around waste stack in a 10x31x188 room.
The EAWG concluded that this EA met the definition and would be considered further.

79 EATF Alternative 14 - Supercompact organics, and inorganics, salt backfill, seal individual rooms, 2,000 drums per room.
The EASWG concluded that this EA met the definition and would be considered further.

87 SPM IT-2 Enhanced cement sludges, shred and cement orgainics and inorganics, salt backfill, change waste container material.
The EASWG concluded that this EA met the definition and would be considered further.

88 SPM IT-3 Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.
The EASWG concluded that this EA is a duplicate of #68, "EATF Alternative 3".

89 SPM IT-4 Enhanced cement sludges, shred and cement organics and inorganics, salt backfill with CaO.
The EASWG concluded that this EA met the definition and would be considered further.

Engineered Alternatives Pass List with Comments

90 SPM IT-5 Enhanced cement sludges, shred and compact orgainics and inorganics, salt backfill, 2,000 drum monolayer, 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

92 SPM IT-7 Enhanced cement sludges, compact organics and inorganics, salt backfill with CaO, 2,000 drums monolayer, 6x33x300 room.
The EASWG concluded that this EA met the definition and would be considered further.

93 SPM IT-8 Enhanced cement sludges, shred and add clay based material to organics and inorganics, salt backfill.
The EASWG concluded that this EA met the definition and would be considered further.

94 SPM IT-9 Enhanced cement sludges, shred and add clay based materials to organics and inorganics, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

95 SPM IT-10 Decontaminate surface of metallic waste for LLW disposal, change waste container material, salt aggregate grout backfill.
The EASWG concluded that this EA met the definition and would be considered further.

110 Enhanced Cementation of Sludges - Accepted
The EASWG concluded that this EA met the definition and would be considered further.

111 Clay Based Backfill
The EASWG concluded that this EA met the definition and would be considered further.

Engineered Alternatives Rejection List with Justifications

The following is a listing of Engineered Alternatives (EA) that failed the screening process, a brief description of the Engineered Alternatives Screening Working Groups (EASWG) rejection justifications are provided.

4 Wet Oxidation

Wet Oxidation alone was not considered an EA and was deleted. The EASWG determined that wet oxidation must be followed by a stabilization process to be an EA so #4 Wet Oxidation was changed to wet oxidation plus two separate solidifiers, #4a and #4b.

11 Melt Metals

The EASWG decided to delete this EA and separate it into two categories: #11a - melt metals and emplace all at WIPP and #11b - melt metals, partition radionuclides in slag and remove, cast metal and dispose as LLW. The EASWG determined that this separations allows for greater flexibilities in the analysis.

13 Add other Sorbents

The EASWG determined that this EA is a duplicate of #15.

14 Add Gas Suppressant

The EASWG concluded that this EA is a duplicate of #19.

16 Acid Digestion

The EASWG concluded that Acid Digestion alone was not considered an EA. Acid digestion must be followed by a stabilization process to be an EA so #16, Acid Digestion, was changed to include two separate solidifiers, #16a and #16b.

17 Sterilization

The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. The EATF rejection justification states, "Not feasible to maintain long-term effectiveness."

Engineered Alternatives Rejection List with Justifications

18 Add Copper Sulfate
The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. The EATF rejection justification states, "Potential for hydrogen generation by galvanic coupling of deposited copper."

20 Add Fillers
The EASWG concluded that this EA was not specific enough to evaluate and is considered by other more specific alternatives (#7,9,13,14,15,18 & 19).

21 Segregate Waste Forms
The EASWG concluded that this EA did not meet the definition of an EA and was inherent with most waste processing EAs. This EA was not considered for further evaluation.

23 Change Waste Generation Process
The EASWG could not define this alternative and rejected it from further consideration. The EASWG determined the original EATF rejection justification was still valid. The EATF rejection justification states, "Scope too broad to be evaluated."

24 Add Anti-Bacterial Material
The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. Adding mercury was discussed and rejected due to the health hazards. The EASWG stated that adding hazardous materials to increase the safety of the repository was self defeating. The EATF rejection justification states, "Unable to identify a long-term, anti-bacterial material."

25 Accelerate Waste Digestion Process
The EASWG determined that the original EATF rejection justification was still valid and that this EA would be rejected. The EASWG discussed the experimental results for culturing digestive materials. The working group was not convinced that the WIPP environment could be controlled to the extent required by the digestion process. The EATF rejection justification states, "Technology for fast waste digestion not demonstrated."

Engineered Alternatives Rejection List with Justifications

26 Alter Corrosion Environment
The EASWG concluded that this EA was not specific enough to evaluate. The technology was less than bench scale and has not been demonstrated. This concept is considered under other alternatives.

27 Alter Bacterial Environment in WIPP
The EASWG concluded that this EA is a duplicate of #24 which was deleted.

28 Transmutation of Radionuclides
The EASWG concluded that transmutation technologies are not feasible for TRU wastes, the process requires the segregation of the pure isotopes from the waste. If waste was placed directly in the reactor, activated (radioactive) materials would be generated. The EATF rejection justification states, "Technology not demonstrated for large amounts."

30 Salt Backfill Only
The EASWG concluded that this EA is a duplicate of #12.

31 Salt Backfill Plus Gas Getters
The EASWG concluded that this EA is a duplicate of #83.

32 Compact Backfill
The EASWG determined that this EA was considered under EA #12 and would not be evaluated further.

34 Preformed Compacted Backfill
The EASWG concluded that this alternative is considered under the salt backfill alternative and would not be evaluated further.

37 Add Gas Suppressant
The EASWG concluded that the original EATF rejection justification was still valid. The EATF rejection justification states, "This alternative was considered together with the 'Salt Plus Gas Getters' alternative, and therefore was not subject to separate evaluation."

Engineered Alternatives Rejection List with Justifications

39 Segregate Waste in WIPP
The EASWG concluded that this EA was part of the baseline repository design. Load management is considered in the compliance documentation. The EASWG concluded that this EA does not meet the definition of an EA.

40 Decrease Amount of Waste per Room
The EASWG concluded that the original EATF rejection justification was still valid. The EATF rejection justification states, "This alternative was considered together with some of the backfill alternatives, and hence not evaluated separately."

41 Emplace Waste and Backfill Simultaneously
The EASWG concluded that this alternative is a subset of other backfill alternatives and was not evaluated separately.

42 Selected Vegetative Uptake
The EASWG determined that the process for vegetative uptake would not allow for proper containment of the alpha emitters. This process would require the waste to be placed in soil with plants. The EASWG determined the original EATF rejection was still valid. The EATF rejection justification states, "Not been laboratory demonstrated for TRU waste."

43 Brine Isolating Dykes
The EASWG determined that the isolation dykes configuration must be maintained to be effective. Room consolidation would alter the configuration and the EA would not be effective. The EA was not considered further.

44 Raise Waste Above the Floor
The EASWG determined that this is a short-term fix for along-term problem. The EA would provide no benefit and therefore would not be considered further. The EASWG also concluded that the original EATF rejection justification was still valid.

Engineered Alternatives Rejection List with Justifications

45 Brine Sump and Drains

The EASWG concluded that this EA is not effective since the required configuration cannot be maintained due to creep closure and rock mechanics of the repository. The EASWG also concluded that the original EATF rejection was still valid. The EATF rejection justification states, "This alternative was deleted because the EAMP (Engineered Alternatives Multidisciplinary Panel) believed that the flow paths leading to the sumps would not remain open long enough to allow substantial amounts of brine to be isolated from the waste."

46 Gas Expansion Volume

The EASWG concluded that this EA was detrimental to repository performance because the extra void volume allows for more stored energy and greater consequences during human intrusion scenarios. The EA was not considered further.

47 Seal Repository Room Walls

The EASWG determined that the rock mechanics of the repository precluded sealing. The technology has not been proven. Creep closure and interaction with the waste would be detrimental to the seal. The EASWG determined the original EATF rejection was still valid. The EATF rejection justification states, "The technology has not been demonstrated."

48 Vent Facility

The EASWG reviewed past data from the EATF data and the Design Analysis Model and determined that higher peak pressures would result for a vented facility. The EAMP also determined the original EATF rejection justification was still valid. The EATF rejection justification states, "Not regulatory feasible after institutional control" (period).

Engineered Alternatives Rejection List with Justifications

49 Ventilate Facility

The EASWG reviewed data from the EATF and concluded that this alternative was not feasible due to both regulatory and technical concerns. Quoting the original EATF, "...regulatory concerns about maintaining active facility controls for such a long period (100 years), the difficulty of assuring continuous ventilation in all spaces, and the potential for rupturing the waste containers during the ventilation period. The difficulty of safely sealing the rooms and panels of the facility, after so many years of creep closure has taken place, was also considered. Also, ventilation might violate the RCRA "no migration" variance proposed for the WIPP." The EASWG concluded that this EA would not be evaluated further.

50 Add floor of Brine Sorbents

The EASWG determined that this EA is a duplicate of #44 which was deleted.

52 Change Room Configurations

The EASWG determined that this EA did not meet the definition of an EA and may be detrimental to the performance of the repository during a human intrusion scenario.

54 Two Level Repository

The EASWG determined that this EA did not meet the definition of an EA and may be detrimental to the performance of the repository during a human intrusion scenario.

55 Monument Forest Over Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

56 Monument Covering the Entire Repository

The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

Engineered Alternatives Rejection List with Justifications

57 Buried Steel Plate Over the Repository
The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

58 Artificial Surface Layer Over the Repository
The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

59 Add Marker Dye to Strata
The EASWG concluded that this EA is a marker and not a barrier and does not meet the definition of an EA because it does not increase the performance or reduce the uncertainty in the performance calculations.

61 Grout Culebra Foundation
The EASWG concluded that grouting the Culebra could be detrimental to the performance of the repository. Technology was not considered feasible in part because the technology has not been demonstrated for this application, verification of the effectiveness is problematic, may create alternative pathways within the Culebre formation, and the long-term effectivity is unknown.

62 Increase Land Withdrawal Area
The EASWG concluded that increasing the area does not reduce the consequences of releases or increase the performance of the repository. Regulatory restriction on resource recovery within the new area would be problematic (resource lease acquisition).

65 EATF Baseline - As Received with Salt Backfill
The EASWG determined that this EA is a duplicate of #12, "Add Salt Backfill".

80 SPM-Baseline
The EASWG determined that the SPM baseline is the current repository baseline. The baseline case is not an alternative and is inherent in the analysis.

Engineered Alternatives Rejection List with Justifications

81 SPM-A Salt backfill
The EASWG concluded that this EA is a duplicate of #12, "Add Salt Backfill".

82 SPM-B Salt/Bentonite backfill 50-50 mix, 50% filling efficiency
The EASWG concluded that this EA is a duplicate of #22, "Salt Plus Clay Backfill".

84 SPM-D Cement grout backfill
The EASWG concluded that this EA is a duplicate of #35, "Salt Aggregate Grout Backfill".

85 SPM-E Salt/Grout backfill
The EASWG concluded that this EA is a duplicate of #35, "Salt Aggregate Grout Backfill".

86 SPM IT-1 Shred and cement organics and inorganics, salt backfill
The EASWG concluded that this EA is a duplicate of #66, "EATF Alternative 1".

88 SPM IT-3 Enhanced cement sludges, shred and cement organics and inorganics, salt aggregate grout backfill.
The EASWG concluded that this EA is a duplicate of #68, "EATF Alternative 3".

91 SPM IT-6 Enhanced cement sludges, shred and compact organics and inorganics, salt aggregate grout backfill, 2,000 drum monolayer, 6x33x300 room.
The EASWG concluded that this EA is a duplicate of #77, "EATF Alternative 12".

96 SPM EATF-8 Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt backfill, change waste container material.
The EASWG concluded that this EA is a duplicate of #73, "EATF Alternative 8".

97 SPM EATF-9 Vitrify sludges, shred and vitrify organics, melt metals with frit to partition actinides (metals are eliminated from the WIPP inventory), salt aggregate grout backfill, change waste container material.
The EASWG concluded that this EA is a duplicate of # 74, "EATF Alternative 9".

Engineered Alternatives Rejection List with Justifications

98 SPM DOE-1 Passive markers - no specific scenario given to reduce human intrusion probability parameters.
The EASWG concluded that this EA dos not meet the definition of an alternative. The proposed alternative is a marker and not a barrier. This alternative does not increase the performance nor reduce the uncertainty in performance assessment.

99 SPM DOE-2 Compartmentalization of waste - various unspecified scenarios.
The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

100 194- Cementation
The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

101 194- Shredding
The EASWG determined that this EA is inherent in several EAs and does not require further consideration in the analysis.

102 194- Supercompaction
The EASWG concluded that this EA is a duplicate of #1, "Compact Waste."

103 194- Incineration
The EASWG concluded that this EA is inherent in #2, "Incinerate and Cement" because incineration is not an EA alone. Incineration must be followed by a form of solidification to meet the particulate restriction in the a WAC.

104 194- Vitrification
The EASWG concluded that this EA is a duplicate of #3, "Shred and Vitrify Waste."

105 194- Improved Waste Containers
The EASWG concluded that this EA is a duplicate of #63, "Change Waste Container Shape" and #64, "Change Waste Container Material."

106 194- Grout and Bentonite Backfill
The EASWG determined that this EA is inherent in several EAs (#33 and #35) and does not require further consideration in the analysis.

Engineered Alternatives Rejection List with Justifications

107 194- Metal Melting
The EASWG concluded that this EA is a duplicate of #11a and 11b, "Melt Metals."

108 194- Alternative Configuration of Waste Emplacement
The EASWG concluded that this EA is inherent in several other EAs and does not require further consideration in the analysis.

109 194- Alternative Disposal System Dimensions
The EASWG concluded that this EA is inherent to several other EAs and does not require further consideration in the analysis.

APPENDIX D
ATTACHMENT D6

PRIORITIZED EAs FOR FURTHER ANALYSIS

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APPENDIX E
DESCRIPTION OF THE DESIGN ANALYSIS MODEL

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DESCRIPTION OF THE DESIGN ANALYSIS MODEL

1.0 DESIGN ANALYSIS (COUPLED PROCESSES) MODEL

The components of the Design Analysis Model (DAM) are defined according to the physical barriers that will exist following waste emplacement at the Waste Isolation Pilot Plant (WIPP). These barriers and modeling regions are:

- Host rock and panel seals surrounding the rooms and drifts—The seven rooms and the equivalent volume of five and one-half rooms existing in the access drifts within a panel (12.5 room equivalents), are modeled on a collective basis to most accurately approximate the conditions within a disposal panel at each time step. The modeling is done using the ROOM-SCALE component of the DAM.

- Shaft and panel seals—The permeabilities of the seals are obtained as a function of time using the SHAFT-SEAL component of the DAM.

The DAM considers the processes that are essential to predicting changes in performance resulting from the application of alternative repository designs, waste forms, and backfills. The simulation by the DAM of the processes described in Section 3.1 is summarized below.

- Creep Closure of the Surrounding Host Rock—The Chabannes (1982) equation has been combined with a nonlinear regression equation based on several years of measured closure rates at 30 locations in the WIPP to predict creep closure rates of the host rock as a function of time. This equation expresses creep closure rates at each time step as a function of the room height, the room width, and the difference between lithostatic stress (14.8 MPa) and the internal stress in the panel. The internal stress is the sum of the effective stress of the waste/backfill composite and the fluid pressure inside the panel.

- Hydrogen Generation by Anoxic Corrosion—The dominant corrosion reaction is assumed to be the reaction of iron, usually in the form of mild steel, with water via one of the following two reactions (SNL/NM, 1991):

  1) $Fe + 2H_2O \rightleftharpoons Fe(OH)_2 + H_2$ E.1

  2) $3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$ E.2

  These two reactions have differing stoichiometry; therefore, an average stoichiometry is derived as:

$$Fe + \frac{4+2x}{3} H_2O \rightleftharpoons \frac{4-x}{3} H_2 + xFe(OH)_2 + \frac{1-x}{3} Fe_3O_4 \qquad \text{E.3}$$

  where x mole fraction of iron is consumed by equation 1. The parameter x is assumed to have a uniform distribution between 0 and 1. The median value of

parameter x is reported as 0.5 (SNL/NM, 1993), resulting in an average reaction which generates seven moles of hydrogen for every ten moles of water consumed.

At each time step, brine in a disposal room (if available) is assumed to react with iron (or steel) to generate hydrogen at a rate of 0 to 0.6 moles of hydrogen per drum per year, depending on the percent saturation within the disposal panel (Brush, 1995). Any brine remaining at the end of a given time step is available for corrosion during the following time step. This corrosion process continues as long as brine (water) and corrodible metal are present in the panel. The corrosion process is self-limiting since the hydrogen that is generated contributes to the pressurization of the room, which in turn inhibits brine inflow.

- Microbial and Radiolytic Gas Generation—Microbial activity by a potentially broad range of microbes, which may be aerobic, anaerobic, halophilic, or halotolerant, is assumed to consume cellulosic materials and perhaps other organic materials in the waste as well. Since microbial activity and radiolysis utilize the same organic substrates, gas generation rates are assumed to represent both microbial and radiolytic gas generation. The total potential for microbial gas generation, along with the rate of generation, have been modeled based on the data provided in Brush (1995). The is based on the following assumptions:

  - Brine inflow is also necessary to sustain significant gas generation from microbial degradation of organic waste. Water is required to foster microbe growth, but it is not known whether microbe activity consumes or creates water. Therefore, it is assumed that microbial degradation results in gas generation without any effect on brine accumulation (Brush, 1995).

  - The gases generated during biodegredation are assumed to be methane, carbon dioxide, and nitrogen in the ratio of 15:20:12 (Lappin et al., 1989).

  - Microbial gas generation rates are assumed to vary from 0.1 to 1.0 moles of gas per drum per year, depending on the percent saturation within the disposal panels (Brush, 1995).

  - Based on the median stoichiometry for microbial gas generation presented in Sandia National Laboratories/New Mexico (SNL/NM) (1993), it is assumed that 0.835 moles of gas are generated for every one mole of cellulosics that are consumed.

- Dissolution of Gases in Brine—The moles of hydrogen, oxygen, and carbon dioxide dissolved in the brine present in a panel are evaluated at each time step. The moles of gas dissolved are calculated from phase equilibria relations using Henry's Law constants in brine (Reid et al., 1987). The Henry's Law constants and gas solubilities are evaluated from experimental correlations. The dissolution of nitrogen and methane is not considered since the brine already contains significant amounts of these gases (DOE, 1983).

- Brine Inflow—The following assumptions are made regarding brine flow into the disposal facility:

- An initial brine inflow rate of 0.597 cubic meters (m^3) per panel per year (Deal et al., 1994) is assumed. This is based on a constant room pressure of 1 atmosphere.

- The rate of brine inflow is assumed to linearly decrease as fluid (brine and gas) pressure in the room increases, and approaches zero when the pressure in the room reaches lithostatic pressure (14.8 MPa). Lithostatic rather than hydrostatic pressure is used since measurements of far-field pore pressures exceed hydrostatic (Lappin et al, 1989). This approach couples brine inflow to creep closure and gas generation, because all of these processes affect fluid pressure in the room, which in turn affects brine inflow.

- <u>CO_2/Brine/Cement Interactions</u>—Carbon dioxide (CO_2) generated by microbial or radiolytic processes will partition into any brine present in the room. This dissolved CO_2 will then react with portlandite to produce calcite plus water according to the reaction shown below. Portlandite is a major phase in Portland cement and is present in cementitious waste materials as well as sludges.

  - Carbon dioxide will react with portlandite (if present) to yield calcite and water according to the reaction:

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O \qquad \text{E.4}$$

  - The reaction rate is assumed to be proportional to the volume of free brine in the room, and the reaction stops when either all of the portlandite or the brine/water in the room is consumed.

  - At each time step, water that is generated by the above reaction is added to the total number of moles of water in the room, and portlandite that is destroyed by the above reaction is subtracted from the number of moles of portlandite in the room.

- <u>Diffusion of Gases into the Host Formation</u>—Since undisturbed Salado brines at lithostatic pressure have significant amounts of dissolved N_2 and CH_4 (DOE, 1983), it is assumed that diffusion of these gases is negligible due to the lack of concentration gradients necessary to drive diffusive transport. Diffusion H_2 and CO_2 into the host rock are considered.

- <u>Advection of Gases into the Host Formation, Across Seals, and into the Overlying and Underlying Anhydrite Beds</u>—The host formation, panel and shaft seals, and the intact anhydrite beds are modeled as parallel routes for the advection of gases out of the panel. The following assumptions and information are being used for modeling purposes:

  - The permeability of the intact halite ranges from 1×10^{-23} m^2 to 1×10^{-18} m^2 with an expected permeability of 3.4×10^{-21} m^2 (Rechard et al., 1990).

- The permeability of the intact anhydrite beds is estimated to be 2 to 3 orders of magnitude greater than the halite (10^{-18} m^2), and as such is assumed to be the most probable pathway for gas advection (Lappin et al., 1989).

Other assumptions include:

- The halite between each room and the anhydrites is fractured such that there is hydrological communication between the rooms and the disturbed anhydrite units.

- The anhydrite beds above and below the repository are extensively fractured due to excavation of the drifts and panels, and therefore all rooms and drifts within each panel are in equilibrium with respect to gas pressure.

- The disturbed anhydrites above and below the repository are assumed to be saturated with brine at the time of WIPP decommissioning.

- The intact anhydrites, and the halite layers above and below the repository (outside the disturbed rock zone), are assumed to be saturated with brine at pore pressures of 10.36 MPa (70% of lithostatic) and 14.8 MPa (lithostatic), respectively. The pressures in the intact Salado are chosen to provide the largest driving force for brine migration as a modeling assumption. Since there are measured values of the pore pressure approaching lithostatic, it has been chosen as the value for the far-field pressure of the brine.

- When the panel fluid pressure exceeds the assumed intact anhydrite pore pressure, the brine in the disturbed anhydrite is assumed to be driven into the undisturbed anhydrite.

- The flow of brine from the disturbed anhydrites to the intact anhydrites and Salado layers, is assumed to be governed by Darcy's equation of flow through porous media.

- The volume from which the brine is expelled is assumed to provide an additional void volume for panel gases to occupy.

A program simulating two-phase flow is used to derive a parametric equation for the advection rate into the intact anhydrites when the panel fluid pressure exceeds 11.3 MPa [brine pore pressure of 10.36 MPa plus a threshold pressure of 0.94 MPa (Davies, 1989)]. Concurrently with gas advection into the anhydrites, the advection of panel gases into the four shaft seals (conductance varying with time) is also simulated. A viscosity correlation which is valid at both low and high pressures is used to estimate the viscosity of the gas mixture for use in the advection calculations.

- Gas Compressibility—The Lee-Kessler Equation of State (Reid et al., 1987) is used to estimate the compressibility of the gas mixture in a panel at each time step based in the mole fractions of each gas present. The fluid pressure is updated at each time step based on the resulting value of compressibility. The fluid pressure is then

used to estimate molar advection rates of gases, volume of brine inflow, creep closure rates, and gas solubilities in brine during the next time step.

- Waste/Backfill Composite Compaction and Resulting Mechanical Resistance to Closure—Stress/density relationships have been obtained for each waste form and backfill material from literature and experimental data. For each engineered alternative, an average density (based upon the mass fraction and density of each component) is calculated at various stress levels of compaction. The density of the waste/backfill composite is evaluated at each time step. The effective stress corresponding to this density is evaluated using the stress/density relationships of the composite. This effective stress is then used as input to the Chabannes equation (see discussion on creep closure above) as the mechanical component of resistance to creep closure.

- Development of a Zone of Enhanced Porosity Surrounding the Panel—The creep of the host rock creates an additional void volume within a zone of enhanced porosity which the panel gases will occupy. The rate and extent of creep closure will govern the magnitude of this void volume. This void volume is calculated at each time step as the product of the porosity of the Intact Salado (0.001) (Marietta et al., 1989, Table 3-9) and the difference between the initial panel volume and the panel volume at the current time step.

  - It is assumed that the zone of enhanced porosity does not contain brine.

  - It is assumed that all the pores in this zone are interconnected.

- Future Human Intrusion Into the Repository—Three human intrusion events (reference figure if there is one included in the report) were evaluated to determine the relative effectiveness of each engineered alternative in reducing radionuclide releases. The three scenarios, the modeling procedure for each scenario, and the assumptions behind them are described as follows:

  - The E1 scenario (Marietta et al., 1989) (see Figure 4-2) (SNL/NM, 1993) assumes a borehole penetration through a waste-filled panel and continuing into or through a pressurized brine pocket existing in the underlying Castile Formation. This event was modeled using a parametric equation relating flow rate through the waste/backfill composite to the hydraulic conductivity of the composite. This equation was developed by statistically regressing data resulting from a series of computer runs using the flow and transport code SWIFT III (Reeves et al., 1986).

    The modeling associated with the E1 scenario is performed on a room basis, since only the area surrounding the actual borehole allows the brine to come in contact with the waste. In order to verify this, the SWIFT III was used to determine the velocities of the fluid flow through the waste/backfill composite. A bounding brine velocity was chosen such that in 5,000 years a fluid particle would not be able to move a distance equal to the height of the room. This velocity defined a radius of influence used to calculate an effective wash-through volume. This volume was simulated as an ellipsoid, with the major axis along

the borehole and the other axes into the room. If the conductivity of the waste/backfill composite was such that the effective radius was greater than the width of the room, the width of the room was chosen for one of the axes since the halite was considered to be impermeable. The other axis was allowed to continue to the edge of the room, but in no case did the effective radius exceed half of the length of one room. The assumption of an infinite reservoir of brine in the Castile allows a constant pressure of 16 MPa to be prescribed for the brine pocket.

- The E2 scenario (Marietta et al., 1989) (see Figure 4-3) (SNL/NM, 1993) is one in the report for intrusion scenarios) assumes a borehole just penetrating into the repository, not passing through. This scenario is modeled using an analytical solution to the radial flow equation through a porous media, simulating the borehole and the panel as concentric circles. The halite is considered to be an impermeable boundary that is located at a sufficient distance to allow the volume of the cylinder to be the volume of a panel. Simplifying assumptions regarding the flow of gas and brine are made. In actuality, the gas phase would be located towards the top of the panel and the brine phase would be located towards the bottom of the panel. In fact, the amount of brine predicted by the model to be present in the panel at 5,000 years would not be enough to fill the borehole to reach the Culebra. The gas being less viscous and towards the top of the panel, would tend to escape preferentially to the brine, thereby reducing the room pressure.

  For the purposes of comparing EAs, a hypothetical "fluid" with the properties of brine is used. This fluid is comprised of the appropriate volumetric proportions of gas and brine, which are predicted by the model for each alternative. This fluid is assumed to saturate the room and be transported to the Culebra through the borehole. The amount of radionuclides within the brine portion of the fluid that is released are then compared for each alternative.

- The E1E2 scenario (Marietta et al., 1989) (see Figure 4-3) (SNL/NM, 1993) assumes a combination of the first two scenarios; two boreholes penetrate the repository in the same panel. One borehole provides a pathway for brine flow from the Castile brine pocket directly into the panel. This borehole is capped above the repository such that no brine can move vertically to the Culebra. The other borehole (occurring later in time) provides a pathway from the repository to the Culebra Dolomite. This pathway consists of a flow path through the panel from the E1 borehole to the E2 borehole. No credit is taken for any processes which may occur or change during the interim between the first and second boreholes. This scheme results in a pressurized flow path directly through a segment of the waste/backfill composite.

  The flow rate through the waste is obtained from an analytical solution to the one-dimensional flow equation through porous media, assuming the two boreholes are separated by the length of one room (300 feet [ft]; 91.44 m). Any effects of the pressure in the room being greater than the pressure of the Castile brine pocket, are neglected due to the assumption of an infinite brine pocket. It should be noted that the E2 scenario is a part of the E1E2 scenario. This

happens when the second borehole breaches the repository, potentially releasing any gases and brine initially located there. This is neglected because the amount of brine originally located in the panel would be extremely small in comparison to the volume produced from the Castile brine pocket.

The following assumptions have been applied to all human intrusion scenarios:

- The intrusion occurs 5,000 years after decommissioning.
- The diameter of the borehole is 0.355 m based upon a survey of current standard drilling practices in the Delaware Basin (SNL/NM, 1993).
- The hydraulic conductivity of the waste/backfill composite is the weighted geometric mean of the properties of the three types of waste and backfill.
- The borehole conductivity is 1×10^{-3} m/second (clean sand/gravel) obtained from Freeze and Cherry (1979, Table 2-2).
- Waste element solubilities are assigned from Attachment 1 of Appendix G (the table is in the Appendix on Radionuclide Solubilities) based on the pH of any brine present in the disposal facility.

The activity of each radionuclide at the time of intrusion is computed using the solutions to differential equations that represent mass balances for each radionuclide. Based upon the radionuclide solubilities in brine and the volume of brine released, the cumulative activity of each radionuclide released to the Culebra was determined. The objective of these human intrusion simulations is to calculate a number which is similar in functional form to the U.S. Environmental Protection Agency (EPA) Summed Normalized Release (EPA, 1993 [40 CFR 191]); the difference being that the DAM calculates the cumulative release of radionuclides into the Culebra. Alternately, the EPA Summed Normalized Release specifies calculation of the cumulative activity of each radionuclide across the regulatory boundary, and in addition, employs scenario probability weighting to each release (EPA, 1993).

The DAM does not consider probabilities of occurrence of scenarios; the scenario is assumed to occur and the effectiveness measure is evaluated. The value generated by the DAM is the singular raw score for the effectiveness of each alternative design. Calculation of the measure of relative effectiveness is performed by dividing the effectiveness measure for the alternative by the effectiveness measure for the baseline case (see Section 3.1.2). The baseline case uses "as received" waste with no backfill. "As received" waste is defined as follows:

- Sludges with some cement added as solidifying agents [i.e., current processes at the Rocky Flats Environmental Technology Site (RFETS) for Content Code 111], but not a concreted monolith (DOE, 1994b).
- Solid organics and inorganics are in unshredded form, wrapped in multiple layers of plastic, inside a 90-mil rigid liner in a steel drum [i.e., current packaging at RFETS and most other sites (DOE, 1994b)].

APPENDIX F
PHYSICAL AND CHEMICAL PROPERTIES OF THE WASTE/BACKFILL COMPOSITE

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PHYSICAL AND CHEMICAL PROPERTIES OF THE WASTE/BACKFILL COMPOSITE

1.0 INTRODUCTION

Quantitative estimates of physical and chemical properties for the combination of waste forms and backfill, when present, are required for the Design Analysis Model (DAM) to determine the relative effectiveness of each engineered alternative. In this section, the term "properties" refers to the physical and chemical properties of a homogeneous "composite" material consisting of the various waste forms (solid organics, solid inorganics, and sludges) and backfill material when present. The properties of a particular Engineered Alternative (EA) are in most cases unique to that alternative; in some cases, similarities occur from one alternative to another. Properties of the composite such as density, porosity, hydraulic conductivity, and effective waste volume, are quantified as a function of compaction stress level and are used in the DAM to predict the long-term performance of the disposal system under undisturbed conditions as well as human intrusion events.

The following sections briefly list the properties developed (Section 1.2), discuss the assumptions made in developing properties for the baseline case and for each of the EAs (Section 1.3), sources of data (Section 1.4), and finally, the quantification of the properties (Section 1.5 and 1.6).

Some of the important properties are coupled; an example is hydraulic conductivity and permeability. Assuming a fixed value for permeability, a mathematical relationship exists to determine hydraulic conductivity. Density and porosity are similarly related.

2.0 COMPOSITE PHYSICAL AND CHEMICAL PROPERTIES

The development of physical and chemical properties for each alternative assumes the waste composite to be a homogeneous mixture. Five physical and chemical properties of the composite as a function of time or stress, are required as input to the DAM.

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

These properties are discussed in more detail in Section 1.6.

3.0 WASTE FORM DISTRIBUTION

The effectiveness of each of the various EAs is evaluated relative to the baseline case. The baseline case is defined as waste treated to the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) that is emplaced in the current panel design with no backfill. "As received" waste composition is assumed to comply with the Butcher (1989) classification of the waste destined for the WIPP, which can be generalized into the three major waste form categories.

The three major waste forms comprise the majority of the stored and projected contact handled transuranic (CH-TRU) waste inventories. On a volumetric basis, the proportions of the three major waste forms for the baseline case are assumed [based on the WIPP Transuranic Waste Baseline Inventory Report (WTWBIR) (DOE, 1995d)] to be:

- 44.5 Percent Solid Organics
  Comprised of:
  - Combustible waste
  - Filter waste
  - Heterogeneous waste
  - Solidified organic waste

- 23.0 Percent Solid Inorganics
  Comprised of:
  - Inorganic non-metal waste
  - Lead/Cadmium metal waste
  - Uncategorized metal waste
  - Graphite waste
  - Salt waste
  - Soil waste

- 32.5 Percent Sludges
  Comprised of:
  - Solidified Inorganic waste

These proportions were developed from the inventory descriptions in the WTWBIR (DOE, 1995d) by grouping waste types with similar physical properties. This proportional distribution for the baseline case is maintained for comparison of each alternative studied, ensuring no calculational bias. Specifying this ratio reduces the number of sensitivity runs necessary to establish the relative effectiveness of the EAs. In addition to the proportional distribution of waste forms, the initial volume of waste contained in a disposal room is assumed constant. Based on the overall capacity of the WIPP repository and the planned room and panel layout, the WIPP underground is assumed to have eight panels for TRU waste and sufficient capacity within the main access drifts to equal two additional panel volumes. Each panel consists of seven waste rooms and two panel access drifts which have a capacity equal to 5.54 additional waste room volumes. Therefore, each panel has 12.54 equivalent waste room volumes. Each "room equivalent" is assumed to contain 6,421 55-gallon drums (or equivalent) of CH-TRU waste.

The initial conditions for the baseline case waste distribution parameters are listed in Table F-1. These values, along with the density of each component as a function of stress (from creep closure), are used in computing the composite physical and chemical properties.

4.0 DATA DEVELOPMENT FOR ENGINEERED ALTERNATIVES

The EAs investigated here are made up of components which include waste treatment methodologies, various backfill material options, and waste emplacement configurations. The following subsections present the data for each of the components used for the computation of the properties for the waste composite. The raw data necessary for computation of waste composite properties were obtained from the previous Engineered Alternative Task Force Report (DOE, 1991), the WTWBIR (DOE, 1995d), and Butcher, et al. (1991).

4.1 Waste Treatments

Waste treatment components of the EAs involve the modification of the physical properties of the waste. Treatment of the CH-TRU waste may also lead to a change in total waste volume to be handled and emplaced in the WIPP underground. Details of the five waste treatment processes, that are components of the EAs investigated in this report, are presented below. The waste treatment processes are supercompaction, shredding, low-force compaction, plasma melting, enhanced cementation of sludges, and adding clay. The effects of each waste treatment process on the physical properties of the composite is also presented.

4.1.1 Supercompaction

The supercompaction process is modeled after the Supercompaction and Repackaging Facility (SARF) which is in operation at the Rocky Flats Environmental Technology Site (RFETS) (DOE 1995c). Only solid organic and solid inorganic wastes are suitable for supercompaction (sludges are excluded).

In preparation for supercompaction, waste is first emptied into a glovebox where it is sorted to remove items which cannot be supercompacted. Items suitable for supercompaction are then compacted into a 132-liter (35-gallon) drum using a low-force (30 metric ton) compactor. The compacted 132-liter (35-gallon) drums are then transferred to the supercompactor. The supercompactor applies a high force (1,500 to 2,000 metric tons) to the 132-liter (35-gallon) drum, called a "puck", to compact the waste material into a smaller volume. The compacted pucks are then transferred to a 208-liter (55-gallon) drum for final packaging to WIPP WAC requirements. On average, 4 pucks can be packaged into each 208-liter (55-gallon) drum. The volume reduction ratio for supercompaction is assumed to be 2.9 : 1. A slight increase in waste mass occurs due to the additional packaging (the 132-liter drums), resulting in a mass increase factor of 1.1. The final waste density is assumed to be 1679 kg/m^3 (104.8 lb/ft^3), compared to an initial density of approximately 534 kg/m^3 (33.3 lb/ft^3). Supercompacted waste materials exhibit the following:

- Lower effective hydraulic conductivity
- Lower total volume of CH-TRU waste.

1

TABLE F-1

WASTE QUANTITIES FOR THE BASELINE CASE

Waste Form	Total Mass[1] (kg)	Total Volume[1] (m^3)	Initial Density[1] (kg/m^3)	Drums per Room Equivalent[2]
Solid Organics	47,234,933	74,339	635	2,857
Solid Inorganics	13,007,073	38,396	339	1,477
Sludges	30,921,720	54,389	569	2,087
Total	91,163,726	167,124		6,421

[1]Total mass, total volume, and initial density are from Appendix O.
[2]The number of drums is computed from the distribution of the waste forms and the total number of drums per room.

4.1.2 Shredding

The shredding process is modeled after commercially available equipment that has been successfully used for low-level waste and TRU waste (Moghissi et al., 1986; Owens, 1995). Only solid organic and solid inorganic wastes are suitable for shredding.

The shredding procedure assumed for alternative evaluations consists of making multiple passes through multiple shredders such that no individual waste item has a dimension greater than 4 inches. Waste material is the primary target of the shredding operation, although a fraction of the waste containers (boxes and drums) may also require this processing technique. Shredding some of the waste containers and repackaging them results in a small mass increase factor of 1.1. Shredded waste materials and containers exhibit the following:

- Improved compaction capability
- Lower effective hydraulic conductivity (especially after compaction)
- Improved strength.

4.1.3 Low-Force Compaction

Low-force compaction consists of compacting waste (typically shredded waste) into a 208-liter (55-gallon) drum using a low-force (30 metric ton) compactor. This process is repeated, adding more waste to the drum and compacting it, until the drum is full. The volume reduction ratio for compaction, in conjunction with shredding the waste first, is assumed to be 1.3 : 1. Low-force compacted waste materials exhibit the following:

- Lower effective hydraulic conductivity
- Lower total volume of CH-TRU waste.

4.1.4 Plasma Processing

The plasma melting treatment system is modeled after the Plasma Arc Centrifugal Treatment (PACT) system. The PACT was developed by Retech, Inc., and is currently being implemented by Lockheed Martin Environmental Systems and Technologies, Co. as part of the Pit 9 Comprehensive Demonstration (LESAT, 1995) at the Idaho National Engineering Laboratory. Plasma processing may be performed to all waste types (solid organics, solid inorganics, and sludges). To achieve optimum operations, it is desirable to process sludges, solid organic, and solid inorganic wastes simultaneously (Nielsen, 1995).

The plasma processing is accomplished with the use of a transferred arc plasma torch operating in an oxygen-rich environment. The operation of the torch in this environment will bring the waste to a molten state, destroy any organic materials, and oxidize or immobilize any heavy metals. The molten slag will then be poured into 208-liter (55-gallon) drums and allowed to cool. The slag is assumed to have varying amounts of entrained air in the form of bubbles. Due to weight limitations for transportation of 55-gallon drums, the drums may not be filled completely, leaving a void space above the slag. Upon cooling, the final molten slag becomes a non-leachable "glass". Plasma melting results in a volume reduction ratio of approximately 3 : 1 (Nielsen, 1995). Final waste form is assumed to have a bulk density of 1,610 kg/m^3 (100.5 lb/ft^3) (including the

entrained air and void space in the drum) compared to an initial average bulk density of 534 kg/m^3 (33.3 lb/ft^3). Plasma melted waste materials and containers exhibit the following:

- Significantly lower effective hydraulic conductivity
- Destruction of organic materials which reduces the gas generation potential
- Oxidation or immobilization of heavy metals.
- Increased strength of composite.

4.1.5 Add Clay

Non-swelling clay (granular or pelletized illite or kaolinite) will be added to the waste to reduce the void spaces in the final waste form. The clay is mixed with the waste and placed into 208-liter (55-gallon) drums. It is assumed that the clay will fill 80% of the initial void volume in the waste package. It is also assumed that there will be no net change to the waste volume (i.e., treatment of one drum of waste results in one drum of treated waste). The final density of the waste is assumed to be 78.5 lb/ft^3 compared to an initial average density of 33.3 lb/ft^3. The mass increase factor due to the addition of the clay is 2.35. The density of the clay pellets added to the waste is assumed to be approximately 1,040 kg/m^3 (65 lb/ft^3) based on information from clay suppliers. Waste materials with clay added exhibit the following:

- Lower effective hydraulic conductivity
- Lower initial void volume.

4.2 Backfills

Backfills as components of the EAs involve the emplacement of earthen or cementitious materials between and around the CH-TRU waste containers. Backfills do not affect the physical properties of the waste but do have an effect on the properties of the waste composite. By both, volume and mass, backfill will typically account for a large proportion of the waste/backfill composite material. The five backfill components presented as part of these EAs are a sand and clay mixture, a salt aggregate based grout, a cementitious grout, a crushed salt and calcium oxide mixture, and a 100% clay based backfill. Details of the five backfills and their physical properties are presented below.

4.2.1 Sand and Clay Mixture Backfill

A backfill consisting of a mixture of medium grained sand and granulated clay is placed around the waste stack and between the drums filling the void space within the rooms. The backfill is 70% sand and 30% clay by volume. The clay is commercially available granulated or pelletized kaolinite or illite having a bulk density of approximately 1,040 kg/m^3 (65 lb/ft^3). Because of the inefficiencies associated with pneumatically placing a dry fine to medium grained material, a filling efficiency of 50% is assumed.

The sand plus clay backfill is placed to a height of approximately 0.6 m (2 ft) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 0.5 m). The total volume of backfill material for the entire underground is approximately 103,500 m^3 (3,655,000 ft^3) filling an available backfill void volume of 207,000 m^3 (7,310,000 ft^3) at a 50% filling efficiency. This translates to 827 m^3 (29,200 ft^3) of backfill material per room equivalent into an available backfill void volume of 1,654 m^3 (58,400 ft^3). The initial

density of the sand plus clay backfill is 1,590 kg/m^3 (99.2 lb/ft^3) at a porosity of 40%. The density and porosity change as the load on the backfill increases due to creep closure to a final density of 1,855 kg/m^3 (115.8 lb/ft^3) and a porosity of 30% at 2,200 psi stress. The hydraulic conductivity of the sand plus clay backfill is expected to range from 6 x 10^{-7} m/second (s) at 0 psi stress to 9 x 10^{-9} m/s at 2,200 psi stress.

The sand plus clay backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite initial void
- Reduces the initial void volume of the room.

4.2.2 Salt Aggregate Grout Backfill

A cementitious based grout backfill using crushed salt as the aggregate and simulated WIPP brine as the added water (Gulick and Wakeley, 1989), is pumped around the waste stack and between the drums filling the void space within the rooms. Some inefficiencies will occur in placing the grout backfill so a filling efficiency of 80% is assumed.

The grout backfill is placed to a height of 0.6 m (1.89 ft) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 0.5 m). The total volume of backfill material for the entire underground is approximately 166,000 m^3 (5,862,000 ft^3) filling an available backfill void volume of 207,000 m^3 (7,310,000 ft^3) at an 80% filling efficiency. This translates to 1,323 m^3 (46,720 ft^3) of grout material per room-equivalent into an available backfill void volume of 1,654 m^3 (58,400 ft^3). The initial density of the salt aggregate grout backfill is 1,884 kg/m^3 (117.6 lb/ft^3) at a porosity of 31.3%. Because of the grout's inherent strength, the density and porosity will not change as the load on the backfill increases due to creep closure. The hydraulic conductivity of the salt aggregate grout backfill is assumed to be constant over all expected stresses at 1.3 x 10^{-12} m/s.

The high salt content will allow the grout to maintain plastic properties under the constant lithostatic load. This will ensure that the grout will not chemically degrade or fracture during the 10,000-year period of performance.

The salt aggregate grout backfill:

- reduces the hydraulic conductivity of the backfill/waste composite
- is chemically compatible with the WIPP brine and surrounding salt.

4.2.3 Cementitious Grout Backfill

A cementitious grout backfill using ordinary Portland cement, sand aggregate, and fresh water, is pumped around the waste stack and between the drums filling the void space within the rooms. As with the salt aggregate grout backfill, some inefficiencies will occur in placing the grout backfill so a filling efficiency of 80% is assumed.

The cementitious grout backfill, as with the other backfills, is placed to a height of approximately 0.6 m (2 ft) above the top of the waste stack (SNL/NM, 1991), between the waste drums, and along the room walls. The material properties, including density, porosity, and hydraulic

conductivity, of the cementitious grout backfill are assumed to be the same as that of the salt aggregate grout backfill.

The cementitious grout backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite.
- Increases the strength of the backfill/waste composite
- Reduces the initial void volume
- Increases the pH of the brines in the repository environment which lowers the radionuclide solubility.

4.2.4 Crushed Salt and Calcium Oxide Mixture Backfill

A backfill consisting of commercially available granulated CaO (quick lime) and crushed salt aggregate is pneumatically placed around the waste stack and between the drums filling the void space within the rooms. The mixture consists of less than 10% CaO and 90% crushed salt aggregate. Because of the inefficiencies associated with pneumatically placing a dry material, a filling efficiency of 50% is assumed.

The crushed salt and CaO backfill, as with the other backfills, is placed to a height approximately 0.6 m (2 ft) above the top of the waste stack (SNL, 1991), between the waste drums, and along the room walls. The total volume and the volume per room of the crushed salt plus CaO backfill are assumed to be the same as for the sand plus clay backfill presented above. Since the mixture is predominantly crushed salt, the properties of a crushed salt aggregate backfill are assumed. The initial density of the crushed salt backfill is 1,193 kg/m^3 (74.4 lb/ft^3) at a porosity of 44.8%. The final density and porosity at 2,200 psi stress is assumed to be 1,960 kg/m^3 (122.3 lb/ft^3) and 9.3%, respectively. The hydraulic conductivity of the CaO and crushed salt backfill is assumed to range from approximately 7 x 10^{-2} m/s at 0 psi stress to approximately 1 x 10^{-11} m/s at 2,200 psi stress.

The crushed salt plus CaO backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite
- Increases the pH of the brines in the repository environment which lowers the radionuclide solubility
- Is chemically compatible with the WIPP underground environment.

4.2.5 Clay Based Backfill

A backfill consisting of commercially available granular or pelletized kaolinite or illite clay (DOE, 1995a) is place pneumatically around the waste stack and between the drums at a filling efficiency of 50%. The initial density of the emplaced clay backfill is approximately 1,000 kg/m^3 (62.4 lb/ft^3) at a porosity of 62.5%. After consolidation at a stress of 2,200 psi due to creep closure, the clay backfill will reach a final density of 1,610 kg/m^3 (100.5 lb/ft^3) at a porosity of

39.7%. The hydraulic conductivity of the clay based backfill is assumed to range from 1×10^{-10} m/s at 0 psi stress to 2×10^{-13} m/s at 2,200 psi stress.

The clay based backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite
- Reduces the initial void volume.

4.3 Emplacement Configurations

Two emplacement configurations are considered as components to the EAs. The differences between the two configurations are the room height and the number of drums of waste per layer within a waste emplacement room. The configurations are presented below.

4.3.1 Baseline in 13 x 33 x 300 ft Rooms

The baseline configuration assumes a waste emplacement room (or room equivalent) to be 13 ft high by 33 ft wide by 300 ft long, with waste containers stacked up to three layers high for a maximum of 6,421 drums per room equivalent. Because it is assumed that the overall radionuclide inventory within a panel cannot be greater than the inventory in the baseline engineered alternative, some of the EAs will have less than 6,421 drums of treated waste per room, resulting in waste containers being stacked less than 3 high. This configuration is still considered the baseline emplacement configuration since the room dimensions and available volume do not change.

4.3.2 Monolayer in 6 x 33 x 300 ft Rooms

The monolayer emplacement configuration assumes waste containers are emplaced in a single layer in a room that is 33 ft wide by 300 ft long but only 6 ft high. Only 2,000 drums are placed in the single layer for this configuration. This emplacement configuration is only used in the 77-series of EAs.

5.0 PHYSICAL/CHEMICAL PROPERTY CALCULATION METHODOLOGY

Initial calculations supply input values for a spreadsheet designed to compute physical/chemical properties of the waste/backfill composite on a per-room or panel basis. Therefore, generating the effective properties resulting from a given combination of engineered alternative components is reduced to specifying the basic input values for that EAs in the spreadsheet. Data files are then generated in the spreadsheet. The default values in the spreadsheet are those corresponding to the baseline case.

Spreadsheet input parameters are listed below:

- The distribution of waste components in an average room. This distribution is dependent on the number of drums of each waste form component (solid organics, solid inorganics, and sludges) present.

- The average weight per drum of each waste form.

- Volume reduction factors, which are unique to the particular engineered alternative, and to the unprocessed waste form. They allow computation of the equivalent drum count, which is the number of unprocessed drums required to produce a processed drum of waste for the particular engineered alternative. The number of processed drums per room equivalent for each of the EAs is presented in Table F-2.

- The average height of the waste stack. Because it is assumed that the overall radionuclide inventory within a panel cannot be greater than the inventory in the baseline case, some of the EAs will have less than 6,421 drums of treated waste per room, resulting in waste containers being stacked less than 3 high. The average height of the waste stack is determined by multiplying the height of the waste stack for the baseline case (2.676 m) by the fraction of the number of drums per room equivalent for the engineered alternative relative to the baseline case (6,421 drums per room equivalent).

- The total volume of backfill (if present), volume of backfill within the waste stack, and void volume within the waste stack. The void volume within the waste stack is an estimation of the void space within the waste stack resulting from inefficiency in the backfilling process. The void volume is used to estimate an initial waste stack density. The total volume of backfill is utilized in the computation of waste/backfill composite density. The volume of backfill within the waste stack is used in the computation of hydraulic conductivity of the waste/backfill composite.

- The density variations of each waste or backfill component as a function of closure stress, from 0 psi (0 MPa) to lithostatic pressure (approximately 2,200 psi [15 MPa]) in 200 psi (1.35 MPa) increments. The waste or backfill component density values are used in the computation of waste/backfill composite density, porosity, and hydraulic conductivity of the room contents.

The effects of an EA on the waste/backfill composite properties are calculated with a computer spreadsheet. To compute physical and chemical properties of an EA, only those input values which deviate from the baseline case need to be modified in the spreadsheet. The remaining input variables are therefore unaltered from the baseline case. Some EAs require no computation of various properties (eg., cement based grout backfill is considered incompressible and therefore has a constant density and hydraulic conductivity). The hydraulic conductivity of a cement grout backfill would be considered a fixed input value for all closure stress levels. This spreadsheet computational methodology is used to evaluate the properties of each EA.

1

TABLE F-2

DRUMS PER ROOM EQUIVALENT FOR EACH ENGINEERED ALTERNATIVE

Engineered Alternative	Number of Drums per Room Equivalent
Baseline Case	6,421
Alternative 1, Supercompact Solid Organics and Solid Inorganics	3,604
Alternative 6, Shred and Compact Solid Organics and Solid Inorganics	5,381
Alternative 10, Plasma Processing	2,120
Alternative 33, Sand Plus Clay Backfill	6,421
Alternative 35a, Salt Aggregate Grout Backfill	6,421
Alternative 35b, Cementitious Grout Backfill	6,421
Alternative 77a, Supercompact, Monolayer of 2000 Drums, Salt Aggregate Grout Backfill	2,000[1]
Alternative 77b, Supercompact, Monolayer of 2000 Drums, Clay Based Backfill	2,000[1]
Alternative 77c, Supercompact, Monolayer of 2000 Drums, Sand Plus Clay Backfill	2,000[1]
Alternative 77d, Supercompact, Monolayer of 2000 Drums, Crushed Salt Plus CaO Backfill	2,000[1]
Alternative 83, Crushed Salt Plus CaO Backfill	6,421
Alternative 94a, Enhanced Cementation, Shred and Add Clay, No Backfill	6,421[2]
Alternative 94b, Enhanced Cementation, Shred and Add Clay, Sand Plus Clay Backfill	6,421[2]
Alternative 94c, Enhanced Cementation, Shred and Add Clay, Cementitious Grout Backfill	6,421[2]
Alternative 94d, Enhanced Cementation, Shred and Add Clay, Salt Aggregate Grout Backfill	6,421[2]
Alternative 94e, Enhanced Cementation, Shred and Add Clay, Clay Based Backfill	6,421[2]
Alternative 94f, Enhanced Cementation, Shred and Add Clay, Crushed Salt Plus CaO Backfill	6,421[2]
Alternative 111, Clay Based Backfill	6,421

[1]2,000 drums per room defined by alternative. This alternative does not provide adequate space for all of the CH-TRU waste and leaves approximately 200,170 drums of waste outside of the WIPP.
[2]The enhanced cementation process increases the total waste volume above the WIPP capacity volume. Approximately 130,600 drums of CH-TRU waste are left outside of the WIPP.

6.0 QUANTIFICATION OF PHYSICAL AND CHEMICAL PROPERTIES

The physical and chemical properties used in the DAM are evaluated over the range of closure stress expected in the repository. The properties of primary importance are as follows

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

The waste composite in the WIPP repository is assumed to contain up to four components. These components consist of the backfill material and the three major categories of waste (solid organics, solid inorganics, and sludges) which may be treated in some manner. The physical and chemical properties of each component will be dependent on the particular engineered alternative being considered. The methodologies and assumptions used to characterize these properties are detailed in the following sections.

Although material compressibility is not a DAM input property, it is a useful parameter upon which to base simplifying assumptions. Material compressibility is used to estimate the effects of creep closure on the physical properties of the waste composite. Waste and backfill materials in the WIPP repository will be subjected to triaxial compressive forces. Compressibility of these materials will affect all physical properties. The extent to which different materials consolidate is largely dependent on the strength of the bulk material. Treated wastes such as enhanced cemented sludges or vitrified glass have compressive strengths in excess of lithostatic pressure of 2,200 psi (14.8 MPa), and are assumed to be incompressible under the stresses expected in the repository.

It is important to note that effects of time on the physical properties of the waste composite are not considered in this analysis. Long-term (10,000 years) effects such as fatigue and degradation are not well quantified and are therefore considered inappropriate for these generalized calculations. Therefore, the density, porosity, and hydraulic conductivity of portland cement based materials used as backfill or sludge solidification are assumed to remain constant during the 10,000 year operating life of the WIPP.

6.1 Density

Density of the waste/backfill composite at any given stress level can be computed from the density of the individual components at that same stress level. The mass of each waste component is obtained from the mass distribution of the three major waste forms defined by Butcher, et al. (1991). The quantity of backfill is estimated from repository room design specifications from SNL/NM's performance assessment modeling (SNL/NM, 1991). Total mass for each alternative is assumed constant over the 10,000-year period for the computation of waste/backfill composite densities. This assumption simplifies the density calculations. It is understood that waste/backfill composite mass fluxes resulting from gas production/dissipation, and brine transport will vary the waste/backfill composite mass (e.g., by chemical degradation, physical erosion, and subsequent mass transfer into and out of the waste stack), though the extent to which these processes will occur is not well defined. Initial component volumes are

known from the baseline design criteria, thus initial waste/backfill composite density is readily quantified.

The waste/backfill composite density resulting from EA evaluations may or may not increase during the consolidation process. For the baseline case, waste component densities as a function of stress level were obtained from Butcher et al. (1991). The methodology of computing density of a multicomponent system is outlined in Butcher et al. (1991). This method utilizes component densities (or mass and volume) to compute waste/backfill composite density. Implicit in the calculation is the assumption that the components act independently.

The formulation can be summarized as follows; the volume occupied by component i at some stress level x is:

$$V_i(x) = \frac{M_i}{D_i(x)} \tag{3.6-1}$$

where,

$V_i(x)$ = *volume of component "i" at stress level x*
M_i = *mass of component "i"*
$D_i(x)$ = *density of component "i" at stress level x.*

The total waste/backfill composite volume at stress level x is the sum of the component volumes:

$$TV(x) = \sum_{i=1}^{n} V_i(x) \tag{3.6-2}$$

where,

TV(x) = total waste/backfill composite volume at stress level x.

The total waste/backfill composite mass is the sum of the "n" component masses, or:

$$TM = \sum_{i=1}^{n} M_i \tag{3.6-3}$$

where,

TM = the total waste/backfill composite mass.

Therefore, the waste/backfill composite density at stress level x can be computed as follows:

$$RD(x) = \frac{TM}{TV(x)} = \sum_{i=1}^{n} \frac{TM}{(M_i/D_i(x))} \qquad (3.6\text{-}4)$$

where,

RD(x) = density of waste/backfill composite at stress level x.

Equation 1.6-4 can be simplified by introducing a component weight fraction, W_i:

$$W_i = \frac{M_i}{TM} \qquad (3.6\text{-}5)$$

After dividing the numerator and denominator of equation 3.6.4 by TM, the expression for the waste/backfill composite density becomes:

$$RD(x) = \sum_{i=1}^{n} \frac{1.0}{(W_i/D_i(x))} \qquad (3.6\text{-}6)$$

In summary, waste/backfill composite density was computed at a given stress level by:

- Using densities as a function of stress level and weights for each component
- Utilizing the experimental densities of individual components such as metal, glass, sorbents and combustibles (all under pressure) as reported by Butcher et al. (1991)
- Using component mass proportions.

Table F-3 contains waste/backfill composite densities as a function of stress for each of the EAs analyzed using the DAM.

6.2 Porosity

Porosity is a measure of void space existing in a material and is defined as the ratio of void volume to total volume of the material. Within the repository, the waste/backfill composite porosity is dependent on waste characteristics, backfill materials (if present), efficiency of waste packaging, efficiency of backfill emplacement, and the extent to which these materials compact during the consolidation process. Computation of waste/backfill composite porosity (assuming constant mass) can be made on either a volume or density basis (Butcher, 1989), for example:

TABLE F-3

COMPOSITE DENSITIES FOR ENGINEERED ALTERNATIVES
(pounds/cubic inch)

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	0.0107	0.0203	0.0136	0.0315	0.0325	0.0427	0.0427	0.0555	0.0324	0.0447	0.0364	0.0266
0	0.0197	0.0375	0.0251	0.0581	0.0378	0.0452	0.0452	0.0582	0.0366	0.0505	0.0411	0.0309
200	0.0437	0.0699	0.0605	0.0953	0.0534	0.0610	0.0610	0.0685	0.0474	0.0609	0.0605	0.0517
400	0.0549	0.0822	0.0822	0.1042	0.0580	0.0649	0.0649	0.0706	0.0525	0.0638	0.0657	0.0583
600	0.0618	0.0839	0.0839	0.1095	0.0606	0.0667	0.0667	0.0709	0.0553	0.0649	0.0678	0.0621
800	0.0672	0.0854	0.0854	0.1142	0.0625	0.0679	0.0679	0.0711	0.0576	0.0658	0.0697	0.0652
1000	0.0716	0.0864	0.0863	0.1175	0.0642	0.0688	0.0688	0.0712	0.0597	0.0667	0.0709	0.0674
1200	0.0754	0.0872	0.0872	0.1204	0.0657	0.0695	0.0695	0.0713	0.0614	0.0676	0.0721	0.0694
1400	0.0787	0.0879	0.0879	0.1229	0.0670	0.0701	0.0701	0.0714	0.0628	0.0684	0.0731	0.0711
1600	0.0818	0.0885	0.0885	0.1250	0.0683	0.0705	0.0705	0.0715	0.0638	0.0693	0.0739	0.0725
1800	0.0845	0.0890	0.0890	0.1270	0.0696	0.0709	0.0709	0.0716	0.0651	0.0701	0.0745	0.0737
2000	0.0870	0.0895	0.0895	0.1289	0.0707	0.0713	0.0713	0.0717	0.0658	0.0709	0.0754	0.0750
2200	0.0895	0.0900	0.0900	0.1308	0.0719	0.0716	0.0716	0.0717	0.0666	0.0717	0.0759	0.0761
Solid	0.1158	0.1171	0.1171	0.1469	0.1004	0.1021	0.1021	0.1023	0.1030	0.1004	0.0873	0.0875

TABLE F-3 (Continued)

COMPOSITE DENSITIES FOR ENGINEERED ALTERNATIVES
(pounds/cubic inch)

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	0.0107	0.0146	0.0357	0.0458	0.0458	0.0269	0.0298	0.0237
0	0.0197	0.0269	0.0415	0.0486	0.0486	0.0313	0.0347	0.0276
200	0.0437	0.0352	0.0477	0.0547	0.0547	0.0378	0.0456	0.0414
400	0.0549	0.0384	0.0500	0.0566	0.0566	0.0412	0.0489	0.0473
600	0.0618	0.0402	0.0515	0.0576	0.0576	0.0435	0.0510	0.0512
800	0.0672	0.0415	0.0526	0.0583	0.0583	0.0452	0.0526	0.0543
1000	0.0716	0.0425	0.0536	0.0588	0.0588	0.0468	0.0537	0.0571
1200	0.0754	0.0433	0.0544	0.0592	0.0592	0.0481	0.0547	0.0594
1400	0.0787	0.0439	0.0552	0.0595	0.0595	0.0491	0.0556	0.0613
1600	0.0818	0.0445	0.0559	0.0598	0.0598	0.0499	0.0563	0.0629
1800	0.0845	0.0450	0.0567	0.0600	0.0600	0.0508	0.0569	0.0646
2000	0.0870	0.0454	0.0573	0.0602	0.0602	0.0513	0.0575	0.0657
2200	0.0895	0.0457	0.0579	0.0604	0.0604	0.0519	0.0580	0.0669
Solid	0.1158	0.1181	0.1022	0.1034	0.1034	0.1051	0.0905	0.1029

On volume basis:

$$Porosity = \frac{(V_{total} - V_{solid})}{V_{total}} \tag{3.6-7}$$

On density basis:

$$Porosity = 1 - \frac{(composite\ density)}{(composite\ solid\ density)} \tag{3.6-8}$$

where,

V_{total} is the total volume ($V_{solid} + V_{void}$) of the room components at some stress level, and V_{solid} is the total solid volume of all room components. Therefore, the quantity ($V_{total} - V_{solid}$) represents V_{void}, the room void volume including the waste/backfill composite void volume minus the volume of the overlying air gap. Due to greater availability of density data for components, waste/backfill composite porosity is computed on a density basis. Table F-4 presents the waste/backfill composite porosities as a function of stress for each of the EAs analyzed using the DAM.

6.3 Hydraulic Conductivity

Hydraulic conductivity is a measure of the permeability of a porous media. It is dependent on the properties of the media as well as the fluid. The hydraulic conductivity of the waste/backfill composite in an average WIPP repository room is dependent on the waste components, backfill material (if present), and the brine present. In multicomponent systems, an effective hydraulic conductivity can be estimated by averaging the individual component hydraulic conductivities comprising the system. The following three different averaging techniques exist:

- Arithmetic mean - applies to flow through a parallel configuration of components
- Harmonic mean - applies to flow through a series configuration of components
- Geometric mean - applies to flow through a randomly distributed configuration of components.

In practice, the effective hydraulic conductivity of randomly distributed components is estimated by using the geometric mean of components. The geometric mean is preferred over arithmetic and harmonic means (parallel and series flow configurations, respectively), because it results in a better representation of randomly distributed components (Scheidegger, 1974).

In the baseline case, hydraulic conductivity of solid inorganic and solid organic waste is assumed to vary with porosity and is estimated from a modified version of the Kozeny-Carmen equation (Bear, 1972). Components such as grout or glass are assumed incompressible under repository conditions (compressive strengths greater than lithostatic pressure) and thus have constant hydraulic conductivities.

TABLE F-4

COMPOSITE POROSITIES FOR ENGINEERED ALTERNATIVES

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	0.908	0.826	0.884	0.785	0.677	0.582	0.582	0.457	0.686	0.686	0.583	0.696
0	0.830	0.680	0.786	0.604	0.623	0.557	0.557	0.431	0.645	0.645	0.529	0.646
200	0.623	0.403	0.484	0.351	0.468	0.402	0.402	0.331	0.540	0.540	0.308	0.409
400	0.526	0.298	0.298	0.291	0.423	0.364	0.364	0.310	0.490	0.490	0.248	0.335
600	0.466	0.284	0.284	0.255	0.397	0.347	0.347	0.307	0.463	0.463	0.223	0.290
800	0.419	0.271	0.271	0.223	0.378	0.335	0.335	0.305	0.441	0.441	0.202	0.256
1000	0.382	0.263	0.263	0.200	0.361	0.326	0.326	0.304	0.420	0.420	0.188	0.230
1200	0.349	0.255	0.255	0.180	0.346	0.319	0.319	0.302	0.403	0.403	0.175	0.208
1400	0.320	0.250	0.250	0.163	0.333	0.314	0.314	0.302	0.390	0.390	0.163	0.188
1600	0.294	0.244	0.244	0.149	0.320	0.309	0.309	0.301	0.380	0.380	0.154	0.172
1800	0.270	0.240	0.240	0.135	0.307	0.305	0.305	0.300	0.367	0.367	0.146	0.158
2000	0.248	0.235	0.235	0.123	0.296	0.301	0.301	0.299	0.361	0.361	0.137	0.143
2200	0.227	0.231	0.231	0.110	0.284	0.298	0.298	0.299	0.353	0.353	0.130	0.131

TABLE F-4 (Continued)

COMPOSITE POROSITIES FOR ENGINEERED ALTERNATIVES

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	0.908	0.876	0.651	0.557	0.557	0.744	0.671	0.770
0	0.830	0.772	0.594	0.530	0.530	0.702	0.617	0.732
200	0.623	0.702	0.533	0.471	0.471	0.640	0.496	0.597
400	0.526	0.675	0.510	0.452	0.452	0.608	0.459	0.540
600	0.466	0.659	0.496	0.443	0.443	0.586	0.436	0.502
800	0.419	0.649	0.486	0.436	0.436	0.570	0.419	0.472
1000	0.382	0.640	0.476	0.431	0.431	0.555	0.406	0.445
1200	0.349	0.634	0.467	0.428	0.428	0.543	0.395	0.422
1400	0.320	0.628	0.460	0.424	0.424	0.533	0.386	0.404
1600	0.294	0.623	0.453	0.422	0.422	0.525	0.378	0.389
1800	0.270	0.619	0.446	0.420	0.420	0.517	0.371	0.372
2000	0.248	0.616	0.440	0.418	0.418	0.512	0.365	0.361
2200	0.227	0.613	0.433	0.416	0.416	0.506	0.359	0.350

The components considered in the averaging process are the three primary waste forms and the backfill material within the waste stack. Backfill contained in the volume above the waste stack is not considered because this region is a physical extension of the host rock.

The values of hydraulic conductivity for each component are estimated on the basis of available data in literature. Components with large void space which compact under compressive stresses will typically have hydraulic conductivities that vary with the degree of compaction. This variability can be estimated or computed from the porosity. For example, the hydraulic conductivity of a crushed salt and CaO mixture is assumed to be a function of porosity and is estimated as a function of compaction with a bi-linear system of equations developed by Case and Kelsall (1987). Once the hydraulic conductivity of each component has been estimated, the effective hydraulic conductivity for the composite can be computed. The governing equation employing the geometric mean for averaging hydraulic conductivities is (Scheidegger, 1974):

$$\ln(K_{eff}) = \sum_{i=1}^{n} (F_i \ln(K_i)) \qquad (3.6\text{-}9)$$

where,

K_{eff} = effective waste/backfill composite hydraulic conductivity at stress level x
F_i = volume fraction of component i at stress level x
K_i = hydraulic conductivity of component i at stress level x.

The component volume fraction and the hydraulic conductivity may be functions of stress level or the state of compaction. The component volume fraction is computed as the component volume divided by the waste/backfill composite volume at a particular stress level:

$$F_i(x) = \frac{V_i(x)}{TV(x)} \qquad (3.6\text{-}10)$$

where,

$F_i(x)$ = volume fraction of component i at stress level x
$V_i(x)$ = volume of component i at stress level x (including the void space within the waste/backfill composite)
$TV(x)$ = volume of waste/backfill composite at stress level x.

The component and waste/backfill composite volumes are obtained from estimated values of component masses and densities:

$$V_i(x) = \frac{M_i}{D_i(x)} \qquad (3.6\text{-}11)$$

$$TV(x) = \sum_{i=1}^{n} V_i(x) \tag{3.6-12}$$

where,

M_i = *mass of commponent "i"*
$D_i(x)$ = *density of component "i" at stress level x.*

The procedure allows computation of an effective hydraulic conductivity for the average contents of a WIPP repository room at various stress levels. Table F-5 contains the hydraulic conductivities for each of the EAs analyzed using the DAM.

6.4 Gas Generation Potential

Gas generation potential is defined as the maximum amount of gas that can be generated under ideal conditions. Two potentials are defined: hydrogen generation form anoxic corrosion, and "biogas" generation from microbial degradation of organics.

The potential for hydrogen is based on the total mass of corrodible metal (metallic waste and container material) present in a panel. In most cases there is insufficient brine available to corrode all of the metal so that the total potential is never reached. It is still important however to define a potential so that the model does not predict the generation of more hydrogen than is physically possible.

The potential for "biogas" gas generation by microbial degradation of organic material is based on the total mass of degradable organics in a panel. The process of microbial gas generation stops when this potential is reached. The plasma treatment alternative is assumed to destroy all degradable organics so that the potential for this option is zero.

6.5 Effective Waste Volume

The effective waste volume is used to determine the radionuclide content in drill cuttings removed from the repository during human intrusion events. The effective waste volume is the volume of the waste/backfill composite minus the volume of the backfill along the sides of the waste stack. The term "drill cuttings" refers to the waste/backfill composite which would be brought to the surface with circulating drilling fluid during an inadvertent human intrusion event. The effective waste volume evaluation requires determination of the waste/backfill composite density as a function of stress, as per Equation (3.6.6). These calculations differ from each other only in that the waste/backfill composite density calculation neglects backfill on the sides of the waste stack. If penetration through the backfill on the sides of the waste stack occurs, the waste stack is assumed to remain intact and the cuttings are assumed not to contain any radionuclides. The backfill above the waste stack is considered because it would be mixed with extracted waste in the event the waste stack is breached by drilling activities.

TABLE F-5

COMPOSITE HYDRAULIC CONDUCTIVITY FOR ENGINEERED ALTERNATIVES

(meters/second)

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	7.39×10^{-04}	1.14×10^{-04}	3.74×10^{-04}	7.35×10^{-16}	6.48×10^{-05}	8.49×10^{-07}	8.49×10^{-07}	1.22×10^{-07}	2.57×10^{-06}	1.20×10^{-05}	6.44×10^{-04}	2.18×10^{-03}
200	6.10×10^{-05}	6.38×10^{-06}	1.44×10^{-05}	7.35×10^{-16}	2.59×10^{-06}	5.43×10^{-09}	5.43×10^{-09}	1.90×10^{-09}	4.57×10^{-08}	6.83×10^{-07}	9.34×10^{-06}	4.09×10^{-05}
400	2.11×10^{-05}	1.89×10^{-06}	1.89×10^{-06}	7.35×10^{-16}	9.30×10^{-07}	1.29×10^{-09}	1.29×10^{-09}	6.06×10^{-10}	1.02×10^{-08}	2.73×10^{-07}	2.22×10^{-06}	9.84×10^{-06}
600	1.11×10^{-05}	1.55×10^{-06}	1.55×10^{-06}	7.35×10^{-16}	5.33×10^{-07}	6.26×10^{-10}	6.26×10^{-10}	5.18×10^{-10}	7.32×10^{-09}	2.32×10^{-07}	1.22×10^{-06}	3.82×10^{-06}
800	6.51×10^{-06}	1.27×10^{-06}	1.27×10^{-06}	7.35×10^{-16}	3.48×10^{-07}	3.76×10^{-10}	3.76×10^{-10}	4.49×10^{-10}	5.59×10^{-09}	1.98×10^{-07}	7.21×10^{-07}	1.70×10^{-06}
1000	4.21×10^{-06}	1.11×10^{-06}	1.11×10^{-06}	7.35×10^{-16}	2.49×10^{-07}	2.58×10^{-10}	2.58×10^{-10}	4.07×10^{-10}	4.64×10^{-09}	1.75×10^{-07}	4.98×10^{-07}	9.19×10^{-07}
1200	2.82×10^{-06}	9.67×10^{-07}	9.66×10^{-07}	7.35×10^{-16}	1.85×10^{-07}	1.88×10^{-10}	1.88×10^{-10}	3.72×10^{-10}	4.04×10^{-09}	1.56×10^{-07}	3.58×10^{-07}	5.26×10^{-07}
1400	1.96×10^{-06}	8.59×10^{-07}	8.59×10^{-07}	7.35×10^{-16}	1.42×10^{-07}	1.45×10^{-10}	1.45×10^{-10}	3.45×10^{-10}	3.64×10^{-09}	1.40×10^{-07}	2.35×10^{-07}	2.71×10^{-07}
1600	1.38×10^{-06}	7.64×10^{-07}	7.64×10^{-07}	7.35×10^{-16}	1.10×10^{-07}	1.15×10^{-10}	1.15×10^{-10}	3.22×10^{-10}	3.27×10^{-09}	1.26×10^{-07}	1.11×10^{-07}	9.14×10^{-08}
1800	9.79×10^{-07}	6.80×10^{-07}	6.80×10^{-07}	7.35×10^{-16}	8.67×10^{-08}	9.34×10^{-11}	9.34×10^{-11}	3.00×10^{-10}	2.98×10^{-09}	1.13×10^{-07}	5.58×10^{-08}	3.33×10^{-08}
2000	7.02×10^{-07}	6.06×10^{-07}	6.06×10^{-07}	7.35×10^{-16}	6.88×10^{-08}	7.74×10^{-11}	7.74×10^{-11}	2.81×10^{-10}	2.76×10^{-09}	1.01×10^{-07}	2.32×10^{-08}	9.36×10^{-09}
2200	4.93×10^{-07}	5.35×10^{-07}	5.34×10^{-07}	7.35×10^{-16}	5.43×10^{-08}	6.42×10^{-11}	6.42×10^{-11}	2.63×10^{-10}	2.54×10^{-09}	9.05×10^{-08}	1.25×10^{-08}	3.62×10^{-09}

TABLE F-5 (Continued)

COMPOSITE HYDRAULIC CONDUCTIVITY FOR ENGINEERED ALTERNATIVES

(meters/second)

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	7.39×10^{-04}	3.59×10^{-06}	1.13×10^{-06}	2.48×10^{-08}	2.48×10^{-08}	2.90×10^{-07}	3.79×10^{-05}	1.66×10^{-05}
200	6.10×10^{-05}	3.85×10^{-07}	1.77×10^{-07}	2.57×10^{-09}	2.57×10^{-09}	2.56×10^{-08}	9.77×10^{-07}	1.81×10^{-07}
400	2.11×10^{-05}	1.72×10^{-07}	9.42×10^{-08}	1.23×10^{-09}	1.23×10^{-09}	9.85×10^{-09}	3.43×10^{-07}	3.30×10^{-08}
600	1.11×10^{-05}	1.09×10^{-07}	6.58×10^{-08}	8.33×10^{-10}	8.33×10^{-10}	5.79×10^{-09}	1.78×10^{-07}	1.27×10^{-08}
800	6.51×10^{-06}	7.94×10^{-08}	5.10×10^{-08}	6.40×10^{-10}	6.40×10^{-10}	4.02×10^{-09}	1.07×10^{-07}	6.21×10^{-09}
1000	4.21×10^{-06}	6.18×10^{-08}	4.15×10^{-08}	5.22×10^{-10}	5.22×10^{-10}	3.03×10^{-09}	7.31×10^{-08}	3.56×10^{-09}
1200	2.82×10^{-06}	5.06×10^{-08}	3.49×10^{-08}	4.45×10^{-10}	4.45×10^{-10}	2.46×10^{-09}	5.30×10^{-08}	2.26×10^{-09}
1400	1.96×10^{-06}	4.27×10^{-08}	3.00×10^{-08}	3.90×10^{-10}	3.90×10^{-10}	2.08×10^{-09}	3.67×10^{-08}	1.54×10^{-09}
1600	1.38×10^{-06}	3.71×10^{-08}	2.64×10^{-08}	3.50×10^{-10}	3.50×10^{-10}	1.81×10^{-09}	2.06×10^{-08}	1.08×10^{-09}
1800	9.79×10^{-07}	3.25×10^{-08}	2.33×10^{-08}	3.16×10^{-10}	3.16×10^{-10}	1.59×10^{-09}	1.21×10^{-08}	7.84×10^{-10}
2000	7.02×10^{-07}	2.92×10^{-08}	2.09×10^{-08}	2.92×10^{-10}	2.92×10^{-10}	1.45×10^{-09}	6.37×10^{-09}	5.93×10^{-10}
2200	4.93×10^{-07}	2.63×10^{-08}	1.88×10^{-08}	2.71×10^{-10}	2.71×10^{-10}	1.33×10^{-09}	4.05×10^{-09}	4.47×10^{-10}

7.0 SUMMARY

Input variables required by the DAM include the physical and chemical properties of the repository contents following waste and backfill emplacement in the WIPP. The contents are assumed to be a homogeneous waste/backfill composite. This composite consists the four following components:

- Solid organics
- Solid inorganics
- Sludges
- Backfill material (if present).

The properties required by the DAM for evaluation of the effectiveness of EAs include the following:

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

Density of the waste-backfill composite is computed by assigning weights to the individual component densities as illustrated with Equation (3.6.6). The porosity of the composite is a function of the composite density. An estimate of the hydraulic conductivity of the waste/backfill composite is the geometric mean of the component hydraulic conductivities. Gas generation (microbial and corrosion) potentials are computed from the equivalent number of unprocessed drums emplaced in a room, taking into account the effect of waste treatment on components. With the exception of total gas generation potential, the physical properties vary with pressure resulting from creep closure. Properties for the three major waste forms and the backfill materials are obtained from available literature, applicable relationships or equations, and information from Appendix O. Using the above evaluation process, physical properties of the waste/backfill composite in an average WIPP repository room are computed for use as input to the DAM.

APPENDIX G
SUMMARY OF LITERATURE SOLUBILITY STUDIES

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SUMMARY OF LITERATURE SOLUBILITY STUDIES

1.0 INTRODUCTION

To obtain relevant solubility data on the actinides of interest, a literature search was conducted and solubility studies on actinide-bearing solids (e.g., $Pu(OH)_3$, UO_2) were compiled into a data base. The data base Attachment 1 contains records that provide information on the solid phase, solution composition, solution description (e.g., dilute, saline or brine), actinide concentration in solution, pH, Eh or atmospheric conditions, temperature, equilibration time of the experimental run, method employed to determine the solubility (e.g., equilibrium approached from an oversaturated solution, calculated with a geochemical code, etc), and reference for the study. Most of the results tabulated in Attachment 1 are presented graphically for the actinides Thorium (Th), Uranium (U), Neptunium (Np), Plutonium (Pu), and Americium (Am) in coordinates of log molar concentration (molar (M) = moles/liter) versus pH.

2.0 THORIUM

Thorium is only stable in the IV valence state in the natural environment. Solubility is usually controlled by thorianite (ThO_2). $Th(OH)_4$ may initially precipitate from an oversaturated solution, but it will age to the more stable ThO_2 (Brookins, 1988).

Figure G-1 summarizes data on Th solubility in saline and brine chloride solutions as reported by Felmy et al. (1991). The solubility of the Th precipitate decreases approximately 6 orders of magnitude over the pH interval of 3 to 6, followed by a flattening of the trend above a pH of 6. Precipitates obtained from these experiments were analyzed by x-ray diffraction (XRD) techniques and found to be amorphous to x-rays until they had been aged for about a year. Some of the 372-day precipitate obtained from the 3M NaCl experiment displayed an XRD pattern similar to crystalline ThO_2. However, these samples do not show significantly different solubilities, and Felmy et al. (1991) concluded that an amorphous phase still controls the solubility despite the presence of some crystalline precipitate.

Based on thermodynamic solubility calculations at 25°C and 1 atm in dilute solutions (e.g., Langmuir and Herman, 1980), the thorianite (crystalline ThO_2) solubility trend lies 4 to 5 orders of magnitude below the trend of the amorphous hydrous Th oxide indicated on Figure G-1. As Th occurs in transuranic waste primarily as oxides (Weiner, 1995), and the hydrous Th oxide is more soluble than the crystalline oxide form, solubility data on Figure G-1 represent a conservative (upper bound) estimate of Th solubility.

3.0 URANIUM

The dominant valence states for U in the natural environment are IV and VI. Uranium (VI) is much more soluble that U (IV), and has a strong affinity for carbonate complexation. Important solubility-controlling minerals include uraninite (UO_2) for U (IV), and schoepite ($UO_3 \cdot 2H_2O$) for

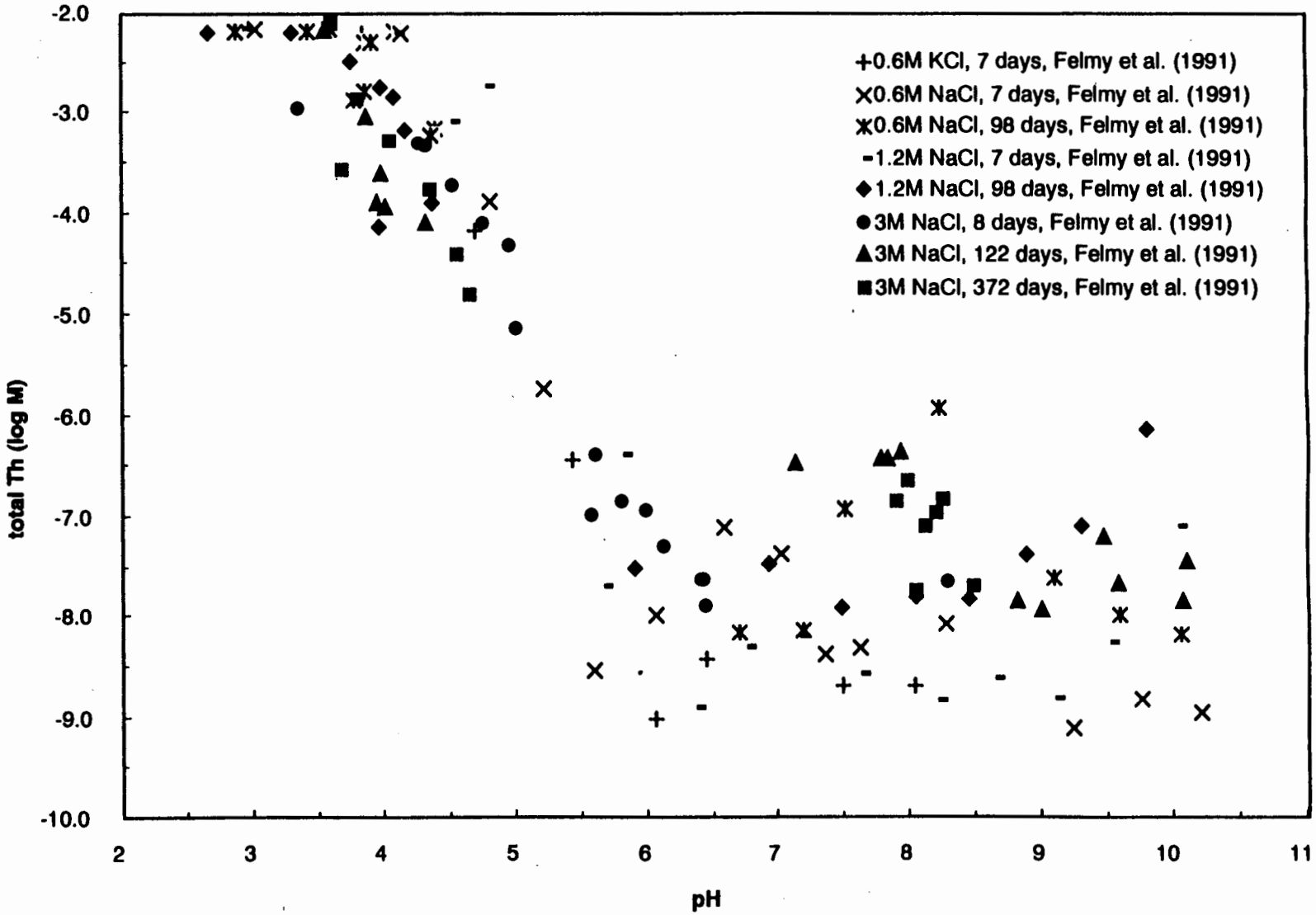


Figure G-1
Hydrous Th(IV) Oxide Solubility as a Function of pH for dilute and Brine Solutions

U (VI). The presence of organic materials and corrodable metals in the repository environment will probably restrict U to the IV state.

Figure G-2 summarizes U solubility data for uraninite (UO_2). Solubility data reported by Parks and Pohl (1988) for UO_2 at 100 and 150°C in dilute NaCl solution (0.1 M) indicate a decrease in the concentration of U from -7 to -9.5 log M as pH increases from 1 to 7. Gray (1986) investigated the solubility of unirradiated UO_2 fuel-rod pellets in a saturated NaCl brine of pH 6.2 to 6.4 and reported U concentrations of -7 to -8 log M, about 1.5 to 2.5 orders of magnitude lower than UO_2 solubility values in dilute NaCl solutions. The solubility data of Gray (1986) serve as a conservative estimate of U concentrations in Salado brine, because the solubility of UO_2 increases with temperature and the solubility data were obtained at elevated temperatures, relative to the ambient temperature of about 30°C in the WIPP repository horizon.

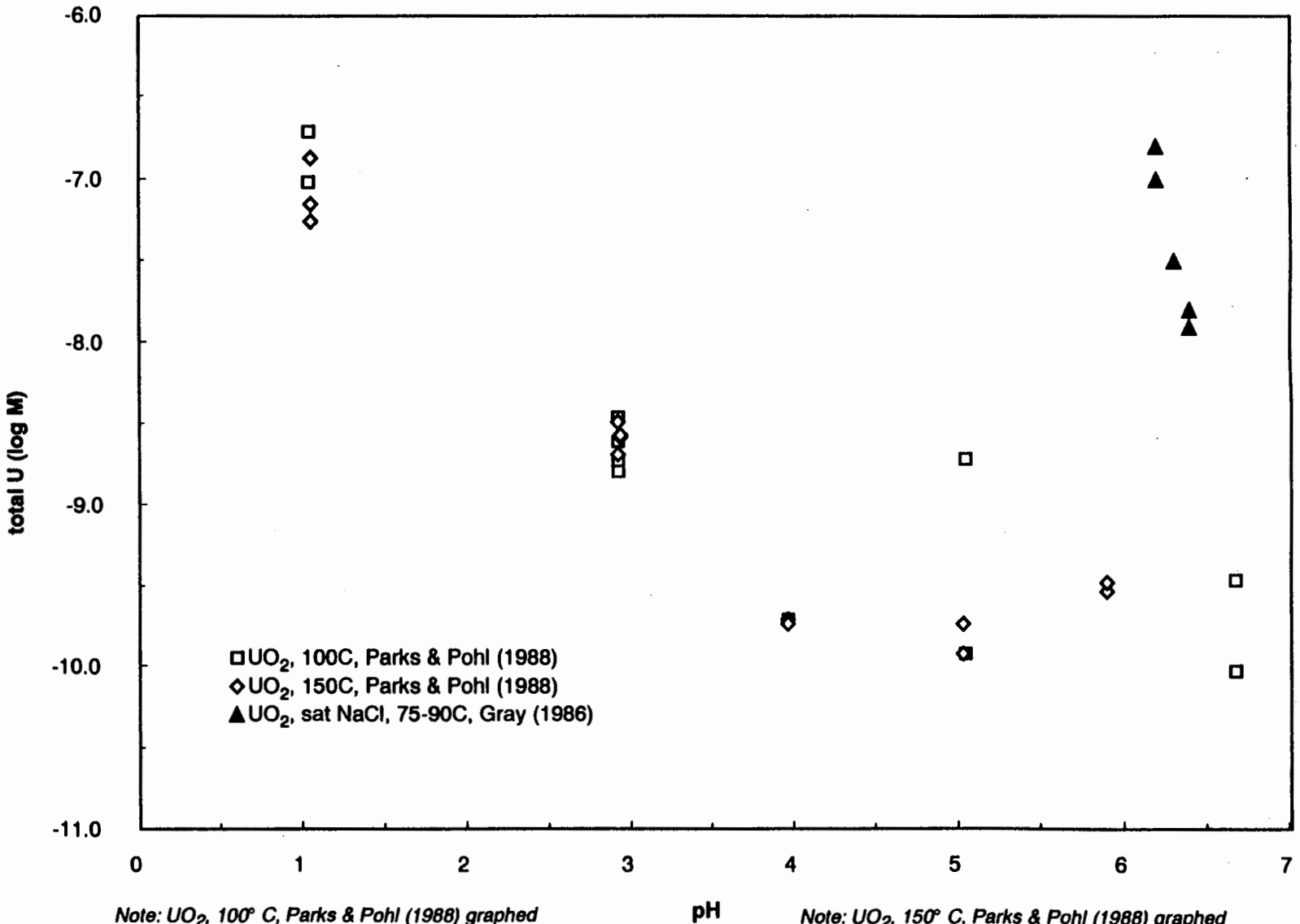
Figure G-3 summarizes U solubility data for schoepite ($UO_3 \bullet 2H_2O$) in $HClO_4$ solutions at 25°C. Krupka et al. (1985) obtained solubility data that indicate a decrease in the U concentration from -2 to -5 log M as pH increased from 3 to 9. This trend was followed by an increase of similar magnitude in the U concentration over the pH interval of 9 to 12. Bruno and Sandino (1989) conducted solubility experiments with amorphous and crystalline $UO_3 \bullet 2H_2O$, which show the amorphous schoepite to be one to two orders of magnitude more soluble than the crystalline form. Solubility studies for schoepite in saturated NaCl brine were not found. However, based on the studies presented on Figure G-2 for UO_2, it is expected that schoepite solubility in Salado brine will be 1 to 2 orders of magnitude greater than the dilute solution data on Figure G-3.

4.0 NEPTUNIUM

The dominant valence states for Np in the natural environment are IV, V, and VI. As is the case with U and Pu, Np solubilities are highly dependent on valence state. Np (IV) is expected to dominate in the reducing repository environment, with solubility being controlled by crystalline NpO_2. Other forms of Np (IV) such as amprphous NpO_2, $NpO_2 \bullet xH_2O$, and $Np(OH)_4$ will age to crystalline NpO_2. An important Np(V) solubility-controlling phase is NpO_2OH.

Figure G-4 summarizes Np (IV) solubility data for NpO_2 and $NpO_2 \bullet xH_2O$ in dilute solutions and NaCl brines. The studies of Rai and Strickert (1980) and Rai et al. (1982) at 25°C show a decrease in Np concentration from -5.5 to -6.5 log M as pH increases from about 2 to 6. The data of Kim et al. (1985b) were obtained in 1M and 5M NaCl solutions at 20 to 25° C. The runs at pH of 5 to 6 resulted in Np concentrations of about -4.5 log M, and those at a pH of 7.5 to 8 show a Np concentration of about -6 log M. Ionic strength does not appear to affect the solubility of Np in these 1M and 5M runs, but a comparison of these data over the pH range of 5 to 6 with the data of Rai and Strickert (1980) suggests the solubility of NpO_2 is increased by about 1.5 orders of magnitude in NaCl solutions of moderate to high ionic strength.

Pryke and Rees (1987) investigated the solubility of $NpO_2 \bullet xH_2O$ in solutions equilibrated with concrete at ambient temperature. Results on Figure G-4 show an apparent decrease in the Np concentration of about one-half log unit as the pH increase from 10 to 13. Comparing the studies of Pryke and Rees (1987) and Rai and Strickert (1980), it appears that the data of Pryke and Rees (1987) anchor the projected trend of the data of Rai and Strickert (1980).



Note: UO_2, 100° C, Parks & Pohl (1988) graphed data does not include 3 outlying points: (E922, F922), (E923, F923) and (E924, F924).

Note: UO_2, 150° C, Parks & Pohl (1988) graphed data does not include 4 outlying points: (E939, F939), (E940, F940), (E941, F941) and (E942, F942).

Figure G-2
UO_2 Solubility as a Function of pH for Dilute and Brine Solutions

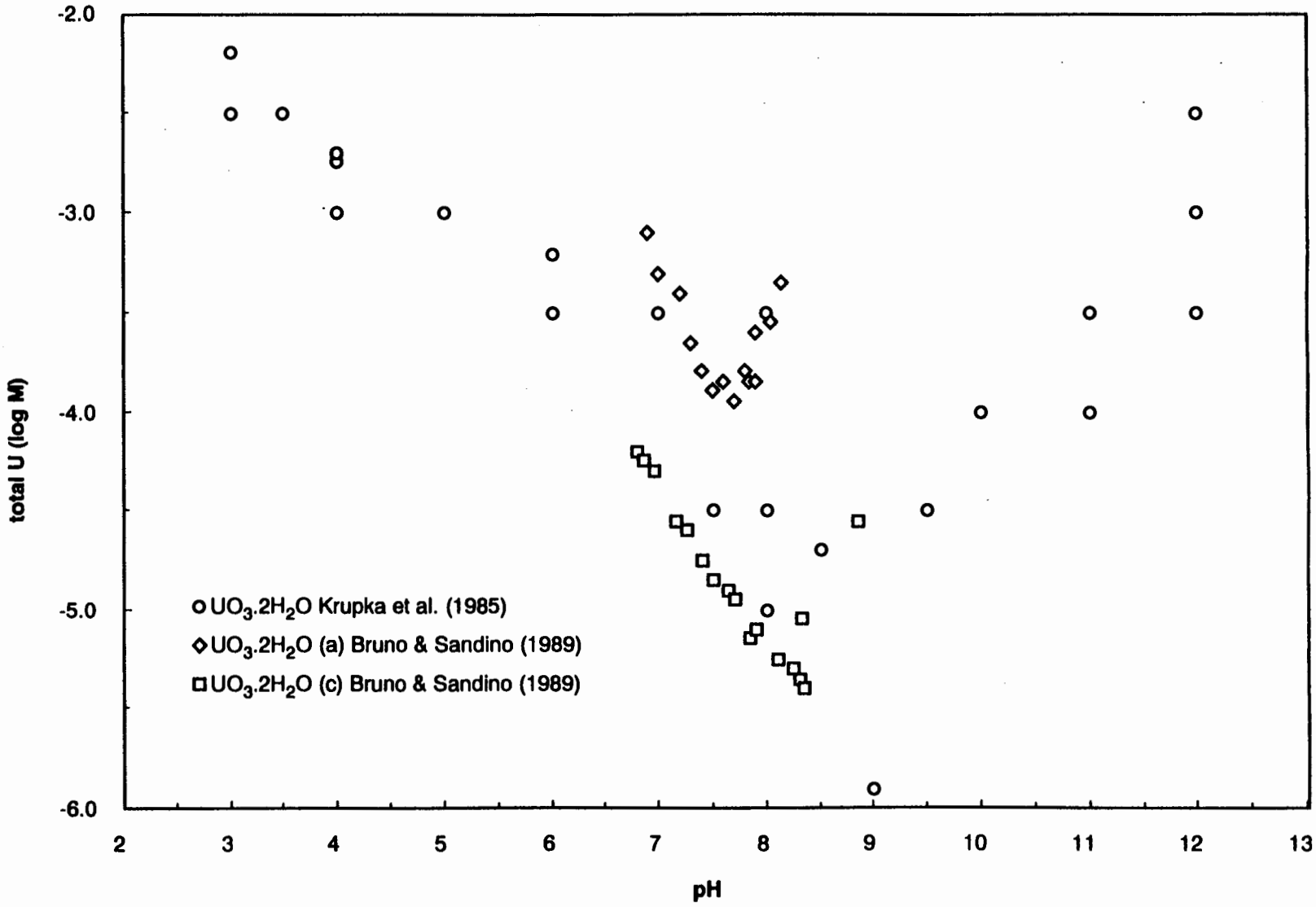


Figure G-3
UO_3:$2H_2O$ Solubility as a Function of pH for Dilute Solutions

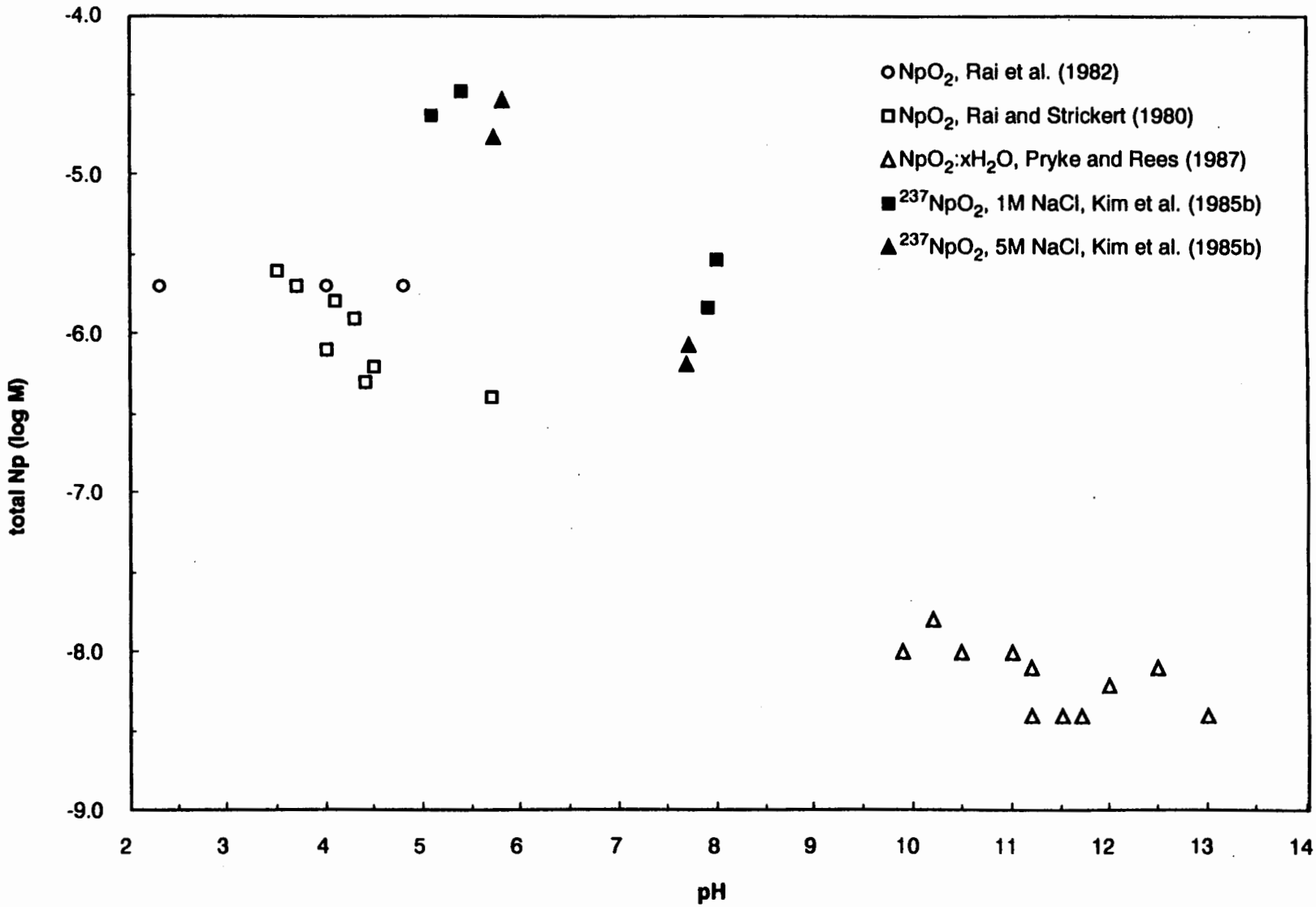


Figure G-4
NpO_2 Solubility as a Function of pH for Dilute, Saline, and Brine Solutions

Results for Np (V) solubility studies are plotted on Figure G-5. Ewart et al. (1985) investigated the solubility of NpO_2OH in cement-equilibrated water. Results for this study illustrate a rapid decrease in the Np concentration from about -5 to -9.5 log M between a pH of 9 to 13. Solubility studies on NpO_2OH in $NaClO_4$ and NaCl solutions were conducted by Kim et al. (1985b) at 20 to 25°C. Results for NpO_2OH in 1M $NaClO_4$ indicate a decrease in the Np concentration from -2 to -6 log M over the pH interval 6 to 11, followed by increasing Np concentration over the pH interval of 11 to 13. The solubility of NpO_2OH in 1M and 5M NaCl solutions is about 2.5 orders of magnitude lower at a pH of about 6.5, relative to the 1M $NaClO_4$ study. This suggests that Np (V) may be reduced to Np (IV) in the NaCl solutions, resulting in solubility control by NpO_2 rather than NpO_2OH. Additional solubility studies by Neck et al. (1992) with NpO_2OH in dilute solution and 1M and 3M $NaClO_4$ solutions indicate decreasing Np concentrations as pH increases from about 7 to 11.5 followed by a rise in the Np concentration as pH increase to 14. In comparing the dilute and 3M brine results of Neck et al. (1992), it is of interest that the 3M results indicate NpO_2OH solubility is about an order of magnitude lower in the brine relative to the dilute solution, which is in contrast to results presented on Figure G-4 for NpO_2.

5.0 PLUTONIUM

Plutonium displays the most complex behavior of the five actinides of interest because of the four (III, IV, V, and VI) possible valence states. In a reducing environment, the solubility-controlling phases are probably $Pu(OH)_3$, $PuO_2 \bullet xH_2O$, PuO_2, or $Pu(OH)_4$. Pu may be controlled in an oxidizing environment by $PuO_2(OH)_2$.

Figure G-6 summarizes Pu (III) solubility data. Rai et al. (1987) measured the Pu concentrations in deionized water and Permian Basin brines at 23°C in contact with amorphous $^{239}Pu(OH)_3$. Results for runs with deionized water show a decrease in Pu concentration from about -3.5 to -10 log M as pH increases from 6 to 9, followed by a flat data trend between pH 9 and 13 that indicates a Pu concentration of about -9.5 log M. A similar trend is observed for Pu concentration in Permian Basin brine, although the Pu concentration appears slightly greater above a pH of 7 relative to the deionized water runs. Based on the measured pH value for the Permian Basin brines, the solubility of $^{239}Pu(OH)_3$ does not appear to be affected greatly by changes in ionic strength of the solutions. However, Felmy et al. (1989) presented the preliminary data of Rai et al. (1987) with pH values of the Permian Basin brines recalculated to account for the difference in liquid junction potential between the solutions and standards. The recalculated pH values were one to two pH units greater than the measured values, which shifts the $^{239}Pu(OH)_3$ sample points in Figure G-6 to the right and suggests the amorphous hydroxide is two to three orders of magnitude more soluble in the brines at the recalculated pH, relative to deionized water.

$Pu(OH)_4$ solubility data for dilute solutions and a NaCl saturated brine are given on Figure G-7. Ewart et al. (1985) investigated the solubility of $Pu(OH)_4$ in cement-equilibrated water over the pH interval of 7 to 13. Their results show a decrease in Pu concentration from about -5.5 to -10.5 as pH increases to 12. Rai et al. (1980) presented results on the solubility of amorphous $^{239}Pu(OH)_4$ at 25°C that show Pu concentration decreases from about -4.5 to -7.5 log M as pH increases from 3 to 8. Flambard et al. (1986) conducted experiments on the solubility of $Pu(OH)_4$ in H_2O saturated with NaCl at 23°C over a pH interval of 1 to 10. Their limited data set show no significant difference in solubility relative to data sets obtained with dilute solutions at a pH of about 5. However, the comparison of the data sets at pH 10 indicates that the Pu concentration

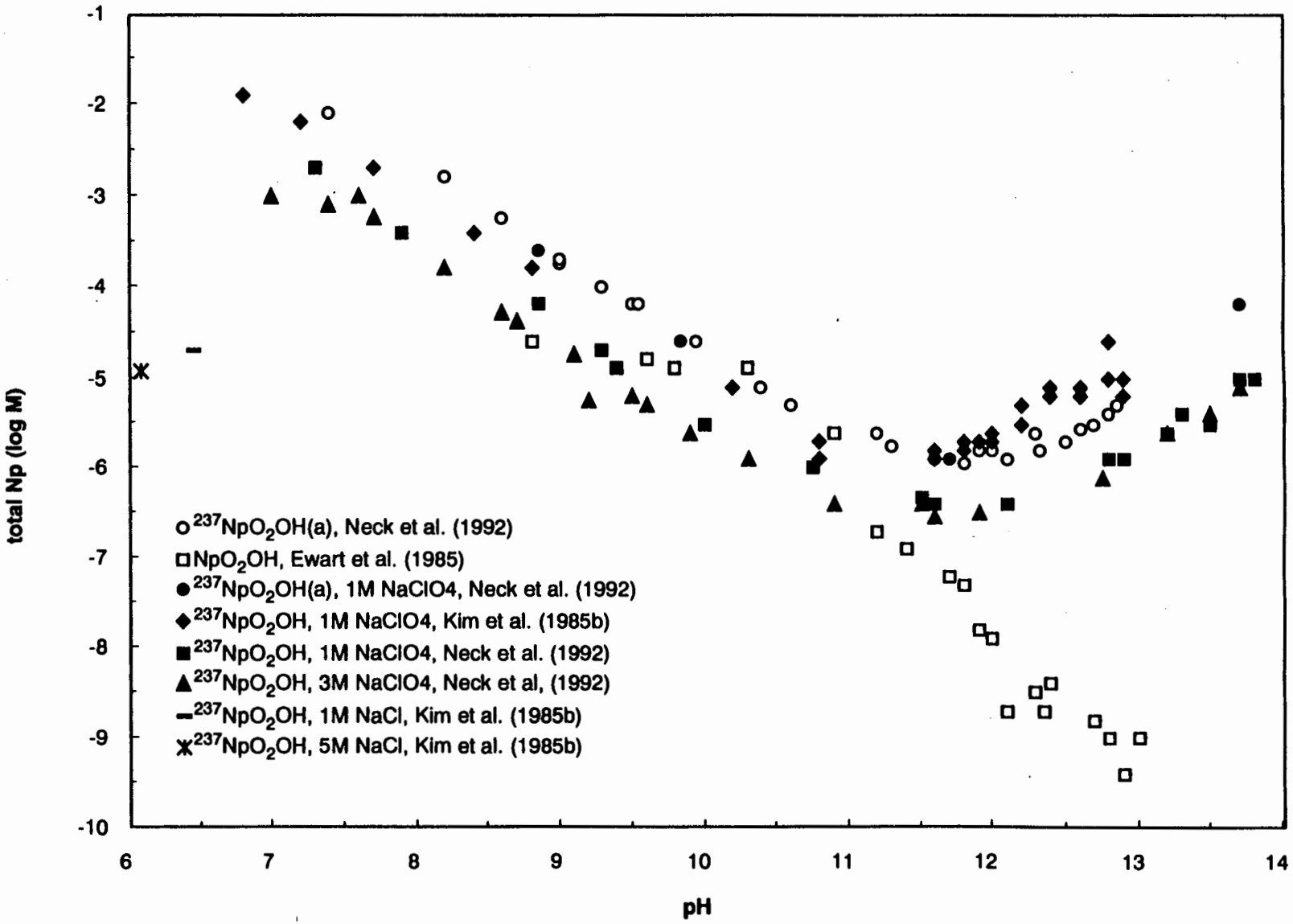


Figure G-5
NpO_2OH Solubility as a Function of pH for Dilute, Saline, and Brine Solutions

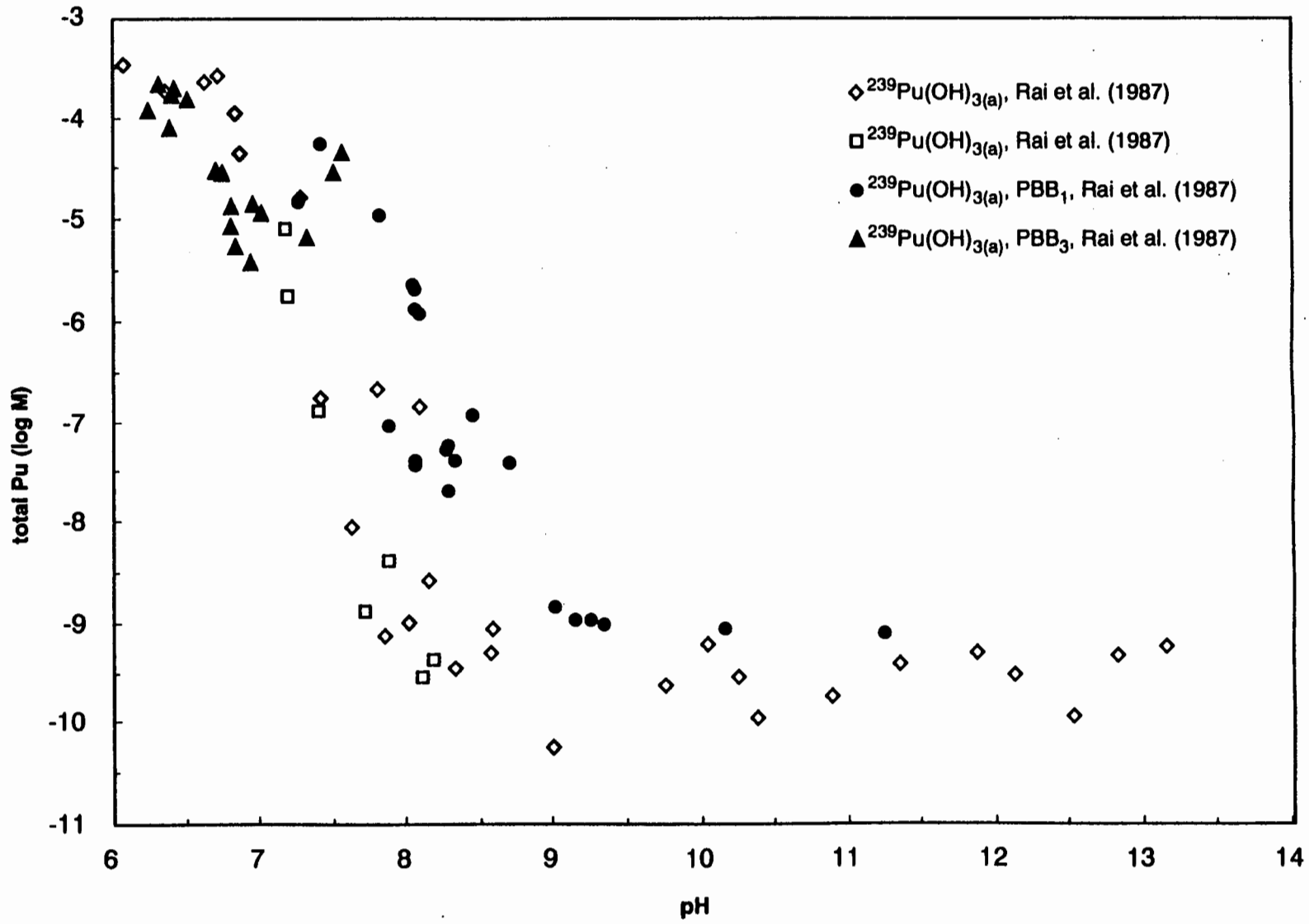


Figure G-6
Amorphous $^{239}Pu(OH)_3$ Solubility as a Function of pH for Dilute Brine and Solutions

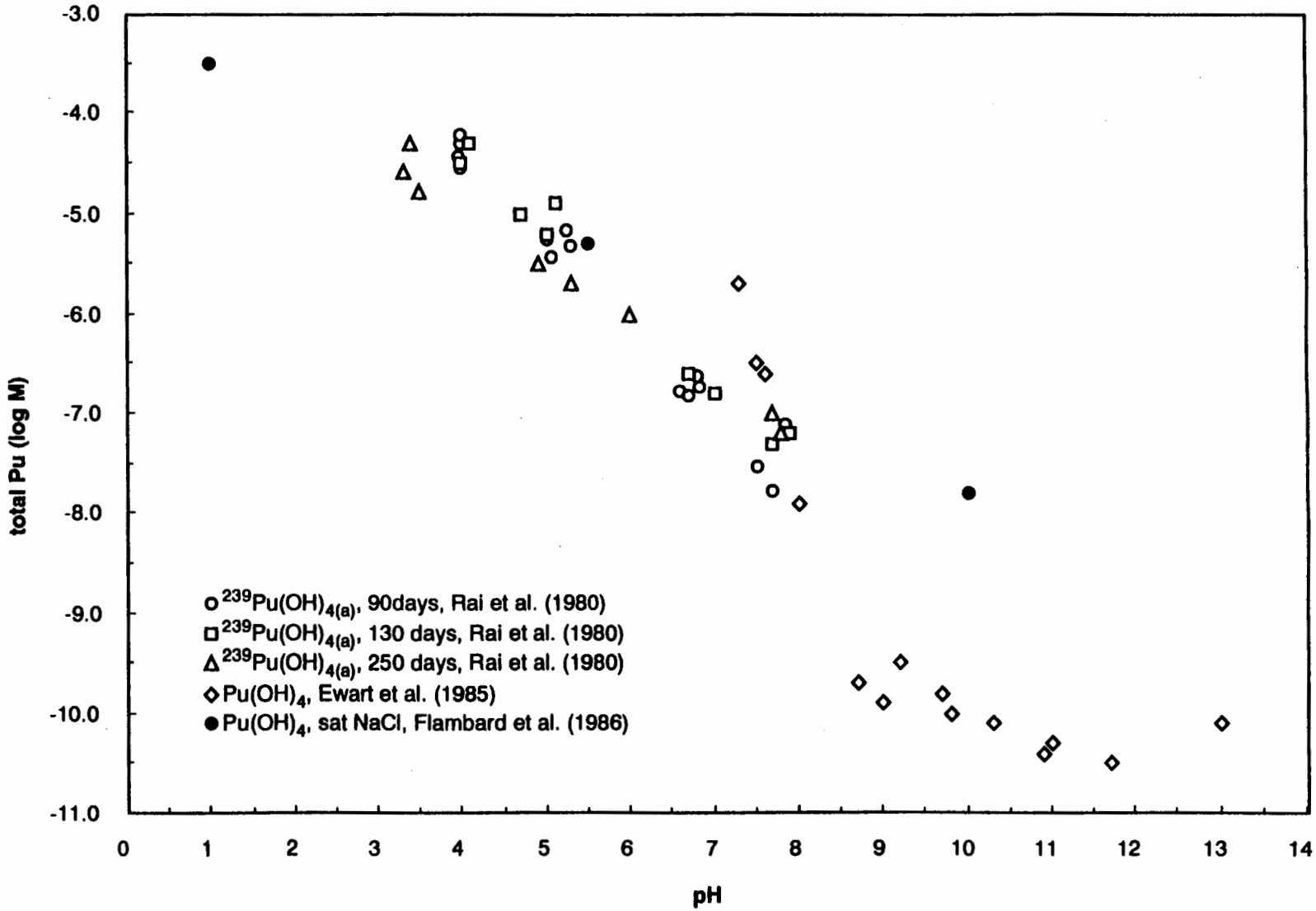


Figure G-7
Amorphous $Pu(OH)_4$ Solubility as a Function of pH for Dilute and Brine Solutions

is about two orders of magnitude greater in the brine relative to the dilute solution used by Ewart et al. (1985).

Figure G-8 summarizes solubility studies carried out by Kim et al. (1985a) and Kim et al. (1985b) with $^{238}PuO_2$ in dilute solutions and NaCl brines. The solubility of $^{238}PuO_2$ in a 0.1M NaCl solution decreases sharply from -5.5 to -7 log M over the pH interval of about 3 to 3.5, followed by an apparent increase in Pu concentration to about -6 log M as the pH rises to 5.5. Data points for the 3M and 5M NaCl brines indicate an increase in Pu concentration as pH increases. These observed trends are the opposite of most actinide solubility trends, which show decreasing actinide concentrations with increasing pH. Kim et al. (1985a) attributed the enhanced solubility to radiolysis effects and colloid formation.

Solubility data for $^{239}PuO_2$ are summarized on Figure G-9. The data reported by Rai et al. (1980) on $^{239}PuO_2$ solubility in dilute solutions shows a decrease in Pu concentration from approximately -5 to -9 log M as pH increases from about 3 to 8. Solubility data reported by Kim et al. (1985b) for $^{239}PuO_2$ follow a decreasing trend that is parallel to the data of Rai et al. (1980) but at Pu concentrations that are one to two orders of magnitude lower over the pH interval of 4 to 6.5. The large difference in the solubility of $^{239}PuO_2$ obtained by these two independent studies may be due to variation in the degree of crystallinity of the $^{239}PuO_2$ solid used in the experiments. Additional solubility studies with $^{239}PuO_2$ were carried out by Kim et al. (1985b) using 5M NaCl solutions, and these data plot below the dilute solution data obtained by Kim et al. (1985b) between pH 3.5 and 5 but then converge around a pH of 7.

Data on the solubility of $PuO_2 \bullet xH_2O$ and $^{238}PuO_2(OH)_2$ in dilute solutions are summarized on Figure G-10. Pryke and Rees (1987) examined the solubility of $PuO_2 \bullet xH_2O$ in cement-equilibrated solutions adjusted to selected pH values with HCl. Their data show a sharp decrease in Pu concentration from about -6 to -10 log M as pH increases from 7 to 9, followed by a shallow decrease as pH rises to 12. Solubility data for Pu (VI) was investigated by Kim et al. (1985b) using $^{238}PuO_2(OH)_2$. The data of Kim et al. (1985b) indicate a decrease in the Pu concentration from about -4 to -8.5 as the pH increases from about 5.5 to 10. Above a pH of 10, the solubility trend for $^{238}PuO_2(OH)_2$ shows a slight increase in Pu concentration.

6.0 AMERICIUM

Americium can be present in the natural environment in the III, IV, and V valence states. The valence state with the largest stability field is the III state.

Figure G-11 summarizes data on the solubility of $Am(OH)_3$. Rai et al. (1983) investigated the solubility of amorphous $^{241}Am(OH)_3$ in dilute solutions adjusted with HCl or NaOH to set pH, and the solubility of amorphous $^{243}Am(OH)_3$ in a pure H_2O solution that had pH adjusted with HCl or tetrapropyl NH_4OH. These data sets indicate a decrease in Am concentration from approximately -4 to -10 log M as the pH increases from about 7 to 10. Above a pH of 10, the trend of the plotted solubility points is essentially flat, and the Am concentration is maintained at around -10 log M.

Kim et al (1985b) examined the solubility of $Am(OH)_3$ in a 0.1M $NaClO_4$ solution and their data follow a trend similar to the data of Rai et al. (1983), but for a given pH the solubility data of

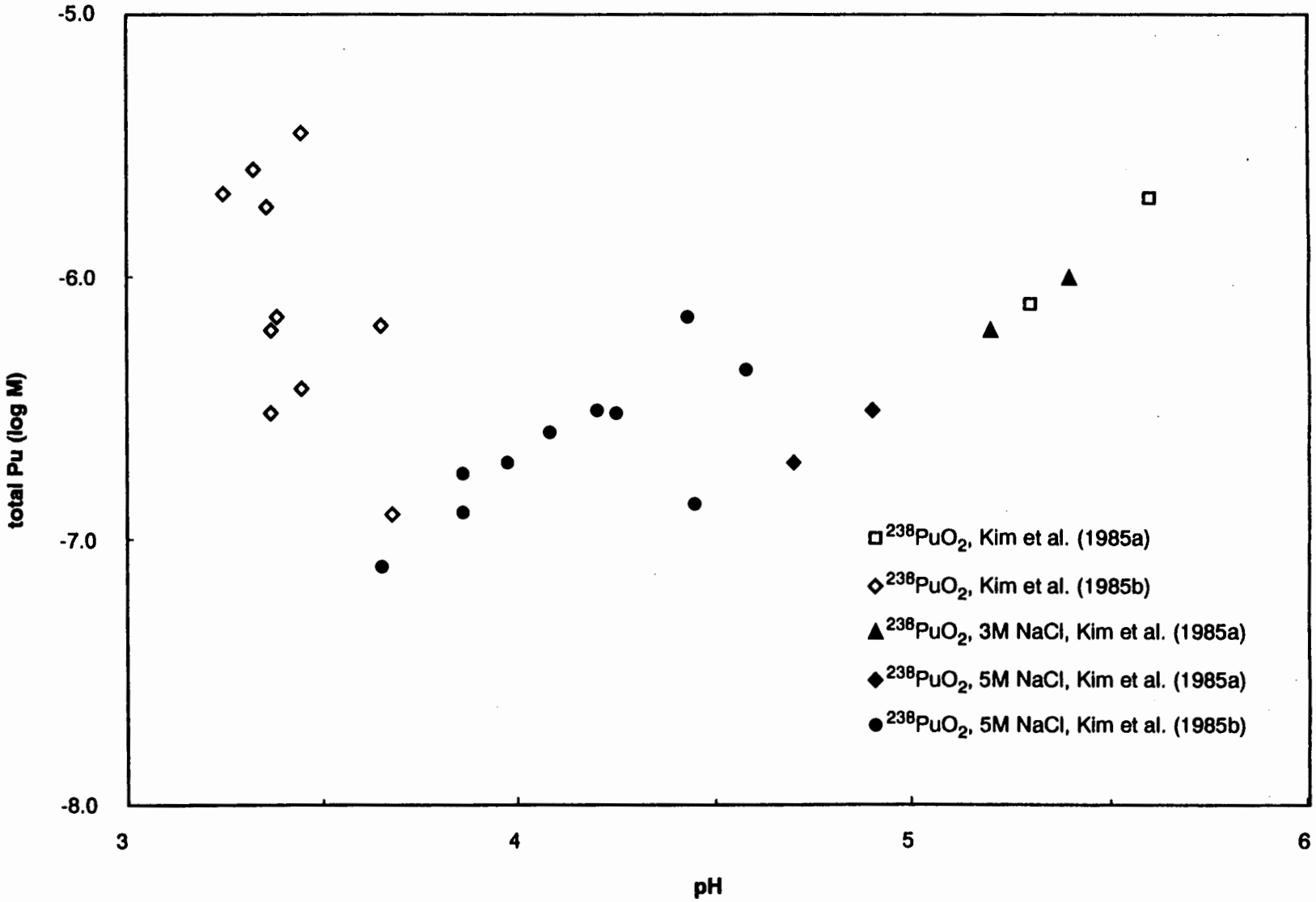


Figure G-8
$^{238}PuO_2$ Solubility as a Function of pH for Dilute and Brine Solutions

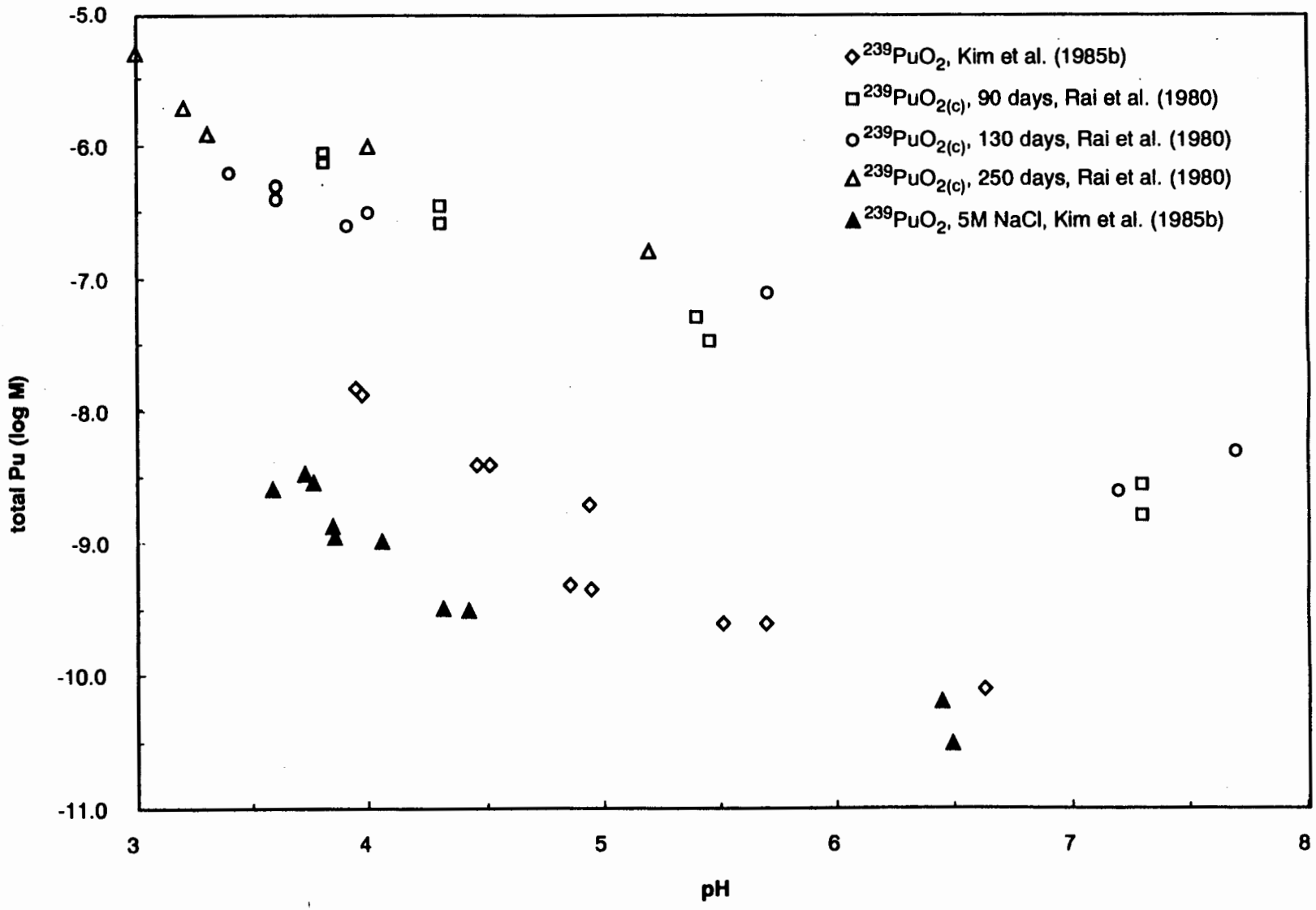


Figure G-9
$^{239}PuO_2$ Solubility as a Function of pH for Dilute and Brine Solutions

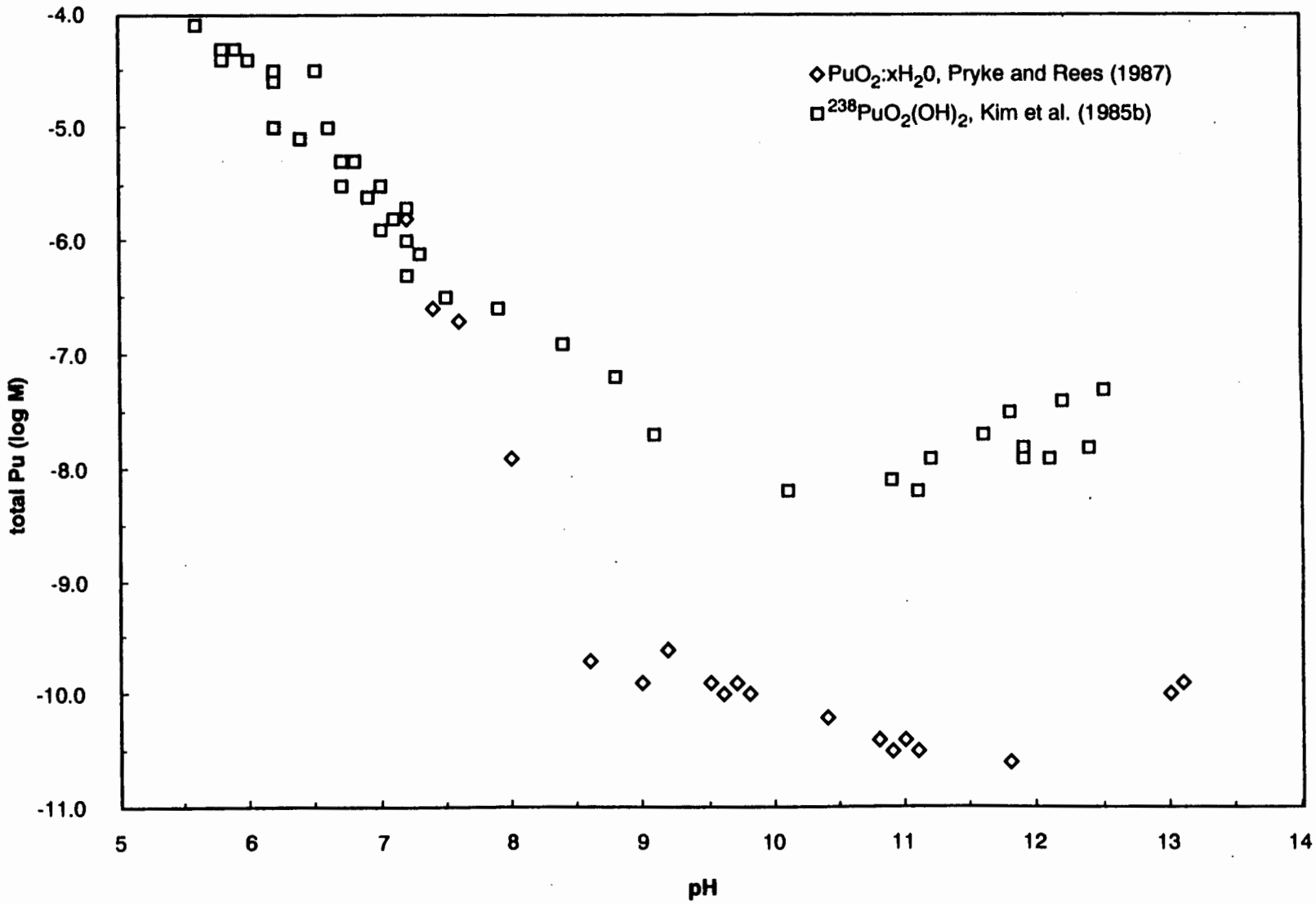


Figure G-10
$PuO_2 \cdot x\ H_2O$ and $PuO_2\ (OH)_2$ Solubilities as a Function of pH for Dilute Solutions

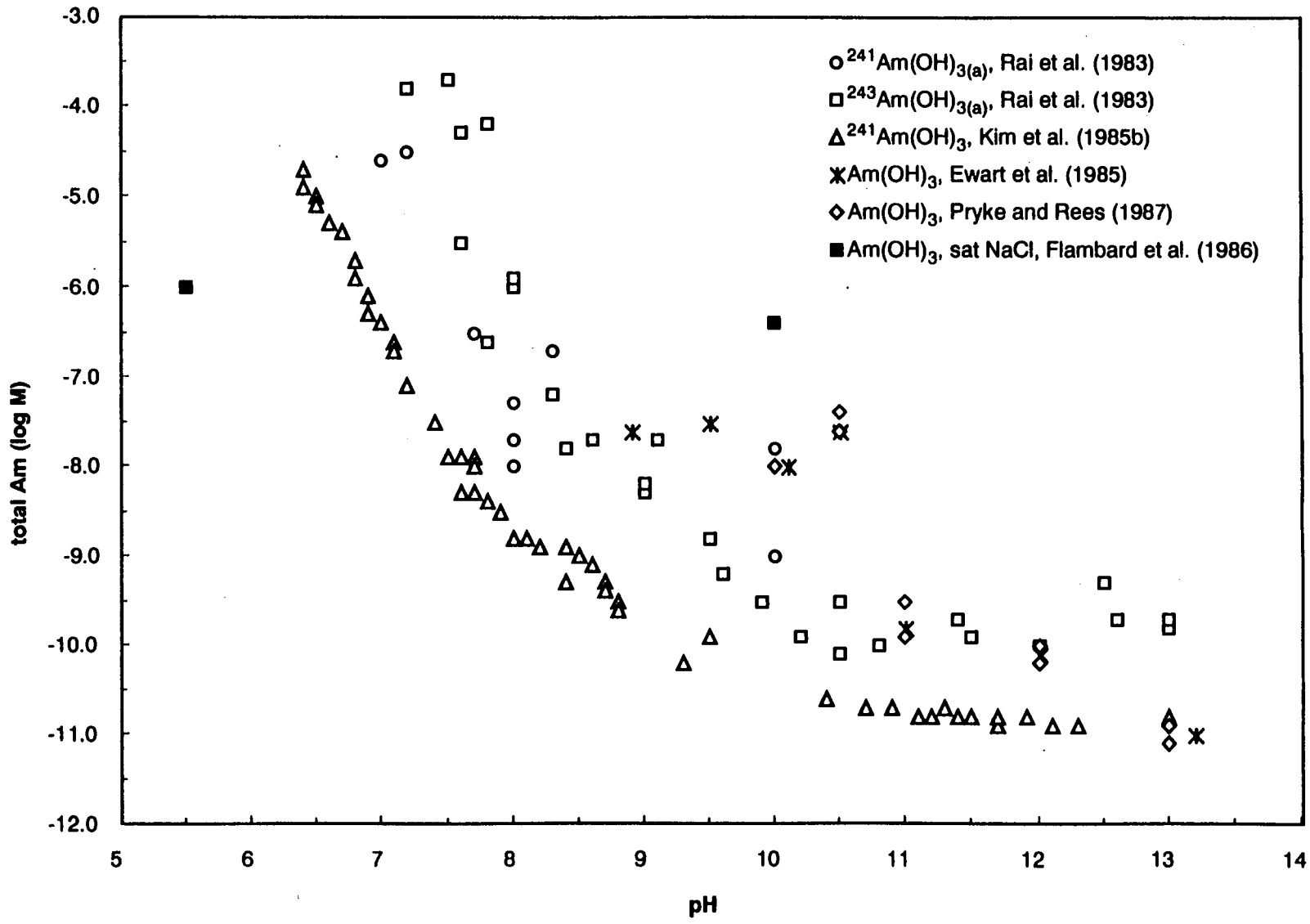


Figure G-11
$Am(OH)_3$ Solubility as a Function of pH for Dilute and Brine Solutions

Kim et al. (1985b) are about 0.5 to 1 order of magnitude lower (Figure G-11). This may indicate that the hydroxide used by Kim et al. (1985b) was aged to a microcrystalline form, relative to the amorphous form used by Rai et al. (1983).

Ewart et al. (1985) investigated the solubility of $Am(OH)_3$ in cement-equilibrated solutions and their results show an abrupt decrease in the Am concentration from about -8 to -10 log M between a pH of 10.5 to 11 (Figure G-11). The data of Pryke and Rees (1987) were also obtained with cement-equilibrated solutions and their results closely follow the trend of data reported by Ewart et al. (1985).

Flambard et al. (1986) reported limited data on the solubility of $Am(OH)_3$ in a saturated NaCl solution (Figure G-11). Their two data points on Figure G-11 suggest a slight decrease in solubility as pH increases from 5.5 to 10. Based on their data point at a pH of 10, the solubility of $Am(OH)_3$ may be 1.5 to 3 orders of magnitude greater in saturated NaCl brines relative to dilute solutions.

Figure G-12 summarizes solubility data for the Am (IV) and Am (V) solids AmO_2, AmO_2OH, and $AmOHCO_3$. Kim et al. (1985b) reported limited data on AmO_2 in 0.5 and 5M NaCl solutions over the pH range of 3.5 to 5. The overlap of data point at a pH near 4 suggests that ionic strength does not have a strong effect on the solubility of AmO_2 in this pH interval. Kim et al. (1985b) also looked at the solubility of AmO_2OH in 5M NaCl solution, and their results indicate a decrease in Am concentration from about -4 to -8 over the pH interval of 8 to 13.

Solubility studies on amorphous $AmOHCO_3$ carried out by Pryke and Rees (1987) show a decrease in Am concentration from about -4.5 to -7.5 as pH increases from 7 to 9.5 (Figure G-12). Similar studies carried out by Felmy et al. (1990) indicate significantly lower Am concentration of -8 to -8.5 log M over the pH range of 7 to 9, due to the aging of their precipitates to crystalline $AmOHCO_3$. The convergence of these independent data sets at a pH near 9.5 is due to the instability of $AmOHCO_3$ above a pH of 9.5 as $Am(OH)_3$ becomes the stable phase.

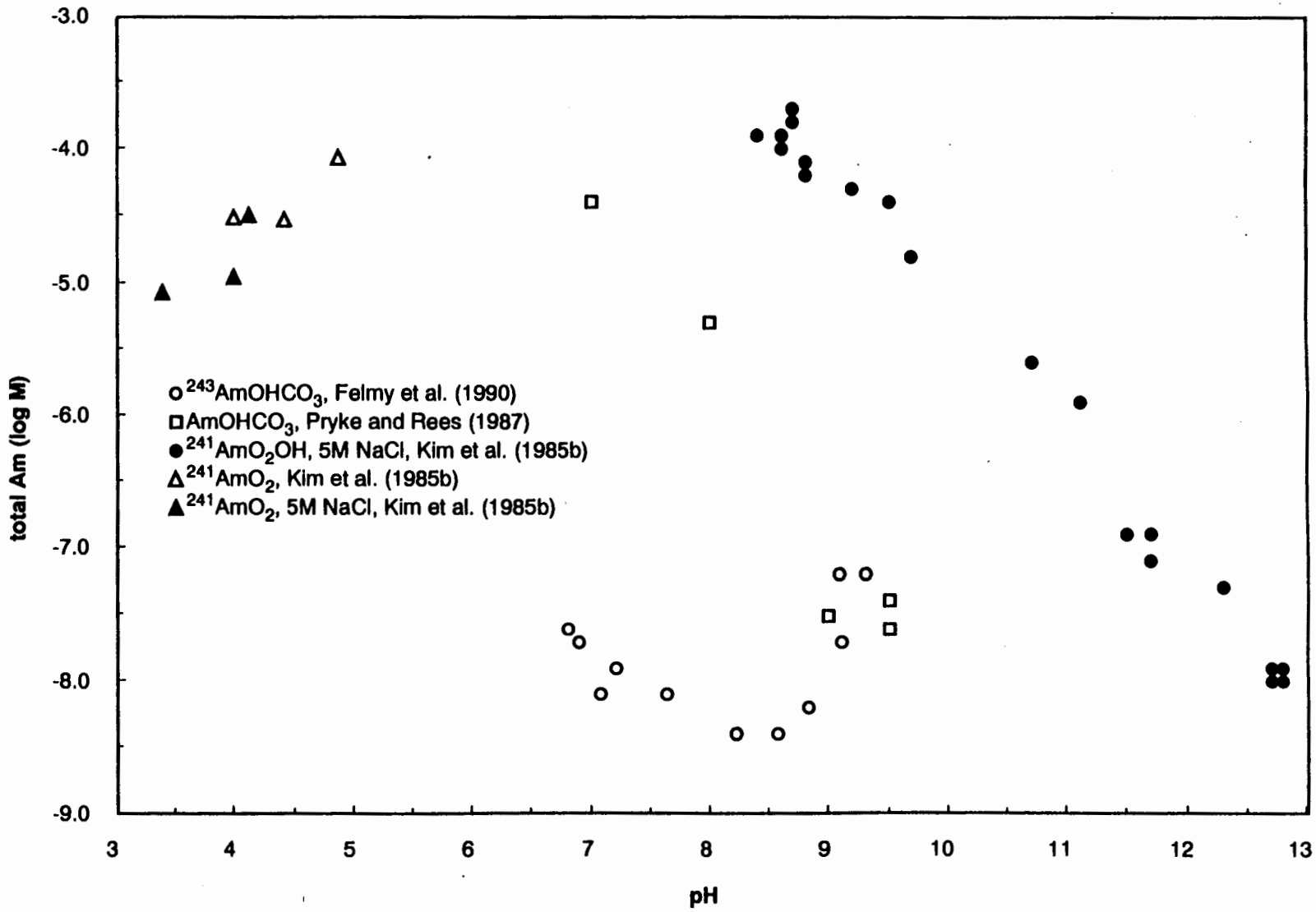


Figure G-12
$AmOHCO_3$, AmO_2OH, and AmO_2 Solubilities as a Function of pH for Dilute and Brine Solutions

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APPENDIX G
ACTINIDE SOLUBILITY DATA BASE
ATTACHMENT 1

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APPENDIX G
ATTACHMENT #1

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Am	amorphous 241am(oh)3	h2o+1.5E-3Mcacl2 + hcl or naoh to adjust pH	dilute	7	-4.6	oversaturation	7	air atm	22	Rai et al., 1983	1,2,6
				8	-6						
				10	-7.8						
Am	amorphous 241am(oh)3	h2o+1.5E-3Mcacl2 + hcl or naoh to adjust pH	dilute	7.7	-6.5	undersaturation	4	air atm	22	Rai et al., 1983	1,2,6,8
				7.2	-4.5		7				
				8.3	-6.7		7				
				10	-9		7				
				8	-7.3		11				
				8	-7.7		14				
				8	-8		26-28				
Am	amorphous 243am(oh)3	h2o + hcl or tetrapropyl nh4oh to adjust pH	dilute	7.8	-4.2	oversaturation	7	ar+n2 atm	22	Rai et al., 1983	1,2
				7.8	-6.6						
				8.3	-7.2						
				9.1	-7.7						
Am	amorphous 243am(oh)3	h2o + hcl or tetrapropyl nh4oh to adjust pH	dilute	7.5	-3.7	undersaturation	3	ar+n2 atm	22	Rai et al., 1983	1,2
				8	-6		3				
				9	-8.3		3				
				9.6	-9.2		3				
				10.2	-9.9		3				
				10.8	-10		3				
				11.5	-9.9		3				
				12	-10		3				
				13	-9.8		3				
				7.6	-4.3		7				
				8	-5.9		7				
				8.6	-7.7		7				
				9	-8.2		7				
				9.5	-8.8		7				
				9.9	-9.5		7				
				10.5	-10.1		7				
				11.5	-9.9		7				
				12.6	-9.7		7				
				13	-9.7		7				
				7.2	-3.8		23				
				7.6	-5.5		23				
				8.4	-7.8		23				
				10.5	-9.5		23				
				11.4	-9.7		23				
				12	-10		23				
				12.5	-9.3		23				
Am	241am(oh)3	h2o + 0.1M naclo4	dilute	6.4	-4.7	undersaturation	NA	ar atm	25	Kim et al., 1985b	1,17
				6.4	-4.9						
				6.5	-5						
				6.5	-5.1						
				6.6	-5.3						
				6.7	-5.4						
				6.8	-5.7						
				6.8	-5.9						
				6.9	-6.1						
				6.9	-6.3						
				7	-6.4						
				7.1	-6.6						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Am	241am(oh)3	h2o + 0.1M naclo4	dilute	7.1	-6.7	undersaturation	NA	ar atm	25	Kim et al., 1985b	1,17
				7.2	-7.1						
				7.4	-7.5						
				7.5	-7.9						
				7.6	-7.9						
				7.7	-7.9						
				7.7	-8						
				7.6	-8.3						
				7.7	-8.3						
				7.8	-8.4						
				7.9	-8.5						
				8	-8.8						
				8.1	-8.8						
				8.2	-8.9						
				8.4	-8.9						
				8.4	-9.3						
				8.5	-9						
				8.6	-9.1						
				8.7	-9.3						
				8.7	-9.4						
				8.8	-9.5						
				8.8	-9.6						
				9.3	-10.2						
				9.5	-9.9						
				10.4	-10.6						
				10.7	-10.7						
				10.9	-10.7						
				11.1	-10.8						
				11.1	-10.8						
				11.2	-10.8						
				11.3	-10.7						
				11.4	-10.8						
				11.5	-10.8						
				11.7	-10.9						
				11.7	-10.8						
				11.9	-10.8						
				12.1	-10.9						
				12.3	-10.9						
				13	-10.8						
Am	crystalline am(oh)3	h2o + 0.1M naclo4	dilute	7	-4.3	calculated	NA	ar atm	25	Silva, 1984	1
				8	-7						
				9	-8.2						
				10	-8.2						
Am	am(oh)3	h2o saturated with nacl	brine	1	>-2.8	undersaturation	NA	NA	25	Flambard et al., 1986	4,10
				5.5	-6						
				10	-6.4						
Am	am(oh)3	cement-equilibrated water + hcl or naoh	dilute	8.9	-7.6	oversaturation	0.02	200	NA	Ewart et al., 1985	1,16
				9.5	-7.5						
				10.1	-8						
				10.5	-7.6						
				11	-9.8						
				12	-10.1						
				13.2	-11						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Am	am(oh)3	deionized water equilibrated with crushed cement, composition(M): ca+2=1E-2; na+=5E-5; mg+2=5E-6; cl-=2E-3; so4-2=3E-3; co3-2=3E-5; pH=12; pH adjusted with hcl or naoh. I = 0.04 M	dilute	10	-8	oversaturation	0.02	200 mV in n2 atm at pH = 12	ambient	Pryke and Rees, 1987	1, 21
				10.5	-7.4						
				10.5	-7.6						
				11	-9.5						
				11	-9.9						
				12	-10						
				12	-10.2						
				13	-10.9						
				13	-11.1						
Am	243amco3 (SB)	h2o + 0.01 M nahco3	dilute	6.8	-7.6	oversaturation	66	10-3 atm CO2 in Ar	ambient	Felmy et al., 1990.	1,2
				6.89	-7.7						
				7.08	-8.1						
				7.21	-7.9						
				7.63	-8.1						
				8.22	-6.4						
				8.57	-8.4						
				8.83	-8.2						
				9.09	-7.2						
				9.11	-7.7						
				9.3	-7.2						
Am	crystalline amohco3	h2o + 0.1M naclo4 + E-3.5atm co2	dilute	6	-4.5	calculated	NA	ar+co2 atm	25	Silva, 1984	1
				7	-7.3						
				8	-9.1						
				8.5	-9.3						
				9	-9.1						
				10	-8.2						
Am	crystalline amohco3	h2o + 0.1M naclo4 + 2E-3M co3	dilute	6	-6.3	calculated	NA	ar+co2 atm	25	Silva, 1984	1
				7	-8						
				8	-9.1						
				9	-9.7						
				10	-9.3						
Am	amohco3	deionized water equilibrated with crushed cement, composition(M): ca+2=1E-2; na+=5E-5; mg+2=5E-6; cl-=2E-3; so4-2=3E-3; co3-2=3E-5; pH=12; pH adjusted with hcl or naoh. I = 0.04 M	dilute	7	-4.4	oversaturation	0.02	200 mV in n2 atm at pH = 12	ambient	Pryke and Rees, 1987	1, 21
				8	-5.3						
				9	-7.5						
				9.5	-7.4						
				9.5	-7.6						
Am	241amo2oh	h2o + 5M nacl	brine	8.4	-3.9	undersaturated	NA	ar atm	25	Kim et al., 1985b	1,17
				8.6	-3.9						
				6.6	-4						
				8.7	-3.7						
				8.7	-3.8						
				8.8	-4.1						
				8.8	-4.2						
				9.2	-4.3						
				9.5	-4.4						
				9.7	-4.8						
				10.7	-5.6						
				11.1	-5.9						
				11.5	-6.9						

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ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Am	241amo2	h2o + 0.1M nacl	dilute	11.7	-6.9	undersaturated	160	ar atm	22	Kim et al., 1985b	4,20
				11.7	-7.1						
				12.3	-7.3						
				12.7	-7.9						
				12.7	-8						
				12.8	-7.9						
				12.8	-8						
				4	-4.51						
				4.42	-4.53						
				4.88	-4.06						
Am	241amo2	h2o + 5M nacl	brine	3.39	-5.08	undersaturated	160	ar atm	22	Kim et al., 1985b	4,20
				4.12	-4.49						
				3.99	-4.95						
Am	243am-doped PNL 76-68 glass	nacl brine, WIPP brine B	brine	NA	-8.72	undersaturation	2	13.8MPa ar	150	Westsik et al., 1983	1,12,13,14
					-9.19		4				
					-8.65		8				
					-8.94		16				
					-8.99		32				
Am	ILW solidified with bitumen	h2o sat w/ca(oh)2,fe(oh)2,nacl,tbp,dbp,edta,cit&ox	brine	NA	-9.64	undersaturation	41	NA	NA	Marx and Keiling, 1989	4,18
Cm	244cm-doped PNL 76-68 glass	nacl brine, WIPP brine B	brine	NA	-10.03	undersaturation	2	13.8MPa ar	150	Westsik et al., 1983	1,12,13,14
					-9.99		8				
					-10		16				
					-10.47		32				
Np	npo2:xh2o	deionized water equilibrated with crushed cement, composition(M): ca+2=1E-2; na+=5E-5; mg+2=5E-6; cl-=2E-3; so4-2=3E-3; co3-2=3E-5; pH=12; pH adjusted with hcl or naoh. I = 0.04 M	dilute	9.9	-8	oversaturation	1	-400 mV in in n2 atm at pH = 12	ambient	Pryke and Rees, 1987	1, 21
				10.2	-7.8						
				10.5	-8						
				11	-8						
				11.2	-8.1						
				11.2	-8.4						
				11.5	-8.4						
				11.7	-8.4						
				12	-8.2						
				12.5	-8.1						
				13	-8.4						
Np	237np-doped PNL 76-68 glass	nacl brine, WIPP brine B	brine	NA	-6.17	undersaturation	2	13.8MPa ar	150	Westsik et al., 1983	1,12,13,14
					-6		4				
					-5.96		8				
					-6.11		16				
					-6.11		32				
Np	237np-doped PNL 76-68 glass	h2o+1.5E-3Mcacl2+E-3Mquinhydrone + hcl or naoh	dilute	6.8	-6.7	undersaturation	5	296	25	Rai et al., 1982	1,2
				6	-6.7		5	343			
				5.2	-6.3		5	391			
				3.9	-6.3		5	467			
				2.8	-5.8		5	533			
				6.5	-6.3		41	314			
				4.8	-6.1		41	414			
				3.8	-5.6		41	473			
				6.4	-6		67-83	320			
				5.3	-6		67-83	385			
				4.3	-5.7		67-83	444			
				5.8	-5.7		288-302	355			

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ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Np	237np-doped PNL 76-68 glass	h2o+1.5E-3Mcacl2+E-3Mquinhydrone + hcl or naoh	dilute	4.4	-5.4	undersaturation	288-302	438	25	Rai et al., 1982	1,2
Np	237np-doped PNL 76-68 glass	h2o+1.5E-3Mcacl2+E-3Mquinhydrone + hcl or naoh	dilute	3	-5.4	undersaturation	NA	NA	NA	Rai and Strickert, 1980	1,5
				3.2	-5.5						
				4.1	-6.1						
				4.8	-6.1						
				6.3	-6.7						
				6.7	-6.8						
				6.8	-6.8						
				6.9	-6.7						
Np	237npo2	h2o+1.5E-3Mcacl2+E-3Mquinhydrone + hcl or naoh	dilute	4.8	-5.7	undersaturation	54	414	25	Rai et al., 1982	1,5
				4	-5.7			462			
				2.3	-5.7			562			
Np	237npo2	h2o+1.5E-3Mcacl2+E-3Mquinhydrone + hcl or naoh	dilute	3.5	-5.6	undersaturation	NA	NA	NA	Rai and Strickert, 1980	1,5
				3.7	-5.7						
				4	-6.1						
				4.1	-5.8						
				4.3	-5.9						
				4.4	-6.3						
				4.5	-6.2						
				5.7	-6.4						
Np	237npo2	h2o + 1M nacl	saline	5.4	-4.48	undersaturation	118	ar atm	25	Kim et al., 1985b	4,20
				5.08	-4.63		118				
				7.91	-5.83		72				
				7.99	-5.54		72				
Np	237npo2	h2o + 5M nacl	brine	5.82	-4.53	undersaturation	118	ar atm	25	Kim et al., 1985b	4,20
				5.72	-4.77		118				
				7.69	-6.19		72				
				7.72	-6.07		72				
Np	npo2oh	cement-equilibrated water + hcl or naoh	dilute	8.8	-4.6	oversaturation	1	200	NA	Ewart et al., 1985	1,16
				9.6	-4.8						
				9.8	-4.9						
				10.3	-4.9						
				10.9	-5.6						
				11.2	-6.7						
				11.4	-6.9						
				11.7	-7.2						
				11.8	-7.3						
				11.9	-7.8						
				12	-7.9						
				12.1	-8.7						
				12.3	-8.5						
				12.4	-8.7						
				12.4	-8.4						
				12.7	-8.8						
				12.8	-9						
				12.9	-9.4						
				13	-9						
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2 and nacl	brine	NA	-3.62	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2, nacl and TBP	brine	NA	-5.26	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2, nacl and DBP	brine	NA	-5.26	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2, nacl and EDTA	brine	NA	-3.76	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2, nacl and citrate	brine	NA	-3.14	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Np	npo2oh	h2o sat w/ ca(oh)2, fe(oh)2, nacl and oxalate	brine	NA	-3	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Np	237npo2oh	h2o + 1M naclo4	saline	6.8	-1.9	undersaturation	NA	ar atm	25	Kim et al., 1985b	1,17
				7.2	-2.2						
				7.7	-2.7						
				8.4	-3.4						
				8.8	-3.8						
				10.2	-5.1						
				10.8	-5.7						
				10.8	-5.9						
				11.6	-5.8						
				11.6	-5.9						
				11.8	-5.8						
				11.8	-5.7						
				11.9	-5.7						
				12	-5.6						
				12	-5.7						
				12.2	-5.3						
				12.2	-5.5						
				12.4	-5.1						
				12.4	-5.2						
				12.6	-5.1						
				12.6	-5.2						
				12.8	-5						
				12.9	-5						
				12.9	-5.2						
				12.8	-4.6						
Np	237npo2oh	h2o + 1M nacl	saline	6.44	-4.7	undersaturation	14	ar atm	22	Kim et al., 1985b	4,19
Np	237npo2oh	h2o + 5M nacl	brine	6.07	-4.91	undersaturation	14	ar atm	22	Kim et al., 1985b	4,19
Np	237npo2oh (amorphous)	np237,10-30mg dissolved as npo2clo4 in 0.1M naclo4	dilute	7.4	-2.1	oversaturation	1-2	ar atm	25	Neck et al., 1992	1,20
				8.2	-2.8						
				8.6	-3.25						
				9	-3.75						
				9	-3.7						
				9.3	-4						
				9.5	-4.2						
				9.55	-4.2						
				9.95	-4.6						
				10.4	-5.1						
				10.6	-5.3						
				11.2	-5.6						
				11.3	-5.75						
				11.6	-5.9						
				11.8	-5.95						
				11.9	-5.8						
				12	-5.8						
				12.1	-5.9						
				12.3	-5.6						
				12.3	-5.8						
				12.5	-5.7						
				12.6	-5.55						
				12.7	-5.5						
				12.8	-5.4						
				12.9	-5.3						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Np	237npo2oh (amorphous)	np237,10-30mg dissolved as npo2clo4 in 1.0M naclo4	saline	8.85	-3.6	oversaturation	1-2	ar atm	25	Neck et al., 1992	1,20
				9.85	-4.6						
				11.7	-5.9						
				13.7	-4.2						
Np	237npo2oh (aged, grey-white ppt)	np237,10-30mg dissolved as npo2clo4 in 1.0M naclo4	saline	7.3	-2.7	oversaturation	14-28	ar atm	25	Neck et al., 1992	1,20
				7.9	-3.4						
				8.85	-4.2						
				9.3	-4.7						
				9.4	-4.9						
				10	-5.5						
				10.8	-6						
				11.5	-6.33						
				11.6	-6.4						
				12.1	-6.4						
				12.8	-5.9						
				12.9	-5.9						
				13.2	-5.6						
				13.3	-5.4						
				13.5	-5.5						
				13.7	-5						
				13.8	-5						
Np	237npo2oh (aged, grey-white ppt)	np237,10-30mg dissolved as npo2clo4 in 3.0M naclo4	brine	7	-3	oversaturation	14-28	ar atm	25	Neck et al., 1992	1,20
				7.4	-3.1						
				7.6	-3						
				7.7	-3.25						
				8.2	-3.8						
				8.6	-4.3						
				8.7	-4.4						
				9.1	-4.75						
				9.2	-5.25						
				9.5	-5.2						
				9.6	-5.3						
				9.9	-5.6						
				10.3	-5.9						
				10.9	-6.4						
				11.5	-6.4						
				11.6	-6.55						
				11.9	-6.5						
				12.8	-6.1						
				13.2	-5.6						
				13.5	-5.4						
				13.7	-5.1						
Pu	puo2:xh2o	deionized water equilibrated with crushed cement,	dilute	7.2	-5.8	oversaturation	0.02	-300 mV in	ambient	Pryke and Rees, 1987	1, 21
		composition(M): ca+2=1E-2; na+=5E-5; mg+2=5E-6;		7.4	-6.6			ar/5%h2 atm			
		cl-=2E-3; so4-2=3E-3; co3-2=3E-5; pH=12; pH adjusted with		7.6	-6.7			at pH = 12			
		hcl or naoh. I = 0.04 M		8	-7.9						
				8.6	-9.7						
				9	-9.9						
				9.2	-9.6						
				9.5	-9.9						
				9.6	-10						

APPENDIX G
ATTACHMENT #1

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	puo2:xh2o	deionized water equilibrated with crushed cement, composition(M): ca+2=1E-2; na+=5E-5; mg+2=5E-6; cl-=2E-3; so4-2=3E-3; co3-2=3E-5; pH=12; pH adjusted with hcl or naoh. I = 0.04 M	dilute	9.7	-9.9	oversaturation	0.02	-300 mV in ar/5%h2 atm at pH = 12	ambient	Pryke and Rees, 1987	1, 21
				9.8	-10						
				10.4	-10.2						
				10.8	-10.4						
				10.9	-10.5						
				11	-10.4						
				11.1	-10.5						
				11.8	-10.6						
				13	-10						
				13.1	-9.9						
Pu	239pu-doped PNL 76-68 glass	nacl brine, WIPP brine B	brine	NA	-8.74	undersaturation	2	13.8MPa ar	150	Westsik et al., 1983	1,12,13,14
				NA	-8.67		4				
				NA	-8.49		8				
				NA	-8.65		16				
				NA	-8.67		32				
Pu	amorphous 239pu(oh)3	h2o + hcl or naoh to adjust pH	dilute	7.85	-9.11	oversaturation	8	-402	23	Rai et al., 1987	2,4
				8.14	-8.57		12	-359			
				10	-9.21		12	-417			
				8.57	-9.05		12	-339			
				8.32	-9.45		13	-283			
				8.99	-10.23		13	-331			
				10.2	-9.54		13	-219			
				10.4	-9.95		13	-233			
				10.9	-9.73		13	-207			
				11.4	-9.39		13	-262			
				11.9	-9.29		13	-293			
				12.1	-9.52		13	-266			
				12.5	-9.93		13	-190			
				12.8	-9.31		13	-237			
				13.2	-9.23		13	-281			
				7.63	-8.04		22	-340			
				6.08	-3.46		2	-185			
				6.36	-3.73		2	-256			
				7.41	-6.74		2	-335			
				6.71	-3.56		2	-310			
				6.86	-4.33		7	-294			
				6.83	-3.95		7	-355			
				6.62	-3.64		8	-278			
				7.8	-6.66		8	-352			
				8.08	-6.83		8	-311			
				7.28	-4.77		8	-282			
				9.76	-9.61		10	-194			
				8.01	-8.99		24	-238			
				8.56	-9.28		24	-295			
Pu	amorphous 239pu(oh)3	h2o + hcl or naoh to adjust pH	dilute	7.19	-5.75	undersaturation	21	-273	23	Rai et al., 1987	2,4
				7.18	-5.09		21	-314			
				7.4	-6.88		21	-310			
				7.71	-8.88		21	-305			
				7.87	-8.37		21	-322			
				8.18	-9.36		21	-330			
				8.1	-9.54		21	-327			
Pu	amorphous 239pu(oh)3	PBB1 + hcl or naoh to adjust pH	brine	7.26	-4.83	oversaturation	3	-267	23	Rai et al., 1987	2,4
				8.06	-5.87		3	-288			

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	amorphous 239pu(oh)3	PBB1 + hcl or naoh to adjust pH	brine	7.41	-4.24	oversaturation	7	-293	23	Rai et al., 1987	2,4
				7.82	-4.94		7	-310			
				8.04	-5.64		7	-310			
				8.05	-5.68		7	-289			
				8.45	-6.93		7	-297			
				8.7	-7.4		7	-301			
				9.01	-8.84		7	-311			
				9.34	-9		7	-334			
				10.2	-9.06		7	-324			
				11.3	-9.09		7	-387			
				8.08	-5.91		14	-269			
Pu	amorphous 239pu(oh)3	PBB1 + hcl or naoh to adjust pH	brine	7.88	-7.03	undersaturation	13	-284	23	Rai et al., 1987	2,4
				8.28	-7.23		19	-268			
				8.28	-7.68		19	-252			
				8.06	-7.39		19	-230			
				8.05	-7.42		19	-218			
				8.32	-7.38		19	-276			
				8.26	-7.28		19	-251			
				9.15	-8.97		19	-338			
				9.25	-8.97		19	-362			
Pu	amorphous 239pu(oh)3	PBB3 + hcl or naoh to adjust pH	brine	6.32	-3.66	oversaturation	3	-244	23	Rai et al., 1987	2,4,11
				6.5	-3.82		3	-262			
				6.41	-3.7		8	-287			
				6.4	-3.77		8	-287			
				6.24	-3.93		8	-285			
				6.95	-4.85		8	-333			
				7.01	-4.92		8	-330			
				7.5	-4.53		8	-355			
				7.57	-4.34		8	-357			
				6.39	-4.09		10	-256			
				6.8	-4.87		10	-286			
Pu	amorphous 239pu(oh)3	PBB3 + hcl or naoh to adjust pH	brine	6.7	-4.52	undersaturation	14	-301	23	Rai et al., 1987	2,4,11
				6.75	-4.53			-302			
				6.81	-5.05			-367			
				6.83	-5.25			-303			
				6.94	-5.42			-303			
				7.32	-5.18			-307			
Pu	238puo2	h2o+0.1Mnacl pH adjusted with hno3?	dilute	5.3	-6.1	undersaturation	120	air atm	25	Kim et al., 1985a	1,7
				5.6	-5.7		210				
Pu	238puo2	h2o+0.5Mnacl pH adjusted with hno3?	saline	5.7	-5.7	undersaturation	120	air atm	25	Kim et al., 1985a	1,7
				5.9	-5.5		210				
Pu	238puo2	h2o+1Mnacl pH adjusted with hno3?	saline	5.4	-5.9	undersaturation	120	air atm	25	Kim et al., 1985a	1,7
				5.7	-5.7		210				
Pu	238puo2	h2o+3Mnacl pH adjusted with hno3?	brine	5.2	-6.2	undersaturation	120	air atm	25	Kim et al., 1985a	1,7
				5.4	-6		210				
Pu	238puo2	h2o+5Mnacl pH adjusted with hno3?	brine	4.7	-6.7	undersaturation	120	air atm	25	Kim et al., 1985a	1,7
				4.9	-6.5		210				
Pu	238puo2	h2o+ 0.1Mnacl	dilute	3.25	-5.68	undersaturation	120	ar atm	21	Kim et al., 1985b	4,20
				3.37	-6.51						
				3.45	-5.45						
				3.45	-6.42						
				3.37	-6.2						
				3.33	-5.59						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	238puo2	h2o+ 0.1Mnacl	dilute	3.68	-6.9	undersaturation	120	ar atm	21	Kim et al., 1985b	4,20
				3.36	-5.73						
				3.65	-6.18						
				3.39	-6.15						
Pu	238puo2	h2o+5Mnacl	brine	3.65	-7.1	undersaturation	120	ar atm	22	Kim et al., 1985b	4,20
				3.86	-6.74						
				3.97	-6.7						
				4.2	-6.5						
				3.86	-6.89						
				4.25	-6.51						
				4.43	-6.15						
				4.08	-6.59						
				4.58	-6.35						
				4.45	-6.86						
Pu	239puo2	h2o+0.1Mnacl pH adjusted with hno3?	dilute	2.48	-8.8	undersaturation	250	air atm	25	Kim et al., 1985a	1,7
Pu	239puo2	h2o+0.5Mnacl pH adjusted with hno3?	saline	2.8	-8.5	undersaturation	250	air atm	25	Kim et al., 1985a	1,7
Pu	239puo2	h2o+1Mnacl pH adjusted with hno3?	saline	2.7	-8.7	undersaturation	250	air atm	25	Kim et al., 1985a	1,7
Pu	239puo2	h2o+3Mnacl pH adjusted with hno3?	brine	2.2	-9.2	undersaturation	250	air atm	25	Kim et al., 1985a	1,7
Pu	239puo2	h2o+5Mnacl pH adjusted with hno3?	brine	2.2	-9.2	undersaturation	250	air atm	25	Kim et al., 1985a	1,7
Pu	239puo2	h2o+ 0.1M nacl	dilute	3.97	-7.88	undersaturation	250	ar atm	21	Kim et al., 1985b	4,20
				3.94	-7.83						
				4.51	-8.4						
				4.46	-8.4						
				4.94	-8.7						
				5.69	-9.6						
				4.85	-9.3						
				4.95	-9.34						
				6.63	-10.1						
				5.51	-9.6						
Pu	239puo2	h2o+5Mnacl	brine	3.76	-8.53	undersaturation	250	ar atm	24	Kim et al., 1985b	4,20
				3.72	-8.47						
				3.85	-8.95						
				3.58	-8.58						
				4.31	-9.48						
				4.42	-9.51						
				4.05	-8.98						
				3.84	-8.86						
				6.49	-10.5						
				6.44	-10.2						
Pu	239puo2(c)	h2o+0.0015Mcacl2	dilute	3.8	-6.12	undersaturation	90	air atm	25	Rai et al., 1980	4,5
				3.8	-6.05						
				4.3	-6.57						
				4.3	-6.44						
				5.4	-7.29						
				5.45	-7.47						
				7.3	-8.55						
				7.3	-8.78						
Pu	239puo2(c)	h2o+0.0015Mcacl2	dilute	3.4	-6.2	undersaturation	130	air atm	25	Rai et al., 1980	1,15
				3.6	-6.3						
				3.6	-6.4						
				4	-6.5						
				3.9	-6.6						
				5.7	-7.1						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	239puo2(c)	h2o+0.0015Mcacl2	dilute	7.2	-8.6	undersaturation	130	air atm	25	Rai et al., 1980	1,15
				7.7	-8.3						
Pu	239puo2(c)	h2o+0.0015Mcacl2	dilute	3	-5.3	undersaturation	250	air atm	25	Rai et al., 1980	1,15
				3.2	-5.7						
				3.3	-5.9						
				4	-6						
				5.2	-6.8						
Pu	freshly declad spent fuel	PBB1	brine	NA	-8.5	undersaturation	5	air atm	25-30	Gray, 1986	1,2,9
				NA	-8.6		5				
				NA	-8.7		14				
				NA	-8.8		14				
				NA	-8.8		28				
				NA	-8.9		28				
				NA	-8.8		60				
				NA	-8.9		60				
Pu	previously declad spent fuel	PBB1	brine	NA	-7.4	undersaturation	5	air atm	25-30	Gray, 1986	1,2,9
				NA	-8		5				
				NA	-7.8		14				
				NA	-7.7		28				
				NA	-8.3		28				
				NA	-7.5		60				
				NA	-8.3		60				
				NA	-7.5		90				
				NA	-8.4		120				
				NA	-7.2		180				
				NA	-7.6		180				
Pu	ILW solidified with bitumen	h2o sat w/ca(oh)2,fe(oh)2,nacl,tbp,dbp,edta,cit&ox	brine	NA	-9.13	undersaturation	41	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2 and nacl	brine	NA	-7.6	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2, nacl and TBP	brine	NA	-7.8	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2, nacl and DBP	brine	NA	-6.8	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2, nacl and EDTA	brine	NA	-5	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2, nacl and citrate	brine	NA	-4.9	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated w/ ca(oh)2, fe(oh)2, nacl and oxalate	brine	NA	-6.4	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
Pu	pu(oh)4	h2o saturated with nacl	brine	1	-3.5	undersaturation	NA	NA	25	Flambard et al., 1986	4,10
				5.5	-5.3						
				10	-7.8						
Pu	239pu(oh)4(a)	h2o+0.0015Mcacl2	dilute	3.95	-4.44	undersaturation	90	air atm	25	Rai et al., 1980	4,15
				4	-4.54						
				4	-4.31						
				4	-4.22						
				5	-5.25						
				5.05	-5.44						
				5.25	-5.17						
				5.3	-5.31						
				6.6	-6.77						
				6.7	-6.83						
				6.8	-6.63						
				6.83	-6.73						
				7.5	-7.54						
				7.7	-7.77						
				7.85	-7.11						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	239pu(oh)4(a)	h2o+0.0015Mcacl2	dilute	4	-4.5	undersaturation	130	air atm	25	Rai et al., 1980	1,15
				4.1	-4.3						
				4.7	-5						
				5	-5.2						
				5.1	-4.9						
				6.7	-6.6						
				7	-6.8						
				7.7	-7.3						
				7.9	-7.2						
Pu	239pu(oh)4(a)	h2o+0.0015Mcacl2	dilute	3.3	-4.6	undersaturation	250	air atm	25	Rai et al., 1980	1,15
				3.4	-4.3						
				3.5	-4.8						
				4.9	-5.5						
				5.3	-5.7						
				6	-6						
				7.7	-7						
				7.8	-7.2						
Pu	pu(oh)4	cement-equilibrated water + hcl or naoh	dilute	7.3	-5.7	oversaturation	0.02	-300	NA	Ewart et al., 1985	1,16
				7.5	-6.5						
				7.6	-6.6						
				8	-7.9						
				8.7	-9.7						
				9	-9.9						
				9.2	-9.5						
				9.7	-9.8						
				9.8	-10						
				10.3	-10.1						
				10.9	-10.4						
				11	-10.3						
				11.7	-10.5						
				13	-10.1						
Pu	pu(oh)4??	cement-equilibrated water + E-5M D-saccharic	dilute	12	-5.14	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M D-saccharic	dilute	12	-5.14	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-3M D-saccharic	dilute	12	-5.09	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M D-saccharic	dilute	12	-5.04	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-5M D-gluconic	dilute	12	-7.15	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M D-gluconic	dilute	12	-6.25	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-3M D-gluconic	dilute	12	-5.24	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M D-gluconic	dilute	12	-5.19	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-5M glutaric	dilute	12	-7.28	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M glutaric	dilute	12	-6.62	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-3M glutaric	dilute	12	-6.22	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M glutaric	dilute	12	-5.59	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-5M glyceric	dilute	12	-7.4	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M glyceric	dilute	12	-6.74	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-3M glyceric	dilute	12	-6.2	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M glyceric	dilute	12	-5.98	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-5M glycolic	dilute	12	-8.19	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M glycolic	dilute	12	-7.33	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-3M glycolic	dilute	12	-6.82	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M glycolic	dilute	12	-6.27	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-5M glyoxylic	dilute	12	-8.48	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-4M glyoxylic	dilute	12	-7.39	oversaturation	0.02	200	80	Cross et al., 1989	4,16

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Pu	pu(oh)4??	cement-equilibrated water + E-3M glyoxylic	dilute	12	-6.92	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	pu(oh)4??	cement-equilibrated water + E-2M glyoxylic	dilute	12	-6.59	oversaturation	0.02	200	80	Cross et al., 1989	4,16
Pu	238puo2(oh)2	h2O + 0.1M naclo4	dilute	5.6	-4.1	undersaturation	NA	ar atm	25	Kim et al., 1985b	1,17
				5.8	-4.3						
				5.8	-4.4						
				5.9	-4.3						
				6	-4.4						
				6.2	-4.5						
				6.2	-4.6						
				6.5	-4.5						
				6.2	-5						
				6.4	-5.1						
				6.6	-5						
				6.7	-5.3						
				6.7	-5.5						
				6.8	-5.3						
				6.9	-5.6						
				7	-5.5						
				7	-5.9						
				7.1	-5.8						
				7.2	-5.7						
				7.2	-6						
				7.2	-6.3						
				7.3	-6.1						
				7.5	-6.5						
				7.9	-6.6						
				8.4	-6.9						
				8.8	-7.2						
				9.1	-7.7						
				10.1	-8.2						
				10.9	-8.1						
				11.1	-8.2						
				11.2	-7.9						
				11.6	-7.7						
				11.8	-7.5						
				11.9	-7.8						
				11.9	-7.9						
				12.1	-7.9						
				12.2	-7.4						
				12.4	-7.8						
				12.5	-7.3						
Th	thorianite-tho2	h2o	dilute	2	-6	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				5-9	-14						
Th	thorianite-tho2	h2o+1ppm{c2o4(oxalate)	dilute	2	-5	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				4.5	-6						
				7-9	-14						
Th	thorianite-tho2	h2o+0.1ppm{EDTA	dilute	2-5	-6	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				8.5	-14						
Th	thorianite-tho2	h2o+0.2ppm{f	dilute	2	-5.5	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				5-7	-14						
Th	thorianite-tho2	h2o+0.1ppm{po4	dilute	2	-6	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				4	-9.5						
				7.5	-14						

APPENDIX G
ATTACHMENT #1

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Th	thorianite-tho2	h2o+100ppm{so4	dilute	2	-3.5	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				5-7.5	-14						
Th	thorianite-tho2	h2o+10ppm{cl+2.5ppm{no3+100ppm{so4+0.3ppm{f+0.1ppm {po4	dilute	2	-4	calculated	NA	NA	25	Langmuir and Herman, 1980	1
				4	-9.5						
				7-8.5	-14						
Th	hydrous thorium (IV) oxide	h2o + 0.6M KCl	saline	3.83	-2.19	undersaturation	7	ar atm	ambient	Felmy et al., 1991	2
				4.68	-4.17						
				5.42	-6.43						
				6.05	-9						
				6.44	-8.41						
				7.48	-8.68						
				8.03	-8.67						
Th	hydrous thorium (IV) oxide	h2o + 0.6M NaCl	saline	3.02	-2.15	undersaturation	7	ar atm	ambient	Felmy et al., 1991	2
				3.59	-2.16		7				
				4.09	-2.17		7				
				4.14	-2.19		7				
				4.81	-3.87		7				
				5.21	-5.73		7				
				5.59	-8.53		7				
				6.06	-7.97		7				
				6.58	-7.08		7				
				7.01	-7.36		7				
				7.34	-8.38		7				
				7.61	-8.3		7				
				8.26	-8.07		7				
				9.23	-9.09		7				
				9.74	-8.82		7				
				10.2	-8.95		7				
				2.87	-2.17		98				
				3.42	-2.18		98				
				3.86	-2.29		98				
				3.91	-2.28		98				
				4.38	-3.14		98				
				3.86	-2.77		98				
				3.77	-2.86		98				
				4.35	-3.21		98				
				6.69	-8.15		98				
				7.18	-8.12		98				
				7.5	-6.92		98				
				8.21	-5.92		98				
				9.08	-7.6		98				
				9.58	-7.97		98				
				10.04	-8.16		98				
Th	hydrous thorium (IV) oxide	h2o + 1.2M NaCl	saline	2.94	-2.16	undersaturation	7	ar atm	ambient	Felmy et al., 1991	2
				3.58	-2.16		7				
				4.1	-2.2		7				
				4.52	-3.09		7				
				4.79	-2.73		7				
				5.68	-7.69		7				
				5.83	-6.39		7				
				6.38	-8.9		7				
				6.76	-8.3		7				

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Th	hydrous thorium (IV) oxide	h2o + 1.2M NaCl	saline	7.16	-8.2	undersaturation	7	ar atm	ambient	Felmy et al., 1991	2
				7.63	-8.57		7				
				8.21	-8.83		7				
				8.64	-8.62		7				
				9.09	-8.8		7				
				9.52	-8.25		7				
				10.03	-7.1		7				
				2.67	-2.2		98				
				3.3	-2.19		98				
				3.76	-2.48		98				
				4.17	-3.16		98				
				4.37	-3.9		98				
				4.08	-2.83		98				
				3.99	-2.75		98				
				3.97	-4.13		98				
				5.91	-7.51		98				
				6.92	-7.46		98				
				7.47	-7.9		98				
				8.05	-7.8		98				
				8.44	-7.82		98				
				8.88	-7.38		98				
				9.3	-7.08		98				
				9.8	-6.14		98				
Th	hydrous thorium (IV) oxide	h2o + 3M NaCl	brine	3.36	-2.95	undersaturation	8	ar atm	ambient	Felmy et al., 1991	2
				4.27	-3.3		8				
				4.32	-3.33		8				
				4.52	-3.71		8				
				4.76	-4.09		8				
				4.96	-4.32		8				
				5	-5.13		8				
				5.58	-6.98		8				
				5.61	-6.39		8				
				5.81	-6.84		8				
				5.99	-6.94		8				
				6.12	-7.28		8				
				6.41	-7.61		8				
				6.42	-7.62		8				
				6.44	-7.89		8				
				8.27	-7.64		8				
				3.56	-2.17		122				
				3.87	-3.03		122				
				3.98	-3.61		122				
				3.95	-3.9		122				
				4.02	-3.94		122				
				4.32	-4.1		122				
				7.12	-6.47		122				
				7.77	-6.44		122				
				7.82	-6.43		122				
				7.93	-6.37		122				
				8.82	-7.84		122				
				9	-7.92		122				
				9.47	-7.2		122				
				9.58	-7.66		122				

APPENDIX G
ATTACHMENT #1

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
Th	hydrous thorium (IV) oxide	h2o + 3M NaCl	brine	10.06	-7.83	undersaturation	122	ar atm	ambient	Felmy et al., 1991	2
				10.1	-7.45		122				
				3.61	-2.09		372				
				3.69	-3.56		372				
				3.81	-2.87		372				
				4.05	-3.28		372				
				4.36	-3.77		372				
				4.56	-4.4		372				
				4.65	-4.79		372				
				7.89	-6.85		372				
				7.98	-6.66		372				
				8.2	-6.96		372				
				8.11	-7.09		372				
				8.04	-7.73		372				
				8.05	-7.73		372				
				8.24	-6.83		372				
				8.48	-7.68		372				
U	233u-doped PNL 76-68 glass	nacl brine, WIPP brine B	brine	NA	-6	undersaturation	2	13.8MPa ar	150	Westsik et al., 1983	1,12,13,14
				NA	-6.13		4				
				NA	-6.1		8				
				NA	-6.03		16				
				NA	-6.15		32				
U	uraninite-uo2	h2o	dilute	2	-10.2	calculated	NA	<200	25	Langmuir, 1978	1
				4	-13			<200			
				9	-8.8			<-100			
U	uraninite-uo2	h2o+E-2atmPco2	dilute	8	-10	calculated	NA	<-200	25	Langmuir, 1978	1
				8	-4			0			
U	uraninite-uo2	h2o+E-3.5atmPco2	dilute	8	-10	calculated	NA	<-100	25	Langmuir, 1978	1
				8	-4			100			
U	uraninite-uo2	h2o+E-2atmPco2+E-6M(po4	dilute	6	-12	calculated	NA	<-100	25	Langmuir, 1978	1
				6	-4			150			
U	uraninite-uo2	h2o+0.11125Mhcl	dilute	1.04	-6.717	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
				1.04	-7.022						
U	uraninite-uo2	h2o+1.51E-3Mhcl+0.098Mnacl	dilute	2.92	-8.452	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
				2.92	-8.733						
U	uraninite-uo2	h2o+1.22E-3Mhcl	dilute	2.93	-8.598	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
				2.93	-8.786						
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	5.03	-8.704	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
				5.03	-9.914						
U	uraninite-uo2	h2o+1.136E-3Mhcl	dilute	3.95	-9.695	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o	dilute	6.67	-9.463	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
				6.67	-10.015						
U	uraninite-uo2	h2o+0.01097Mhcl	dilute	2.01	-9.381	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+1.26E-3Mhcl	dilute	1.85	-9.377	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+0.01569Mnaoh+0.0866Mnacl	dilute	1.04	-9.583	undersaturation	NA	h2=50MPa	100	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+0.11125Mhcl	dilute	1.05	-6.875	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				1.05	-7.147						
				1.05	-7.259						
U	uraninite-uo2	h2o+1.51E-3Mhcl+0.098Mnacl	dilute	2.93	-8.479	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				2.93	-8.678						
U	uraninite-uo2	h2o+1.22E-3Mhcl	dilute	2.94	-8.57	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				2.94	-8.557						
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	5.02	-9.733	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	5.02	-9.914	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+1.136E-3Mhcl	dilute	3.95	-9.704	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				3.95	-9.733						
U	uraninite-uo2	h2o	dilute	5.89	-9.532	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				5.89	-9.474						
U	uraninite-uo2	h2o+0.01097Mhcl	dilute	2.01	-9.347	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				2.01	-9.263						
U	uraninite-uo2	h2o+1.26E-3Mhcl	dilute	1.86	-9.335	undersaturation	NA	h2=50MPa	150	Parks and Pohl, 1988	3,4
				1.86	-9.422						
U	uraninite-uo2	h2o+0.11125Mhcl	dilute	1.08	-7.075	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				1.08	-7.2						
				1.08	-7.45						
U	uraninite-uo2	h2o+1.51E-3Mhcl+0.098Mnacl	dilute	2.95	-8.507	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				2.95	-8.514						
U	uraninite-uo2	h2o+1.22E-3Mhcl	dilute	2.94	-8.256	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				2.94	-8.652						
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	5.01	-8.283	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				5.01	-9.714						
U	uraninite-uo2	h2o+1.136E-3Mhcl	dilute	3.95	-9.403	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				3.95	-9.551						
U	uraninite-uo2	h2o	dilute	5.64	-9.474	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				5.64	-9.598						
U	uraninite-uo2	h2o+0.01097Mhcl	dilute	2.02	-9.237	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				2.02	-9.598						
U	uraninite-uo2	h2o+1.26E-3Mhcl	dilute	1.87	-9.098	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				1.87	-9.335						
U	uraninite-uo2	h2o+1.00E-3Mhcl+0.0988Mnacl	dilute	3.43	-8.652	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				3.43	-8.468						
U	uraninite-uo2	h2o+0.0342Mhcl+0.0662Mnacl	dilute	1.6	-8.013	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				1.6	-8.021						
U	uraninite-uo2	h2o+3.07E-3Mhcl+0.0969Mnacl	dilute	2.64	-8.839	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+3.17E-4Mhcl+0.0992Mnacl	dilute	3.59	-9.034	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+0.0601Mhcl+0.0399Mnacl	dilute	2.35	-8.885	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				2.35	-9.175						
U	uraninite-uo2	h2o+0.0601Mhcl+0.0399Mnacl+1.23E-5uo2(no3)2	dilute	1.35	-8.067	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				1.35	-8.228						
U	uraninite-uo2	h2o+0.01569Mnaoh+0.0866Mnacl	dilute	9.3	-9.024	undersaturation	NA	h2=50MPa	200	Parks and Pohl, 1988	3,4
				9.3	-9.189						
U	uraninite-uo2	h2o+0.11125Mhcl	dilute	1.14	-7.132	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				1.14	-6.466						
				1.14	-7.117						
U	uraninite-uo2	h2o+1.51E-3Mhcl+0.098Mnacl	dilute	3.02	-8.437	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				3.02	-8.413						
U	uraninite-uo2	h2o+1.22E-3Mhcl	dilute	2.94	-8.305	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				2.94	-8.621						
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	5	-9.82	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				5	-9.644						
U	uraninite-uo2	h2o+1.136E-3Mhcl	dilute	3.95	-9.473	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o	dilute	5.55	-9.519	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+0.01097Mhcl	dilute	2.04	-8.917	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				2.04	-9.531						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
U	uraninite-uo2	h2o+1.26E-3Mhcl	dilute	1.89	-8.774	undersaturation	NA	h2=50MPa	250	Parks and Pohl, 1988	3,4
				1.89	-8.889						
U	uraninite-uo2	h2o+0.11125Mhcl	dilute	1.23	-6.096	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				1.23	-6.128						
				1.23	-6.056						
				1.23	-6.121						
U	uraninite-uo2	h2o+1.51E-3Mhcl+0.098Mnacl	dilute	3.12	-7.945	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				3.12	-8.089						
U	uraninite-uo2	h2o+1.22E-3Mhcl	dilute	2.95	-8.146	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
U	uraninite-uo2	h2o+9.366E-6Mhcl	dilute	4.99	-9.502	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				4.99	-9.502						
U	uraninite-uo2	h2o+1.136E-3Mhcl	dilute	3.96	-9.036	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				3.96	-9.82						
U	uraninite-uo2	h2o	dilute	5.57	-9.39	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				5.57	-9.403						
U	uraninite-uo2	h2o+0.01097Mhcl	dilute	2.07	-8.339	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				2.07	-9.297						
U	uraninite-uo2	h2o+1.26E-3Mhcl	dilute	1.93	-8.774	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				1.93	-8.652						
U	uraninite-uo2	h2o+1.00E-3Mhcl+0.0988Mnacl	dilute	3.59	-8.544	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				3.59	-8.479						
U	uraninite-uo2	h2o+0.0342Mhcl+0.0662Mnacl	dilute	1.75	-7.761	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				1.75	-7.88						
U	uraninite-uo2	h2o+3.07E-3Mhcl+0.0969Mnacl	dilute	2.8	-8.287	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				2.8	-8.532						
U	uraninite-uo2	h2o+3.17E-4Mhcl+0.0992Mnacl	dilute	3.76	-8.275	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				3.76	-8.977						
U	uraninite-uo2	h2o+0.0601Mhcl+0.0399Mnacl	dilute	2.51	-8.623	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				2.51	-8.531						
U	uraninite-uo2	h2o+0.0601Mhcl+0.0399Mnacl+1.23E-5uo2(no3)2	dilute	1.5	-7.191	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
				1.5	-7.464						
U	uraninite-uo2	h2o+0.01569Mnaoh+0.0866Mnacl	dilute	9.07	-9.387	undersaturation	NA	h2=50MPa	300	Parks and Pohl, 1988	3,4
U	uraninite-uo2	saturated NaCl solution	brine	6.2	-6.8	undersaturation	NA	air	75-90	Gray, 1986	1,2,9
				6.2	-7						
				6.3	-7.5						
				6.4	-7.9						
				6.4	-7.8						
				6.4	-7.8						
U	carnotite-k2(uo2)2(vo4)2	h2o+E-2atmPco2+E-3Mk+E-6M(v	dilute	3	-2.5	calculated	NA	NA	25	Langmuir, 1978	1
				6	-7.5			>100			
				8.5	-1			>50			
U	carnotite-k2(uo2)2(vo4)2	h2o+E-3.5atmPco2+E-3Mk+E-6M(v	dilute	3	-2.5	calculated	NA	NA	25	Langmuir, 1978	1
				7	-9			>100			
				9	-4			>50			
U	tyuyamunite-ca(uo2)2(vo4)2	h2o+E-2atmPco2+E-2.7Mca+E-6M(v	dilute	3	-2	calculated	NA	NA	25	Langmuir, 1978	1
				6	-7						
				8.5	-1						
U	tyuyamunite-ca(uo2)2(vo4)2	h2o+E-3.5atmPco2+E-2.7Mca+E-6M(v	dilute	3	-2	calculated	NA	NA	25	Langmuir, 1978	1
				7	-8						
				9	-3.5						
U	autunite-ca(uo2)2(po4)2	h2o+E-2atmPco2+E-2.7Mca+E-6M(po4	dilute	7	-4	calculated	NA	NA	25	Langmuir, 1978	1
				9.5	0						
U	autunite-ca(uo2)2(po4)2	h2o+E-3.5atmPco2+E-2.7Mca+E-6M(po4	dilute	7	-6	calculated	NA	NA	25	Langmuir, 1978	1

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
U	autunite-ca(uo2)2(po4)2	h2o+E-3.5atmPco2+E-2.7Mca+E-6M(po4	dilute	10	-0.5	calculated	NA	NA	25	Langmuir, 1978	1
U	k-autunite-k2(uo2)2(po4)2	h2o+E-2atmPco2+E-3Mk+E-6M(po4	dilute	6	-6	calculated	NA	NA	25	Langmuir, 1978	1
				9.5	0						
U	k-autunite-k2(uo2)2(po4)2	h2o+E-3.5atmPco2+E-3Mk+E-6M(po4	dilute	6	-7	calculated	NA	NA	25	Langmuir, 1978	1
				10	-1.5						
U	schoepite-uo3.2h2o(syn)	h2o + hclo4 or tetramethyl nh4oh to adjust pH	dilute	3.5	-2.5	oversaturation	9	ox	25	Krupka et al., 1985	1,2
				4	-3		9				
				6	-3.5		9				
				8	-4.5		9				
				11	-4		9				
				12	-3		9				
				3	-2.2		14-53				
				4	-2.7		14-53				
				5	-3		14-53				
				6	-3.2		14-53				
				7	-3.5		14-53				
				8	-3.5		14-53				
				10	-4		14-53				
				11	-3.5		14-53				
				12	-2.5		14-53				
U	schoepite-uo3.2h2o(syn)	h2o + hclo4 or tetramethyl nh4oh to adjust pH	dilute	4	-2.75	undersaturation	14	ox	25	Krupka et al., 1985	1,2
				8	-5		14				
				9	-5.9		14				
				11	-4		14				
				12	-3.5		14				
				3	-2.5		14-53				
				4	-2.7		14-53				
				5	-3		14-53				
				7.5	-4.5		14-53				
				8.5	-4.7		14-53				
				9.5	-4.5		14-53				
				11	-3.5		14-53				
				12	-3.5		14-53				
U	schoepite-uo3.2h2o(a)	h2o + 0.5M naclo4	dilute	6.9	-3.1	undersaturation	NA	n2 atm	25	Bruno and Sandino, 1989	1,17
				7	-3.3						
				7.2	-3.4						
				7.3	-3.65						
				7.4	-3.8						
				7.5	-3.9						
				7.6	-3.85						
				7.7	-3.95						
				7.8	-3.8						
				7.85	-3.85						
				7.9	-3.85						
				7.9	-3.6						
				8.05	-3.55						
				8.15	-3.35						
U	schoepite-uo3.2h2o(c)	h2o + 0.5M naclo4	dilute	6.8	-4.2	undersaturation	NA	n2 atm	25	Bruno and Sandino, 1989	1,17
				6.85	-4.25						
				6.95	-4.3						
				7.15	-4.55						
				7.25	-4.6						
				7.4	-4.75						

ACTINIDE	SOLID	SOLUTION COMPOSITION	SOLUTION DESCRIPTION	pH	SOLUBILITY (log M)	METHOD	EQtime (days)	Eh (mV) or atm	T (oC)	REFERENCE	NOTES
U	schoepite-uo3.2h2o(c)	h2o + 0.5M naclo4	dilute	7.5	-4.85	undersaturation	NA	n2 atm	25	Bruno and Sandino, 1989	1,17
				7.65	-4.9						
				7.7	-4.95						
				7.85	-5.15						
				7.9	-5.1						
				8.1	-5.25						
				8.25	-5.3						
				8.3	-5.35						
				8.35	-5.4						
				8.33	-5.05						
				8.85	-4.55						
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, and nacl	brine	NA	-4.69	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, nacl and TBP	brine	NA	-4.98	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, nacl and DBP	brine	NA	-4.34	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, nacl and EDTA	brine	NA	-3.28	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, nacl and citrate	brine	NA	-3.51	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	na2u2o7	h2o sat w/ ca(oh)2, fe(oh)2, nacl and oxalate	brine	NA	-3.69	undersaturation	NA	NA	NA	Marx and Keiling, 1989	4,18
U	freshly declad spent fuel	PBB1	brine	NA	-6.7	undersaturation	5	air atm	25-30	Gray, 1986	1,2,9
				NA	-5.7		5				
				NA	-5.4		14				
				NA	-5.6		14				
				NA	-5.3		28				
				NA	-4.9		28				
				NA	-4.9		60				
				NA	-4.8		60				
U	previously declad spent fuel	PBB1	brine	NA	-4.2	undersaturation	5	air atm	25-30	Gray, 1986	1,2,9
				NA	-4.3		5				
				NA	-4.1		14				
				NA	-3.9		28				
				NA	-4		28				
				NA	-3.9		60				
				NA	-4.5		60				
				NA	-4		90				
				NA	-4.2		120				
				NA	-4		180				
				NA	-4.8		180				
U	uo2	PBB1	brine	NA	-6.4	undersaturation	5	air atm	25-30	Gray, 1986	1,2,9
				NA	-6.3		14				
				NA	-6.2		28				
				NA	-6		60				

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NOTES

1 = data obtained from graphical results
2 = concentration in 18A filtrate
3 = concentration in 2000A filtrate
4 = data obtained from tabulated results
5 = concentration in 150A filtrate
6 = some solutions contained 10mg caco3
7 = concentration in 10A filtrate
8 = in pH solutions <7, essentially all am(oh)3 dissolved
i.e., maximum am+3 = E-3
9 = pH of sample not reported, initial pH = 6.2 to 6.4
10 = concentration in 20A filtrate
11 = PBB3 is similar to BSEP brines
12 = nonfiltered solutions acidified with HNO3
13 = log M calculated from normalized release value
14 = glass wt loss increased linearly with time
15 = concentration in 1000A filtrate
16 = actinide conc in solution determined by difference
between added conc and activity of 18A filtered ppt
17 = filter size unknown
18 = no details on the experimental conditions
19 = concentration in 13A filtrate
20 = concentration in 2200A filtrate
21 = ultrafiltration noted; size unknown
NA = not available

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APPENDIX H
STATISTICAL ANALYSIS AND RESULTS OF SOLUBILITY DATA

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STATISTICAL ANALYSIS AND RESULTS OF SOLUBILITY DATA

1.0 INTRODUCTION

Engineered Alternatives (EA) that increase the pH of the brine in the repository by two to three pH units results in improved performance of the repository because of lower actinide solubilities. Statistical analysis of existing relevant solubility data was performed to quantify the effects of such a pH increase on radionuclide solubilities.

Linear segments of the data sets displayed in Appendix E (Figures E-1 through E-12) were evaluated with a simple linear regression model to establish estimates of actinide solubilities at pH values of 6.1 and 8.3. Generally, the solubility of the radionuclides followed a linear trend between these pH values. The pH value of 6.1 corresponds to an indigenous Salado Formation brine (Deal et al., 1995) evaluated in the baseline case. The pH value of 8.3 corresponds to the approximate pH established in Salado brine by the brucite buffer when a limited amount of lime (CaO) is added to the backfill (Appendix G). A simple linear regression analysis was carried out on the linear or near linear data segments using Statgraphics Plus Version 7.0 software. The results of the regression analyses are shown in Figures H-1 through H-5. The estimated actinide solubilities and ranges are summarized in Table H-1 and additional statistical parameters are given in Table H-2.

2.0 REGRESSION ANALYSIS METHODOLOGY

Figures H-1 through H-5 show the data points used for regression analysis as well as the bold regression line. The solubility data were regressed using a least squares linear regression. Curved lines directly above and below the regression line (Figures H-1 through H-5) indicate the 95 percent confidence on the regression line. The true population regression line has a 95 percent chance of occurring between these two curves. The two curved lines farthest from the regression line in Figures H-1 through H-5 are the upper and lower 95 percent prediction intervals. These curves indicate the confidence interval for predicting a single value of the concentration at any pH. Upper and lower values reported for the 95 percent prediction interval represent the estimated range of solubility for the given actinide at the pH values of 6.1 and 8.3. The range takes into account the experimental uncertainties in the data and the uncertainties introduced by predicting a solubility at a pH value of interest. The estimated actinide solubilities and ranges determined from these curves are summarized in Table H-1.

In addition to the regression line and the confidence and prediction intervals around the regression line, several other regression analysis statistics were also calculated. These additional statistics are, the intercept and slope of the regression line, the correlation coefficient, the coefficient of determination, the standard error of the estimate, a T-test for significance of slope and intercept, and an analysis of variance (F-test) for significance of slope. These statistics are summarized in Table H-2.

The correlation coefficient (r), the coefficient of determination (r^2), and the standard error of the estimate are statistical parameters which describe how well the data points fit the linear regression line. The T-test and the analysis of variance test determine whether the concentration

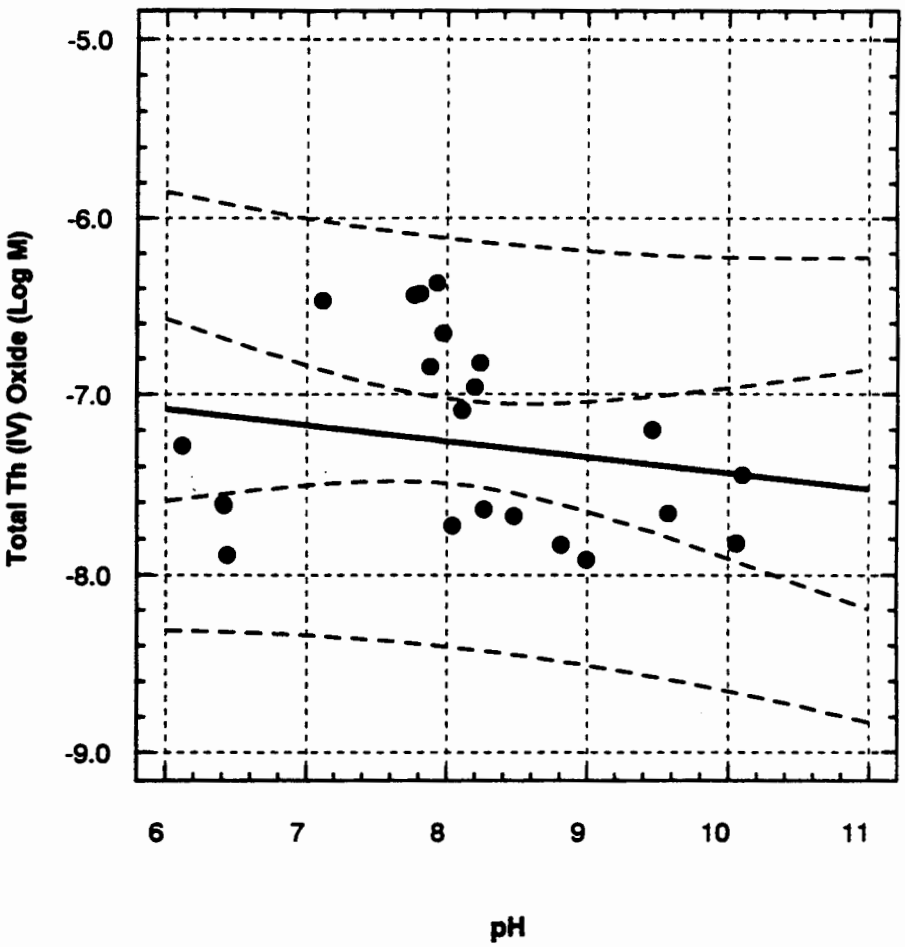

Figure H-1
Linear Regression for Hydrous Th (IV) oxide Solubility as a Function of pH for 3 M Solutions of NaCl; Data from Felmy et al. (1991)

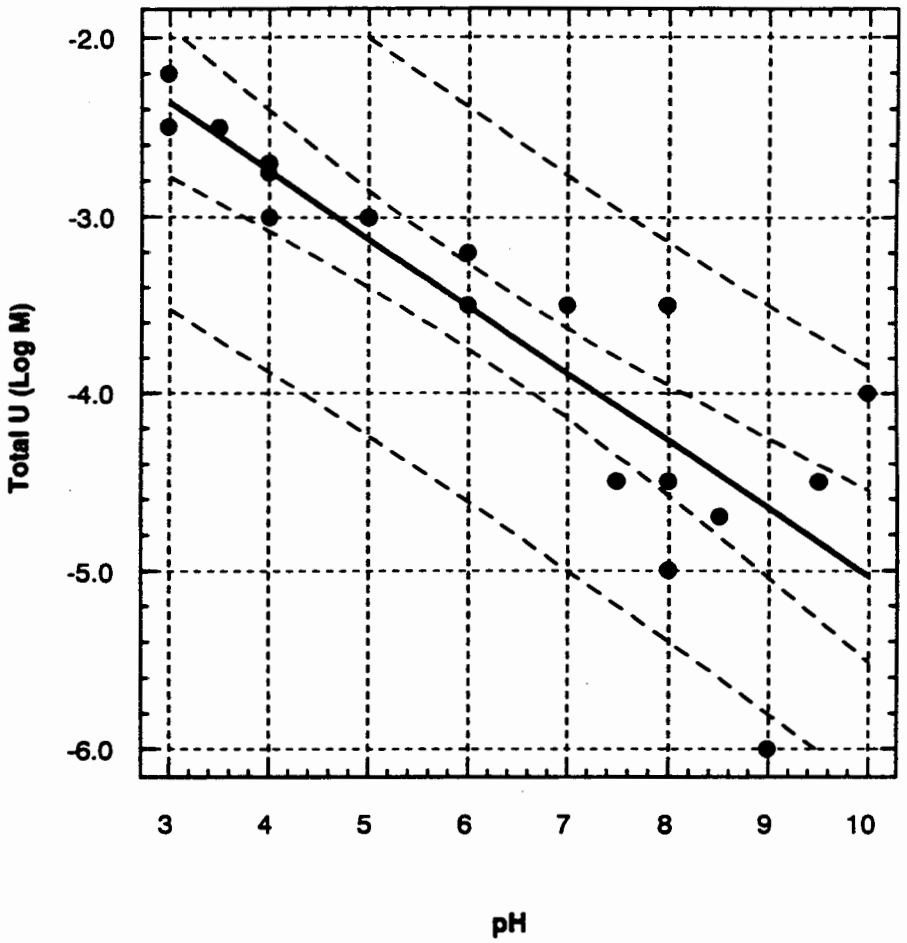

Figure H-2
Linear Regression for UO_3:$2H_2O$ Solubility as a Function of pH for Dilute Solutions; Data from Krupka et al. (1985)

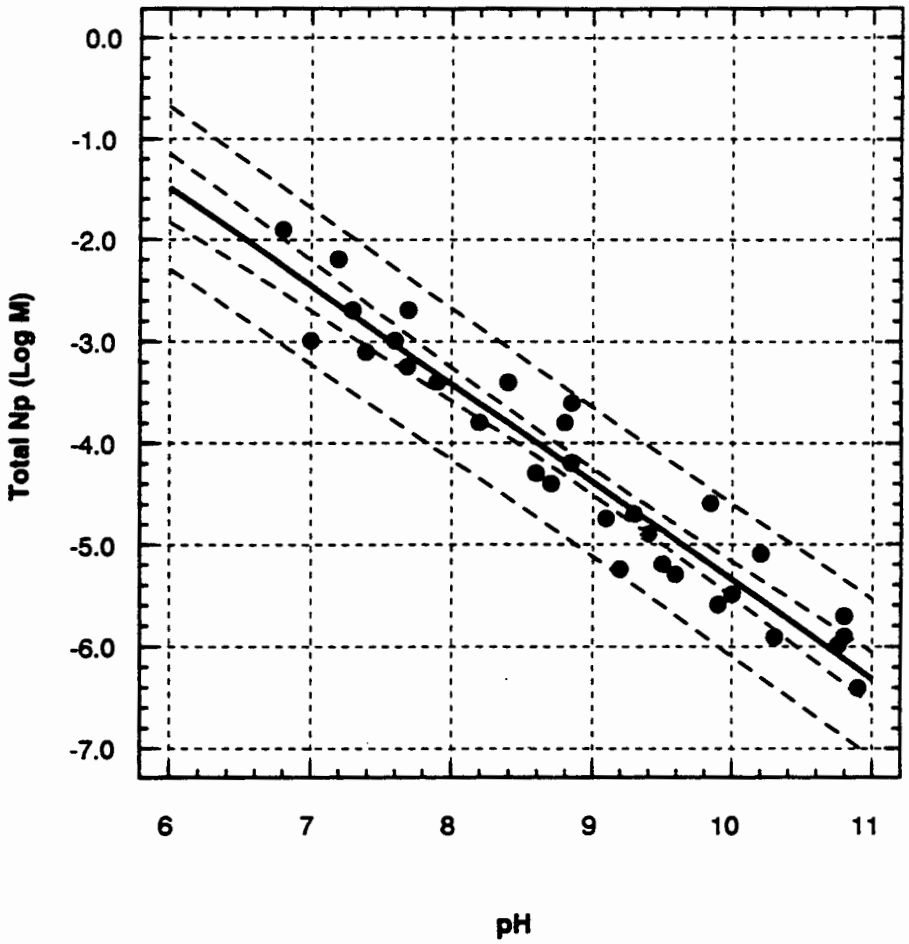

Figure H-3
Linear Regression for $NpO_2(OH)$ Solubility as a Function of pH for 1 M and 3 M Solutions of $NaClO_4$; Data from Kim et al. (1985b) and Neck et al. (1992).

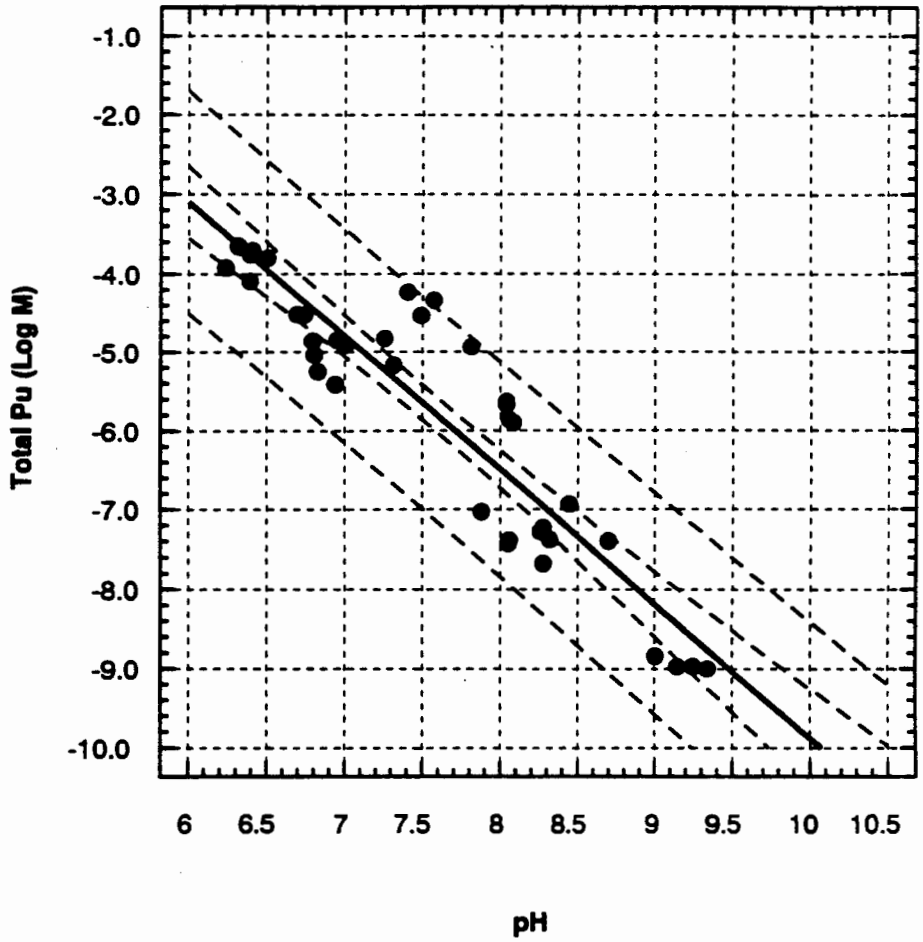

Figure H-4
Linear Regression for Amorphous $^{239}Pu(OH)_3$ Solubility as a Function of pH for PBB1 and PBB3 Brine Solutions; Data from Rai et al. (1987)

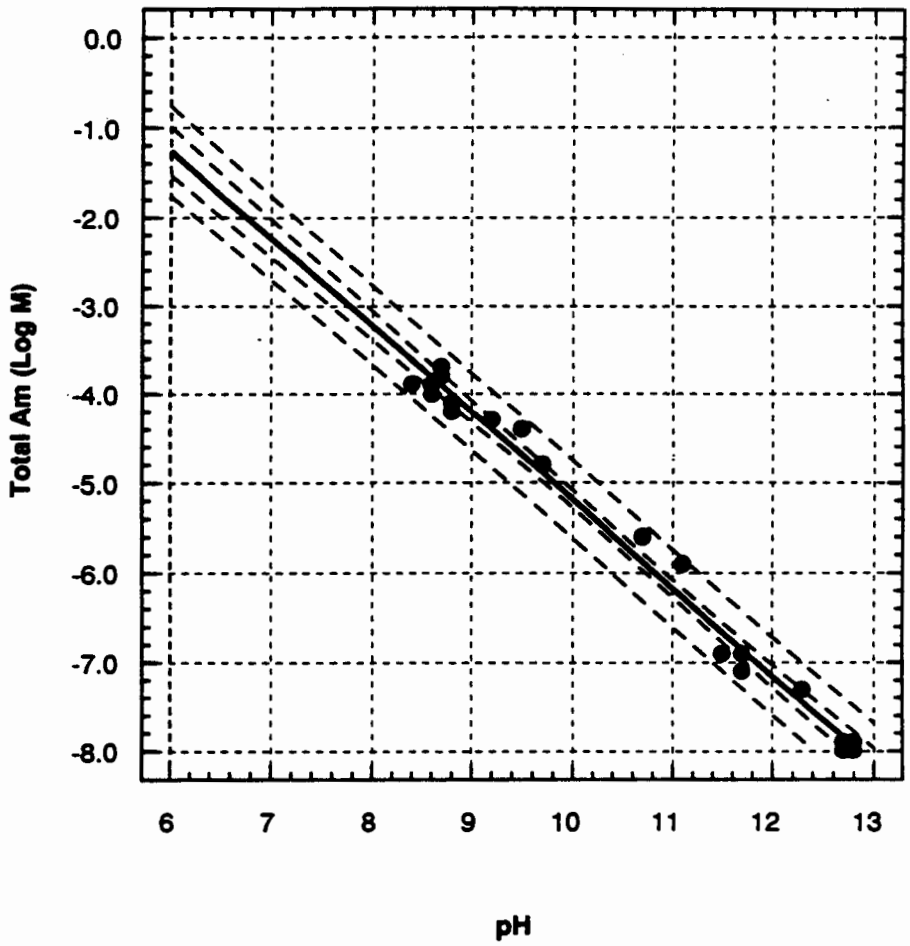

Figure H-5
Linear Regression for AmO2(OH) Solubility as a Function of pH for 5 M Solutions of NaCl; Data from Kim et al. (1985b)

and pH values are linearly correlated by examining the slope and intercept of the regression line. Each of these statistical parameters and procedures are described below.

The coefficient of determination (r^2) is the square of the correlation coefficient (r). The coefficient of determination is defined as the ratio of the sum of squares of the error in the regression line (explained variation) to the sum of squares of the total error (Kennedy and Neville, 1986). This ratio must lie between zero and unity. When $r^2 = 1$, all the variation is explained and the data points have a perfect fit with the regression line. The closer r^2 is to unity the less unexplained variation exists and the better the data points fit the regression line.

The standard error of the estimate is a measure of the variability of the dependent variable estimated by the regression line. The standard error of the estimate is defined as the square root of the sum of the squares of the residuals divided by the number of degrees of freedom (Kennedy and Neville, 1986). The residuals or deviations are the amount of difference between the modeled regression line and the measured value of concentration. Thus, if the sum of the squares of the residuals are small, the data points all fall close to or on the regression line, and the value of The Standard Error of the Estimate is low. The lower the Standard Error of the Estimate, the greater the confidence that the linear regression fits the data.

The T-test for significance of slope and intercept is used to determine if the slope or intercept of the regression line are significantly different than zero (Kennedy and Neville, 1986). Likewise, the analysis of variance (F-test), tests for the significance of slope (Kennedy and Neville, 1986). A slope and/or intercept of zero may indicate no correlation or dependence of concentration on pH. These tests are performed under the hypothesis that the slope or the intercept are equal to zero (null hypothesis), and then testing this hypothesis against the alternative hypothesis that the slope or the intercept are not equal to zero. The test results are indicated by the probability level. The probability level is the probability of a Type I error or the probability of rejecting the null hypothesis when it is true (Kennedy and Neville, 1986). Thus, if the probability level is greater than 0.05, there is no reasonable doubt to reject the null hypothesis at the 95th percent confidence level and it is concluded that the slope or intercept is equal to zero. If the probability level is less than 0.05, the null hypothesis is rejected at the 95th percent confidence level and it is concluded that the slope or the intercept are not equal to zero.

These statistical parameters and tests were used to determine how well the linear model fits the solubility data over the pH range of interest. If the solubility data follow a linear trend the coefficient of determination (r^2) will be close to unity, and the standard error of the estimate will be low. If there is a strong correlation between concentration of the radionuclides and pH, the regression line will also have a non-zero slope. If the linear model fits the solubility data and the regression line is significant, then there is a high degree of confidence in the predicted values of solubility at pH values of 6.1 and 8.3.

3.0 RESULTS OF REGRESSION ANALYSES

A discussion of the solubility of Th, U, Np, Pu and Am with respect to Ph is presented below. Results from the regression analysis and predicted solubilities at Ph values of 6.1 and 8.3 are discussed.

3.1 Thorium

The Th solubility data of Felmy et al. (1991) for amorphous $ThO_2 \bullet xH_2O$ in 3M NaCl solutions (Figure H-1) are the closest approximation to saturated NaCl conditions imposed by Salado brine. Data points falling in the pH interval of 6 to 10 were used in the linear regression model and results are displayed on Figure H-1, with Table H-1 and Table H-2 summarizing results of the regression analysis. The coefficient of determination value (r^2 = 3 percent) given on Figure H-1 indicate the data are a very poor fit to the linear model. Additionally, results from the T-test for significance of slope and results from the analysis of variance (Table H-2) indicate that the slope is equal to zero at the 95th percent confidence limit (probability level = 0.4).

Felmy et al. (1991) noted that most of the measured Th concentrations above a pH of 6 are near the analytical detection limit of about -8.5 log M, and greater error in analytical precision probably accounts for the large scatter in the data set. However, the solubility of ThO_2 is known to be independent of pH above near neutral pH values (Felmy et al., 1991), and theoretical calculations of the solubility of crystalline ThO_2 indicate a linear trend for Th concentration above a pH of 6, corresponding to an intercept of -14 log M and a slope of zero (Langmuir and Herman, 1980). Therefore, the solubility estimates determined from linear regression (Table H-1) were used to estimate $ThO_2 \bullet xH_2O$ solubility because analytical measurement of Th concentration is difficult above a pH of 7, due to the insoluble nature of ThO_2, and a linear relationship is known to exist once ThO_2 solubility becomes independent of pH.

3.2 Uranium

Uranium solubility data (Figures H-2 and H-3) indicate that schoepite ($UO_3 \bullet 2H_2O$) is more soluble than uraninite (UO_2) and, as a conservative measure, the most soluble U phase is selected for this analysis. The solubility data reported by Krupka et al. (1985) for amorphous schoepite were selected over that of Bruno and Sandino (1989) because of the greater pH range studied. Similar U concentrations are reported for amorphous schoepite when the two studies overlap in pH space (Figure H-3). Figure H-2 displays results for the linear model over the pH range of 3 to 10, Table H-1 and Table H-2 summarize the results from the regression analysis. The coefficient of determination on Figure H-2 indicate that the data of Krupka et al. (1985) are a fair fit to the model (r^2 = 75 percent). Additionally, results from the T-test for significance and the analysis of variance indicate that the slope and intercept are not equal to zero at the 95th percent confidence level (probability level = 0.0).

Solubility data for schoepite in saturated NaCl brine was not found during this study. Examining Figure H-2, it appears that the solubility of uraninite is increased by about 2 orders of magnitude in the presence of a saturated NaCl brine. Therefore, results summarized in Table H-1 for shoepite solubility in dilute solutions are recommended to be increased by two orders of magnitude to account for the expected enhancement of schoepite solubility in Salado brine.

3.3 Neptunium

Solubility data on Np solids (Figures H-4 and H-5) indicate that NpO_2OH is more soluble than NpO_2 and, as a conservative measure, the most soluble Np phase is selected for this analysis. The 1M and 3M $NaClO_4$ data sets of Neck et al. (1992) and Kim et al. (1985b) are in good agreement and the closest approximation to saturated NaCl conditions imposed by Salado brine. Therefore, these data sets were selected for regression analysis over the pH interval of 6 to 11.

Figure H-3 summarizes the regression analysis for the data sets. The r^2 value of 92 percent, indicates that the data sets are a good fit to the linear model and the T-test and analysis of variance indicate a non zero slope at the 95th percent confidence limit (probability level = 0.0). Table H-1 summarizes the model results for the pH values of interest and Table H-2 summarizes additional regression statistics.

3.4 Plutonium

Figures H-6 through H-10 summarize data on the solubility of Pu solids. The most soluble phase over the pH interval of interest (6 to 9) is amorphous $Pu(OH)_3$ (Figure H-6) and, as a conservative measure, the most soluble Pu phase is selected for this analysis. Rai et al. (1987) studied the solubility of amorphous $Pu(OH)_3$ in Permian Basin brines (PBB), and these data sets are chosen for regression analysis because the saturated NaCl PBB are good analog for Salado brine. Regression results presented on Figure H-4 indicate the linear model is a fair to good fit to the data sets [r^2 = 85 percent, slope and intercept are not equal to zero (probability level = 0.0)]. Table H-1 summarizes the model results for the pH values of interest and Table H-2 summarizes additional regression statistics.

3.5 Americium

Americium solubility data are presented on Figures H-11 and A-12, and the most soluble phase indicted on these plots is AmO_2OH (Figure H-12). The solubility data of Kim et al. (1985b) for $^{241}AmO_2OH$ in 5M NaCl solution is selected for this analysis, because these data represent the closest approximation to saturated NaCl conditions imposed by Salado brine. Figure H-5 summarizes the regression analysis and indicates that the linear model is an excellent fit to the data over the pH interval of 8 to 13 [r^2 = 99 percent, slope and intercept are not equal to zero (probability level = 0.0)]. Note that the regression analysis has been extrapolated to a pH of 6 to allow a calculation of the solubility estimate at a pH of 6.1 (baseline case for Salado brine). Table H-1 summarizes the model results for the pH values of interest and Table H-2 summarizes additional regression statistics.

TABLE H-1

RESULTS OF REGRESSION ANALYSIS ON ACTINIDE SOLUBILITY

Actinide	Most Soluble Oxide/Hydroxide Phase	Solution Composition	pH	Estimated Solubility	Estimated Range of Solubility
				log (mole/liter)	
Thorium	$ThO_2 \bullet xH_2O$	3M NaCl	6.1	-7.1	-5.9 to -8.3
			8.3	-7.3	-6.1 to -8.4
Uranium	$UO_3 \bullet 2H_2O(a)$	dilute	6.1	-3.5[a]	-2.4 to -4.7[a]
			8.3	-4.4[a]	-3.2 to -5.5[a]
Neptunium	$NpO_2OH(a)$	1M and 3M $NaClO_4$	6.1	-1.6	-0.8 to -2.4
			8.3	-3.7	-3.0 to -4.4
Plutonium	$Pu(OH)_3(a)$	Permian Basin Brines	6.1	-3.3	-1.9 to -4.7
			8.3	-7.0	-5.6 to -8.4
Americium	$AmO_2OH(a)$	5M NaCl	6.1	-1.4[b]	-0.9 to -1.8[b]
			8.3	-3.5	-3.1 to -4.0

[a]It is recommended that values be increased by 2 log units to account for enhanced solubility in saturated NaCl solutions. See text for discussion.
[b]Value is obtained from extrapolation of regression analysis to pH 6.1.

TABLE H-2

REGRESSION STATISTICS ON ACTINIDE SOLUBILITY

1) Regression Analysis - Thorium

Dependent variable: Th(IV) Oxide Independent variable: pH

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-6.5484	0.847345	-7.72814	0.00000
Slope	-0.0889158	0.103675	-0.857641	0.40077

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.2137470	1	0.2137470	0.735547	0.40077
Residual	6.102514	21	0.290596		
Total (Corr.)	6.316261	22			

Correlation Coefficient = -0.183959 R-squared = 3.38 percent

Stnd. Error of Est. = 0.539069

2) Regression Analysis - Uranium

Dependent variable: UO3+2H2O Independent variable: pH

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-1.21305	0.337455	-3.59472	0.00207
Slope	-0.382024	0.0515513	-7.41055	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	14.674492	1	14.674492	54.91627	0.00000
Residual	4.809883	18	0.267216		
Total (Corr.)	19.484375	19			

Correlation Coefficient = -0.867837 R-squared = 75.31 percent

Stnd. Error of Est. = 0.516929

TABLE H-2 (CONTINUED)

REGRESSION STATISTICS ON ACTINIDE SOLUBILITY

3) Regression Analysis - Neptunium

Dependent variable: NpO2OH Independent variable: pH

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	4.30194	0.476779	9.02292	0.00000
Slope	-0.964968	0.052955	-18.2224	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	41.85969	1	41.85969	332.0563	0.00000
Residual	3.655798	29	0.126062		
Total (Corr.)	45.515484	30			

Correlation Coefficient = -0.959 R-squared = 91.97 percent

Stnd. Error of Est. = 0.355052

4) Regression Analysis - Plutonium

Dependent variable: Pu(OH)3 Independent variable: pH

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	7.07026	0.928106	7.61794	0.00000
Slope	-1.69515	0.121298	-13.9751	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	83.86683	1	83.86683	195.3031	0.00000
Residual	15.029656	35	0.429419		
Total (Corr.)	98.896481	36			

Correlation Coefficient = -0.920883 R-squared = 84.80 percent

Stnd. Error of Est. = 0.6553

TABLE H-2 (CONTINUED)

REGRESSION STATISTICS ON ACTINIDE SOLUBILITY

5) Regression Analysis - Americium

Dependent variable: AmO2OH Independent variable: pH

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	4.64694	0.284859	16.3131	0.00000
Slope	-0.983439	0.0269227	-36.5283	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	53.1451	1	53.1451	1334.316	0.00000
Residual	0.716930	18	0.039829		
Total (Corr.)	53.862000	19			

Correlation Coefficient = -0.993322 R-squared = 98.67 percent

Stnd. Error of Est. = 0.199573

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APPENDIX I
GEOCHEMICAL SIMULATIONS OF ENGINEERED ALTERNATIVES WITH SALADO BRINE

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GEOCHEMICAL SIMULATIONS OF ENGINEERED ALTERNATIVES WITH SALADO BRINE

1.0 INTRODUCTION

One pathway considered for the release of radionuclides to the accessible environment is the dissolution of radionuclides in brine that may come in contact with the waste, followed by transport of the contaminated brine to the accessible environment. Brine can be transported via fractures caused by excessive pressurization of the repository by gas generation, or by pathways created by human intrusions. A key factor controlling the release of radionuclides by these mechanisms is the solubility of the radionuclides in brine. Solubility is defined, in this case, as the maximum mass of a given actinide element that can dissolve in a unit volume of brine of a specified composition. The solubilities of the actinide elements of concern are complex functions of several parameters, however, they all show similar behavior with respect to pH. Solubility decreases as the pH rises above neutrality, often reaching a solubility minimum in the range of 8.5 to 10.

The ability of brine to transport radionuclides could be greatly reduced if the pH of any brine that accumulates in the repository is raised from the ambient value of around 6.1 to a value that is closer to the solubility minimum range. Engineered alternatives (EA) that buffer the pH to a more favorable range (by the addition of lime [calcium oxide, or CaO] or portland-type cement, which contains a large percentage of hydrated lime [portlandite, or $Ca(OH)_2$], to either the drum contents or backfill) will show improved performance because of lower actinide solubilities.

An increase in pH by the addition of lime can be thought of as a two-step reaction in which calcium oxide forms portlandite by the reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2 \qquad \text{I.1}$$

followed by portlandite dissociation by the reaction:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^- \qquad \text{I.2}$$

to yield calcium ions (Ca^{2+}) and hydroxide ions (OH-). The additional hydroxide ions increases the pH of the Salado brine which has a desirable effect of lowering actinide solubilities.

The addition of lime to pure water at and above the saturation point will raise the pH to an equilibrium value of ~11.8. A significant difference between pure water and Salado brine however, is the very high magnesium concentration which buffers the pH at values significantly below 11.8.

Computer simulations were performed to predict the effects of the addition of lime to Salado brine to determine the equilibrium pH value and buffer capacity. These simulations were performed using the EQ3NR and EQ6 geochemical speciation-solubility-reaction path models (Wolery, 1992a and Wolery, 1992b). The following sections describe some background information on the EQ3NR/EQ6 geochemical model, the modeling approach used for the simulations, and the results and conclusions of the geochemical simulations.

2.0 BACKGROUND

The computer code EQ3NR/EQ6 is an industry-standard chemical reaction model that performs solubility, speciation, and reaction-path calculations. The initial version of the EQ3NR/EQ6 code was developed in 1979 at Lawrence Livermore National Laboratory for predicting the behavior of metals, radionuclides, and other contaminants in the natural environment. The code has been actively maintained and improved over the last fourteen years with funding from a wide variety of sources. The current version of the code accesses a database containing the thermodynamic properties of 78 elements, 862 aqueous species, 886 minerals, and 76 gases; and is valid over a temperature range of 0° to $300^{o}C$.

The database also contains references for all of the values to provide traceability, and can be modified or expanded by the user. EQ3NR/EQ6 has been validated using standard geochemistry problems such as the speciation of sea water, basalt/sea water interactions, and numerous comparisons with experimentally determined mineral solubilities. Successful benchmark comparisons with the results of similar codes have also been performed. The code allows the use of the Pitzer approach as an option for the calculation of activity coefficients. This approach allows accurate modeling of high ionic strength solutions such as Salado brines using a specifically designed thermodynamic data base (Harvie, Moller, and Weare data base).

The main advantage of EQ3NR/EQ6 over other chemical reaction codes is the ability to perform reaction path simulations. When operated in this mode, an assemblage of reactants (liquids, solids, or gases) are introduced to an aqueous solution in a series of small steps. An unlimited number of reactants can be added in parallel, each at its own rate. At each step, the composition of the fluid is recalculated and the data base of solid minerals is scanned to determine if any minerals are oversaturated. If oversaturation of a particular mineral occurs, then it is allowed to precipitate so that it is maintained in equilibrium with the fluid. The code then loops back to add another small mass of reactants, recalculate fluid composition, and solve for saturation. This process is repeated (typically hundreds to thousands of times) until the either the system reaches equilibrium with the reactants or the originally specified mass of reactants are exhausted. The output of the code includes tables that chart the composition, pH, and redox state of the fluid; the mass of each reactant consumed, and the mass of each mineral that has precipitated, all as functions of reaction progress.

3.0 MODELING APPROACH

For this application, the composition of an average Salado brine is first defined. This composition is based on data presented in the *1992-1993 Brine Sampling and Analysis Program report* (Deal et al., 1995). Lime is then added in a series of small increments to the brine to determine the effects on pH as a function of the amount of lime added. These simulations are appropriate for EAs that include lime as a backfill additive, or include a portland-based grout backfill. These grouts contain lime as a principal component. The simulations were performed using the Pitzer approach as an option for the calculation of activity coefficients, and accessed the Harvie-Moller-Weare data base which yields accurate results for high ionic strength solutions such as brines.

Results of these simulations directly provide the changes in solution composition and pH as a function of the mass of lime added to a unit mass of brine. Results also provide the mass of lime consumed and the mass of new minerals precipitated during the process.

4.0 RESULTS

Figure I-1 summarizes the results of the simulation of lime addition to Salado brine. The addition of a very small amount of lime to the brine raises the pH from the ambient value of 6.1 to a value of ~8 corresponding to the solubility of magnesium-oxychloride [$Mg_2Cl(OH)_3 \bullet 4H_2O$]. At this point, the further addition of lime results in precipitation of Mg-oxychloride and brucite [$Mg(OH)_2$] with little change in pH. After the addition of 1.1 moles of lime to the original kilogram of brine, almost all of the original Mg present in the brine will have precipitated. At this point, further addition of lime will raise the pH to values above 11, corresponding to the portlandite [$Ca(OH)_2$] pH buffer. The presence of the original Mg concentration of 22,700 mg/l (0.93 moles/liter) thus serves as an effective pH buffer, maintaining the pH between 8.0 and 9.0 in response to the addition of anywhere between 0.05 to 1.1 moles of lime per kg of brine.

The results suggest that the addition of 0.5 moles of lime per kilogram of Salado brine anticipated to flow into the room will poise the system in the middle of the pH-buffer zone at a pH of about 8.2.

Effects of Boron on pH buffer

Boron is present in the brine at an average concentration of 0.13 moles/l (Deal et al., 1995). Boron can act under some conditions as a pH buffer. The results shown in Figure I-1 do not consider the effects of boron in the simulation because boron is not present in the Harvie-Moller-Weare database.

To investigate the role of boron on the effects of lime addition, the simulation was rerun with the extended Debye-Hückel activity coefficient option. This option produces less accurate results than the Pitzer option when simulating brine interactions, but it accesses a different thermodynamic database that does contain boron species.

Results from this simulation indicate brucite will buffer the brine pH between 8.5 and 9 until magnesium ion is depleted. Boron speciation is initially dominated by $B(OH)_3^o$ at near neutral pH, but the speciation changes to $CaB(OH)_4^+$, $NaB(OH)_4^o$, and to $MgB(OH)_4^+$ (aqueous species of Boron) as pH and calcium (Ca) ion concentration increases. Assuming an average boron concentration in Salado brine of 0.13 mole/L, the addition of 0.13 mole/L of hydroxide ion is necessary to convert all $B(OH)_3^o$ to metal-$B(OH)_4$ species. The addition of 0.13 mole/L of hydroxide ion is equivalent to the addition of 0.07 moles of lime, since two moles of hydroxide ions are liberated for each mole of lime that goes into solution by the reaction:

$$CaO + H_2O \rightarrow Ca^{+2} + 2OH^- \qquad \text{I.3}$$

Thus, conversion of all $B(OH)_3^o$ to metal-$B(OH)_4$ species requires the addition of 0.07 moles of lime This is a small amount of lime compared to the 0.5 moles/L necessary to reach the midpoint of the Mg-oxychloride/brucite pH buffer. Additionally, at the pH-buffer value of about 8.5, only 65

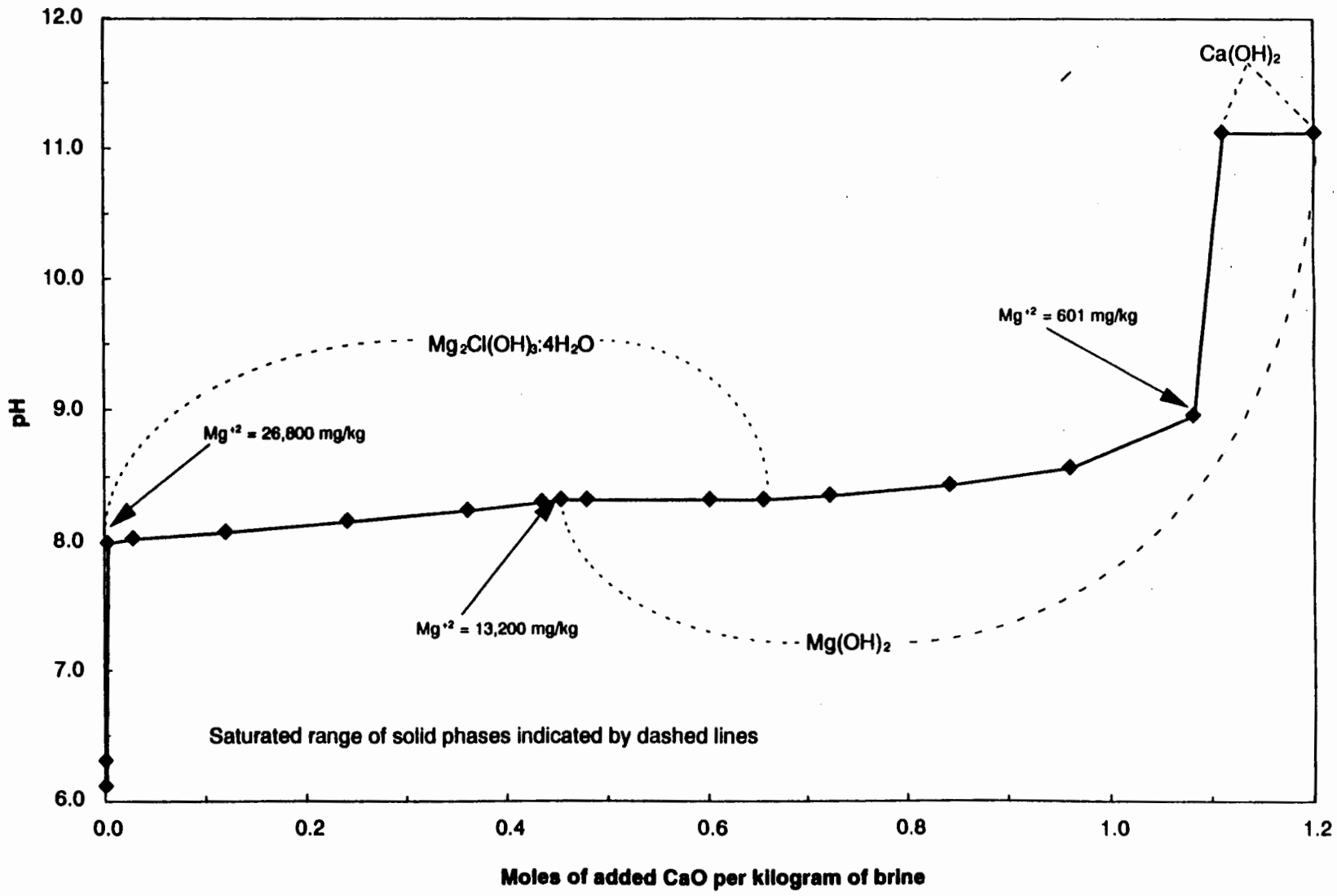

Figure I-1
EQ6 Modeling Results Showing pH as a function of Moles of CaO Added per Kilogram of WIPP Brine

percent of the $B(OH)_3^o$ would be converted to metal-$B(OH)_4$ species. Therefore, it appears that the presence of boron in the brine does not require any significant increase in the amount of lime that must be added to the brine to reach the midpoint of the Mg-oxychloride/brucite pH buffer.

5.0 CONCLUSIONS

The pH of the brine can be controlled by adding 0.5 moles of lime per kilogram of Salado brine expected to flow into the disposal rooms. The addition of this amount of lime would raise the pH to ~8.2 and fix the system in the middle of the Mg-oxychloride/brucite pH buffer zone. The anticipated volume of brine inflow does not need to be accurately known because the addition of anywhere between 0.05 to 1.1 moles of lime per kg of brine will maintain the pH between 8 and 9.

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APPENDIX J
DESCRIPTION OF UNCERTAINTY CALCULATIONS

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DESCRIPTION OF UNCERTAINTY CALCULATIONS

1.0 MONTE CARLO SAMPLING WITH THE STADIC CODE

1.1 General Description

The Monte Carlo technique maps uniform, random numbers through a cumulative distribution function (CDF) of a physical or decision parameter of the FORTRAN code to generate a value of that parameter for use in the analysis. Given a uniform density of random deviates on the ordinate, n, the total number of random deviates on any interval, dy, is n(dy). The corresponding interval on the abscissa then has density n(dy/dx). Since the probability density function (PDF) of a random variable is proportional to the derivative of the corresponding CDF, this method of mapping uniform deviates through the CDF, in effect, simulates the PDF of the random variable.

The STADIC code was developed by PLG to accomplish Monte Carlo sampling for engineering oriented applications. The STADIC code has been certified under QA and is used by PLG as a production code on the PC. It is designed to generate values of input parameters from user specified distributions and pass them to a subroutine for calculation. The results of each iteration is then stored for statistical and trend analysis. Thus, STADIC automates the Monte Carlo technique by providing a convenient platform to run standard FORTRAN engineering code. Further information on the code can be found in Wakefield and Fleming (1990).

1.2 Description of STADIC Subroutine for EA Evaluations

The STADIC subroutine specifies the probability distributions to be sampled for use in the Design Analysis Model (DAM) calculation cases. The code has the capability to accept the parameters for some of the standard distributions used in this study. These include those parameters that specify normal, lognormal, uniform, and discrete distributions. Other distributions (such as piece wise continuous and triangular distributions) are converted into CDFs for input to the Monte Carlo algorithms in the STADIC code.

Dependencies are established by standard FORTRAN programming. For example, full dependence corresponds to use of the same random number to sample the two separate CDFs for the dependent variables. The subroutine first queries the Monte Carlo random number generator with an intermediate variable corresponding to a uniform distribution between 0 and 1. It then uses the resulting value to select a sample value from the CDFs of each of the dependent variables.

For the Engineered Alternatives (EA) Cost Effectiveness Study, the STADIC code was used to generate a file consisting of 1,000 sets of input for the uncertain variables, indexed from 1 to 1,000. The modeling of the probability distributions for these variables is discussed in Section 2.0 of this appendix. The input file was then used to run 1,000 iterations of the DAM code. One set of input initiated a 10,000 year calculation in the DAM. The results of each calculation were then saved with the index number corresponding to the input set. In this manner the output of each DAM calculation can be easily correlated with its input set for calculation of Measures of Relative Effectiveness (MRE) and examination of sensitivities to obtain physical insight into the influence of the EA on performance.

The same random number seed was used to generate the input set for the baseline and all the EAs. This insured that the "unknown future conditions" that sampling process simulates is consistent across all the EA options so that the relative response of the to the conditions can be compared. Thus, the uncertainty associated with the resultant MRE may be considered to be due to the uncertainty in our state-of-knowledge regarding physical processes under those future conditions and not the nature of the random sampling process.

2.0 INPUT PARAMETER DISTRIBUTIONS

2.1 Summary of Uncertain Parameters Modeled

This section summarizes the modeling of the DAM parameters whose uncertainties were considered important to determining the significance of the various for improving confidence of compliance. Table J-1 provides summary information regarding these parameters and references to the sources of evidence used to establish their probability distributions.

Figure J-1(a–p) presents a graphical representation of the cumulative distribution functions generated by the STADIC code for the baseline design. The graphs are presented in the same order as they are listed in Table J-1. As a matter of clarification, the graphs of hydrogen generation rate under humid conditions (HHUMRATE) and negative log permeability of the anhydrite units (KPANH) appear to be step functions. This reflects the fact that these two variables are discrete distributions. For example, all random numbers between 0 and 0.2 would return a value of 17 for KPANH.

2.2 Dependencies Among Variables

The following dependencies and correlations among input parameters are modeled in the STADIC sampling subroutine:

- Inundated and Humid anoxic corrosion gas generation rates: The same random number is used to sample the distributions for the variables HINURATE and HHUMRATE that represent these two processes. These two processes could proceed in parallel within the repository, depending on the amounts of brine available for the conversion reaction. The dependency reflects the similarity of the chemical conversion involved, with the differences in brine saturation producing a different model for the rate of the process. The use of the same random number for the two processes reflects the judgement that the humid gas generation rate should never exceed the inundated anoxic gas generation rate, since the cumulative distribution of the humid process has lower values at all percentiles of the distribution.

- Inundated and Humid biodegradation gas generation rates: The same random number is used to sample the distributions for the variables BINURATE and BHUMRATE that represent these two processes. These two processes could proceed in parallel within the repository, depending on the amounts of brine available for the conversion reaction. The dependency reflects the similarity of the chemical conversion involved, with the differences in brine saturation producing a

TABLE J-1

INPUT VARIABLES TO THE DAM THAT ARE MODELED WITH UNCERTAINTY

DAM Variable Name	Variable Description (units)	Point Estimate[a]	Range of Values[b]	Type of Distribution	Dependencies	Comments	Reference
BHUMRATE	Microbial gas generation rate under humid facility conditions (moles/kg cellulosics-yr)	0.01	0 - 0.1	Piece-wise Uniform	BINURATE >= BHUMRATE	Range of values above and below point estimate weighted to make overall mean value of distribution equal to the point estimate.	Brush, 1994, and SNL/NM, 1993, Vol. 3, p. 3-52
BINURATE	Microbial gas generation rate from anoxic corrosion under inundated facility conditions (moles/kg cellulosics-yr)	0.1	0 - 0.5	Piece-wise Uniform	BINURATE >= BHUMRATE	Range of values above and below point estimate weighted to make overall mean value of distribution equal to the point estimate.	Brush, 1994, and SNL/NM, 1993, Vol. 3, pp. 3-50, 3-51
BIOSTOIC	Ratio of moles of biogas generated to moles of cellulosics consumed (dimensionless)	0.835	0 - 1.67	Uniform	None		See Note h.
CB	Brine inflow rate at a pressure difference of lithostatic minus atmospheric (m^3/yr-panel)	0.60	0 - 1.19	Uniform	None		See Note h.
H2MAX	Maximum hydrogen gas generation potential from anoxic corrosion (mol/panel)	7.9E+07	5.5E7 - 1.1E8	Derived distribution	Derived directly from RHTORW.	H2MAX=H2MAX0*RHTORW/0.7 See comments for variable RHTORW.	See Note g.
HHUMRATE	Hydrogen gas generation rate from anoxic corrosion under humid facility conditions (moles/drum-yr)	9.0E-04	0 - 0.06	Discrete	HINURATE >= HHUMRATE	Three values assigned the following weights: 97.5% .@ 0.0, 2% @ 0.03, 0.5% @ 0.06 See Note i	Brush, 1994, and SNL/NM, 1993, Vol. 3, pp. 3-46, 3-47
HINURATE	Hydrogen gas generation rate from anoxic corrosion under inundated facility conditions (moles/drum-yr)	0.6	0 - 10	Piece-wise Uniform	HINURATE >= HHUMRATE	Range of values above and below point estimate weighted to make overall mean value of distribution equal to the point estimate.	Brush, 1994, and SNL/NM, 1993, Vol. 3, pp. 3-44, 3-45
KPANH	Negative log of the permeability of the anhydrite beds (dimensionless)	18	17,18,19,20	Discrete	None	Due to DAM code, probability assigned to 17,18,19, or 20 only. Assigned equal probability weight.	See Note f.

Refer to footnotes at end of table.

TABLE J-1 (Continued)

INPUT VARIABLES TO THE DAM THAT ARE MODELED WITH UNCERTAINTY

DAM Variable Name	Variable Description (units)	Point Estimate[a]	Range of Values[b]	Type of Distribution	Dependencies	Comments	Reference
RADFAC	Factor used to estimate the effective borehole radius during intrusion (dimensionless)	3.0	2.1 - 3.9	Triangular	None	Range to minimum and maximum values estimated as plus or minus 30% of the point estimate.	See Note g.
RADSOL (1)	Pu-240 solubility in brine (mol/l)	5.01E-04	2E-05 - 0.013	Lognormal[c,d]	None		See Note e.
RADSOL (2)	U-236 solubility in brine (mol/l)	3.16E-02	2E-03 - 0.39	Lognormal[c,d]	None		See Note e.
RADSOL (3)	Am-241 solubility in brine (mol/l)	3.98E-02	0.0158 - 0.126	Lognormal[c,d]	None		See Note e.
RADSOL (5)	Np-237 solubility in brine (mol/l)	2.51E-02	0.005 - 0.158	Lognormal[c,d]	None		See Note e.
RADSOL (5)	U-233 solubility in brine (mol/l)	3.16E-02	2E-03 - 0.39	Lognormal[c,d]	See comments	Assigned same value as RADSOL (2) and RADSOL (8)	See Note e.
RADSOL (6)	Th-229 solubility in brine (mol/l)	7.94E-08	5E-09 - 1.26E-06	Lognormal[c,d]	None		See Note e.
RADSOL (7)	Pu-238 solubility in brine (mol/l)	5.01E-04	2E-05 - 0.013	Lognormal[c,d]	See comments	Assigned same value as RADSOL (1) and RADSOL (12)	See Note e.
RADSOL (8)	U-234 solubility in brine (mol/l)	3.16E-02	2E-03 - 0.39	Lognormal[c,d]	See comments	Assigned same value as RADSOL (2) and RADSOL (5)	See Note e.
RADSOL (9)	Th-230 solubility in brine (mol/l)	7.94E-08	5E-09 - 1.26E-06	Lognormal[c,d]	See comments	Assigned same value as RADSOL (6)	See Note e.
RADSOL (12)	Pu-239 solubility in brine (mol/l)	5.01E-04	2E-05 - 0.013	Lognormal[c,d]	See comments	Assigned same value as RADSOL (1) and RADSOL (7)	See Note e.

Refer to footnotes at end of table.

TABLE J-1 (Continued)

INPUT VARIABLES TO THE DAM THAT ARE MODELED WITH UNCERTAINTY

DAM Variable Name	Variable Description (units)	Point Estimate[a]	Range of Values[b]	Type of Distribution	Dependencies	Comments	Reference
RBOR	Radius of borehole for intrusion scenarios (m)	0.18	0.134-0.222	Uniform	None	Distributions taken directly from 92PA due to the lack new data.	Distribution Type and range from SNL/NM, 1993
RHTORW	Ratio of hydrogen gas generation rate to water consumption rate during anoxic corrosion (dimensionless)	0.72	0.5 - 1	Derived Distribution	None	RHTORW=(4-x)/(4+2x) where x is uniform between 0 and 1.	See Note g.

Notes:

[a]Point estimate value is the mean of the distribution for all distribution types except for the lognormal distribution.

[b]Range of values represent all possible values of the distribution (0th to 100th percentile) for all distributions except for the lognormal distribution.

[c]For lognormal distribution, the point estimate value is the median.

[d]For lognormal distribution, the range of values is between 5th percentile and 95th percentile.

[e]Point estimate (median) and range values for these variables are taken from Table H-1 Results of Regression Analysis on Actinide Solubility

[f]KPANH distribution from EATF Report (DOE, 1991).

[g]Guidance regarding these variables are taken from equations provided in SNL/NM, 1993.

[h]The complete distributions for these variables are from SNL/NM, 1993, considerations.

[i]This discrete distribution is formulated to recognize that the humid anoxic gas generation rate is very likely zero, but there is some chance that it could be as high as 0.06. Use of discrete distribution would permit examination of a distinct set of cases if an impact is found.

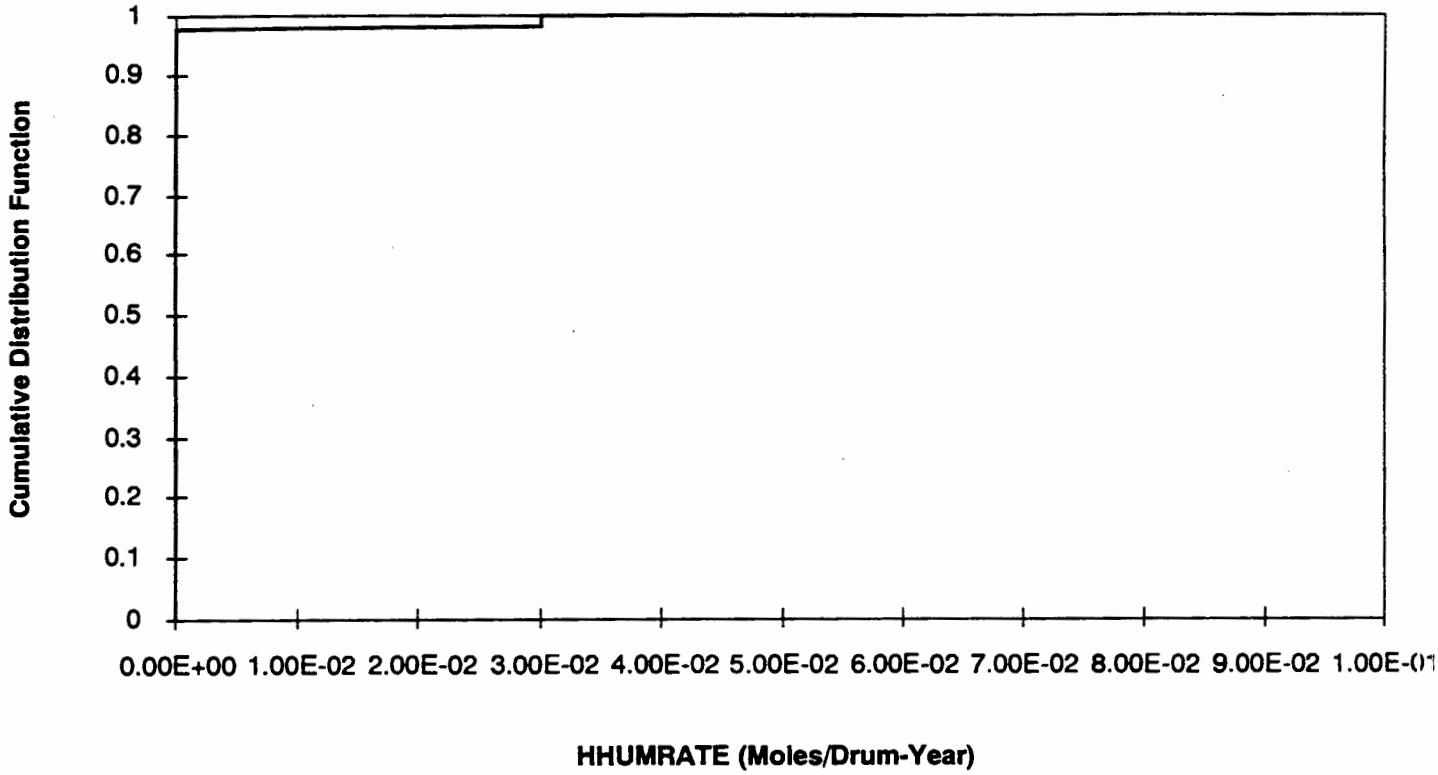

Figure J-1a
Cumulative Distribution Function

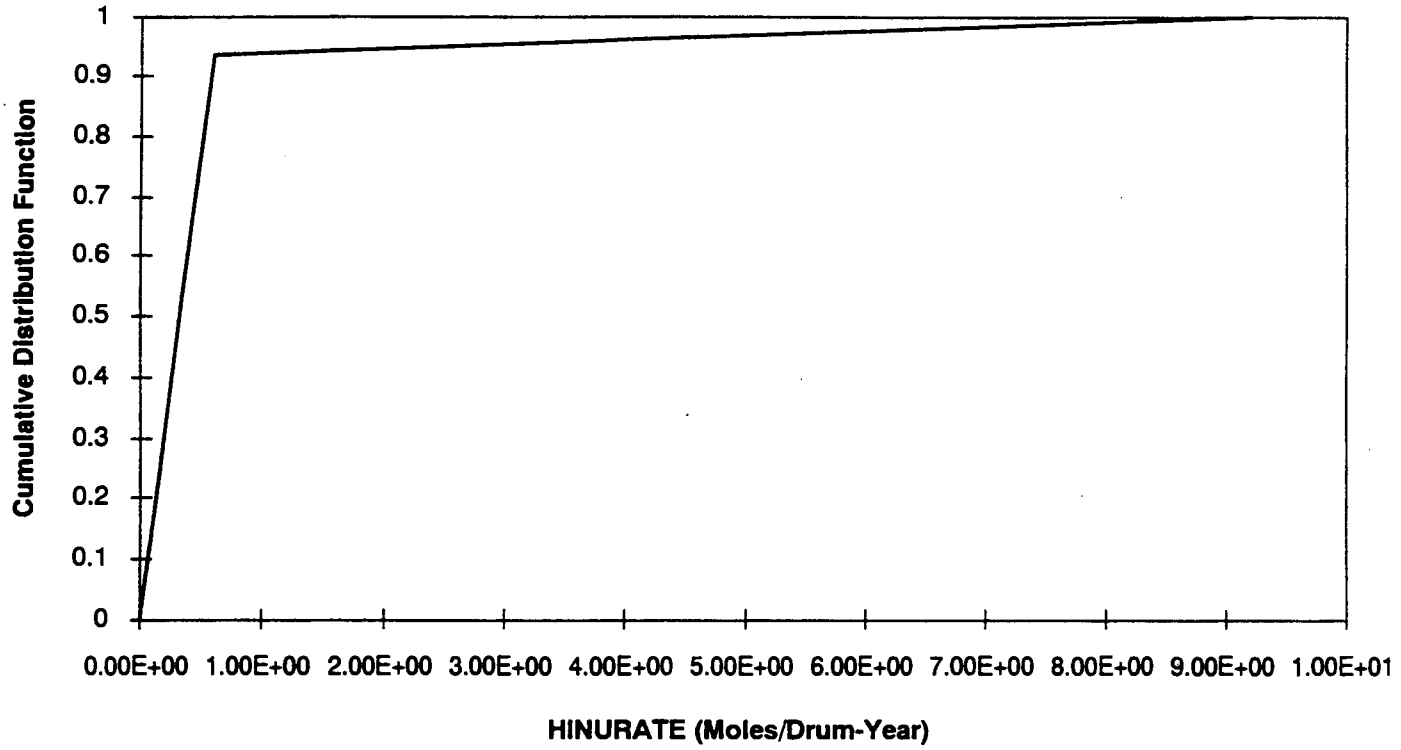

Figure J-1b
Cumulative Distribution Function

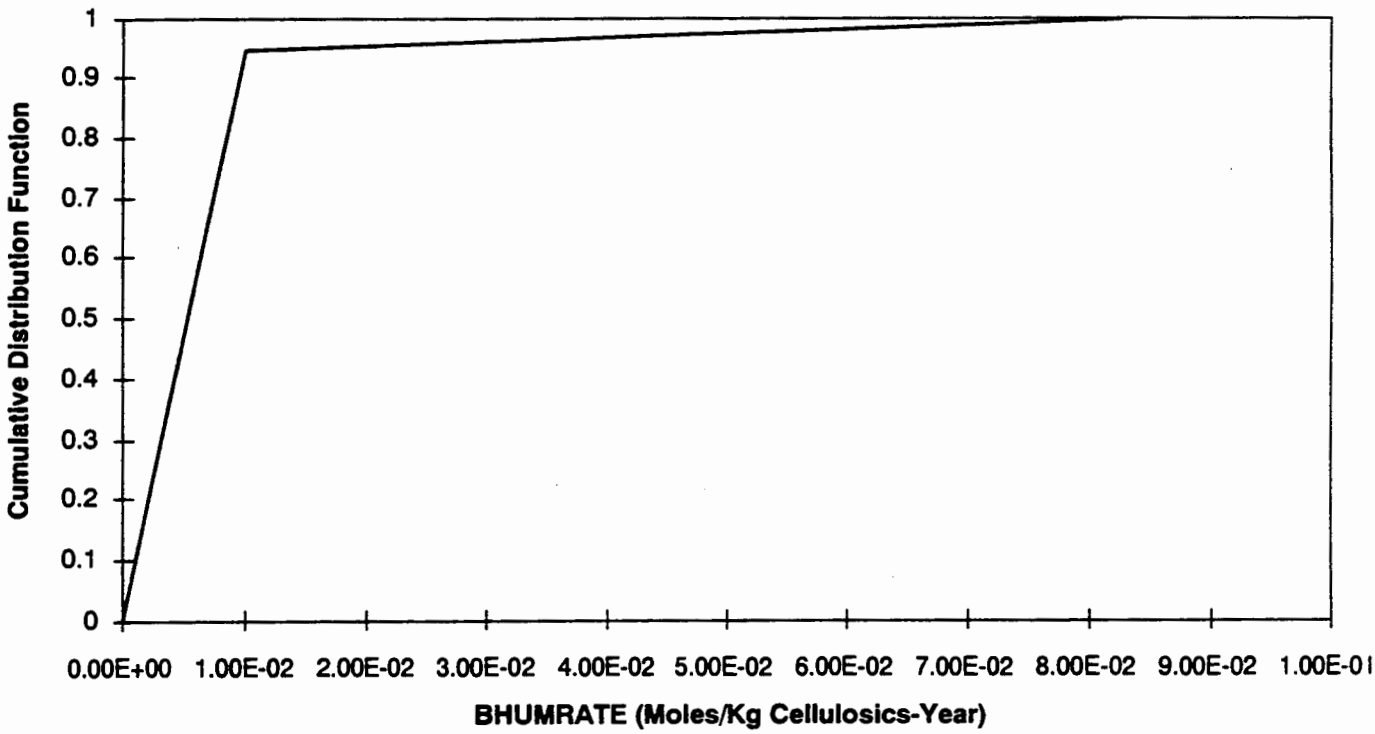

Figure J-1c
Cumulative Distribution Function

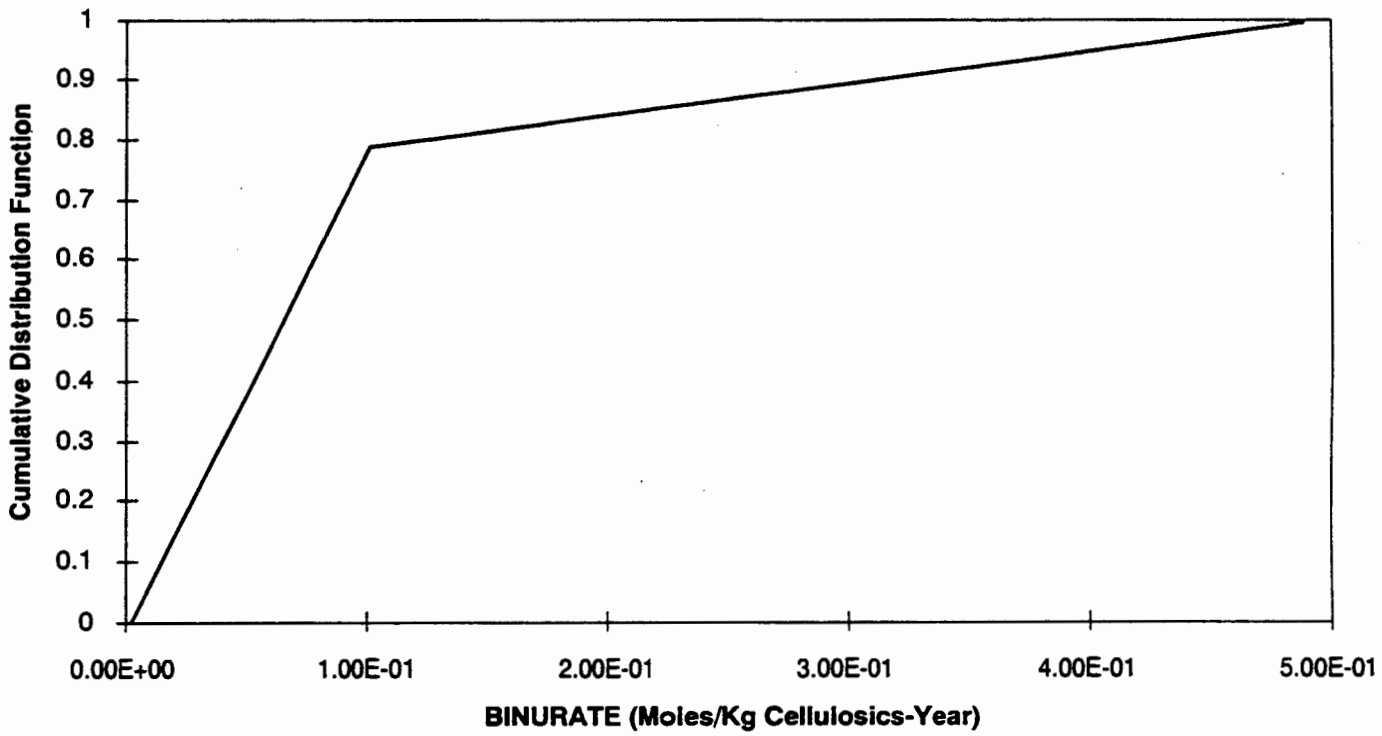

Figure J-1d
Cumulative Distribution Function

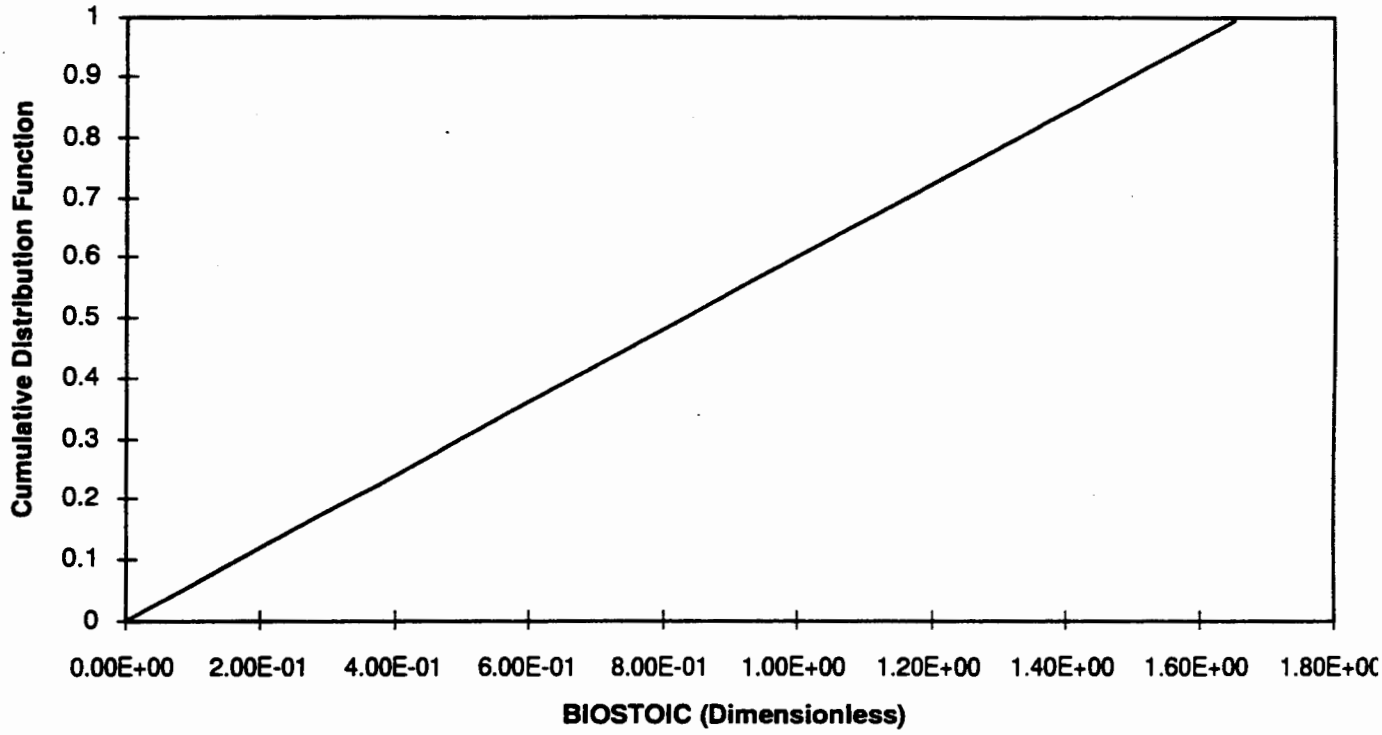

Figure J-1e
Cumulative Distribution Function

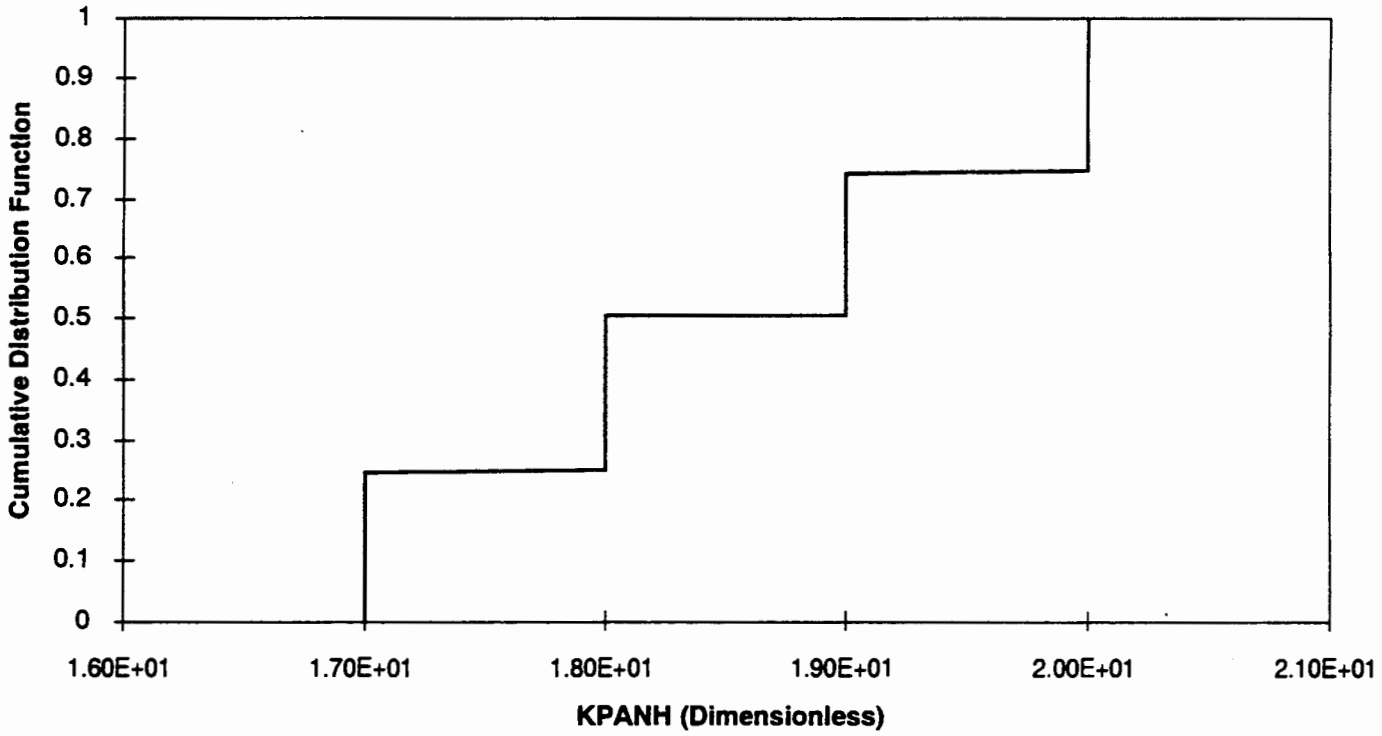

Figure J-1f
Cumulative Distribution Function

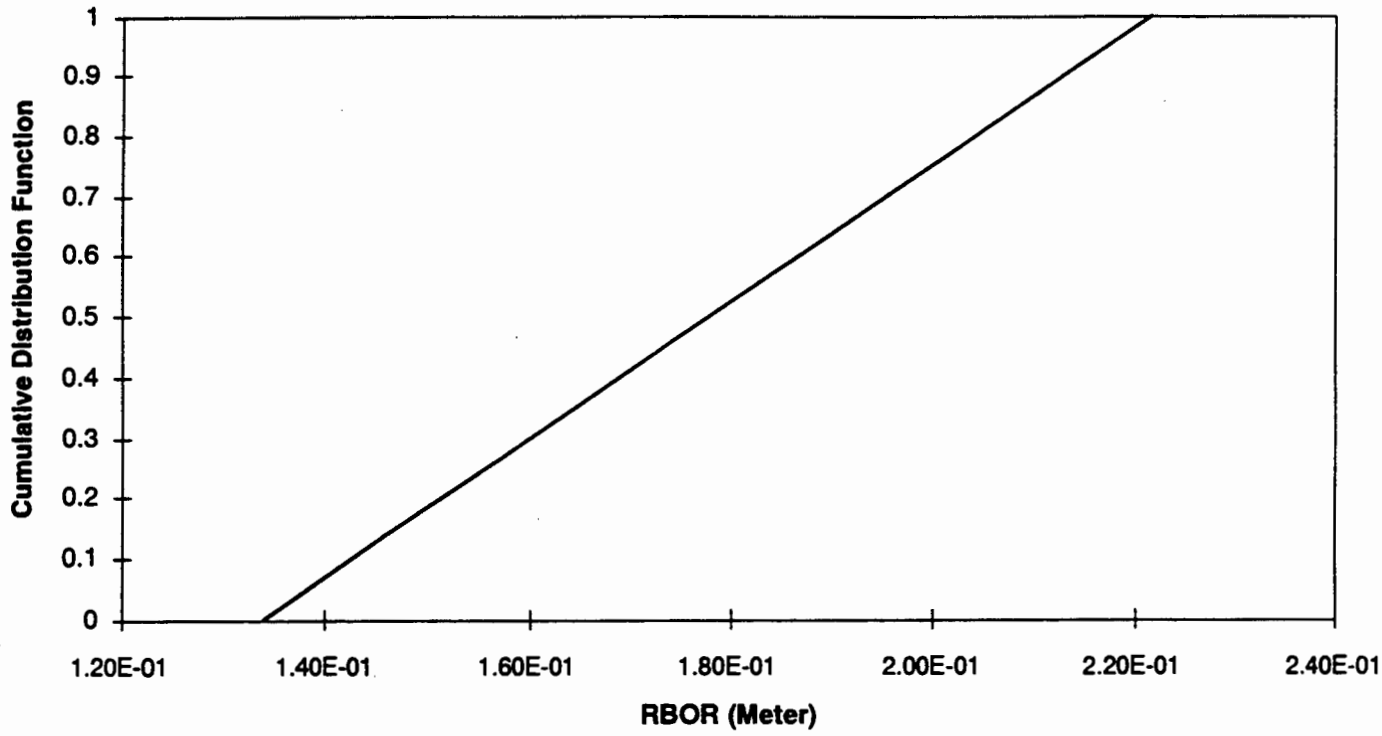

Figure J-1g
Cumulative Distribution Function

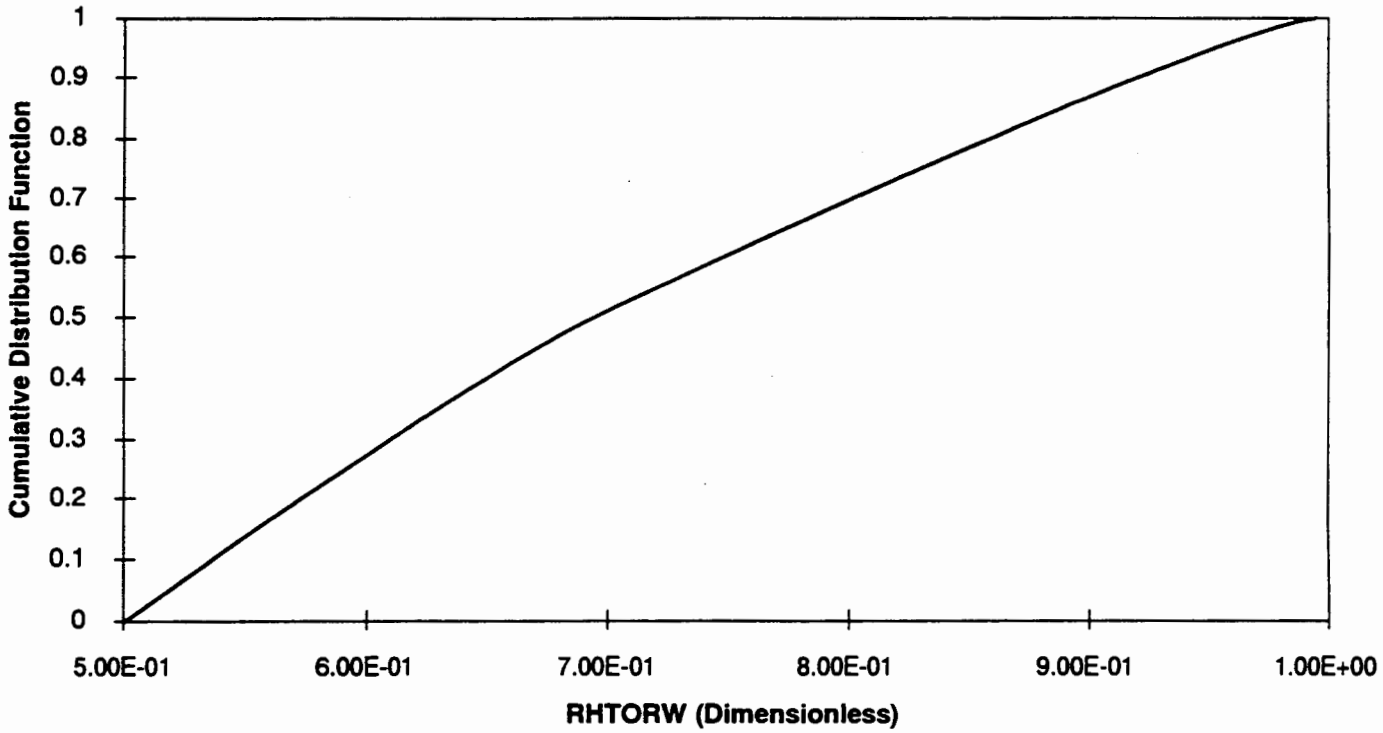

Figure J-1h
Cumulative Distribution Function

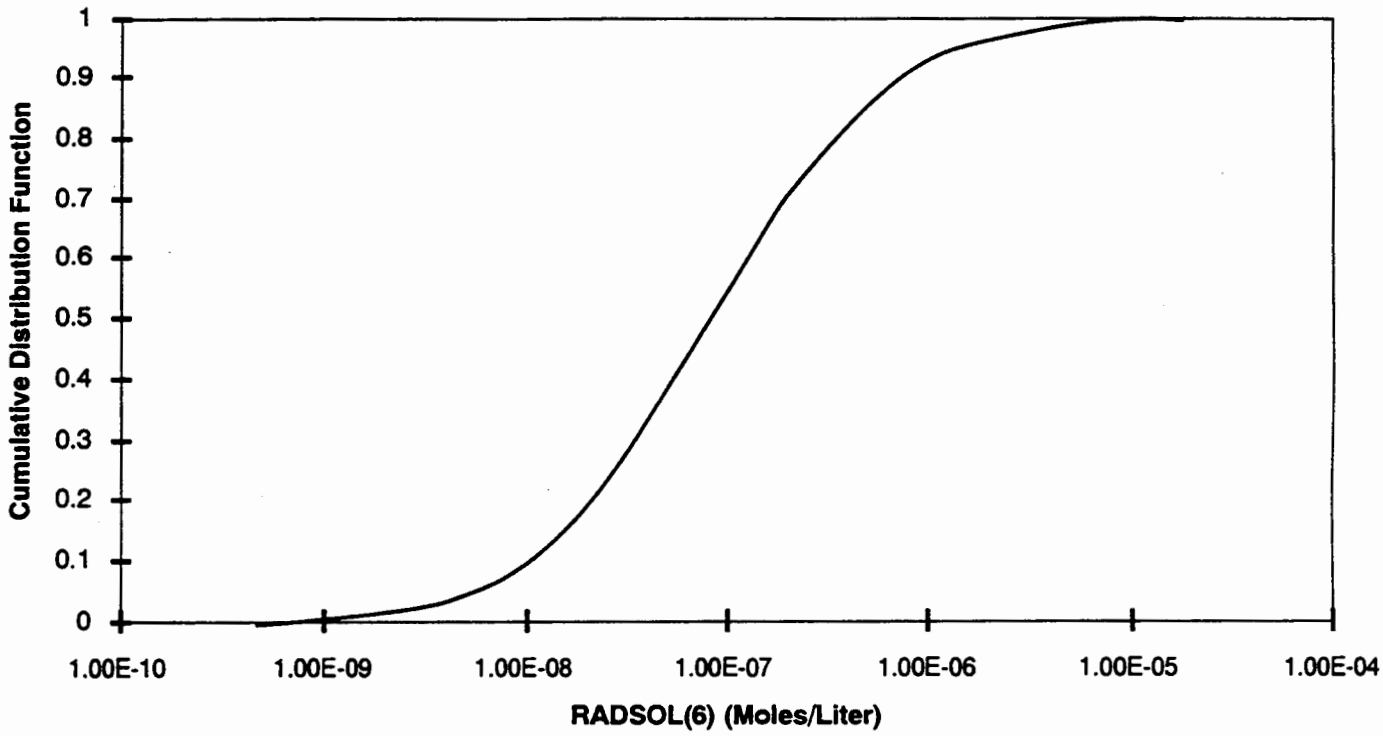

Figure J-1i
Cumulative Distribution Function

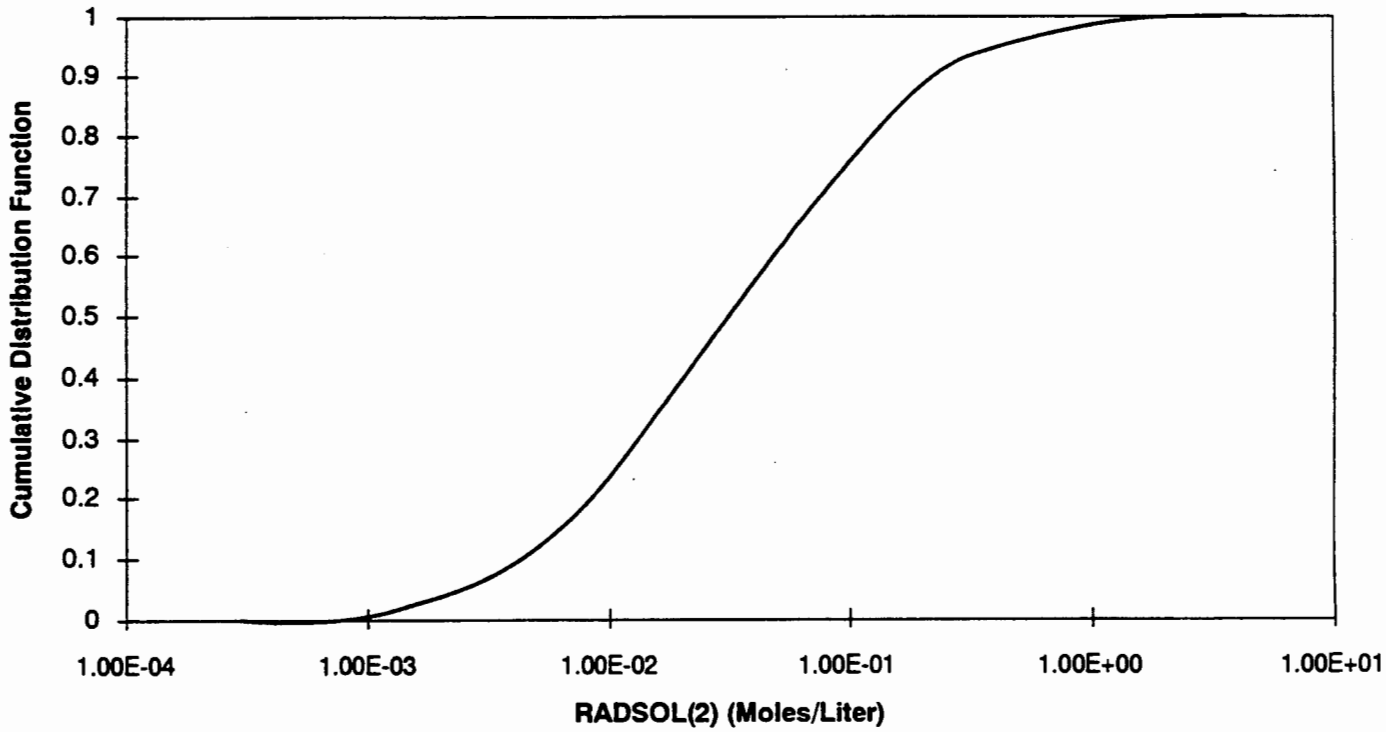

Figure J-1j
Cumulative Distribution Function

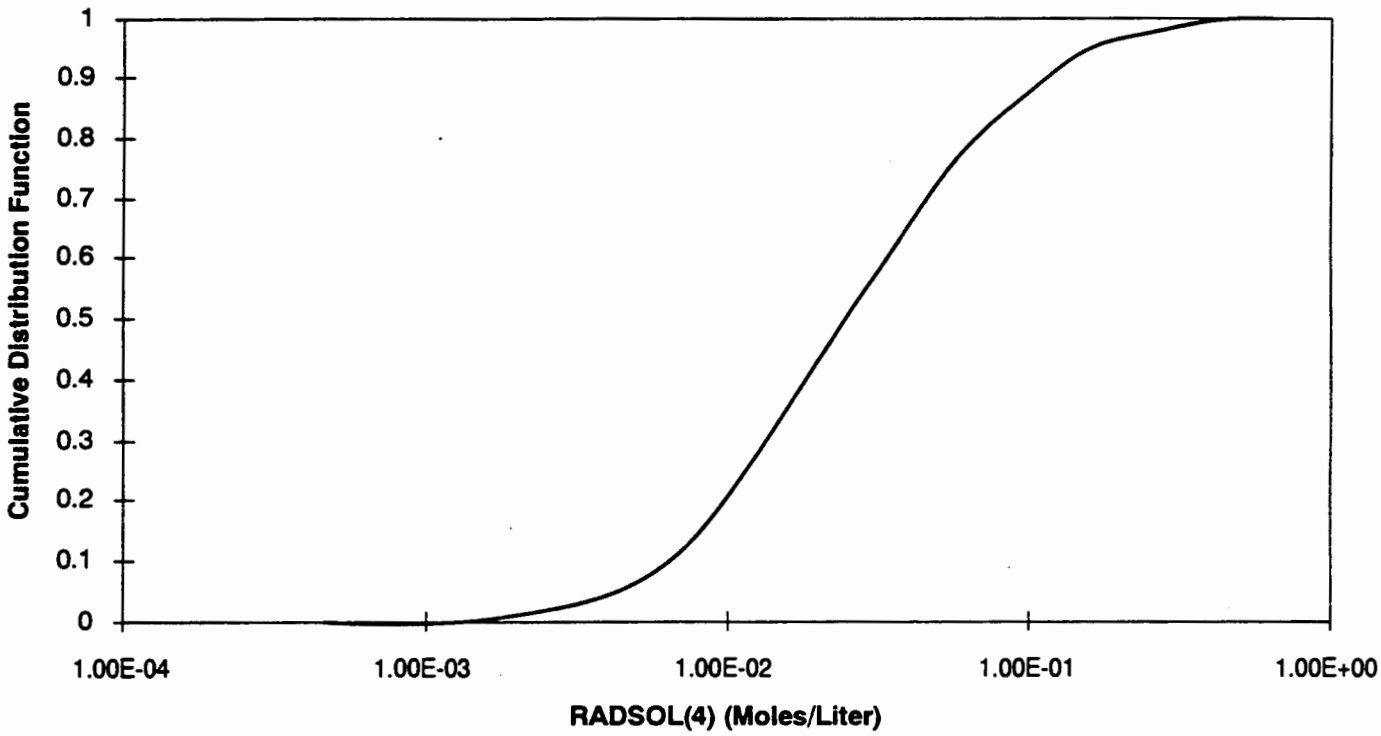

Figure J-1k
Cumulative Distribution Function

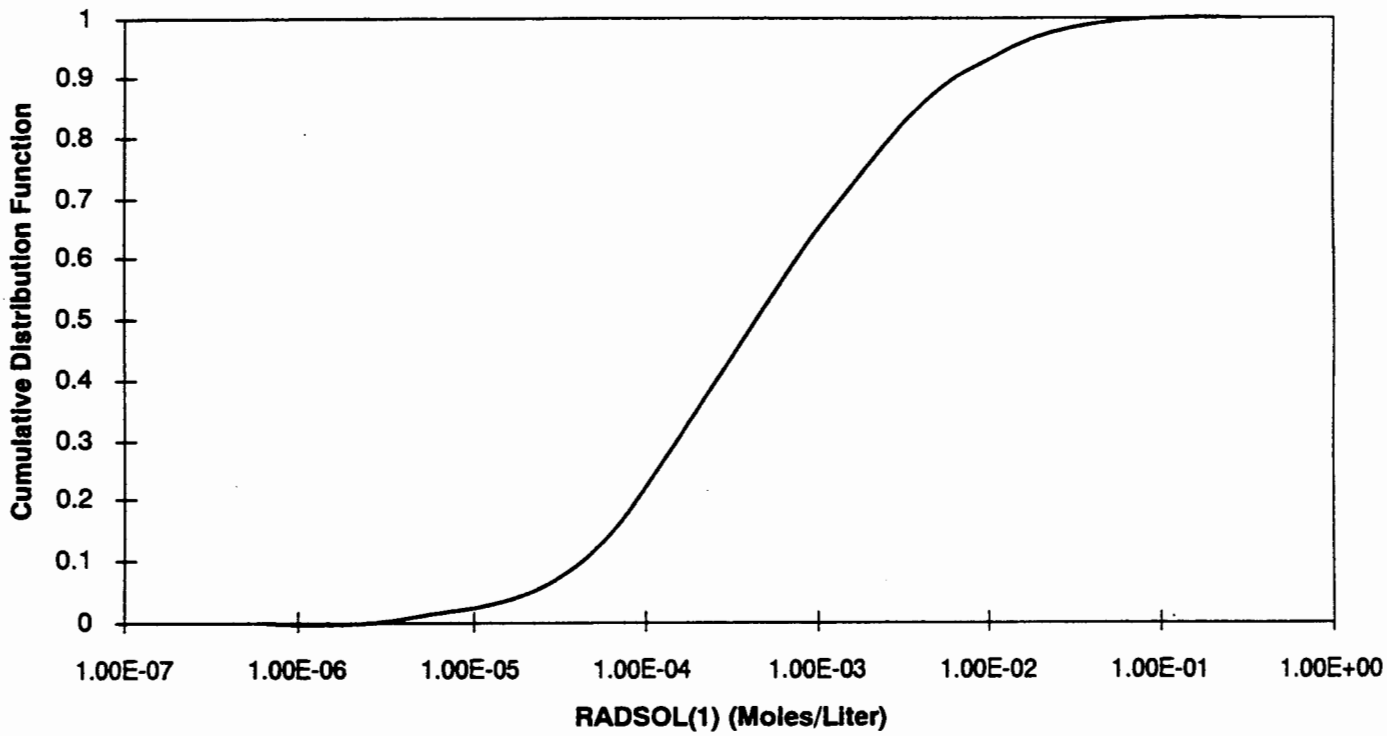

Figure J-1I
Cumulative Distribution Function

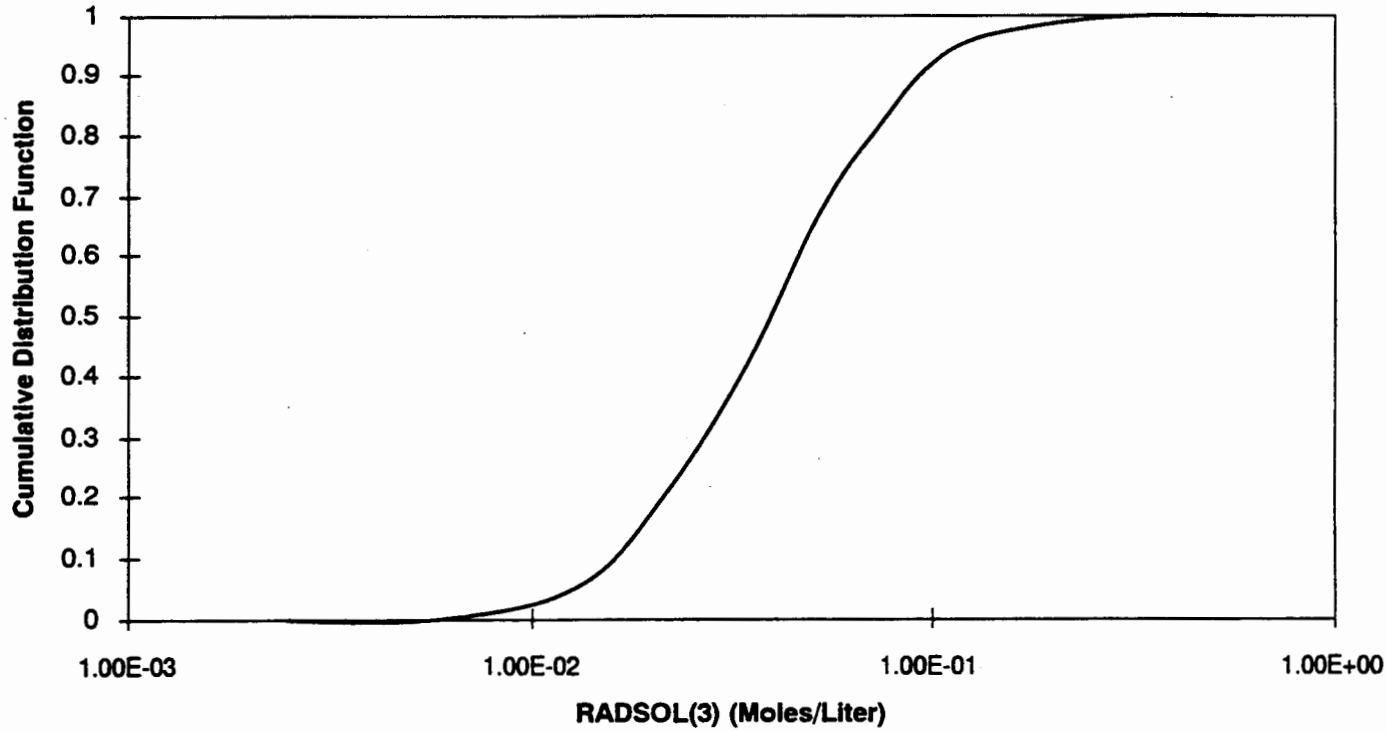

Figure J-1m
Cumulative Distribution Function

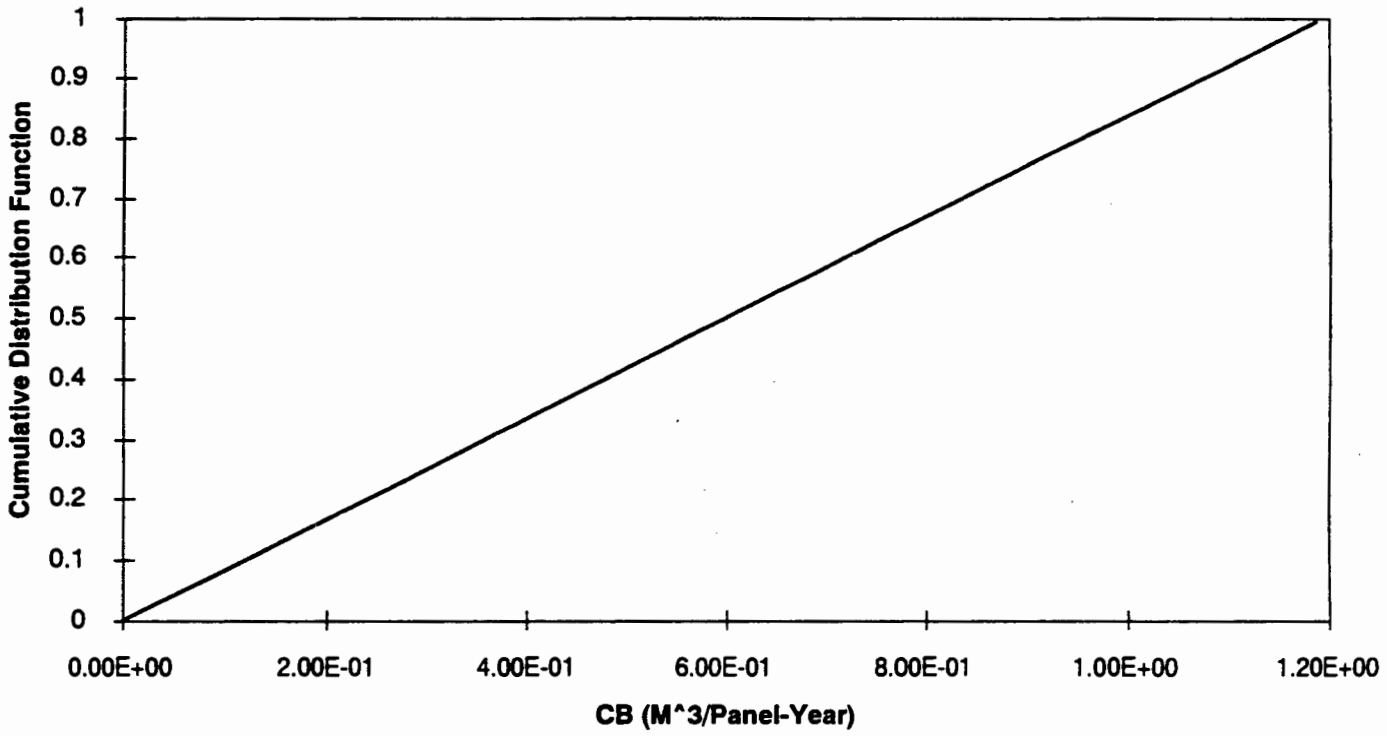

Figure J-1n
Cumulative Distribution Function

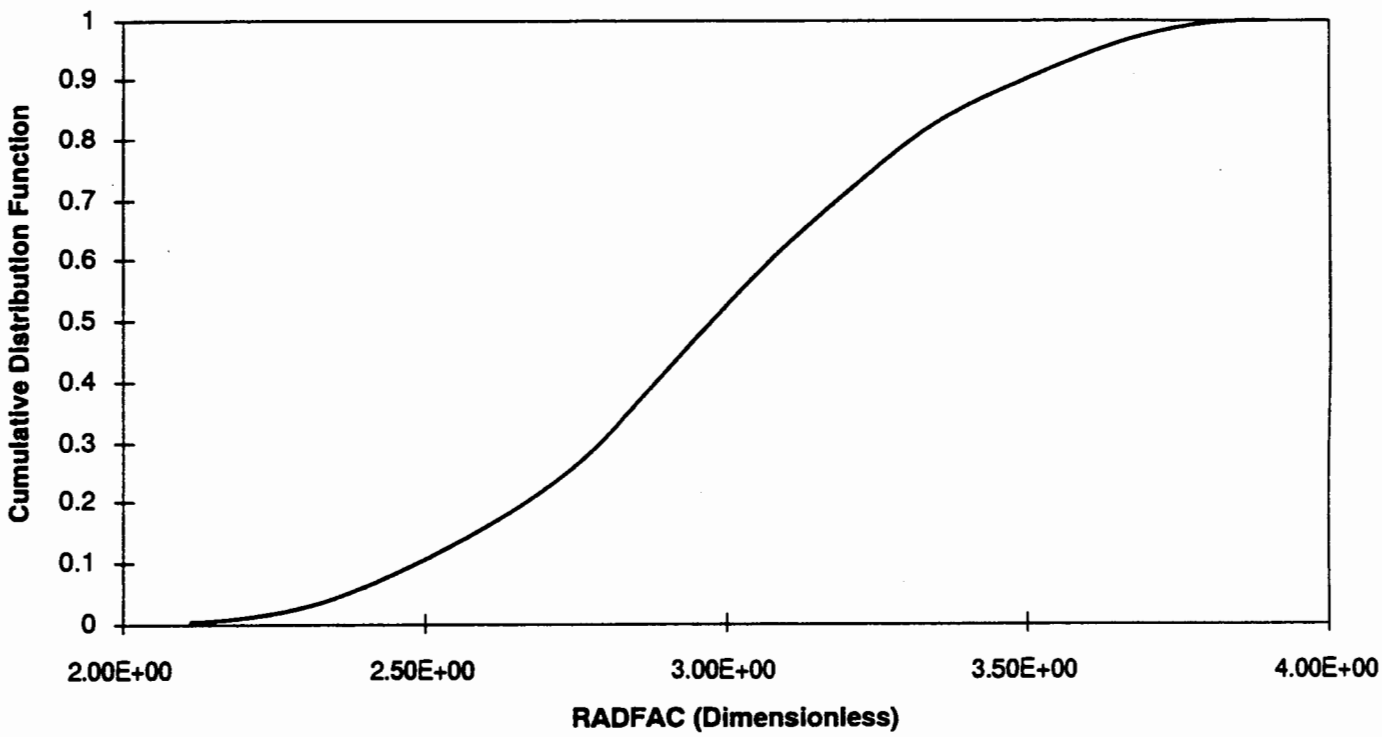

Figure J-1o
Cumulative Distribution Function

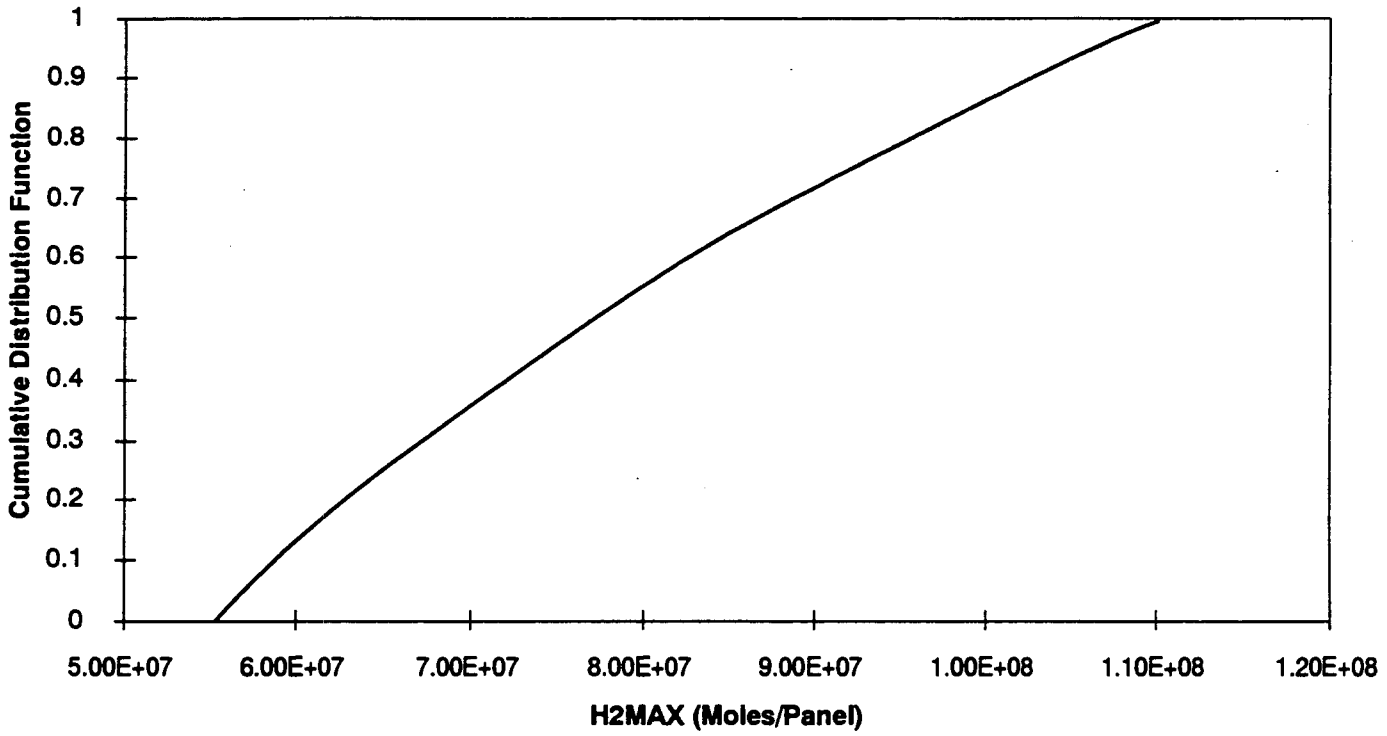

Figure J-1p
Cumulative Distribution Function

- Different Model for the Rate of the Process. The use of the same random number for the two processes reflects the judgement that the humid gas generation rate should never exceed the inundated biodegradation gas generation rate, since the cumulative distribution of the humid process has lower values at all percentiles of the distribution.

- Solubility of Actinides: The solubility of all the isotopes of a given actinide element are considered to be the same, and the elemental distribution is sampled only once for any given random sample calculation. Individual radioelements are sampled independently.

- Maximum Hydrogen Gas Generation Potential for Anoxic Corrosion (H2MAX): This parameter is calculated by multiplying H2MAX0, the parameter that relates the maximum potential based on metal inventory, and RHTORW, the ratio of the hydrogen gas generation rate to water consumption rate. The parameter H2MAX0 is based on an assumed metallic inventory, and is expressed as a constant. Consequently, the value of H2MAX is totally dependent on the random number used to produce RHTORW.

3.0 IMPACT OF ENGINEERED ALTERNATIVES ON INPUT PARAMETER DISTRIBUTIONS

This section documents the changes to the probability distributions of parameters given in Section 2.0 that result from each engineered alternative. The engineered alternative may also impact best point estimates of input parameters to the DAM whose uncertainties were not modeled. Documentation of the those changes can be found in Appendix E.

Table J-2 identifies the changes made to the uncertain input parameters to reflect the influence of the various EAs. The impacts of these changes are discussed below.

3.1 Changes to H2MAX

Waste processing options that reduce the total number of steel waste containers that would be impacted in a given panel of the Waste Isolation Pilot Plant repository have the potential to reduce the maximum hydrogen gas generation potential from anoxic corrosion. This reduction in potential is reflected by changing the value of H2MAX0, the constant coefficient of the equation that generates the distribution for H2MAX.

Three of the waste processing options have the potential to reduce the number of steel waste containers. Table J-3 below relates the quantities by which the containers would be reduced per room to the reduction in H2MAX0. It should be noted that the values of H2MAX0 do not scale directly with the reduction in equivalent drums, since the mass of contaminated metallic waste and interior metallic containers must also be accounted for.

Figure J-2(a-d) compares the CDF for each of these processing options with that of the baseline value of H2MAX. The net effect of the engineered alternative is to shift the maximum potential anoxic gas generation rate in proportion to the reduction in steel available for the reaction. This

TABLE J-2

IMPACT OF ENGINEERED ALTERNATIVES ON UNCERTAIN INPUT PARAMETERS IN THE DESIGN ANALYSIS MODEL

Parameters Having Uncertainty	Variable Description (units)	Impact of EA on Probability Distribution															
		1	6	10	33	35a,b	77a	77b	77c	77d	83	94a	94b	94c,d	94e	94f	111
BHUMRATE	Microbial gas generation rate under humid facility conditions (moles/kg cellulosics-yr)	No Change From Baseline															
BINURATE	Microbial gas generation rate under inundated facility conditions (moles/kg cellulosics-yr)	No Change From Baseline															
BIOSTOIC	Ratio of moles of biogas generated to moles of cellulosics consumed (dimensionless)	No Change From Baseline															
CB	Brine inflow rate at a pressure difference of lithostatic minus atmospheric (m^3/yr-panel)	No Change From Baseline															
H2MAX	Maximum hydrogen gas generation potential from anoxic corrosion (mol/panel)	A	A	A	Baseline		A	A	A	A	No Change from Baseline						
HHUMRATE	Hydrogen gas generation rate from anoxic corrosion under humid facility conditions (moles/drum-yr)	No Change From Baseline															
HINURATE	Hydrogen gas generation rate from anoxic corrosion under inundated facility conditions (moles/drum-yr)	No Change From Baseline															
KPANH	Negative log of the permeability of the anhydrite beds (dimensionless)	No Change from Baseline															
RADFAC	Factor that the drill bit radius (RBOR) is multiplied by to yield an effective radius for use in the cuttings model.	B	B	B	BL	B	B	B	B	B	BL	B	B	B	B	B	BL
RADSOL (1)	Pu-240 solubility in brine (mol/l)	No Change from Baseline								C	C	No Change from BL				C	BL
RADSOL (2)	U-236 solubility in brine (mol/l)	No Change from Baseline								C	C	No Change from BL				C	BL
RADSOL (3)	Am-241 solubility in brine (mol/l)	No Change from Baseline								C	C	No Change from BL				C	BL

TABLE J-2 (Continued)

IMPACT OF ENGINEERED ALTERNATIVES ON UNCERTAIN INPUT PARAMETERS IN THE DESIGN ANALYSIS MODEL

Parameters Having Uncertainty	Variable Description (units)	Impact of EA on Probability Distribution														
		1	6	10	33	35a,b	77a	77b	77c	77d	83	94a	94b	94c,d	94e	94f	111
RADSOL (4)	Np-237 solubility in brine (mol/l)	No Change from Baseline								C	C	No Change from BL				C	BL
RADSOL (5)	U-233 solubility in brine (mol/l)	Completely Correlated With RADSOL(2)															
RADSOL (6)	Th-229 solubility in brine (mol/l)	No Change from Baseline								C	C	No Change from BL				C	BL
RADSOL (7)	Pu-238 solubility in brine (mol/l)	Completely Correlated With RADSOL(1)															
RADSOL (8)	U-234 solubility in brine (mol/l)	Completely Correlated With RADSOL(2)															
RADSOL (9)	Th-230 solubility in brine (mol/l)	Completely Correlated With RADSOL(4)															
RADSOL (12)	Pu-239 solubility in brine (mol/l)	Completely Correlated With RADSOL(1)															
RBOR	Radius of borehole for intrusion scenarios (m)	No Change From Baseline															
RHTORW	Ratio of hydrogen gas generation rate to water consumption rate during anoxic corrosion (dimensionless)	No Change From Baseline															

Notes:

BL No Change from Baseline
A Reflects reduction in the metallic content of waste composite expected to be present with these engineered alternatives.
B Factor reduced to various degrees to reflect improved strength and toughness of waste composite to resist borehole erosion.
C Modified to reflect reduced solubility of actinides at as pH moves from 6.1 to 8.3 due to presence of CaO.

1

TABLE J-3

VALUES OF H2MAX0 BASED ON INVENTORIES OF METAL ASSOCIATED WITH VARIOUS ENGINEERED ALTERNATIVES

Waste Processing Option	Impacted EAs	Equivalent Number Drums per Room	H2MAX0 (moles/panel)
None	Baseline	6421	7.0E+07
Shred and Compact	6	5381	6.7E+07
Super Compact	1	3604	6.1E+07
Super Compact	77a-d	2000	3.4E+07
Plasma Processing	10	2120	3.7E+07

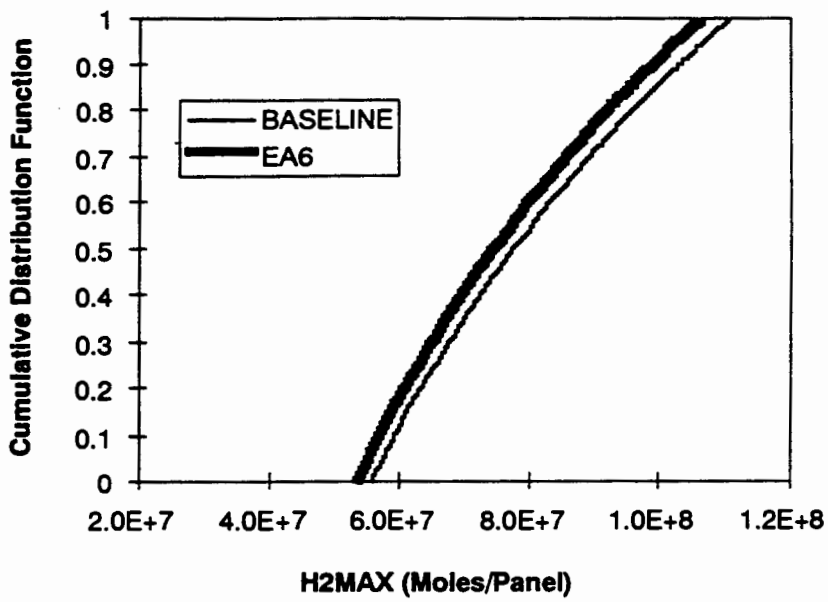

Figure J-2a
Uncertainty Distribution of Input Variable H2MAX for EA6

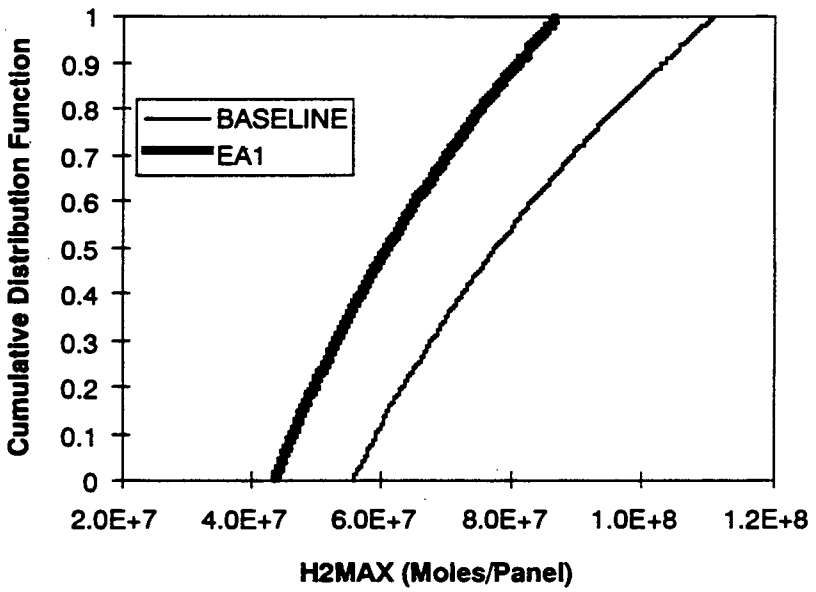

Figure J-2b
Uncertainty Distribution of Input Variable H2MAX for EA1

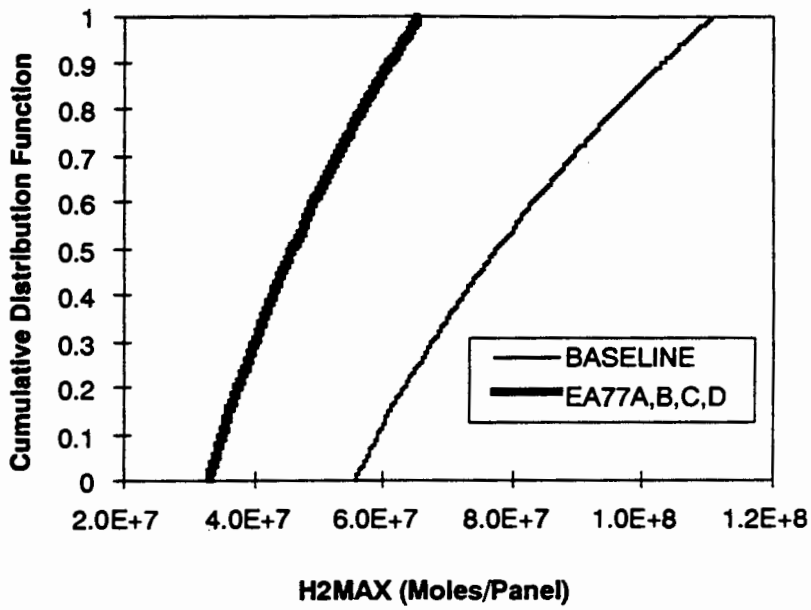

Figure J-2c
Uncertainty Distribution of Input Variable H2MAX for EA77A,B,C,D

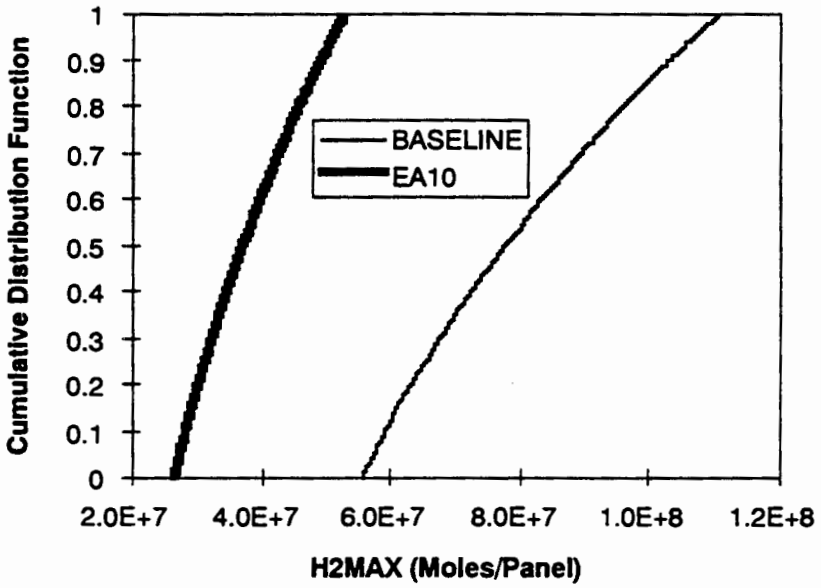

Figure J-2d
Uncertainty Distribution of Input Variable H2MAX for EA10

impact is believed to become important only when there is sufficient water available to totally react with that quantity of steel.

3.2 Changes to RADFAC

Some EAs improve the shear strength and toughness of the waste/backfill composite that forms at the waste horizon after consolidation. As a result, these EAs are expected to exhibit enhanced resistance to enlargement of borehole due to erosion and slurry action during the drilling process. The first principles model of borehole erosion is still under development in Sandia Performance Assessment Model. In the absence of available insights from that model, the strength and toughness of the waste/backfill composite anticipated to be achieved by the various were grouped and judgmentally ranked from highest to lowest resistance to erosion based on their anticipated strength and toughness. The variable RADFAC is a factor that the drill bit radius is multiplied by to determine the effective radius for use in the cuttings release model. The results of the RADFAC ranking is given in the Table J-4.

TABLE J-4

SUMMARY OF STRENGTH AND TOUGHNESS RANKS FOR ASSESSMENT OF RADFAC

Waste/Backfill Composition	EA Case Number	RADFAC Range	Comments
Solid resulting from Plasma Processing, no backfill	10	50% at 1 50% 1->1.3	If the solid does not degrade it should cut cleanly. Minor erosion if it does degrade.
Supercompacted waste both with and without backfill	1, 77a-d	1.5 ± 30%	Super compaction creates a very dense composite structure
Solids shredded and packed with clay, enhanced sludge cement with cementitious or salt aggregate grout backfill	94c,d	1.75 ± 30%	Combination of enhanced cementation of sludges and grout backfill creates strong composite
No waste processing, but cementitious or salt aggregate grout backfill	35a,b	2.0 ± 30%	Grout backfills increase strength of composite
Solids shredded and packed with clay, enhanced sludge cement, with backfills providing no additional toughness	94a,b,e,f	2.3 ± 30%	Enhanced cementation of sludges provides minor strength increase
Shred and Compact Solid Waste, no backfill	6	2.6 ± 30%	Low-force compaction provides only slight increase in strength of composite
Alternatives providing no additional toughness	33,83	3.0 ± 30%	Resistance to erosion taken to be the same as that used for the baseline design.

Figure J-3(a-f) compares the CDF for each of the modified RADFAC values for with that of the baseline value of RADFAC.

3.3 Changes to RADSOL (All Actinide Elements)

When lime is used in the backfill of the repository it raises the pH of the brine flowing into waste horizon. The solubility of actinides that the repository is designed to contain are strongly dependent on the pH of the brine. Within the DAM, this impact is modeled by changing the CDFs for the solubility for five elemental actinide solubility from those corresponding to a pH of 6.1 in the baseline to solubilities for a pH of 8.3. The CDFs associated with these solubility changes are shown in Figure J-4(a-e). These changes are based a regression analysis on actinide solubility presented in Appendix H.

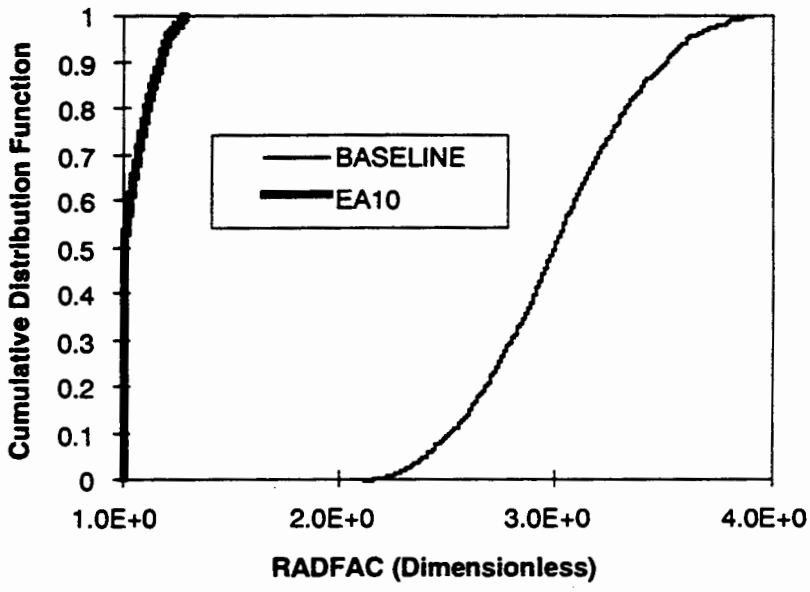

Figure J-3a
Uncertainty Distribution of Input Variable RADFAC for EA10

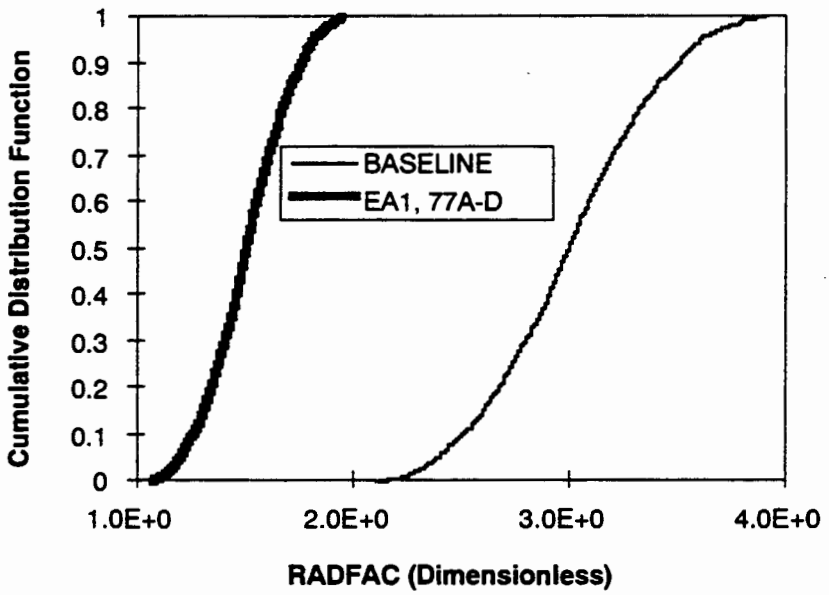

Figure J-3b
Uncertainty Distribution of Input Variable RADFAC for EA1,77A-D

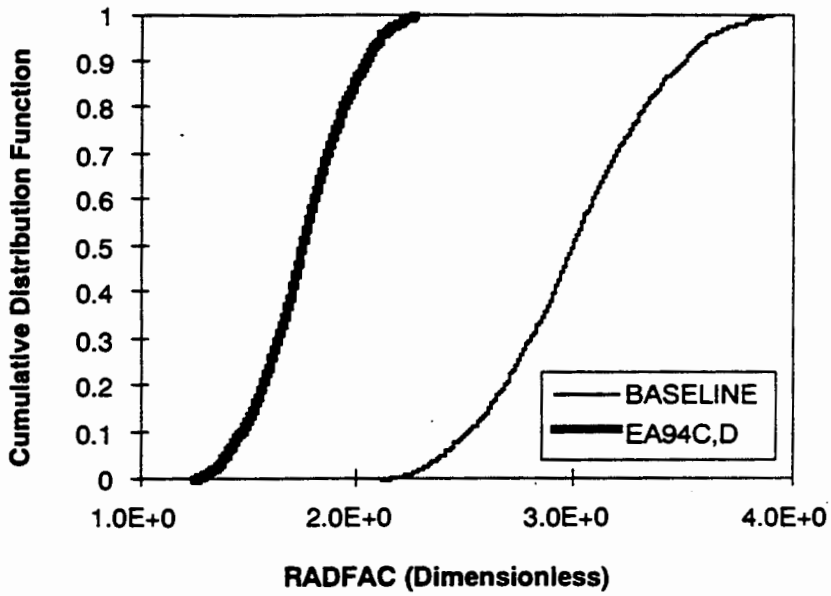

Figure J-3c
Uncertainty Distribution of Input Variable RADFAC for EA94C,D

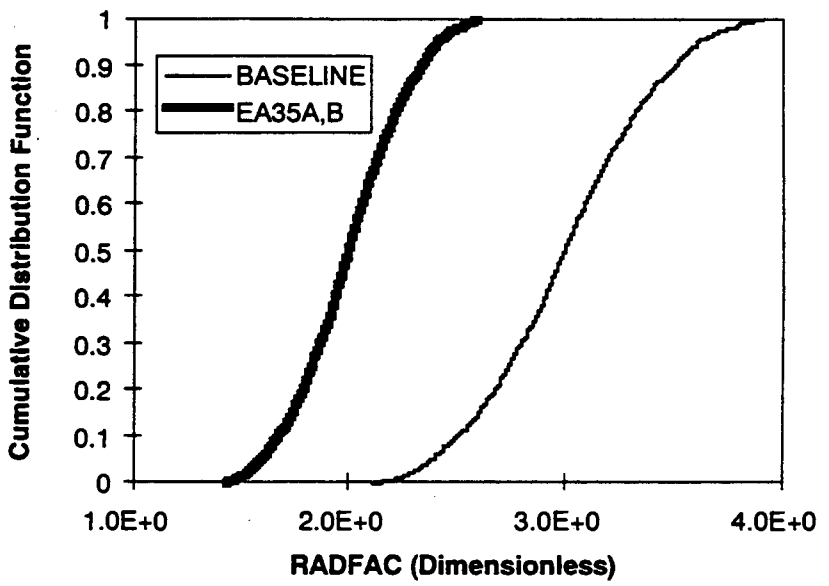

Figure J-3d
Uncertainty Distribution of Input Variable RADFAC for EA35A,B

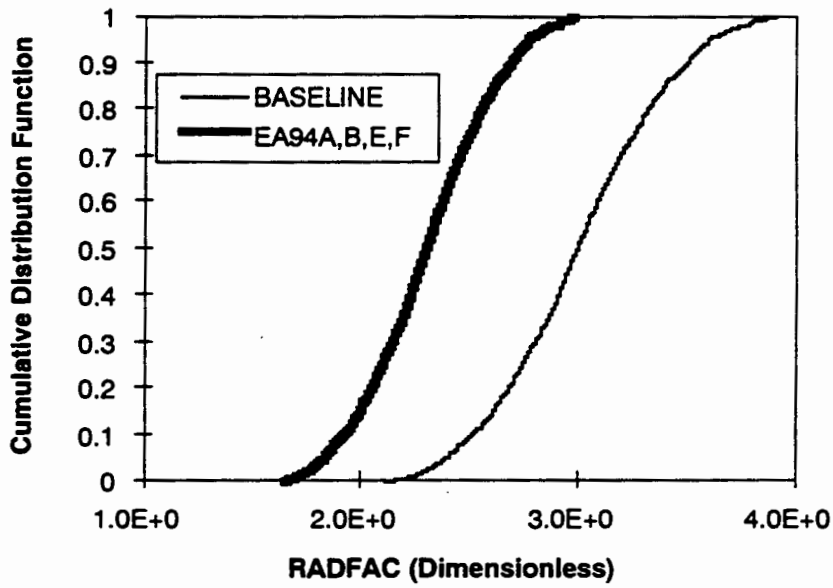

Figure J-3e

Uncertainty Distribution of Input Variable RADFAC for EA94A,B,E,F

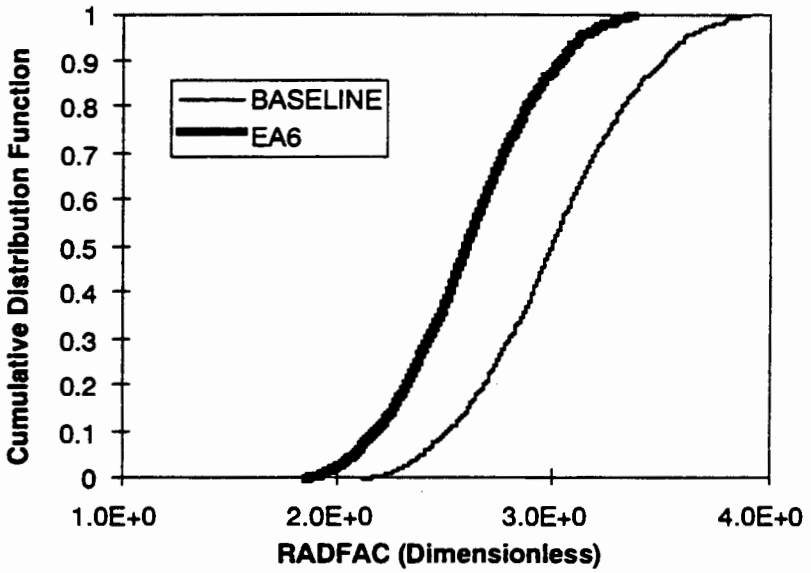

Figure J-3f
Uncertainty Distribution of Input Variable RADFAC for EA6

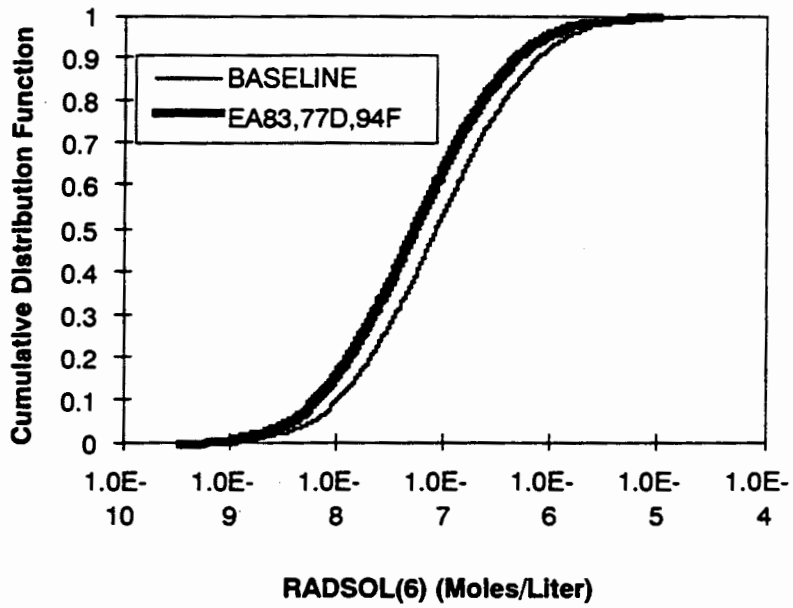

Figure J-4a
Uncertainty Distribution of Input Variable RADSOL(6) for EA83,77D,94F

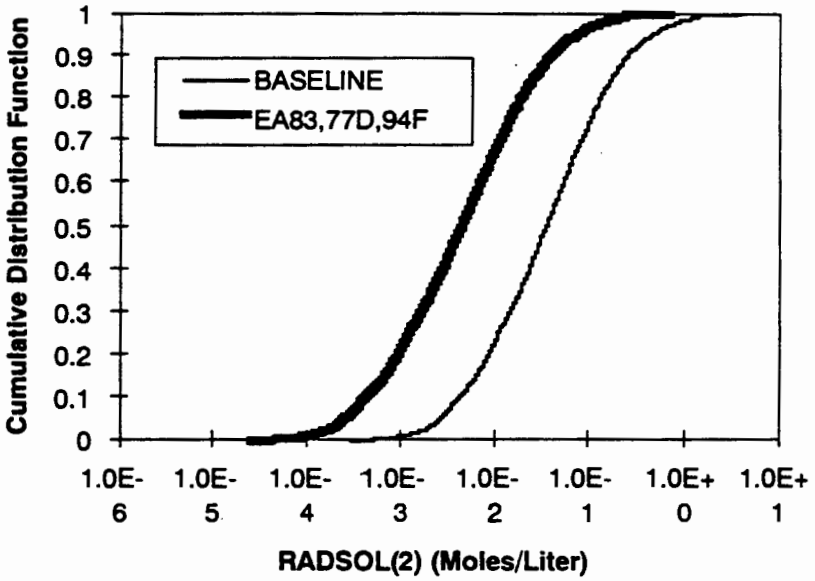

Figure J-4b

Uncertainty Distribution of Input Variable RADSOL(2) for EA83,77D,94F

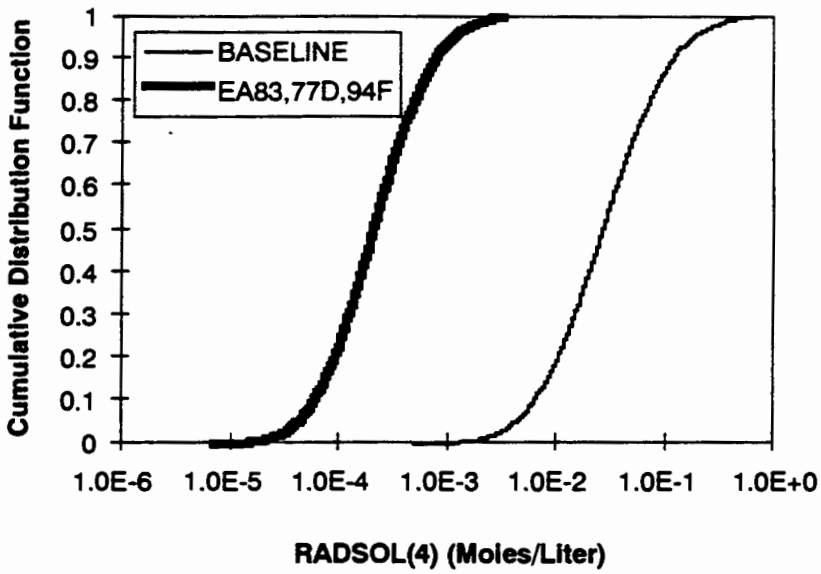

Figure J-4c
Uncertainty Distribution of Input Variable RADSOL(4) for EA83,77D,94F

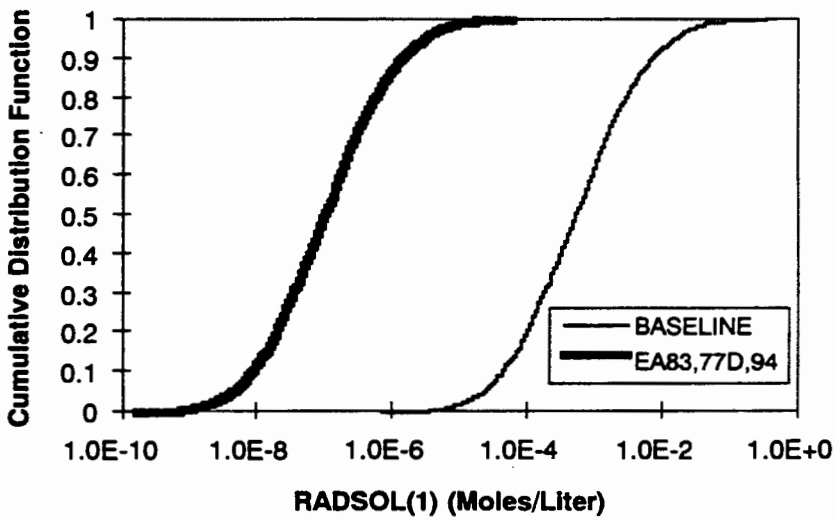

Figure J-4d
Uncertainty Distribution of Input Variable RADSOL(1) for EA83,77D,94F

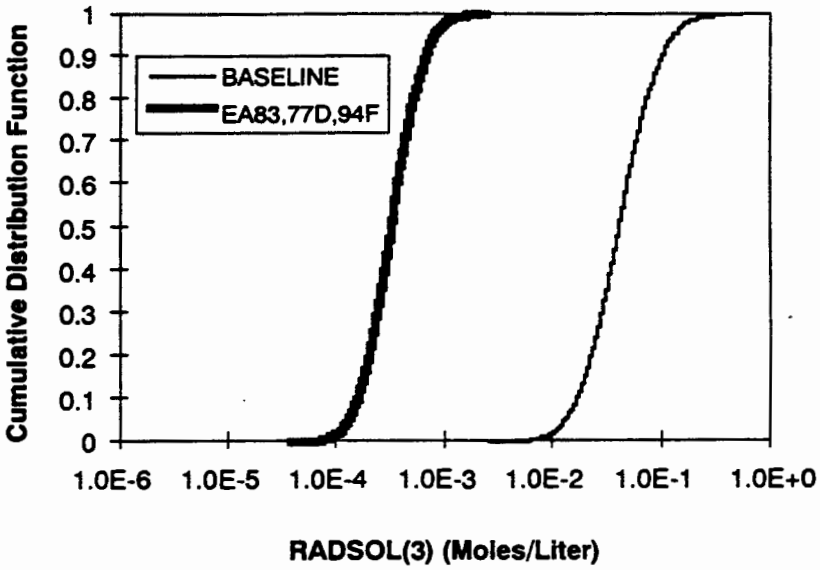

Figure J-4e
Uncertainty Distribution of Input Variable RADSOL(3) for EA83,77D,94F

APPENDIX K

MODELING OF HUMAN HEALTH IMPACTS

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MODELING OF HUMAN HEALTH IMPACTS

1.0 INTRODUCTION

This appendix describes in greater detail the modeling performed to support the data presented in Section 3.3, IMPACT ON WORKER AND PUBLIC RISK. The sections in this appendix are described below. Section 1.0 describes the way scaling factors were used, a general discussion of how they were developed, and the relationships between the available data and the scaling factors developed. Section 2.0 presents the data used from the Waste Management Programmatic Environmental Impact Statement (PEIS). Section 3.0 presents a brief description of the waste volume data, the source, and use of the data. Section 4.0 is a discussion of the Full-Time Equivalent (FTE) curves, the development of scaling factors from the data in those curves, and the application of the derived scaling factors. Section 5.0 describes the site specific risk models and scaling factors developed from those models. Sections 2.0 through 5.0 deal primarily with modeling for waste handling and processing facilities throughout the U.S. Department of Energy (DOE) system. Section 6.0 details the models used to estimate the human health impacts from specific Waste Isolation Pilot Plant (WIPP) waste handling and disposal activities including aboveground waste handling, emplacement below ground, and installation of backfill materials after emplacement of the waste.

2.0 GENERAL SCALING PRINCIPLES USED IN SECTION 3.3

As described in Section 3.3.2.1 of the report, estimation of the impacts to the various groups for differing activities performed at multiple sites and combinations of sites requires very complex models and involves large data sets, both of which are beyond the needs and scope of this report. The method used to analyze the numerous combinations of waste processes and processing configurations was to develop scaling factors specific to the available analytical results. The PEIS data include DOE system-wide summations for an adequate range of risk endpoints but only for a limited number of processes and processing configurations (see Section 2.0 for a complete discussion of results available from the PEIS). Overall scaling factors are needed to apply to the site-wide risk data to model additional treatment facility configurations and additional types of processing. Risk factors are available for sites with a significant amount of transuranic (TRU) waste but only for certain combinations of risk factors. Modeling was performed to adjust the available data to account for more recent estimates of TRU waste currently available and estimated to be generated in the future. This allowed the development of system-wide scaling factors to be applied to the PEIS system-wide data for those processes and configurations applicable to the selected engineered alternatives (EA).

Additional modeling was required to adjust the individual site estimates of risk found in the PEIS for differences between processes and configurations in the PEIS and those analyzed in the EA report. This involved not only the modeling of waste processing of varying amounts of waste at processing facilities, but also risks involved with retrieving and preparing the waste for shipment to the waste processing facilities. In the case of alternates involving supercompaction of waste, data were combined from both the PEIS and another source to develop the scaling factors to be applied to the appropriate PEIS data. The new estimates of site risks were combined and used

to calculate system-wide scaling factors to be applied to the most appropriate PEIS system-wide risk data.

3.0 PEIS DATA

The cases for which program-wide and individual facility risk data are available in the PEIS are described in Section 3.3.3 of the report. The March 1995 draft of the PEIS (DOE, 1995b) included program-wide risk data for the four cases that are used as the basis of the EA risk estimations by applying appropriate scaling factors. Tables K-1[1] through K-4 show the applicable system-wide data from the March draft of the PEIS.

The PEIS also listed site-specific risk data but did not use the same breakdown of risk parameters. Table K-5 shows the acronyms used to identify the sites in the remainder of the appendix. Tables K-6 through K-9 show the PEIS site-specific data for the four applicable cases. The fatalities shown for the individual sites include fatalities associated with both radiation exposures and physical hazards. The cancer incidence shown on these tables includes those associated with both radiation and chemical carcinogen exposures.

The waste volumes on which the PEIS risk estimates were based are shown in Table K-10. The source for these data was the November 4, 1994, draft of the PEIS (DOE, 1994a). For each site, the PEIS data included the total assumed to be in storage and an estimated annual generation rate. The total waste shown in the last column was calculated by multiplying the annual rate shown by the 20-year waste processing period and adding that to the waste in storage at that facility.

4.0 SCALING FACTORS FOR CO-LOCATED WORKERS AND OFF-SITE INDIVIDUALS

The major contributor to the risks for off-site personnel is the material released to the air during waste handling. That is also true for co-located worker personnel. The model assumes that air releases are a function of the process and throughput. The relationship between process and release rate is too complex to be addressed in this model so each process is treated uniquely. That is, there is no effort to use releases from shred and compact waste to estimate the releases from plasma processing. The model treats airborne releases as proportional to throughput. That is, if throughput is increased by 20 percent, the normal airborne releases also increase by 20 percent.

The airborne releases from a given process or module may be proportional to the waste throughput, but the impact of those releases is not. For a given amount of material released to the air, the impact on off-site personnel and co-located workers is a very complex function of meteorology, population density, and distribution around the facility, and the location of the individuals who may be candidates for the most exposed individual. However, for long-term

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[1]Please note that throughout this appendix, the following notation is frequently used in tables: 1.23e-4 is equivalent to 1.23×10^{-4}.

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TABLE K-1

SYSTEM-WIDE HUMAN HEALTH IMPACTS
MEET WIPP WAC AT 10 LOCATIONS
PEIS CASE 4

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Co-located Workers	Dose (person-rem)	2.30e-02			
	Excess Fatalities	1.10e-05			
	Excess Cancers		3.40e-08		
Most Exposed Co-located Individual	Dose (rem)	9.50e-06			
	Excess Risk	4.80e-09			
	Excess Cancers		8.90e-12		
	Hazard Index			1.40e-09	
Offsite Population	Dose (person-rem)	2.40e-01			
	Excess Fatalities	1.20e-04			
	Excess Cancers		1.30e-07		
Most Exposed Offsite Individual	Dose (rem)	1.10e-05			
	Excess Risk	5.70e-09			
	Excess Cancers		2.80e-12		
	Hazard Index			1.50e-10	
Workers	Dose (FTE-rem)	1.50e+03			
	Excess Fatalities	6.00e-01			
	Excess Cancers		1.00e-05		
	Exposure Index			3.10e-05	
	Construction Fatalities				7.80e-01
	Construction Injuries				6.70e+02
	Operations Fatalities				1.40e+00
	Operations Injuries				5.90e+02

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TABLE K-2

SYSTEM-WIDE HUMAN HEALTH IMPACTS
SHRED AND GROUT AT 5 LOCATIONS
PEIS CASE 5

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Co-located Workers	Dose (person-rem)	3.20e-01			
	Excess Fatalities	1.60e-05			
	Excess Cancers		5.80e-08		
Most Exposed Co-located Individual	Dose (rem)	1.50e-05			
	Excess Risk	7.70e-09			
	Excess Cancers		1.50e-11		
	Hazard Index			2.50e-09	
Offsite Population	Dose (person-rem)	3.40e-01			
	Excess Fatalities	1.70e-04			
	Excess Cancers		2.30e-07		
Most Exposed Offsite Individual	Dose (rem)	1.40e-05			
	Excess Risk	6.90e-09			
	Excess Cancers		4.80e-12		
	Hazard Index			2.20e-10	
Workers	Dose (FTE-rem)	1.60e+03			
	Excess Fatalities	6.30e-01			
	Excess Cancers		2.00e-05		
	Exposure Index			3.10e-05	
	Construction Fatalities				1.00e+00
	Construction Injuries				8.70e+02
	Operations Fatalities				1.70e+00
	Operations Injuries				7.50e+02

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TABLE K-3

SYSTEM-WIDE HUMAN HEALTH IMPACTS
INCINERATE AT 5 LOCATIONS
PEIS CASE 6

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Co-located Workers	Dose (person-rem)	6.90e+02			
	Excess Fatalities	3.40e-01			
	Excess Cancers		5.60e-08		
Most Exposed Co-located Individual	Dose (rem)	4.90e-01			
	Excess Risk	2.40e-04			
	Excess Cancers		1.50e-11		
	Hazard Index			1.30e-07	
Offsite Population	Dose (person-rem)	6.70e+03			
	Excess Fatalities	3.30e+00			
	Excess Cancers		2.20e-07		
Most Exposed Offsite Individual	Dose (rem)	1.30e-01			
	Excess Risk	6.70e-05			
	Excess Cancers		4.80e-12		
	Hazard Index			1.10e-08	
Workers	Dose (FTE-rem)	1.50e+03			
	Excess Fatalities	6.10e-01			
	Excess Cancers		2.50e-05		
	Exposure Index			8.60e-04	
	Construction Fatalities				1.80e+00
	Construction Injuries				1.50e+03
	Operations Fatalities				2.60e+00
	Operations Injuries				1.10e+03

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TABLE K-4

SYSTEM-WIDE HUMAN HEALTH IMPACTS
INCINERATE AT 1 LOCATION
PEIS CASE 9

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Co-located Workers	Dose (person-rem)	9.90e+01			
	Excess Fatalities	5.00e-02			
	Excess Cancers		6.60e-08		
Most Exposed Co-located Individual	Dose (rem)	3.80e-01			
	Excess Risk	1.90e-04			
	Excess Cancers		1.50e-11		
	Hazard Index			4.60e-07	
Offsite Population	Dose (person-rem)	1.20e+03			
	Excess Fatalities	6.10e-01			
	Excess Cancers		2.30e-07		
Most Exposed Offsite Individual	Dose (rem)	3.20e-01			
	Excess Risk	1.60e-04			
	Excess Cancers		4.80e-12		
	Hazard Index			7.60e-08	
Workers	Dose (FTE-rem)	1.70e+03			
	Excess Fatalities	6.80e-01			
	Excess Cancers		8.60e-05		
	Exposure Index			1.10e-03	
	Construction Fatalities				1.20e+00
	Construction Injuries				1.10e+03
	Operations Fatalities				1.80e+00
	Operations Injuries				7.90e+02

TABLE K-5

FACILITY ACRONYMS

Department of Energy Facility	Acronym
Ames Laboratory	Ames
Argonne National Laboratory-East	ANL-E
Bettes	BT
Energy Technology Engineering Center	ETEC
Hanford	Hanford
Idaho National Engineering Laboratory	INEL
Knolls Atomic Propulsion Laboratory	KAPL
Los Alamos National Laboratory	LANL
Lawrence Berkeley Laboratory	LBL
Lawrence Livermore National Laboratory	LLNL
Mound Plant	Mound
University of Missouri at Columbia	UMC
Nevada Test Site	NTS
Oak Ridge National Laboratory	ORNL
Paducah Gaseous Diffusion Plant	PGDP
Pantex Plant	Pantex
Rocky Flats Environmental Technology Site	RFETS
Sandia National Laboratories	SNL
Savannah River Site	SRS

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TABLE K-6

PEIS RISK DATA
TREAT TO MEET WIPP WAC (CASE 4)

	Fatalities			Cancer Incidence		
Site	Public	Offsite MEI	Worker	Public	Offsite MEI	Public
ANL-E	1.80e-06	9.90e-12	1.00e-01	6.10e-06	3.40e-11	3.00e-02
Hanford	1.40e-06	2.90e-11	3.30e-01	4.80e-06	9.90e-11	3.60e-01
INEL	1.10e-06	1.40e-10	1.00e+00	3.80e-06	4.80e-10	8.70e-01
LANL	5.40e-05	5.70e-09	4.90e-01	1.80e-04	1.90e-08	5.00e-01
LBL	6.30e-09	9.40e-14	8.40e-03	2.10e-08	3.20e-13	7.60e-09
LLNL	3.50e-06	5.70e-11	1.10e-01	1.20e-05	2.00e-10	2.00e-03
Mound	8.40e-07	4.80e-11	3.20e-02	2.90e-06	1.60e-10	4.80e-04
NTS	1.10e-10	3.00e-14	6.80e-02	3.90e-10	1.00e-13	7.30e-04
ORNL	0.00e+00	0.00e+00	4.70e-04	0.00e+00	0.00e+00	7.90e-14
PGDP	3.50e-09	3.50e-09	1.30e-02	1.20e-08	1.30e-12	1.60e-06
RFETS	9.30e-06	1.30e-10	2.20e-01	3.20e-05	4.30e-10	2.70e-02
SNL	2.70e-09	1.10e-13	8.70e-03	9.10e-09	3.60e-13	2.10e-08
SRS	5.10e-05	4.80e-10	3.50e-01	1.70e-04	1.60e-09	3.10e-01

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TABLE K-7

PEIS RISK DATA
SHRED AND GROUT (CASE 5)

	Fatalities			Cancer Incidence		
Site	Public	Offsite MEI	Worker	Public	Offsite MEI	Public
ANL-E	1.50e-06	8.50e-12	4.50e-02	5.20e-06	2.90e-11	3.00e-02
Hanford	2.30e-06	4.70e-11	5.30e-01	7.70e-06	1.60e-10	4.50e-01
INEL	1.40e-06	1.80e-10	1.20e+00	4.90e-06	6.00e-10	8.70e-01
LANL	6.50e-05	6.90e-09	6.40e-01	2.20e-04	2.30e-08	5.00e-01
LBL	9.80e-09	1.50e-13	1.80e-04	3.40e-08	5.00e-13	7.50e-09
LLNL	3.60e-06	5.90e-11	5.70e-02	1.30e-05	2.10e-10	2.00e-03
Mound	1.50e-06	8.60e-11	1.40e-02	5.10e-06	2.90e-10	4.70e-04
NTS	1.50e-10	3.90e-14	4.20e-02	5.10e-10	1.30e-13	7.00e-04
ORNL						
PGDP	5.30e-09	5.90e-13	2.50e-03	1.80e-08	2.00e-12	1.70e-06
RFETS	1.50e-05	2.00e-10	3.40e-01	5.10e-05	6.90e-10	2.70e-02
SNL	3.50e-09	1.40e-13	4.50e-04	1.20e-08	4.80e-13	2.10e-08
SRS	8.10e-05	7.70e-10	4.60e-01	2.80e-04	2.60e-09	3.10e-01

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TABLE K-8

PEIS RISK DATA
INCINERATE AT 5 SITES (CASE 6)

	Fatalities			Cancer Incidence		
Site	Public	Offsite MEI	Worker	Public	Offsite MEI	Public
ANL-E	1.50e-06	8.50e-12	4.50e-02	5.20e-06	2.90e-11	3.00e-02
Hanford	4.50e-03	9.40e-08	8.10e-01	1.60e-02	3.20e-07	4.90e-01
INEL	7.30e-03	9.10e-07	1.80e+00	2.50e-02	3.10e-06	8.30e-01
LANL	6.40e-01	6.70e-05	9.60e-01	2.20e+00	2.30e-04	4.80e-01
LBL	9.80e-09	1.50e-13	1.80e-04	3.40e-08	5.00e-13	7.50e-09
LLNL	3.60e-06	5.90e-11	5.70e-02	1.30e-05	2.10e-10	2.00e-03
Mound	1.50e-06	8.60e-11	1.40e-02	5.10e-06	2.90e-10	4.70e-04
NTS	1.50e-10	3.90e-14	4.20e-02	5.10e-10	1.30e-13	7.00e-04
ORNL						
PGDP	5.30e-09	5.90e-13	2.50e-03	1.80e-08	2.00e-12	1.70e-06
RFETS	1.10e-01	1.50e-06	5.70e-01	3.70e-01	5.00e-06	2.50e-02
SNL	3.50e-09	1.40e-13	4.50e-04	1.20e-08	4.80e-13	2.10e-08
SRS	2.60e+00	2.40e-05	6.80e-01	8.80e+00	8.20e-05	3.00e-01

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TABLE K-9

PEIS RISK DATA
INCINERATE AT 1 SITE (CASE 9)

	Fatalities			Cancer Incidence		
Site	Public	Offsite MEI	Worker	Public	Offsite MEI	Public
ANL-E	1.50e-06	8.50e-12	4.50e-02	5.20e-06	2.90e-11	3.00e-02
Hanford	1.30e-06	2.70e-11	2.40e-01	4.40e-06	9.10e-11	3.30e-01
INEL	1.60e-06	2.00e-10	7.60e-01	5.30e-06	6.60e-10	8.50e-01
LANL	7.10e-05	7.40e-09	3.80e-01	2.40e-04	2.50e-08	5.00e-01
LBL	9.80e-09	1.50e-13	1.80e-04	3.40e-08	5.00e-13	7.50e-09
LLNL	3.60e-06	5.90e-11	5.70e-02	1.30e-05	2.10e-10	2.00e-03
Mound	1.50e-06	8.60e-11	1.40e-02	5.10e-06	2.90e-10	4.70e-04
NTS	1.50e-10	3.90e-14	4.20e-02	5.10e-10	1.30e-13	7.00e-04
ORNL						
PGDP	5.30e-09	5.90e-13	2.50e-03	1.80e-08	2.00e-12	1.70e-06
RFETS	1.20e-05	1.60e-10	1.60e-01	4.10e-05	5.60e-10	1.00e-01
SNL	3.50e-09	1.40e-13	4.50e-04	1.20e-08	4.80e-13	2.10e-08
SRS	6.40e-05	6.00e-10	2.20e-01	2.20e-04	2.00e-09	3.30e-01

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TABLE K-10

PEIS TRANSURANIC WASTE VOLUMES
TOTAL WASTE IN STORAGE AND GENERATED OVER 20 YEARS

Site	Stored Waste (cubic meters)	Annual Generation (cubic meters / year)	Total (cubic meters)
ANL-E	15.00	47.00	955.00
Hanford	9987.00	465.00	19287.00
INEL	38095.00	14.00	38375.00
LANL	8199.00	125.00	10699.00
LBL	0.80	0.01	1.00
LLNL	200.00	74.00	1680.00
Mound	255.00	60.00	1455.00
NTS	612.00	0.00	612.00
ORNL	670.00	18.00	1030.00
PGDP	14.00	0.00	14.00
RFETS	1480.00	238.00	6240.00
SNL	1.00	0.00	1.00
SRS	5371.00	605.00	17471.00
UMC	0.10	2.00	40.10
Total	64899.90	1648.01	97860.10

releases, the impacts at individual sites may be modeled as a function of waste throughput.

Therefore, the modeling is performed for each process at each site and the impacts combined to establish a combined impact for all facilities.

Waste throughput at each site may vary for three reasons. One reason is that the total amount of waste processed in the PEIS would not be the amount needed to fill WIPP to capacity. The second reason is that more recent estimates of waste currently stored at sites or likely to be generated at sites have a different distribution throughout the DOE system than were used in the PEIS calculations. Thirdly, as the consolidation configuration changes, the throughput at individual sites varies from that used in the PEIS. For example, the PEIS Case 5 involves transporting waste from throughout the system to five selected sites where it is processed by shredding and grouting the waste. More recent data on waste volumes and estimated generation make the amounts to be treated at each of the five selected sites different in this model from the PEIS model. The EA model must also assume a greater total waste, distributed among the five sites, to meet WIPP's design limit. Finally, this model must also estimate the impact of the shredding and grouting of waste at 10 selected sites and a single site.

The first two volume effects are treated simultaneously by comparing the waste to be handled at each site in the PEIS, without regard to what process is to be performed, to that estimated to be handled in the EA model. The latter data were determined as part of the estimation of cost and schedule and are explained in Section 3.7.2.1 of the report. The EA scaled waste totals are shown in Table K-11. A linear scaling factor was determined for each site by dividing the EA scaled throughput for each site by the PEIS throughput for that site.

The volume effect from consolidating waste at various sites was performed in an analogous way for each consolidation configuration. For each site where waste is to be consolidated, the sum of waste from all sites contributing to that site was determined. Table K-12 shows the consolidation configurations used. This was done based on both the PEIS waste total for each site and the EA waste total. Scaling factors for each consolidation configuration were developed by dividing the total EA throughput by the PEIS throughput for the same combination of sites. For example, in the distributed configuration, where waste processing is performed at 10 sites, Hanford processes only it's own waste. Therefore, the volume scaling factor for Hanford in the distributed configuration (10 sites) is

$$\begin{aligned} Scaling\ Factor_{Hanford,\ 10\ site} &= \frac{EA\ Throughput_{Hanford}}{PEIS\ Throughput_{Hanford}} \\ &= \frac{48044.55}{19287.00} \\ &= 2.49 \end{aligned}$$

In the regional (five site) configuration, the wastes from Lawrence Berkeley Laboratory (LBL) and Lawrence Livermore National Laboratory (LLNL) are shipped to Hanford for treatment. The scaling factor for Hanford in the regional configuration (five sites) is

These scaling factors are then used to estimate corrections to the PEIS risk data by multiplying the appropriate PEIS risk factor for the Hanford site by the desired scaling factor. See

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TABLE K-11

ENGINEERED ALTERNATIVES SCALED TOTAL WASTE VOLUMES TOTAL WASTE IN STORAGE AND GENERATED OVER 20 YEARS

Site	Total Waste (cubic meters)
Ames	0.13
ANL-E	31.31
BT	159.90
ETEC	8.61
Hanford	48044.55
INEL	39203.61
KAPL	2.40
LANL	20805.18
LBL	6.57
LLNL	1158.04
Mound	263.29
UMC	2.14
NTS	612.60
ORNL	1124.94
PGDP	2.10
Pantex	0.62
RFETS	6249.25
SNL	17.11
SRS	26653.39
Total	144345.73

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TABLE K-12

WIPP ENGINEERED ALTERNATIVES HUMAN HEALTH IMPACTS TRU WASTE CONSOLIDATION CONFIGURATIONS

Consolidation Configuration	Processing Site	Sites Supplying Waste
Distributed (10 sites)	ANL-E	Ames, ANL-E, UMC
	Hanford	Hanford
	INEL	INEL
	LANL	LANL, Pantex, SNL
	LLNL	LBL, LLNL
	Mound	BT, KAPL, Mound, WVDP
	NTS	ETEC, NTS
	ORNL	ORNL, Paducah
	RFETS	RFETS
	SRS	SRS
Regional (5 Sites)	Hanford	Hanford, LBL, LLNL
	INEL	ETEC, INEL, NTS
	LANL	LANL, Pantex, SNL
	RFETS	RFETS
	SRS	Ames, ANL-E, BT, KAPL, Mound, MU, ORNL, Paducah, SRS, WVDP
Centralized (1 Site)	WIPP	All sites

$$Scaling\ Factor_{Hanford,\ 5\ site} = \frac{EA\ Throughput_{Hanford+LBL+LLNL}}{PEIS\ Throughput_{Hanford+LBL+LLNL}} = \frac{48044.55+6.57+1158.04}{19287.00+1.00+1680.00} = 2.35$$

Section 5.0 of this appendix for a more extended explanation of the use of the scaling factors.

5.0 SCALING FACTORS FOR WASTE HANDLING WORKERS

The primary influences on the impacts to workers are materials released to the working environment, especially the air, and external exposures from radioactive material, especially from waste and processing equipment. Exposures from these sources are more a function of the time spent in the work area than the amount of material processed. The amount of work time is expressed in FTEs. The number of injuries and fatalities from physical hazards are also a function of the FTEs. FTEs are a function of waste throughput, but because of volume efficiencies and other factors, the function is not linear with respect to waste throughput. Therefore, scaling factors for adjusting the PEIS risk data for workers are based on variations in the total number of FTEs projected for the 20-year processing facility lifetime.

The PEIS analysis used selections of individual process modules (waste receiving and inspection, waste compaction, incineration, etc.) to model different types of waste process streams. Curves of FTEs as a function of waste throughput were developed to model each module (Feizollahi and Shropshire, 1994). For each type of module, curves have been plotted for construction, preoperational activities, 10- and 20-year operations and maintenance (O&M), decontamination and decommissioning (D&D), and 10- and 20-year total FTEs. Polynomial equations were developed to fit each of the curves. Table K-13 shows an example of the curves and curve equations.

Two of the components of the greatest importance in estimating worker impacts are the 20-year O&M total FTEs and the construction FTEs. The O&M activities are not only the major contributor to the total FTEs, but it is during O&M activities that most worker exposures are expected to occur. Construction activities are of particular importance because they involve a large number of FTEs and often represent a time of increased risks from physical hazards. Equations were used to calculated O&M and construction FTEs for the following modules: waste retrieval, receipt and inspection, waste characterization, waste compaction, shred and grout, incineration, vitrification, and certification and shipping. Table K-14 lists the equations developed for each of the modules. The equations were used to calculate the total FTEs required for each type of module at each site for each consolidation configuration based on the throughputs used in the PEIS. Because the PEIS throughputs were given in cubic meters, the conversion to kilograms per hour (kg/hr) was made based on 20 years of operation, 4,032 hours per year, and an average waste density of 594 kg/cubic meter. Similar calculations were also performed based on the mass-flows representing the EA volumes shown in Table K-11.

TABLE K-13

FULL TIME EQUIVALENTS (FTES) AS A FUNCTION OF WASTE THROUGHPUT
WASTE RECEIPT AND INSPECTION

TABLE K-14

MODELING
FULL TIME EQUIVALENTS AS A FUNCTION OF WASTE THROUGHPUT (KG/HR)

Waste Handling Module	Construction Curve Fit Equation	O&M Curve Fit Equation
Retrieval	1.79e-0x + 10.1	3.64x + 181.37
Receipt and Inspection	$-3.3e-6x^2 + 4.68e-2x + 9.37$	$4.50e-9x^3 - 6.00e-5x^2 + 3.45e-1x + 16.27$
Waste Characterization	4.78x + 156.89	9.56x + 313.77
Compaction	1.13e-1x +170.18	$1.70e-7x^3 - 6.70e-4x^2 + 1.20x + 491.7$
Shred and Grout	$-3.9e-5x^2 + 1.85e-1x + 214.4$	$9.1e-8x^3 - 3.80e-4x^2 + 6.13e-1x + 264.4$
Incineration	3.14e-1x + 275	1.09x + 767.2
Vitrification	$-3.5e-8x^4 + 4.1e-5x^3 - 0.0173x^2 + 3.582x + 480.1$	$1.61e-3x^2 + 2.95x + 937$
Certification and Shipping	1.22e-2x + 45.752	1.02e-1x + 298.61

System-wide FTE scaling factors were calculated for each alternative case and configuration. The methods used to calculate the scaling factor were the same for each case and configuration but the details of what combination of modules and waste throughputs were used were different for each case and configuration. The following paragraphs describe the common method used. Details are presented in tabular form. All calculations were performed for both construction and O&M scaling factors. Only one set of calculations will be described. The only difference between the calculations for construction and O&M scaling factors is the values for the individual FTE totals, the initial database.

For each PEIS case, modules were selected that would be used in the particular waste process. Table K-15 lists the modules used for each PEIS case. It was assumed that the process of shipping waste to another site for treatment, including the necessary inspections, is numerically equivalent in FTEs and exposures to the receipt and inspection of incoming waste at a processing facility. For each PEIS case, the total FTEs were calculated for each site by summing the FTEs from the individual modules. FTE site totals were calculated for each waste processing used in the alternatives in the same way as the PEIS totals. Table K-15 shows which modules were used in each EA waste processing.

Site FTE scaling factors were calculated for each EA waste process and each consolidation configuration. Whenever possible, the site FTE total for the EA waste process was divided by the site FTE total from the equivalent PEIS case. However, there are more combinations of EA waste processes and consolidation configurations than there are PEIS cases that are equivalent. In these cases, the ratio was formed between EA and PEIS cases that involved different consolidation configurations or between two EA alternatives, one of which was established by comparing it to an equivalent PEIS case. Table K-16 lists the combinations of cases used to assess each alternative and consolidation configuration.

It should be noted that not all modules apply to each site in a particular PEIS case or EA alternative; nor are the EA and PEIS sets of modules necessarily the same. Each site must be considered individually in each waste processing and configuration combination. As an example of how modules were combined, Table K-17 displays the module combinations used to establish the FTE scaling factor for plasma processing at 10 sites by comparing FTEs for EA modules at 10 sites with the PEIS modules at 5 sites.

As described in Section 5.0, the site-specific scaling factors were used to adjust the PEIS-based worker risk estimates.

6.0 SYSTEM-WIDE SCALING FACTORS

6.1 Volume-based Scaling Factors

In order to extend the PEIS system-wide risk estimates, as shown in Tables K-1 through K-4, to additional consolidation configurations and processes, the analysis model must provide system-wide scaling factors. These were developed by comparing the total of the PEIS site risk results with the totals of the scaled site-specific data. The effect is to produce a weighted average of the individual site scaling factor for co-located worker/off-site personnel risks and for worker risks for each waste process and consolidation configuration. As an example, Table K-18 shows the

TABLE K-15

TRU WASTE HANDLING MODULES USED TO MODEL WASTE PROCESSING PEIS CASES AND ENGINEERED ALTERNATIVES

	RETRV[1]	INSHP[2]	RCINS[3]	GROUT[4]	CSHIP[5]	CMPCT[6]	INCIN[7]	WCHA[8]	VITRFY[9]
PEIS									
Treat to Meet WIPP WAC	●				●			●	
Shred and Grout	●	●	●	●	●				
Incinerate	●	●	●		●		●		
Engineered Alternatives									
Baseline	●				●			●	
Shred and Grout	●	●	●	●	●				
Incinerate	●	●	●		●				●
Supercompaction	●	●	●		●	●			

[1]Waste Retrieval
[2]Waste Inspection and Shipping (Numerically identical to Waste Receipt and Inspection)
[3]Waste Receipt and Inspection
[4]Shred and Grout
[5]Certification and Shipping
[6]Compaction
[7]Incineration
[8]Waste Characterization
[9]Vitrification

1

TABLE K-16

TRU WASTE FULL-TIME EQUIVALENT SCALING FACTORS CASES USED FOR EACH WASTE PROCESS AND CONSOLIDATION CONFIGURATION

Treatment Process	Configuration	FTE Modules for Base Numbers	FTE Modules for Scaled Numbers
Baseline	10 sites	PEIS Case 4	EA Scaled for all sites
Supercompaction	10 sites	Scaled Shred & Grout at 10 sites	Scaled Supercompaction at 10 sites
Supercompaction	5 sites	Scaled Shred & Grout at 5 sites	Scaled Supercompaction at 5 sites
Supercompaction	1 site	Scaled Shred & Grout at 1 site	Scaled Supercompaction at 1 site
Shred and Compact	10 sites	Scaled Shred & Grout at 5 sites	Scaled Shred & Grout at 10 sites
Shred and Compact	5 sites	PEIS Shred & Grout at 5 sites	Scaled Shred & Grout at 5 sites
Shred and Compact	1 site	Scaled Shred & Grout at 5 sites	Scaled Shred & Grout at 1 site
Plasma Processing	10 sites	PEIS Vitrify at 5 sites	Scaled Vitrify at 10 sites
Plasma Processing	5 sites	PEIS Incinerate at 5 sites	Scaled up Vitrify at 5 sites
Plasma Processing	1 site	PEIS Incinerate at 1 site	Scaled up Vitrify at 1 site
Shred and Add Clay	10 sites	Scaled Shred & Grout at 5 sites	Scaled Shred & Grout at 10 sites
Shred and Add Clay	5 sites	PEIS Shred & Grout at 5 sites	Scaled Shred & Grout at 5 sites
Shred and Add Clay	1 site	Scaled Shred & Grout at 5 sites	Scaled Shred & Grout at 1 site

TABLE K-17

TRU WASTE HANDLING MODULES USED TO MODEL WASTE PROCESSING INCINERATION AT 10 SITES COMPARED TO PEIS INCINERATION AT 5 SITES

	PEIS Incineration at 5 Sites					Engineered Alternatives Incineration at 10 Sites				
Location[1]	RETRV[2]	INSHP[3]	RCINS[4]	VITRFY[5]	CSHIP[6]	RETRV	INSHP	RCINS	VITRFY	CSHIP
ANL-E	•	•				•		•	•	•
Hanford	•		•	•	•	•		•	•	•
INEL	•		•	•	•	•		•	•	•
LANL	•		•	•	•	•		•	•	•
LBL	•	•				•	•			
LLNL	•	•				•		•	•	•
Mound	•	•				•		•	•	•
NTS	•	•				•		•	•	•
ORNL	•	•				•		•	•	•
PGDP	•	•				•	•			
RFETS	•		•	•	•	•		•	•	•
SNL	•	•				•	•			
SRS	•		•	•	•	•		•	•	•

[1]See Table XX-5
[2]Waste Retrieval
[3]Waste Inspection and Shipping
[4]Waste Receipt and Inspection
[5]Vitrification
[6]Certification and Shipping

TABLE K-18

ENGINEERED ALTERNATIVES HUMAN HEALTH IMPACTS
CALCULATION OF SYSTEM-WIDE SCALING FACTORS FOR BASELINE

	PEIS Risk Value						Volume Scaling Factor	FTE Scaling Factor	Scaled Risk Value					
	Fatalities			Cancer Incidence					Fatalities			Cancer Incidence		
Location	Public	Offsite MEI	Worker	Public	Offsite MEI	Worker			Public	Offsite MEI	Worker	Public	Offsite MEI	Worker
ANL-E	1.80e-06	9.90e-12	1.00e-01	6.10e-06	3.40e-11	3.00e-02	0.03	0.89	5.90e-08	3.25e-13	8.89e-02	2.00e-07	1.11e-12	2.67e-02
Hanford	1.40e-06	2.90e-11	3.30e-01	4.80e-06	9.90e-11	3.60e-01	2.49	1.97	3.49e-06	7.22e-11	6.49e-01	1.20e-05	2.47e-10	7.08e-01
INEL	1.10e-06	1.40e-10	1.00e+00	3.80e-06	4.80e-10	8.70e-01	1.02	1.02	1.12e-06	1.43e-10	1.02e+00	3.88e-06	4.90e-10	8.85e-01
LANL	5.40e-05	5.70e-09	4.90e-01	1.80e-04	1.90e-08	5.00e-01	1.94	1.48	1.05e-04	1.11e-08	7.25e-01	3.50e-04	3.69e-08	7.40e-01
LBL	6.30e-09	9.40e-14	8.40e-03	2.10e-08	3.20e-13	7.60e-09	6.57	1.00	4.14e-08	6.17e-13	8.41e-03	1.38e-07	2.10e-12	7.61e-09
LLNL	3.50e-06	5.70e-11	1.10e-01	1.20e-05	2.00e-10	2.00e-03	0.69	0.96	2.41e-06	3.93e-11	1.06e-01	8.27e-06	1.38e-10	1.93e-03
Mound	8.40e-07	4.80e-11	3.20e-02	2.90e-06	1.60e-10	4.80e-04	0.18	0.88	1.52e-07	8.69e-12	2.83e-02	5.25e-07	2.90e-11	4.24e-04
NTS	1.10e-10	3.00e-14	6.80e-02	3.90e-10	1.00e-13	7.30e-04	1.00	1.00	1.10e-10	3.00e-14	6.80e-02	3.90e-10	1.00e-13	7.30e-04
ORNL	0.00e0	0.00e0	4.70e-04	0.00e0	0.00e0	7.90e-14	1.09	1.01	0.00e0	0.00e0	4.76e-04	0.00e0	0.00e0	7.99e-14
PGDP	3.50e-09	3.50e-09	1.30e-02	1.20e-08	1.30e-12	1.60e-06	0.15	1.00	5.25e-10	5.25e-10	1.30e-02	1.80e-09	1.95e-13	1.60e-06
RFETS	9.30e-06	1.30e-10	2.20e-01	3.20e-05	4.30e-10	2.70e-02	1.00	1.00	9.31e-06	1.30e-10	2.20e-01	3.20e-05	4.31e-10	2.70e-02
SNL	2.70e-09	1.10e-13	8.70e-03	9.10e-09	3.60e-13	2.10e-08	17.11	1.00	4.62e-08	1.88e-12	8.72e-03	1.56e-07	6.16e-12	2.10e-08
SRS	5.10e-05	4.80e-10	3.50e-01	1.70e-04	1.60e-09	3.10e-01	1.53	1.38	7.78e-05	7.32e-10	4.83e-01	2.59e-04	2.44e-09	4.27e-01
Total	1.23e-04		2.73e+00	4.12e-04		2.10e+00			1.99e-04		3.42e+00	6.67e-04		2.82e+00
Maximum										1.11e-08			3.69e-08	
System-Wide Scaling Factor									1.62		1.25	1.62		1.34

calculation of the effective scaling factors for the Baseline. The PEIS values are those from PEIS Case 4 (also shown on Table K-6). The Volume Scaling Factor column is made up of the site-specific scaling factors for the Baseline calculated as described in Section 3.0. The FTE Scaling Factors are those calculated for the Baseline as described in Section 4.0. The Scaled Risk Values for the public and off-site maximum exposed individual (MEI) are calculated by multiplying the equivalent PEIS risk value by the appropriate Volume Scaling Factor. The Scaled Risk Values for the workers are calculated by multiplying the equivalent PEIS worker risk values by the appropriate FTE Scaling Factor. The System-Wide Scaling Factor is calculated for the public and worker risk values by dividing the total Scaled Risk Value for all sites by the total PEIS Risk Value summed over all sites. A weighted average risk value is not meaningful for the off-site MEI. Instead, the site with the maximum value for the scaled risk is reported as the off-site MEI risk.

In addition to the Baseline, three other waste processing alternatives have PEIS equivalents and use the same calculation method: Shred and Grout at five sites, Incineration at five sites, and Incineration at one site.

6.2 Supercompaction Scaling Factors

The system-wide scaling factors for the three consolidation configurations for supercompaction are calculated using a single technique. Because supercompaction does not add to the airborne releases, the public and off-site MEI risk numbers are the same as for the respective configurations of Shred and Grout. The worker risk estimates are calculated using the following formulas:

$$\textit{Worker cancers} = \textit{shred \& grout worker cancers} + (\textit{Cancer Risk Factor} \times \textit{supercompactor FTEs})$$
$$\textit{Worker fatalities} = \textit{shred \& grout worker fatalities} + (\textit{Fatality Risk Factor} \times \textit{supercompactor FTEs})$$

where

$$\textit{Cancer Risk Factor} = \textit{SARF doses} \times \frac{\textit{ICRP Cancer Risk Coefficent}}{\textit{SARF FTEs}}$$
$$\textit{Fatality Risk Factor} = \textit{SARF doses} \times \frac{\textit{ICRP Fatality Risk Coefficent}}{\textit{SARF FTEs}}$$

and

$$\textit{ICRP Cancer Risk Coefficient} = 8.00 \times 10^{-5}$$
$$\textit{ICRP Fatality Risk Coefficient} = 4.00 \times 10^{-4} \quad \text{(ICRP,1990)}$$

The supercompactor FTEs are calculated as described in Section 4.0. Supercompaction and Repackaing Facility doses and FTEs are taken from the environmental assessment of the supercompactor at the Rocky Flats Environmental Technology Site (DOE, 1990a).

6.3 Scaling Factors for Significant Configuration Cases

Three of the consolidation configurations did not parallel PEIS configurations: Shred and Grout at 10 sites, Shred and Grout at 1 site, and Incineration at 10 sites. In these circumstances, the calculation of each site was analyzed separately and the sum of the risk factors for all sites was used to calculate the system-wide scaling factors. The calculation methods for each site could be classed as one of four types of formulas.

6.3.1 Site Actions Unchanged from Other Cases

Five sites (LANL, LBL, PGDP, RFETS, and SNL) do not change activities between regional consolidation (5 sites) and distributed (10 sites). In these circumstances, all the risk values remain the same so data used in the regional configuration was used in the distributed configuration.

6.3.2 Site Actions Involve Only Retrieval and Shipping

With the exception of the WIPP, all sites in the Shred and Grout at one site perform exactly the same activities as they do for incinerate at one site, PEIS Case 9. Because the activities and volumes involved are the same, all non-WIPP risk values are the same in Shred and Grout at one site and Incinerate at one site.

6.3.3 Waste Volume Adjustments

Five of the processing sites in the distributed (10 site) configuration are also processing sites in the regional (5 site) configuration. These five sites perform the same activities and have the same facilities. Only the volume processed is changed. The risk values for these five sites were calculated by applying the correct scaling factors in the same manner as described in Section 5.1 except that the scaled regional risk values (which are based on PEIS values) are used in place of the PEIS values.

6.3.4 Process Ratio Adjustments

The remaining sites in these three configurations are designated as waste processing sites for a particular process in the EA but not in the PEIS. Because FTE curves were available for the necessary processes and worker impacts are not dependant on site characteristics like the public or co-located worker impacts, the FTE Scale Factor was calculated and applied as described in Section 5.3.3. To permit estimation of the public and co-located worker risk values, the concept of process ratio was introduced.

For any given site, the impact on the public and co-located workers was modeled at a function of the total releases from the facility. The risks values are modeled as a function of the process and the throughput. That is,

$$Risk_{process,\ throughput}$$

If the Risk Rate is defined as the risk value divided by the throughput:

$$\frac{Risk_{process,\ throughput}}{throughput} = Risk\ Rate_{process}$$

For two selected processes (p1 and p2), the ratio of the Risk Rates, called the process ratio, is a constant:

$$\frac{Risk\ Rate_{p1}}{Risk\ Rate_{p2}} = K_{p1,p2}$$

Process p1 was chosen to have PEIS data for all sites, such as preparation for shipment to WIPP from PEIS Case 9. Process p2, for which PEIS data did not exist for the sites of interest, was known for other sites. $K_{p1,p2}$ was calculated for one or more sites for which the risks for both p1 and p2 were represented in the PEIS. Then the unknown risk value was calculated as:

$$Risk_{p1} = k_{p1,p2} \times Risk\ Rate_{p2} \times throughput$$

Using the scaled throughputs, risk values for the remaining sites may be calculated, allowing the summing of risk values for all sites and calculation of the system-wide scaling factor as described previously.

7.0 WASTE HANDLING, EMPLACEMENT, AND BACKFILL

Modeling for waste handling and emplacement was performed separately from the modeling for backfill activities. The total impacts were calculated as the sum of the two models.

7.1 Waste Handling and Emplacement

As described in Section 3.3.2.2 of the report, radiation doses for emplacement are modeled as being the same for all emplacement alternatives and waste forms because the amount of radioactivity is unchanged. While some waste forms may decrease the dose rate from the package, the increased handling time for those heavier waste forms offsets the decrease in dose rate. Chemical and radioactive material releases are modeled as being linear with waste volume handled. All risk values for released material are compared to those given in the Final Supplement Environmental Impact Statement Waste Isolation Pilot Plant (DOE, 1990b) using the following formula:

$$Case\ risk\ value = FEIS\ risk\ value \times \frac{case\ waste\ volume}{FEIS\ waste\ volume}$$

Case waste volumes were taken from the summary of waste inventories.

Doses are converted to risk estimates using the dose conversion factors from the 1990 Recommendations of the International Commission of Radiological Protection (ICRP,1990):

Doses to the public: 5.00×10^{-4} cancer fatalities per rem
Doses to worker: 4.00×10^{-4} cancer fatalities per rem

Injuries and fatalities from industrial accidents were calculated based on the number of FTEs expected to be working multiplied by the appropriate incident rate (IR). The total FTEs were calculated from the following formula:

$$\textit{Total FTEs} = \textit{Daily FTEs} \times \textit{activity hours/shift} \times \textit{days per year} \times \textit{WIPP operational lifetime}$$

Table K-19 shows the daily FTEs estimated for aboveground waste handling, emplacement, and backfill activities for each of the EAs. The number of FTEs per shift was provided by WIPP personnel.

As explained in Section 3.3.3.7 of the report, the IR for underground work was taken from industry data for salt mine operation (USDL, 1978–1993) adjusted for types of accidents that were judged not likely to be applicable to WIPP. Because of a lack of applicable data for aboveground IR data, it was assumed that waste handling above ground would have half the mining IR. The following formula was used to calculate the injury and accident risks for the 35-year lifetime of the WIPP:

$$\textit{Accident Impact} = \frac{\textit{Total FTEs}}{200000} \times \textit{IR} \times \textit{Effective Fraction}$$

where:

IR (injuries, waste handling) = 2.3603
IR (injuries, underground) = 4.7206
Effective Fraction (injuries) = 0.805
IR (fatalities, waste handling) = 0.02059
IR (fatalities, underground) = 0.04118
Effective Fraction (fatalities) = 0.275

Effective Fraction is the fraction of salt mining industry average incident rates that are likely to occur at the WIPP. It excludes incidents involving falls of the roof, face, or sides of panels; explosives handling; fires; and explosions (D'Appolonia, 1976). The formula includes the divisor of 200,000 because the data from which the IR values were taken are based on incidents per 200,000 person-hours worked.

7.2 Backfill Operations

Backfill operations only impact workers. The calculation of injuries and fatalities from physical hazards was calculated the same way as for emplacement activities. No chemical risks are calculated because it is assumed that all leakage from waste containers was addressed during waste handling and emplacement activities and no further leakage routinely occurs. Radiation doses from working around the emplaced waste during backfill operations was modeled using the

1

TABLE K-19

WASTE HANDLING, EMPLACEMENT, AND BACKFILL ACTIVITIES NUMBER OF FULL-TIME EQUIVALENTS PER DAY REQUIRED

		Full-Time Equivalents per Shift to accomplish the task		
Identifier	Case Description	Waste Handling	Emplacement	Backfill
0	Baseline	44	20	0
1	Compact Waste	33	18	0
6	Shred and Compact	33	18	0
10	Plasma Processing	32	10	0
33	Salt + Clay backfill	44	20	15
35(a)	Salt Aggregate Grout	44	20	23
35(b)	Cementitious Grout	44	20	23
111	Clay-based backfill	44	20	13
77(a)	Supercompact, salt aggregate	33	18	10
77(b)	Supercompact, clay based	33	18	9
77(c)	Supercompact, clay/sand	33	18	11
77(d)	Supercompact, CaO backfill	33	18	8
83	CaO Backfill	44	20	11
94(a)	Shred & add clay	44	20	0
94(b)	Shred & add clay, clay/sand	44	20	16
94(c)	Shred & add clay, cementitious	44	20	29
94(d)	Shred & add clay, salt aggregate	44	20	14
94(e)	Shred & add clay, clay based	44	20	13
94(f)	Shred & add clay, CaO backfill	44	20	11

same dose rate as emplacement. The radiation doses were calculated using the following formula:

$$Backfill\ Impact = Emplacement\ Impact \times \frac{backfill\ total\ FTEs}{emplacement\ total\ FTEs}$$

The impacts from backfill operations were added to those from waste handling and emplacement for the totals shown in the report.

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APPENDIX L
TRANSPORTATION RISK ANALYSIS

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TRANSPORTATION RISK

Tables L-1 through L-29 provide the detailed analysis results for Factor 5. Factor 5 evaluates human health impacts associated with the transportation of contact-handled (CH) and remote-handled (RH) transuranic (TRU) waste to the Waste Isolation Pilot Plant (WIPP). Impacts are presented for the baseline and engineered alternative/configuration combinations on a per-shipment and cumulative WIPP lifetime basis. The analysis methodology, results overview, and conclusions are presented in Section 3.5.

TABLE L-1

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE BASELINE

Waste Origin Site	To Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	1.06×10^{-01}	6.36×10^{-01}	5.45×10^{-07}	1.78×10^{-03}
INEL	WIPP	8.81×10^{-03}	5.27×10^{-02}	5.86×10^{-08}	5.97×10^{-04}
LANL	WIPP	1.01×10^{-03}	6.14×10^{-03}	2.81×10^{-08}	6.54×10^{-04}
RFETS	WIPP	6.03×10^{-05}	3.53×10^{-04}	7.61×10^{-10}	4.09×10^{-03}
SRS	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.13×10^{-02}
Small CH-TRU Waste Sites					
AMES	ANL-E	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	9.75×10^{-03}	5.64×10^{-02}	5.86×10^{-08}	8.44×10^{-04}
ANL-E	WIPP	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	4.75×10^{-04}
BETTIS	MOUND	2.69×10^{-03}	1.33×10^{-02}	5.86×10^{-08}	6.14×10^{-04}
	WIPP	1.06×10^{-02}	6.10×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
ETEC	NTS	1.78×10^{-02}	9.27×10^{-02}	3.28×10^{-07}	4.02×10^{-04}
	WIPP	4.17×10^{-02}	2.55×10^{-01}	3.28×10^{-07}	2.08×10^{-04}
KAPL	MOUND	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	1.06×10^{-02}	6.10×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
LBL	LLNL	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	6.05×10^{-05}
LLNL	WIPP	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	5.22×10^{-04}
MOUND	WIPP	1.06×10^{-04}	6.10×10^{-04}	5.86×10^{-10}	2.44×10^{-02}
MU	ANL-E	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	1.90×10^{-04}
NTS	WIPP	7.45×10^{-03}	4.54×10^{-02}	5.86×10^{-08}	7.24×10^{-04}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	1.26×10^{-05}	1.60×10^{-03}
PADUCAH	ORNL	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1.01×10^{-04}	5.88×10^{-04}	5.86×10^{-10}	6.99×10^{-03}

TABLE L-1 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE BASELINE

Waste Origin Site	To Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.10×10^{-05}	1.28×10^{-04}	5.86×10^{-10}	3.45×10^{-06}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.10×10^{-05}	1.28×10^{-04}	5.86×10^{-10}	4.27×10^{-07}

TABLE L-2

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY BASELINE

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$6.05x10^{+02}$	$3.63x10^{+03}$	$3.11x10^{-03}$	$1.02x10^{+01}$
INEL	WIPP	4974	$4.38x10^{+01}$	$2.62x10^{+02}$	$2.91x10^{-04}$	$2.97x10^{+00}$
LANL	WIPP	2835	$2.86x10^{+00}$	$1.74x10^{+01}$	$7.97x10^{-05}$	$1.85x10^{+00}$
RFETS	WIPP	931	$5.61x10^{-02}$	$3.29x10^{-01}$	$7.08x10^{-07}$	$3.81x10^{+00}$
SRS	WIPP	2827	$3.05x10^{-01}$	$1.71x10^{+00}$	$1.66x10^{-06}$	$6.02x10^{+01}$
		Subtotal	**$6.52x10^{+02}$**	**$3.91x10^{+03}$**	**$3.48x10^{-03}$**	**$7.90x10^{+01}$**
Small CH-TRU Waste Sites						
AMES	ANL-E	1	$2.35x10^{-03}$	$1.37x10^{-02}$	$5.86x10^{-08}$	$1.66x10^{-04}$
	WIPP	1	$9.75x10^{-03}$	$5.64x10^{-02}$	$5.86x10^{-08}$	$8.44x10^{-04}$
ANL-E	WIPP	5	$4.88x10^{-04}$	$2.82x10^{-03}$	$2.93x10^{-09}$	$2.38x10^{-03}$
BETTIS	MOUND	17	$4.57x10^{-02}$	$2.26x10^{-01}$	$9.96x10^{-07}$	$1.04x10^{-02}$
	WIPP	17	$1.80x10^{-01}$	$1.04x10^{+00}$	$9.96x10^{-07}$	$1.80x10^{-02}$
ETEC	NTS	2	$3.56x10^{-02}$	$1.85x10^{-01}$	$6.56x10^{-07}$	$8.04x10^{-04}$
	WIPP	2	$8.34x10^{-02}$	$5.10x10^{-01}$	$6.56x10^{-07}$	$4.16x10^{-04}$
KAPL	MOUND	1	$6.17x10^{-03}$	$3.08x10^{-02}$	$5.86x10^{-08}$	$1.06x10^{-03}$
	WIPP	1	$1.06x10^{-02}$	$6.10x10^{-02}$	$5.86x10^{-08}$	$1.06x10^{-03}$
LBL	LLNL	1	$9.84x10^{-06}$	$4.30x10^{-05}$	$5.86x10^{-10}$	$2.57x10^{-05}$
	WIPP	1	$9.54x10^{-05}$	$5.61x10^{-04}$	$5.86x10^{-10}$	$6.05x10^{-05}$
LLNL	WIPP	136	$1.30x10^{-02}$	$7.63x10^{-02}$	$7.97x10^{-08}$	$7.10x10^{-02}$
MOUND	WIPP	29	$3.07x10^{-03}$	$1.77x10^{-02}$	$1.70x10^{-08}$	$7.08x10^{-01}$
MU	ANL-E	1	$2.94x10^{-05}$	$1.61x10^{-04}$	$5.86x10^{-10}$	$9.30x10^{-05}$
	WIPP	1	$9.75x10^{-05}$	$5.64x10^{-04}$	$5.86x10^{-10}$	$1.90x10^{-04}$
NTS	WIPP	66	$4.92x10^{-01}$	$3.00x10^{+00}$	$3.87x10^{-06}$	$4.78x10^{-02}$
ORNL	WIPP	119	$1.57x10^{+01}$	$8.78x10^{+01}$	$1.50x10^{-03}$	$1.90x10^{-01}$
PADUCAH	ORNL	1	$2.26x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$1.86x10^{-03}$
	WIPP	1	$1.01x10^{-04}$	$5.88x10^{-04}$	$5.86x10^{-10}$	$6.99x10^{-03}$
PANTEX	LANL	1	$2.05x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$3.83x10^{-06}$
	WIPP	1	$2.10x10^{-05}$	$1.28x10^{-04}$	$5.86x10^{-10}$	$3.45x10^{-06}$

TABLE L-2 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY BASELINE

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	6.30×10^{-05}	3.84×10^{-04}	1.76×10^{-09}	1.28×10^{-06}
		Subtotal	**$1.66 \times 10^{+01}$**	**$9.30 \times 10^{+01}$**	**1.51×10^{-03}**	**$1.06 \times 10^{+00}$**
		TOTAL	**$6.69 \times 10^{+02}$**	**$4.00 \times 10^{+03}$**	**4.99×10^{-03}**	**$8.01 \times 10^{+01}$**

TABLE L-3

RADIOLOGICAL DOSES PER SHIPMENT FOR RH-TRU WASTE BASELINE

Waste Origin Site	To Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major RH-TRU Waste Sites					
HANFORD	WIPP	1.12×10^{-01}	4.75×10^{-01}	2.08×10^{-06}	8.27×10^{-05}
ORNL	WIPP	2.80×10^{-02}	4.08×10^{-01}	5.87×10^{-07}	9.86×10^{-05}
Small RH-TRU Waste Sites					
BATTELLE	ORNL	1.90×10^{-04}	3.50×10^{-03}	1.14×10^{-08}	4.73×10^{-05}
	WIPP	5.43×10^{-04}	1.14×10^{-02}	1.14×10^{-08}	5.91×10^{-05}
BETTIS	ORNL	2.18×10^{-04}	4.17×10^{-03}	9.59×10^{-09}	7.11×10^{-06}
	WIPP	4.57×10^{-04}	9.63×10^{-03}	9.59×10^{-09}	8.89×10^{-06}
INEL	WIPP	3.00×10^{-03}	6.48×10^{-02}	7.19×10^{-08}	2.19×10^{-05}
KNOLL	ORNL	7.07×10^{-04}	1.35×10^{-02}	2.13×10^{-08}	9.55×10^{-06}
	WIPP	1.01×10^{-03}	2.13×10^{-02}	2.13×10^{-08}	8.89×10^{-06}
LANL	WIPP	3.86×10^{-04}	8.49×10^{-03}	3.90×10^{-08}	8.02×10^{-06}
SRS	WIPP	2.38×10^{-02}	4.19×10^{-01}	4.64×10^{-07}	1.47×10^{-04}

TABLE L-4

CUMULATIVE RADIOLOGICAL DOSES FOR RH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY BASELINE

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major RH-TRU Waste Sites						
HANFORD	WIPP	5176	$5.80 \times 10^{+02}$	$2.46 \times 10^{+03}$	1.08×10^{-02}	4.28×10^{-01}
ORNL	WIPP	2002	$5.61 \times 10^{+01}$	$8.17 \times 10^{+02}$	1.18×10^{-03}	1.97×10^{-01}
		Subtotal	**$6.36 \times 10^{+02}$**	**$3.28 \times 10^{+03}$**	**1.20×10^{-02}**	**6.25×10^{-01}**
Small RH-TRU Waste Sites						
BATTELLE	ORNL	123	2.34×10^{-02}	4.31×10^{-01}	1.40×10^{-06}	5.82×10^{-03}
	WIPP	123	6.68×10^{-02}	$1.40 \times 10^{+00}$	1.40×10^{-06}	7.27×10^{-03}
BETTIS	ORNL	3	6.54×10^{-04}	1.25×10^{-02}	2.88×10^{-08}	2.13×10^{-05}
	WIPP	3	1.37×10^{-03}	2.89×10^{-02}	2.88×10^{-08}	2.67×10^{-05}
INEL	WIPP	109	3.27×10^{-01}	$7.06 \times 10^{+00}$	7.84×10^{-06}	2.39×10^{-03}
KNOLL	ORNL	57	4.03×10^{-02}	7.70×10^{-01}	1.21×10^{-06}	5.44×10^{-04}
	WIPP	57	5.76×10^{-02}	$1.21 \times 10^{+00}$	1.21×10^{-06}	5.07×10^{-04}
LANL	WIPP	249	9.61×10^{-02}	$2.11 \times 10^{+00}$	9.71×10^{-06}	2.00×10^{-03}
SRS	WIPP	56	$1.33 \times 10^{+00}$	$2.35 \times 10^{+01}$	2.60×10^{-05}	8.23×10^{-03}
		Subtotal	**$1.94 \times 10^{+00}$**	**$3.65 \times 10^{+01}$**	**4.88×10^{-05}**	**2.68×10^{-02}**
		TOTAL	**$6.38 \times 10^{+02}$**	**$3.32 \times 10^{+03}$**	**1.20×10^{-02}**	**6.52×10^{-01}**

TABLE L-5

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVES No. 1 & 77 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	9.11×10^{-02}	5.46×10^{-01}	4.68×10^{-07}	1.06×10^{-04}
INEL	WIPP	7.93×10^{-03}	4.75×10^{-02}	5.27×10^{-08}	2.38×10^{-05}
LANL	WIPP	1.42×10^{-03}	8.69×10^{-03}	3.98×10^{-08}	2.71×10^{-05}
RFETS	WIPP	4.18×10^{-05}	2.45×10^{-04}	5.27×10^{-10}	1.68×10^{-04}
SRS	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	1.71×10^{-03}
Small CH-TRU Waste Sites					
AMES	ANL-E	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	8.78×10^{-03}	5.08×10^{-02}	5.27×10^{-08}	5.13×10^{-05}
ANL-E	WIPP	1.07×10^{-04}	6.22×10^{-04}	6.44×10^{-10}	9.55×10^{-06}
BETTIS	MOUND	2.69×10^{-03}	1.33×10^{-02}	5.86×10^{-08}	6.14×10^{-04}
	WIPP	9.55×10^{-03}	5.49×10^{-02}	5.27×10^{-08}	6.42×10^{-05}
ETEC	NTS	1.78×10^{-02}	9.27×10^{-02}	3.28×10^{-07}	4.02×10^{-04}
	WIPP	9.68×10^{-02}	5.70×10^{-01}	7.61×10^{-07}	2.57×10^{-05}
KAPL	MOUND	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	9.55×10^{-03}	5.49×10^{-02}	5.27×10^{-08}	6.42×10^{-05}
LBL	LLNL	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	1.05×10^{-04}	6.18×10^{-04}	6.44×10^{-10}	9.27×10^{-06}
LLNL	WIPP	1.05×10^{-04}	6.18×10^{-04}	6.44×10^{-10}	4.89×10^{-05}
MOUND	WIPP	1.17×10^{-04}	6.71×10^{-04}	6.44×10^{-10}	2.82×10^{-03}
MU	ANL-E	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	1.07×10^{-04}	6.22×10^{-04}	6.44×10^{-10}	1.63×10^{-05}
NTS	WIPP	6.70×10^{-03}	4.08×10^{-02}	5.27×10^{-08}	8.92×10^{-05}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	6.21×10^{-06}	1.68×10^{-04}

TABLE L-5 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVES No. 1 & 77 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1.11×10^{-04}	6.47×10^{-04}	6.44×10^{-10}	3.00×10^{-04}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.30×10^{-05}	1.41×10^{-04}	6.44×10^{-10}	4.16×10^{-07}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.30×10^{-05}	1.41×10^{-04}	6.44×10^{-10}	5.19×10^{-08}

TABLE L-6

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVES No. 1 & 77 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$5.20x10^{+02}$	$3.12x10^{+03}$	$2.67x10^{-03}$	$6.05x10^{-01}$
INEL	WIPP	4974	$3.94x10^{+01}$	$2.36x10^{+02}$	$2.62x10^{-04}$	$1.18x10^{-01}$
LANL	WIPP	2835	$4.03x10^{+00}$	$2.46x10^{+01}$	$1.13x10^{-04}$	$7.68x10^{-02}$
RFETS	WIPP	931	$3.89x10^{-02}$	$2.28x10^{-01}$	$4.91x10^{-07}$	$1.56x10^{-01}$
SRS	WIPP	2827	$3.36x10^{-01}$	$1.88x10^{+00}$	$1.82x10^{-06}$	$4.83x10^{+00}$
		Subtotal	**$5.64x10^{+02}$**	**$3.38x10^{+03}$**	**$3.05x10^{-03}$**	**$5.79x10^{+00}$**
Small CH-TRU Waste Sites						
AMES	ANL-E	1	$2.35x10^{-03}$	$1.37x10^{-02}$	$5.86x10^{-08}$	$1.66x10^{-04}$
	WIPP	1	$8.78x10^{-03}$	$5.08x10^{-02}$	$5.27x10^{-08}$	$5.13x10^{-05}$
ANL-E	WIPP	5	$5.35x10^{-04}$	$3.11x10^{-03}$	$3.22x10^{-09}$	$4.78x10^{-05}$
BETTIS	MOUND	17	$4.57x10^{-02}$	$2.26x10^{-01}$	$9.96x10^{-07}$	$1.04x10^{-02}$
	WIPP	17	$1.62x10^{-01}$	$9.33x10^{-01}$	$8.96x10^{-07}$	$1.09x10^{-03}$
ETEC	NTS	2	$3.56x10^{-02}$	$1.85x10^{-01}$	$6.56x10^{-07}$	$8.04x10^{-04}$
	WIPP	2	$1.94x10^{-01}$	$1.14x10^{+00}$	$1.52x10^{-06}$	$5.14x10^{-05}$
KAPL	MOUND	1	$6.17x10^{-03}$	$3.08x10^{-02}$	$5.86x10^{-08}$	$1.06x10^{-03}$
	WIPP	1	$9.55x10^{-03}$	$5.49x10^{-02}$	$5.27x10^{-08}$	$6.42x10^{-05}$
LBL	LLNL	1	$9.84x10^{-06}$	$4.30x10^{-05}$	$5.86x10^{-10}$	$2.57x10^{-05}$
	WIPP	1	$1.05x10^{-04}$	$6.18x10^{-04}$	$6.44x10^{-10}$	$9.27x10^{-06}$
LLNL	WIPP	136	$1.43x10^{-02}$	$8.40x10^{-02}$	$8.76x10^{-08}$	$6.65x10^{-03}$
MOUND	WIPP	29	$3.39x10^{-03}$	$1.95x10^{-02}$	$1.87x10^{-08}$	$8.18x10^{-02}$
MU	ANL-E	1	$2.94x10^{-05}$	$1.61x10^{-04}$	$5.86x10^{-10}$	$9.30x10^{-05}$
	WIPP	1	$1.07x10^{-04}$	$6.22x10^{-04}$	$6.44x10^{-10}$	$1.63x10^{-05}$
NTS	WIPP	66	$4.42x10^{-01}$	$2.69x10^{+00}$	$3.48x10^{-06}$	$5.89x10^{-03}$
ORNL	WIPP	119	$1.57x10^{+01}$	$8.78x10^{+01}$	$7.39x10^{-04}$	$2.00x10^{-02}$
PA	ORNL	1	$2.26x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$1.86x10^{-03}$
	WIPP	1	$1.11x10^{-04}$	$6.47x10^{-04}$	$6.44x10^{-10}$	$3.00x10^{-04}$
PANTEX	LANL	1	$2.05x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$3.83x10^{-06}$
	WIPP	1	$2.30x10^{-05}$	$1.41x10^{-04}$	$6.44x10^{-10}$	$4.16x10^{-07}$

TABLE L-6 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVES No. 1 & 77 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	6.90×10^{-05}	4.23×10^{-04}	1.93×10^{-09}	1.56×10^{-07}
		Subtotal	$1.66 \times 10^{+01}$	$9.32 \times 10^{+01}$	$\mathbf{7.47 \times 10^{-04}}$	$\mathbf{1.30 \times 10^{-01}}$
		TOTAL	$5.81 \times 10^{+02}$	$3.47 \times 10^{+03}$	$\mathbf{3.80 \times 10^{-03}}$	$\mathbf{5.92 \times 10^{+00}}$

TABLE L-7

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVES No. 1 & 77 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	9.11×10^{-02}	5.46×10^{-01}	4.68×10^{-07}	1.06×10^{-04}
INEL	WIPP	7.93×10^{-03}	4.75×10^{-02}	5.27×10^{-08}	2.38×10^{-05}
LANL	WIPP	1.42×10^{-03}	8.69×10^{-03}	3.98×10^{-08}	2.71×10^{-05}
RFETS	WIPP	4.18×10^{-05}	2.45×10^{-04}	5.27×10^{-10}	1.68×10^{-04}
SRS	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	1.71×10^{-03}
Small CH-TRU Waste Sites					
AMES	SRS	8.88×10^{-03}	4.85×10^{-02}	5.86×10^{-08}	1.07×10^{-03}
	WIPP	9.73×10^{-03}	5.43×10^{-02}	5.27×10^{-08}	7.78×10^{-05}
ANL-E	SRS	7.06×10^{-05}	3.71×10^{-04}	5.86×10^{-10}	6.35×10^{-04}
	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	1.45×10^{-05}
BETTIS	SRS	5.30×10^{-03}	2.85×10^{-02}	5.86×10^{-08}	7.15×10^{-04}
	WIPP	9.73×10^{-03}	5.43×10^{-02}	5.27×10^{-08}	7.78×10^{-05}
ETEC	INEL	4.06×10^{-02}	2.23×10^{-01}	3.28×10^{-07}	6.88×10^{-04}
	WIPP	1.15×10^{-01}	6.62×10^{-01}	7.61×10^{-07}	3.78×10^{-05}
KAPL	SRS	7.49×10^{-03}	3.97×10^{-02}	5.86×10^{-08}	9.92×10^{-04}
	WIPP	9.73×10^{-03}	5.43×10^{-02}	5.27×10^{-08}	7.78×10^{-05}
LBL	HANFORD	6.53×10^{-05}	3.57×10^{-04}	5.86×10^{-10}	6.10×10^{-05}
	WIPP	1.25×10^{-04}	7.52×10^{-04}	6.44×10^{-10}	7.28×10^{-06}
LLNL	HANFORD	6.70×10^{-05}	3.66×10^{-04}	5.86×10^{-10}	5.42×10^{-04}
	WIPP	1.25×10^{-04}	7.52×10^{-04}	6.44×10^{-10}	3.84×10^{-05}
MOUND	SRS	5.14×10^{-05}	2.70×10^{-04}	5.86×10^{-10}	1.77×10^{-02}
	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	3.43×10^{-03}
MU	SRS	6.81×10^{-05}	3.63×10^{-04}	5.86×10^{-10}	2.49×10^{-04}
	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	2.48×10^{-05}
NTS	INEL	4.92×10^{-03}	2.82×10^{-02}	5.86×10^{-08}	1.17×10^{-03}
	WIPP	7.93×10^{-03}	4.75×10^{-02}	5.27×10^{-08}	1.31×10^{-04}
ORNL	SRS	3.65×10^{-02}	1.87×10^{-01}	1.26×10^{-05}	7.15×10^{-04}
	WIPP	1.41×10^{-01}	7.59×10^{-01}	6.21×10^{-06}	2.50×10^{-04}

TABLE L-7 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVES No. 1 & 77 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	SRS	4.61×10^{-05}	2.42×10^{-04}	5.86×10^{-10}	6.34×10^{-03}
	WIPP	1.19×10^{-04}	6.65×10^{-04}	6.44×10^{-10}	4.48×10^{-04}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.30×10^{-05}	1.41×10^{-04}	6.44×10^{-10}	4.16×10^{-07}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.30×10^{-05}	1.41×10^{-04}	6.44×10^{-10}	5.19×10^{-08}

TABLE L-8

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVES No. 1 & 77 - REGIONALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	To Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$5.20x10^{+02}$	$3.12x10^{+03}$	$2.67x10^{-03}$	$6.05x10^{-01}$
INEL	WIPP	4974	$3.94x10^{+01}$	$2.36x10^{+02}$	$2.62x10^{-04}$	$1.18x10^{-01}$
LANL	WIPP	2835	$4.03x10^{+00}$	$2.46x10^{+01}$	$1.13x10^{-04}$	$7.68x10^{-02}$
RFETS	WIPP	931	$3.89x10^{-02}$	$2.28x10^{-01}$	$4.91x10^{-07}$	$1.56x10^{-01}$
SRS	WIPP	2827	$3.36x10^{-01}$	$1.88x10^{+00}$	$1.82x10^{-06}$	$4.83x10^{+00}$
		Subtotal	**$5.64x10^{+02}$**	**$3.38x10^{+03}$**	**$3.05x10^{-03}$**	**$5.79x10^{+00}$**
Small CH-TRU Waste Sites						
AMES	SRS	1	$8.88x10^{-03}$	$4.85x10^{-02}$	$5.86x10^{-08}$	$1.07x10^{-03}$
	WIPP	1	$9.73x10^{-03}$	$5.43x10^{-02}$	$5.27x10^{-08}$	$7.78x10^{-05}$
ANL-E	SRS	5	$3.53x10^{-04}$	$1.86x10^{-03}$	$2.93x10^{-09}$	$3.18x10^{-03}$
	WIPP	5	$5.95x10^{-04}$	$3.33x10^{-03}$	$3.22x10^{-09}$	$7.25x10^{-05}$
BETTIS	SRS	17	$9.01x10^{-02}$	$4.85x10^{-01}$	$9.96x10^{-07}$	$1.22x10^{-02}$
	WIPP	17	$1.65x10^{-01}$	$9.23x10^{-01}$	$8.96x10^{-07}$	$1.32x10^{-03}$
ETEC	INEL	2	$8.12x10^{-02}$	$4.46x10^{-01}$	$6.56x10^{-07}$	$1.38x10^{-03}$
	WIPP	2	$2.30x10^{-01}$	$1.32x10^{+00}$	$1.52x10^{-06}$	$7.56x10^{-05}$
KAPL	SRS	1	$7.49x10^{-03}$	$3.97x10^{-02}$	$5.86x10^{-08}$	$9.92x10^{-04}$
	WIPP	1	$9.73x10^{-03}$	$5.43x10^{-02}$	$5.27x10^{-08}$	$7.78x10^{-05}$
LBL	HANFORD	1	$6.53x10^{-05}$	$3.57x10^{-04}$	$5.86x10^{-10}$	$6.10x10^{-05}$
	WIPP	1	$1.25x10^{-04}$	$7.52x10^{-04}$	$6.44x10^{-10}$	$7.28x10^{-06}$
LLNL	HANFORD	136	$9.11x10^{-03}$	$4.98x10^{-02}$	$7.97x10^{-08}$	$7.37x10^{-02}$
	WIPP	136	$1.70x10^{-02}$	$1.02x10^{-01}$	$8.76x10^{-08}$	$5.22x10^{-03}$
MOUND	SRS	29	$1.49x10^{-03}$	$7.83x10^{-03}$	$1.70x10^{-08}$	$5.13x10^{-01}$
	WIPP	29	$3.45x10^{-03}$	$1.93x10^{-02}$	$1.87x10^{-08}$	$9.95x10^{-02}$
MU	SRS	1	$6.81x10^{-05}$	$3.63x10^{-04}$	$5.86x10^{-10}$	$2.49x10^{-04}$
	WIPP	1	$1.19x10^{-04}$	$6.65x10^{-04}$	$6.44x10^{-10}$	$2.48x10^{-05}$

TABLE L-8 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVES No. 1 & 77 - REGIONALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	To Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	66	$3.25x10^{-01}$	$1.86x10^{+00}$	$3.87x10^{-06}$	$7.72x10^{-02}$
	WIPP	66	$5.23x10^{-01}$	$3.14x10^{+00}$	$3.48x10^{-06}$	$8.65x10^{-03}$
ORNL	SRS	119	$4.34x10^{+00}$	$2.23x10^{+01}$	$1.50x10^{-03}$	$8.51x10^{-02}$
	WIPP	119	$1.68x10^{+01}$	$9.03x10^{+01}$	$7.39x10^{-04}$	$2.98x10^{-02}$
PADUCAH	SRS	1	$4.61x10^{-05}$	$2.42x10^{-04}$	$5.86x10^{-10}$	$6.34x10^{-03}$
	WIPP	1	$1.19x10^{-04}$	$6.65x10^{-04}$	$6.44x10^{-10}$	$4.48x10^{-04}$
PANTEX	LANL	1	$2.05x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$3.83x10^{-06}$
	WIPP	1	$2.30x10^{-05}$	$1.41x10^{-04}$	$6.44x10^{-10}$	$4.16x10^{-07}$
SNL	LANL	3	$2.32x10^{-05}$	$1.28x10^{-04}$	$1.76x10^{-09}$	$1.31x10^{-06}$
	WIPP	3	$6.90x10^{-05}$	$4.23x10^{-04}$	$1.93x10^{-09}$	$1.56x10^{-07}$
		Subtotal	$2.26x10^{+01}$	$1.21x10^{+02}$	$2.25x10^{-03}$	$9.20x10^{-01}$
		TOTAL	**$5.87x10^{+02}$**	**$3.50x10^{+03}$**	**$5.30x10^{-03}$**	**$6.71x10^{+00}$**

TABLE L-9

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE CENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	1.06×10^{-01}	6.36×10^{-01}	5.45×10^{-07}	1.78×10^{-03}
INEL	WIPP	8.81×10^{-03}	5.27×10^{-02}	5.86×10^{-08}	5.97×10^{-04}
LANL	WIPP	1.01×10^{-03}	6.14×10^{-03}	2.81×10^{-08}	6.54×10^{-04}
RFETS	WIPP	6.03×10^{-05}	3.53×10^{-04}	7.61×10^{-10}	4.09×10^{-03}
SRS	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.13×10^{-02}
Small CH-TRU Waste Sites					
AMES	WIPP	8.06×10^{-03}	4.79×10^{-02}	5.86×10^{-08}	6.23×10^{-04}
ANL-E	WIPP	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	4.75×10^{-04}
BETTIS	WIPP	1.27×10^{-02}	7.17×10^{-02}	5.86×10^{-08}	1.42×10^{-03}
ETEC	WIPP	4.44×10^{-02}	2.55×10^{-01}	3.28×10^{-07}	5.26×10^{-04}
KAPL	WIPP	1.62×10^{-02}	8.93×10^{-02}	5.86×10^{-08}	1.86×10^{-03}
LBL	WIPP	1.05×10^{-04}	6.02×10^{-04}	5.86×10^{-10}	8.60×10^{-05}
LLNL	WIPP	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	5.22×10^{-04}
MOUND	WIPP	1.06×10^{-04}	6.10×10^{-04}	5.86×10^{-10}	2.44×10^{-02}
MU	WIPP	7.44×10^{-05}	4.39×10^{-04}	5.86×10^{-10}	1.48×10^{-04}
NTS	WIPP	7.45×10^{-03}	4.54×10^{-02}	5.86×10^{-08}	7.24×10^{-04}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	1.26×10^{-05}	1.60×10^{-03}
PADUCAH	WIPP	8.99×10^{-05}	5.25×10^{-04}	5.86×10^{-10}	6.01×10^{-03}
PANTEX	WIPP	2.72×10^{-05}	1.65×10^{-04}	5.86×10^{-10}	5.01×10^{-06}
SNL	WIPP	1.93×10^{-05}	1.16×10^{-04}	5.86×10^{-10}	4.36×10^{-07}

TABLE L-10

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY CENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$6.05 \times 10^{+02}$	$3.63 \times 10^{+03}$	3.11×10^{-03}	$1.02 \times 10^{+01}$
INEL	WIPP	4974	$4.38 \times 10^{+01}$	$2.62 \times 10^{+02}$	2.91×10^{-04}	$2.97 \times 10^{+00}$
LANL	WIPP	2835	$2.86 \times 10^{+00}$	$1.74 \times 10^{+01}$	7.97×10^{-05}	$1.85 \times 10^{+00}$
RFETS	WIPP	931	5.61×10^{-02}	3.29×10^{-01}	7.08×10^{-07}	$3.81 \times 10^{+00}$
SRS	WIPP	2827	3.05×10^{-01}	$1.71 \times 10^{+00}$	1.66×10^{-06}	$6.02 \times 10^{+01}$
		Subtotal	$6.52 \times 10^{+02}$	$3.91 \times 10^{+03}$	3.48×10^{-03}	$7.90 \times 10^{+01}$
Small CH-TRU Waste Sites						
AMES	WIPP	1	8.06×10^{-03}	4.79×10^{-02}	5.86×10^{-08}	6.23×10^{-04}
ANL-E	WIPP	5	4.88×10^{-04}	2.82×10^{-03}	2.93×10^{-09}	2.38×10^{-03}
BETTIS	WIPP	17	2.16×10^{-01}	$1.22 \times 10^{+00}$	9.96×10^{-07}	2.41×10^{-02}
ETEC	WIPP	2	8.88×10^{-02}	5.10×10^{-01}	6.56×10^{-07}	1.05×10^{-03}
KAPL	WIPP	1	1.62×10^{-02}	8.93×10^{-02}	5.86×10^{-08}	1.86×10^{-03}
LBL	WIPP	1	1.05×10^{-04}	6.02×10^{-04}	5.86×10^{-10}	8.60×10^{-05}
LLNL	WIPP	136	1.30×10^{-02}	7.63×10^{-02}	7.97×10^{-08}	7.10×10^{-02}
MOUND	WIPP	29	3.07×10^{-03}	1.77×10^{-02}	1.70×10^{-08}	7.08×10^{-01}
MU	WIPP	1	7.44×10^{-05}	4.39×10^{-04}	5.86×10^{-10}	1.48×10^{-04}
NTS	WIPP	66	4.92×10^{-01}	$3.00 \times 10^{+00}$	3.87×10^{-06}	4.78×10^{-02}
ORNL	WIPP	119	$1.57 \times 10^{+01}$	$8.78 \times 10^{+01}$	1.50×10^{-03}	1.90×10^{-01}
PADUCAH	WIPP	1	8.99×10^{-05}	5.25×10^{-04}	5.86×10^{-10}	6.01×10^{-03}
PANTEX	WIPP	1	2.72×10^{-05}	1.65×10^{-04}	5.86×10^{-10}	5.01×10^{-06}
SNL	WIPP	3	5.79×10^{-05}	3.48×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
		Subtotal	$1.65 \times 10^{+01}$	$9.28 \times 10^{+01}$	1.51×10^{-03}	$1.05 \times 10^{+00}$
		TOTAL	**$6.69 \times 10^{+02}$**	**$4.00 \times 10^{+03}$**	**4.99×10^{-03}**	**$8.01 \times 10^{+01}$**

TABLE L-11

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 6 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	8.54×10^{-02}	5.13×10^{-01}	4.39×10^{-07}	1.61×10^{-03}
INEL	WIPP	7.66×10^{-03}	4.59×10^{-02}	5.09×10^{-08}	4.89×10^{-04}
LANL	WIPP	1.38×10^{-03}	8.43×10^{-03}	3.87×10^{-08}	5.46×10^{-04}
RFETS	WIPP	4.18×10^{-05}	2.45×10^{-04}	5.27×10^{-10}	3.39×10^{-03}
SRS	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.06×10^{-02}
Small CH-TRU Waste Sites					
AMES	ANLE-E	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	8.49×10^{-03}	4.91×10^{-02}	5.09×10^{-08}	6.92×10^{-04}
ANL-E	WIPP	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	1.48×10^{-04}
BETTIS	MOUND	2.69×10^{-03}	1.33×10^{-02}	5.86×10^{-08}	6.14×10^{-04}
	WIPP	9.23×10^{-03}	5.30×10^{-02}	5.09×10^{-08}	8.65×10^{-04}
ETEC	NTS	1.78×10^{-02}	9.27×10^{-02}	3.28×10^{-07}	4.02×10^{-04}
	WIPP	5.51×10^{-02}	3.36×10^{-01}	4.33×10^{-07}	2.02×10^{-04}
KAPL	MOUND	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	9.23×10^{-03}	5.30×10^{-02}	5.09×10^{-08}	8.65×10^{-04}
LBL	LLNL	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	6.19×10^{-05}
LLNL	WIPP	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	4.76×10^{-04}
MOUND	WIPP	1.06×10^{-04}	6.10×10^{-04}	5.86×10^{-10}	2.32×10^{-02}
MU	ANL-E	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	1.39×10^{-04}
NTS	WIPP	6.48×10^{-03}	3.95×10^{-02}	5.09×10^{-08}	6.94×10^{-04}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	7.79×10^{-06}	1.51×10^{-03}
PADUCAH	ORNL	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1.01×10^{-04}	5.88×10^{-04}	5.86×10^{-10}	5.12×10^{-03}

TABLE L-11 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 6 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.10×10^{-05}	1.28×10^{-04}	5.86×10^{-10}	3.33×10^{-06}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.10×10^{-05}	1.28×10^{-04}	5.86×10^{-10}	4.11×10^{-07}

TABLE L-12

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 6 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$4.88 \times 10^{+02}$	$2.93 \times 10^{+03}$	2.51×10^{-03}	$9.20 \times 10^{+00}$
INEL	WIPP	4974	$3.81 \times 10^{+01}$	$2.28 \times 10^{+02}$	2.53×10^{-04}	$2.43 \times 10^{+00}$
LANL	WIPP	2835	$3.91 \times 10^{+00}$	$2.39 \times 10^{+01}$	1.10×10^{-04}	$1.55 \times 10^{+00}$
RFETS	WIPP	931	3.89×10^{-02}	2.28×10^{-01}	4.91×10^{-07}	$3.16 \times 10^{+00}$
SRS	WIPP	2827	3.05×10^{-01}	$1.71 \times 10^{+00}$	1.66×10^{-06}	$5.82 \times 10^{+01}$
		Subtotal	**$5.30 \times 10^{+02}$**	**$3.18 \times 10^{+03}$**	**2.88×10^{-03}**	**$7.45 \times 10^{+01}$**
Small CH-TRU Waste Sites						
AMES	ANL-E	1	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	1	8.49×10^{-03}	4.91×10^{-02}	5.09×10^{-08}	6.92×10^{-04}
ANL-E	WIPP	5	4.88×10^{-04}	2.82×10^{-03}	2.93×10^{-09}	7.40×10^{-04}
BETTIS	MOUND	17	4.57×10^{-02}	2.26×10^{-01}	9.96×10^{-07}	1.04×10^{-02}
	WIPP	17	1.57×10^{-01}	9.01×10^{-01}	8.65×10^{-07}	1.47×10^{-02}
ETEC	NTS	2	3.56×10^{-02}	1.85×10^{-01}	6.56×10^{-07}	8.04×10^{-04}
	WIPP	2	1.10×10^{-01}	6.72×10^{-01}	8.66×10^{-07}	4.04×10^{-04}
KAPL	MOUND	1	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	1	9.23×10^{-03}	5.30×10^{-02}	5.09×10^{-08}	8.65×10^{-04}
LBL	LLNL	1	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	1	9.54×10^{-05}	5.61×10^{-04}	5.86×10^{-10}	6.19×10^{-05}
LLNL	WIPP	136	1.30×10^{-02}	7.63×10^{-02}	7.97×10^{-08}	6.47×10^{-02}
MOUND	WIPP	47	4.98×10^{-03}	2.87×10^{-02}	2.75×10^{-08}	$1.09 \times 10^{+00}$
MU	ANL-E	1	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	1	9.75×10^{-05}	5.64×10^{-04}	5.86×10^{-10}	1.39×10^{-04}
NTS	WIPP	66	4.28×10^{-01}	$2.61 \times 10^{+00}$	3.36×10^{-06}	4.58×10^{-02}
ORNL	WIPP	119	$1.57 \times 10^{+01}$	$8.78 \times 10^{+01}$	9.27×10^{-04}	1.80×10^{-01}

TABLE L-12 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 6 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	1	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1	1.01×10^{-04}	5.88×10^{-04}	5.86×10^{-10}	5.12×10^{-03}
PANTEX	LANL	1	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1	2.10×10^{-05}	1.28×10^{-04}	5.86×10^{-10}	3.33×10^{-06}
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	6.30×10^{-05}	3.84×10^{-04}	1.76×10^{-09}	1.23×10^{-06}
		Subtotal	**$1.65 \times 10^{+01}$**	**$9.27 \times 10^{+01}$**	**9.34×10^{-04}**	**$1.42 \times 10^{+00}$**
		TOTAL	**$5.47 \times 10^{+02}$**	**$3.27 \times 10^{+03}$**	**3.81×10^{-03}**	**$7.59 \times 10^{+01}$**

TABLE L-13

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 6 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	8.54×10^{-02}	5.13×10^{-01}	4.39×10^{-07}	1.61×10^{-03}
INEL	WIPP	7.66×10^{-03}	4.59×10^{-02}	5.09×10^{-08}	4.89×10^{-04}
LANL	WIPP	1.38×10^{-03}	8.43×10^{-03}	3.87×10^{-08}	5.46×10^{-04}
RFETS	WIPP	4.18×10^{-05}	2.45×10^{-04}	5.27×10^{-10}	3.39×10^{-03}
SRS	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.06×10^{-02}
Small CH-TRU Waste Sites					
AMES	SRS	8.88×10^{-03}	4.85×10^{-02}	5.86×10^{-08}	1.07×10^{-03}
	WIPP	9.41×10^{-03}	5.26×10^{-02}	5.09×10^{-08}	1.05×10^{-03}
ANL-E	SRS	7.06×10^{-05}	3.71×10^{-04}	5.86×10^{-10}	6.35×10^{-04}
	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.25×10^{-04}
BETTIS	SRS	5.30×10^{-03}	2.85×10^{-02}	5.86×10^{-08}	7.15×10^{-04}
	WIPP	9.41×10^{-03}	5.26×10^{-02}	5.09×10^{-08}	1.05×10^{-03}
ETEC	INEL	4.06×10^{-02}	2.23×10^{-01}	3.28×10^{-07}	6.88×10^{-04}
	WIPP	6.52×10^{-02}	3.90×10^{-01}	4.33×10^{-07}	2.98×10^{-04}
KAPL	SRS	7.49×10^{-03}	3.97×10^{-02}	5.86×10^{-08}	9.92×10^{-04}
	WIPP	9.41×10^{-03}	5.26×10^{-02}	5.09×10^{-08}	1.05×10^{-03}
LBL	HANFORD	6.53×10^{-05}	3.57×10^{-04}	5.86×10^{-10}	6.10×10^{-05}
	WIPP	1.14×10^{-04}	6.84×10^{-04}	5.86×10^{-10}	4.96×10^{-05}
LLNL	HANFORD	6.70×10^{-05}	3.66×10^{-04}	5.86×10^{-10}	5.42×10^{-04}
	WIPP	1.14×10^{-04}	6.84×10^{-04}	5.86×10^{-10}	3.81×10^{-04}
MOUND	SRS	5.14×10^{-05}	2.70×10^{-04}	5.86×10^{-10}	1.77×10^{-02}
	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.82×10^{-02}
MU	SRS	6.81×10^{-05}	3.63×10^{-04}	5.86×10^{-10}	2.49×10^{-04}
	WIPP	1.08×10^{-04}	6.05×10^{-04}	5.86×10^{-10}	2.11×10^{-04}

TABLE L-13 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 6 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	$4.92X10^{-03}$	$2.82X10^{-02}$	$5.86x10^{-08}$	$1.17X10^{-03}$
	WIPP	$7.66X10^{-03}$	$4.59X10^{-02}$	$5.09X10^{-08}$	$1.03X10^{-03}$
ORNL	SRS	$3.65X10^{-02}$	$1.87X10^{-01}$	$1.26X10^{-05}$	$7.15X10^{-04}$
	WIPP	$1.41X10^{-01}$	$7.58X10^{-01}$	$7.79X10^{-06}$	$2.14X10^{-03}$
PADUCAH	SRS	$4.61X10^{-05}$	$2.42X10^{-04}$	$5.86X10^{-10}$	$6.34X10^{-03}$
	WIPP	$1.08X10^{-04}$	$6.05X10^{-04}$	$5.86X10^{-10}$	$7.68X10^{-03}$
PANTEX	LANL	$2.05X10^{-05}$	$1.26X10^{-04}$	$5.86X10^{-10}$	$3.83X10^{-06}$
	WIPP	$2.10X10^{-05}$	$1.28X10^{-04}$	$5.86X10^{-10}$	$3.33X10^{-06}$
SNL	LANL	$7.74X10^{-06}$	$4.27X10^{-05}$	$5.86X10^{-10}$	$4.36X10^{-07}$
	WIPP	$2.10X10^{-05}$	$1.28X10^{-04}$	$5.86X10^{-10}$	$4.11X10^{-07}$

TABLE L-14

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 6 - REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$4.88x10^{+02}$	$2.93x10^{+03}$	$2.51x10^{-03}$	$9.20x10^{+00}$
INEL	WIPP	4974	$3.81x10^{+01}$	$2.28x10^{+02}$	$2.53x10^{-04}$	$2.43x10^{+00}$
LANL	WIPP	2835	$3.91x10^{+00}$	$2.39x10^{+01}$	$1.10x10^{-04}$	$1.55x10^{+00}$
RFETS	WIPP	931	$3.89x10^{-02}$	$2.28x10^{-01}$	$4.91x10^{-07}$	$3.16x10^{+00}$
SRS	WIPP	2827	$3.05x10^{-01}$	$1.71x10^{+00}$	$1.66x10^{-06}$	$5.82x10^{+01}$
		Subtotal	**$5.30x10^{+02}$**	**$3.18x10^{+03}$**	**$2.88x10^{-03}$**	**$7.45x10^{+01}$**
Small CH-TRU Waste Sites						
AMES	SRS	1	$8.88x10^{-03}$	$4.85x10^{-02}$	$5.86x10^{-08}$	$1.07x10^{-03}$
	WIPP	1	$9.41x10^{-03}$	$5.26x10^{-02}$	$5.09x10^{-08}$	$1.05x10^{-03}$
ANL-E	SRS	5	$3.53x10^{-04}$	$1.86x10^{-03}$	$2.93x10^{-09}$	$3.18x10^{-03}$
	WIPP	5	$5.40x10^{-04}$	$3.03x0^{-03}$	$2.93x10^{-09}$	$1.13x10^{-03}$
BETTIS	SRS	17	$9.01x10^{-02}$	$4.85x10^{-01}$	$9.96x10^{-07}$	$1.22x10^{-02}$
	WIPP	17	$1.60x10^{-01}$	$8.94x10^{-01}$	$8.65x10^{-07}$	$1.79x10^{-02}$
ETEC	INEL	2	$8.12x10^{-02}$	$4.46x10^{-01}$	$6.56x10^{-07}$	$1.38x10^{-03}$
	WIPP	2	$1.30x10^{-01}$	$7.80x10^{-01}$	$8.66x10^{-07}$	$5.96x10^{-04}$
KAPL	SRS	1	$7.49x10^{-03}$	$3.97x10^{-02}$	$5.86x10^{-08}$	$9.92x10^{-04}$
	WIPP	1	$9.41x10^{-03}$	$5.26x10^{-02}$	$5.09x10^{-08}$	$1.05x10^{-03}$
LBL	HANFORD	1	$6.53x10^{-05}$	$3.57x10^{-04}$	$5.86x10^{-10}$	$6.10x10^{-05}$
	WIPP	1	$1.14x10^{-04}$	$6.84x10^{-04}$	$5.86x10^{-10}$	$4.96x10^{-05}$
LLNL	HANFORD	136	$9.11x10^{-03}$	$4.98x10^{-02}$	$7.97x10^{-08}$	$7.37x10^{-02}$
	WIPP	136	$1.55x10^{-02}$	$9.30x10^{-02}$	$7.97x10^{-08}$	$5.18x10^{-02}$
MOUND	SRS	29	$1.49x10^{-03}$	$7.83x10^{-03}$	$1.70x10^{-08}$	$5.13x10^{-01}$
	WIPP	29	$3.13x10^{-03}$	$1.75x10^{-02}$	$1.70x10^{-08}$	$8.18x10^{-01}$
MU	SRS	1	$6.81x10^{-05}$	$3.63x10^{-04}$	$5.86x10^{-10}$	$2.49x10^{-04}$
	WIPP	1	$1.08x10^{-04}$	$6.05x10^{-04}$	$5.86x10^{-10}$	$2.11x10^{-04}$

TABLE L-14 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 6 - REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	66	$3.25x10^{-01}$	$1.86x10^{+00}$	$3.87x10^{-06}$	$7.72x10^{-02}$
	WIPP	66	$5.06x10^{-01}$	$3.03x10^{+00}$	$3.36x10^{-06}$	$6.80x10^{-02}$
ORNL	SRS	119	$4.34x10^{+00}$	$2.23x10^{+01}$	$1.50x10^{-03}$	$8.51x10^{-02}$
	WIPP	119	$1.68x10^{+01}$	$9.02x10^{+01}$	$9.27x10^{-04}$	$2.55x10^{-01}$
PADUCAH	SRS	1	$4.61x10^{-05}$	$2.42x10^{-04}$	$5.86x10^{-10}$	$6.34x10^{-03}$
	WIPP	1	$1.08x10^{-04}$	$6.05x10^{-04}$	$5.86x10^{-10}$	$7.68x10^{-03}$
PANTEX	LANL	1	$2.05x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$3.83x10^{-06}$
	WIPP	1	$2.10x10^{-05}$	$1.28x10^{-04}$	$5.86x10^{-10}$	$3.33x10^{-06}$
SNL	LANL	3	$2.32x10^{-05}$	$1.28x10^{-04}$	$1.76x10^{-09}$	$1.31x10^{-06}$
	WIPP	3	$6.30x10^{-05}$	$3.84x10^{-04}$	$1.76x10^{-09}$	$1.23x10^{-06}$
		Subtotal	**$2.25x10^{+01}$**	**$1.20x10^{+02}$**	**$2.44x10^{-03}$**	**$2.00x10^{+00}$**
		TOTAL	**$5.53x10^{+02}$**	**$3.28x10^{+03}$**	**$5.32x10^{-03}$**	**$7.65x10^{+01}$**

TABLE L-15

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 10 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	1.12×10^{-01}	6.70×10^{-01}	5.74×10^{-07}	2.86×10^{-05}
INEL	WIPP	1.06×10^{-02}	6.32×10^{-02}	7.03×10^{-08}	1.00×10^{-05}
LANL	WIPP	2.10×10^{-03}	1.28×10^{-02}	5.86×10^{-08}	1.19×10^{-05}
RFETS	WIPP	8.35×10^{-05}	4.90×10^{-04}	1.05×10^{-09}	8.49×10^{-05}
SRS	WIPP	1.30×10^{-04}	7.25×10^{-04}	7.03×10^{-10}	3.00×10^{-04}
Small CH-TRU Waste Sites					
AMES	ANLE-E	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	1.17×10^{-02}	6.78×10^{-02}	7.03×10^{-08}	1.40×10^{-05}
ANL-E	WIPP	1.17×10^{-04}	6.78×10^{-04}	7.03×10^{-10}	3.01×10^{-06}
BETTIS	MOUND	2.69×10^{-03}	1.33×10^{-02}	5.86×10^{-08}	6.14×10^{-04}
	WIPP	1.27×10^{-02}	7.32×10^{-02}	7.03×10^{-08}	1.75×10^{-05}
ETEC	NTS	1.78×10^{-02}	9.27×10^{-02}	3.28×10^{-07}	4.02×10^{-04}
	WIPP	9.72×10^{-02}	5.70×10^{-01}	8.20×10^{-07}	3.03×10^{-06}
KAPL	MOUND	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	1.27×10^{-02}	7.32×10^{-02}	7.03×10^{-08}	1.75×10^{-05}
LBL	LLNL	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	1.14×10^{-04}	6.74×10^{-04}	7.03×10^{-10}	1.06×10^{-06}
LLNL	WIPP	1.14×10^{-04}	6.74×10^{-04}	7.03×10^{-10}	8.79×10^{-06}
MOUND	WIPP	1.27×10^{-04}	7.32×10^{-04}	7.03×10^{-10}	3.46×10^{-04}
MU	ANL-E	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	1.17×10^{-04}	6.78×10^{-04}	7.03×10^{-10}	1.77×10^{-06}
NTS	WIPP	8.94×10^{-03}	5.45×10^{-02}	7.03×10^{-08}	1.05×10^{-05}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	6.73×10^{-06}	2.29×10^{-05}

TABLE L-15 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 10 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1.21×10^{-04}	7.06×10^{-04}	7.03×10^{-10}	6.59×10^{-05}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	4.74×10^{-08}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	5.65×10^{-09}

TABLE L-16

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 10 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$6.40 \times 10^{+02}$	$3.83 \times 10^{+03}$	3.28×10^{-03}	1.63×10^{-01}
INEL	WIPP	4974	$5.27 \times 10^{+01}$	$3.14 \times 10^{+02}$	3.50×10^{-04}	4.97×10^{-02}
LANL	WIPP	2835	$5.95 \times 10^{+00}$	$3.63 \times 10^{+01}$	1.66×10^{-04}	3.37×10^{-02}
RFETS	WIPP	931	7.77×10^{-02}	4.56×10^{-01}	9.78×10^{-07}	7.90×10^{-02}
SRS	WIPP	2827	3.68×10^{-01}	$2.05 \times 10^{+00}$	1.99×10^{-06}	8.48×10^{-01}
		Subtotal	**$6.99 \times 10^{+02}$**	**$4.18 \times 10^{+03}$**	**3.80×10^{-03}**	**$1.17 \times 10^{+00}$**
Small CH-TRU Waste Sites						
AMES	ANL-E	1	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	1	1.17×10^{-02}	6.78×10^{-02}	7.03×10^{-08}	1.40×10^{-05}
ANL-E	WIPP	5	5.85×10^{-04}	3.39×10^{-03}	3.52×10^{-09}	1.51×10^{-05}
BETTIS	MOUND	17	4.57×10^{-02}	2.26×10^{-01}	9.96×10^{-07}	1.04×10^{-02}
	WIPP	17	2.16×10^{-01}	$1.24 \times 10^{+00}$	1.20×10^{-06}	2.98×10^{-04}
ETEC	NTS	2	3.56×10^{-02}	1.85×10^{-01}	6.56×10^{-07}	8.04×10^{-04}
	WIPP	2	1.94×10^{-01}	$1.14 \times 10^{+00}$	1.64×10^{-06}	6.06×10^{-06}
KAPL	MOUND	1	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	1	1.27×10^{-02}	7.32×10^{-02}	7.03×10^{-08}	1.75×10^{-05}
LBL	LLNL	1	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	1	1.14×10^{-04}	6.74×10^{-04}	7.03×10^{-10}	1.06×10^{-06}
LLNL	WIPP	136	1.55×10^{-02}	9.17×10^{-02}	9.56×10^{-08}	1.20×10^{-03}
MOUND	WIPP	47	5.97×10^{-03}	3.44×10^{-02}	3.30×10^{-08}	1.63×10^{-02}
MU	ANL-E	1	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	1	1.17×10^{-04}	6.78×10^{-04}	7.03×10^{-10}	1.77×10^{-06}
NTS	WIPP	66	5.90×10^{-01}	$3.60 \times 10^{+00}$	4.64×10^{-06}	6.93×10^{-04}
ORNL	WIPP	119	$1.57 \times 10^{+01}$	$8.78 \times 10^{+01}$	8.01×10^{-04}	2.73×10^{-03}

TABLE L-16 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 10 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	1	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	1	1.21×10^{-04}	7.06×10^{-04}	7.03×10^{-10}	6.59×10^{-05}
PANTEX	LANL	1	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	4.74×10^{-08}
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	7.53×10^{-05}	4.59×10^{-04}	2.11×10^{-09}	1.70×10^{-08}
		Subtotal	**$1.68 \times 10^{+01}$**	**$9.45 \times 10^{+01}$**	**8.11×10^{-04}**	**3.58×10^{-02}**
		TOTAL	**$7.16 \times 10^{+02}$**	**$4.27 \times 10^{+03}$**	**4.61×10^{-03}**	**$1.21 \times 10^{+00}$**

TABLE L-17

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 10 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	$1.12x10^{-01}$	$6.70x10^{-01}$	$5.74x10^{-07}$	$2.86x10^{-05}$
INEL	WIPP	$1.06x10^{-02}$	$6.32x10^{-02}$	$7.03x10^{-08}$	$1.00x10^{-05}$
LANL	WIPP	$2.10x10^{-03}$	$1.28x10^{-02}$	$5.86x10^{-08}$	$1.19x10^{-05}$
RFETS	WIPP	$8.35x10^{-05}$	$4.90x10^{-04}$	$1.05x10^{-09}$	$8.49x10^{-05}$
SRS	WIPP	$1.30x10^{-04}$	$7.25x10^{-04}$	$7.03x10^{-10}$	$3.00x10^{-04}$
Small CH-TRU Waste Sites					
AMES	SRS	$8.88x10^{-03}$	$4.85x10^{-02}$	$5.86x10^{-08}$	$1.07x10^{-03}$
	WIPP	$1.30x10^{-02}$	$7.25x10^{-02}$	$7.03x10^{-08}$	$2.12x10^{-05}$
ANL-E	SRS	$7.06x10^{-05}$	$3.71x10^{-04}$	$5.86x10^{-10}$	$6.35x10^{-04}$
	WIPP	$1.30x10^{-04}$	$7.25x10^{-04}$	$7.03x10^{-10}$	$4.56x10^{-06}$
BETTIS	SRS	$5.30x10^{-03}$	$2.85x10^{-02}$	$5.86x10^{-08}$	$7.15x10^{-04}$
	WIPP	$1.30x10^{-02}$	$7.25x10^{-02}$	$7.03x10^{-08}$	$2.12x10^{-05}$
ETEC	INEL	$4.06x10^{-02}$	$2.23x10^{-01}$	$3.28x10^{-07}$	$6.88x10^{-04}$
	WIPP	$1.15x10^{-01}$	$6.62x10^{-01}$	$8.20x10^{-07}$	$4.41x10^{-06}$
KAPL	SRS	$7.49x10^{-03}$	$3.97x10^{-02}$	$5.86x10^{-08}$	$9.92x10^{-04}$
	WIPP	$1.30x10^{-02}$	$7.25x10^{-02}$	$7.03x10^{-08}$	$2.12x10^{-05}$
LBL	HANFORD	$6.53x10^{-05}$	$3.57x10^{-04}$	$5.86x10^{-10}$	$6.10x10^{-05}$
	WIPP	$1.37x10^{-04}$	$8.21x10^{-04}$	$7.03x10^{-10}$	$7.99x10^{-07}$
LLNL	HANFORD	$6.70x10^{-05}$	$3.66x10^{-04}$	$5.86x10^{-10}$	$5.42x10^{-04}$
	WIPP	$1.37x10^{-04}$	$8.21x10^{-04}$	$7.03x10^{-10}$	$6.61x10^{-06}$
MOUND	SRS	$5.14x10^{-05}$	$2.70x10^{-04}$	$5.86x10^{-10}$	$1.77x10^{-02}$
	WIPP	$1.30x10^{-04}$	$7.25x10^{-04}$	$7.03x10^{-10}$	$4.18x10^{-04}$
MU	SRS	$6.81x10^{-05}$	$3.63x10^{-04}$	$5.86x10^{-10}$	$2.49x10^{-04}$
	WIPP	$1.30x10^{-04}$	$7.25x10^{-04}$	$7.03x10^{-10}$	$2.69x10^{-06}$

TABLE L-17 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 10 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	4.92×10^{-03}	2.82×10^{-02}	5.86×10^{-08}	1.17×10^{-03}
	WIPP	1.06×10^{-02}	6.32×10^{-02}	7.03×10^{-08}	1.53×10^{-05}
ORNL	SRS	3.65×10^{-02}	1.87×10^{-01}	1.26×10^{-05}	7.15×10^{-04}
	WIPP	1.41×10^{-01}	7.59×10^{-01}	6.73×10^{-06}	3.38×10^{-05}
PADUCAH	SRS	4.61×10^{-05}	2.42×10^{-04}	5.86×10^{-10}	6.34×10^{-03}
	WIPP	1.30×10^{-04}	7.25×10^{-04}	7.03×10^{-10}	9.73×10^{-05}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	4.74×10^{-08}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	5.65×10^{-09}

TABLE L-18

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 10 - REGIONALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	To Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$6.40 \times 10^{+02}$	$3.83 \times 10^{+03}$	3.28×10^{-03}	1.63×10^{-01}
INEL	WIPP	4974	$5.27 \times 10^{+01}$	$3.14 \times 10^{+02}$	3.50×10^{-04}	4.97×10^{-02}
LANL	WIPP	2835	$5.95 \times 10^{+00}$	$3.63 \times 10^{+01}$	1.66×10^{-04}	3.37×10^{-02}
RFETS	WIPP	931	7.77×10^{-02}	4.56×10^{-01}	9.78×10^{-07}	7.90×10^{-02}
SRS	WIPP	2827	3.68×10^{-01}	$2.05 \times 10^{+00}$	1.99×10^{-06}	8.48×10^{-01}
		Subtotal	**$6.99 \times 10^{+02}$**	**$4.18 \times 10^{+03}$**	**3.80×10^{-03}**	**$1.17 \times 10^{+00}$**
Small CH-TRU Waste Sites						
AMES	SRS	1	8.88×10^{-03}	4.85×10^{-02}	5.86×10^{-08}	1.07×10^{-03}
	WIPP	1	1.30×10^{-02}	7.25×10^{-02}	7.03×10^{-08}	2.12×10^{-05}
ANL-E	SRS	5	3.53×10^{-04}	1.86×10^{-03}	2.93×10^{-09}	3.18×10^{-03}
	WIPP	5	6.50×10^{-04}	3.63×10^{-03}	3.52×10^{-09}	2.28×10^{-05}
BETTIS	SRS	17	9.01×10^{-02}	4.85×10^{-01}	9.96×10^{-07}	1.22×10^{-02}
	WIPP	17	2.21×10^{-01}	$1.23 \times 10^{+00}$	1.20×10^{-06}	3.60×10^{-04}
ETEC	INEL	2	8.12×10^{-02}	4.46×10^{-01}	6.56×10^{-07}	1.38×10^{-03}
	WIPP	2	2.30×10^{-01}	$1.32 \times 10^{+00}$	1.64×10^{-06}	8.82×10^{-06}
KAPL	SRS	1	7.49×10^{-03}	3.97×10^{-02}	5.86×10^{-08}	9.92×10^{-04}
	WIPP	1	1.30×10^{-02}	7.25×10^{-02}	7.03×10^{-08}	2.12×10^{-05}
LBL	HANFORD	1	6.53×10^{-05}	3.57×10^{-04}	5.86×10^{-10}	6.10×10^{-05}
	WIPP	1	1.37×10^{-04}	8.21×10^{-04}	7.03×10^{-10}	7.99×10^{-07}
LLNL	HANFORD	136	9.11×10^{-03}	4.98×10^{-02}	7.97×10^{-08}	7.37×10^{-02}
	WIPP	136	1.86×10^{-02}	1.12×10^{-01}	9.56×10^{-08}	8.99×10^{-04}
MOUND	SRS	29	1.49×10^{-03}	7.83×10^{-03}	1.70×10^{-08}	5.13×10^{-01}
	WIPP	29	3.77×10^{-03}	2.10×10^{-02}	2.04×10^{-08}	1.21×10^{-02}
MU	SRS	1	6.81×10^{-05}	3.63×10^{-04}	5.86×10^{-10}	2.49×10^{-04}
	WIPP	1	1.30×10^{-04}	7.25×10^{-04}	7.03×10^{-10}	2.69×10^{-06}

TABLE L-18 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 10 - REGIONALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	To Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	66	3.25×10^{-01}	$1.86 \times 10^{+00}$	3.87×10^{-06}	7.72×10^{-02}
	WIPP	66	7.00×10^{-01}	$4.17 \times 10^{+00}$	4.64×10^{-06}	1.01×10^{-03}
ORNL	SRS	119	$4.34 \times 10^{+00}$	$2.23 \times 10^{+01}$	1.50×10^{-03}	8.51×10^{-02}
	WIPP	119	$1.68 \times 10^{+01}$	$9.03 \times 10^{+01}$	8.01×10^{-04}	4.02×10^{-03}
PADUCAH	SRS	1	4.61×10^{-05}	2.42×10^{-04}	5.86×10^{-10}	6.34×10^{-03}
	WIPP	1	1.30×10^{-04}	7.25×10^{-04}	7.03×10^{-10}	9.73×10^{-05}
PANTEX	LANL	1	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1	2.51×10^{-05}	1.53×10^{-04}	7.03×10^{-10}	4.74×10^{-08}
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	7.53×10^{-05}	4.59×10^{-04}	2.11×10^{-09}	1.70×10^{-08}
		Subtotal	**$2.29 \times 10^{+01}$**	**$1.23 \times 10^{+02}$**	**2.31×10^{-03}**	**7.93×10^{-01}**
		TOTAL	**$7.22 \times 10^{+02}$**	**$4.30 \times 10^{+03}$**	**6.11×10^{-03}**	**$1.96 \times 10^{+00}$**

TABLE L-19

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 94 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	6.72×10^{-02}	4.04×10^{-01}	3.46×10^{-07}	1.30×10^{-03}
INEL	WIPP	4.49×10^{-03}	2.69×10^{-02}	2.99×10^{-08}	3.03×10^{-04}
LANL	WIPP	9.01×10^{-04}	5.50×10^{-03}	2.52×10^{-08}	4.01×10^{-04}
RFETS	WIPP	3.71×10^{-05}	2.18×10^{-04}	4.68×10^{-10}	2.91×10^{-03}
SRS	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	1.56×10^{-02}
Small CH-TRU Waste Sites					
AMES	ANLE-E	2.35×10^{-03}	1.37×10^{-02}	5.86×10^{-08}	1.66×10^{-04}
	WIPP	4.97×10^{-03}	2.88×10^{-02}	2.99×10^{-08}	4.29×10^{-04}
ANL-E	WIPP	7.80×10^{-05}	4.52×10^{-04}	4.68×10^{-10}	9.08×10^{-05}
BETTIS	MOUND	2.69×10^{-03}	1.33×10^{-02}	5.86×10^{-08}	6.14×10^{-04}
	WIPP	5.41×10^{-03}	3.11×10^{-02}	2.99×10^{-08}	5.37×10^{-04}
ETEC	NTS	1.78×10^{-02}	9.27×10^{-02}	3.28×10^{-07}	4.02×10^{-04}
	WIPP	7.45×10^{-02}	4.54×10^{-01}	5.86×10^{-07}	1.53×10^{-04}
KAPL	MOUND	6.17×10^{-03}	3.08×10^{-02}	5.86×10^{-08}	1.06×10^{-03}
	WIPP	5.41×10^{-03}	3.11×10^{-02}	2.99×10^{-08}	5.37×10^{-04}
LBL	LLNL	9.84×10^{-06}	4.30×10^{-05}	5.86×10^{-10}	2.57×10^{-05}
	WIPP	7.63×10^{-05}	4.49×10^{-04}	4.68×10^{-10}	4.42×10^{-05}
LLNL	WIPP	7.63×10^{-05}	4.49×10^{-04}	4.68×10^{-10}	3.75×10^{-04}
MOUND	WIPP	8.49×10^{-05}	4.87×10^{-04}	4.68×10^{-10}	1.72×10^{-02}
MU	ANL-E	2.94×10^{-05}	1.61×10^{-04}	5.86×10^{-10}	9.30×10^{-05}
	WIPP	7.80×10^{-05}	4.52×10^{-04}	4.68×10^{-10}	1.39×10^{-04}
NTS	WIPP	3.80×10^{-03}	2.31×10^{-02}	2.99×10^{-08}	5.29×10^{-04}
ORNL	WIPP	1.32×10^{-01}	7.38×10^{-01}	4.02×10^{-06}	1.03×10^{-03}

TABLE L-19 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 94 - DECENTRALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	2.26×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	1.86×10^{-03}
	WIPP	8.07×10^{-05}	4.71×10^{-04}	4.68×10^{-10}	2.05×10^{-03}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1.68×10^{-05}	1.02×10^{-04}	4.68×10^{-10}	2.54×10^{-06}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	1.68×10^{-05}	1.02×10^{-04}	4.68×10^{-10}	3.13×10^{-07}

TABLE L-20

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 94 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$3.84x10^{+02}$	$2.31x10^{+03}$	$1.98x10^{-03}$	$7.43x10^{+00}$
INEL	WIPP	4974	$2.23x10^{+01}$	$1.34x10^{+02}$	$1.49x10^{-04}$	$1.51x10^{+00}$
LANL	WIPP	2835	$2.55x10^{+00}$	$1.56x10^{+01}$	$7.14x10^{-05}$	$1.14x10^{+00}$
RFETS	WIPP	931	$3.45x10^{-02}$	$2.03x10^{-01}$	$4.36x10^{-07}$	$2.71x10^{+00}$
SRS	WIPP	2827	$2.45x10^{-01}$	$1.37x10^{+00}$	$1.32x10^{-06}$	$4.41x10^{+01}$
		Subtotal	**$4.09x10^{+02}$**	**$2.46x10^{+03}$**	**$2.20x10^{-03}$**	**$5.69x10^{+01}$**
Small CH-TRU Waste Sites						
AMES	ANL-E	1	$2.35x10^{-03}$	$1.37x10^{-02}$	$5.86x10^{-08}$	$1.66x10^{-04}$
	WIPP	1	$4.97x10^{-03}$	$2.88x10^{-02}$	$2.99x10^{-08}$	$4.29x10^{-04}$
ANL-E	WIPP	5	$3.90x10^{-04}$	$2.26x10^{-03}$	$2.34x10^{-09}$	$4.54x10^{-04}$
BETTIS	MOUND	17	$4.57x10^{-02}$	$2.26x10^{-01}$	$9.96x10^{-07}$	$1.04x10^{-02}$
	WIPP	17	$9.20x10^{-02}$	$5.29x10^{-01}$	$5.08x10^{-07}$	$9.13x10^{-03}$
ETEC	NTS	2	$3.56x10^{-02}$	$1.85x10^{-01}$	$6.56x10^{-07}$	$8.04x10^{-04}$
	WIPP	2	$1.49x10^{-01}$	$9.08x10^{-01}$	$1.17x10^{-06}$	$3.06x10^{-04}$
KAPL	MOUND	1	$6.17x10^{-03}$	$3.08x10^{-02}$	$5.86x10^{-08}$	$1.06x10^{-03}$
	WIPP	1	$5.41x10^{-03}$	$3.11x10^{-02}$	$2.99x10^{-08}$	$5.37x10^{-04}$
LBL	LLNL	1	$9.84x10^{-06}$	$4.30x10^{-05}$	$5.86x10^{-10}$	$2.57x10^{-05}$
	WIPP	1	$7.63x10^{-05}$	$4.49x10^{-04}$	$4.68x10^{-10}$	$4.42x10^{-05}$
LLNL	WIPP	136	$1.04x10^{-02}$	$6.11x10^{-02}$	$6.36x10^{-08}$	$5.10x10^{-02}$
MOUND	WIPP	29	$2.46x10^{-03}$	$1.41x10^{-02}$	$1.36x10^{-08}$	$4.99x10^{-01}$
MU	ANL-E	1	$2.94x10^{-05}$	$1.61x10^{-04}$	$5.86x10^{-10}$	$9.30x10^{-05}$
	WIPP	1	$7.80x10^{-05}$	$4.52x10^{-04}$	$4.68x10^{-10}$	$1.39x10^{-04}$
NTS	WIPP	66	$2.51x10^{-01}$	$1.52x10^{+00}$	$1.97x10^{-06}$	$3.49x10^{-02}$
ORNL	WIPP	119	$1.57x10^{+01}$	$8.78x10^{+01}$	$4.78x10^{-04}$	$1.23x10^{-01}$

TABLE L-20 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 94 - DECENTRALIZED CONFIGURATION

			Incident-Free Doses			Accident Risk Dose
Waste Origin Site	Route Segment Destination	No. Of Shipments	Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
PADUCAH	ORNL	1	$2.26x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$1.86x10^{-03}$
	WIPP	1	$8.07x10^{-05}$	$4.71x10^{-04}$	$4.68x10^{-10}$	$2.05x10^{-03}$
PANTEX	LANL	1	$2.05x10^{-05}$	$1.26x10^{-04}$	$5.86x10^{-10}$	$3.83x10^{-06}$
	WIPP	1	$1.68x10^{-05}$	$1.02x10^{-04}$	$4.68x10^{-10}$	$2.54x10^{-06}$
SNL	LANL	3	$2.32x10^{-05}$	$1.28x10^{-04}$	$1.76x10^{-09}$	$1.31x10^{-06}$
	WIPP	3	$5.04x10^{-05}$	$3.06x10^{-04}$	$1.40x10^{-09}$	$9.39x10^{-07}$
		Subtotal	**$1.63x10^{+01}$**	**$9.14x10^{+01}$**	**$4.84x10^{-04}$**	**$7.35x10^{-01}$**
		TOTAL	**$4.25x10^{+02}$**	**$2.55x10^{+03}$**	**$2.68x10^{-03}$**	**$5.76x10^{+01}$**

TABLE L-21

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 94 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites					
HANFORD	WIPP	6.72×10^{-02}	4.04×10^{-01}	3.46×10^{-07}	1.30×10^{-03}
INEL	WIPP	4.49×10^{-03}	2.69×10^{-02}	2.99×10^{-08}	3.03×10^{-04}
LANL	WIPP	9.01×10^{-04}	5.50×10^{-03}	2.52×10^{-08}	4.01×10^{-04}
RFETS	WIPP	3.71×10^{-05}	2.18×10^{-04}	4.68×10^{-10}	2.91×10^{-03}
SRS	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	1.56×10^{-02}
Small CH-TRU Waste Sites					
AMES	SRS	8.88×10^{-03}	4.85×10^{-02}	5.86×10^{-08}	1.07×10^{-03}
	WIPP	5.51×10^{-03}	3.08×10^{-02}	2.99×10^{-08}	6.52×10^{-04}
ANL-E	SRS	7.06×10^{-05}	3.71×10^{-04}	5.86×10^{-10}	6.35×10^{-04}
	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	1.38×10^{-04}
BETTIS	SRS	5.30×10^{-03}	2.85×10^{-02}	5.86×10^{-08}	7.15×10^{-04}
	WIPP	5.51×10^{-03}	3.08×10^{-02}	2.99×10^{-08}	6.52×10^{-04}
ETEC	INEL	4.06×10^{-02}	2.23×10^{-01}	3.28×10^{-07}	6.88×10^{-04}
	WIPP	8.81×10^{-02}	5.27×10^{-01}	5.86×10^{-07}	2.25×10^{-04}
KAPL	SRS	7.49×10^{-03}	3.97×10^{-02}	5.86×10^{-08}	9.92×10^{-04}
	WIPP	5.51×10^{-03}	3.08×10^{-02}	2.99×10^{-08}	6.52×10^{-04}
LBL	HANFORD	6.53×10^{-05}	3.57×10^{-04}	5.86×10^{-10}	6.10×10^{-05}
	WIPP	9.11×10^{-05}	5.46×10^{-04}	4.68×10^{-10}	3.54×10^{-05}
LLNL	HANFORD	6.70×10^{-05}	3.66×10^{-04}	5.86×10^{-10}	5.42×10^{-04}
	WIPP	9.11×10^{-05}	5.46×10^{-04}	4.68×10^{-10}	3.00×10^{-04}
MOUND	SRS	5.14×10^{-05}	2.70×10^{-04}	5.86×10^{-10}	1.77×10^{-02}
	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	2.09×10^{-02}
MU	SRS	6.81×10^{-05}	3.63×10^{-04}	5.86×10^{-10}	2.49×10^{-04}
	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	2.11×10^{-04}

TABLE L-21 (Continued)

RADIOLOGICAL DOSES PER SHIPMENT FOR CH-TRU WASTE ENGINEERED ALTERNATIVE No. 94 - REGIONALIZED CONFIGURATION

Waste Origin Site	Route Segment Destination	Incident-Free Doses			Accident Risk Dose
		Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	4.92×10^{-03}	2.82×10^{-02}	5.86×10^{-08}	1.17×10^{-03}
	WIPP	4.49×10^{-03}	2.69×10^{-02}	2.99×10^{-08}	7.82×10^{-04}
ORNL	SRS	3.65×10^{-02}	1.87×10^{-01}	1.26×10^{-05}	7.15×10^{-04}
	WIPP	1.41×10^{-01}	7.59×10^{-01}	4.02×10^{-06}	1.54×10^{-03}
PADUCAH	SRS	4.61×10^{-05}	2.42×10^{-04}	5.86×10^{-10}	6.34×10^{-03}
	WIPP	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	3.07×10^{-03}
PANTEX	LANL	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1.68×10^{-05}	1.02×10^{-04}	4.68×10^{-10}	2.54×10^{-06}
SNL	LANL	7.74×10^{-06}	4.27×10^{-05}	5.86×10^{-10}	4.36×10^{-07}
	WIPP	1.68×10^{-05}	1.02×10^{-04}	4.68×10^{-10}	3.13×10^{-07}

TABLE L-22

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 94 - REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
Major CH-TRU Waste Sites						
HANFORD	WIPP	5712	$3.84 \times 10^{+02}$	$2.31 \times 10^{+03}$	1.98×10^{-03}	$7.43 \times 10^{+00}$
INEL	WIPP	4974	$2.23 \times 10^{+01}$	$1.34 \times 10^{+02}$	1.49×10^{-04}	$1.51 \times 10^{+00}$
LANL	WIPP	2835	$2.55 \times 10^{+00}$	$1.56 \times 10^{+01}$	7.14×10^{-05}	$1.14 \times 10^{+00}$
RFETS	WIPP	931	3.45×10^{-02}	2.03×10^{-01}	4.36×10^{-07}	$2.71 \times 10^{+00}$
SRS	WIPP	2827	2.45×10^{-01}	$1.37 \times 10^{+00}$	1.32×10^{-06}	$4.41 \times 10^{+01}$
		Subtotal	**$4.09 \times 10^{+02}$**	**$2.46 \times 10^{+03}$**	**2.20×10^{-03}**	**$5.69 \times 10^{+01}$**
Small CH-TRU Waste Sites						
AMES	SRS	1	8.88×10^{-03}	4.85×10^{-02}	5.86×10^{-08}	1.07×10^{-03}
	WIPP	1	5.51×10^{-03}	3.08×10^{-02}	2.99×10^{-08}	6.52×10^{-04}
ANL-E	SRS	5	3.53×10^{-04}	1.86×10^{-03}	2.93×10^{-09}	3.18×10^{-03}
	WIPP	5	4.33×10^{-04}	2.42×10^{-03}	2.34×10^{-09}	6.90×10^{-04}
BETTIS	SRS	17	9.01×10^{-02}	4.85×10^{-01}	9.96×10^{-07}	1.22×10^{-02}
	WIPP	17	9.37×10^{-02}	5.24×10^{-01}	5.08×10^{-07}	1.11×10^{-02}
ETEC	INEL	2	8.12×10^{-02}	4.46×10^{-01}	6.56×10^{-07}	1.38×10^{-03}
	WIPP	2	1.76×10^{-01}	$1.05 \times 10^{+00}$	1.17×10^{-06}	4.50×10^{-04}
KAPL	SRS	1	7.49×10^{-03}	3.97×10^{-02}	5.86×10^{-08}	9.92×10^{-04}
	WIPP	1	5.51×10^{-03}	3.08×10^{-02}	2.99×10^{-08}	6.52×10^{-04}
LBL	HANFORD	1	6.53×10^{-05}	3.57×10^{-04}	5.86×10^{-10}	6.10×10^{-05}
	WIPP	1	9.11×10^{-05}	5.46×10^{-04}	4.68×10^{-10}	3.54×10^{-05}
LLNL	HANFORD	136	9.11×10^{-03}	4.98×10^{-02}	7.97×10^{-08}	7.37×10^{-02}
	WIPP	136	1.24×10^{-02}	7.43×10^{-02}	6.36×10^{-08}	4.08×10^{-02}
MOUND	SRS	29	1.49×10^{-03}	7.83×10^{-03}	1.70×10^{-08}	5.13×10^{-01}
	WIPP	29	2.51×10^{-03}	1.40×10^{-02}	1.36×10^{-08}	6.06×10^{-01}
MU	SRS	1	6.81×10^{-05}	3.63×10^{-04}	5.86×10^{-10}	2.49×10^{-04}
	WIPP	1	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	2.11×10^{-04}

TABLE L-22 (Continued)

CUMULATIVE RADIOLOGICAL DOSES FOR CH-TRU WASTE SHIPMENTS OVER THE LIFETIME OF THE WIPP FACILITY ENGINEERED ALTERNATIVE No. 94 - REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Incident-Free Doses			Accident Risk Dose
			Crew (person-rem)	Public (person-rem)	Max Individual (rem)	Public (person-rem)
NTS	INEL	66	3.25×10^{-01}	$1.86 \times 10^{+00}$	3.87×10^{-06}	7.72×10^{-02}
	WIPP	66	2.96×10^{-01}	$1.78 \times 10^{+00}$	1.97×10^{-06}	5.16×10^{-02}
ORNL	SRS	119	$4.34 \times 10^{+00}$	$2.23 \times 10^{+01}$	1.50×10^{-03}	8.51×10^{-02}
	WIPP	119	$1.68 \times 10^{+01}$	$9.03 \times 10^{+01}$	4.78×10^{-04}	1.83×10^{-01}
PADUCAH	SRS	1	4.61×10^{-05}	2.42×10^{-04}	5.86×10^{-10}	6.34×10^{-03}
	WIPP	1	8.65×10^{-05}	4.83×10^{-04}	4.68×10^{-10}	3.07×10^{-03}
PANTEX	LANL	1	2.05×10^{-05}	1.26×10^{-04}	5.86×10^{-10}	3.83×10^{-06}
	WIPP	1	1.68×10^{-05}	1.02×10^{-04}	4.68×10^{-10}	2.54×10^{-06}
SNL	LANL	3	2.32×10^{-05}	1.28×10^{-04}	1.76×10^{-09}	1.31×10^{-06}
	WIPP	3	5.04×10^{-05}	3.06×10^{-04}	1.40×10^{-09}	9.39×10^{-07}
		Subtotal	**$2.23 \times 10^{+01}$**	**$1.19 \times 10^{+02}$**	**1.99×10^{-03}**	**$1.67 \times 10^{+00}$**
		TOTAL	**$4.31 \times 10^{+02}$**	**$2.58 \times 10^{+03}$**	**4.19×10^{-03}**	**$5.86 \times 10^{+01}$**

TABLE L-23

CHEMICAL AIRBORNE RELEASES FOR A POSTULATED VERY SEVERE ACCIDENT (CH-TRU TRUCK SHIPMENT) - BASELINE[1,3,4,5,6]

Chemical	Release Form	Release Fraction	Fraction of Waste Chemical is Present	Chemical Fraction in Waste Matrix	Quantity Released (mg)	Receptor Concentration (mg/m3)	Adjusted ERPG-2 Value (mg/m3)	Receptor Concentration/ Adj.'d ERPG-2 Value
Beryllium	particulate	$2.0x10^{-04}$	$2.1x10^{-01}$	$1.0x10^{-02}$	$2.6x10^{+03}$	$4.1x10^{-05}$	$2.5x10^{-03}$	$1.6x10^{-02}$
Bromine	vapor	$5.0x10^{-01}$	$6.6x10^{-02}$	$1.0x10^{-02}$	$2.0x10^{+06}$	$3.2x10^{-02}$	$3.3x10^{+00}$	$9.7x10^{-03}$
Cadmium	particulate	$2.0x10^{-04}$	$1.9x10^{-01}$	$3.0x10^{-01}$	$7.0x10^{+04}$	$1.1x10^{-03}$	$1.5x10^{-01}$	$7.3x10^{-03}$
Cadmium	vapor	$1.6x10^{-02}$	$1.9x10^{-01}$	$3.0x10^{-01}$	$5.6x10^{+08}$	$8.8x10^{-02}$	$1.5x10^{-01}$	$5.9x10^{-01}$
Carbon Tetrachloride	vapor	$5.0x10^{-01}$	$1.3x10^{-01}$	$3.0x10^{-01}$	$1.2x10^{+08}$	$1.9x10^{+00}$	$7.9x10^{+01}$	$2.4x10^{-02}$
Cellulose	particulate	$2.0x10^{-02}$	$9.1x10^{-02}$	$3.0x10^{-01}$	$3.4x10^{+08}$	$5.3x10^{-02}$	$2.5x10^{+01}$	$2.1x10^{-03}$
Chloroform	vapor	$5.0x10^{-01}$	$6.0x10^{-03}$	$3.0x10^{-01}$	$5.5x10^{+06}$	$8.7x10^{-02}$	$2.4x10^{+02}$	$3.6x10^{-04}$
Chlorosulporic acid	vapor	$5.0x10^{-01}$	$1.8x10^{-01}$	$1.0x10^{-02}$	$5.5x10^{+06}$	$8.7x10^{-02}$	$5.0x10^{+00}$	$1.7x10^{-02}$
Chromium VI compounds	particulate	$2.0x10^{-04}$	$1.9x10^{-01}$	$1.0x10^{-02}$	$2.3x10^{+03}$	$3.7x10^{-05}$	$1.3x10^{-01}$	$2.8x10^{-04}$
Copper	particulate	$2.0x10^{-04}$	$1.9x10^{-01}$	$1.0x10^{-01}$	$2.3x10^{+04}$	$3.7x10^{-04}$	$5.0x10^{-01}$	$7.3x10^{-04}$
Hydrazine	vapor	$5.0x10^{-01}$	$1.3x10^{-01}$	$1.0x10^{-02}$	$4.0x10^{+06}$	$6.3x10^{-02}$	$5.5x10^{-01}$	$1.1x10^{-01}$
Lead	particulate	$2.0x10^{-04}$	$1.9x10^{-01}$	$3.0x10^{-01}$	$7.0x10^{+04}$	$1.1x10^{-03}$	$3.8x10^{-01}$	$2.9x10^{-03}$
Mercury	vapor	$5.0x10^{-01}$	$3.6x10^{-02}$	$1.0x10^{-02}$	$1.1x10^{+06}$	$1.7x10^{-02}$	$5.0x10^{-02}$	$3.5x10^{-01}$
Oxalic acid	vapor	$5.0x10^{-01}$	$1.8x10^{-01}$	$1.0x10^{-02}$	$5.5x10^{+06}$	$8.7x10^{-02}$	$2.5x10^{+00}$	$3.5x10^{-02}$
Platinum	particulate	$2.0x10^{-04}$	$2.8x10^{-01}$	$1.0x10^{-01}$	$3.4x10^{+04}$	$5.4x10^{-04}$	$2.5x10^{+00}$	$2.2x10^{-04}$

Refer to footnotes at end of table.

TABLE L-23 (Continued)

CHEMICAL AIRBORNE RELEASES FOR A POSTULATED VERY SEVERE ACCIDENT (CH-TRU TRUCK SHIPMENT) - BASELINE[1,3,4,5,6]

Chemical	Release Form	Release Fraction	Fraction of Waste Chemical is Present	Chemical Fraction in Waste Matrix	Quantity Released (mg)	Receptor Concentration (mg/m3)	Adjusted ERPG-2 Value (mg/m3)	Receptor Concentration/ Adj.'d ERPG-2 Value
Phosphoric acid	particulate	$2.0x10^{-04}$	$6.0x10^{-03}$	$1.0x10^{-02}$	$7.4x10^{+01}$	$1.2x10^{-06}$	$2.5x10^{+00}$	$4.6x10^{-07}$
Silver	particulate	$2.0x10^{-04}$	$1.5x10^{-01}$	$1.0x10^{-02}$	$1.8x10^{+03}$	$2.9x10^{-05}$	$2.5x10^{-01}$	$1.2x10^{-04}$
Sodium hydroxide	particulate	$2.0x10^{-04}$	$1.6x10^{-01}$	$1.0x10^{-02}$	$2.0x10^{+03}$	$3.1x10^{-05}$	$1.0x10^{+00}$	$3.1x10^{-05}$
Tributyl phosphate	vapor	$5.0x10^{-01}$	$2.4x10^{-02}$	$3.0x10^{-01}$	$2.2x10^{+07}$	$3.5x10^{-01}$	$5.5x10^{+00}$	$6.3x10^{-02}$
Tungsten	particulate	$2.0x10^{-04}$	$1.9x10^{-01}$	$1.0x10^{-01}$	$2.3x10^{+04}$	$3.7x10^{-04}$	$2.5x10^{+00}$	$1.5x10^{-04}$
Uranium	particulate	$2.0x10^{-04}$	$1.5x10^{-01}$	$1.0x10^{-02}$	$1.8x10^{+03}$	$2.9x10^{-05}$	$5.0x10^{-01}$	$5.8x10^{-05}$
TOTAL								$1.2X10^{+00}$

[1]Assumes a severity category VIII accident.
[2]See Section 3.5.2.1.3 text for basis of chemicals evaluated and release quantities.
[3]The receptor is the maximum exposed member of the public, with downwind dispersion characteristics based on a wind speed of 1 meter/sec and Pasquill Stability Class F (X/Q = $1.13x10^{-04}$).
[4]Quantity Released = Release Fraction x Fraction of Waste Chemical is Present x Chemical Fraction in Waste x Weight of Waste/Shipment.
[5]Weight of Waste/Shipment (mg) = 3.67 (m3/TRUPACT) x 3 (TRUPACT/Shipment) x 559 (kg/m3) x $1x10^{+06}$; TRUPACT cargo volume based on 2 SWBs.
[6]Receptor Concentration = X/Q (max individual) x Release rate (mg/sec); = 1.13x10-04 (sec/^{m3}) x Release Quantity (mg)/7200 (sec); assumes a two hour release.

TABLE L-24

CHEMICAL AIRBORNE RELEASES FOR A POSTULATED VERY SEVERE ACCIDENT (CH-TRU TRUCK SHIPMENT) - ENGINEERED ALTERNATIVES[1,2,3,4,5,6]

		Engineered Alternatives No. 1 & 77		Engineered Alternative No. 6		Engineered Alternative No. 10		Engineered Alternative No. 94	
Chemical	Release Form	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value
Beryllium	particulate	$2.0x10^{-05}$	$2.4x10^{-03}$	$2.0x10^{-04}$	$1.6x10^{-02}$	$7.0x10^{-08}$	$1.6x10^{-05}$	$2.0x10^{-04}$	$1.1x10^{-02}$
Bromine	vapor	$5.0x10^{-01}$	$1.4x10^{-02}$	$5.0x10^{-01}$	$9.4x10^{-03}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$6.4x10^{-03}$
Cadmium	particulate	$2.0x10^{-05}$	$1.1x10^{-03}$	$2.0x10^{-04}$	$7.2x10^{-03}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$2.0x10^{-04}$	$4.9x10^{-03}$
Cadmium	vapor	$1.6x10^{-02}$	$8.6x10^{-01}$	$1.6x10^{-02}$	$5.7x10^{-01}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$1.6x10^{-02}$	$3.9x10^{-01}$
Carbon Tetrachloride	vapor	$5.0x10^{-01}$	$3.5x10^{-02}$	$5.0x10^{-01}$	$2.3x10^{-02}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$1.6x10^{-02}$
Cellulose	particulate	$2.0x10^{-02}$	$3.1x10^{-03}$	$2.0x10^{-02}$	$2.1x10^{-03}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$2.0x10^{-02}$	$1.4x10^{-03}$
Chloroform	vapor	$5.0x10^{-01}$	$5.3x10^{-04}$	$5.0x10^{-01}$	$3.5x10^{-04}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$2.4x10^{-04}$
Chlorosulporic acid	vapor	$5.0x10^{-01}$	$2.5x10^{-02}$	$5.0x10^{-01}$	$1.7x10^{-02}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$1.2x10^{-02}$
Chromium VI compounds	particulate	$2.0x10^{-05}$	$4.1x10^{-05}$	$2.0x10^{-04}$	$2.8x10^{-04}$	$7.0x10^{-08}$	$2.8x10^{-07}$	$2.0x10^{-04}$	$1.9x10^{-04}$
Copper	particulate	$2.0x10^{-05}$	$1.1x10^{-04}$	$2.0x10^{-04}$	$7.2x10^{-04}$	$7.0x10^{-08}$	$7.3x10^{-07}$	$2.0x10^{-04}$	$4.9x10^{-04}$
Hydrazine	vapor	$5.0x10^{-01}$	$1.7x10^{-01}$	$5.0x10^{-01}$	$1.1x10^{-01}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$7.6x10^{-02}$
Lead	particulate	$2.0x10^{-05}$	$4.2x10^{-04}$	$2.0x10^{-04}$	$2.8x10^{-03}$	$7.0x10^{-08}$	$2.9x10^{-06}$	$2.0x10^{-04}$	$1.9x10^{-03}$

Refer to footnotes at end of table.

TABLE L-24 (Continued)

CHEMICAL AIRBORNE RELEASES FOR A POSTULATED VERY SEVERE ACCIDENT (CH-TRU TRUCK SHIPMENT) - ENGINEERED ALTERNATIVES[1,2,3,4,5,6]

		Engineered Alternatives No. 1 & 77		Engineered Alternative No. 6		Engineered Alternative No. 10		Engineered Alternative No. 94	
Chemical	Release Form	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value	Release Fraction	Receptor Concentration/ Adj'd ERPG-2 Value
Mercury	vapor	$5.0x10^{-01}$	$5.x10^{-01}$	$5.0x10^{-01}$	$3.4x10^{-01}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$2.3x10^{-01}$
Oxalic acid	vapor	$5.0x10^{-01}$	$5.1x10^{-02}$	$5.0x10^{-01}$	$3.4x10^{-02}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$2.3x10^{-02}$
Platinum	particulate	$2.0x10^{-05}$	$3.2x10^{-05}$	$2.0x10^{-04}$	$2.1x10^{-04}$	$7.0x10^{-08}$	$2.2x10^{-07}$	$2.0x10^{-04}$	$1.4x10^{-04}$
Phosphoric acid	particulate	$2.0x10^{-05}$	$6.8x10^{-08}$	$2.0x10^{-04}$	$4.5x10^{-07}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$2.0x10^{-04}$	$3.1x10^{-07}$
Silver	particulate	$2.0x10^{-05}$	$1.7x10^{-05}$	$2.0x10^{-04}$	$1.1x10^{-04}$	$7.0x10^{-08}$	$1.2x10^{-07}$	$2.0x10^{-04}$	$7.7x10^{-05}$
Sodium hydroxide	particulate	$2.0x10^{-05}$	$4.5x10^{-06}$	$2.0x10^{-04}$	$3.0x10^{-05}$	$7.0x10^{-08}$	$3.1x10^{-08}$	$2.0x10^{-04}$	$2.0x10^{-05}$
Tributyl phosphate	vapor	$5.0x10^{-01}$	$9.2x10^{-02}$	$5.0x10^{-01}$	$6.2x10^{-02}$	$0.0x10^{+00}$	$0.0x10^{+00}$	$5.0x10^{-01}$	$4.2x10^{-02}$
Tungsten	particulate	$2.0x10^{-05}$	$2.1x10^{-05}$	$2.0x10^{-04}$	$1.4x10^{-04}$	$7.0x10^{-08}$	$1.5x10^{-07}$	$2.0x10^{-04}$	$9.7x10^{-04}$
Uranium	particulate	$2.0x10^{-05}$	$8.5x10^{-06}$	$2.0x10^{-04}$	$5.7x10^{-05}$	$7.0x10^{-08}$	$5.8x10^{-08}$	$2.0x10^{-04}$	$3.8x10^{-05}$
TOTAL			**$1.8x10^{+00}$**		**$1.2x10^{+00}$**		**$2.1x10^{-05}$**		**$8.1x10^{-01}$**

[1]The receptor is the maximum exposed member of the public and the analysis assumes a severity category VIII accident.
[2]See Section 3.5.2.1.3 text for basis of chemicals evaluated and analysis methodology.
[3]Engineered Alternatives No. 1 & 77 calculation basis: system-wide average waste density of 1031 kg/m^3, waste shipped in drums, particulate releases assumed to be the same as radiological particulate releases for the same alternative, vapor releases assumed to be the same as the baseline.
[4]Engineered Alternative No. 6 basis: system-wide average waste density of 689 kg/m^3, waste shipped in drums, particulate releases assumed to be the same as radiological particulate releases for the same alternative, vapor releases assumed to be the same as the base case.
[5]Engineered Alternative No. 10 basis: system-wide average waste density of 1595 kg/m^3, waste may be shipped in SWBs, all organics and cadmium (low vaporization temperature) removed by processing and would have no accident releases, particulate releases assumed to be the same as radiological particulate releases for the same alternative.
[6]Engineered Alternative No. 94 basis: system-wide average waste density of 997 kg/m^3, waste shipped in drums, same release fractions as Alternative No. 6, addition of clay reduces average chemical constituent fraction in the waste matrix to a value equal to 0.468 of the baseline value.

TABLE L-25

NONRADIOLOGICAL/NONCHEMICAL PER-SHIPMENT RISK FOR CH-TRU AND RH-TRU WASTE

Waste Origin Site	To Route Segment Destination	Zone	Injuries	Fatalities
AMES	ANL-E	Rural	8.00×10^{-04}	6.56×10^{-05}
		Suburban	6.35×10^{-05}	2.70×10^{-06}
		Urban	2.59×10^{-06}	6.47×10^{-08}
AMES	SRS	Rural	2.35×10^{-03}	1.92×10^{-04}
		Suburban	3.69×10^{-04}	1.57×10^{-05}
		Urban	1.93×10^{-05}	4.84×10^{-07}
AMES	WIPP	Rural	2.98×10^{-03}	2.44×10^{-04}
		Suburban	1.49×10^{-04}	6.34×10^{-08}
		Urban	1.93×10^{-05}	4.84×10^{-07}
ANL-E	SRS	Rural	1.56×10^{-03}	1.28×10^{-04}
		Suburban	3.36×10^{-04}	1.43×10^{-05}
		Urban	2.92×10^{-05}	7.30×10^{-07}
ANL-E	WIPP	Rural	3.29×10^{-03}	2.70×10^{-04}
		Suburban	2.57×10^{-04}	1.09×10^{-05}
		Urban	1.70×10^{-05}	4.25×10^{-07}
BATTELLE	ORNL	Rural	6.45×10^{-04}	5.29×10^{-05}
		Suburban	1.91×10^{-04}	8.15×10^{-06}
		Urban	1.84×10^{-05}	4.59×10^{-07}
BETTIS	MOUND	Rural	4.12×10^{-04}	3.38×10^{-05}
		Suburban	1.44×10^{-04}	6.12×10^{-06}
		Urban	2.46×10^{-05}	6.16×10^{-07}
BETTIS	SRS	Rural	1.29×10^{-03}	1.06×10^{-04}
		Suburban	2.38×10^{-04}	1.01×10^{-05}
		Urban	1.53×10^{-05}	3.82×10^{-07}
BETTIS	WIPP	Rural	3.86×10^{-03}	3.17×10^{-04}
		Suburban	4.02×10^{-04}	1.71×10^{-05}
		Urban	3.87×10^{-05}	9.67×10^{-07}

TABLE L-25 (Continued)

NONRADIOLOGICAL/NONCHEMICAL PER-SHIPMENT RISK FOR CH-TRU AND RH-TRU WASTE

Waste Origin Site	To Route Segment Destination	Zone	Injuries	Fatalities
ETEC	INEL	Rural	2.01×10^{-03}	1.65×10^{-04}
		Suburban	1.79×10^{-04}	7.61×10^{-06}
		Urban	7.60×10^{-05}	1.90×10^{-06}
ETEC	NTS	Rural	7.16×10^{-04}	5.87×10^{-05}
		Suburban	7.75×10^{-05}	3.30×10^{-06}
		Urban	5.49×10^{-05}	1.37×10^{-06}
ETEC	WIPP	Rural	2.65×10^{-03}	2.17×10^{-04}
		Suburban	1.28×10^{-04}	5.43×10^{-06}
		Urban	6.50×10^{-05}	1.63×10^{-06}
HANFORD	WIPP	Rural	4.38×10^{-03}	3.59×10^{-04}
		Suburban	1.83×10^{-04}	7.77×10^{-06}
		Urban	2.23×10^{-05}	5.57×10^{-07}
INEL	WIPP	Rural	3.36×10^{-03}	2.75×10^{-04}
		Suburban	1.44×10^{-04}	6.14×10^{-06}
		Urban	1.90×10^{-05}	4.74×10^{-07}
KAPL	MOUND	Rural	1.02×10^{-03}	8.32×10^{-05}
		Suburban	3.68×10^{-04}	1.57×10^{-05}
		Urban	2.54×10^{-05}	6.34×10^{-07}
KAPL	ORNL	Rural	7.83×10^{-04}	6.42×10^{-05}
		Suburban	1.80×10^{-04}	7.68×10^{-06}
		Urban	6.04×10^{06}	1.51×10^{-07}
KAPL	SRS	Rural	1.71×10^{-03}	1.40×10^{-04}
		Suburban	3.73×10^{-04}	1.59×10^{-05}
		Urban	1.44×10^{-05}	3.60×10^{-07}
KAPL	WIPP	Rural	4.47×10^{-03}	3.66×10^{-04}
		Suburban	6.27×10^{-04}	2.67×10^{-05}
		Urban	3.93×10^{-05}	9.83×10^{-07}

TABLE L-25 (Continued)

NONRADIOLOGICAL/NONCHEMICAL PER-SHIPMENT RISK FOR CH-TRU AND RH-TRU WASTE

Waste Origin Site	To Route Segment Destination	Zone	Injuries	Fatalities
LANL	WIPP	Rural	8.47×10^{-04}	6.94×10^{-05}
		Suburban	2.70×10^{-05}	1.15×10^{-06}
		Urban	2.59×10^{-06}	6.47×10^{-08}
LBL	HANFORD	Rural	1.78×10^{-03}	1.46×10^{-04}
		Suburban	2.11×10^{-04}	8.99×10^{-06}
		Urban	4.34×10^{-05}	1.08×10^{-06}
LBL	LLNL	Rural	5.29×10^{-05}	4.34×10^{-08}
		Suburban	4.02×10^{-05}	1.71×10^{-06}
		Urban	2.86×10^{-05}	7.15×10^{-07}
LBL	WIPP	Rural	3.51×10^{-03}	2.88×10^{-04}
		Suburban	1.65×10^{-04}	7.02×10^{-06}
		Urban	8.75×10^{-05}	2.19×10^{-06}
LLNL	HANFORD	Rural	1.80×10^{-03}	1.47×10^{-04}
		Suburban	2.32×10^{-04}	9.89×10^{-08}
		Urban	3.79×10^{-05}	9.49×10^{-07}
LLNL	WIPP	Rural	3.47×10^{-03}	2.84×10^{-04}
		Suburban	1.27×10^{-04}	5.40×10^{-06}
		Urban	5.90×10^{-05}	1.48×10^{-06}
MOUND	SRS	Rural	1.13×10^{-03}	9.25×10^{-05}
		Suburban	2.61×10^{-04}	1.11×10^{-05}
		Urban	1.28×10^{-05}	3.20×10^{-07}
MOUND	WIPP	Rural	3.46×10^{-03}	2.84×10^{-04}
		Suburban	2.96×10^{-04}	1.26×10^{-05}
		Urban	2.56×10^{-05}	6.41×10^{-07}
MU	ANL-E	Rural	7.84×10^{-04}	6.43×10^{-05}
		Suburban	1.12×10^{-04}	4.79×10^{-06}
		Urban	1.13×10^{-05}	2.83×10^{-07}

TABLE L-25 (Continued)

NONRADIOLOGICAL/NONCHEMICAL PER-SHIPMENT RISK FOR CH-TRU AND RH-TRU WASTE

Waste Origin Site	To Route Segment Destination	Zone	Injuries	Fatalities
MU	SRS	Rural	1.61×10^{-03}	1.32×10^{-04}
		Suburban	2.92×10^{-04}	1.24×10^{-05}
		Urban	3.35×10^{-05}	8.38×10^{-07}
MU	WIPP	Rural	2.71×10^{-03}	2.22×10^{-04}
		Suburban	1.38×10^{-04}	5.89×10^{-06}
		Urban	2.21×10^{-05}	5.51×10^{-07}
NTS	INEL	Rural	1.60×10^{-03}	1.31×10^{-04}
		Suburban	1.17×10^{-04}	4.97×10^{-06}
		Urban	2.50×10^{-05}	6.25×10^{-07}
NTS	WIPP	Rural	3.02×10^{-03}	2.48×10^{-04}
		Suburban	8.06×10^{-05}	3.43×10^{-06}
		Urban	1.65×10^{-05}	4.13×10^{-07}
ORNL	SRS	Rural	6.51×10^{-04}	5.33×10^{-05}
		Suburban	1.40×10^{-04}	5.94×10^{-06}
		Urban	3.70×10^{-06}	9.24×10^{-08}
ORNL	WIPP	Rural	3.50×10^{-03}	2.87×10^{-04}
		Suburban	2.30×10^{-04}	9.80×10^{-06}
		Urban	2.60×10^{-05}	6.50×10^{-07}
PADUCAH	ORNL	Rural	6.68×10^{-04}	5.47×10^{-05}
		Suburban	7.80×10^{-05}	3.32×10^{-06}
		Urban	5.42×10^{-06}	1.36×10^{-07}
PADUCAH	SRS	Rural	1.01×10^{-03}	8.29×10^{-05}
		Suburban	2.16×10^{-04}	9.21×10^{-06}
		Urban	2.17×10^{-05}	5.42×10^{-07}
PADUCAH	WIPP	Rural	3.12×10^{-03}	2.56×10^{-04}
		Suburban	2.17×10^{-04}	9.22×10^{-06}
		Urban	1.71×10^{-05}	4.28×10^{-07}

TABLE L-25 (Continued)

NONRADIOLOGICAL/NONCHEMICAL PER-SHIPMENT RISK FOR CH-TRU AND RH-TRU WASTE

Waste Origin Site	To Route Segment Destination	Zone	Injuries	Fatalities
PANTEX	LANL	Rural	8.36×10^{-04}	6.85×10^{-05}
		Suburban	2.14×10^{-05}	9.09×10^{-07}
		Urban	4.68×10^{-06}	1.17×10^{-07}
PANTEX	WIPP	Rural	1.10×10^{-03}	8.99×10^{-05}
		Suburban	3.37×10^{-05}	1.44×10^{-06}
		Urban	4.44×10^{-06}	1.11×10^{-07}
RFETS	WIPP	Rural	1.65×10^{-03}	1.35×10^{-04}
		Suburban	8.99×10^{-05}	3.83×10^{-06}
		Urban	1.74×10^{-05}	4.34×10^{-07}
SNL	LANL	Rural	2.18×10^{-04}	1.79×10^{-05}
		Suburban	2.11×10^{-05}	8.98×10^{-07}
		Urban	6.41×10^{-06}	1.60×10^{-07}
SNL	WIPP	Rural	7.67×10^{-04}	6.28×10^{-05}
		Suburban	2.36×10^{-05}	1.01×10^{-06}
		Urban	4.80×10^{-06}	1.20×10^{-07}
SRS	WIPP	Rural	3.15×10^{-03}	2.58×10^{-04}
		Suburban	3.85×10^{-04}	1.64×10^{-05}
		Urban	2.44×10^{-05}	6.10×10^{-07}

TABLE L-26

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
Major CH-TRU Waste Sites					
HANFORD	WIPP	5712	Rural	$2.50x10^{+01}$	$2.05x10^{+00}$
			Suburban	$1.05x10^{+00}$	$4.44x10^{-02}$
			Urban	$1.27x10^{-01}$	$3.18x10^{-03}$
INEL	WIPP	4974	Rural	$1.67x10^{+01}$	$1.37x10^{+00}$
			Suburban	$7.16x10^{-01}$	$3.05x10^{-02}$
			Urban	$9.45x10^{-02}$	$2.36x10^{-03}$
LANL	WIPP	2835	Rural	$2.40x10^{+00}$	$1.97x10^{-01}$
			Suburban	$7.65x10^{-02}$	$3.26x10^{-03}$
			Urban	$7.34x10^{-03}$	$1.83x10^{-04}$
RFETS	WIPP	931	Rural	$1.54x10^{+00}$	$1.26x10^{-01}$
			Suburban	$8.37x10^{-02}$	$3.57x10^{-02}$
			Urban	$1.62x10^{-03}$	$4.04x10^{-04}$
SRS	WIPP	2827	Rural	$8.91x10^{+00}$	$7.29x10^{-01}$
			Suburban	$1.09x10^{+00}$	$4.64x10^{-02}$
			Urban	$6.90x10^{+00}$	$1.72x10^{-03}$
			Subtotal	**$6.47x10^{+01}$**	**$4.64x10^{+00}$**
Small CH-TRU Waste Sites					
AMES	ANL-E	1	Rural	$8.00x10^{-04}$	$6.56x10^{-05}$
			Suburban	$6.35x10^{-05}$	$2.70x10^{-06}$
			Urban	$2.59x10^{-06}$	$6.47x10^{-08}$
	WIPP	1	Rural	$3.29x10^{-03}$	$2.70x10^{-04}$
			Suburban	$2.57x10^{-04}$	$1.09x10^{-05}$
			Urban	$1.70x10^{-05}$	$4.25x10^{-07}$
ANL-E	WIPP	5	Rural	$1.65x10^{-02}$	$1.35x10^{-03}$
			Suburban	$1.29x10^{-03}$	$5.45x10^{-05}$
			Urban	$8.50x10^{-05}$	$2.13x10^{-06}$

TABLE L-26(Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
BETTIS	MOUND	17	Rural	$7.00x10^{-03}$	$5.75x10^{-04}$
			Suburban	$2.45x10^{-03}$	$1.04x10^{-04}$
			Urban	$4.18x10^{-05}$	$1.05x10^{-05}$
	WIPP	17	Rural	$5.88x10^{-02}$	$4.83x10^{-03}$
			Suburban	$5.03x10^{-03}$	$2.14x10^{-04}$
			Urban	$4.35x10^{-04}$	$1.09x10^{-05}$
ETEC	NTS	2	Rural	$1.43x10^{-03}$	$1.17x10^{-04}$
			Suburban	$1.55x10^{-04}$	$6.60x10^{-06}$
			Urban	$1.10x10^{-04}$	$2.74x10^{-05}$
	WIPP	2	Rural	$6.04x10^{-03}$	$4.96x10^{-04}$
			Suburban	$1.61x10^{-04}$	$6.86x10^{-06}$
			Urban	$3.30x10^{-05}$	$8.36x10^{-07}$
KAPL	MOUND	1	Rural	$1.02x10^{-03}$	$8.32x10^{-05}$
			Suburban	$3.68x10^{-04}$	$1.57x10^{-05}$
			Urban	$2.54x10^{-05}$	$6.34x10^{-07}$
	WIPP	1	Rural	$3.46x10^{-03}$	$2.84x10^{-04}$
			Suburban	$2.96x10^{-04}$	$1.28x10^{-05}$
			Urban	$2.56x10^{-05}$	$6.41x10^{-07}$
LBL	LLNL	1	Rural	$5.29x10^{-05}$	$4.34x10^{-06}$
			Suburban	$4.02x10^{-05}$	$1.71x10^{-06}$
			Urban	$2.86x10^{-05}$	$7.15x10^{-07}$
	WIPP	1	Rural	$3.47x10^{-03}$	$2.84x10^{-04}$
			Suburban	$1.27x10^{-04}$	$5.40x10^{-06}$
			Urban	$5.90x10^{-05}$	$1.48x10^{-06}$
LLNL	WIPP	136	Rural	$4.72x10^{-01}$	$3.86x10^{-02}$
			Suburban	$1.73x10^{-02}$	$7.34x10^{-03}$
			Urban	$8.02x10^{-03}$	$2.01x10^{-04}$

TABLE L-26 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
MOUND	WIPP	29	Rural	$1.00x10^{-01}$	$8.24x10^{-03}$
			Suburban	$8.58x10^{-03}$	$3.65x10^{-05}$
			Urban	$7.42x10^{-04}$	$1.86x10^{-05}$
MU	ANL-E	1	Rural	$7.84x10^{-04}$	$6.43x10^{-05}$
			Suburban	$1.12x10^{-04}$	$4.79x10^{-06}$
			Urban	$1.13x10^{-05}$	$2.83x10^{-07}$
	WIPP	1	Rural	$3.29x10^{-03}$	$2.70x10^{-04}$
			Suburban	$2.57x10^{-04}$	$1.09x10^{-05}$
			Urban	$1.70x10^{-05}$	$4.25x10^{-07}$
NTS	WIPP	66	Rural	$1.99x10^{-01}$	$1.64x10^{-02}$
			Suburban	$5.32x10^{-03}$	$2.26x10^{-04}$
			Urban	$1.09x10^{-03}$	$2.73x10^{-05}$
ORNL	WIPP	119	Rural	$4.17x10^{-01}$	$3.42x10^{-02}$
			Suburban	$2.74x10^{-02}$	$1.17x10^{-01}$
			Urban	$3.09x10^{-03}$	$7.74x10^{-05}$
PADUCAH	ORNL	1	Rural	$6.68x10^{-04}$	$5.47x10^{-05}$
			Suburban	$7.80x10^{-05}$	$3.32x10^{-06}$
			Urban	$5.42x10^{-06}$	$1.36x10^{-07}$
	WIPP	1	Rural	$3.50x10^{-03}$	$2.87x10^{-04}$
			Suburban	$2.30x10^{-04}$	$9.80x10^{-06}$
			Urban	$2.60x10^{-05}$	$6.50x10^{-07}$
PANTEX	LANL	1	Rural	$8.36x10^{-04}$	$6.85x10^{-05}$
			Suburban	$2.14x10^{-05}$	$9.09x10^{-07}$
			Urban	$4.68x10^{-06}$	$1.17x10^{-07}$
	WIPP	1	Rural	$8.47x10^{-04}$	$6.94x10^{-05}$
			Suburban	$2.70x10^{-05}$	$1.15x10^{-06}$
			Urban	$2.59x10^{-06}$	$6.47x10^{-08}$

TABLE L-26 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
SNL	LANL	3	Rural	6.54×10^{-04}	5.37×10^{-05}
			Suburban	6.33×10^{-05}	2.99×10^{-06}
			Urban	1.92×10^{-05}	4.80×10^{-07}
	WIPP	3	Rural	2.54×10^{-03}	2.08×10^{-04}
			Suburban	8.10×10^{-05}	3.45×10^{-06}
			Urban	7.77×10^{-06}	1.94×10^{-07}
			Subtotal	**$1.39 \times 10^{+00}$**	**2.32×10^{-01}**
			TOTAL	**$6.61 \times 10^{+01}$**	**$4.87 \times 10^{+00}$**

TABLE L-27

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
Major CH-TRU Waste Sites					
HANFORD	WIPP	5712	Rural	$2.50x10^{+01}$	$2.05x10^{+00}$
			Suburban	$1.05x10^{+00}$	$4.44x10^{-02}$
			Urban	$1.27x10^{-01}$	$3.18x10^{-03}$
INEL	WIPP	4974	Rural	$1.67x10^{+01}$	$1.37x10^{+00}$
			Suburban	$7.16x10^{-01}$	$3.05x10^{-02}$
			Urban	$9.45x10^{-02}$	$2.36x10^{-03}$
LANL	WIPP	2835	Rural	$2.40x10^{+00}$	$1.97x10^{-01}$
			Suburban	$7.65x10^{-02}$	$3.26x10^{-03}$
			Urban	$7.34x10^{-03}$	$1.83x10^{-04}$
RFETS	WIPP	931	Rural	$1.54x10^{+00}$	$1.26x10^{-01}$
			Suburban	$8.37x10^{-02}$	$3.57x10^{-03}$
			Urban	$1.62x10^{-02}$	$4.04x10^{-04}$
SRS	WIPP	2836	Rural	$8.93x10^{+00}$	$7.32x10^{-01}$
			Suburban	$1.09x10^{+00}$	$4.65x10^{-02}$
			Urban	$6.92x10^{-02}$	$1.73x10^{-03}$
			Subtotal	**$5.79x10^{+01}$**	**$4.61x10^{+00}$**
Small CH-TRU Waste Sites					
AMES	SRS	1	Rural	$1.56x10^{-03}$	$1.28x10^{-04}$
			Suburban	$3.36x10^{-04}$	$1.43x10^{-05}$
			Urban	$2.92x10^{-05}$	$7.30x10^{-07}$
	WIPP	1	Rural	$3.15x10^{-03}$	$2.58x10^{-04}$
			Suburban	$3.85x10^{-04}$	$1.64x10^{-05}$
			Urban	$2.44x10^{-05}$	$6.10x10^{-07}$
ANL-E	SRS	5	Rural	$7.80x10^{-03}$	$6.40x10^{-04}$
			Suburban	$1.68x10^{-03}$	$7.15x10^{-05}$
			Urban	$1.46x10^{-04}$	$3.65x10^{-06}$

TABLE L-27 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
BETTIS	SRS	17	Rural	$2.19x10^{-02}$	$1.80x10^{-03}$
			Suburban	$4.05x10^{-03}$	$1.72x10^{-04}$
			Urban	$2.60x10^{-04}$	$6.49x10^{-06}$
	WIPP	17	Rural	$5.36x10^{-02}$	$4.39x10^{-03}$
			Suburban	$6.55x10^{-03}$	$2.79x10^{-04}$
			Urban	$4.15x10^{-04}$	$1.04x10^{-05}$
ETEC	INEL	2	Rural	$4.02x10^{-03}$	$3.30x10^{-04}$
			Suburban	$3.58x10^{-04}$	$1.52x10^{-05}$
			Urban	$1.52x10^{-04}$	$3.80x10^{-06}$
	WIPP	2	Rural	$5.30x10^{-03}$	$4.34x10^{-04}$
			Suburban	$2.56x10^{-04}$	$1.09x10^{-05}$
			Urban	$1.30x10^{-04}$	$3.26x10^{-06}$
KAPL	SRS	1	Rural	$1.71x10^{-03}$	$1.40x10^{-04}$
			Suburban	$3.73x10^{-04}$	$1.59x10^{-05}$
			Urban	$1.44x10^{-05}$	$3.60x10^{-07}$
	WIPP	1	Rural	$3.15x10^{-03}$	$2.58x10^{-04}$
			Suburban	$3.85x10^{-04}$	$1.64x10^{-05}$
			Urban	$2.44x10^{-05}$	$6.10x10^{-07}$
LBL	HANFORD	1	Rural	$1.78x10^{-03}$	$1.46x10^{-04}$
			Suburban	$2.11x10^{-04}$	$8.99x10^{-06}$
			Urban	$4.34x10^{-05}$	$1.08x10^{-06}$
	WIPP	1	Rural	$4.38x10^{-03}$	$3.59x10^{-04}$
			Suburban	$1.83x10^{-04}$	$7.77x10^{-06}$
			Urban	$2.23x10^{-05}$	$5.57x10^{-07}$

TABLE L-27 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
LLNL	HANFORD	136	Rural	$2.45x10^{-01}$	$2.00x10^{-02}$
			Suburban	$3.16x10^{-02}$	$1.35x10^{-03}$
			Urban	$5.15x10^{-03}$	$1.29x10^{-04}$
	WIPP	136	Rural	$4.72x10^{-01}$	$3.86x10^{-02}$
			Suburban	$1.73x10^{-02}$	$7.34x10^{-04}$
			Urban	$8.02x10^{-03}$	$2.01x10^{-04}$
MOUND	SRS	29	Rural	$3.28x10^{-02}$	$2.68x10^{-03}$
			Suburban	$7.57x10^{-03}$	$3.22x10^{-04}$
			Urban	$3.71x10^{-04}$	$9.28x10^{-06}$
	WIPP	29	Rural	$1.00x10^{-01}$	$8.24x10^{-03}$
			Suburban	$8.58x10^{-03}$	$3.65x10^{-04}$
			Urban	$7.42x10^{-04}$	$1.86x10^{-05}$
MU	SRS	1	Rural	$1.61x10^{-03}$	$1.32x10^{-04}$
			Suburban	$2.92x10^{-04}$	$1.24x10^{-05}$
			Urban	$3.35x10^{-05}$	$8.38x10^{-07}$
	WIPP	1	Rural	$3.15x10^{-03}$	$2.58x10^{-04}$
			Suburban	$3.85x10^{-04}$	$1.64x10^{-05}$
			Urban	$2.44x10^{-05}$	$6.10x10^{-07}$
NTS	INEL	66	Rural	$1.06x10^{-01}$	$8.65x10^{-03}$
			Suburban	$7.72x10^{-03}$	$3.28x10^{-04}$
			Urban	$1.65x10^{-03}$	$4.13x10^{-05}$
	WIPP	66	Rural	$1.99x10^{-01}$	$1.64x10^{-02}$
			Suburban	$5.32x10^{-03}$	$2.26x10^{-04}$
			Urban	$1.09x10^{-03}$	$2.73x10^{-05}$
ORNL	SRS	119	Rural	$7.75x10^{-02}$	$6.34x10^{-03}$
			Suburban	$1.67x10^{-02}$	$7.07x10^{-04}$
			Urban	$4.40x10^{-04}$	$1.10x10^{-05}$
	WIPP	119	Rural	$3.75x10^{-01}$	$3.07x10^{-02}$
			Suburban	$4.58x10^{-02}$	$1.95x10^{-03}$
			Urban	$2.90x10^{-03}$	$7.26x10^{-05}$

TABLE L-27 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE
REGIONALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
PADUCAH	ORNL	1	Rural	$6.68x10^{-04}$	$5.47x10^{-05}$
			Suburban	$7.80x10^{-05}$	$3.32x10^{-06}$
			Urban	$5.42x10^{-06}$	$1.36x10^{-07}$
	WIPP	1	Rural	$3.50x10^{-03}$	$2.87x10^{-04}$
			Suburban	$2.30x10^{-04}$	$9.80x10^{-06}$
			Urban	$2.60x10^{-05}$	$6.50x10^{-07}$
PANTEX	LANL	1	Rural	$8.36x10^{-04}$	$6.85x10^{-05}$
			Suburban	$2.14x10^{-05}$	$9.09x10^{-07}$
			Urban	$4.68x10^{-06}$	$1.17x10^{-07}$
	WIPP	1	Rural	$8.47x10^{-04}$	$6.94x10^{-05}$
			Suburban	$2.70x10^{-05}$	$1.15x10^{-06}$
			Urban	$2.59x10^{-06}$	$6.47x10^{-08}$
SNL	LANL	3	Rural	$6.54x10^{-04}$	$5.37x10^{-05}$
			Suburban	$6.33x10^{-05}$	$2.69x10^{-06}$
			Urban	$1.92x10^{-05}$	$4.80x10^{-07}$
	WIPP	3	Rural	$2.30x10^{-03}$	$1.88x10^{-04}$
			Suburban	$7.08x10^{-05}$	$3.03x10^{-06}$
			Urban	$1.44x10^{-05}$	$3.60x10^{-07}$
			Subtotal	**$1.91x10^{+00}$**	**$1.49x10^{-01}$**
			TOTAL	**$5.98x10^{+01}$**	**$4.76x10^{+00}$**

TABLE L-28

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE CENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
Major CH-TRU Waste Sites					
HANFORD	WIPP	5712	Rural	$2.50x10^{+01}$	$2.05x10^{+00}$
			Suburban	$1.05x10^{+01}$	$4.44x10^{-02}$
			Urban	$1.27x10^{-01}$	$3.18x10^{-03}$
INEL	WIPP	4974	Rural	$1.67x10^{+01}$	$1.37x10^{+00}$
			Suburban	$7.16x10^{-01}$	$3.05x10^{-02}$
			Urban	$9.45x10^{-02}$	$2.36x10^{-03}$
LANL	WIPP	2835	Rural	$2.40x10^{+00}$	$1.97x10^{-01}$
			Suburban	$7.65x10^{-02}$	$3.26x10^{-03}$
			Urban	$7.34x10^{-03}$	$1.83x10^{-04}$
RFETS	WIPP	931	Rural	$1.54x10^{+00}$	$1.26x10^{-01}$
			Suburban	$8.37x10^{-02}$	$3.57x10^{-03}$
			Urban	$1.62x10^{-02}$	$4.04x10^{-04}$
SRS	WIPP	2827	Rural	$8.91x10^{+00}$	$7.29x10^{-01}$
			Suburban	$1.09x10^{+00}$	$4.64x10^{-02}$
			Urban	$6.90x10^{-02}$	$1.72x10^{-03}$
			Subtotal	**$6.73x10^{+01}$**	**$4.61x10^{+00}$**
Small CH-TRU Waste Sites					
AMES	WIPP	1	Rural	$2.98x10^{-03}$	$2.44x10^{-04}$
			Suburban	$1.49x10^{-04}$	$6.34x10^{-06}$
			Urban	$1.93x10^{-05}$	$4.84x10^{-07}$
ANL-E	WIPP	5	Rural	$1.65x10^{-02}$	$1.35x10^{-03}$
			Suburban	$1.29x10^{-03}$	$5.45x10^{-05}$
			Urban	$8.50x10^{-05}$	$2.13x10^{-06}$
BETTIS	WIPP	17	Rural	$6.56x10^{-02}$	$5.39x10^{-03}$
			Suburban	$6.83x10^{-03}$	$2.91x10^{-04}$
			Urban	$6.58x10^{-04}$	$1.64x10^{-05}$

TABLE L-28 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE CENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
ETEC	WIPP	2	Rural	$5.30x10^{-03}$	$4.34x10^{-04}$
			Suburban	$2.56x10^{-04}$	$1.09x10^{-05}$
			Urban	$2.00x10^{+00}$	$3.26x10^{-06}$
KAPL	WIPP	1	Rural	$4.47x10^{-03}$	$3.66x10^{-04}$
			Suburban	$6.27x10^{-04}$	$2.67x10^{-05}$
			Urban	$3.93x10^{-05}$	$9.83x10^{-07}$
LBL	WIPP	1	Rural	$3.51x10^{-03}$	$2.88x10^{-04}$
			Suburban	$1.65x10^{-04}$	$7.02x10^{-06}$
			Urban	$8.75x10^{-05}$	$2.19x10^{-06}$
LLNL	WIPP	136	Rural	$4.72x10^{-01}$	$3.86x10^{-02}$
			Suburban	$1.73x10^{-02}$	$7.34x10^{-04}$
			Urban	$8.02x10^{-03}$	$2.01x10^{-04}$
MOUND	WIPP	29	Rural	$3.28x10^{-02}$	$2.68x10^{-03}$
			Suburban	$7.57x10^{-03}$	$3.22x10^{-04}$
			Urban	$3.71x10^{-04}$	$9.28x10^{-06}$
MU	WIPP	1	Rural	$2.71x10^{-03}$	$2.22x10^{-04}$
			Suburban	$1.38x10^{-04}$	$5.89x10^{-06}$
			Urban	$2.21x10^{-05}$	$5.51x10^{-07}$
NTS	WIPP	66	Rural	$1.99x10^{-01}$	$1.64x10^{-02}$
			Suburban	$5.32x10^{-03}$	$2.26x10^{-04}$
			Urban	$1.09x10^{-03}$	$2.73x10^{-05}$
ORNL	WIPP	119	Rural	$4.17x10^{-01}$	$3.42x10^{-02}$
			Suburban	$2.74x10^{-02}$	$1.17x10^{-03}$
			Urban	$3.09x10^{-03}$	$7.74x10^{-05}$
PADUCAH	WIPP	1	Rural	$3.12x10^{-03}$	$2.56x10^{-04}$
			Suburban	$2.17x10^{-04}$	$9.22x10^{-06}$
			Urban	$1.71x10^{-05}$	$4.28x10^{-07}$

TABLE L-28 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
CH-TRU WASTE CENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
PADUCAH	WIPP	1	Rural	$3.12x10^{-03}$	$2.56x10^{-04}$
			Suburban	$2.17x10^{-04}$	$9.22x10^{-06}$
			Urban	$1.71x10^{-05}$	$4.28x10^{-07}$
PANTEX	WIPP	1	Rural	$1.10x10^{-03}$	$8.99x10^{-05}$
			Suburban	$3.37x10^{-05}$	$1.44x10^{-06}$
			Urban	$4.44x10^{-06}$	$1.11x10^{-07}$
SNL	WIPP	3	Rural	$2.30x10^{-03}$	$1.88x10^{-04}$
			Suburban	$7.08x10^{-05}$	$3.03x10^{-06}$
			Urban	$1.44x10^{-05}$	$3.60x10^{-07}$
			Subtotal	**$3.31x10^{+00}$**	**$1.04x10^{-01}$**
			TOTAL	**$7.06x10^{+01}$**	**$4.71x10^{+00}$**

TABLE L-29

NONCHEMICAL/NONRADIOLOGICAL RISK
RH-TRU WASTE DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
Major RH-TRU Waste Sites					
HANFORD	WIPP	5176	Rural	$2.27x10^{+01}$	$1.86x10^{+00}$
			Suburban	$9.47x10^{-01}$	$4.02x10^{-02}$
			Urban	$1.15x10^{-01}$	$2.88x10^{-03}$
ORNL	WIPP	2002	Rural	$7.01x10^{+00}$	$5.75x10^{-01}$
			Suburban	$4.60x10^{-01}$	$1.96x10^{-02}$
			Urban	$5.21x10^{-02}$	$1.30x10^{-03}$
			Subtotal	**$3.13x10^{+01}$**	**$2.50x10^{+00}$**
Small RH-TRU Waste Sites					
BATTELLE	ORNL	123	Rural	$7.93x10^{-02}$	$6.51x10^{-03}$
			Suburban	$2.35x10^{-02}$	$1.00x10^{-03}$
			Urban	$2.26x10^{-03}$	$5.65x10^{-05}$
	WIPP		Rural	$4.31x10^{-01}$	$3.53x10^{-02}$
			Suburban	$2.83x10^{-02}$	$1.21x10^{-03}$
			Urban	$3.20x10^{-03}$	$8.00x10^{-05}$
BETTIS	ORNL	3	Rural	$1.94x10^{-03}$	$1.59x10^{-04}$
			Suburban	$5.73x10^{-04}$	$2.45x10^{-05}$
			Urban	$5.52x10^{-05}$	$1.38x10^{-06}$
	WIPP		Rural	$1.05x10^{-02}$	$8.61x10^{-04}$
			Suburban	$6.90x10^{-04}$	$2.94x10^{-05}$
			Urban	$7.80x10^{-05}$	$1.95x10^{-06}$
INEL	WIPP	109	Rural	$9.66x10^{-01}$	$3.00x10^{-02}$
			Suburban	$1.57x10^{-02}$	$6.69x10^{-04}$
			Urban	$2.07x10^{-03}$	$5.17x10^{-05}$

TABLE L-29 (Continued)

NONCHEMICAL/NONRADIOLOGICAL RISK
RH-TRU WASTE DECENTRALIZED CONFIGURATION

Waste Origin Site	To Route Segment Destination	No. Of Shipments	Zone	Injuries	Fatalities
KAPL	ORNL		Rural	4.46×10^{-02}	3.66×10^{-03}
			Suburban	1.03×10^{-02}	4.38×10^{-04}
			Urban	3.44×10^{-04}	8.61×10^{-06}
	WIPP		Rural	2.00×10^{-01}	1.64×10^{-02}
			Suburban	1.31×10^{-02}	5.59×10^{-04}
			Urban	1.48×10^{-04}	3.71×10^{-05}
LANL	WIPP	249	Rural	2.11×10^{-01}	1.73×10^{-02}
			Suburban	6.73×10^{-03}	2.86×10^{-04}
			Urban	6.45×10^{-04}	1.61×10^{-05}
SRS	WIPP	56	Rural	1.76×10^{-01}	1.44×10^{-02}
			Suburban	2.16×10^{-02}	9.18×10^{-04}
			Urban	1.37×10^{-03}	3.42×10^{-05}
			Subtotal	**$2.55 \times 10^{+00}$**	**1.30×10^{-01}**
			TOTAL	**$3.35 \times 10^{+01}$**	**$2.63 \times 10^{+00}$**

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APPENDIX M

WASTE ISOLATION PILOT PLANT FOCUS GROUP DISCUSSIONS CONCERNS STATED

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WASTE ISOLATION PILOT PLANT FOCUS GROUP DISCUSSIONS
CONCERNS STATED

1.0 INTRODUCTION

The U.S. Department of Energy Carlsbad Area Office (DOE-CAO) is conducting an Engineered Alternatives (EA) Cost/Benefit Study. In support of that study, focus group discussions were held in Carlsbad, Albuquerque, and Santa Fe, New Mexico. The focus group setting and format were consistent at each location. The purpose of these discussions was to identify public concerns about the ability of the Waste Isolation Pilot Plant (WIPP) to protect the public health and the environment once waste is emplaced and WIPP is closed and sealed.

2.0 CARLSBAD, NEW MEXICO

SESSION I, June 26, 1995

At the focus group discussion held in Carlsbad, New Mexico on June 26, 1995, seven participants were present for the discussion. Mr. Steve Wilkes was the moderator. Other attendees were Maggie Wood and Rebecca Grohler from the S.M. Stoller Corporation; Ann Marshall, Advanced Sciences, Inc.(who served as note takers); and Patty Barratti-Sallani, a DOE-CAO public affairs representative.

Mr. Wilkes opened the meeting with a brief discussion of the purpose of focus groups in general and how this particular session would be conducted. He addressed the ground rules for the discussions, the desired outcome, the assumptions to be used as a basis for the discussions, and then introduced Maggie Wood.

Ms. Wood's presentation addressed the purpose and objectives of the focus group discussion, how participants were selected, and how comments would be used.

Ms. Wood advised the focus group that the Environmental Evaluation Group (EEG) had requested that she give the participants copies of a paper prepared by EEG stating their position on Engineered Barriers at the WIPP site. Copies of the paper were distributed to the participants at the end of the discussion.

Mr. Wilkes then led the remainder of the session, beginning with a discussion of concerns about the long-term performance of the WIPP disposal system. After all the concerns had been stated, Mr. Wilkes asked each participant to summarize their concerns in the form of a one minute statement to the DOE. The focus group session was then concluded.

Verbatim notes were not taken. The comments are shown in the order in which they were presented.

CONCERNS STATED[1]

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

WIPP should be marked so that any future society knows the site is there to prevent intrusion inadvertently. Adequate records must be maintained. **[2.4, 3.1 - Y]**

Concerned about oil exploration or recovery of oil far below the WIPP, but by the time WIPP is closed, it will not be a concern. Oil recovery is only a 25-year concern. **[3.1 - Y]**

Concerned about BLM management of drilling programs, but don't want to add huge costs to drilling. **[3.1 - Y]**

Concerned about gas generation in the waste after it is buried. **[1.2 - Y]**

The formation is adequate, stable, solid, for holding waste. Adding unnecessary engineered alternatives will just add cost and complexity that aren't needed. **[2.1 - Y]**

Potash mining has been conducted in same formation [as WIPP] for over 60 years. We have a good understanding of what that formation does, and it is relatively stable, even in blasting. Historical proof is that the underground is dry and stable. **[2.1 - Y]**

Strong belief that future generations will be as knowledgeable as we are. The 10,000- year period is a ridiculous requirement. Fairherst said it's like asking the Wright Brothers to develop a plane that can fly 400 people to Europe. Within 100 years we will come up with other solutions. It is impossible to predict what technology will exist at that time. **[3.3 - Y]**

Oil and potash reserves can be removed from around the site without penetrating or affecting the site in any way. **[2.1 - Y]**

Concerned that EAs will be used that simply have no merit. **[7.1 - Y]**

Concerned that DOE is not educating the public enough about WIPP. People wouldn't be concerned if they knew more about the project. **[7.2 - N]**

Some people have said that they don't believe DOE is telling the truth. DOE needs to be open and honest about everything that is going on. **[7.2 - N]**

As long as EPA requirements are met there shouldn't be any additional EAs. Additional EAs add no value. **[7.1 - Y]**

Numbers in brackets at the end of each comment indicate the taxonomic category to which each comment was assigned. In some cases a comment was assigned to more than one category. In other cases separate statements within one comment were assigned different categories and were counted as separate comments. The Y or N letter that follows the category number(s) indicates whether the comment was related to postclosure [Y] or not related to postclosure [N].

Our [society's] body of knowledge is constantly changing and improving. In even as few as 25 years many of the things that may have been of concern are no longer relevant. **[3.3 - Y]**

Some resentment has been expressed that this [WIPP project] didn't go to a local vote. How was the site chosen? **[7.2 - N]**

People don't like the perception that it's secretive--they think the government is not telling the truth. **[7.2 - N]**

Moderator: Is there anything about the waste itself which concerns you?

Human intrusion isn't a serious concern because the waste being put in there isn't very hazardous now, and hundreds of years from now it will be continually less hazardous. If a breach were to occur from drilling, it may allow some gas to come to the surface, but not the actual waste materials. **[1.4 - Y]**

Any gas generated will be under high pressure and, if drilled into, it may be released along with some brine. Once saturation occurs, though, the brine doesn't move. **[1.2 - Y]**

Moderator: If you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment once it is closed, what would you say?

Keep good records and be open and honest with people. **[2.4, 7.2 - Y]**

Keep accurate records and continue to look for solutions like isolation or neutralizing the waste. **[1.3, 2.4 - Y]**

Continue to support the [Carlsbad] Environmental Monitoring [and Research] Center. **[not counted]**

DOE has done a good job, the public's concerns have been addressed. The markings and records will last forever. WIPP is ready to go and it's safe--open it. **[2.4 - Y]**

Don't abandon the project. **[97.4 - N]**

Continue keeping good records and monitoring. Keep researching new technologies--not just for this site, but for other sites, too. **[2.4 - Y]**

If there is this much trouble getting low-level waste repository open, how will DOE ever handle high-level waste? This level of indecision would not be tolerated in industry. When will you say, "enough is enough." Either do it [open WIPP] or pull out. You will never convince every single person. You have the authority to open WIPP, so use it. **[7.4 - N]**

WIPP has undergone all the scrutiny it needs to. It's ready to open tomorrow. **[7.4 - N]**

WIPP is technologically and scientifically sound. DOE should proceed and get it open. Move forward. **[7.4 - N]**

SESSION II, July 6, 1995

An independent interview was held on July 6, 1995, with two participants, in lieu of their attendance at the focus group discussion held June 26, 1995. Both of the participants were knowledgeable about the WIPP site and had been actively involved since about 1980. Ms. Wood, served as the moderator and also prepared summarized notes. Ms. Grohler was also present at this session to take more detailed notes.

Ms. Wood opened the interview by introducing the purpose and objectives of the focus group session, how participants were selected, and how comments would be used.

Verbatim notes were not taken. The comments are shown in the order in which they were presented.

CONCERNS STATED

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

Don't want the waste to be migrating from room to room. Water may get into a room and could dissolve the salt around the waste, allowing the water to flow from room to room. If inflow isn't kept out of the rooms, it can migrate throughout the site. **[3.1 - Y]**

Due to the presence of oil and gas in the area of the site, human intrusion will occur. We know that WIPP will be drilled into someday, and the drill would probably use a water circulation drill which could introduce water into the repository. This is of concern because when the site is breached it could result in massive contamination to the surrounding ecosystem. **[3.1 - Y]**

The water flow into and around the site hasn't been studied enough. They don't realize that water flow could eventually become a problem and it could contaminate the water table. If contamination reaches the surface it could be carried into the Pecos River if there were a flood through that area. **[2.1, 4.0, - Y]**

Concern that Pecos River could be contaminated. If WIPP were breached, the contamination could migrate to the Rustler Formation and be carried through the Formation to the river. Seals or other engineered barriers sound like a needed safety measure to these concerns. **[4.0, - Y]**

Concerned about the adequacy of seals in the underground and shafts. If the site isn't sealed properly, fresh water could get into the site and erode the salt, creating a bigger hole and dissolving the natural barrier. **[2.2, 4.0 - Y]**

Primarily concerned about the integrity of the site. When the DOE discovered water at the original proposed site, they just moved the site a half-mile away. WIPP shouldn't have been located where it is. **[2.1, 4.0 - Y]**

Moderator: Is there anything about the waste itself which concerns you?

The mixed waste concerns me. They [DOE] don't really know what all is going in it, and mixing it together concerns me. I would feel better if waste were characterized better. But perhaps good

engineered barriers would take care of that. If the waste were encased in glass or cement or whatever, that may negate the need for better characterization. **[1.1, 1.3 - Y]**

Moderator: Do you have any other concerns that we haven't addressed?

Transportation. The WIPP bypass road is planned for the north side of town [Carlsbad], but the south side won't have a bypass. Even though they could use highway 31, which is a natural bypass for the south, they are going to bring the waste all the way through the south part of town. **[7.3 - N]**

The "rich side" of town has a bypass, but the "poor side" not only won't have a bypass, but they won't even use Route 31 even though it is available. All the money is being spent on the north end, and the south end of town is unprotected. **[7.3 - N]**

The cost/benefit analysis should also look at the way money is being spent. There is an incredible amount of money wasted right now. Why do they need to fully staff the site when there won't be any waste there for two years? Also, why do DOE managers come all the way into town for lunch when there's a cafeteria right there at the site? They're using government cars and it's the taxpayers who are paying for that. **[7.2 - N]**

A cost/benefit study of safety issues is mandatory, but the government will eventually have to do a cost/benefit study of comfort, too, because someday someone is really going to sink their teeth into the way money is being spent. **[6.0, 7.2 - N]**

Moderator: If you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment once it is closed, what would you say?

I would say that I hear what you are saying, but what you are doing doesn't match what you are saying. It is supposed to be a new, open DOE, but I would like to see the DOE stop covering up problems and tell people the truth about WIPP. Admit to the people that there is risk, and talk about the risk openly. DOE said that water was no problem. Then the site was moved a half-mile years ago when water was discovered. The whole concept of WIPP was to have dry salt, and now it isn't dry salt--there **is** water in the area. DOE has promised that there will be no breach of the site. They need to tell the truth. People who live here should be aware of the truth. People can deal with it if they know the facts. **[4.0, 7.2 - Y]**

SESSION III, July 10, 1995

An independent interview was held on July 10, 1995 with one participant in lieu of her attendance at the focus group discussion held June 26, 1995 (see Section B.1). The interview was conducted via conference call and included the participant; Maggie Wood, who acted as the moderator; and Rebecca Grohler, who took detailed notes.

Ms. Wood opened the interview by introducing the purpose and objectives of the focus group session, how participants were selected, and how comments would be used.

Verbatim notes were not taken. The comments are shown in the order in which they were presented.

CONCERNS STATED

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

It may be naive on my part, but I have no major concerns. We have the best technologies available to any of us in this country, and I feel that the topography of the area and the geological aspect of the site where DOE is looking at storing these wastes provides tremendous safety compared to where the waste is now--at sites, because there is no place to take it. **[2.2 - N]**

Moderator: Is there anything about the waste itself which concerns you?

Anyone would have some concerns about radiation. I certainly don't want to see any releases of radiation which could contaminate the region, or cause illnesses or deaths. However, with the technology we have to handle this material, I believe we're more at risk right now, prior to storage, rather than after it is stored. **[5.0 - Y]**

Moderator: Can you tell me the nature of your concerns about the current risks?

The current risk is at the site locations where they are creating nuclear waste. It is a fact that human risk factors are involved, and mistakes can be made. It [the waste] is in a temporary holding position at the sites, compared to a long-term position at WIPP. Currently I'm concerned that there could be an event that could result in contamination of the region, soil, water, and air around these site locations. **[4.0. 5.0 - N]**

Moderator: If you were living thousands of years in the future in southeast New Mexico and you learned that there was a repository for radioactive materials in the area, what would be your concerns?

I imagine the biggest concern would be to make sure that it's [WIPP is] sealed properly and is being handled properly. I would want to be sure that there is no movement of the waste to the surrounding soil or movement into water sources in the area. I would want to be sure that there is no migration to places not intended for the waste to migrate to and that the site continues to be handled as it is supposed to be handled. I would want a check system [monitoring system] to ensure it is maintained as it should be. **[2.2, 2.4, 4.0 - Y]**

Moderator: If you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment once it is closed, what would you say?

I think we have now invested tremendous time, energy, and money in creating a technical environment to properly handle nuclear and radioactive waste, and it is critical that we take advantage of these technological developments and start cleaning the vast areas of this country that we recognize are tremendously contaminated, such as the Rocky Flats area, soils around Pantex and other sites. We need to place these radioactive materials into a safeguarded environment, which WIPP provides. **[7.2 - N]**

Moderator: Is there anything else you'd like to say?

If I have any concern about WIPP at all it's that we seem to have continually delayed, through continuing regulations and requirements, the opening of this facility, which in the long run is jeopardizing other areas of this country, like the sites where this waste is now being kept. **[7.2 - N]**

I would like to see WIPP in operation and to start collecting the material it is designed to collect. **[7.4 - N]**

I believe WIPP is a great benefit to the State of New Mexico, and our region is fortunate that we have the geologic formations to be the pilot center and to go into operations. It will be a benefit to the entire country. **[7.4 - N]**

I have been aware of WIPP since about 1981. The nature of my involvement has primarily been because of the proximity of WIPP's location with regard to economic development of this region (i.e., relocation of companies to the area, and the economic impact of WIPP in this region). I was very active in getting funding for a bypass to take the waste around Roswell rather than going down the main street in Roswell, not because we were concerned about the physical danger, but mainly because of the psychological impact to residents. People are afraid of anything called "radioactive" and the bypass solves an emotional need and will make them [the residents] feel safer. **[7.3 - N]**

3.0 ALBUQUERQUE, NEW MEXICO

June 27, 1995

A focus group discussion was held in Albuquerque, New Mexico on June 27, 1995. There were eight participants present for the discussion. Mr. Steve Wilkes was the moderator. Other attendees were Maggie Wood and Rebecca Grohler from the S.M. Stoller Corporation; Ann Marshall, Advanced Sciences, Inc.(who served as note takers); and Patty Barratti-Sallani, a DOE-CAO public affairs representative.

Mr. Wilkes opened the meeting with a brief discussion of the purpose of focus groups in general and how this particular session would be conducted. He addressed the ground rules for the discussions, the desired outcome, the assumptions to be used as a basis for the discussions, and then introduced Maggie Wood.

Ms. Wood's presentation addressed the purpose and objectives of the focus group discussion, how participants were selected, and how comments would be used. Ms. Wood advised the focus group that the EEG had requested that she give the participants copies of a paper prepared by EEG stating their position on Engineered Barriers at the WIPP site. Copies of the paper were then distributed to the participants at the end of the discussion.

Mr. Wilkes then led the remainder of the session, beginning with a discussion of concerns about the long-term performance of the WIPP disposal system. After all the concerns had been stated,

Mr. Wilkes asked each participant to summarize their concerns in the form of a one minute statement to the DOE. The focus group session was then concluded.

Verbatim notes were not taken. The major comments or points that were made during the focus group discussion are shown in the order in which they were presented in the following section.

CONCERNS STATED[2]

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

My confidence levels of the long-term stability of the waste facility shot way up after hearing about vitrification. I have zero confidence in mixed waste stored in salt caverns that will crush and collapse on the waste mixture. Some other concerns are drilling, boreholes, and flooding. I have zero confidence in a system designed like this. Characterizing waste is the first step in improving my confidence [in the facility]. **[1.1, 1.3, 2.2, 3.1 - Y]**

My confidence level would be greatly improved if the waste were vitrified. There is no way to evaluate whether waste would drain into gas, brine, or water. If waste is encapsulated, it will be fully characterized in order to be vitrified. **[1.1, 1.3, 4.0 - Y]**

Flooding into WIPP from oil operations can't be avoided. **[3.1 - Y]**

There are two premises with which I disagree. First, the WIPP is a facility planned to put waste away forever. This is a long time concern. In a recent DOE news release, WIPP is being hailed as a "pilot" plant. Been told for years that this is a "pilot" plant. In reality, all along, WIPP has been geared as a permanent repository. Recently high level delegates from France toured the plant and were quoted as saying that it is a wonderful "pilot research and development" facility. But WIPP is still being planned [by DOE] for permanent disposal. This is the same as using Agent Orange during Operation Harvest. This is another example of the government's propensity to lie. Stop calling WIPP a "pilot" facility and a research and development facility. Just call it what it is--a permanent facility. Don't apologize for the past, but start calling it what it is in the future. Secondly, engineered barriers are not simply frosting on the cake. 40 CFR 191 section 141 clearly requires the use of engineered barriers. Again, these are not "extra" or "frosting on the cake," as described by Ms. Wood. **[7.1, 7.2 - N]**

Calling WIPP a low-level waste facility is incorrect. Even news releases as recently as a couple of weeks ago still refer to it [WIPP] as a low-level facility, and that is not true. It is a transuranic waste repository. **[1.4 - N]**

Engineered barriers are a requirement. DOE will not change the name of WIPP, but will say that using room seals is okay. The facility will be built with inferior engineered barriers incapable of

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Numbers in brackets at the end of each comment indicate the taxonomic category to which each comment was assigned. In some cases a comment was assigned to more than one category. In other cases separate statements within one comment were assigned different categories and were counted as separate comments. The Y or N letter that follows the category number(s) indicates whether the comment was related to postclosure [Y] or not related to postclosure [N].

withstanding natural and man-made intrusion events. WIPP will still be dangerous because future generations cannot deal with it. DOE doesn't understand its job. **[3.3, 7.1 - Y]**

Engineered barriers will not prevent human intrusion. Engineered barriers need to withstand future slant drilling. Slant drilling can be done right now. WIPP must protect against intrusion for thousands of years. **[3.1, 3.3 - Y]**

Public confidence should be a serious concern. We're looking at future concerns, but we should look at present concerns. Troubled by assuming WIPP "already filled and sealed." Present concerns for safety and health must be met in order to talk about long-term concerns. DOE is so committed to opening WIPP, and will do whatever it takes to open it. It is prepared to cut corners to get it open quickly. Environmental safety and health issues are being deferred. These should be addressed in the present. DOE needs to be candid and frank with these issues, but is being pressured by waste management issues to get WIPP open. Not very many who would be talking about disposal [of radioactive waste] in a salt medium like WIPP. I am concerned with intrusion and barriers and safety and health. There are too many unknowns and uncertainties. No one knows how to deal with high-level or mixed-waste forms. **[1.4, 2.1, 3.1, 7.2, 7.4 - Y]**

DOE talks like this is a closed issue. DOE has this dimension of arrogance. **[7.2 - N]**

It is not possible to prevent intrusion. Public health and environment cannot be assured. There are too many unknowns and uncertainties. **[3.1, 3.3, 4.0, 5.0 - Y]**

What I'm hearing is a distrust of the government and that the WIPP site is unequivocally going to leak radiation--that there are no controls. We are looking at something that is 2,150 feet below ground. We have been dicking around with this since 1972. Where is the stuff being currently produced being stored? In generator warehouses and docks sitting in barrels. 2,150 feet below is more secure than where it is now. A concern is if someone [people] forgets that waste is stored in the WIPP. The buildings will go away, the area will be replanted. Hundreds of years from now, this might possibly still be remembered. Thousands of years from now, drilling may not be necessary, but some exploration might occur. But we need to be sure it is historically remembered. I'm not concerned about radiation leakage. **[3.3 - Y]**

I do not support nor discourage the use of nuclear energy. My concern is with high-level waste and mixed-waste storage. My concerns mirror the same concerns expressed here. High-level waste is a valid concern. The salt bins would collapse. **[1.4 - Y]**

I have been shocked by DOE presentations about transportation. **[7.3 - N]**

A 55-gallon steel barrel is a ridiculous container that won't last. Who decided on the 55-gallon drum as the container of choice ... the janitor at Los Alamos 50 years ago? There is the mindset that everything would be buried. Why not store it in better containers. I am shocked that the TRUPACT was designed around the 55-gallon drum. **[2.3 - Y]**

My confidence is shattered after reading the EEG report about active oil wells being around the site and not being addressed by the EIS [*Environmental Impact Statement*]. Why haven't alternate sites been considered. **[2.1 - N]**

Once WIPP is open all sort of things will go into it. WIPP seems to be it [the site of choice]. DOE doesn't seem willing to consider any other sites, containers, methods, etc. Vitrification would greatly improve public confidence. But even with the vitrification there are other concerns with the long-term destructive effects of plutonium on the glass. **[1.2, 1.3, 1.4, 2.1, 2.3, 7.2 - Y]**

[A participant gave the following explanation of the characteristics of TRU and high-level waste.] High-level waste, like fuel rods, in 1,000 years becomes like TRU. TRU is not lower level waste. Eighty percent of TRU waste not planned for WIPP will remain above ground and [DOE] is not planning to do anything with it. Waste is not even in drums--its just buried a few feet underground. DOE has to say what they're going to do with it. **[not counted]**

Some other concerns include performance assessments and projections. I am humbled by trying to project 10,000 years from now. In 100,000 years the waste will still be radioactive; 10,000 years was used randomly by EPA. By using all these modeling tools, we give the impression that we know with certainty what will occur thousands of years from now. For example, if 300 years ago, we had been asked to look at 1995, no one would have predicted that we would be drilling thousands of feet underground for oil or minerals. We don't know and there is no way of knowing what will occur, even hundreds of years into the future. That's where engineered barriers come in--to give an extra assurance that inadvertent human intrusion will not result in a release of radioactivity. Considering drilling scenarios in the future, let's do something to the waste, the drum, and use engineered barriers to make sure the waste stays buried. **[3.3, 7.1 - Y]**

Shaft or panel seals are clumsy attempts to undo what we are doing to the environment. Creating panel and shaft seals may be worse than using the rock already there. The rock is more solid; the seals would be a patch and may actually weaken the rock. It would be easier to penetrate a patch than the rock. A rock is much better than a seal. **[2.2, 7.1 - Y]**

Also, a canister, like a 55-gallon drum was going to be certified in the Waste Acceptance Criteria Revision 4, for 20 years longevity. However, the 20-year criteria was removed because the drums were already 20 years old and falling apart. **[2.3 - Y]**

DOE will not do vitrification and is leaning toward not using backfill. **[1.3, 7.1 - Y]**

Regarding future uncertainties, use engineered and natural barriers to keep waste forms from entering the environment. **[3.3, 7.1 - Y]**

DOE has said that they will **not** do vitrification--they **will not** do it. **[1.3 - Y]**

The [WIPP] repository could be reopened by future generations. There could be intentional intrusion to study reopening the repository to store more waste in there. I would feel more comfortable if DOE pre-treats the solid waste stuff, and not just future waste but existing waste. For example, at Rocky Flats Plant, there is a process for looking into barrels with something like x-rays to catch previously undetected liquids in WIPP-bound barrels. Improvements need to be made to the up-front procedures. That is, pre-analyze, assess and characterization. This is a problem--the uncertainty with the barrel contents. There needs to be better engineered barrier systems. There will be a problem with salt migration. I am uncertain if the WIPP site would be permanently closed. **[1.1, 1.3, 3.1, 2.2, 7.1 - Y]**

[DOE] has to admit that we can't predict the future, so we must just do the best we can right now, using the best technologies available. Use engineered barriers as well as natural barriers to get as much confidence as possible. **[3.3 - Y]**

Once WIPP is closed it could be opened by future generations because of interest in what was done. **[3.1 - Y]**

The government may make a decision to expand from just disposal of military waste to include civilian high-level waste as well. Intrusion may not be unintentional--they may say "let's open it and put more stuff in it." **[3.3, 7.2 - Y]**

Would feel more confident if DOE would make decision to go back and pre-treat some of this waste before they ship it. Not just future waste, but some of the waste now existing. **[1.3 - Y]**

Characterization is inadequate--it is very impressive, but still needs improvement. Barrels could contain **anything**. May not really know what is inside, so whatever engineered barrier is used, it may not work for that type of waste. **[1.1 - Y]**

I am concerned with current waste improprieties. That is, illegal openings [of waste disposal sites] that are politically driven. Recently an old, unsafe landfill was reopened, illegally. What's to stop the government from doing this at WIPP? Can't predict political situation. **[3.3, 7.2 - Y]**

WIPP should not be near locations with significant natural resources, such as potash.
How do we let future people know that waste is buried? Do we want to let future people know that waste is buried? **[2.1, 2.4 - Y]**

In the future, people may actually be looking for radioactive waste or other materials. They may dig up WIPP deliberately--like King Tut's tomb. **[3.1 - Y]**

Mixed waste--for example, plutonium--is long-lived, and hazardous chemicals are long-lived. The mixed waste, plutonium, and hazardous chemicals are going to be dangerous for a very long time, and we don't really know how they will interact. **[1.2 - Y]**

I have some high-level waste concerns, like putting more high-level waste in. The heat generated by the high-level waste will affect other natural processes such as geologic and hydrologic processes. **[1.2, 7.4 - Y]**

WIPP is more than a mixed-waste facility. If another place is used to store waste, WIPP can be use to store other types of waste. **[7.4 - N]**

This creates a situation where waste is all around and there are possibilities of additional intrusions by people landfilling around these areas. **[3.1 - Y]**

Concerned that WIPP will open and will continue to be used even if it is not safe because nothing else is even close to opening. **[7.2 - N]**

People may want to get into WIPP [in the future] for reasons that can't even be imagined at this time. **[3.1, 3.3 - Y]**

Per the Land Withdrawal Act, no high-level waste can be emplaced [into WIPP]. But the DOE is trying to change the Land Withdrawal Act. WIPP as the forerunner, as the showpiece, is actually the bastard child of the nuclear industry. It is a result of the nuclear community, but it doesn't even require an NRC [Nuclear Regulatory Commission] certification license. WIPP will not be certified by the NRC. It was called an R&D facility so that it wouldn't have to be licensed by the NRC--DOE wanted it that way, so they got it. The regional control was given to the EPA because DOE didn't want to reverse its decision [about NRC] but now they say they want NRC regulation instead of EPA. **[7.2 - N]**

High-level and low-level waste is certified by the NRC. Why not TRU waste? **[1.1 - N]**

WIPP is put in a natural resource rich area. The standard that DOE has to comply with talks about resources being avoided. WIPP was placed in an area of rich resources, so it already violates these requirements. **[2.1 - N]**

Other countries are looking at vitrification, containers other than 55-gallon drums, and other methods [of storing waste]. If we [U.S.] really want to do this, we must spend the money to do it right. **[1.3, 2.3 - Y]**

The Land Withdrawal Act does allow "remote-handled" [RH] waste that is actually **more** radioactive than that considered "high-level waste." **[1.4 - N]**

Part of the Waste Handling Building [at WIPP] has equipment to handle RH waste. There hasn't been any characterization at all of RH waste. Characterization of RH-TRU waste needs to be done soon, before emplacement. There is no idea of how it will react and affect the long-term performance of the facility. **[1.1, 1.2 - Y]**

If we were going to do WIPP right, we'd be talking about doing the very best we can and not looking at engineered alternatives as icing on the cake. DOE is trying to get away with not doing any backfill. **[7.1, 7.2 - Y]**

We need to construct the best containers possible and use the best waste form modifications possible. We can do a lot better than 55-gallon drums today, so why isn't DOE going to use more robust containers? If people [in the future] were to encounter these more robust containers, it would give them a reason to stop and consider what they might be getting into. **[2.3, 3.1 - Y]**

Let's leave the future the best that we can. DOE is not wanting to improve, for example, containers and salt backfill. DOE has been avoiding doing this. **[2.3, 7.2 - Y]**

We [the public] have been saying these same things since the 70s, so this is **not** an attempt by DOE to get "early public participation." **[7.2 - N]**

No transportation cask [for RH TRU] has been built. The first will be ready in 2015. **[2.3, 7.3 - N]**

Remote-handled waste leaves a wide open door. It may be much more hazardous, or "hotter" in radioactivity than high-level waste. **[1.4 - Y]**

Moderator: Suppose you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment, what would you say?

[DOE] should characterize the waste first, and not just be mixing it and storing it away. I can't believe that this hasn't been done already. DOE should be putting efforts into this now, not waiting until WIPP opens and putting it [the waste] all together. **[1.1 - Y]**

Salt is not as thought [ideal storage medium] because it cracks. Clay is proven to limit movement of waste, but it is not even being considered. Existing reports say that use of specific proportions of a soil and clay mixture will work. DOE is backtracking on C&C agreement to use backfill. In official meetings with the EPA and regulators, they [DOE] have said they are not going to use backfill unless it is required by regulations. Just put salt around it. **[2.2, 7.2 - Y]**

DOE's got a big problem--they must solve the problem of getting rid of waste, but if they try to appease the general public and all the special interest groups, WIPP will never be opened. **[7.2 - N]**

The Land Withdrawal Act requires the DOE to comply with the EPA's 40 CFR 191. They haven't done so yet. Two things are required. The containment requirements include doing computer projections of the future about how the waste might get out [of the repository], and doing engineered barriers. The assurance requirements address engineered and natural barriers, because of the uncertainties of computer projections. **[3.3 - Y]**

The DOE is in the process of trashing the standard. DOE should show compliance. Instead of trying to get out of it, just do it. **[7.2 - N]**

Give assurances that engineered barriers will be used. Don't use panel seals. A panel seal is not a barrier. **[7.1 - Y]**

Get down to using public solutions. I believe that the DOE has generated some solutions. Just use them. Don't gather intelligence and then ignore it. Stop wasting our time. **[7.2 - N]**

[DOE needs to] do it right. Do more than just the minimum. DOE is trying to avoid doing the best that it could and doing it right. DOE is spending too much time fighting the Land Withdrawal Act. Become more definitive with getting waste in the ground after showing that the best has been done using robust engineered barriers. DOE needs to move from saying "Our job is to get waste in the ground and we don't care how much contamination there is" to "Our job is to get waste in the ground once we prove that it will remain there." **[7.1, 7.2 - Y]**

DOE should obey existing laws and standards rather than trying to water them down. **[7.2 - N]**

Characterize waste beforehand. Use the best containers. Engineered and natural barriers must be used. **[1.1, 2.3, 7.1 - Y]**

Do the disposition question soundly and well, and show that the environment and human health is protected. The history of WIPP has been pushing through solutions quickly. DOE has made major steps in the right direction to reach out for public support. Continue to gage public confidence, and get public involvement and participation. Use a rigorous scientific approach. Attain the highest standards of safety and environmental protection. **[7.2 - Y]**

The nuclear industry is ignoring disposition issues and is in a mess. They felt it was a technical problem, easily solved. Now it is learning that disposition has given rise to major problems. It needs to approach the question of waste management as a whole and get public involvement and participation. In some ways it [nuclear industry] is still assuming that the solution is somewhere in the future and isn't handling it now. **[7.2 - Y]**

Regarding the disposition question, DOE has ignored the concerns expressed over many years. Approach the question of waste management and disposition with the best science possible and winning the support of the public. The public should feel it is not being coerced into accepting currently proposed solutions. **[7.2 - Y]**

Since 1993, the DOE has made great strides in trying to involve the public much more than ever before; for example, it abandoned the idea of burying waste for the sake of experimenting with something like gas generation. It went from 200,000 drums to 12 to zero. The new administration feels the public pressure for money spent. The public is questioning the [WIPP] progress. Perhaps DOE has spent too much money in the past, but it now must do the right thing and not bend to pressure to rush this through. Doing the right thing requires time and money. DOE has hard-working, well-intentioned people. Nuclear waste is a universal problem. There are some good public servants at DOE who are feeling the new pressure. **[7.2 - Y]**

How about a contingency plan? What will happen if the DOE is abolished? **[3.3 - Y]**

4.0 SANTA FE, NEW MEXICO

AFTERNOON SESSION, June 28, 1995

A focus group discussion was held in Santa Fe, New Mexico the afternoon of June 28, 1995. Six participants attended this discussion. Mr. Steve Wilkes was the moderator. Other attendees were Maggie Wood, Rebecca Grohler, and Richard Quintana from the S.M. Stoller Corporation; Ann Marshall, from Advanced Sciences, Inc.(who served as note takers); and Patty Barratti-Sallani, a DOE-CAO public affairs representative

Mr. Wilkes opened the meeting with a brief discussion of the purpose of focus groups in general and how this particular session would be conducted. He addressed the ground rules for the discussions, the desired outcome, the assumptions to be used as a basis for the discussions, and then introduced Maggie Wood.

Ms. Wood's presentation addressed the purpose and objectives of the focus group discussion, how participants were selected, and how comments would be used. Ms. Wood advised the focus group that the EEG had requested that she give the participants copies of a paper prepared by EEG stating their position on Engineered Barriers at the WIPP site. Copies of the paper were then distributed to the participants at the end of the discussion.

Mr. Wilkes then led the remainder of the session, beginning with a discussion of concerns about the long-term performance of the WIPP disposal system. After all the concerns had been stated, Mr. Wilkes asked each participant to summarize their concerns in the form of a one minute statement to the DOE. The focus group session was then concluded.

Verbatim notes were not taken. The comments presented during the focus group discussion are shown in the order in which they were expressed.

CONCERNS STATED[3]

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

WIPP can't meet all criteria unless engineered and natural barriers are used. Both natural and engineered barriers are required by EPA. If these rules are followed, I would have fewer concerns. **[7.1 - Y]**

Even if all the requirements for the integrity of WIPP are met, future climate conditions on the planet could change; weather patterns could be altered globally. Models predict 15 inches of rain, but what if pattern changes to 150 inches per year? What will that do? Will integrity of repository be breached and contamination leaked to aquifers? **[3.3 - Y]**

Models used for WIPP show geology unchanged by any climatic or geologic changes, but earthquakes do occur here. Are assumptions upon which WIPP is based (seismic, climate, etc.) valid? I'm concerned about Westinghouse's attitude that the EPA 194 requirements are burdensome, duplicative, and unnecessary, and about their unwillingness to meet the criteria because they interfere with their expectations. **[3.2, 3.3, 7.2 - Y]**

I am concerned about the whole premise on which WIPP is based. Assumptions and values are what dictates integrity of facility--DOE/Westinghouse have no values. They lie, look down on [patronize] the public, and cover up; there's no basis for trust. On **whose** values are "criteria" predicated on? On what are they based? The workers, scientists, and engineers believe environmentalists are simply using delay tactics. These are the people who will have to enforce requirements, so how can we trust them to do that if they don't believe requirements are necessary? **[7.2 - Y]**

I have a major problem with the assumption that human beings, through questionable science, are trying to make these predictions. Nature cannot be fooled--we're trying to make predictions, but the earth doesn't care. Nature can't be controlled and there is no way to predict the future. The views of the worth of natural resources will change in the future. What will be valuable later? Perhaps the waste itself will be valuable and intrusion will occur to get material; or terrorists may intrude. This [WIPP] is political rather than "natural" need. There is a prevailing problem of politics ruling over science. **[3.3, 7.2 - Y]**

The repository's placement in an area rich with natural resources is a mistake. Drill holes [boreholes] and the effect of pressurization underground due to gas generation is a problem. The waste will come out; the loose waste of the waste will facilitate surface releases. The waste

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Numbers in brackets at the end of each comment indicate the taxonomic category to which each comment was assigned. In some cases a comment was assigned to more than one category. In other cases separate statements within one comment were assigned different categories and were counted as separate comments. The Y or N letter that follows the category number(s) indicates whether the comment was related to postclosure [Y] or not related to postclosure [N].

should be treated to minimize the release of pressurized gas. Engineered alternatives should be pursued to prevent waste migration and increase the sheer strength. **[2.1, 1.2, 5.2, 1.3, 7.1 - Y]**

In a closed system there is no real disposal; the wastes may be hidden, but they are still down there and will eventually be exposed. Above-ground, accessible waste that could be continually monitored is better solution. **[3.3 - Y]**

I am concerned that signs and site markers may be interpreted differently in the future. Monuments themselves may be destroyed, or the materials from which the monuments are made could become valuable and the monuments could be stolen or "harvested." **[2.4, 3.3 - Y]**

There is a lot of momentum for the WIPP site being built simply because we have to continue since so much money has been spent on it [WIPP] already. **[7.2 - N]**

I'm really concerned that continuous monitoring is not being planned; there are no provisions for monitoring for more than a short time after WIPP is closed. There are also no plans for remediation. What if better technology comes about? Once collapsed, how do you remediate? There is a whole national debate on nuclear issue of waste that hasn't been done. **[2.4 - Y]**

There is a need for independent oversight of WIPP. There is no long-range planning and there is a lot of rule breaking. DOE "paperworks" their way around concerns instead of dealing with them. **[7.2 - N]**

EPA rules have been weakened by DOE. The standards and requirements are lessened by government pressure. We have no power to change/shape overall policy. There needs to be independent agency to track DOE. Past agreements have been broken. Government violates its own laws. It doesn't matter that public says they don't want it [WIPP], it just continues. DOE can't be trusted. Whistleblowers have said that waste has already been secretly shipped to WIPP, but DOE hasn't done anything about it. If WIPP is so safe, why has such an effort been made to locate it in unpopulated areas? TRUST is the issue. **[7.2 - N]**

I am concerned about institutional controls; record keeping control. How do you mark something in perpetuity? We may lose all knowledge that waste is down there, or WIPP may become a "treasure" site. **[2.4, 3.3 - Y]**

Moderator: What about the waste itself concerns you?

My concerns include insufficient waste characterization and inadequate sampling. Some of this waste is very old and accurate records haven't been kept of what's in the drums. DOE has said that they'll only sample 10 drums in 1000. That leaves 990 drums that could be a nuclear soup, with no way to control interactions among the waste. Each drum should be sampled. Carbon detectors can't detect most explosive wastes. Waste may mutate over time. **[1.1, 1.2 - Y]**

If characterization is not adequately done, then DOE can't meet the criteria because they won't really know what is in the drums. If characterization is properly done, DOE will be able to predict gas generation and other reactions; otherwise they won't. "Legal" methods to ensure accurate characterization is fallible. **[1.1 - Y]**

DOE has exempted themselves from having to meet safety considerations such as flammability, gas, moisture, etc. based on assumptions that nothing in the waste will be explosive. If they're wrong about what [waste] is going down there, then how can they control what will happen if there is a spark or fumes or something else from the equipment being used. **[1.1, 1.2 - Y]**

Some low-level waste is actually very "hot" thermally and radioactively and could contaminate workers or the water supply. Even without an explosion, the waste could present huge problems if it got to the surface. The fracture structure of the surrounding geology is a problem. Thermal heat from the waste could attract moisture from salt. **[1.2, 4.0 - Y]**

DOE has assumed that the waste won't generate heat, but now they're saying that it may very well increase the temperature of the area. How will that affect brine movement or water supplies? **[1.2, 4.1 - Y]**

WIPP is not being designed to be monitored, so basically it is an uncontrolled experiment. There's not even any remote monitoring planned. Test wells are the only plan for monitoring. **[2.4 - Y]**

What if water is injected into wells near WIPP at instead of below the repository level? If water injection penetrates the site and waste moves into the McNutt Potash Zone, it won't have to migrate all the way to the Culebra, it will get out in the potash. **[4.1 - Y]**

Potash resources should be included in Performance Assessments. **[2.1 - N]**

Look at changes in the physical form of the waste. Efforts should be made to cement or vitrify the waste to prevent mobility of the waste. **[1.3 - Y]**

This is a political issue - you're either for or against the nuclear industry. Even God standing at WIPP's gates saying it was safe couldn't convince some people. This is about educating the public about what is going on. Tests like those conducted at Idaho Falls contributed to my confidence about WIPP. I think WIPP has gone overboard with the protection issue; there are so many safeguards. Gasoline trucks are much more dangerous than the TRUPACT, which poses no danger at all, but people aren't concerned at all about it [the gasoline truck]. **[7.2 - Y]**

Technology will change, and there is no way of knowing exactly what will happen, but I have no concerns about WIPP. **[3.3 - Y]**

Moderator: Are there other concerns that we haven't yet addressed?

Concerned about systematic, bureaucratic breakdown; war; institutional collapse; changes in society's values, etc. **[3.3 - Y]**

If the gold mines of the past were trying to be built today, they'd never make it.
Difference between things like gold mines and WIPP is that those [harmful byproducts] don't last as long. It is the longevity of the waste at WIPP that is the problem. We're dealing with the most dangerous product in the world and it will last for hundreds of thousands of years. **[1.4, 3.3 - Y]**

DOE has looked at alternatives such as cementation, clay, better containment methods, etc., but DOE won't use these. **[1.3, 2.0, 7.1, 7.2 - Y]**

DOE is a much stronger agency than EPA, so it can run right over them. Also, the EPA has invited the OMB [Office of Management and Budget] into the process, but they are much stronger than EPA as well. The entire process is "non-public." **[7.2 - N]**

The future of the EPA will be one of cutbacks, breakdown, and collapse. **[3.3 - N]**

DOE may try to change WIPP to store something it is not designed for, such as Yucca Mountain waste if it isn't approved. **[3.3, 7.2 - Y]**

There may be no EPA or DOE in the near future, much less 10,000 years from now. What will happen then? **[3.3 - Y]**

Showing causality is so difficult, how will it ever be found? For example, 50 years ago a village was using cobalt as jewelry, and even after they all started getting sick they didn't relate it to the cobalt. **[3.3 - Y]**

On the other hand, there is no way to know, so why go on at all, with anything? We just have to use the best technology now and go on. **[3.3 - Y]**

There are political and economic drivers. Why are there 600 employees at WIPP if there's no waste there? Who's benefitting at the expense of other people's values. **[7.2 - N]**

I'm concerned about how actual costs are determined. There is no continuity over these little parts, like this focus group meeting and public confidence study. There are gaps in the way things are done because they're being done in a vacuum. Nobody's "minding the store." People state their feelings and concerns but they seem to drop into a bottomless hole. **[7.2 - N]**

WIPP is a symbol of something that people have no control over. Most people realize that they can get much more exposure from other things, but WIPP symbolizes DOE's total unconcern for the <u>individual</u>. That the government really cares about people is a faulty premise. **[7.2 - N]**

Concerned that all criteria will not be met because the government can refuse funding in future. If they stop funding, then markers may not get put up even if they are planned now. **[3.3, 7.2 - Y]**

Oldest written history we have is less than 5,000 years. Governments come and go, as does currency, language, and everything else, so how can we be sure written records will mean anything? **[3.3 - Y]**

If we continue with these assumptions [that we can't predict future] then we can't do <u>anything</u>--not just WIPP. **[3.3 - Y]**

The 10,000-year expert projections don't fool anyone, so stop faking it. We can't predict that far into the future, so don't try to have experts assume that they can. We need to take the best technologies available now and use them instead of fighting it. **[3.3, 7.2 - Y]**

Money and time should be spent on the whole scenario, like shortening the half-lives, reducing volume, characterizing waste, and neutralizing the waste. Things like this should have been done first instead of using all that money to bury the waste. **[1.0, 2.0 - N]**

There isn't an iterative process in the federal government planning process. They never stop to consider what went wrong in the past in order to improve the future. The existing process doesn't allow for goal evaluation and changes. **[7.2 - N]**

Moderator: If you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment once it is closed, what would you say?

WIPP is a bad idea. A national debate is needed on how to deal with the country's nuclear waste. This needs a more holistic focus. **[7.2 - N]**

What is needed is more open public debate and stakeholder involvement in the policy making. Empower stakeholders to solve the problems. **[7.2 - N]**

Educate the public, educate the public, educate the public. WIPP won't work forever; it will eventually fail. The issue cannot be swept under the rug; the problems will just be passed on to future generations. **[3.3, 7.2 - Y]**

Stop letting the schedule drive the process. It leaves no room for questions or change. The process needs to be more open. The EPA will be making important scientific determinations with a small group of dedicated people evaluating the work of much more experienced scientists. The EPA staff won't have as much experience and qualifications as the DOE. **[7.2 - N]**

Stakeholders have very little scientific knowledge. Don't fake the performance assessments with fancy numbers and expert panel projections. These are just devices to fake confidence, and the public won't be fooled. Don't avoid consideration of natural resources like potash. **[7.2 - N]**

If the determination that WIPP has met all compliance requirements is totally open to the public, the public may accept it; but they won't if the determination is government-controlled. **[7.2 - N]**

EVENING SESSION I, June 28, 1995

A focus group discussion was held in Santa Fe, New Mexico the evening of June 28, 1995. Three participants attended this discussion. Mr. Steve Wilkes was the moderator. Other attendees were Maggie Wood, Rebecca Grohler, and Richard Quintana from the S.M. Stoller Corporation; Ann Marshall, from Advanced Sciences, Inc. (who served as note takers), and Patty Barratti-Sallani, a DOE-CAO public affairs representative.

Mr. Wilkes opened the meeting with a brief discussion of the purpose of focus groups in general and how this particular session would be conducted. He addressed the ground rules for the discussions, the desired outcome, the assumptions to be used as a basis for the discussions, and then introduced Maggie Wood.

Ms. Wood's presentation addressed the purpose and objectives of the focus group discussion, how participants were selected, and how comments would be used. Ms. Wood advised the focus group that the EEG had requested that she give the participants copies of a paper prepared by EEG stating their position on Engineered Barriers at the WIPP site. Copies of the paper were then distributed to the participants at the end of the discussion.

Mr. Wilkes led the remainder of the session, beginning with a discussion about participants' concerns about the long-term performance of the WIPP disposal system. After all the concerns had been stated, Mr. Wilkes asked each participant to summarize their concerns in the form of a one minute statement to the DOE. The focus group session was then concluded.

Verbatim notes were not taken. The major comments or points made during the focus group discussion are presented in the following section. The comments are shown in the order in which they were presented.

CONCERNS STATED

Moderator: What are your concerns about the ability of WIPP to protect human health and the environment once WIPP is closed, waste is emplaced, and the site is sealed?

How can we predict what will happen in the future? We thought we knew in the past and we were wrong. We can surmise, but there is no way of knowing. How do we know the site will work the way it is designed? **[3.3 - Y]**

I sat in on a National Academy of Science (NAS) meeting where they told DOE that man-made cavern in salt will not work; it would be better to use a natural cavern in the salt. With movement expected from both the top and the bottom, the capsules can't resist the moisture for thousands of years. They recently found out that water flow from the Rio Grande is not what they thought. Nature will fill the void. **[2.1 - Y]**

DOE says that no water goes through or near the site, but the Ogallala Aquifer, one of the main aquifers that feeds the southwest, is in that area. Concerned that the waste containment capsules will not be water resistant and if water were to get into the facility the capsules could break down and allow contamination to enter the aquifer or contaminate the air. **[2.3, 4.1, 5.2 - Y]**

What happened to create all the layers above WIPP and how do we know the earth won't revert to those conditions? **[3.3 - Y]**

One citizen asked what kind of waste will be put into the WIPP. DOE representative Patty Barratti-Sallani provided a brief description of transuranic waste. **[not counted]**

Citizen: Plutonium is plutonium whether it's a lab coat or a fuel rod; DOE can't simply cut a fuel rod in small pieces and call it low-level waste. Should consider it the same material regardless of what kind of item it is. Need to have one standard for all waste. Even if the [contaminated] lab coat disintegrates, the part containing the radionuclides will have an impact for 240,000 years. How can we look at 240,000 years and predict what affect it [plutonium] will have on the genetic makeup of society? We don't know how Mother Earth might react--she might through it out if we stuff her. That's longer than the history of man. The entire gene pool of my tribe could be wiped out if there were an incident. **[3.3, 5.2, 7.2 - Y]**

We don't know what kind of effect there will be from burying this waste in the earth. We don't know what the Arabs might do or the Bosnians in 100 years. They might bombard the site. **[3.3 - Y]**

I sit squarely on the fence, but in 240,000 years we should be able to fix that [the waste problem]. **[3.3 - Y]**

A citizen asked "Once waste is emplaced, can it ever be taken out?" The DOE Representative explained that the area could be remined, but it could result in exposure and mining risks to the workers. **[not counted]**

A concern was expressed if the salt would act as predicted and collapsed on the waste. **[1.2 - Y]**

Concerned that we won't be able to continue to monitor the site in the future to ensure that it is performing as expected. **[2.4, 3.3 - Y]**

We've done this to ourselves. All of this [waste] is out there now and poses a danger and great risk to this generation and those in the next few hundred years, so surely we would be better off if the waste were isolated in the WIPP. **[7.4 - N]**

I agree. Maybe we get the technology to clean the water if it gets into the water, but we don't know. **[7.4 - N]**

The unknown itself is the concern. With not being able to monitor, we need to do the best we can now. Then, in the future, if better technology is developed, it could be used...**[2.4, 3.3 - Y]**

Society's tendency is to bury what we don't understand-- "out of sight, out of mind." I hope in 500 years we will find ways to mine and neutralize it--with all safety networks. Maybe we'll have submarines to go in and neutralize it. **[3.3, 7.2 - Y]**

I'm concerned about whether or not we'll be able to get back to the waste and retrieve it if we find a better way. Or, perhaps we will have the technology to clean any contaminated water or air that might result from burying the waste. **[2.0, 3.3 - Y]**

No other society has lived over 500 years--who will be in charge? Will the United States even exist then? **[3.3 - Y]**

Concerned that enough money isn't being put into finding ways to neutralize the substances produced instead of putting all the money into developing disposal facilities. A proportion of the money spent for these facilities should be used on finding ways to prevent these problems. Similar to forest service--spends 90% on suppression and only 10% on prevention. **[7.2 - N]**

Moderator: Is there anything about the waste itself which concerns you?

Concerned about both hazardous and radioactive wastes being placed together in the facility. Perhaps the waste should be more homogeneous. **[1.1, 1.2 - Y]**

I'm concerned about the byproducts of hazardous waste degradation. Biodegradation of natural substances may create oils or other liquids as a result of decomposition. These decomposed products may get into the water. **[1.2, 4.1 - Y]**

We get oil and gas from the earth - that doesn't really bother me. Life is precious and we need to protect our water system; maybe we can, maybe we can't, but [the waste] is still safer underground than on top. **[7.2 - N]**

Moderator: Are there additional concerns which have not yet been addressed?

DOE has a real public relations problem. Past errors, blunders, blatant deceit have created considerable distrust of DOE. DOE is an amorphous body; there's not an "individual" that the public can look to and learn to trust. Some of its blunders are just from ignorance, but DOE lies and tries to cover up and tell the public that everything's fine; later we discover it wasn't fine--look at Agent Orange. How can they [DOE] assure us that everything's fine when there is no way to predict what will happen? God help us if we say in 50 years that this salt experiment didn't work. **[3.3, 7.2 - Y]**

What if WIPP doesn't work? What prevents area from becoming prone to earthquakes or floods? **[3.2 - Y]**

Participant question: When they detonate underground explosions, is this worse than that? **[not counted]**

WIPP may not be as bad as other sites that do underground detonation, but it's like comparing two bad apples. My concern is that we don't just bury it and forget it. We need to know that the government is doing its very best to protect the southeast corner of our state. We need to continue to monitor for as long as the waste is hazardous, no matter what agency or government is in charge. **[2.4, 7.2 - Y]**

We were told that Los Alamos [National Laboratory] wouldn't contaminate our aquifer because it was 2,500 feet underneath Los Alamos; then two years later they [DOE] admitted that there is contamination, but tried to say it came from the Chernobyl incident. **[7.2 - N]**

What good is open, honest communication by DOE? When PR people start talking, it's a scam. DOE is a con artist. We need to be able to look up information ourselves. Everything should be public record. There is public involvement and willingness to listen. An ongoing dialog is important to maintain. **[7.2 - N]**

Moderator: If you had one minute to talk to DOE about WIPP and its ability to protect human health and the environment once it is closed, what would you say?

I need more information based on what we discussed. I don't know enough about the site. From a humanitarian point of view we have, because of a hunger for exploration of new and different elements and a thirst for knowledge and going forward, created a problem for ourselves and future generations; now how do we best serve future generations. How can we neutralize the waste and resolve this problem? **[7.2 - N]**

With information we have, I would have to do the "ostrich thing" and bury my head in the ground until we can divert our attention from burying/generating waste to actually finding an antidote. **[7.2 - N]**

I would like to know what's wrong with the existing storage situation. Just because we've spent two billion dollars on [WIPP], we must be able to pull back from it--not just do it because we've gone too far. We need to be cautious. If some other technology can be developed in next ten years or so, then they [DOE] should walk away from it [WIPP]. Don't succumb to pressure--if we need WIPP that badly, explain what is the situation in other areas. **[7.2 - N]**

OTHER DISCUSSIONS

Can we cause the salt to collapse instead of letting it happen naturally? Can we encapsulate the waste by deliberately collapsing the salt around it, and then let the natural occurrence we expect to happen naturally. My understanding is that it will generate so much heat it will melt the salt and encapsulate everything. NAS is very creative. Now they're trying to encase it in glass at Hanford. **[1.2, 1.3, 2.2 - Y]**

Concerned about transportation risks with regard to tourism in Santa Fe and New Mexico. An accident, no matter how minor, would affect tourism for the whole state because it would be exaggerated by the media and the public. **[6.1, 7.3 - N]**

We've spent billions on everything else so don't scrimp on the transportation--not just on equipment, but with escorts or whatever it takes to ensure safety. Block the roadways so no one can overtake the TRUPACTs, have police escorts surrounding it, or whatever is necessary. What kind of qualifications do drivers need--airline pilots have to go through years of training, will these drivers have special training? Will they be under time constraints or can they take two days instead of one day to get to WIPP? **[7.3 - N]**

A citizen asked if shipments would be escorted or if drivers were on their own. The DOE representative said drivers would be on their own. The citizen then asked how DOE could keep track of the shipments. The DOE representative said that there would be a satellite tracking system that would verify the vehicle's location every 15 minutes and that communication via computer would be made, if no answer, emergency vehicles will be sent to investigate.**[7.3 - N]**

One citizen said that measures should not be reactive, but proactive, to prevent any mishaps, such as terrorists. **[7.4 - Y]**

The tribes are not being kept informed. Recently there was an incident in the State of New Mexico. They couldn't handle it and had to bring responders in from Oklahoma. In every exercise we have participated in, our people died because of a lack of communication. We need one common frequency with police, fire department, WIPP, and all other emergency participants. Also expressed concern that if pueblo emergency personnel are first on the scene, that they have the same equipment (such as protective suits) that police and fire department have. **[5.0, 7.3 - N]**

Also expressed some concern about the emergency response system. Who responds? Who coordinates? How do we know that it will work? **[7.3 - N]**

EVENING SESSION II, June 28, 1995

An independent interview was conducted on the evening of June 28, 1995, with one individual who was invited to participate in the focus group discussions but was unable to participate in the Albuquerque focus group due to a misunderstanding about the location where the focus group discussion was held. The participant was invited to attend other focus group discussions in Santa Fe but was unable to attend these sessions. This interview was therefore conducted subsequent to the evening session of the Santa Fe focus group discussion. Maggie Wood of the S.M. Stoller Corporation lead the interview using the same questions that were used in other focus group discussions. She started the interview with a presentation on the objectives and purpose of the interview and focus group discussions. This presentation was also given at all the other focus group discussions and is attached to this report as Exhibit A. Ms. Ann Marshall, Advanced Sciences, Inc. took notes and Patty Barratti-Sallani, a DOE-CAO public affairs representative was also present.

Verbatim notes were not taken. The major comments or points made during the interview are presented in the following section. The comments are shown in the order in which they were expressed.

CONCERNS PRESENTED

Moderator: What are your concerns about WIPP's ability to protect human health and the environment once waste has been emplaced, it is closed, and sealed?

I am concerned that WIPP relies too much on passive measures rather using than active measures to protect the waste. DOE expects the waste to stay where it is emplaced. I am concerned because this is not a 10,000 year problem, which is an arbitrarily number, but rather a 100,000 to 200,000 year problem. **[2.0, 3.3 - Y]**

I believe that the containers which are used to store the waste [55-gallon drums] are inadequate. We heard that the geologic containment was deemed sufficient because they couldn't come up with a container that would last. There was a failure of common sense at the beginning with the use of this premise which may lead to a failure of common sense latter. It would be common sense to design a waste container that would last the entire period of time that the waste is radioactive or 200,000 years. **[2.3, Y]**

Monitoring. I think that the current plans for monitoring are totally inadequate. It is ethically repugnant to emplace the waste and then just walk away from it. **[2.4 - Y]**

Moderator: If you were going to monitor what would you monitor for?

I would keep people on the site for the 200,000 year period of risk to identify any problems that might come up and materials that might sneak out. The biggest thing is water intrusion into the site. You need to monitor for water intrusion into the site. If water intrusion occurred you would need to detect it so that you could remediate the site. You need to figure out what should be done if water intrusion occurs. Salt will move, and there will be a mobility of the elements [e.g., hazardous and radioactive constituents].. There are no real barriers to contain the radioactive and hazardous elements and with the inadequate containers what will indicate movement of the

elements? Monitoring of heat was ruled out decades ago because they know that there will be heat. Will there be an expanding bubble of elements and will they be monitored? **[2.0, 2.3, 2.4, 3.2, 4.1 - Y]**

How will we know if WIPP has failed? There really isn't any way to make a plug (seal), and there is no way to prevent a borehole from releasing pressurized brine. DOE initially predicted a 2 percent to 70 percent chance of an inadvertent intrusion into the site. Then finally the prediction moved to 2 percent to 48 percent over a 100,000 to 200,000 year period. I believe that human intrusion is highly probable with a probability of 1.0. Even if you were monitoring the site for human intrusion, how would you detect intrusion from the side, like in slant drilling? Or what would you do? **[2.4, 3.1 - Y]**

Brine pockets which reside in the site itself could create a shaft. How do you monitor for pressurized gas? **[1.2, 2.1, 2.4 - Y]**

My preference is retrievable waste which will be monitored outside each container, which is imbedded in a steel matrix - so you could pull it out. That should be specified. **[2.2, 2.3 - Y]**

There are a variety of ways that could be used to get the containers out of the salt beds once they are emplaced such as a cable system with computer codes. **[2.2, 2.3 - Y]**

Once the stuff [waste] is out of the bottle [container], it just doesn't make any sense at all. The waste should be put in a stable container so that it can't get out. Then you could mine out the containers in the future. **[2.3 - Y]**

I am also concerned about the current methods that are used to perform risk assessments which are woefully inadequate. Do we know how to predict thousands of years in the future? If we used comparable techniques in medicine, they would be considered primitive. Current risk analysis only uses single element analysis. In medical science we know that there is a synergy of multiple factors like birth defects or lead poisoning. Those factors that are in the ground and all other potential factors should be used in performing risk assessments. **[3.3, 5.1 - Y]**

WIPP is symbolic of society's attitude toward waste and how we produce, handle, and store toxic materials. **[7.2 - N]**

I am concerned about the opportunity costs associated with WIPP. If we allow waste to be emplaced too quickly, society will not take the effort to solve the problems that occur from exposure to radioactive materials like plutonium and other exposures. **[7.2 - N]**

WIPP fits in with other vectors of illness and disease. WIPP has a function to serve as it gives us the opportunity to perform research and development on toxins and improve global health. If waste is emplaced in WIPP and it is closed and you walk away from it, you will lose the impetus for research and development. **[7.2 - N]**

Geo-satellite monitoring could be used to monitor the facility. You could monitor activity in the vicinity by implanting sensor devices and monitoring geological data for the introduction of water into the site. **[2.4 - Y]**

I am also concerned about treatment, pretreatment, and stabilization of the waste. Is the waste in the best form for storage? **[1.3 - Y]**

I also believe that waste characterization should be performed on a barrel-by-barrel basis and that an analysis of the waste should be performed so that we will know what we are putting in there. Without knowing the exact composition of the waste we lose the ability to know what you're protecting the public from and a particular isotope could become a key factor. **[1.1 - Y]**

We should be building a system that will allow improvements over time, not degrade over time. **[7.2 - N]**

Another concern is future generations mining the site out of curiosity and the potential health impacts from such activities. The use of markers will be as likely to attract as repel efforts of this nature. What should we do if someone decides what is in WIPP is valuable and wants it? **[2.4, 3.1 - Y]**

Moderator: If you were living thousands of years in the future in southeastern New Mexico, and you knew that radioactive waste was buried in WIPP, what do you wish people had thought of?

I would want people to tell the whole story of nuclear weapons. Why we made them, and why we made so many of them. If future generations knew about the production of nuclear waste and the waste by-products it would reduce the potential of people messing around with the waste in the future. **[7.2 - Y]**

I am concerned that in the future people might want to mine the waste for the materials which could be used for the production of weapons. I am concerned that uranium and plutonium could be mined. If this mining were to occur these materials could get into the food chain. **[3.1, 5.0 - Y]**

Looking at 1 ppm - biological organisms could concentrate these elements [plutonium and uranium] and move them into the food chain. We are now finding micro-organisms way underground. The radioactive elements in the waste might become a medium for these micro-organisms and a microbial bridge could be formed and mutate the organisms. **[4.3, 5.0 - Y]**

I am truly concerned about adequate monitoring of the site in the future and container retrievability. DOE currently has no real plan for retrievability. We want to see more modern materials considered for the waste containers. We would like studies of what materials can be used to achieve a longer container life. **[2.3, 2.4 - Y]**

We need specific sensors that can track specific elements. Invitro stabilization techniques, ways to pretreat and separate the waste should be explored and then decide what's the best way to store these wastes. A variety of stabilization techniques should be explored. I am concerned about mobility of the waste in the salt, gas pressure build up, and the lack of boundaries and barriers to prevent the waste from getting out and affecting human health and the total ecological environment. There could be indirect health effects on other species, like coyotes, deer mice, it could be like the hanta virus. **[1.1, 1.3, 2.4, 4.0, 4.3, 5.0 - Y]**

Moderator: If you had one minute to talk to DOE what would you want to say?

The plan of putting the waste into containers and walking away from it does not use the best available technology. Its not even using the best technology that we have gained over the last 30 years. We should prepare waste containment strategies so we can improve containment in the future. Something that will give assurance of an ability to improve rather than degrade - Go for 10,000 year or 100,000 year improvements. We currently don't know the right balance between concentration and dispersal - or somewhere in-between. That is the problem for the stuff in WIPP and other stuff too. **[2.3, 7.2 - Y]**

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APPENDIX N

WASTE ISOLATION PILOT PLANT RELATIVE FREQUENCY OF COMMENTS BY CATEGORY

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Phase 2
Fosuc Group Comments Pertinent or Not Pertinent
Postclosure WIPP

	Carlsbad		Albuquerque		Santa Fe		Total				
	Yes	No	Yes	No	Yes	No	Yes + No	Yes		No	
1.0 Waste Conditions	6	0	22	3	25	4	60	53	88%	7	12%
2.0 Technology Applied	13	1	15	3	39	1	72	67	93%	5	7%
3.0 Disposal Period Events	7	0	23	0	40	0	70	70	100%	0	0%
4.0 Ecological Impacts	6	1	2	0	11	0	20	19	95%	1	5%
5.0 Human Health	1	1	1	0	8	1	12	10	83%	2	17%
6.0 Economic Impacts	0	1	0	0	0	1	2	0	0%	2	100%
7.0 Other	4	17	23	13	20	28	105	47	45%	58	55%
Total	37 64%	21 36%	86 82%	19 18%	143 80%	35 20%	341 100%	266	78%	75	22%

Relative Frequency of Comments by Category
(Focus Group Meetings—June, 1995)

	CBAD #	CBAD %	SF #	SF %	ABQ #	ABQ %	Composite #	Composite %
1.0 Waste Conditions	1	2%	1	1%	0	0%	2	1%
1.1 Characterization/Identification	1	2%	6	4%	10	10%	17	5%
1.2 In-Storage Reaction	2	3%	10	6%	5	5%	17	5%
1.3 Treatment	1	2%	6	4%	8	8%	15	5%
1.4 Characteristics	1	2%	1	1%	2	2%	4	1%
2.0 Technology Applied	1	2%	5	3%	0	0%	6	2%
2.1 Siting	5	9%	4	2%	4	4%	13	4%
2.2 Site Design	2	3%	3	2%	4	4%	9	3%
2.3 Containers	0	0%	8	5%	9	9%	17	5%
2.4 Monitoring & Marking	2	3%	15	9%	1	1%	18	6%
3.0 Disposal Period Events	1	2%	0	0%	0	0%	1	0%
3.1 Human-Caused Intrusion	5	9%	3	2%	11	11%	19	6%
3.2 Intrusion Due to Natural Causes	0	0%	3	2%	0	0%	3	1%
3.3 Disposal Period Uncertainties	5	9%	32	19%	12	12%	49	15%
4.0 Ecological Impacts	2	3%	2	1%	0	0%	4	1%
4.1 Water (ground water and surface water)	5	9%	5	3%	1	1%	11	3%
4.2 Air	0	0%	0	0%	0	0%	0	0%
4.3 Flora and Fauna	0	0%	2	1%	0	0%	2	1%
5.0 Human Health	1	2%	4	2%	0	0%	5	2%
5.1 Risk Assessment	0	0%	1	1%	0	0%	1	0%
5.2 Toxic Effects	1	2%	3	2%	0	0%	4	1%
6.0 Economic Impacts	1	2%	0	0%	0	0%	1	0%
6.1 Tourism	0	0%	1	1%	0	0%	1	0%
7.0 Other	0	0%	0	0%	0	0%	0	0%
7.1 Engineered Alternatives Study	2	3%	3	2%	9	9%	14	4%
7.2 Value/Ethics	10	17%	39	24%	19	19%	68	21%
7.3 Transportation	3	5%	5	3%	2	2%	10	3%
7.4 Miscellaneous	6	10%	3	2%	3	3%	12	4%
	58	100%	165	100%	100	100%	323	100%

APPENDIX O

WASTE INVENTORY

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WASTE INVENTORY

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) has initiated a cost benefit study to provide a technical basis for the selection and rejection of engineered alternatives (EAs) for the Waste Isolation Pilot Plant (WIPP) should it be determined that additional barriers are desirable. The EAs are analyzed with respect to the following eight factors:

- Effects of EAs impact on long-term performance of the disposal system
- Worker and public exposures
- Impact on removing waste from the repository
- Risk of transportation
- Impact on uncertainty in compliance assessment
- Impact on public confidence in performance of the repository
- Impact on total system cost and schedule
- Impact on other waste disposal programs.

Processed waste masses and volumes are used to support the analyses associated with many of these factors.

The purpose of this appendix is to describe the methodology used in determining final waste form masses and volumes for the baseline and each of the EAs in greater detail than provided in the report.

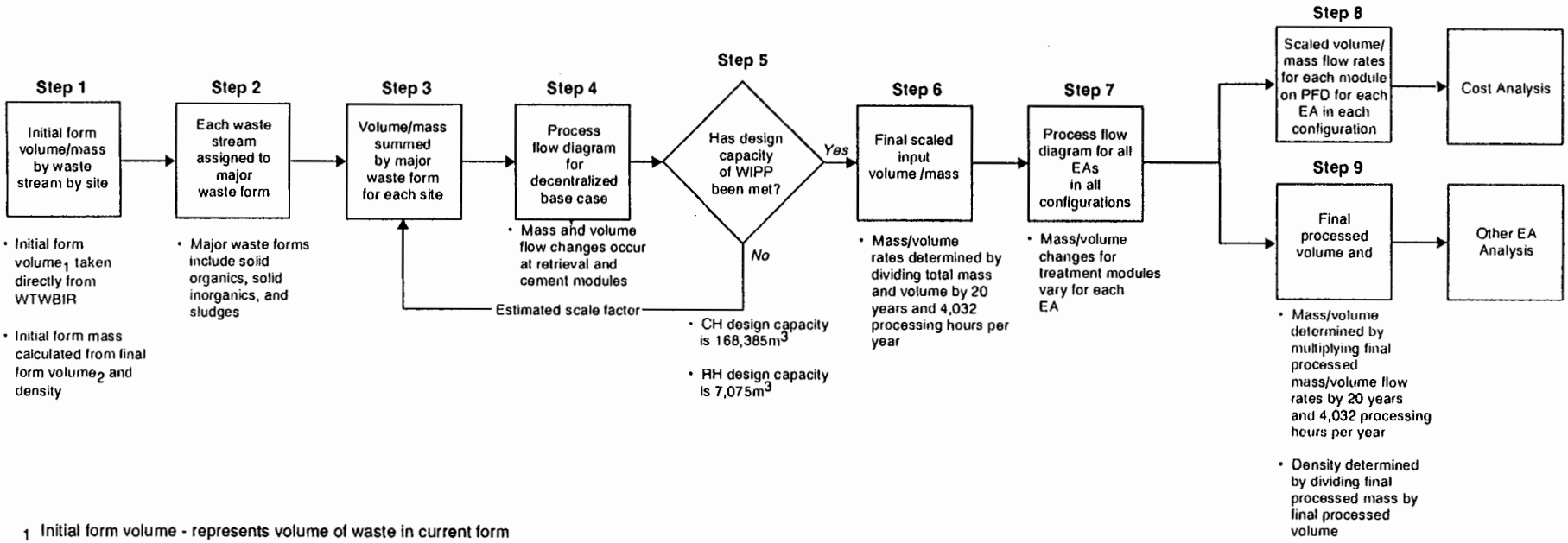
2.0 METHODOLOGY

The methodology for determining final processed masses and volumes for the WIPP inventory is depicted in Figure O-1. Each step is described in the following subsections.

2.1 STEP 1: WASTE STREAM-SPECIFIC MASS AND VOLUME

Initial waste stream-specific volumes (i.e., pre-processed volumes) were obtained from the Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (WTWBIR), CAO-94-1005, Revision 1, February 1995. The WTWBIR contained two types of waste volumes: (1) the "initial" volume, which represents the volume of the waste in its current form and (2) the final form volume, which represents the volume of the final form of the waste for shipment to WIPP. The initial volumes were used in this methodology. The following data were obtained from the waste stream profile:

- Site name
- WIPP ID
- Handling (i.e., contact-handled [CH] or remote-handled [RH])
- Waste type (i.e., transuranic [TRU] or TRU mixed [TRUM])
- Waste matrix code group



1 Initial form volume - represents volume of waste in current form
2 Final form volume - represents volume of waste in final form for shipment to WIPP

Figure O-1
Methodology for Determining Final Processed Mass and Volume of WIPP Inventory

- Volume of retrievable waste (stored inventory)
- Volume of projected waste (projected inventory).

Mass data were not provided in the WTWBIR; masses were obtained by multiplying the volume of each waste stream by an average density for the waste matrix code group associated with that waste stream. The average densities are shown in Table O-1 for CH waste and Table O-2 for RH waste. The WTWBIR includes waste material parameters, in terms of kilograms per cubic meter, for iron-based, aluminum-based, other metals, other inorganics, cellulose, rubber, plastics, solidified inorganic material, and solidified-organic material constituents for both CH and RH waste. These parameters were summed to obtain the density for the waste matrix code group. However, these densities represent the final form waste densities. Therefore, the final form waste volume was multiplied by the sum of the material parameters to calculate final form mass. As a simplifying assumption, it was assumed that the initial form and final form masses for the stored sludges, solid organics, and solid inorganics were equal. However, for projected sludges, it was assumed that the final form mass represented the initial form mass plus the cement added to the sludges in grouting; as a result, the contribution of cement was subtracted from the final form masses of the projected sludges to obtain the initial form mass. The average weight percent of cement in grouted sludge was calculated at approximately 62 percent, based upon a memo from E.R. Naimon to A.E. Whiteman (Naimon, 1988), thus the final form projected sludge mass was multiplied by (1-0.62) to obtain the initial form of the sludge mass.

2.2 STEP 2: ASSIGNMENT OF MAJOR WASTE FORM TO WASTE STREAMS

As shown in step 2 of Figure 1, the waste streams were assigned to three major waste form categories: sludges, solid organics, and solidified inorganics, based on waste matrix code group. The correlation between waste matrix code group and the major waste forms was obtained from the Final Report on Cost and Schedule of Selected Engineered Alternatives, IT Corporation, September 27, 1994, and is presented in Table O-3.

2.3 STEP 3: SUMMATION BY MAJOR WASTE FORM

As shown in step 3 of Figure 1, waste streams were summed by site by major waste form category. Initial masses for CH and RH waste are shown in Tables O-4 and O-5, respectively. Initial volumes for CH and RH waste are shown in Tables O-6 and O-7.

Mass and volume flow rates were calculated assuming a 20-year inventory processing period and 4,032 hours of operation per year (three 8-hour shifts, 240 days per year at 70 percent availability). Initial mass rates for CH and RH waste are shown in Tables O-8 and O-9, respectively. Initial volume rates for CH and RH waste are shown in Tables O-10 and O-11.

2.4 STEP 4: APPLICATION OF MASSES AND VOLUMES TO THE PROCESS FLOW DIAGRAM FOR THE DECENTRALIZED BASELINE

The mass and volume flow rates were applied to the process flow diagrams for the decentralized baseline for CH waste (Figure O-2) and RH waste (Figure O-3), respectively. The modules included in Figure O-2 and Figure O-3 are discussed in more detail in Section 2.7. The process flow diagrams are based on the DOE Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task

1

TABLE O-1

SUM OF WASTE MATRIX CODE GROUP PARAMETERS FOR CH WASTE

Final Waste Form	Sum of Waste Matrix Code Group Parameters (kg/m^3)
Combustible	463.24
Filter	171.75
Graphite	245.90
Heterogeneous	691.59
Inorganic Nonmetal	274.57
Lead/Cadmium Metal Waste	336.76
Salt Waste	270.81
Soils	688.04
Solidified Inorganics	769.98
Solidified Organics	776.93
Uncategorized Metal	328.56
Unknown	000.00

1

TABLE O-2

SUM OF WASTE MATRIX CODE GROUP PARAMETERS FOR RH WASTE

Final Waste Form	Sum of Waste Matrix Code Group Parameters (kg/m^3)
Combustible	354.10
Filter	241.30
Heterogeneous	239.74
Lead/Cadmium Metal Waste	344.04
Salt Waste	270.81
Solidified Inorganics	793.27
Uncategorized Metal	519.14
Unknown	000.00

1

TABLE O-3

CORRELATION BETWEEN WASTE MATRIX CODE GROUP AND MAJOR TRU WASTE FORMS

Waste Matrix Code Group	Major Waste Form
Combustible Waste	Solid Organics
Filter Waste	Solid Organics
Graphite Waste	Solid Inorganics
Heterogeneous Waste	Solid Organics
Inorganic Nonmetal Waste	Solid Inorganics
Lead/Cadmium Metal Waste	Solid Inorganics
Salt Waste	Solid Inorganics
Soil	Solid Inorganics
Solidified Inorganic Waste	Sludges
Solidified Organic Waste	Solid Organics
Unspecified Metal Waste	Solid Inorganics

TABLE O-4

CH SITE-SPECIFIC MASS (IN KILOGRAMS)

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Retrievable	Projected	Projected
AMES	0	29	0	0	0	0	0	0
ANL-E	17,744	328	19	0	2,000	184	0	0
ANL-W	0	0	0	2,324	7	835	0	0
BT	0	0	0	85,630	0	0	0	0
ETEC	0	0	1,148	3,596	71	0	0	0
HANFORD	2,256	922,709	6,174,947	6,478,969	133,813	4,759,249	0	0
INEL	9,366,245	0	7,748,875	692	2,943,209	0	0	0
KAPL	0	0	1,660	0	0	0	0	0
LANL	3,733,153	602,456	819,162	1,141,703	1,433,799	1,087,211	0	0
LBL	0	0	581	3,057	0	0	0	0
LLNL	10,243	19,354	25,501	178,078	47,589	81,944	0	0
MOUND	5,605	0	3,318	0	134,721	0	0	0
MU	0	0	41	1,109	0	0	0	0
NTS	0	0	428,439	0	0	0	0	0
ORNL	26,888	0	465,426	182,510	0	0	0	0
PA	2,656	0	0	0	0	0	0	0
PANTEX	0	0	432	0	0	0	0	0
RFETS	176,040	874,298	337,402	781,162	109,011	296,437	0	0
SNL/NM	0	0	5,560	4,841	0	0	0	0
SRS	31	0	9,205,766	7,501,480	0	0	0	0

TABLE O-5

RH SITE-SPECIFIC MASS (IN KILOGRAMS)

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
ANL-W	0	0	356	523	3,723	830	0	0
BCLDP	0	0	0	17,021	0	0	0	0
BT	0	0	0	373	0	0	0	0
HANFORD	0	0	7,950	712,915	0	0	0	0
INEL	1,666	0	3,269	671	2,134	5,592	0	0
KAPL	0	0	2,692	6,049	0	0	0	0
LANL	0	0	5,255	1,119	39,694	41,272	0	0
ORNL	153,869	52,451	91,775	43,800	0	0	0	0
SRS	0	0	0	15,324	0	0	0	0

TABLE O-6

CH SITE-SPECIFIC VOLUME (IN CUBIC METERS)

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
AMES LAB	0	0	0	0	0	0	0	0
ANL-E	23	1	0	0	6	1	0	0
ANL-W	0	0	0	3	0	2	0	0
BT	0	0	0	123	0	0	0	0
ETEC	0	0	2	5	0	0	0	0
HANFORD	3	3,154	7,798	13,557	259	14,147	0	0
INEL	18,150	0	11,043	0	8,752	0	1,252	0
KAPL	0	0	2	0	0	0	0	0
LANL	4,848	2,059	1,768	2,465	4,244	3,151	0	0
LBL	0	0	1	4	0	0	0	0
LLNL	13	66	66	405	145	250	0	0
MOUND	7	0	7	0	249	0	0	0
MU	0	0	0	2	0	0	0	0
NTS	0	0	613	0	0	0	0	0
ORNL	110	0	673	264	0	0	0	0
PA	2	0	0	0	0	0	0	0
PANTEX	0	0	1	0	0	0	0	0
RFETS	188	1,346	533	1,684	341	972	0	0
SNL/NM	0	0	8	7	0	0	0	0
SRS	0	0	9,336	13,365	0	0	0	0

TABLE O-7

RH SITE-SPECIFIC VOLUME (IN CUBIC METERS)

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
ANL-W	0	0	1	2	7	2	0	24
BCLDP	0	0	0	71	0	0	0	0
BT	0	0	0	2	0	0	0	0
HANFORD	0	0	32	2,974	0	0	0	0
INEL	2	0	14	3	4	6	11	0
KAPL	0	0	11	25	0	0	0	0
LANL	0	0	15	3	76	80	0	0
ORNL	611	174	383	183	0	0	0	0
SRS	0	0	0	32	0	0	0	0

1

TABLE O-8

INITIAL MASS RATES FOR CH WASTE
(kg/hr)

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
AMES LAB	0	0	0	0	0	0	0	0
ANL-E	< 1	< 1	< 1	0	< 1	< 1	0	0
BT	0	0	0	1	0	0	0	0
ETEC	0	0	< 1	< 1	< 1	0	0	0
HANFORD	< 1	11	77	80	2	59	0	0
INEL/ANL-W	116	0	96	< 1	36	< 1	0	0
KAPL	0	0	< 1	0	0	0	0	0
LANL	46	7	10	14	18	13	0	0
LBL	0	0	< 1	< 1	0	0	0	0
LLNL	< 1	< 1	< 1	2	< 1	1	0	0
MOUND	< 1	0	< 1	0	2	0	0	0
MU	0	0	< 1	< 1	0	0	0	0
NTS	0	0	5	0	0	0	0	0
ORNL	1	0	6	2	0	0	0	0
PANTEX	0	0	< 1	0	0	0	0	0
PA	< 1	0	0	0	0	0	0	0
RFETS	2	11	4	10	1	4	0	0
SNL/NM	0	0	< 1	< 1	0	0	0	0
SRS	< 1	0	114	93	0	0	0	0

1

TABLE O-9

INITIAL MASS RATES FOR RH WASTE
(kg/hr x 10^{-5})

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
BCLDP	0	0	0	0	0	0	0	0
BT	0	0	0	463	0	0	0	0
HANFORD	0	0	9,859	884,071	0	0	0	0
INEL/ANL-W	2,066	0	4,495	1,482	7,263	7,964	0	0
KAPL	0	0	3,339	7,501	0	0	0	0
LANL	0	0	6,516	1,388	49,223	51,181	0	0
ORNL	601,051	65,043	113,808	54,316	0	0	0	0
SRS	0	0	0	19,003	0	0	0	0

TABLE O-10

INITIAL VOLUME RATES FOR CH WASTE
(cu. m/hr x 10^{-5})

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
AMES LAB	0	< 1	0	0	0	0	0	0
ANL-E	29	1	< 1	0	8	< 1	0	0
BT	0	0	0	153	0	0	0	0
ETEC	0	0	2	6	< 1	0	0	0
HANFORD	4	3,911	9,670	16,812	322	17,543	0	0
INEL/ANL-W	22,508	0	13,694	4	10,853	2	1,553	0
KAPL	0	0	3	0	0	0	0	0
LANL	6,012	2,553	2,193	3,056	5,263	3,907	0	0
LBL	0	0	1	5	0	0	0	0
LLNL	16	82	81	502	180	310	0	0
MOUND	9	0	8	0	309	0	0	0
MU	0	0	< 1	2	0	0	0	0
NTS	0	0	760	0	0	0	0	0
ORNL	136	0	835	327	0	0	0	0
PANTEX	0	0	< 1	0	0	0	0	0
PA	3	0	0	0	0	0	0	0
RFETS	234	1,670	661	2,088	423	1,206	0	0
SNL/NM	0	0	10	9	0	0	0	0
SRS	< 1	0	11,577	16,573	0	0	0	0

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TABLE O-11

INITIAL VOLUME RATES FOR RH WASTE
(cu. m/hr x 10^{-5})

	Sludges		Solid Organics		Solid Inorganics		Unknown	
Site	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected	Retrievable	Projected
BCLDP	0	0	0	0	0	0	0	0
BT	0	0	0	2	0	0	0	0
HANFORD	0	0	40	3,688	0	0	0	0
INEL/ANL-W	3	0	19	6	14	9	14	29
KAPL	0	0	14	31	0	0	0	0
LANL	0	0	18	4	95	99	0	0
ORNL	758	216	475	227	0	0	0	0
SRS	0	0	0	40	0	0	0	0

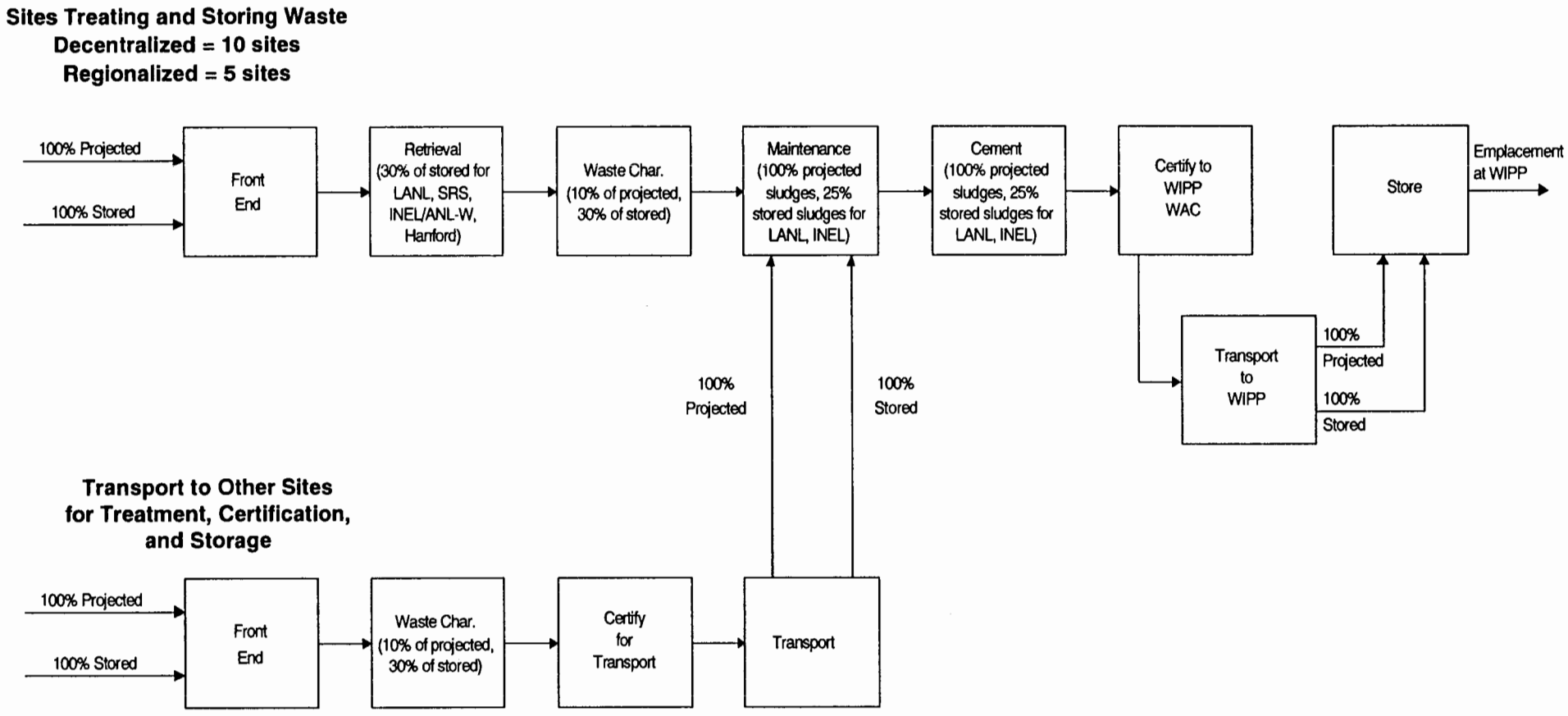


Figure O-2

Decentralized and Regionalized Base Cases and Alternative ID #s 33, 35(a&b), 83, and 111 Contact Handled

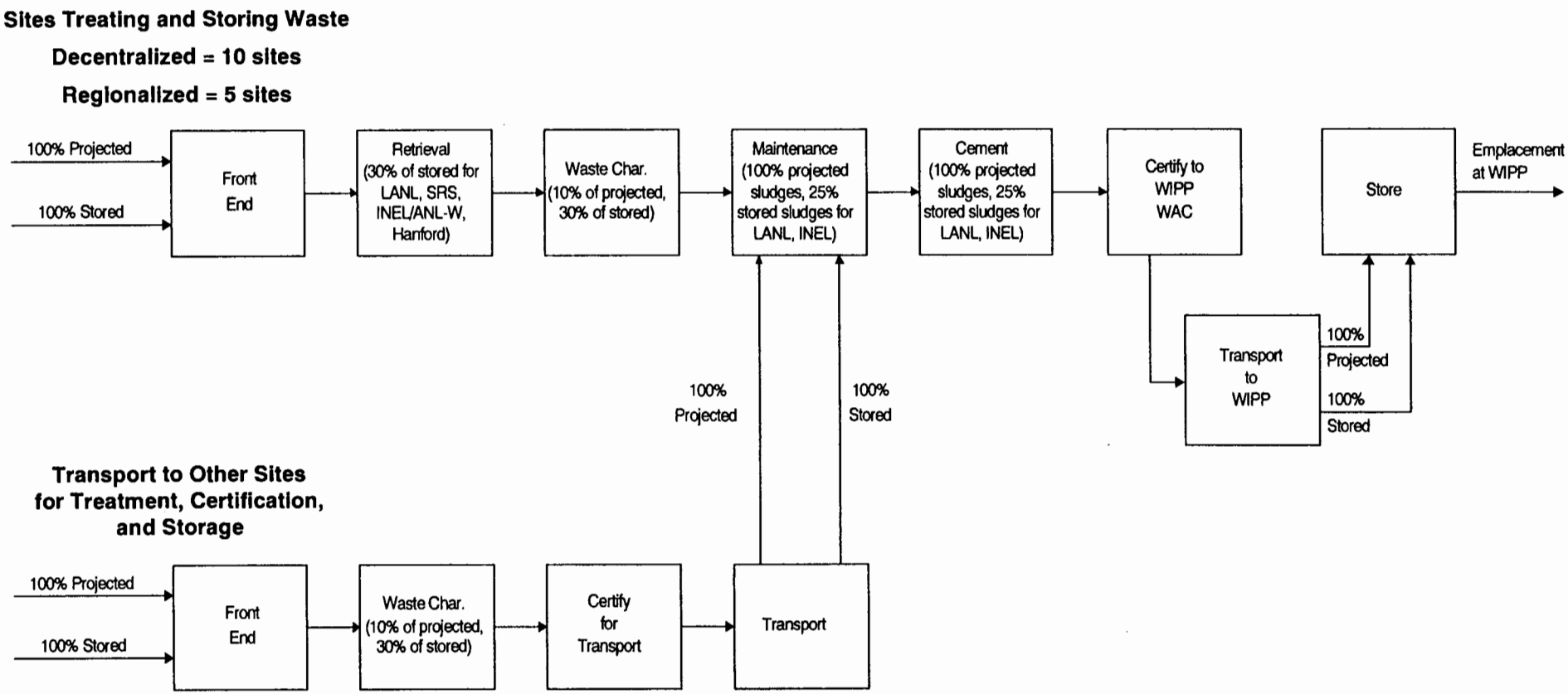


Figure O-3
Decentralized and Regionalized Base Cases Remote Handled

Force (DOE, 1991), the draft Environmental Management Programmatic Environmental Impact Statement (EM-PEIS) report (DOE, 1995b), and the Waste Management Facility Cost Information for Transuranic Waste (WMFCITRUW) report (Feizollahi and Shropshire, 1994). Information from these sources was used to correct each of the modules and to construct a visual description of mass and volume flow through each treatment process. The process flow diagrams were designed mostly in accordance with the EM-PEIS and the WMFCITRUW report; however, not every module recommended in the WMFCITRUW report was included in this study. The reasons for deviating from the recommended WMFCITRUW guidance include (1) minimizing the costs of duplicate equipment contained in more than one module and (2) more accurately representing the functions in existing and planned TRU waste facilities.

For the decentralized baseline, mass and volume changes result from both the retrieval and grouting modules. The results of applying the process flow diagram to the initial mass and volume flow rates are new flow rates that represent the final processed waste. Changes to mass and volume are discussed further in Section 2.7.

2.5 STEP 5: DETERMINATION OF WHETHER WIPP DESIGN CAPACITY HAS BEEN REACHED

The final processed flow rates were multiplied by 20 years and 4,032 working hours per year to determine the final processed masses and volumes. The final processed volume was compared against the design capacity of WIPP. For the purposes of this study, the design capacity of WIPP was considered to be 168,385 cubic meters for CH waste and 7,075 cubic meters for RH waste.

If the final processed volume was less than the design capacity of WIPP, a scale factor was estimated and applied to the mass and volume flow rates in Step 3 for projected waste. Steps 4 and 5 were then repeated until the final processed volume was slightly less than or equal to the design capacity of WIPP. The final scale factor for CH waste was determined to be 1.296775896, and the final scale factor for RH waste was calculated to be 1.537947416.

2.6 STEP 6: DETERMINATION OF FINAL SCALED INPUT MASS AND VOLUMES

As shown in Figure O-1, after the initial masses and volumes have been scaled to the design capacity of WIPP for the decentralized baseline, these scaled initial masses and volumes were used as inputs for each of the EAs in each of the configurations. In other words, the same scale factor developed for CH waste in the baseline was applied to each of the EAs for CH waste. The scaled initial mass and volume flow rates were calculated assuming a 20-year inventory processing period and 4,032 hours of operation per year (three 8-hour shifts, 240 days per year at 70 percent availability).

2.7 STEP 7: APPLICATION OF PROCESS FLOW DIAGRAM TO EACH ALTERNATIVE IN EACH CONFIGURATION

Ten EAs were considered in addition to the baseline. Table O-12 shows treatment options for sludges, solid organics, and solid inorganics for each EA. Processing schemes for EAs 33, 35(a-b), 83, and 111 are identical to the processing schemes for the baseline for each of the configurations; therefore, mass and volume changes are assumed to be identical to the mass and volume changes for the baseline. The processing scheme for EA 77(a-d) is the same as the

1

TABLE O-12

WIPP ENGINEERED ALTERNATIVES

	Waste Type		
ID Number	Sludges	Solid Organic	Solid Inorganic
#1	Baseline	Supercompact	Supercompact
#6	Baseline	Shred and compact	Shred and compact
#10	Plasma	Plasma	Plasma
#33	Baseline	Baseline	Baseline
#35 (a and b)	Baseline	Baseline	Baseline
#77 (a–d)	Baseline	Supercompact	Supercompact
#83	Baseline	Baseline	Baseline
#94 (a–f)	Enhanced cement	Shred and add clay	Shred and add clay
#111	Baseline	Baseline	Baseline

processing scheme for EA 1 for each of the configurations; therefore, its mass and volume changes are assumed to be equal to those of EA 1. EA 33, 35(a-b), 77(a-d), 83, and 111 are omitted from further discussion in this section because they are not unique with respect to mass and volume.

Additionally, each EA is defined in Section 2.2.1, Engineered Alternative Definition. Each EA was also considered with respect to three configurations: decentralized, regionalized, and centralized. Table O-13 indicates which sites send waste to other sites to be processed and/or stored for each configuration.

Waste flow diagrams for each EA are shown in Figures O-4 through O-12. Figures O-4 through O-7 represent both the decentralized and regionalized configurations for EAs 1, 6, 10, and 94 for CH waste, including sites that treat and store waste and sites that ship pre-processed waste to other sites for treatment and storage. Figures O-8 through O-12 represent the centralized configuration for CH waste, which includes shipment of pre-processed waste to WIPP for treatment, storage, and disposal.

2.7.1 Front End Module

Front-end support facilities consist of all administrative and laboratory buildings required for the waste management support functions. Front-end support functions include security, personnel decontamination (radioactive and hazardous), maintenance of noncontaminated areas and equipment, health physics, radiation badges, facility access control, sanitary facilities, work control and personnel support, internal and external communications, spill or emergency response provisions (radioactive and hazardous), analytical laboratory, environmental field sampling, environmental regulatory reporting, and records management. Front-end support facilities include all administrative and laboratory buildings required for the waste management support functions.

2.7.2 Waste Retrieval Module

This module consists of all-weather excavation, inspection, and repackaging of bermed waste. The module includes three principal unit operations: earthen cover extraction and decontamination, waste container retrieval and inspection, and packaging and staging for shipment.

2.7.3 Waste Characterization Module

This module is a self-contained facility in which waste characterization is performed. Activities include extracting physical samples of waste; conducting chemical, physical, and radiological sampling of waste; and repackaging drums and boxes to remove and stabilize noncompliant waste.

2.7.4 Maintenance Module

A maintenance facility is used in conjunction with treatment facilities. It consists of a failed equipment receiving and repair building housing machinery and tools.

1

TABLE O-13

TRANSFER OF WASTE FOR THE DECENTRALIZED, REGIONALIZED, AND CENTRALIZED CONFIGURATIONS

Decentralized			Regionalized			Centralized		
Site	CH	RH	Site	CH	RH	Site	CH	RH
ANL-E*	WIPP	ORNL+	ANL-E	SRS	ORNL	ANL-E	WIPP	WIPP
AMES	ANL-E#		AMES	SRS		AMES	WIPP	
BCLDP		ORNL+	BCLDP		ORNL	BCLDP		WIPP
BT	MOUND	ORNL+	BT	SRS	ORNL	BT	WIPP	WIPP
ETEC	NTS		ETEC	INEL/ANL-W		ETEC	WIPP	
INEL/ANL-W*	WIPP	WIPP	INEL/ANL-W*	WIPP	HANFORD	INEL/ANL-W	WIPP	WIPP
KAPL	MOUND	ORNL+	KAPL	SRS	ORNL	KAPL	WIPP	WIPP
LANL*	WIPP	WIPP	LANL*	WIPP	HANFORD	LANL	WIPP	WIPP
LBL	(LLNL)		LBL	HANFORD		LBL	WIPP	
LLNL*	WIPP		LLNL	HANFORD		LLNL	WIPP	
MOUND*	WIPP		MOUND	SRS		MOUND	WIPP	
MU	ANL-E#		MU	SRS		MU	WIPP	
NTS*	WIPP	WIPP	NTS	INEL/ANL-W	HANFORD	NTS	WIPP	WIPP
ORNL*	WIPP	WIPP	ORNL* (rh)	SRS	WIPP	ORNL	WIPP	WIPP
PA	ORNL		PA	SRS		PA	WIPP	
PANTEX	LANL		PANTEX	LANL		PANTEX	WIPP	
RFETS*	WIPP		RFETS*	WIPP		RFETS	WIPP	
HANFORD*	WIPP	WIPP	HANFORD*	WIPP	WIPP	HANFORD	WIPP	WIPP
SNL/NM	LANL		SNL/NM	LANL		SNL/NM	WIPP	
SRS*	WIPP	WIPP	SRS*	WIPP	ORNL	SRS	WIPP	WIPP

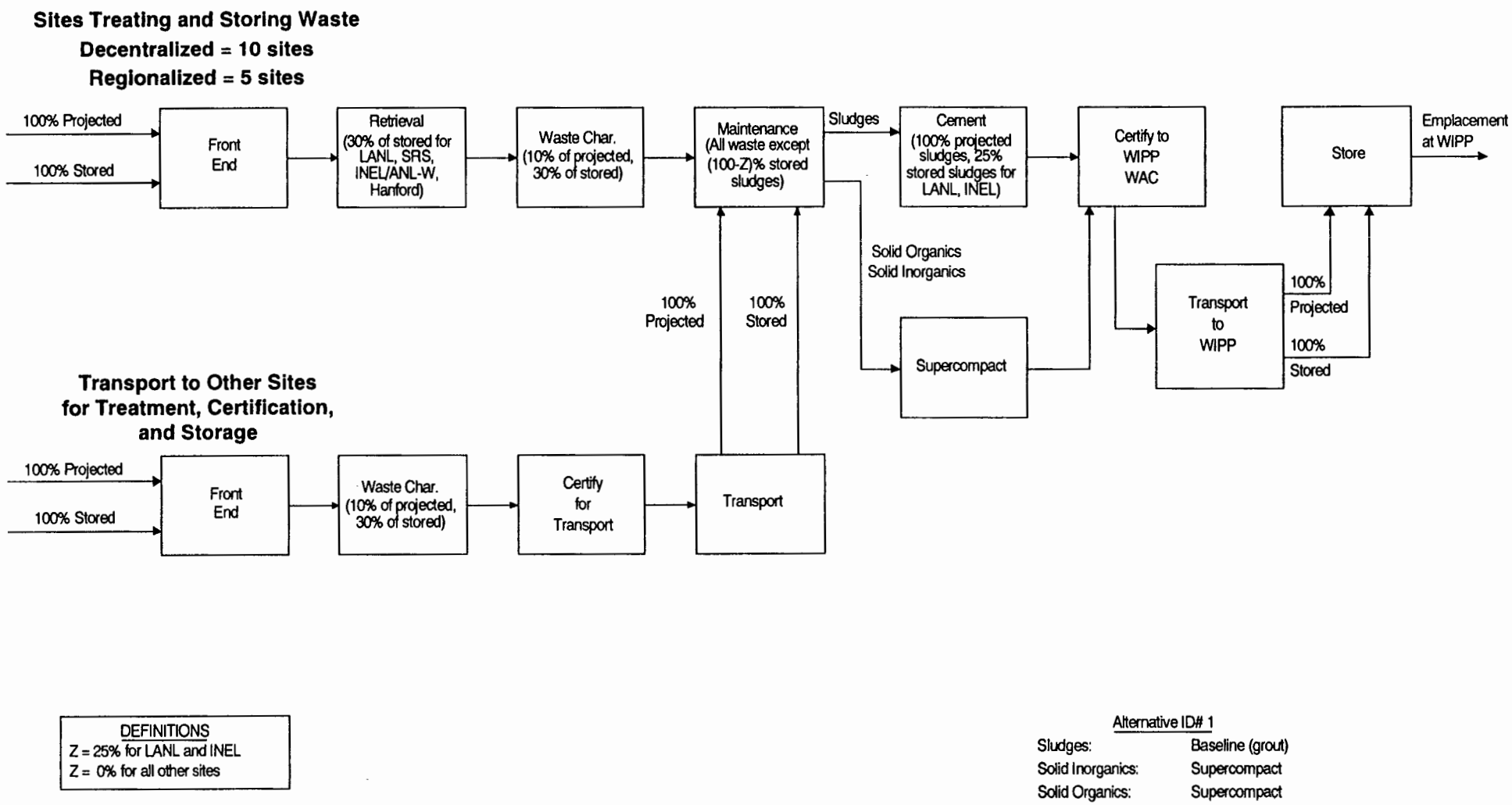
Notes:

* Denotes a processing site.

ORNL+ Remote handled wastes from BCLDP, BT, KAPL, (these are not discussed in the EM-PEIS) and ANL-E should be processed at ORNL instead of Mound because Mound currently does not process or store RH waste.

ANL-E# The EM-PEIS discusses that ANL-E will process and ship its own CH waste but does not cover Ames and MU which are closer to ANL-E than ORNL.

(LLNL) EM-PEIS indicates LBL waste will be shipped to Hanford. LBL waste should be shipped to LLNL because it is much closer.



DEFINITIONS
Z = 25% for LANL and INEL
Z = 0% for all other sites

Alternative ID# 1

Sludges:	Baseline (grout)
Solid Inorganics:	Supercompact
Solid Organics:	Supercompact

Figure O-4

Decentralized and Regionalized Alternative ID #s 1 and 77(a-d) Contact Handled

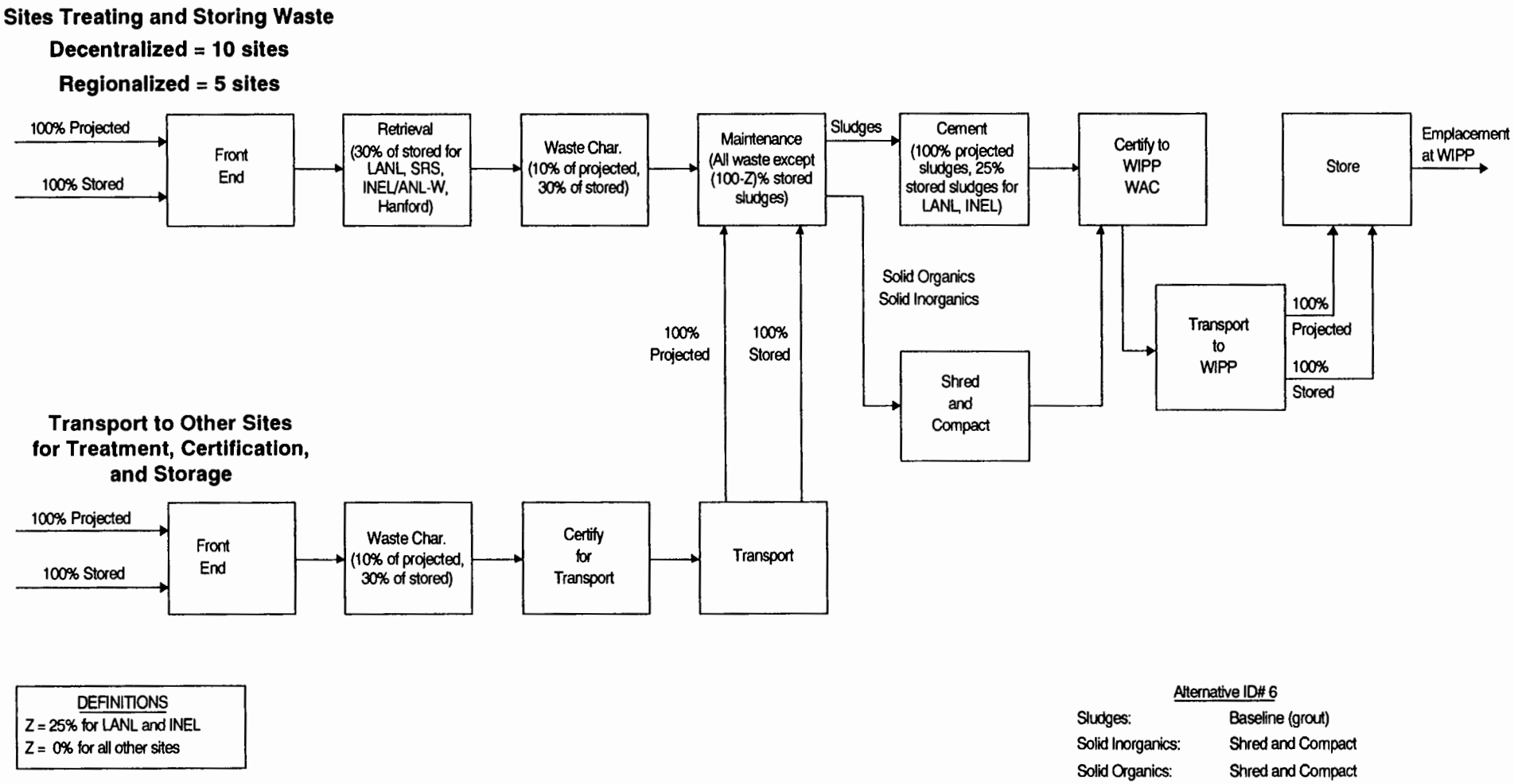
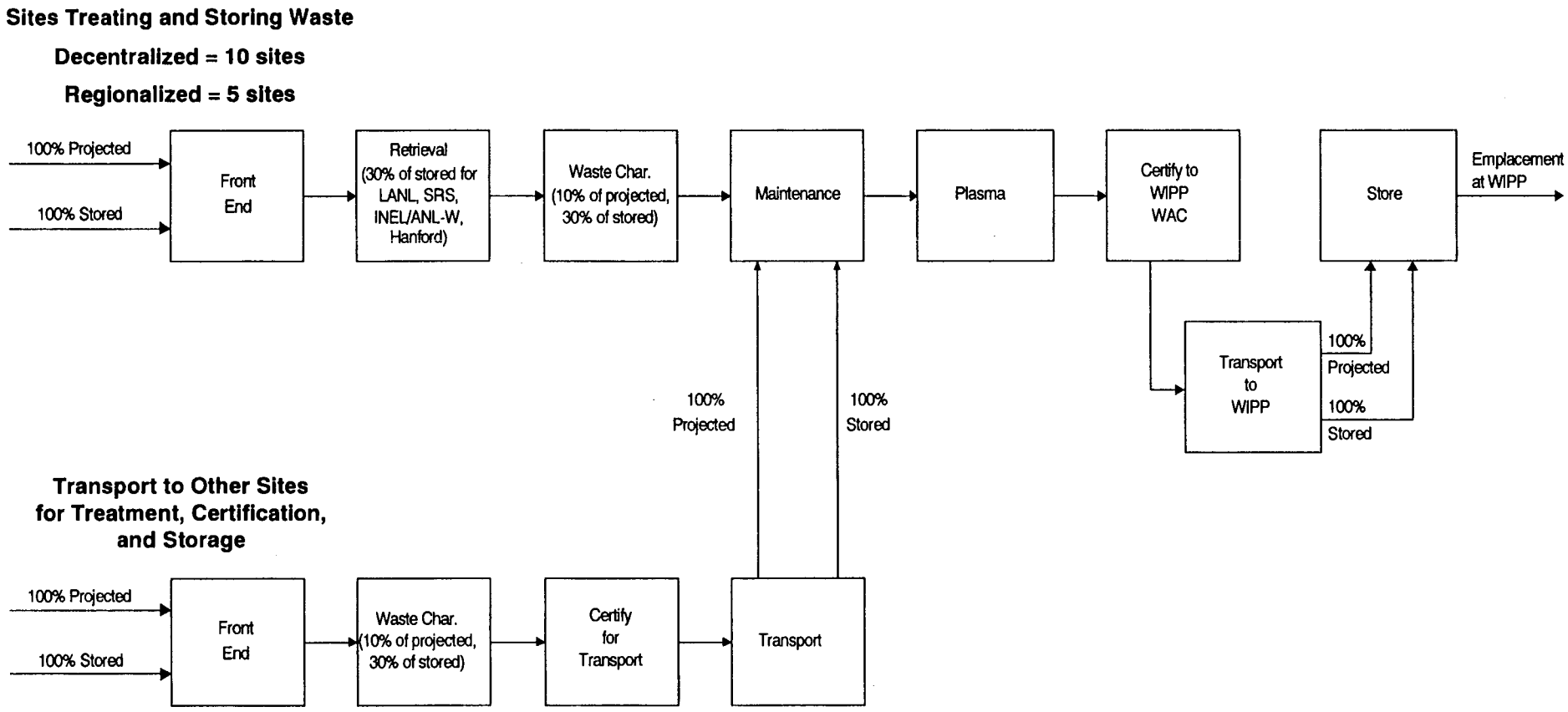


Figure O-5

Decentralized and Regionalized Alternative ID# 6 Contact Handled

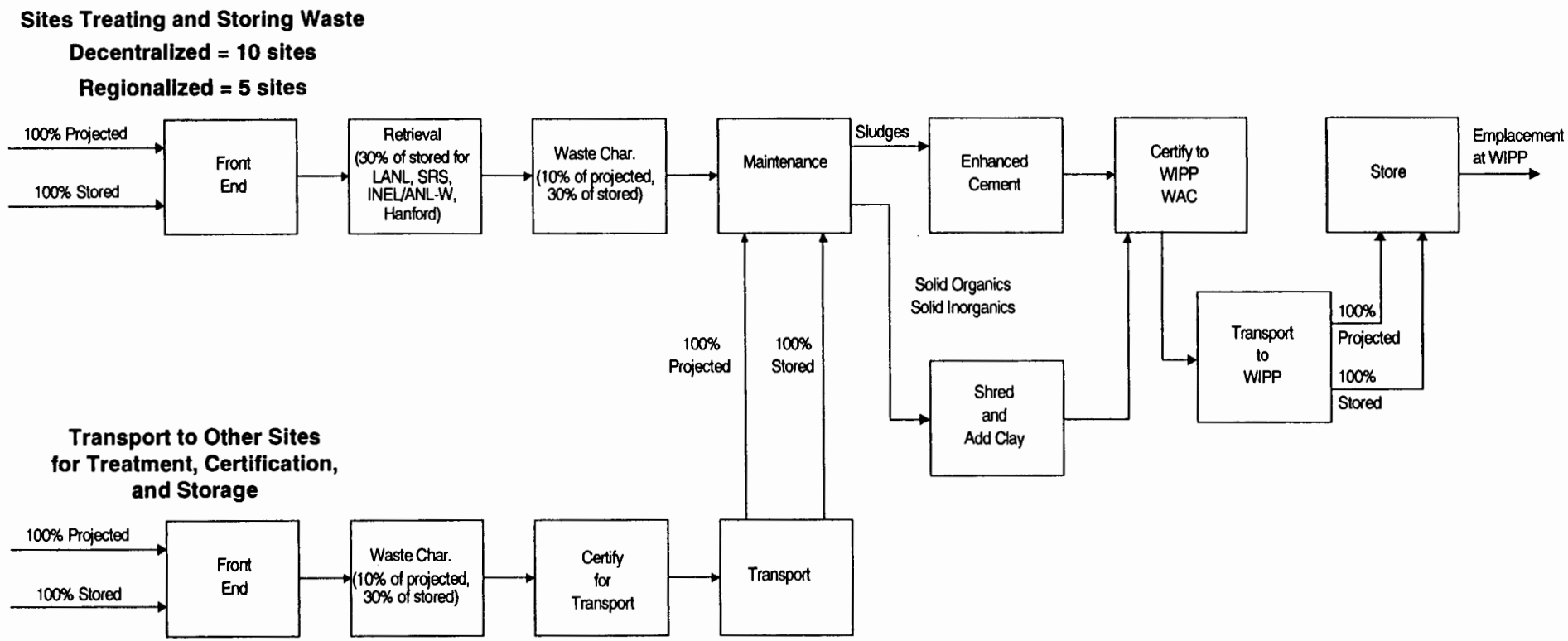


Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure O-6

Decentralized and Regionalized Alternative ID# 10 Contact Handled



Alternative ID# 94(a-f)

Sludges:	Enhanced Cement
Solid Inorganics:	Shred and Add Clay
Solid Organics:	Shred and Add Clay

Figure O-7

Decentralized and Regionalized Alternative ID# 94(a-f) Contact Handled

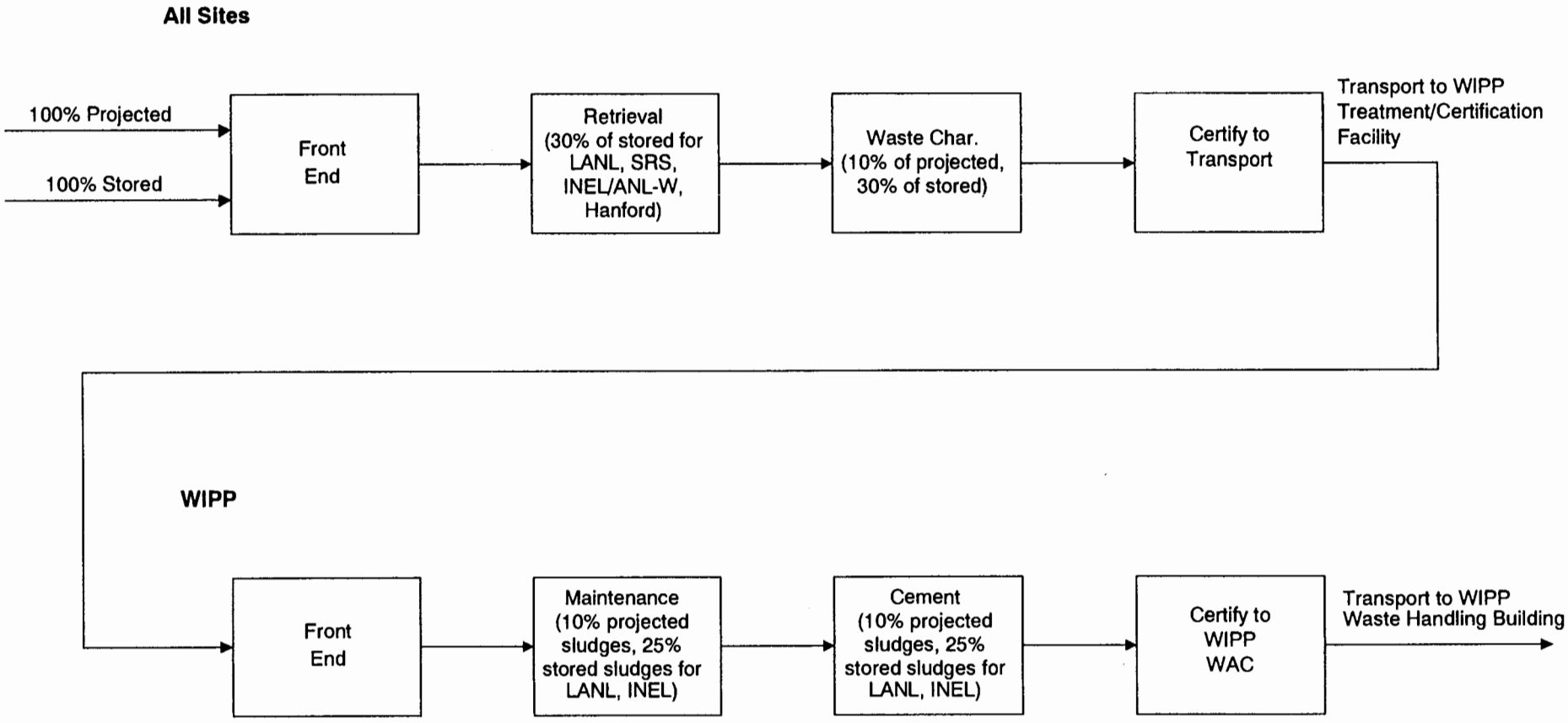


Figure O-8

Centralized Base Case and Alternative ID #s 33, 35(a&b), 83, and 111 Contact Handled

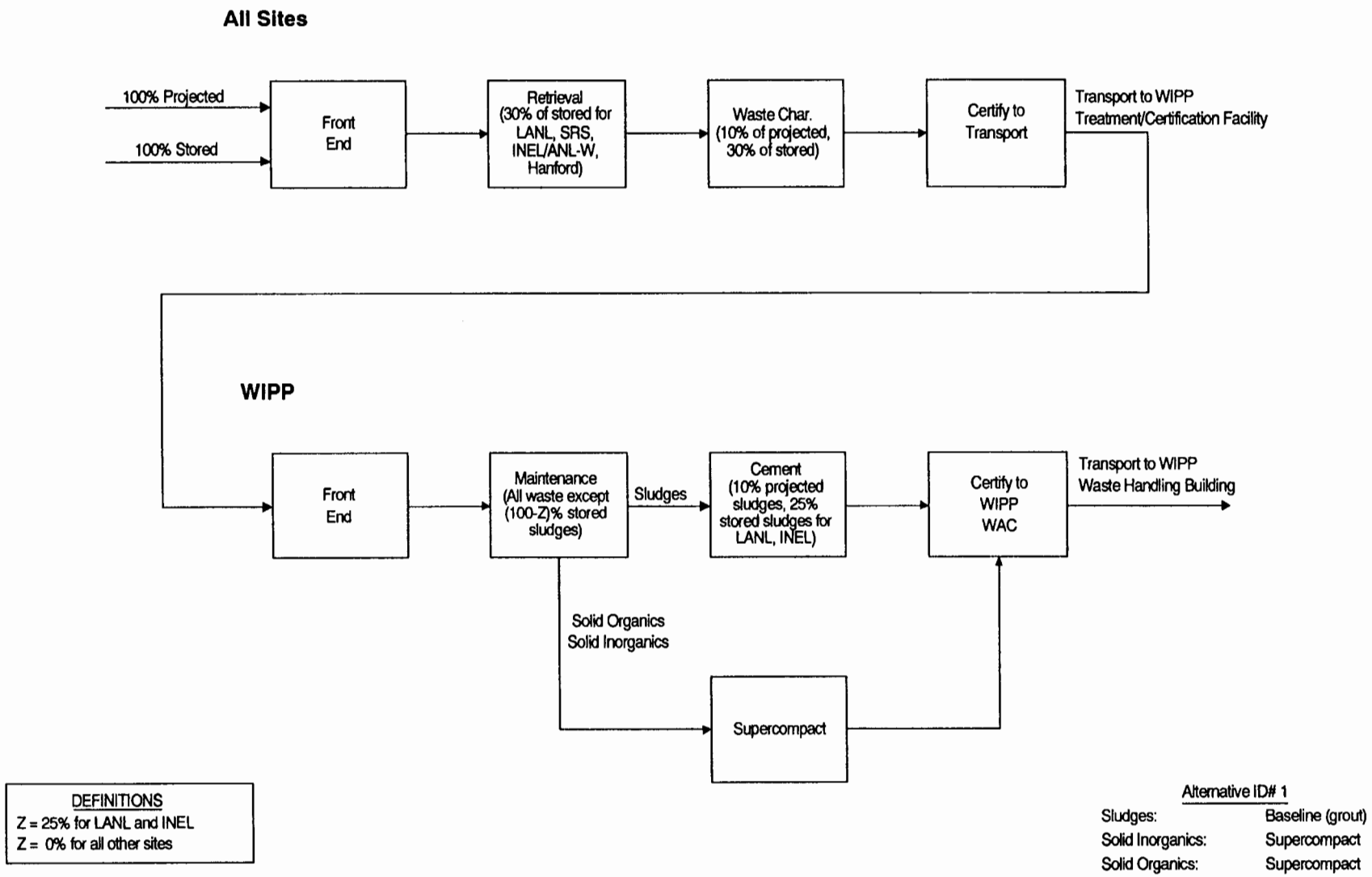


Figure O-9
Centralized Alternative ID#s 1 and 77(a-d) Contact Handled

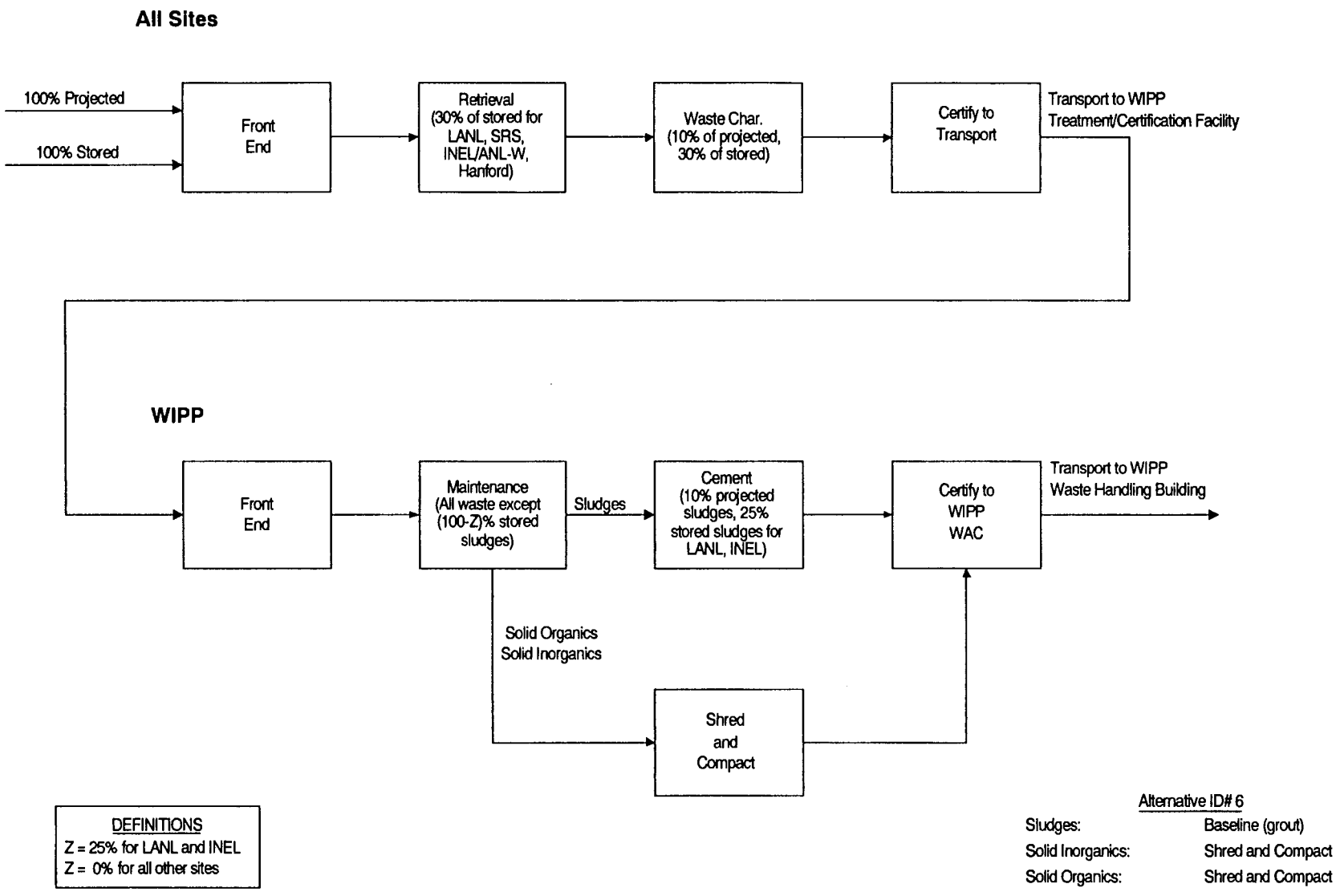
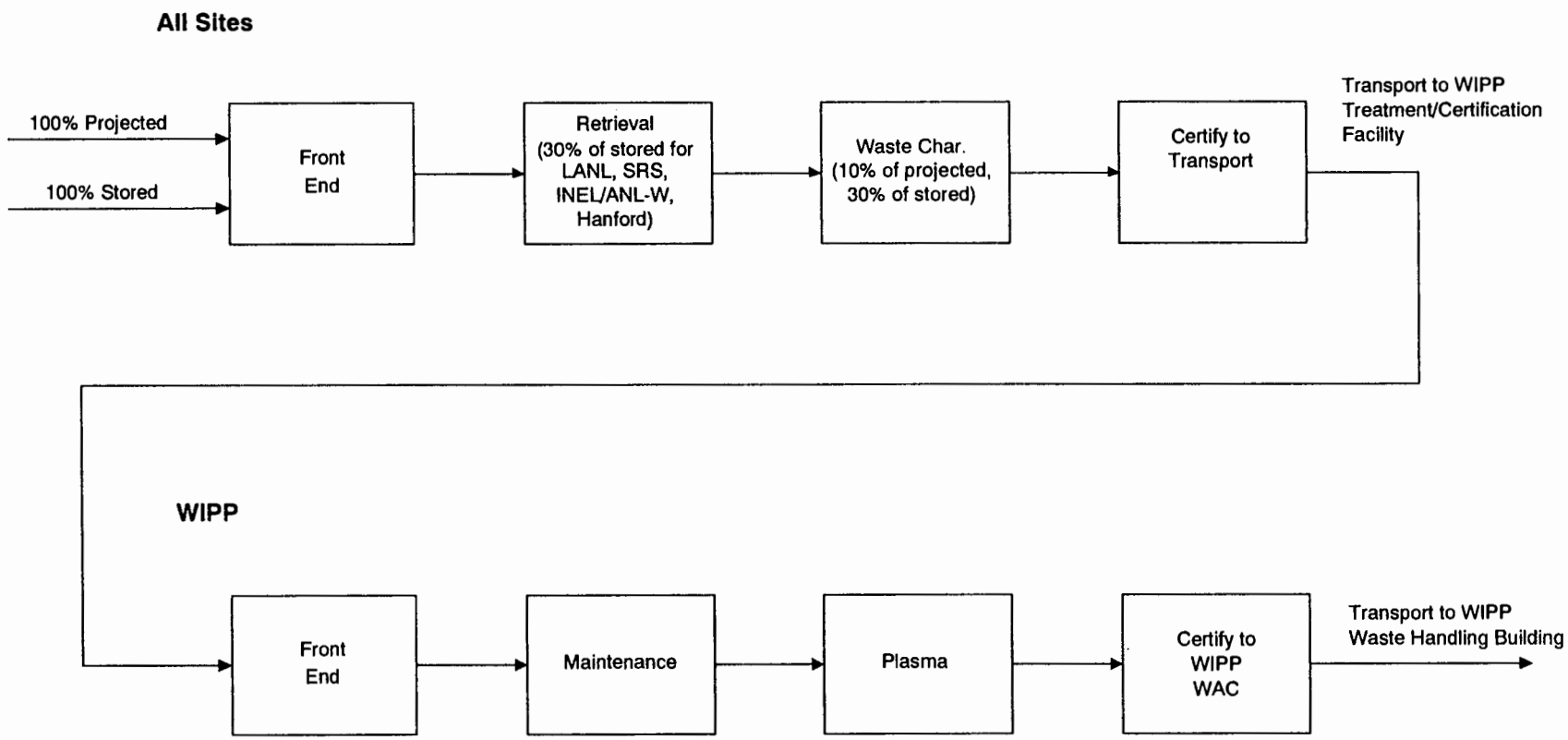


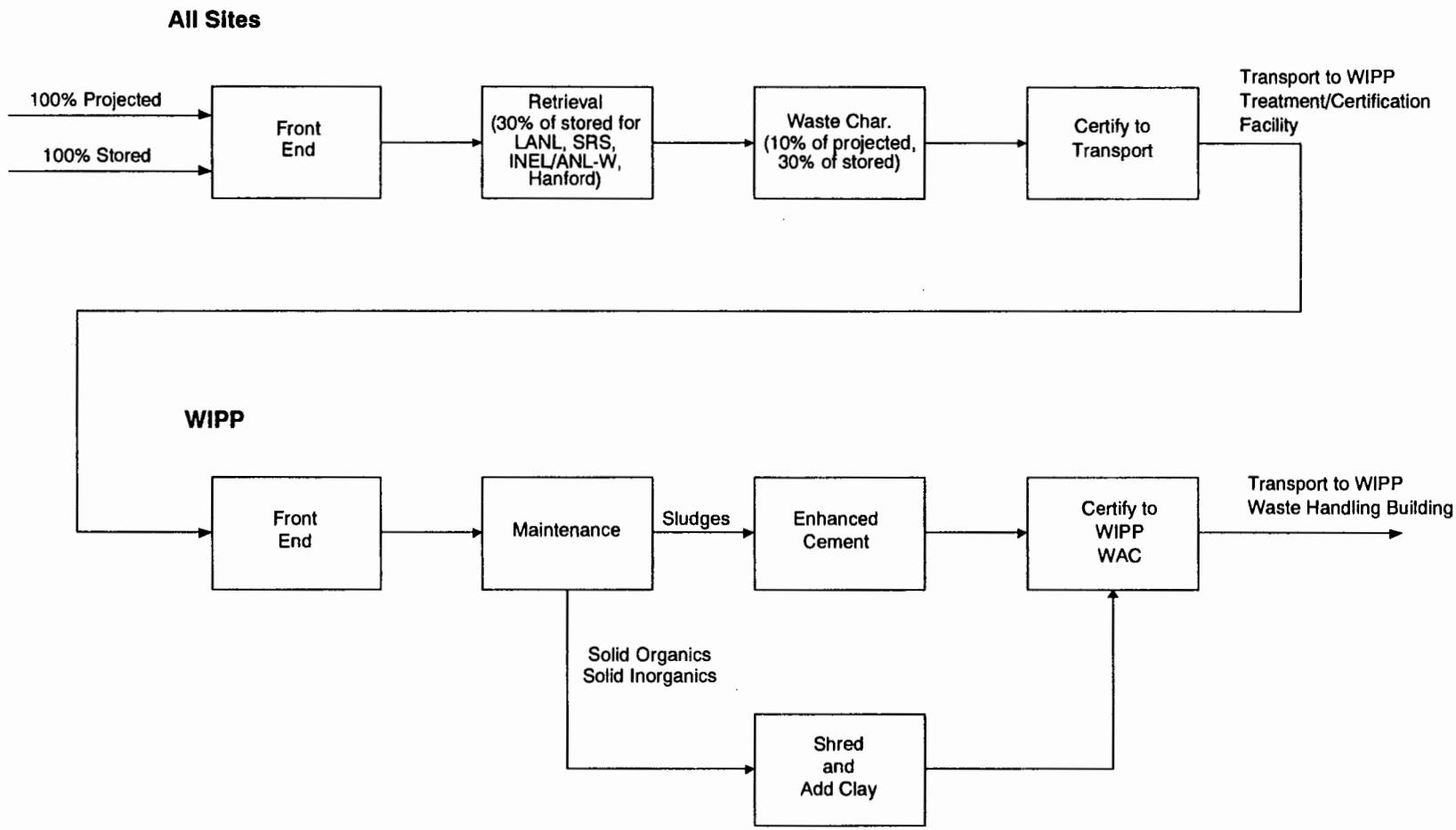
Figure O-10
Centralized Alternative ID# 6 Contact Handled



Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure O-11
Centralized Alternative ID# 10 Contact Handled



Alternative ID# 94(a-f)	
Sludges:	Enhanced Cement
Solid Inorganics:	Shred and Add Clay
Solid Organics:	Shred and Add Clay

Figure O-12
Centralized Alternative ID# 94(a-f)

2.7.5 Treatment Module

The treatment module varies based on the EA being considered. Treatment options include grouting, supercompacting, shredding and compacting, plasma melting, enhanced- cement processing, and shredding and adding clay.

2.7.6 Storage Module

This module consists of a Resource Conservation and Recovery Act compliant storage building sized to accommodate an accumulation of waste from treatment modules for a maximum of 20 years. Storage area features include spill collection, sloping floors, sumps, and concrete berms. Monitoring is included for both gamma and alpha radiation control.

2.7.7 Certification and Shipping Module

Certification and shipping consists of storage of incoming material, assay and certification, and truck loading. The facility is equipped with a bridge crane and a forklift. It is assumed that certification and shipping operations will take place indoors.

2.7.8 Transportation Module

Transportation consists of truck shipments, including a tractor and trailer transporting three Transuranic Package Transporter-IIs (TRUPACT-IIs) for CH waste or one RH-72B cask (a cylinder consisting of a separate inner vessel within an outer cask protected by impact limiters at each end) for RH waste.

Mass and volume changes occur in the retrieval module and the treatment modules. Table O-14 summarizes these changes. Several other assumptions were made in addition to the mass and volume changes:

- All waste within a major waste form category (i.e., sludges, solid organics, solid inorganics) can be treated using a selected technology.

- The volume of waste categorized as "unknown" in the WTWBIR is processed the same as solid organics and inorganics. However, the mass of unknown waste is assumed to be zero because no information was available regarding the density of the unknown waste and the volume of this waste is small compared to the total volume of waste destined for WIPP.

- All projected sludges were grouted in the baseline. In general, stored sludges were not treated in the baseline because they were assumed to have been grouted previously; however, 25 percent of the stored sludges from Los Alamos National Laboratory (LANL) and the Idaho National Engineering Laboratory (INEL) were regrouted and all of the stored sludges at Oak Ridge National Laboratory (ORNL) were grouted.

- All sludges, including stored, are treated in the enhanced-cement treatment option.

- All sludges, solid organics, and solid inorganics are treated in the plasma melter.

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TABLE O-14

MASS AND VOLUME CHANGES FOR WASTE TREATMENT/PROCESSING MODULES

Module	Mass Ratio (Output/Input)	Volume Ratio (Output/Input)
Front End	1.00[1]	1.00[2]
Retrieval	1.10[1]	1.10[2]
Waste Characterization	1.00[2]	1.00[2]
Maintenance	1.00[2]	1.00[2]
Grout	3.15[1]	2.50[2]
Supercompact	1.10[1]	0.35[2]
Shred and Compact	1.10[1]	0.76[2]
Shred and Add Clay	2.35[2]	1.00[2]
Plasma	1.00[1]	0.33[2]
Certification and Shipping	1.00[2]	1.00[2]
Storage	1.00[2]	1.00[2]

[1]Source (Feizollahi and Shropshire, 1994)
[2]Values derived from engineering calculations

- Ten percent of projected waste and 30 percent of stored waste requires characterization.

- Thirty percent of stored waste from LANL, Savannah River Site (SRS), INEL/Argonne National Laboratory-West (ANL-W), and Hanford requires retrieval.

3.0 RESULTS

Tables O-15 through O-30 show the mass and volume processing rates (i.e., inputs) to each of the modules for each of the EAs in each of the configurations that were calculated based on the methodology and assumptions provided previously in this appendix. These flow rates were then used to calculate the costs associated with each module. The cost analysis is described in Section 3.7 and Appendix P of this report.

Tables O-31 and O-32 show final treated mass and volume by EA and primary waste form for each EA, for CH waste and RH waste, respectively. The final mass and volume do not differ by configuration, because the same amount of waste is treated regardless of the site at which the waste is treated. The treated volume of waste for EA 94 exceeds the design capacity of WIPP; it is assumed that this waste would have to be managed in some other way when the WIPP reaches full capacity.

The final processed mass and volume were used as inputs to other EA analyses.

TABLE O-15

INPUTS TO MODULES FOR THE CONTACT-HANDLED WASTE DECENTRALIZED BASELINE

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.01	0.01	0.28	1.80
BT	1.38	0.00	0.14	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	14.83	14.83	307.90	2720.79
INEL/ANL-W	248.80	74.62	76.87	29.91	29.91	320.57	2369.50
KAPL	0.02	0.00	0.01	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	21.60	21.60	168.55	1351.17
LBL	0.06	0.00	0.01	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.31	0.31	6.25	64.66
MOUND	1.78	0.00	0.53	0.00	0.00	4.37	35.92
MU	0.02	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	5.39	31.06
ORNL	9.04	0.00	2.12	0.33	0.33	9.79	56.35
PANTEX	0.01	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	14.05	14.05	69.29	443.31
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	238.12	1346.67
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.93	0.00

TABLE O-16

INPUTS TO MODULES FOR DECENTRALIZED ALTERNATIVE 1

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Supercompact Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.03	0.01	0.03	0.29	1.51
BT	1.38	0.00	0.14	1.38	0.00	1.38	1.51	0.00
ETEC	0.07	0.00	0.01	0.07	0.00	0.07	0.08	0.00
HANFORD	273.67	23.48	43.72	275.99	14.83	261.16	334.01	1284.39
INEL/ANL-W	248.80	74.62	76.87	166.54	29.91	136.63	334.23	1664.74
KAPL	0.02	0.00	0.01	0.02	0.00	0.02	0.02	0.00
LANL	119.73	22.27	27.49	86.19	21.60	64.59	175.03	912.85
LBL	0.06	0.00	0.01	0.06	0.00	0.06	0.06	0.00
LLNL	5.52	0.00	0.76	5.40	0.31	5.08	6.76	30.03
MOUND	1.78	0.00	0.53	1.71	0.00	1.71	4.80	12.96
MU	0.02	0.00	0.00	0.02	0.00	0.02	0.02	0.00
NTS	5.31	0.00	1.59	5.31	0.00	5.31	5.92	10.87
ORNL	9.04	0.00	2.12	9.04	0.33	8.70	10.66	23.37
PANTEX	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	36.90	14.05	22.85	71.57	303.03
SNL/NM	0.15	0.00	0.03	0.15	0.00	0.15	0.16	0.00
SRS	234.70	34.25	47.33	238.12	0.00	238.12	261.93	471.34
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00

TABLE O-17

INPUTS TO MODULES FOR DECENTRALIZED ALTERNATIVE 6

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Shred & Compact Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.03	0.01	0.03	0.29	1.69
BT	1.38	0.00	0.14	1.38	0.00	1.38	1.51	0.00
ETEC	0.07	0.00	0.01	0.07	0.00	0.07	0.08	0.00
HANFORD	273.67	23.48	43.72	275.99	14.83	261.16	334.01	2190.43
INEL/ANL-W	248.80	74.62	76.87	166.54	29.91	136.63	334.23	2109.28
KAPL	0.02	0.00	0.01	0.02	0.00	0.02	0.02	0.00
LANL	119.73	22.27	27.49	86.19	21.60	64.59	175.03	1189.33
LBL	0.06	0.00	0.01	0.06	0.00	0.06	0.06	0.00
LLNL	5.52	0.00	0.76	5.40	0.31	5.08	6.76	51.87
MOUND	1.78	0.00	0.53	1.71	0.00	1.71	4.80	27.44
MU	0.02	0.00	0.00	0.02	0.00	0.02	0.02	0.00
NTS	5.31	0.00	1.59	5.31	0.00	5.31	5.92	23.61
ORNL	9.04	0.00	2.12	9.04	0.33	8.70	10.66	44.17
PANTEX	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	36.90	14.05	22.85	71.57	391.52
SNL/NM	0.15	0.00	0.03	0.15	0.00	0.15	0.16	0.00
SRS	234.70	34.25	47.33	238.12	0.00	238.12	261.93	1023.47
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00

TABLE O-18

INPUTS TO MODULES FOR DECENTRALIZED ALTERNATIVE 10

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Plasma Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.25	0.25	0.27	0.55
BT	1.38	0.00	0.14	1.38	1.38	1.38	0.00
ETEC	0.07	0.00	0.01	0.07	0.07	0.07	0.00
HANFORD	273.67	23.48	43.72	276.02	276.02	276.02	796.72
INEL/ANL-W	248.80	74.62	76.87	256.26	256.26	256.26	666.26
KAPL	0.02	0.00	0.01	0.02	0.02	0.02	0.00
LANL	119.73	22.27	27.49	121.96	121.96	122.11	348.95
LBL	0.06	0.00	0.01	0.06	0.06	0.06	0.00
LLNL	5.52	0.00	0.76	5.52	5.52	5.58	19.22
MOUND	1.78	0.00	0.53	1.78	1.78	4.37	11.85
MU	0.02	0.00	0.00	0.02	0.02	0.02	0.00
NTS	5.31	0.00	1.59	5.31	5.31	5.39	10.25
ORNL	9.75	0.00	2.34	9.75	9.75	9.79	18.60
PANTEX	0.01	0.00	0.00	0.01	0.01	0.01	0.00
PA	0.03	0.00	0.01	0.03	0.03	0.03	0.00
RFETS	39.08	0.00	5.45	39.08	39.08	39.08	103.11
SNL/NM	0.15	0.00	0.03	0.15	0.15	0.15	0.00
SRS	234.70	34.25	47.33	238.12	238.12	238.12	444.40
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-19

INPUTS TO MODULES FOR DECENTRALIZED ALTERNATIVE 94

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Enhanced Cement Mass (kg/hr)	Shred & Add Clay Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.25	0.23	0.03	0.82	3.53
BT	1.38	0.00	0.14	1.38	0.00	1.38	3.24	0.00
ETEC	0.07	0.00	0.01	0.07	0.00	0.07	0.17	0.00
HANFORD	273.67	23.48	43.72	276.02	14.86	261.16	661.29	2721.02
INEL/ANL-W	248.80	74.62	76.87	256.26	119.63	136.63	698.32	3421.07
KAPL	0.02	0.00	0.01	0.02	0.00	0.02	0.05	0.00
LANL	119.73	22.27	27.49	121.96	57.36	64.59	333.03	1632.08
LBL	0.06	0.00	0.01	0.06	0.00	0.06	0.13	0.00
LLNL	5.52	0.00	0.76	5.52	0.44	5.08	13.48	65.66
MOUND	1.78	0.00	0.53	1.78	0.07	1.71	10.38	36.81
MU	0.02	0.00	0.00	0.02	0.00	0.02	0.04	0.00
NTS	5.31	0.00	1.59	5.31	0.00	5.31	12.67	31.06
ORNL	9.75	0.00	2.34	9.75	1.05	8.70	23.89	64.76
PANTEX	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
PA	0.03	0.00	0.01	0.03	0.03	0.00	0.10	0.00
RFETS	39.08	0.00	5.45	39.08	16.23	22.85	104.90	457.44
SNL/NM	0.15	0.00	0.03	0.15	0.00	0.15	0.35	0.00
SRS	234.70	34.25	47.33	238.12	0.00	238.12	560.28	1346.67
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE O-20

INPUTS TO MODULES FOR REGIONALIZED BASELINE

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grout Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	15.14	15.14	314.14	2785.45
INEL/ANL-W	248.80	74.62	76.87	29.91	29.91	325.95	2400.56
KAPL	0.02	0.00	0.01	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	21.60	21.60	168.55	1351.17
LBL	0.06	0.00	0.01	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	14.05	14.05	69.29	443.31
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.34	0.34	252.57	1440.74
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-21

INPUTS TO MODULES FOR REGIONALIZED ALTERNATIVE 1

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Supercompact Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	281.44	15.14	266.30	340.77	1314.42
INEL/ANL-W	248.80	74.62	76.87	171.92	29.91	142.02	340.15	1675.61
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	86.35	21.60	64.74	175.03	912.85
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	36.90	14.05	22.85	71.57	303.03
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	251.47	0.34	251.13	277.68	509.17
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-22

INPUTS TO MODULES FOR REGIONALIZED ALTERNATIVE 6

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Shred & Compact Mass (kg/hr)	CERT & SHIP MASS (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	281.44	15.14	266.30	340.77	2242.30
INEL/ANL-W	248.80	74.62	76.87	171.92	29.91	142.02	340.15	2132.89
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	86.35	21.60	64.74	175.03	1189.33
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	36.90	14.05	22.85	71.57	391.52
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	251.47	0.34	251.13	277.68	1096.77
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-23

INPUTS TO MODULES FOR REGIONALIZED ALTERNATIVE 10

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	PLASMA MASS (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	281.60	281.60	281.60	815.94
INEL/ANL-W	248.80	74.62	76.87	261.65	261.65	261.65	676.51
KAPL	0.02	0.00	0.01	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	122.11	122.11	122.11	348.95
LBL	0.06	0.00	0.01	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	5.31	0.00
ORNL	9.75	0.00	2.34	0.00	0.00	9.75	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	39.08	39.08	39.08	103.11
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	252.56	252.56	252.56	475.40
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-24

INPUTS TO MODULES FOR REGIONALIZED ALTERNATIVE 94

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Enhanced Cement Mass (kg/hr)	Shred & Add Clay Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	281.60	15.29	266.3045	674.77	2786.67
INEL/ANL-W	248.80	74.62	76.87	261.65	119.63	142.0159	711.00	3452.13
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	122.11	57.36	64.74	333.03	1632.08
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.75	0.00	2.34	0.00	0.00	0.00	9.75	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	39.08	16.23	22.85	104.90	457.44
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	252.56	1.42	251.13	595.37	1451.77
WIPP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-25

INPUTS TO MODULES FOR CENTRALIZED BASELINE

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grout Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/2-week period)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	0.00	0.00	276.02	0.00
INEL/ANL-W	248.80	74.62	76.87	0.00	0.00	256.26	0.00
KAPL	0.02	0.00	0.01	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	0.00	0.00	121.96	0.00
LBL	0.06	0.00	0.01	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	0.00	0.00	39.08	0.00
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	238.12	0.00
WIPP	940.81	0.00	0.00	81.04	81.04	1130.50	323.89
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-26
INPUTS TO MODULES FOR CENTRALIZED ALTERNATIVE 1

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Supercompact Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/2-week period)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	0.00	0.00	0.00	276.02	0.00
INEL/ANL-W	248.80	74.62	76.87	0.00	0.00	0.00	256.26	0.00
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	0.00	0.00	0.00	121.96	0.00
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	0.00	0.00	0.00	39.08	0.00
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	0.00	238.12	0.00
WIPP	940.81	0.00	0.00	828.08	81.04	747.05	1205.21	181.35
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-27

INPUTS TO MODULES FOR CENTRALIZED ALTERNATIVE 6

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Shred & Compact Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/2-week period)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	0.00	0.00	0.00	276.02	0.00
INEL/ANL-W	248.80	74.62	76.87	0.00	0.00	0.00	256.26	0.00
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	0.00	0.00	0.00	121.96	0.00
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.04	0.00	2.12	0.00	0.00	0.00	9.04	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	0.00	0.00	0.00	39.08	0.00
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	0.00	238.12	0.00
WIPP	940.81	0.00	0.00	828.08	81.04	747.05	1205.21	271.26
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-28

INPUTS TO MODULES FOR CENTRALIZED ALTERNATIVE 10

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Plasma Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/2-week period)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	0.00	0.00	276.02	0.00
INEL/ANL-W	248.80	74.62	76.87	0.00	0.00	256.26	0.00
KAPL	0.02	0.00	0.01	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	0.00	0.00	121.96	0.00
LBL	0.06	0.00	0.01	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	5.31	0.00
ORNL	9.75	0.00	2.34	0.00	0.00	9.75	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	0.00	0.00	39.08	0.00
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	238.12	0.00
WIPP	941.53	0.00	0.00	956.99	956.99	956.99	93.07
PORTABLE	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-29

INPUTS TO MODULES FOR CENTRALIZED ALTERNATIVE 94

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Enhanced Cement Mass (kg/hr)	Shred & Add Clay Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/2-week period)
AMES LAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ANL-E	0.25	0.00	0.07	0.00	0.00	0.00	0.25	0.00
BT	1.38	0.00	0.14	0.00	0.00	0.00	1.38	0.00
ETEC	0.07	0.00	0.01	0.00	0.00	0.00	0.07	0.00
HANFORD	273.67	23.48	43.72	0.00	0.00	0.00	276.02	0.00
INEL/ANL-W	248.80	74.62	76.87	0.00	0.00	0.00	256.26	0.00
KAPL	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00
LANL	119.73	22.27	27.49	0.00	0.00	0.00	121.96	0.00
LBL	0.06	0.00	0.01	0.00	0.00	0.00	0.06	0.00
LLNL	5.52	0.00	0.76	0.00	0.00	0.00	5.52	0.00
MOUND	1.78	0.00	0.53	0.00	0.00	0.00	1.78	0.00
MU	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
NTS	5.31	0.00	1.59	0.00	0.00	0.00	5.31	0.00
ORNL	9.75	0.00	2.34	0.00	0.00	0.00	9.75	0.00
PANTEX	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PA	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00
RFETS	39.08	0.00	5.45	0.00	0.00	0.00	39.08	0.00
SNL/NM	0.15	0.00	0.03	0.00	0.00	0.00	0.15	0.00
SRS	234.70	34.25	47.33	0.00	0.00	0.00	238.12	0.00
WIPP	941.53	0.00	0.00	956.99	209.94	747.05	2419.07	376.16
PORTABLE	0.00	0.00	0.00	0.00	0.00	0.00	2.92	0.00

TABLE O-30

INPUTS TO MODULES FOR REMOTE-HANDLED WASTE BASELINE

Site	Front End Mass (kg/hr)	Retrieval Mass (kg/hr)	Waste Char Mass (kg/hr)	Maintenance Mass (kg/hr)	Grouting Mass (kg/hr)	Cert & Ship Mass (kg/hr)	Storage Volume (cu m/yr.)
BCLDP	0.32	0.00	0.03	0.00	0.00	0.32	0.00
BT	0.01	0.00	0.00	0.00	0.00	0.01	0.00
HANFORD	13.70	0.03	1.39	0.00	0.00	13.70	230.32
INEL/ANL-W	0.28	0.04	0.06	0.01	0.01	0.30	4.85
KAPL	0.15	0.00	0.02	0.00	0.00	0.15	0.00
LANL	1.37	0.17	0.25	0.00	0.00	1.38	11.07
ORNL	4.88	0.00	1.10	2.91	2.91	11.62	105.27
SRS	0.29	0.00	0.03	0.00	0.00	0.29	2.46

TABLE O-31

CH SUMMARY
MASS AND VOLUME OUTPUT
WIPP ENGINEERED ALTERNATIVES
JULY 1995

	Sludges			Solid Organics			Solid Inorganics		
Case #	Total Mass (kg)	Total Volume (cu. m)	Density (kg/cu. m)	Total Mass (kg)	Total Volume (cu. m)	Density (kg/cu. m)	Total Mass (kg)	Total Volume (cu. m)	Density (kg/cu. m)
Baseline	30,921,720	54,389	569	47,234,933	74,339	635	13,007,073	38,396	339
Alternative 1	30,921,720	54,389	569	51,958,427	26,019	1,997	14,307,781	13,438	1,065
Alternative 6	30,921,720	54,389	569	51,958,427	56,498	920	14,307,781	29,181	490
Alternative 10	16,929,945	10,767	1,572	47,234,933	24,532	1,925	13,007,073	12,671	1,027
Alternative 94	53,329,327	81,566	654	69,576,926	74,339	936	19,159,383	38,396	499

TABLE O-32

RH SUMMARY, RH MASS, AND VOLUME OUTPUT
WIPP ENGINEERED ALTERNATIVES
JULY 1995

Baseline	Sludges	Solid Organics	Solid Inorganics
Total Mass (kg)	741,427	1,338,770	120,268
Total Volume (cu. m)	1,283	5,524	224
Density (kg/cu. m)	578	242	537

APPENDIX P
COST ASSOCIATED WITH SCREENED ENGINEERING ALTERNATIVES

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COST ASSOCIATED WITH SCREENED ENGINEERING ALTERNATIVES

1.0 INTRODUCTION

This appendix describes the methodology for determining estimated costs associated with the screened engineering alternatives (EA). Costs will be calculated for each of the screened EAs in the Decentralized, Regionalized, and Centralized configuration. The cost consists of summarizing waste processing, transportation, repository backfill, and emplacement handling for the selected EAs. The collection of the analyzed costs includes comparative analysis of the incremental change of the screened EAs relative to the repository baseline cost. The impact of cost for each EA will be an important tool for planning the implementation of an EA since it will typically determine the level of funding that must be appropriated. Costs are analyzed by developing process flow diagrams that segment the EA into conceptual elements. The costs for the EAs are developed on the basis of waste quantities and rate to meet schedule constraints.

Cost are based on an approach that utilized an approach consistent with current U.S. Department of Energy (DOE) methodologies and assumptions. The results of the analysis are presented according to backup calculations and summarized according to each EA.

2.0 METHODOLOGY USED TO EVALUATE COSTS

2.1 Process Costing Methodology

The waste processing costs were estimated using information contained in "Interim Report: Waste Management Facilities Cost Information for Transuranic Waste" (WMFCITRUW) (Feizollahi and Shropshire, 1994). The cost estimating method used by Feizollahi and Shropshire involves segmenting waste management facilities into discrete modules which are used to estimate the costs for building and operating facilities to perform various waste management functions. Cost estimates for different types of integrated transuranic (TRU) waste facilities are created by linking modules for different functions together in such a way that they closely approximate an actual waste management facility. This methodology provides the flexibility to estimate the costs many different sized facilities with many different functions without having to perform a rigorous conceptual design and cost estimate for each facility configuration.

Figure P-1 shows the information flow diagram used to develop waste processing cost estimates. Information from process flow diagrams and mass flow rates are required as input to the cost modules. A combination of data sources were used to develop this information, including existing waste inventories and waste generation projections (Appendix O), processing schedules (Appendix Q), a listing of EAs that require waste processing (Section 2), and the system configuration for the waste processing facilities (i.e., centralized, regionalized, or decentralized) (Section 2).

Process flow diagrams were developed for each alternative in each configuration (see Figures P-2 to P-12). These flow schemes were based on the DOE "Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives:

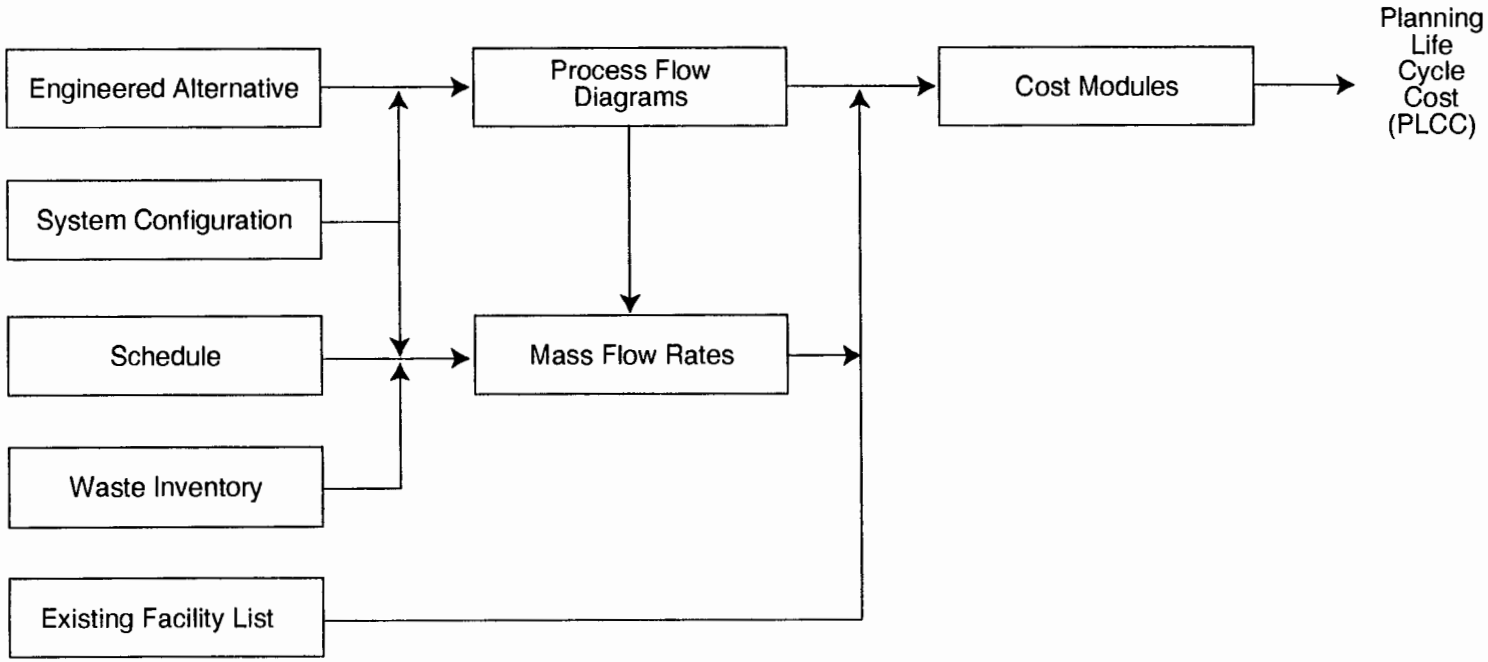
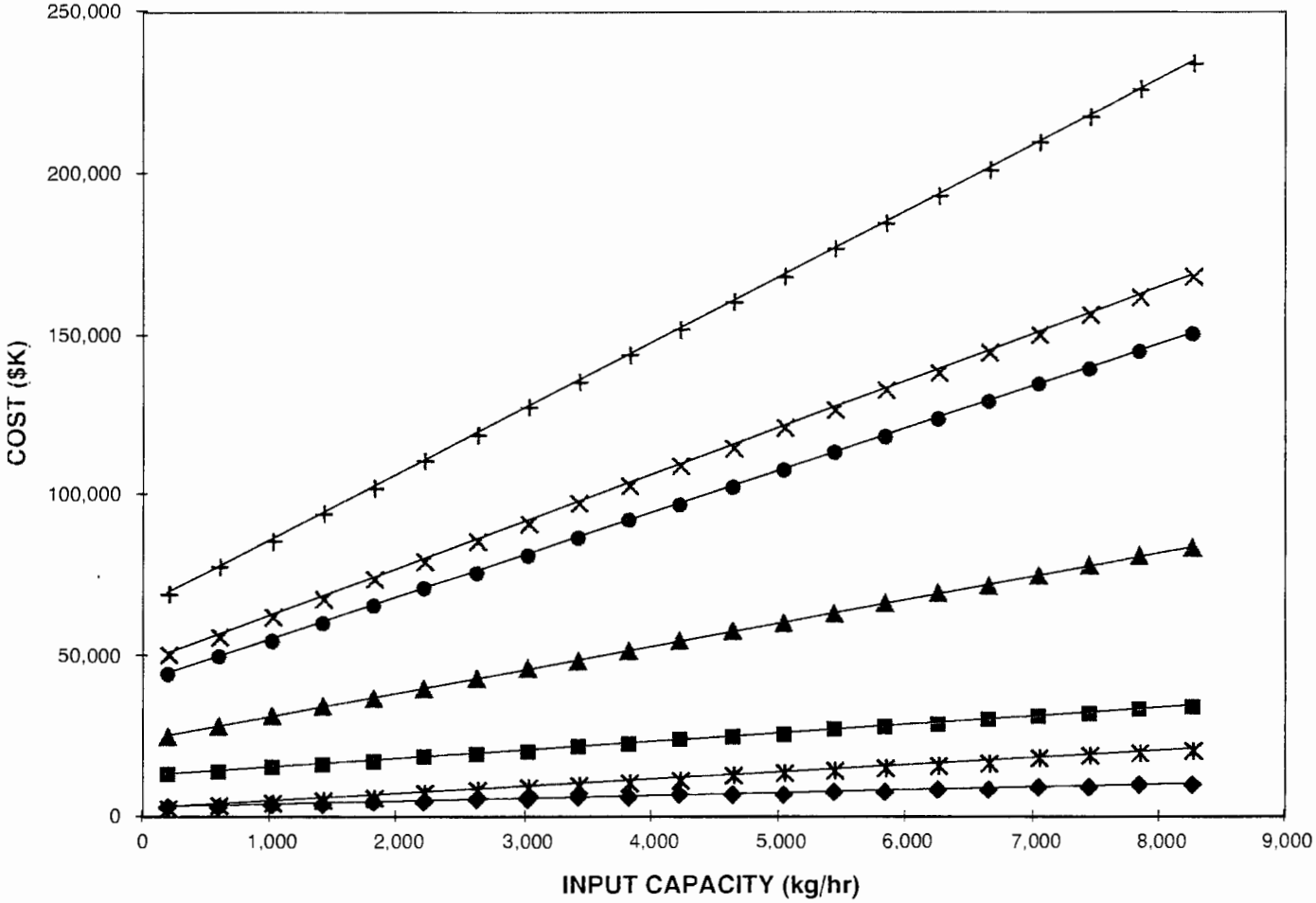


Figure P-1
Process Costing Methodology Flow Diagram



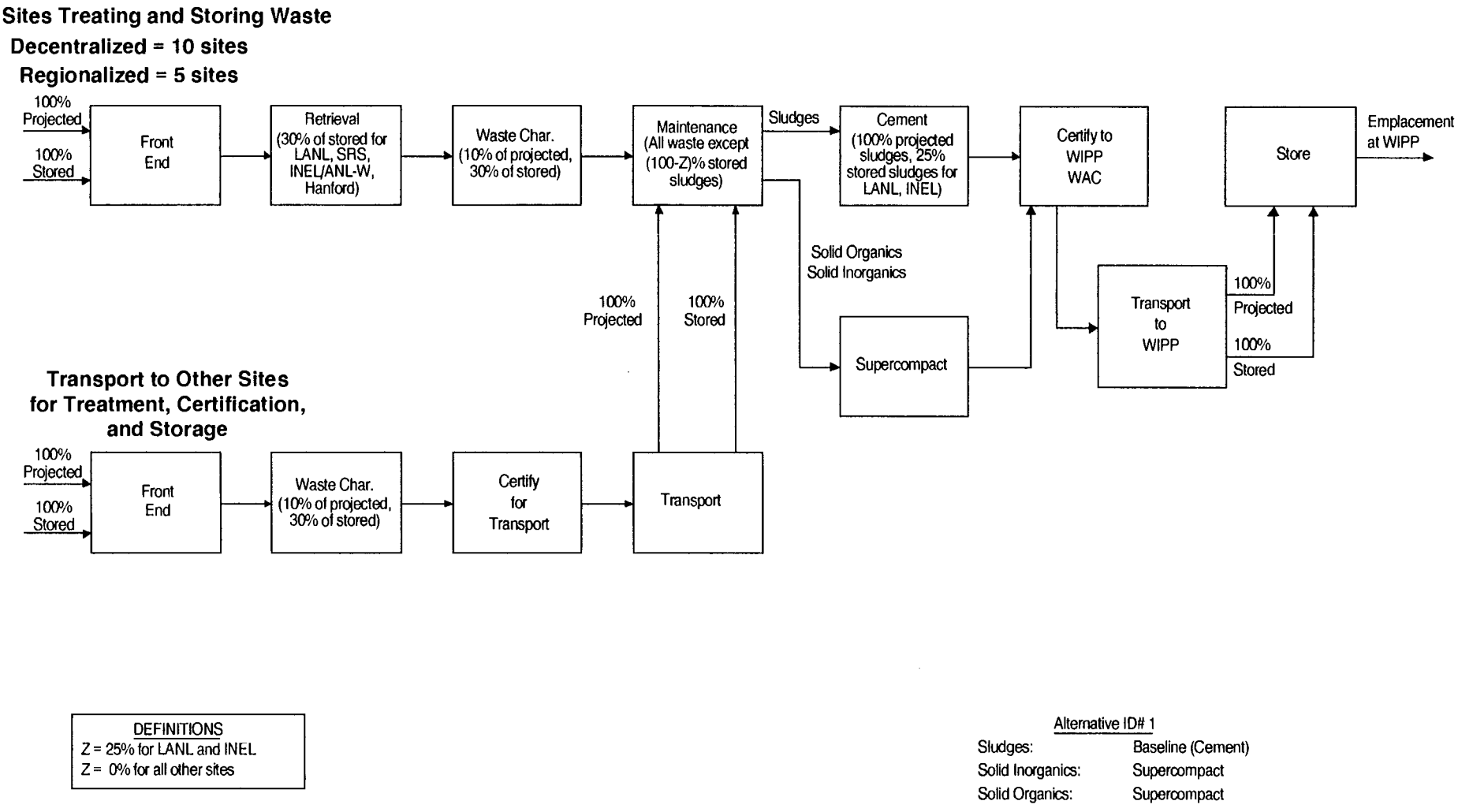
LEGEND

- ◆ 1.0 PRE-OPERATION
  y = 0.878x + 2969.1
  $R^2 = 1$
- ■ 2.0 CONSTRUCTION
  y = 2.6672x + 12644
  $R^2 = 1$
- ▲ 3.0 O& M (10 yr)
  y = 7.3151x + 23831
  $R^2 = 1$
- × 3.0 O& M (20 yr)
  y = 14.63x + 47661
  $R^2 = 1$
- ✱ 4.0 D & D
  y = 2.2816x + 2395.4
  $R^2 = 1$
- ● TOTAL PLCC (10 yr) $K
  y = 13.142x + 41839
  $R^2 = 1$
- + TOTAL PLCC (20 yr) $K
  y = 20.457x + 65670
  $R^2 = 1$

- Linear (TOTAL PLCC (20 yr) $K)
- Linear (3.0 O& M (20 yr))
- Linear (TOTAL PLCC (10 yr) $K)
- Linear (3.0 O& M (10 yr))
- Linear (2.0 CONSTRUCTION)
- Linear (4.0 D & D)
- Linear (1.0 PRE-OPERATION)

Figure P-2

CH-RH Certification and Shipping Cost Curves



DEFINITIONS
Z = 25% for LANL and INEL
Z = 0% for all other sites

Alternative ID# 1

Sludges:	Baseline (Cement)
Solid Inorganics:	Supercompact
Solid Organics:	Supercompact

Figure P-3

Decentralized and Regionalized Alternative ID #s 1 and 77(a-d) Contact Handled Process Flow Diagram B

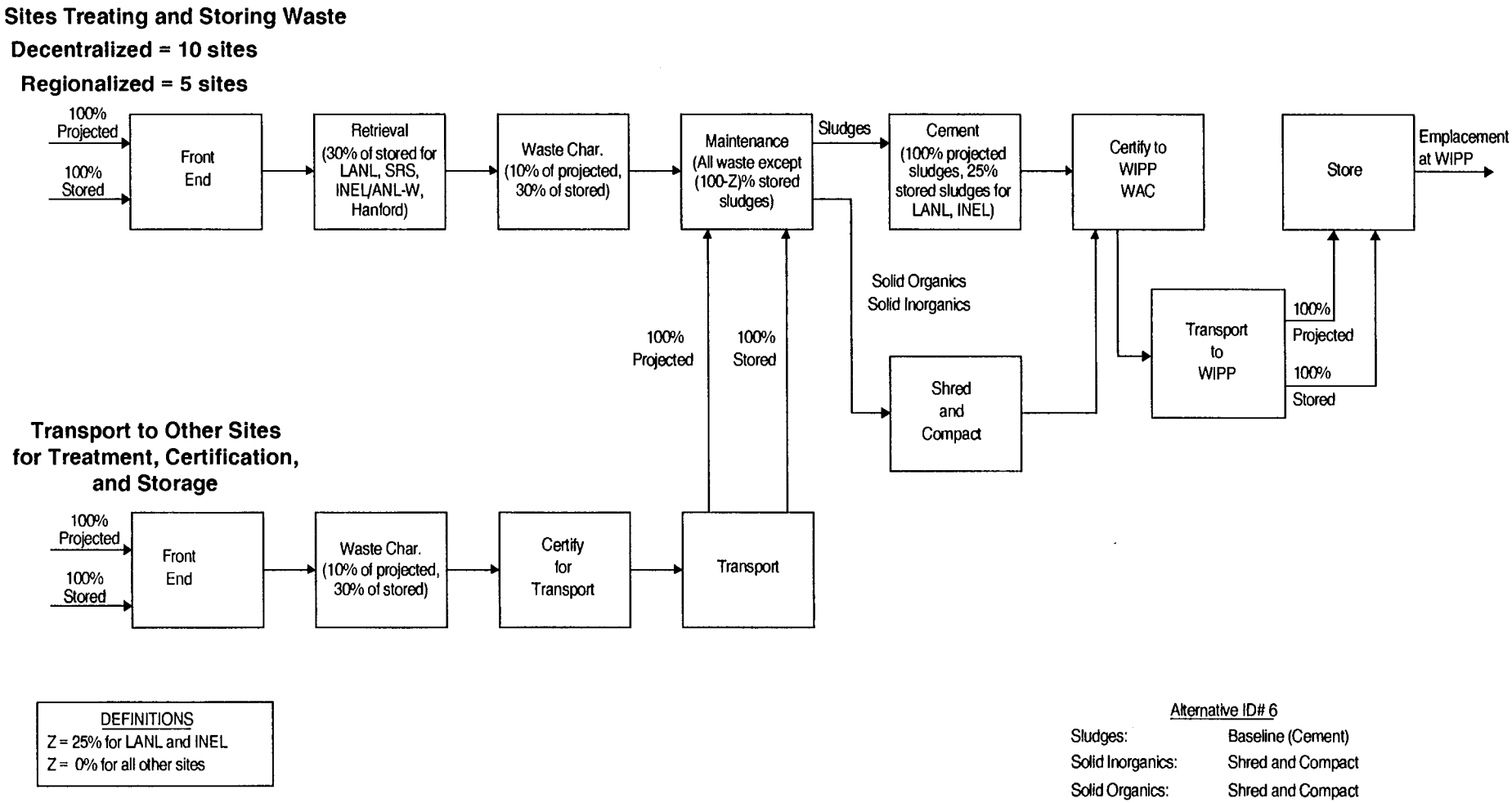
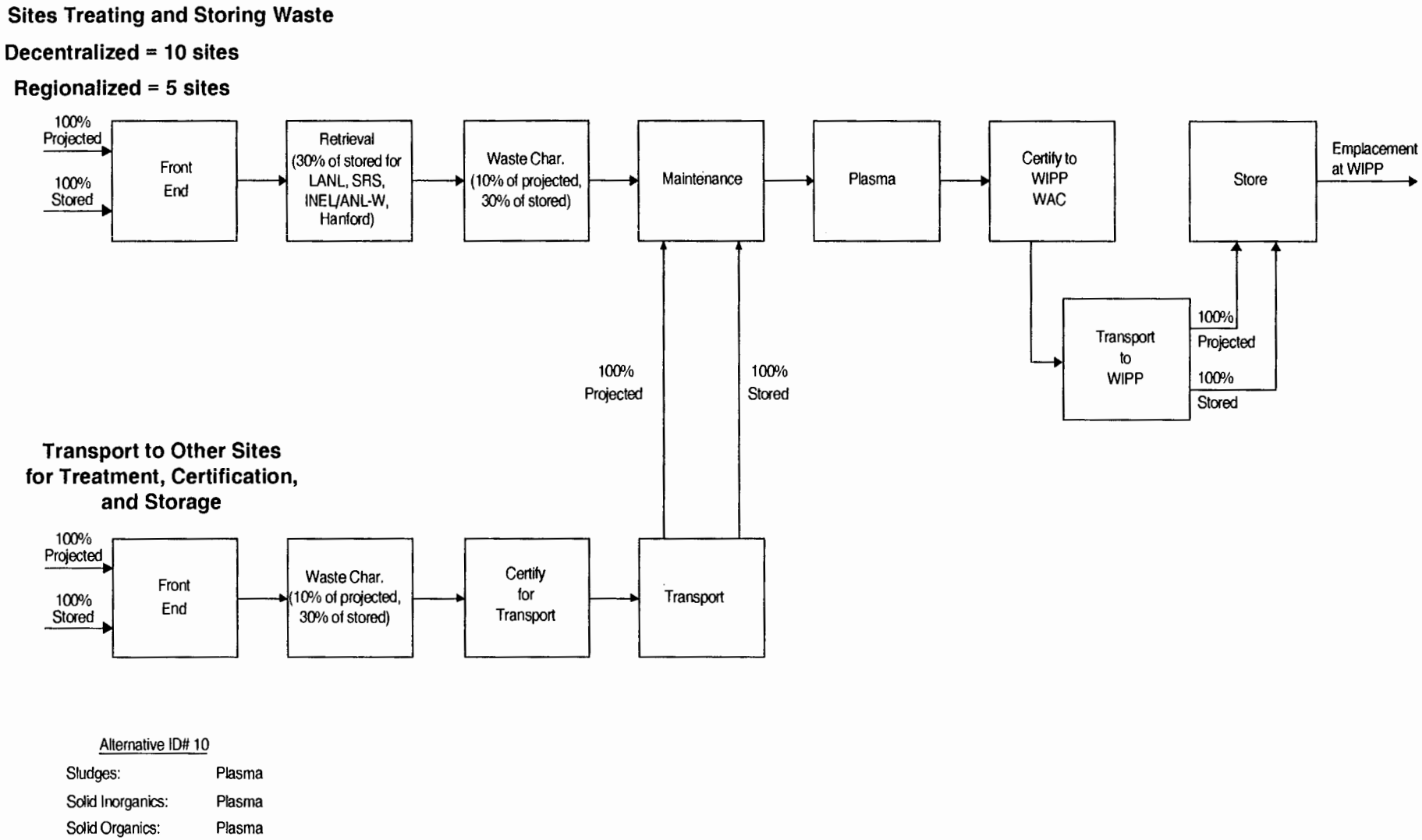


Figure P-4

Decentralized and Regionalized Alternative ID# 6 Contact Handled Process Flow Diagram C

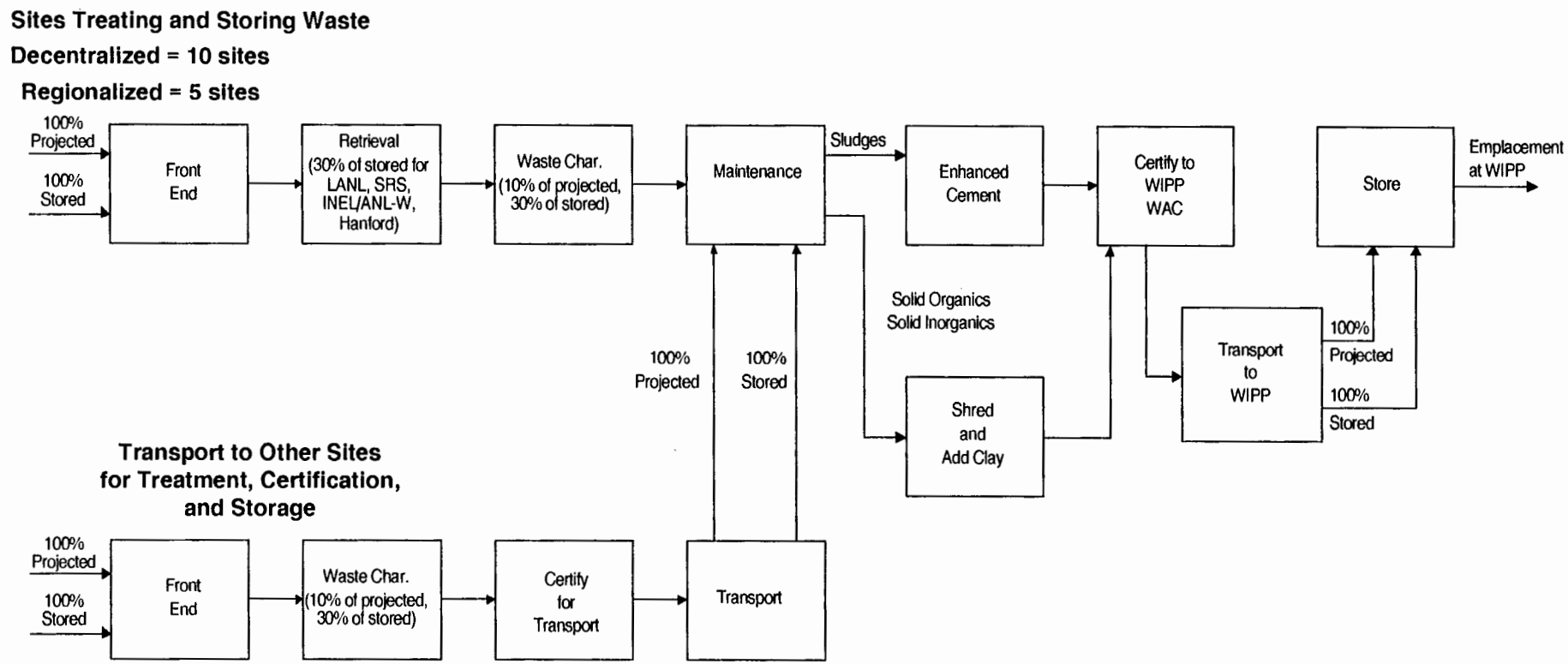


Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure P-5

Decentralized and Regionalized Alternative ID# 10 Contact Handled Process Flow Diagram D



Alternative ID# 94(a-f)

Sludges:	Enhanced Cement
Solid Inorganics:	Shred and Add Clay
Solid Organics:	Shred and Add Clay

Figure P-6

Decentralized and Regionalized Alternative ID# 94(a-f) Contact Handled Process Flow Diagram E

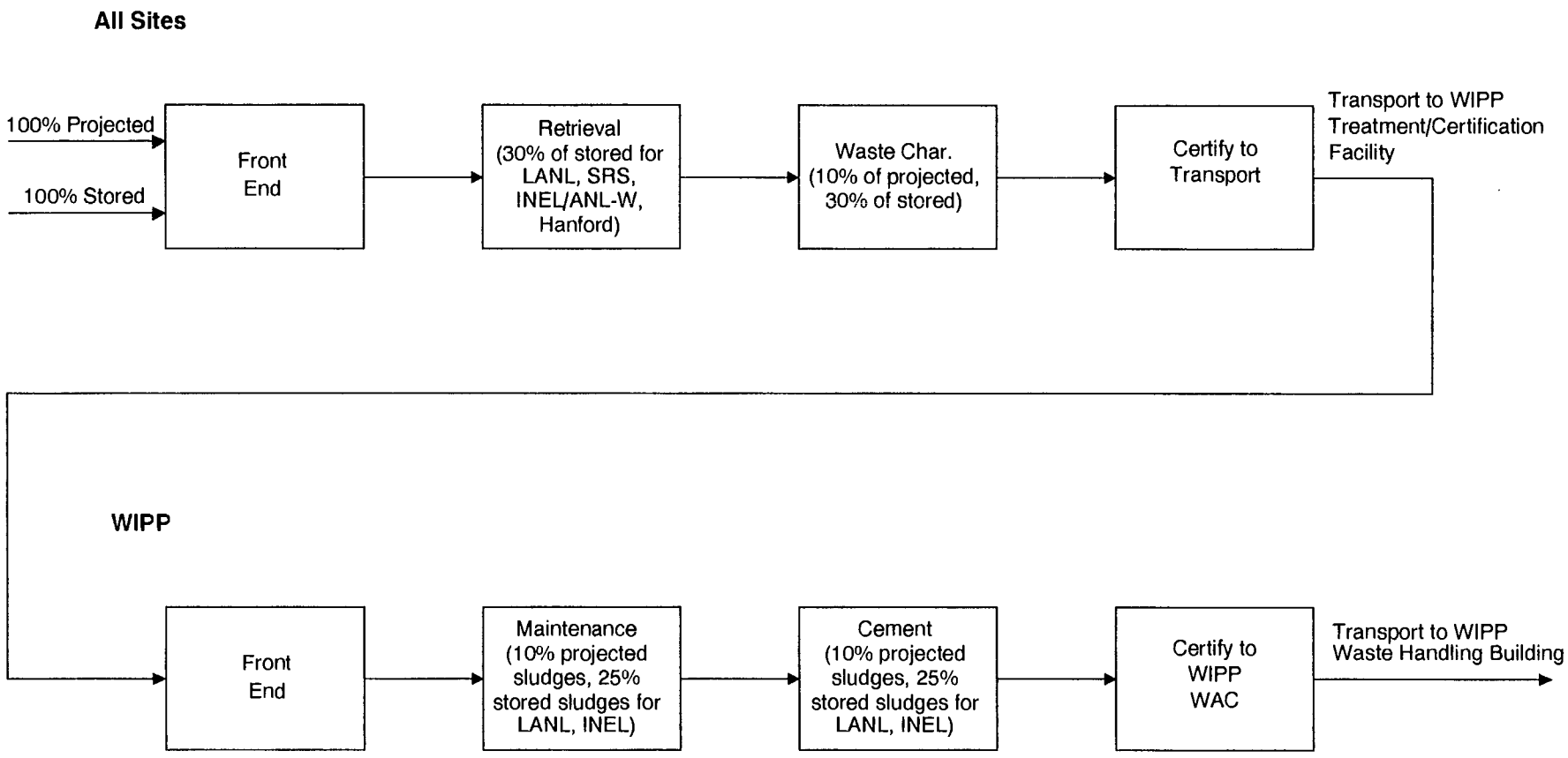


Figure P-7

Centralized Base Case and Alternative ID #s 33, 35(a&b), 83, and 111 Contact Handled Process Flow Diagram F

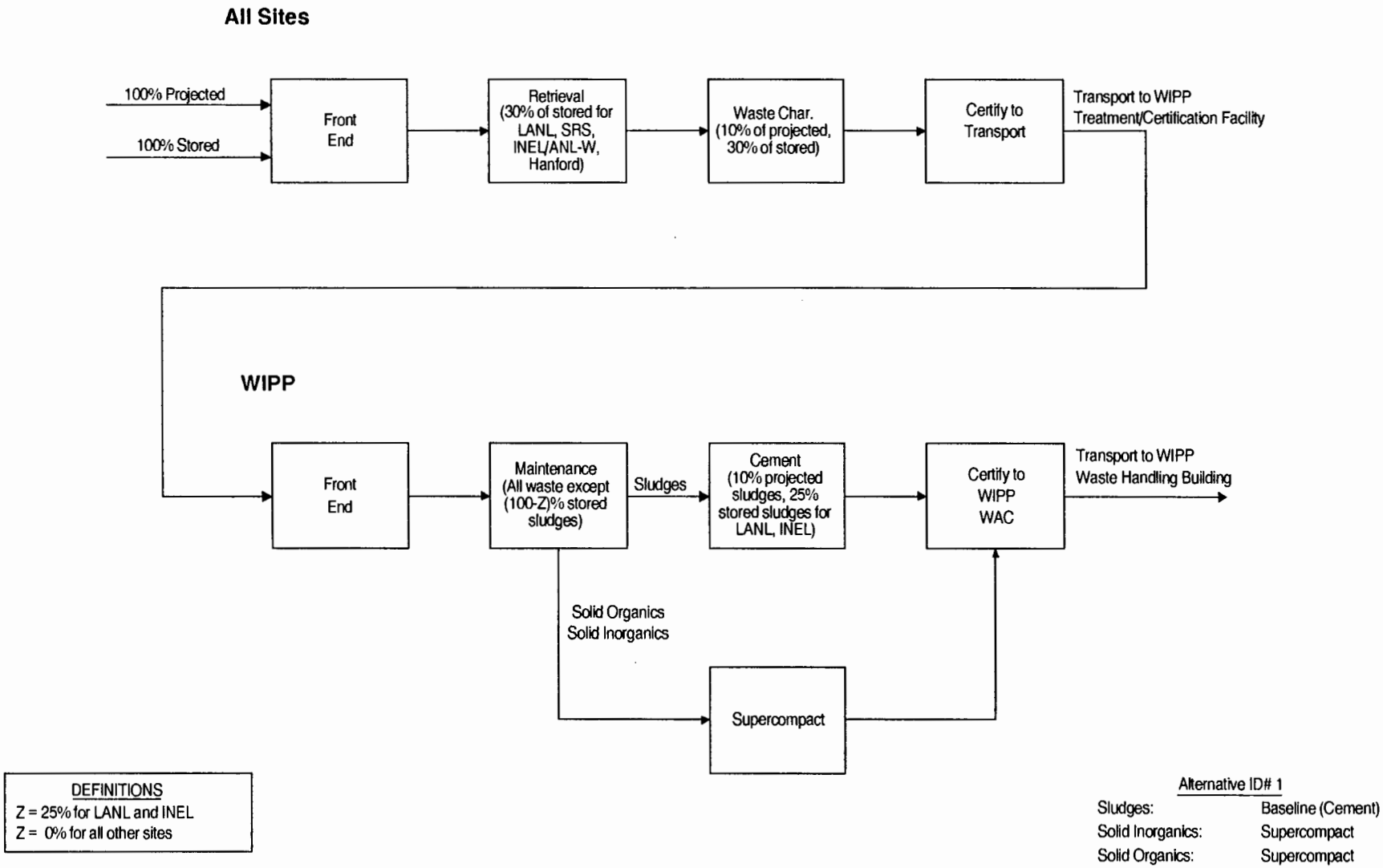


Figure P-8

Centralized Alternative ID#s 1 and 77(a-d) Contact Handled Process Flow Diagram G

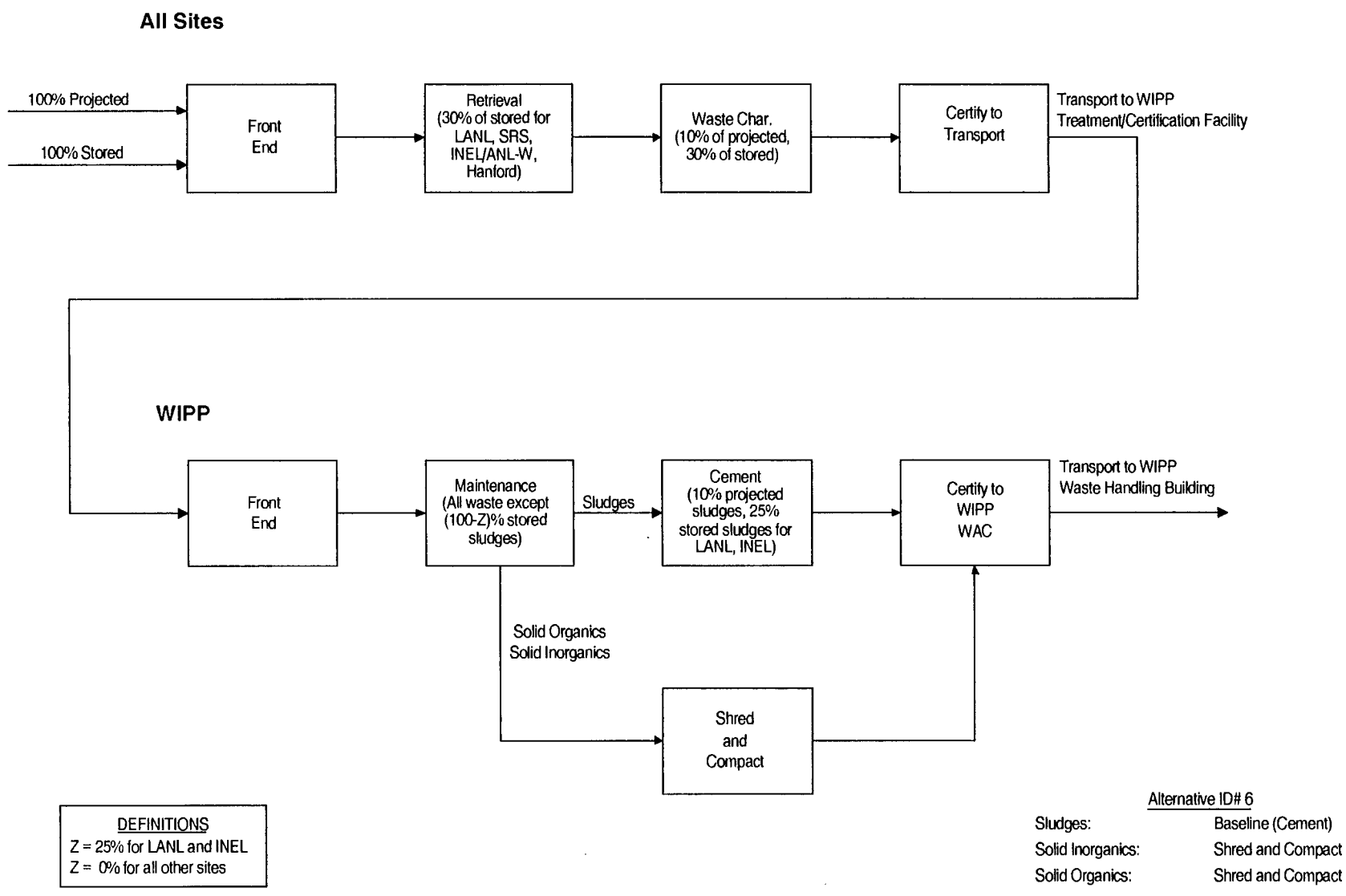
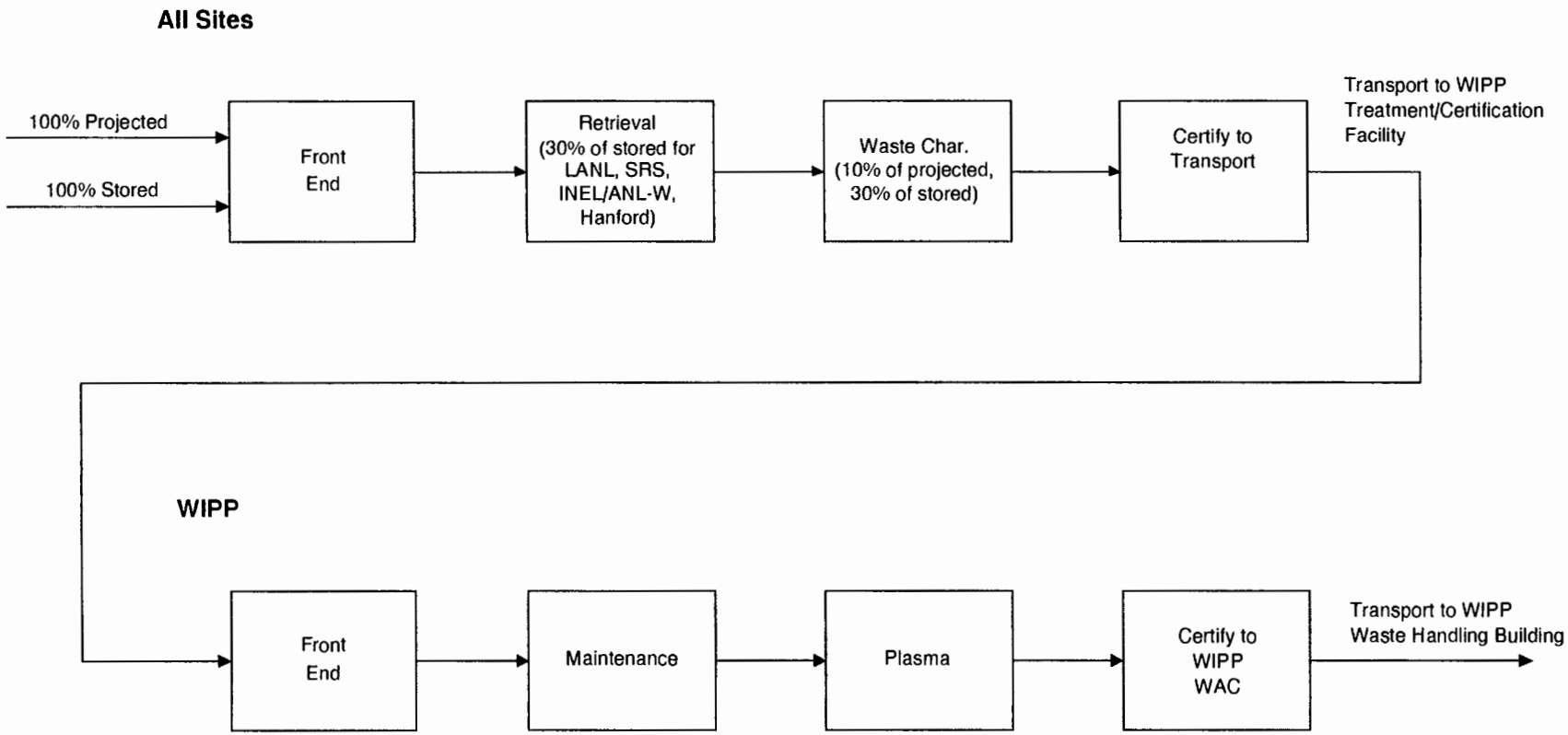


Figure P-9

Centralized Alternative ID# 6 Contact Handled Process Flow Diagram H



Alternative ID# 10

Sludges:	Plasma
Solid Inorganics:	Plasma
Solid Organics:	Plasma

Figure P-10
Centralized Alternative ID# 10 Contact Handled Process Flow Diagram I

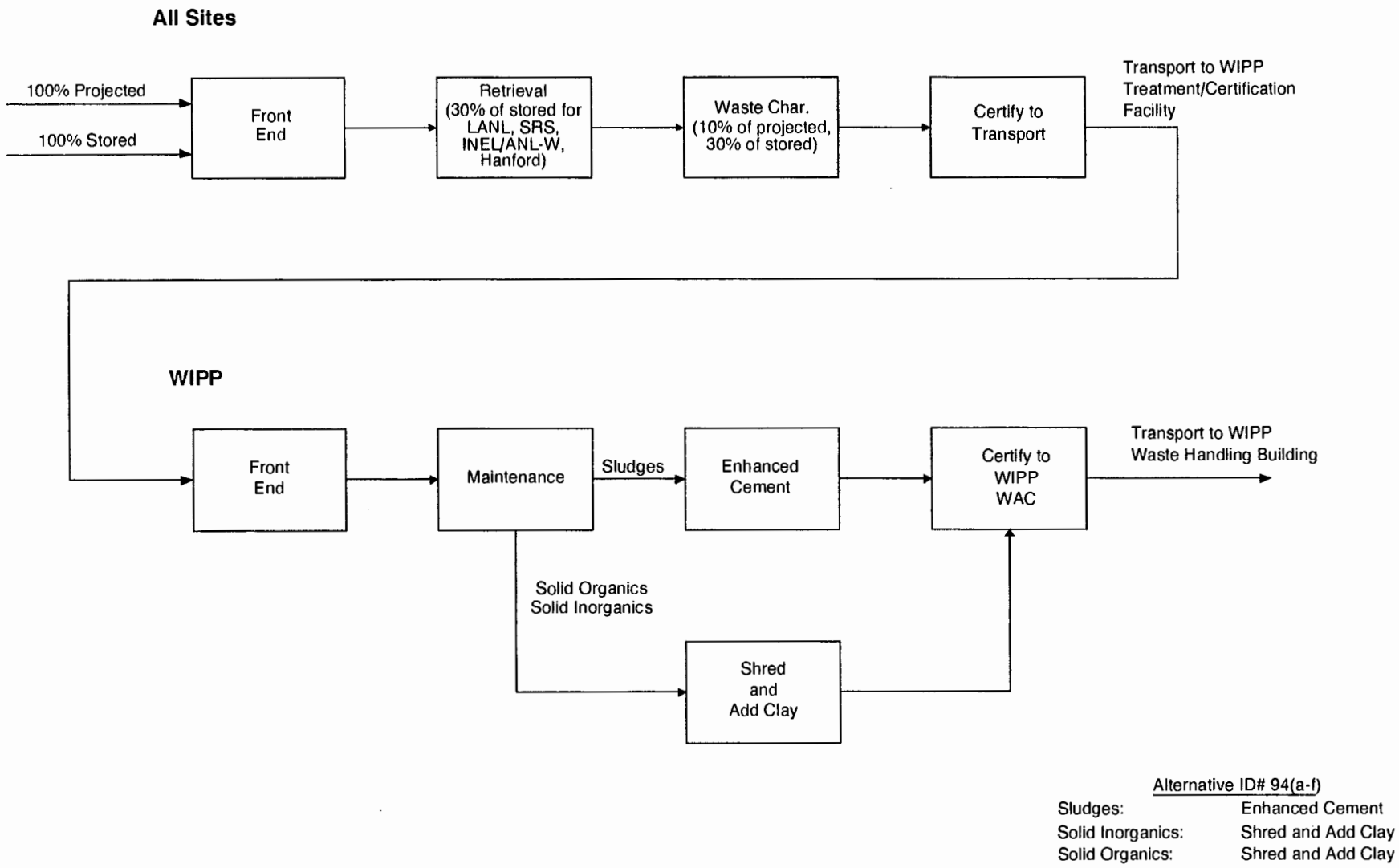


Figure P-11
Centralized Alternative ID# 94(a-f)
Process Flow Diagram J

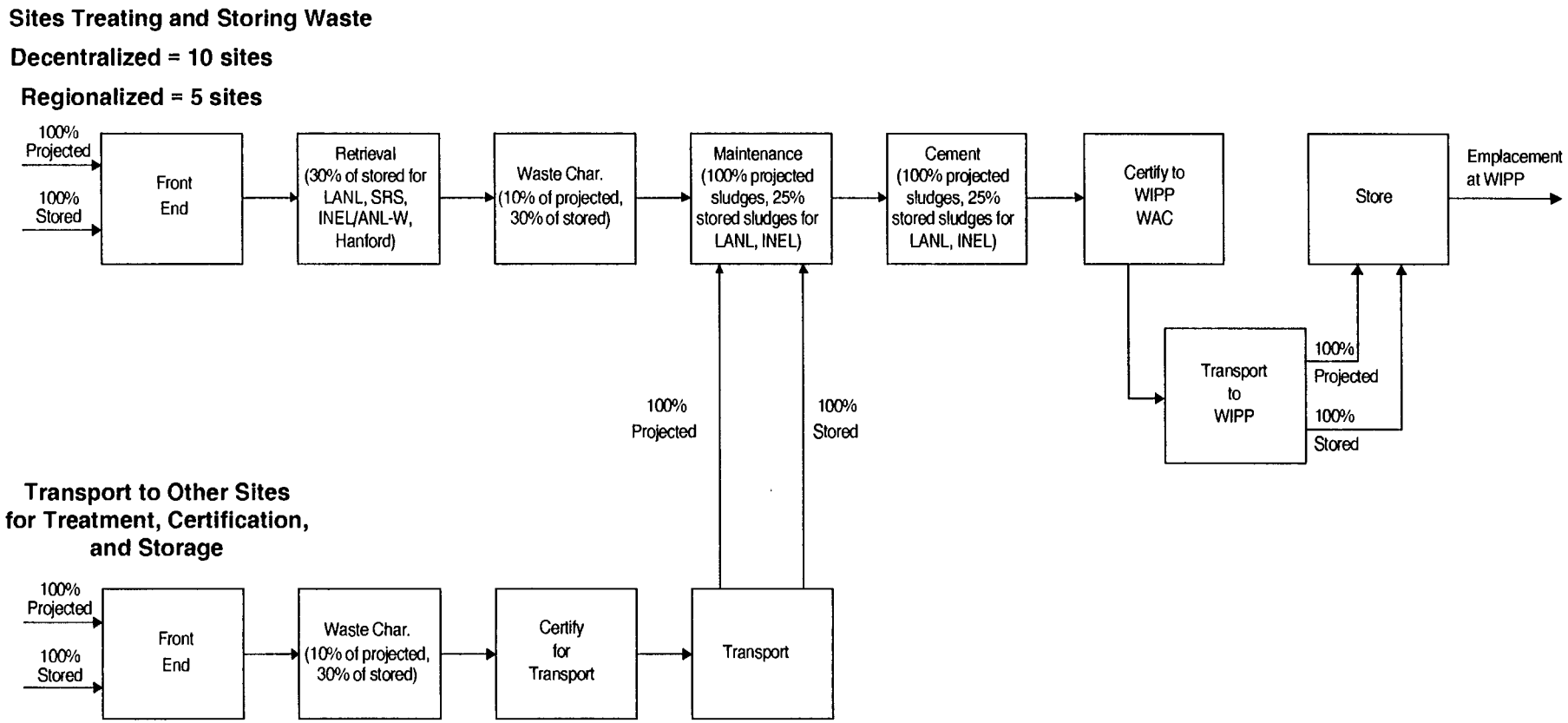


Figure P-12

Decentralized Base Case Remote Handled Process Flow Diagram K

Final Report of the Engineered Alternatives Task Force" (DOE, 1991), the Draft Environmental Management Programmatic Environmental Impact Statement (EM-PEIS) report (DOE, 1995b), and the WMFCITRUW report (Feizollahi and Shropshire, 1994). Information from these sources were used to connect each of the modules and to construct a visual description of mass and volume flow through each treatment process.

The modules are described below:

- Front End: Front-end support facilities consist of all administrative and laboratory buildings required for the waste management support functions. Front-end support functions include security, personnel decontamination (radioactive and hazardous), maintenance of noncontaminated areas and equipment, health physics, radiation badges, facility access control, sanitary facilities, work control and personnel support, internal and external communications, spill or emergency response provisions (hazardous and radioactive), analytical laboratory, environmental field sampling, environmental regulatory reporting, and records management.

- Retrieval: This module consists of all-weather excavation, inspection, and repackaging of bermed waste. The module includes three principal unit operations: earthen-cover extraction and decontamination, waste-container retrieval and inspection, and packaging and staging for shipment.

- Waste Characterization: This module is a self-contained facility in which waste characterization is performed. Activities include extracting physical samples of waste; conducting chemical, physical, and radiological analysis of waste samples; and repackaging drums and boxes to remove and stabilize noncompliant waste.

- Maintenance: A maintenance facility is used in conjunction with treatment facilities. It consists of a failed-equipment receiving and repair building housing machinery and tools.

- Treatment: The treatment module varies based on the alternative being considered. Treatment options include grouting, supercompacting, shredding and compacting, plasma melting, enhanced-cement processing, and shredding and adding clay.

- Storage: This module consists of a Resource Conservation and Recovery Act (RCRA)-compliant storage building sized to accommodate an accumulation of up to 20 years' volume of waste input from treatment modules. Storage area features include spill collection, sloping floors, sumps, and concrete berms. Monitoring is included for both gamma and alpha radiation control.

- Certification: Certification consists of storage of incoming material, assay and certification, and truck loading. The facility is equipped with a bridge crane and a forklift. It is assumed that certification operations will take place indoors.

- Transportation: Transportation consists of truck shipments. Equipment includes a tractor and trailer transporting three Transuranic Package Transporter-II (TRUPACT-IIs) for contact-handled (CH) waste or one remote-handled (RH) cask (RH-72B) (a cylinder consisting of a separate inner canister within an outer cask protected by impact limiters at each end) for RH waste.

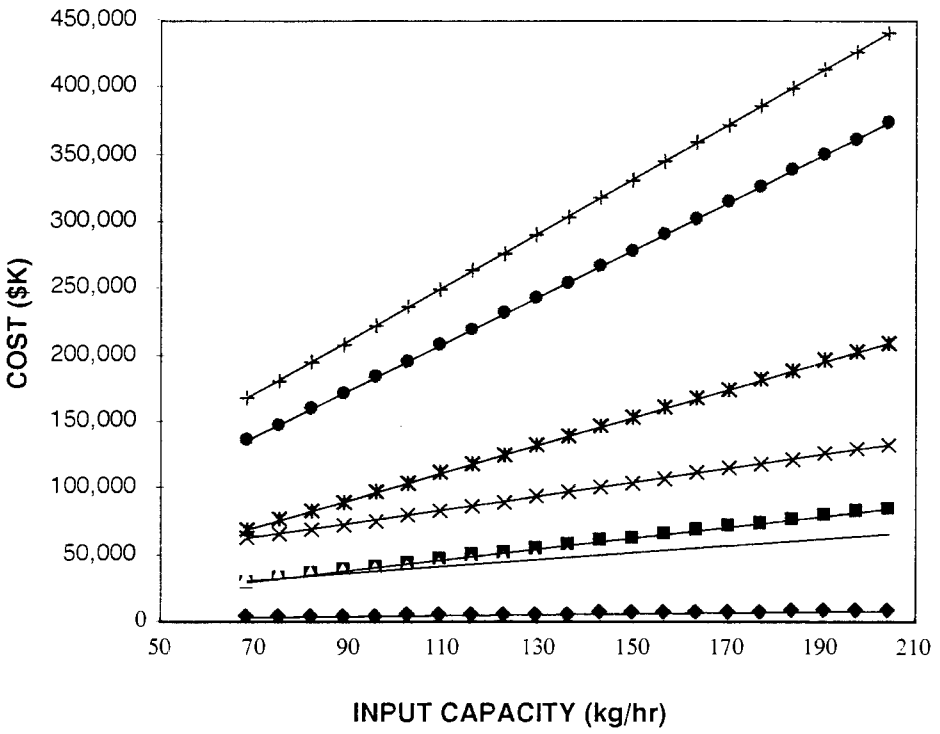
The process flow diagrams are developed from multiple data sources, and TRU waste processing knowledge from various sources; therefore, the uncertainty of the process flow diagrams cannot be quantified, but should be in the same order of magnitude as the documents used as guidelines for this study. The process flow diagrams developed for this study were designed mostly in accordance with the EM-PEIS and the WMFCITRUW report; however, not every module recommended in the WMFCITRUW report was included in this study. The reasons for deviating from the recommended WMFCITRUW guidance include (1) minimizing the costs of duplicate equipment contained in more than one module, and (2) more accurately representing the functions in existing and planned TRU waste facilities.

Mass and volume throughput are calculated using data from the Waste Isolation Pilot Plant (WIPP) Transuranic Waste Baseline Inventory Report (BIR) (DOE, 1995d). These rates are calculated using a 20-year processing period and a 4,032-hour working year. The mass or volume input to each of the individual modules is shown in Appendix O and is used as the basis for the module throughput which is the primary data used to estimate the cost of the module.

"The TRU waste disposal inventory in the BIR is derived from existing information on waste, which has been provided by DOE TRU waste generator/storage sites and is predominately based on process knowledge" (DOE, 1995d). Any uncertainty within the BIR is carried into this EA study. Calculated processing rates using a 20-year period and 4,032-hour working year may also introduce a level of uncertainty in estimating the costs. Many of the calculated processing rates were below or beyond the range of processing rates listed in the WMFCITRUW report and may cause the calculated costs to be skewed.

Numerical data values for cost versus flow rate information were obtained from the authors of the WMFCITRUW and used to construct approximate relations or curve fits for cost versus mass or volume throughput for a specific processing module, as shown in Figures P-13 through P-23. Cost data are available in the WMFCITRUW report according to specific project activities including pre-operations (pre-ops), planning life-cycle cost (PLCC), construction, operations and maintenance (O&M), and decontamination and decommissioning (D&D). Appendix P provides additional information on the method for establishing the modules. The PLCC is the summation of pre-ops, construction, O&M and D&D cost.

The WMFCITRUW was developed specifically to calculate facility costs in the EM-PEIS. Neither the WMFCITRUW nor the EM-PEIS provide a quantitative uncertainty of the costing data. From the costing categories listed in Plant Design and Economics for Chemical Engineers (Peters et al., 1991), the WMFCITRUW study cost estimates fall into the Study Estimate cost category where the probable accuracy of the estimate is plus or minus 30 percent.
To ensure that the waste processing cost estimates presented in this study account for those facilities that currently exist, a list of existing facilities was assembled from information gathered from several sources, including personal communications (Bjotvedt, 1995; George, 1995) and preliminary information being developed by the DOE National TRU Program Office. Data from these sources were consolidated into a single list used to describe existing TRU waste processing

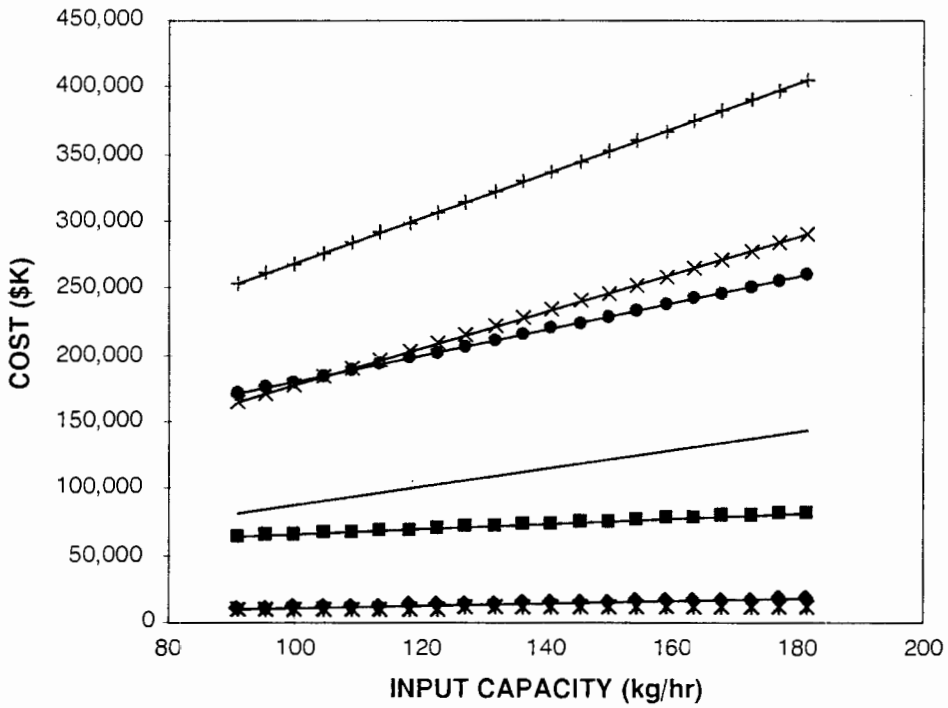


LEGEND

- 1.0 PRE-OPERATIONS
  y = 39.957x + 1603.4
  R^2= 1
- 2.0 CONSTRUCTION
  y = 410.93x + 2820.7
  R^2= 1
- 3.0 O & M 10 years
  y = 260.51x + 13871
  R^2= 1
- 3.0 O & M 20 years
  y = 521.02x + 27742
  R^2= 1
- 4.0 D & D
  y = 1035.7x - 3E-10
  R^2= 1
- TOTAL PLCC (10 yr)
  y = 1747.1x + 18295
  R^2= 1
- TOTAL PLCC (20 yr)
  y = 2007.6x + 32166
  R^2= 1

- Linear (TOTAL PLCC (20 yr) $K)
- Linear (TOTAL PLCC (10 yr) $K)
- Linear (4.0 D&D)
- Linear (3.0 O& M 20 years)
- Linear (2.0 Const)
- Linear (3.0 O& M 10 years)
- Linear (1.0 Pre-Ops)

Figure P-13
CH-RH Retrieval



LEGEND

◆ 1.0 PRE-OPERATIONS
y = 81.515x + 4188.3

■ 2.0 CONSTRUCTION
y = 200.17x + 47294
$R^2 = 1$

3.0 O& M
10 years
y = 691x + 20625
$R^2 = 1$

× 3.0 O& M
20 years
y = 1382x + 41250
$R^2 = 1$

✱ 4.0 D&D
y = 12.555x + 10374
$R^2 = 1$

● TOTAL PLCC (10 yr)
$K
y = 1676.3x + 103106
$R^2 = 1$

+ TOTAL PLCC (20 yr)
$K
y = 985.25x + 82481
$R^2 = 1$

—— Linear (TOTAL PLCC (20 yr) $K)

—— Linear (TOTAL PLCC (10 yr) $K)

—— Linear (3.0 O& M 10 years)

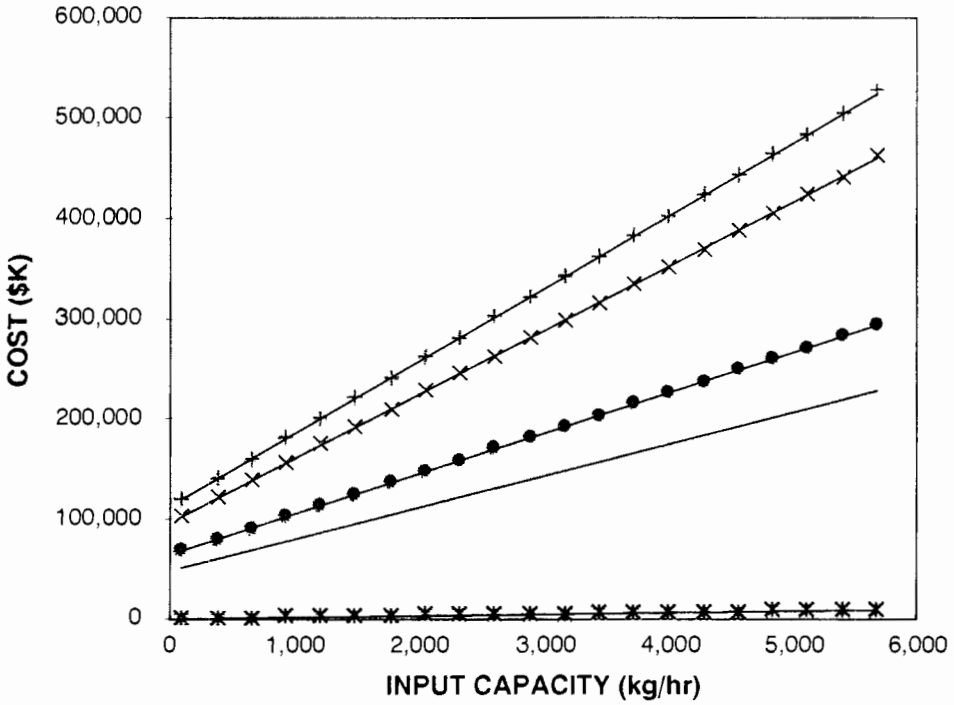
—— Linear (2.0 Const)

—— Linear (1.0 Pre-Ops)

—— Linear (4.0 D&D)

—— Linear (3.0 O& M 20 years)

Figure P-14
Waste Characterization



LEGEND

3.0 O& M
10 years
y = 31.836x + 49523
R^2 = 1

× 3.0 O& M
20 years
y = 63.673x + 99046
R^2 = 1

✱ 4.0 D&D
y = 1.5643x + 2136.6
R^2 = 1

● TOTAL PLCC (10 yr)
$K
y = 40.578x + 65777
R^2 = 1

+ TOTAL PLCC (20 yr)
$K
y = 72.415x + 115300
R^2 = 1

—— Linear (TOTAL PLCC (20 yr) $K)

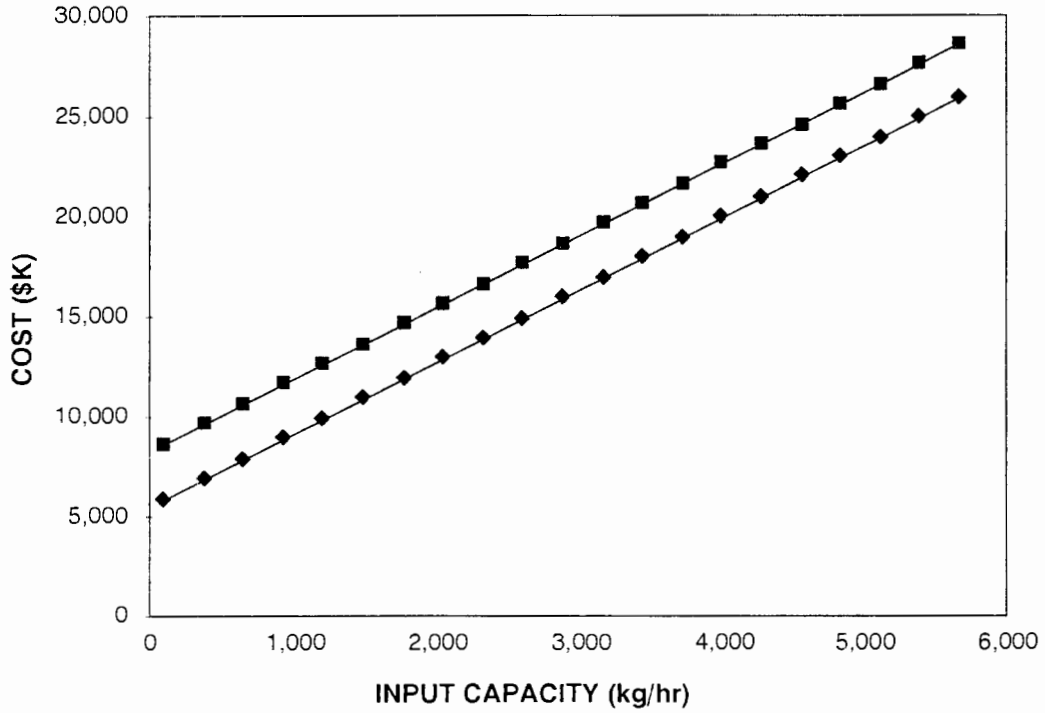
—— Linear (3.0 O& M 20 years)

—— Linear (TOTAL PLCC (10 yr) $K)

—— Linear (3.0 O& M 10 years)

—— Linear (4.0 D&D)

Figure P-15
CH-RH Front End Support (TADMIN)



LEGEND

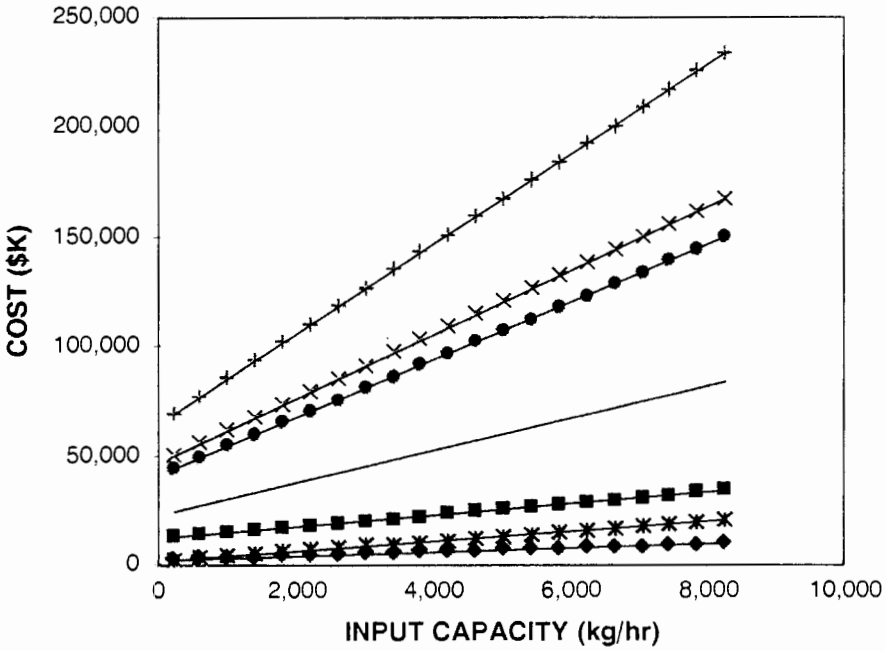
◆ 1.0 PRE-OPERATIONS
y = 3.6004x + 5679.6
$R^2 = 1$

■ 2.0 CONSTRUCTION
y = 3.5771x + 8437.9
$R^2 = 1$

——Linear (2.0 Const)

——Linear (1.0 Pre-Ops)

Figure P-16
CH-RH (TADMIN)

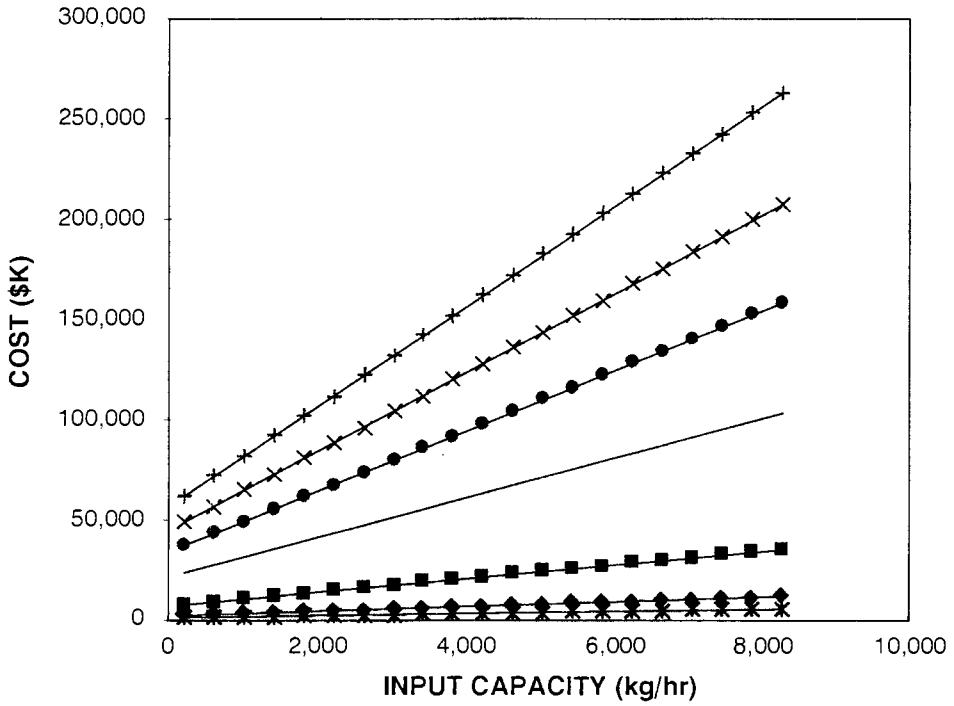


LEGEND

- ◆ 1.0 PRE-OPERATIONS
  y = 0.878x + 2969.1
  R^2 = 1
- ■ 2.0 Const
  y = 2.6672x + 12644
  R^2 = 1
- 3.0 O& M
  10 years
  y = 7.3151x + 23831
  R^2 = 1
- × 3.0 O& M
  20 years
  y = 14.63x + 47661
  R^2 = 1
- ✱ 4.0 D&D
  y = 2.2816x + 2395.4
  R^2 = 1
- ● TOTAL PLCC (10 yr)
  $K
  y = 13.142x + 41839
  R^2 = 1
- + TOTAL PLCC (20 yr)
  $K
  y = 20.457x + 65670
  R^2 = 1

- —— Linear (TOTAL PLCC (20 yr) $K)
- —— Linear (3.0 O& M 20 years)
- —— Linear (TOTAL PLCC (10 yr) $K)
- —— Linear (3.0 O& M 10 years)
- —— Linear (2.0 Const)
- —— Linear (4.0 D&D)
- —— Linear (1.0 Pre-Ops)

Figure P-17
CH-RH Certify and Ship



LEGEND

- ◆ 1.0 PRE-OPERATIONS
  y = 1.181x + 2724.3
  R^2= 1
- ■ 2.0 CONSTRUCTION
  y = 3.458x + 7922
- 3.0 O& M
  10 years
  y = 9.8717x + 22786
  R^2= 1
- × 3.0 O& M
  20 years
  y = 19.743x + 45572
  R^2= 1
- ✱ 4.0 D&D
  y = 0.6254x + 1592
  R^2= 1
- ● TOTAL PLCC (10 yr)
  $K
  y = 15.136x + 35024
  R^2= 1
- + TOTAL PLCC (20 yr)
  $K
  y = 25.008x + 57811
  R^2= 1

——Linear (TOTAL PLCC (20 yr) $K)

——Linear (3.0 O& M 20 years)

——Linear (TOTAL PLCC (10 yr) $K)

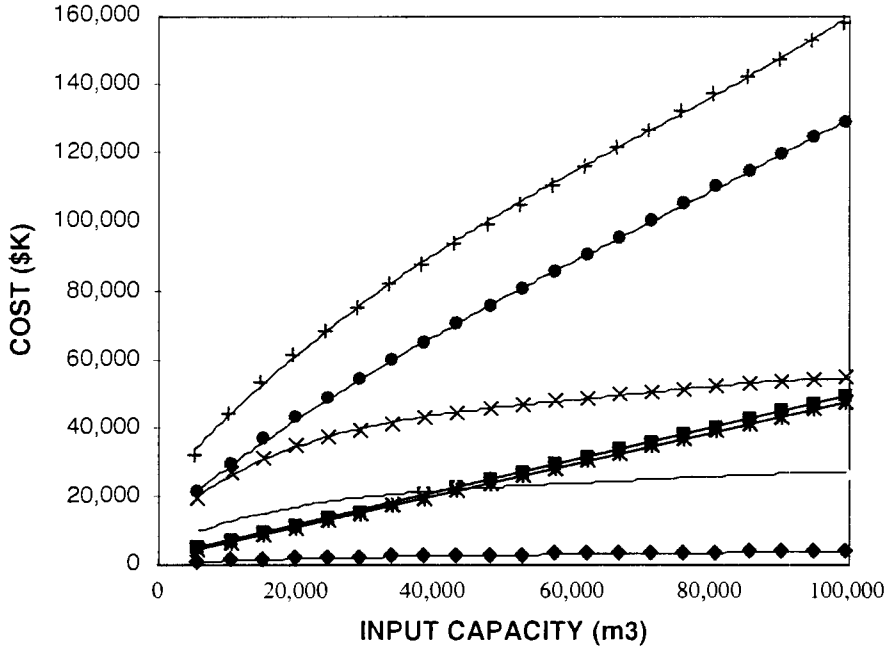
——Linear (3.0 O& M 10 years)

——Linear (2.0 Const)

——Linear (1.0 Pre-Ops)

——Linear (4.0 D&D)

Figure P-18
CH-RH Maintenance



LEGEND

◆ 1.0 PRE-OPERATIONS
$y = -7.905E-17^4x + 2.058E-11^4x - 1.997E-06^2x + 1.095E-01x + 7.279E+02$
$R^2 = 9.995E-01$

■ 2.0 CONSTRUCTION
$y = 0.4628x + 2222.5$
$R^2 = 1$

3.0 O& M
10 years
$y = 0.4715x + 2753$
$R^2 = 1$

× 3.0 O& M
20 years
$y = -1.437E-15^4x - 3.631E-05^3x + 3.743E-10^2x + 1.756E+00x + 1.186E+04$
$R^2 = 9.985E-01$

✱ 4.0 D&D
$y = -7.186E-16^4x + 1.871E-10^3x - 1.816E-05^2x + 8.778E-01x + 5.929E+03$
$R^2 = 9.985E-01$

● TOTAL PLCC (10 yr)
$K
$y = 4.012E-11^3x - 8.584E-06^2x + 1.631E+00x + 1.358E+04$
$R^2 = 9.998E-01$

+ TOTAL PLCC (20 yr)
$K
$y = 7.626E-11^3x - 1.632E-05x^2 + 2.247E+00x + 2.126E+04$
$R^2 = 9.996E-01$

——Poly. (TOTAL PLCC (20 yr) $K)

——Poly. (TOTAL PLCC (10 yr) $K)

——Poly. (3.0 O& M 20 years)

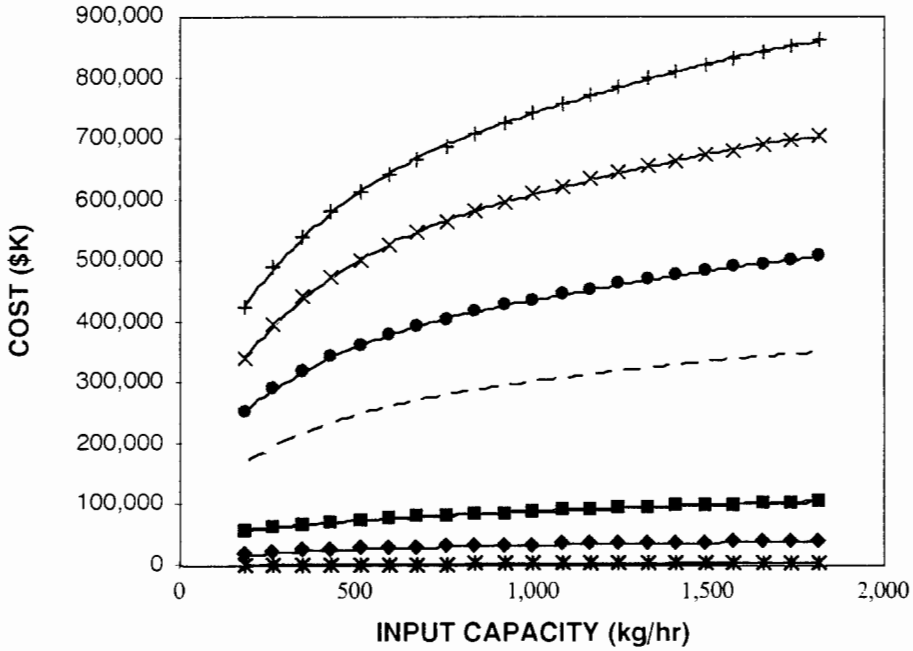
——Linear (2.0 Const)

——Linear (4.0 D&D)

——Poly. (3.0 O& M 10 years)

——Poly. (1.0 Pre-Ops)

Figure P-19
CH-RH Storage



LEGEND

◆ 1.0 PRE-OPERATIONS
$y = -5.890E-09^4x + 2.963E-05^3x - 5.700E-02^2x + 5.747E+01x + 1.195E+04$
$R^2 = 9.997E-01$

■ 2.0 CONSTRUCTION
$y = -8.831E-09^4x + 4.443E-05^3x - 8.547E-02^2x + 9.580E+01x + 4.519E+04$
$R^2 = 9.998E-01$

3.0 O& M
10 years
$y = -5.133E-08^4x + 2.583E-04^3x - 4.968E-01^2x + 4.985E+02x + 9.730E+04$
$R^2 = 9.996E-01$

× 3.0 O& M
20 years
$y = -1.027E-07^4x + 5.166E-04^3x9.937E-01^2x + 9.970E+02x + 1.946E+05$
$R^2 = 9.996E-01$

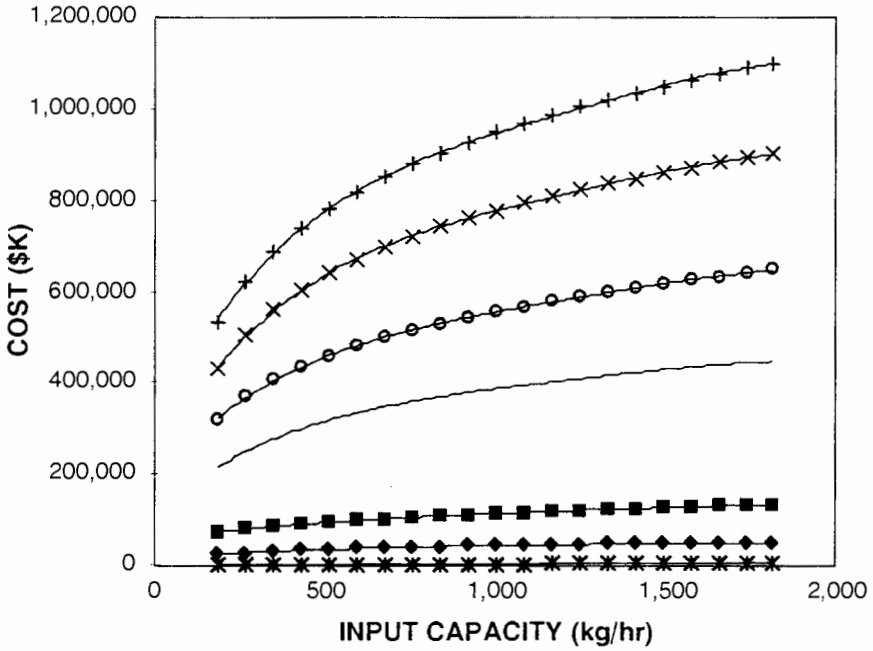
✱ 4.0 D&D
$y = 1.6149x + 3941.1$
$R^2 = 1$

● TOTAL PLCC (10 yr)
$K
$y = -6.605E-08^4x + 3.323E-04^3x - 6.393E-01^2x + 6.534E+02x + 1.584E+05$
$R^2 = 9.997E-01$

+ TOTAL PLCC (20 yr)
$K
$y = -1.174E-07^4x + 5.906E-04^3x - 1.136E+00^2x + 1.152E+03x + 2.557E+05$
$R^2 = 9.997E-01$

—— Poly. (TOTAL PLCC (20 yr) $K)
—— Poly. (2.0 Const)
—— Poly. (3.0 O& M 20 years)
—— Poly. (2.0 Const)
—— Poly. (TOTAL PLCC (10 yr) $K)
—— Poly. (1.0 Pre-Ops)
—— Poly. (3.0 O& M 10 years)
—— Linear (4.0 D&D)

Figure P-20
CH Cement



LEGEND

◆ 1.0 PRE-OPERATIONS
$y = -7.612E-09^4x + 3.830E-05^3x - 7.367E-02^2x + 7.427E+01x + 1.489E+04$
$R^2 = 9.996E-01$

■ 2.0 CONSTRUCTION
$y = 1.226E-05^3x - 5.104E-02^2x + 9.489E+01x + 6.073E+04$
$R^2 = 9.991E-01$

3.0 O& M
10 years
$y = -6.625E-08^4x + 3.333E-04^3x - 6.412E-01^2x + 6.434E+02x + 1.214E+05$
$R^2 = 9.996E-01$

× 3.0 O& M
20 years
$y = -1.325E-07^4x + 6.667E-04^3x - 1.282E+00^2x + 1.287E+03x + 2.428E+05$
$R^2 = 9.996E-01$

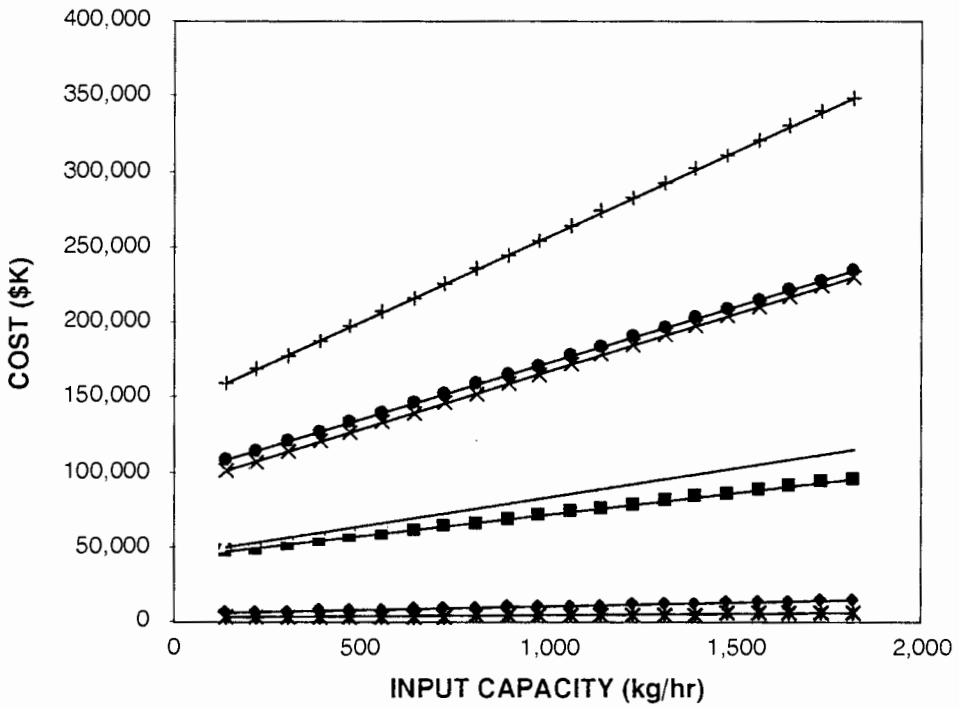
✱ 4.0 D&D
$y = 1.9412x + 4832.6$
$R^2 = 1$

o TOTAL PLCC (10 yr.)
$K
$y = -8.57E-08^4x + 4.31E-04^3x - 8.29E-01^2x + 8.47E+02x + 1.97E+05$
$R^2 = 1.00E+00$

+ TOTAL PLCC (20 yr.)
$K
$y = -1.519E-07^4x + 7.643E-04^3x - 1.470E+00^2x + 1.490E+03x + 3.184E+05$
$R^2 = 9.997E-01$

——Poly. (TOTAL PLCC (20 yr.) $K)
——Poly. (3.0 O& M 20 years)
——Poly. (TOTAL PLCC (10 yr.) $K)
——Poly. (3.0 O& M 10 years)
——Poly. (2.0 Const)
——Poly. (1.0 Pre-Ops)
——Linear (4.0 D&D)

Figure P-21
RH Cement Grout



LEGEND

- ◆ 1.0 PRE-OPERATIONS
  y = 5.0482x + 6231.2
  R^2 = 1
- ■ 2.0 CONSTRUCTION
  y = 29.447x + 43598
  R^2 = 1
- 3.0 O& M
  10 years
  y = 38.531x + 45748
  R^2 = 1
- × 3.0 O& M
  20 years
  y = 77.062x + 91496
  R^2 = 1
- ✱ 4.0 D&D
  y = 2.0512x + 3408.2
  R^2 = 1
- ● TOTAL PLCC (10 yr)
  $K
  y = 75.077x + 98986
  R^2 = 1
- + TOTAL PLCC (20 yr)
  $K
  y = 113.61x + 144734
  R^2 = 1

——Linear (TOTAL PLCC (20 yr) $K)

——Linear (TOTAL PLCC (10 yr) $K)

——Linear (3.0 O& M 20 years)

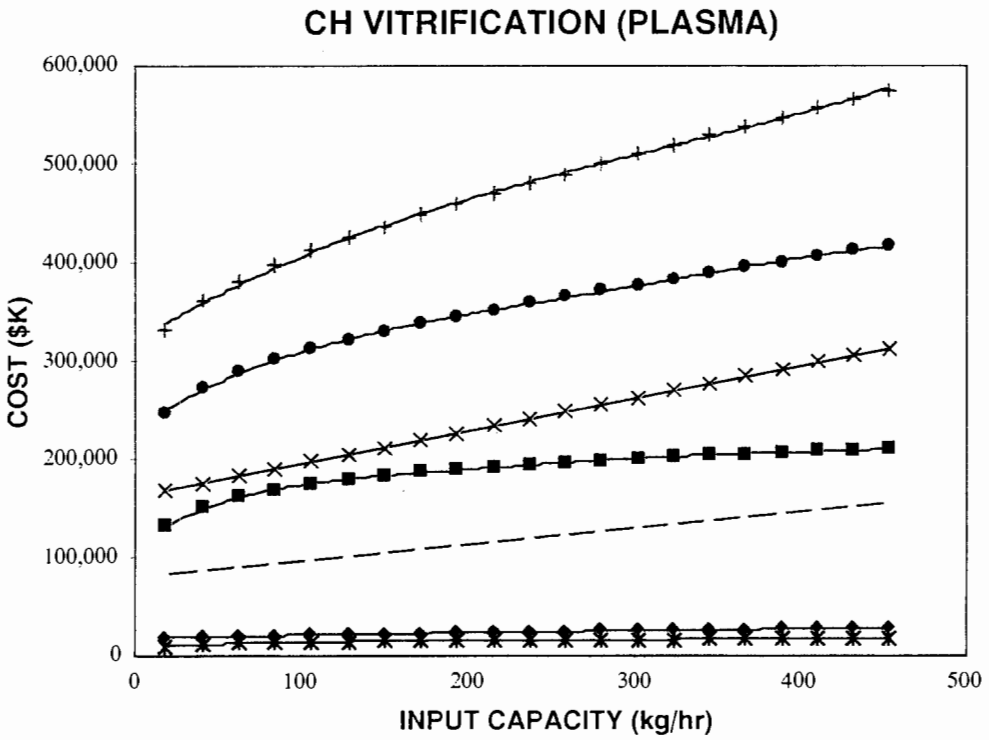
——Linear (3.0 O& M 10 years)

——Linear (2.0 Const)

——Linear (1.0 Pre-Ops)

——Linear (4.0 D&D)

Figure P-22
CH Compact



LEGEND

1.0 PRE-OPERATIONS
$y = -0.0122^2x + 28.113x + 19882$
$R^2 = 0.9987$

2.0 CONSTRUCTION
$y = 4.233E\text{-}08^5x - 5.855E\text{-}05^4x + 3.112E\text{-}02^3x - 8.093E+00^3x + 1.155E+03x + 1.157E+05$
$R^2 = 9.991E\text{-}01$

3.0 O& M 10 years
10 years
$y = 167.24x + 82022$
$R^2 = 1$

3.0 O& M 20 years
20 years
$y = 334.48x + 164045$
$R^2 = 1$

4.0 D&D
$y = 3.943E\text{-}09^5x - 5.454E\text{-}06^4x + 2.899E\text{-}03^3x - 7.538E\text{-}01^2x + 1.075E+02x + 9.789E+03$
$R^2 = 9.991E\text{-}01$

TOTAL PLCC (10 yr)
$K
$y = -9.666E\text{-}06^4x + 1.119E\text{-}02^3x - 4.763E+00^2x + 1.168E+03x + 2.329E+05$
$R^2 = 9.993E\text{-}01$

TOTAL PLCC (20 yr)
$K
$y = 2.073E\text{-}03^3x - 1.965E+00^2x + 1.030E+03x + 3.232E+05$
$R^2 = 9.988E\text{-}01$

Poly. (TOTAL PLCC (20 yr) $K)
Poly. (TOTAL PLCC (10 yr) $K)
Linear (3.0 O& M 20 years)
Poly. (2.0 Const)
Linear (3.0 O& M 10 years)
Poly. (4.0 D&D)
Poly. (1.0 Pre-Ops)

Figure P-23
CH Vitrification (Plasma)

facilities for this study, as shown in Table P-1. All of the information sources have not been subject to extensive review, thus uncertainty of the data arises from the uncertainties associated with the sources themselves, and any changes that have occurred between the current time and the time these sources were compiled.

The existing facility list was used to adjust process cost estimates. O&M and D&D costs were added and applied to facilities that had current existing TRU waste processing facilities for a specific module, while the PLCC was applied to facilities that did not have existing processing capabilities for a specific module.

Combining all of the information gathered, computer cost-model programs have been developed using Visual Basic computer programming language and cost equations were applied based on a calculated mass or volume throughput for a specific module. These programs were implemented using a computer spreadsheet with mass and volume throughput data. The computer cost model programs calculate the cost for each processing module for each alternative in each configuration. Summary results for process costs are presented in Section 4.1 of this appendix.

2.2 TRU Waste Transportation Cost Estimation Methodology

This section will supply information on the sources and assumptions used to complete transportation cost estimations for the various EAs.

The guidance chosen for development of transportation cost estimates is based on a report titled "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials," co-authored by Fred Feizollahi and David Shropshire of the Idaho National Engineering Laboratory (INEL) (Feizollahi and Shropshire, 1994). This report is also used as guidance for development of transportation cost estimation in the Draft EM-PEIS. The report also covers the procedure for estimating the costs of various types of wastes, including an entire section on RH and CH-TRU waste transportation.

It is important to note that the report does not make an attempt to limit the volume or radionuclides of the waste being transported; all shipments are mass-limited. The report includes only guidance for estimating the cost of transportation of waste; loading and unloading operations are included in the facility operating and maintenance costs.

It is assumed that all CH-TRU waste will be shipped by truck in TRUPACT-II containers, which have weight, volume, and radionuclide restrictions that limit the amount of waste transported in one shipment. Given waste volume and mass data for each of the sites, both mass-limited and volume-limited cases were developed. It was found that the treatment of the weight results in the majority of the shipments will carry waste of sufficiently high density to be mass-limited. The mass limitation of the TRUPACT-II shipments requires that the transportation of the waste be load

managed. The load management of the waste requires that payload scenarios be taken into account for the shipment of TRUPACT-IIs. RH-TRU waste, however, did have limitations on the radionuclide content and the volumes had to be further reduced to meet container and shipping specifications. The number of shipments was ultimately derived by making assumptions not included in the report. It was assumed that a 60/40 split between 55-gallon drums and standard waste boxes would be made (for volume limited shipments). The mass limited shipments required that the waste be packaged into 55-gallon drums to maintain loading efficiency (see Tables P-53 through P-74). Fourteen 55-gallon drums or two standard waste boxes can fit into a TRUPACT-II container. A truck shipment has the capacity for three TRUPACT-II containers. The mass limited shipments varied the number of drums that were shipped from 42 drums to 7 drums per TRUPACT-II. Additionally, the number of TRUPACT-II per shipment varied from 3 to 1.

The planned route and total mileage traveled for each of the shipments is determined by the HIGHWAY 3.3 Routing Model that was prepared by the Oak Ridge National Laboratory for use by DOE. The model is an extensive computerized atlas that determines the optimum route for a given origin and destination. The DOE sites that produce and treat TRU waste are all included, as is the WIPP repository. The program allows the user to place constraints on route choices, and several were invoked in order to choose the most preferred route for TRU waste transportation. Route constraints include the barred use of roads that prohibit truck use, the preferred use of routes already designated for hazardous waste transportation, and the use of roads in New Mexico designated as preferred shipment routes to the WIPP. The model is described in Section 3.5.2 of this report, Methodology Used to Evaluate Factor 5 (Risk of Transportation).

There are three types of costs associated with transportation. Carrier costs and hardware costs are functions of a moving vehicle and are combined to make up the "costs per loaded mile" (CPLM). Carrier costs include tractor, fuel, labor, insurance, security escort, taxes, tools, permit fees, and related costs incurred during waste transportation. Hardware costs are associated with maintenance of the specialized trailers and railroad cars used to transport waste. Fixed costs are independent of the distance traveled and are considered separately. Fixed costs include demurrage costs of the carrier and the hardware used in the shipment. The total cost for a single shipment can be determined by adding the fixed costs to the product of the CPLM and the number of miles traveled. It should be noted that the CPLM unit rate is based on one-way mileage from origin to destination, but that the total cost for one shipment includes the return trip (see Section 3.5.2.5).

Finally, the process of estimating the costs is a straightforward analysis. The costs are derived from the number of shipments based on a volumetric and mass calculation, taking into consideration the volume and mass of drums or standard waste boxes. The number of shipments are applied to the CPLM and the round-trip mileage, and the fixed costs are added to determine the total transportation costs for each individual site. Transportation cost estimations were performed for the decentralized and regionalized cases and each EA therein. An estimation was also made for the centralized baseline. Since the centralized transportation configuration requires that all waste be treated at the WIPP, all the centralized EAs are similar from a transportation point of view. Results are discussed in Section 4.2.

There are relatively few sources of uncertainty in the development of the transportation cost estimations. Included in these are the uncertainty of the waste volumes and masses requiring

transportation and the uncertainty in the numbers provided in the report used as guidance for estimate development. The level of uncertainty is discussed in Section 4.2.

2.3 Backfill Emplacement Cost Estimation Methodology

Backfill emplacement costs were developed by analyzing a logical approach to emplacing material into a panel. The approach had to be generic in nature to accommodate the fact that an exact method of emplacement has not been developed. The approach for estimating the costs of emplacement are generated by applying mine development data sources to an activity that is not characteristic the mining industry. The backfilling of waste emplaced in a mine has not been an activity that is common practice for the DOE or mining industry.

The cost estimation of a backfill operation was developed based on the rate at which backfill would be emplaced. The assumptions for this estimation are listed in Section 3.0. Once the capacity of the equipment requirement was determined a cost model was developed to determine the cost requirements for backfill.

The primary source of costing information is the SME Mining Engineering Handbook (Hartman, 1992), which provided a logical approach to the activities that would be performed. Assumptions had to be made in order to provide some logical data points for performing a backfill activity. An estimation of this type would be categorized as a Study Estimate where the uncertainty of the estimate is plus or minus 30 percent.

Data for the estimate was dependent on the mass and volume of backfill material. The backfill was to be emplaced daily as a batch and would not interrupt the waste emplacement activities. The rate for backfill was assumed to be 960 hours per year for 35 years.

Calculation of the cost estimation was developed utilizing a spreadsheet format that applied the cost equations to the rate at which the backfill would be emplaced. The spreadsheet calculated the cost for each EA that had a backfill associated with it.

Costs included in the estimate are based on capital equipment design and development and on operation and maintenance. The capital is based on actual equipment costs and the tons per day of emplacement capacity (Hartman, 1992). The operating costs are calculated as the total number of FTEs for backfill operations multiplied by the number of hours to perform the backfill times a labor rate. Maintenance costs are assumed to be 30 percent of total capital equipment costs. Design and development of the backfill emplacement activities is calculated as 30 percent of the total capital equipment expenditures. A contingency factor of 25 percent was applied to the overall cost. The manpower for the backfill emplacement was analyzed similarly to an unmechanized shrinkage mine. This facilitated the complexity of departmental requirements for safety of operations.

2.4 WIPP Waste Operations Emplacement Cost Estimation Methodology

The cost estimation for the impacts associated with the WIPP operations only analyzed the incremental costs to the actual activities associated with waste handling and emplacement. These impacts provide a measure of the planning necessary to implementing an EA.

For each of the EAs and configuration (i.e., decentralized, regionalized, or centralized) the throughput of the waste was determined in order to handle and emplace the waste at WIPP. The throughput rate was based on the number of transported waste shipments that were to be handled at WIPP. The waste work-off and repository configuration is analyzed and accounted for to determine additional equipment requirements or modifications. The next parameter is to determine the manpower necessary to handle the waste. Guidance was provided (Palanca, 1995) in order to determine the size of a crew and the waste handling capacity.

The number of waste shipments to the WIPP was determined based on the methodology for transportation (see Section 2.2) The throughput rate was calculated by applying the number of shipments to the operational period of the WIPP. The waste transported to the WIPP site had to meet the time constraint of a 35 year operational life for the treatment and emplacement. The alternatives that required waste treatment would not have waste available for approximately 10 years, which only allows 25 years for transportation and emplacement. Additionally, the manpower requirements for the waste handling operation were given as three possible crews based on the throughput rate. The capital equipment requirement was estimated and totaled for the applicable EA.

Calculation of the WIPP handling cost estimation was developed utilizing a spreadsheet format that applied the capital requirements and the throughput rate of the waste to the manpower requirement. The cost was calculated for each EA and configuration. A comparative analysis was performed to the baseline decentralized EA.

3.0 ASSUMPTIONS AND DATA FOR FACTOR 7

Two major sources of data were used for the analysis of cost and schedule:

- The initial retrievable and projected waste volumes were obtained from the WIPP BIR (DOE, 1995d)
- Guidance for process flow diagrams and costing and cost curves were obtained from the draft EM-PEIS (DOE, 1995b).

The major assumptions follow:

- Cited references are the most current information source of the reference subject and the information gathered from these references are correct.
- Mass and volume changes occur during certain processing activities. A summary of the mass and volume changes is presented in Table P-1.

- The volume of waste categorized as "unknown" was processed the same as solid organics and inorganics. However, the mass of unknown waste was assumed to be zero because no information was available regarding the density of the unknown waste and the volume of this waste was small compared to the total volume of waste destined for WIPP.

- Thirty percent of the stored waste at Los Alamos National Laboratory (LANL), Savannah River Site (SRS), INEL/Argonne National Laboratory-West (ANL-W), and Hanford requires retrieval.

- Twenty-five percent of stored sludges at LANL and INEL require re-grouting.

- Waste is treated and or stored according to the site configurations denoted in Table P-2.

- Waste is processed 4,032 hours per year over a 20-year waste treatment facility operating life.

- All waste within a major waste form category (i.e., sludges, solid organic, solid inorganic) can be treated using a specified technology.

- The supercompaction module does not include shredding.

- Costs for supercompaction processing were analyzed as a modified cost module for the WMFCITRUW supercompaction module.

- Costs for a vitrification unit were considered adequate for the costs for a plasma melter.

- Costs for enhanced cement processing are identical to costs for grouting except for material costs.

- Costs for shredding and adding clay are identical to costs for grouting except for material costs.

- Costs for shredding and compacting were analyzed as a modified cost module for supercompaction.

- Transportation of waste to WIPP is either mass or volume limited. The limiting factor determines the number of shipments.

- Costs for a throughput of 0.05 kg/hr or less to any processing module are considered zero.

- Costs are in 1994 dollars and do not take into account escalation or the time value of dollars.

- The operations at WIPP are 35 years. Waste treatment alternatives require 10 years for start-up to turnkey operations.

- The waste emplacement operations at WIPP consists of two eight hour shift operation five days a week.

- EAs 94(a-f) decentralized and regionalized requires 28.6 years of waste emplacement which exceeds the time constraint of 35 years by 3.6 years.

- Both waste handling and backfill is completed in the 35 year operational period.

- Waste emplacement is dependent upon the number of TRUPACT-IIs per day.

- Backfill costs are based on a batch per day (tons) of material that would be emplaced each day.

- Backfill of the rooms does not impact operations.

4.0 RESULTS OF ANALYSIS FOR FACTOR 7

4.1 Process Costing Results

As described in Section 2.1, process costs are calculated using computer program cost models developed for this study. Costs are calculated for each EA in each configuration for CH waste and for decentralized baseline for RH waste. Cost values are based on 1994 cost data and do not take into consideration time value of money or escalation for expenditures occurring during the planning life cycle cost (Feizollahi and Shropshire, 1994). Summaries of these costs are presented in Tables P-3 and P-4. These tables present the summary of process costs for the baseline and each of the different EAs in each of the configurations for CH waste and for the decentralized baseline for RH waste.

Processing schemes for EAs 33, 35(a&b), 83, and 111 are identical to the processing schemes for the baseline for each of the configurations, therefore their processing costs are assumed to be identical to the processing costs for the baseline. The processing scheme for EA 77 (a-d) is the same as the processing scheme for Alternative 1 for each of the configurations; therefore, its processing costs are identical to the process costs for EA 1. EA 33, 35 (a and b), 77 (a through d), 83, and 111 will be omitted from further discussion in this section because they are not unique with respect to processing cost.

The range of processing costs for CH waste varies between $3.2 billion for the centralized baseline and $6.3 billion for decentralized EAs 94(a-f). The process costs for the decentralized EAs are the highest for a specific EA; the process costs for the centralized configuration are the lowest. This was expected because process costs for treatment (maintenance and specific alternative treatments) are applied to a larger number of sites in the decentralized (10 sites) and regionalized (5 sites) configuration as compared to the centralized (1 site) configuration.

The processing costs for the baseline case were least expensive when compared to the EAs; processing costs for EA 94 (a-f) were most expensive. This results from a combination of effects. One explanation for this is that the treatment module throughput values for the baselines are lowest; treatment module throughput values for EA 94 (a-f) are highest. The baseline consists

of treating to the WIPP-Waste Acceptance Criteria (WAC) standards. Treatment to WIPP-WAC entailed shredding and grouting a portion of the existing sludges and all of the projected sludges, along with repackaging waste as necessary to meet transportation and WIPP requirements. In EA 94(a-f) all of the waste was treated in some way by either repackaging, enhanced-cement processing, or shredding and adding clay. Thus, the "treatment" processing throughput for EA 94 (a-f) is higher than the baseline.

The second explanation is that for the shred-and-add-clay and, enhanced-cement cost modules, it was assumed that there were currently no facilities that had these processing capabilities. The result was that the PLCC was applied to all appropriate sites (decentralized, regionalized and centralized configurations) making EA 94 (a-f) more costly than other EAs (e.g EA 1, etc.) where some facilities currently do have a specific processing capability.

Another observation from the information presented in Table P-3 is that after taking the level of uncertainty of the cost estimations plus or minus 30 percent (Section 2.1), that the centralized EA processing costs are approximately the same as compared to the decentralized baseline. The decentralized baseline represents the current strategy for managing CH waste. Thus, a greater benefit may be obtained by implementing a centralized case for the same cost as the current strategy.

The RH process costs for the baseline decentralized configuration is $1.01 billion.

Costs are calculated for each EA in each configuration, for CH waste, on the basis of sites and processing modules. The results of these calculations are presented in Tables P-5 to P-34. Information contained in these tables represent the highest level of cost detail per EA. The purpose of these tables is to present detailed cost for an individual EA not provided in the summary table.

Costs are calculated for each Decentralized, Regionalized and Centralized configurations on the basis of EA ID number and site. The results of these calculations are presented in Tables P-35 to P-37. The purpose of these tables is to provide a comparative view of site costs per EA.

Costs percentages are calculated on the basis of cost percentage of each EA cost attributed to a specific site for each EA. These results are presented in Tables P-38 to P-40. The purpose of these tables is to provide normalized view of the data presented in Tables P-35 to P-37 and in assist in comparing the site costs to each other for all configurations.

Cost percentages are calculated on the basis of cost percentage of the each EA total cost attributed to a specific cost module (front end, retrieval, waste characterization, etc.). The results of these calculations are presented in Tables P-41 to P-43. The purpose off these tables is to present a normalized view of the data presented in Tables P-5 to P-34 and in assist in comparing the module costs to each other for all configurations.

Cost percentages are calculated on the bases of cost percentage of the total cost attributed to a specific area of processing. The results are presented in Tables P-44 to P-46 For the basis of this comparison, the total processing scheme is divided into three sections. The first section is named "Front-End Processing" and is a roll-up of the Front End, Retrieval and Waste Characterization processing modules. The second section is named "Treatment Process" and is a roll-up of the Maintenance and any EA specific treatment modules (e.g. Plasma,

Supercompaction, etc.). The third processing area is named "Back-End Processing" and is a roll-up of the Certification and Shipping, and the Storage modules. The purpose of these tables to determine how costs are distributed throughout the total processing scheme.

Similar results are available for RH waste process cost data. Table P-47 presents the Decentralized Base Case cost per module for each site processing or shipping RH waste. Table P-48 presents the cost percentage of the total cost on a per site basis. Table P-50 presents the costs attributed to each processing module. Table P-49 presents the cost percentages of the total cost attributed to each processing module and lastly, Table P-51 presents the cost percentages attributed to each area of processing (Front End, Treatment and Back End).

4.2 TRU Waste Transportation Cost Estimation Results

This section provides information on the results of the transportation cost estimations for the various EAs. For information regarding the sources and assumptions used to complete transportation cost estimations, refer to Section CS.2.2.

Transportation cost estimations are performed for each configuration and EA. Within the centralized, regionalized, and decentralized configurations, some of the EAs are identical from a transportation standpoint, making the transportation costs for these EAs the same. For example, the centralized configuration provides only one set of transportation requirements because all treatment occurs at the WIPP, making the transportation costs for all centralized EAs the same. Similarly, the regionalized and decentralized EAs that vary backfill options do not provide unique situations to transportation, so these cases have transportation costs equal to those of other EAs. EAs that present transportation with a unique scheme include base case EAs and EAs 1, 6, 10, and 94(a-f).

The transportation scheme chosen has little effect on cost for any given EA. This is clearly demonstrated by the decentralized, regionalized, and centralized base cases. The total costs for transportation of CH-TRU waste are $690 million, $701 million, and $611 million, respectively. The centralized scheme requires that all waste be transported directly from its current site to the WIPP. Even though not treated, the waste must be handled only one time. The regionalized transportation configuration resulted in the highest percentage of waste to be handled twice; once from its storage site to the treatment site, and then on to the WIPP. The decentralized case avoids some of this "double handling" by treating at more sites, allowing more waste to take a more direct route to the WIPP. The overwhelming factor in determining transportation costs, as described below, is the volume of waste being transported.

As explained in Section 2.2, each case is found to be mass-limited. Logically, therefore, the effect each EA has on mass will have a proportional effect on transportation costs. The baseline EA and EA 94(a-f) treat sludges by grouting and enhanced cement, respectively. These are processes that increase the volume of waste. Solid organics and solid inorganics are treated by processes that have little effect on volume in these EAs. These are clearly the two most expensive EAs from a transportation point of view. Transportation of wastes treated with EAs 1, 6, and 10 are less expensive because they reduce volume. EA 6 grouts sludges, which initially increases their volume, but further shredding and compaction of solid wastes reduces volumes by a ratio of approximately 1.3:1. EA 1, which grouts sludges but supercompacts solid wastes,

is less expensive still. Supercompaction reduces solid wastes by a ratio of 2.9:1. EA 10 is the least expensive. It treats waste by plasma melting, reducing volume by a ratio of approximately 3:1.

The transportation costs range from a minimum of $611 million for centralized EA's, which are transported directly to the WIPP, to a maximum of $1,146 million for regionalized EA 94(a-f), which not only increases the original volume of waste by the largest percentage, but also has the highest percentage of "double handled" waste. An estimate to handle RH waste for the decentralized baseline is also prepared. In addition to the $611 million estimated to transport CH waste for this EA, $318.3 million is estimated to transport RH waste. Even though the volume of RH waste is significantly smaller than CH waste, to avoid radionuclide limitations during transportation, a much smaller volume is carried by each shipment. The Transportation Cost Estimation Summary, Table P-52 presents the estimated transportation costs for each EA.

Detailed costs are presented in Tables P-53 to P-77. These tables include site specific information used to calculate total site costs for shipping. This information includes waste destination, CPLM, number of shipments, total miles traveled, fixed cost, variable cost, and total cost. These tables present the costs in the highest level of detail and provide information not otherwise found in Table P-52.

The level of uncertainty in the cost estimates comes from two sources. One, the level of uncertainty in the stored and projected waste volumes in the Baseline Inventory Report (DOE, 1995d) and two, the level of uncertainty in the studies used as guidance to develop the transportation cost estimates. For guidance in estimating transportation costs, a report titled "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials" (Feizollahi and Shropshire, 1994), was contracted by the DOE, and Revision 1 was completed in September, 1994. A report of this nature would be classified as a "study estimate" (Peters and Timmerhaus, 1991), and would have a probable accuracy only within plus or minus 30 percent.

4.3 Backfill Emplacement Cost Results

Backfill emplacement costs were performed for each of the EAs that specified backfill. The cost for emplacement activities was independent to the case of the EA (decentralized, regionalized, centralized) and was only affected by the mass and volume of the backfill. This costs for the EAs were dependent upon the amount and type of backfill that was to be utilized.

Table P-75 (Backfill Emplacement Cost Total Summary) provides a summary of the estimated cost total for each EA. The lowest cost for backfill are EAs 77 (a-d) which consists of the least amount of backfill material due to the reduced room height for waste. The highest cost for backfill are EAs 35 (a-b) and 94c, respectively. This is due to the increased complexity of emplacing a wet (grout) backfill.

Cost of backfill is categorized as a planning cost estimate and has an uncertainty of plus or minus 30 percent. In addition the estimation does not include the cost of the material to be utilized for backfill. It is assumed that backfill materials consisting of salt would utilize the existing mined materials.

4.4 WIPP Waste Operations Emplacement Cost Results

Incremental cost information for the emplacement activities associated with the waste handling at the WIPP are discussed in this section. The discussion includes the assumptions and limitations of the results.

The comparative analysis of the WIPP waste handling and emplacement activities is discussed is shown in Table P-76. The cost of WIPP handling and emplacing the waste is primarily independent of the cases (decentralized, regionalized, centralized) for this cost estimate study. For this estimate there were three waste handling/emplacement crew configuration that were utilized as input for the EAs. The crew sized was dependent upon the number of TRUPACT-IIs that were processed per day as shown in Table P-77. The number of TRUPACT-IIs that were processed was based on the number of waste shipment and the limiting factor of a 35 year operational life for WIPP.

Baseline cost is established based on the required labor to handle and emplace the waste. The EAs 33, 35 (a-b) and 111 have the same comparable cost as the baseline. The EA with the highest handling savings are number 10 and 94 (a-f) in emplacement activities for 25 years instead of 35 years based on 100% processing of waste. This is due to the decrease in the total waste generated by approximately 3:1. EAs 1 and 6 have the same handling savings. EA 77(a-d) has a reduced savings as compared to EA 1. This is due to the reduced room height which does not accommodate the current remote handled underground handling equipment or emplacement configuration.

The limitation of this estimate is that the total WIPP budget is not included in this estimate. The only costs included are labor and anticipated capital equipment or modifications. Additional cost not included in this comparative analysis is the required budget that would be needed to manage and operate the WIPP, departmental management, and any additional research and development. This estimate is only intended to provide a measure of the relative cost savings or burden for an EA.

TABLE P-1

EXISTING TRU FACILITIES

	Waste Processing Functions								
								Treatment[2]	
Site	Retrieve	Waste Char	Front End	Certify/ Ship	Maint	Storage	Grout	Super Cmpct	Plasma
Major Generator/Storage Sites									
ANL-E	–		X		X	X			
Hanf		X	X	X	X	X			
INEL/ ANL-W		X	X	X	X	X			X[3]
LANL		X	X		X	X	X		
LLNL	–	X	X	X	X	X			
Mound	–		X		X				
NTS	–		X		X	X			
ORNL	–	X	X	X	X	X			
RFETS	–	X	X	X	X	X	X	X	
SRS			X		X	X			
Small Quantity Sites									
Ames	–	P	[1]	P	–	–	–	–	–
BCLDP	–	P	[1]	P	–	–	–	–	–
BT	–	P	[1]	P	–	–	–	–	–
ETEC	–	P	[1]	P	–	–	–	–	–
KAPL	–	P	[1]	P	–	–	–	–	–
LBL	–	P	[1]	P	–	–	–	–	–
Pad	–	P	[1]	P	–	–	–	–	–
Pantex	–	P	[1]	P	–	–	–	–	–
SNL	–	P	[1]	P	–	–	–	–	–
U Mo	–	P	[1]	P	–	–	–	–	–
WVDP	–	P	[1]	P	–	–	–	–	–

Notes:
X = Site has existing facilities to perform this function. No credit was given for planned facilities. Costs only include 20 years of O&M and D&D.
– = Site will not require this function.
P = This function will be accomplished utilizing portable equipment.
[1]For sites which will use portable equipment for waste characterization and certification and shipment, it is assumed that existing facilities will be sufficient for administrative purposes.
[2]No facilities exist to treat TRU waste using shred/compact, shred/add clay, or enhanced cement.
[3]It is assumed that the INEL Pit 9 treatment facility will be available to treat stored waste.

TABLE P-2

SITE TRANSFERS FOR THE DECENTRALIZED, REGIONALIZED, AND CENTRALIZED CONFIGURATIONS

Decentralized			Regionalized			Centralized		
Site	CH	RH	Site	CH	RH	Site	CH	RH
ANL-E*	WIPP	ORNL+	ANL-E	SRS	ORNL	ANL-E	WIPP	WIPP
Ames	ANL-E#		Ames	SRS		Ames	WIPP	
BCLDP		ORNL+	BCLDP		ORNL	BCLDP		WIPP
BT	Mound	ORNL+	BT	SRS	ORNL	BT	WIPP	WIPP
ETEC	NTS		ETEC	INEL/ ANL-W		ETEC	WIPP	
INEL/ ANL-W*	WIPP	WIPP	INEL/ ANL-W*	WIPP	Hanford	INEL/ ANL-W	WIPP	WIPP
KAPL	Mound	ORNL+	KAPL	SRS	ORNL	KAPL	WIPP	WIPP
LANL*	WIPP	WIPP	LANL*	WIPP	Hanford	LANL	WIPP	WIPP
LBL	(LLNL)		LBL	Hanford		LBL	WIPP	
LLNL*	WIPP		LLNL	Hanford		LLNL	WIPP	
Mound*	WIPP		Mound	SRS		Mound	WIPP	
MU	ANL-E#		MU	SRS		MU	WIPP	
NTS*	WIPP	WIPP	NTS	INEL/ ANL-W	Hanford	NTS	WIPP	WIPP
ORNL*	WIPP	WIPP	ORNL* (rh)	SRS	WIPP	ORNL	WIPP	WIPP
PA	ORNL		PA	SRS		PA	WIPP	
Pantex	LANL		Pantex	LANL		Pantex	WIPP	
RFETS*	WIPP		RFETS*	WIPP		RFETS	WIPP	
Hanford*	WIPP	WIPP	Hanford*	WIPP	WIPP	Hanford	WIPP	WIPP
SNL/NM	LANL		SNL/NM	LANL		SNL/NM	WIPP	
SRS*	WIPP	WIPP	SRS*	WIPP	ORNL	SRS	WIPP	WIPP

Notes:

* Denotes a processing site.

ORNL+ Remote handled wastes from BCLDP, BT, KAPL, (these are not discussed in the EM-PEIS) and ANL-E should be processed at ORNL instead of Mound because Mound currently does not process or store RH waste.

ANL-E# The EM-PEIS discusses that ANL-E will process and ship their own CH waste, but does not cover Ames and MU, which are closer to ANL-E than ORNL.

(LLNL) EM-PEIS indicates LBL waste will be shipped to Hanford. LBL waste should be shipped to LLNL because it is much closer.

TABLE P-3

CH PROCESS GRAND TOTALS
($K)

Alternative ID #	Decentralized	Regionalized	Centralized
Base Case	3,576,954	3,418,650	3,202,376
1	4,379,357	3,974,696	3,411,991
6	4,117,678	3,757,294	3,329,333
10	5,966,427	4,992,885	3,960,139
33	3,576,954	3,418,650	3,202,376
35 (a&b)	3,576,954	3,418,650	3,202,376
77	4,379,357	3,974,696	3,411,991
83	3,576,954	3,418,650	3,202,376
94 (a-f)	6,301,672	5,502,932	4,217,091
111	3,576,954	3,418,650	3,202,376

TABLE P-4

RH DECENTRALIZED BASELINE COST PER SITE ($K)

Site	Cost
BCLDP	0
BT	0
HANFORD	173,279
INEL/ANL-W	170,849
KAPL	0
LANL	206,932
ORNL	339,190
SRS	121,730
GRAND TOTAL	**1,011,980**

TABLE P-5

CH DECENTRALIZED BASELINE COST SUMMARY ($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,466	119,034	88,819	55,263	15,878	513,712
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,477	14,413	693,385
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,170	101,543	88,819	10,831	4,850	288,556
MOUND	0	50,674	0	101,299	0	14,123	6,405	172,502
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	4,850	171,177
ORNL	0	35,343	47,171	101,772	88,819	10,831	4,850	288,786
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	9,705	461,273
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**284,635**	**1,073,005**	**532,831**	**398,857**	**80,380**	
GRAND TOTAL								**3,576,954**

TABLE P-6

CH DECENTRALIZED ALTERNATIVE ID #1
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,786	119,034	88,819	146,500	55,705	9,388	659,484
INEL/ANL-W	181,977	158,617	50,556	117,412	117,717	134,615	55,708	11,257	827,859
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,920	108,993	76,332	96,559	55,150	7,392	548,034
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	47,274	101,543	88,819	26,162	10,831	4,850	314,822
MOUND	0	50,674	47,199	101,299	0	26,162	14,123	6,405	245,862
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	47,272	101,529	0	26,162	14,123	4,850	244,611
ORNL	0	35,343	47,348	101,772	88,819	26,162	10,831	4,850	315,125
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	30,731	22,617	4,850	317,515
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,015	116,492	0	144,301	71,028	4,850	655,350
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**441,285**	**1,073,005**	**532,831**	**657,355**	**404,089**	**63,546**	
GRAND TOTAL									**4,379,357**

TABLE P-7

CH DECENTRALIZED ALTERNATIVE ID #6
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Shred and Compaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,786	119,034	88,819	83,714	55,705	13,642	600,952
INEL/ANL-W	181,977	158,617	50,556	117,412	117,717	76,923	55,708	13,286	772,196
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,920	108,993	76,332	55,177	55,150	8,896	508,155
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	47,274	101,543	88,819	14,950	10,831	4,850	303,610
MOUND	0	50,674	47,199	101,299	0	14,950	14,123	6,405	234,650
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	47,272	101,529	0	14,950	14,123	4,850	233,399
ORNL	0	35,343	47,348	101,772	88,819	14,950	10,831	4,850	303,913
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	26,661	22,617	4,850	313,444
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,015	116,492	0	82,458	71,028	8,009	596,665
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**441,285**	**1,073,005**	**532,831**	**384,731**	**404,089**	**74,490**	
GRAND TOTAL									**4,117,678**

TABLE P-8

CH DECENTRALIZED ALTERNATIVE ID #10
COST SUMMARY ($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Plasma	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	47,169	101,199	67,478	14,123	4,850	285,494
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	52,787	119,034	501,386	54,724	6,721	921,904
INEL/ANL-W	181,977	158,617	52,384	117,412	267,218	54,390	5,930	837,927
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	49,648	108,993	423,349	42,865	4,850	784,392
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,276	101,543	168,035	10,831	4,850	367,879
MOUND	0	50,674	47,200	101,299	76,105	14,123	6,405	295,807
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	47,272	101,529	163,545	14,123	4,850	381,994
ORNL	0	35,343	47,363	101,819	250,235	10,831	4,850	450,441
PANTEX	0	Portable	0	0	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,960	103,732	360,578	14,808	4,850	567,272
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	52,015	116,492	485,036	68,413	4,850	993,469
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**491,074**	**1,073,051**	**2,762,966**	**379,080**	**53,009**	
GRAND TOTAL								**5,966,427**

TABLE P-9

CH DECENTRALIZED ALTERNATIVE ID #33
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,466	119,034	88,819	55,263	15,878	513,712
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,477	14,413	693,385
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,170	101,543	88,819	10,831	4,850	288,556
MOUND	0	50,674	0	101,299	0	14,123	6,405	172,502
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	4,850	171,177
ORNL	0	35,343	47,171	101,772	88,819	10,831	4,850	288,786
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	9,705	461,273
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**284,635**	**1,073,005**	**532,831**	**398,857**	**80,380**	
GRAND TOTAL								**3,576,954**

TABLE P-10

CH DECENTRALIZED ALTERNATIVE ID #35 (A&B)
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,466	119,034	88,819	55,263	15,878	513,712
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,477	14,413	693,385
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,170	101,543	88,819	10,831	4,850	288,556
MOUND	0	50,674	0	101,299	0	14,123	6,405	172,502
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	4,850	171,177
ORNL	0	35,343	47,171	101,772	88,819	10,831	4,850	288,786
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	9,705	461,273
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**284,635**	**1,073,005**	**532,831**	**398,857**	**80,380**	
GRAND TOTAL								**3,576,954**

TABLE P-11

CH DECENTRALIZED ALTERNATIVE ID #77 (A-D)
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,786	119,034	88,819	146,500	55,705	9,388	659,484
INEL/ANL-W	181,977	158,617	50,556	117,412	117,717	134,615	55,708	11,257	827,859
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,920	108,993	76,332	96,559	55,150	7,392	548,034
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	47,274	101,543	88,819	26,162	10,831	4,850	314,822
MOUND	0	50,674	47,199	101,299	0	26,162	14,123	6,405	245,862
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	47,272	101,529	0	26,162	14,123	4,850	244,611
ORNL	0	35,343	47,348	101,772	88,819	26,162	10,831	4,850	315,125
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	30,731	22,617	4,850	317,515
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,015	116,492	0	144,301	71,028	4,850	655,350
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**441,285**	**1,073,005**	**532,831**	**657,355**	**404,089**	**63,546**	
GRAND TOTAL									**4,379,357**

TABLE P-12

CH DECENTRALIZED ALTERNATIVE ID #83
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,466	119,034	88,819	55,263	15,878	513,712
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,477	14,413	693,385
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,170	101,543	88,819	10,831	4,850	288,556
MOUND	0	50,674	0	101,299	0	14,123	6,405	172,502
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	4,850	171,177
ORNL	0	35,343	47,171	101,772	88,819	10,831	4,850	288,786
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	9,705	461,273
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**284,635**	**1,073,005**	**532,831**	**398,857**	**80,380**	
GRAND TOTAL								**3,576,954**

TABLE P-13

CH DECENTRALIZED ALTERNATIVE #94
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Enhanced Cement	Shred and Add Clay	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	47,169	101,199	92,751	0	14,123	4,850	310,767
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,787	119,034	92,751	500,396	61,239	15,879	1,029,337
INEL/ANL-W	181,977	158,617	52,384	117,412	324,409	348,839	61,865	18,639	1,264,140
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	49,648	108,993	193,928	206,476	72,483	11,102	797,317
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	47,276	101,543	92,751	90,879	10,831	4,850	383,473
MOUND	0	50,674	47,200	101,299	92,751	90,879	14,123	6,405	403,332
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	47,272	101,529	0	90,879	14,123	4,850	309,328
ORNL	0	35,343	47,363	101,819	92,751	90,879	10,831	4,850	383,836
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,960	103,732	92,751	99,766	29,556	4,850	413,958
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,015	116,492	0	484,177	77,132	9,705	1,006,183
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	0	0	0
Module Total	**444,535**	**762,712**	**491,074**	**1,073,051**	**1,074,840**	**2,003,170**	**366,307**	**85,981**	
GRAND TOTAL									**6,301,672**

TABLE P-14

CH DECENTRALIZED ALTERNATIVE #111
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	4,850	170,847
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,466	119,034	88,819	55,263	15,878	513,712
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,477	14,413	693,385
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	47,170	101,543	88,819	10,831	4,850	288,556
MOUND	0	50,674	0	101,299	0	14,123	6,405	172,502
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	4,850	171,177
ORNL	0	35,343	47,171	101,772	88,819	10,831	4,850	288,786
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	9,705	461,273
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**284,635**	**1,073,005**	**532,831**	**398,857**	**80,380**	
GRAND TOTAL								**3,576,954**

TABLE P-15

CH REGIONALIZED BASELINE COST SUMMARY ($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,472	119,034	88,819	55,369	16,141	514,087
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,568	14,545	693,609
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	47,171	116,492	88,819	70,837	10,174	600,156
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**237,471**	**1,073,005**	**444,012**	**401,478**	**55,438**	
GRAND TOTAL								**3,418,650**

TABLE P-16

CH REGIONALIZED ALTERNATIVE ID #1
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,897	119,034	88,819	146,991	55,819	9,541	660,353
INEL/ANL-W	181,977	158,617	50,666	117,412	117,717	135,129	55,808	11,309	828,635
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,923	108,993	76,332	96,719	55,150	7,392	548,196
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	30,731	22,617	4,850	317,515
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,286	116,492	88,819	145,543	71,351	4,912	746,066
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**252,688**	**1,073,005**	**444,012**	**555,112**	**404,626**	**38,005**	
GRAND TOTAL									**3,974,696**

TABLE P-17

CH REGIONALIZED ALTERNATIVE ID #6
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Shred and Compaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,897	119,034	88,819	83,995	55,819	13,867	601,683
INEL/ANL-W	181,977	158,617	50,666	117,412	117,717	77,217	55,808	13,390	772,803
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,923	108,993	76,332	55,268	55,150	8,896	508,249
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	26,661	22,617	4,850	313,444
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,286	116,492	88,819	83,167	71,351	8,406	687,184
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**252,688**	**1,073,005**	**444,012**	**326,307**	**404,626**	**49,409**	
GRAND TOTAL									**3,757,294**

TABLE P-18

CH REGIONALIZED ALTERNATIVE ID #10
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Plasma	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	52,900	119,034	503,717	54,818	6,834	924,555
INEL/ANL-W	181,977	158,617	52,494	117,412	269,074	54,481	5,994	840,048
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	49,651	108,993	423,447	42,865	4,850	784,492
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,819	0	10,831	0	147,993
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,960	103,732	360,578	14,808	4,850	567,272
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	52,309	116,492	491,390	70,837	4,850	1,002,541
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**255,314**	**1,073,051**	**2,048,205**	**381,689**	**27,379**	
GRAND TOTAL								**4,992,885**

TABLE P-19

CH REGIONALIZED ALTERNATIVE ID #33
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,472	119,034	88,819	55,369	16,141	514,087
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,568	14,545	693,609
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	47,171	116,492	88,819	70,837	10,174	600,156
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	**444,535**	**762,712**	**237,471**	**1,073,005**	**444,012**	**401,478**	**55,438**	
GRAND TOTAL								**3,418,650**

TABLE P-20

CH REGIONALIZED ALTERNATIVE ID #35
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,472	119,034	88,819	55,369	16,141	514,087
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,568	14,545	693,609
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	47,171	116,492	88,819	70,837	10,174	600,156
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	237,471	1,073,005	444,012	401,478	55,438	
GRAND TOTAL								3,418,650

TABLE P-21

CH REGIONALIZED ALTERNATIVE ID #77 (A-D)
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,897	119,034	88,819	146,991	55,819	9,541	660,353
INEL/ANL-W	181,977	158,617	50,666	117,412	117,717	135,129	55,808	11,309	828,635
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	48,923	108,993	76,332	96,719	55,150	7,392	548,196
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,916	103,732	72,326	30,731	22,617	4,850	317,515
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,286	116,492	88,819	145,543	71,351	4,912	746,066
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	252,688	1,073,005	444,012	555,112	404,626	38,005	
GRAND TOTAL									3,974,696

TABLE P-22

CH REGIONALIZED ALTERNATIVE ID #83
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,472	119,034	88,819	55,369	16,141	514,087
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,568	14,545	693,609
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	47,171	116,492	88,819	70,837	10,174	600,156
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	237,471	1,073,005	444,012	401,478	55,438	
GRAND TOTAL								**3,418,650**

TABLE P-23

CH REGIONALIZED ALTERNATIVE ID #94
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Enhanced Cement	Shred and Add Clay	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	52,900	119,034	92,751	503,907	61,467	16,146	1,033,457
INEL/ANL-W	181,977	158,617	52,494	117,412	324,409	358,409	62,079	18,757	1,274,152
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	49,651	108,993	193,928	206,816	72,483	11,102	797,660
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,819	0	0	10,831	0	147,993
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	47,960	103,732	92,751	99,766	29,556	4,850	413,958
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	52,309	116,492	92,751	493,433	77,850	10,229	1,109,726
WIPP	0	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	255,314	1,073,051	796,588	1,662,331	447,315	61,084	
GRAND TOTAL									**5,502,932**

TABLE P-24

CH REGIONALIZED ALTERNATIVE ID #111
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	47,472	119,034	88,819	55,369	16,141	514,087
INEL/ANL-W	181,977	158,617	47,773	117,412	117,717	55,568	14,545	693,609
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	47,604	108,993	76,332	53,714	9,727	451,057
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	47,450	103,732	72,326	22,109	4,850	285,810
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	47,171	116,492	88,819	70,837	10,174	600,156
WIPP	0	0	0	0	0	0	0	0
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	237,471	1,073,005	444,012	401,478	55,438	
GRAND TOTAL								**3,418,650**

TABLE P-25

CH CENTRALIZED BASELINE COST SUMMARY ($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	48,815	162,552	236,513	88,797	6,405	543,082
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	48,815	1,235,557	236,513	467,839	6,405	
GRAND TOTAL								3,202,376

TABLE P-26

CH CENTRALIZED ALTERNATIVE ID #1
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	0	42,827	0	306,507
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	0	68,413	0	451,568
WIPP	0	0	64,032	162,552	236,513	192,869	90,325	6,405	752,697
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	64,032	1,235,557	236,513	192,869	469,368	6,405	
GRAND TOTAL									3,411,991

TABLE P-27

CH CENTRALIZED ALTERNATIVE ID #6
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Shred and Compaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	0	42,827	0	306,507
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	0	68,413	0	451,568
WIPP	0	0	64,032	162,552	236,513	110,211	90,325	6,405	670,039
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	64,032	1,235,557	236,513	110,211	469,368	6,405	
GRAND TOTAL									**3,329,333**

TABLE P-28

CH CENTRALIZED ALTERNATIVE ID #10
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Plasma	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,819	0	10,831	0	147,993
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	66,658	162,599	979,888	85,247	6,405	1,300,797
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	66,658	1,235,650	979,888	464,290	6,405	
GRAND TOTAL								3,960,139

TABLE P-29

CH CENTRALIZED ALTERNATIVE ID #33
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	48,815	162,552	236,513	88,797	6,405	543,082
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	48,815	1,235,557	236,513	467,839	6,405	
GRAND TOTAL								3,202,376

TABLE P-30

CH CENTRALIZED ALTERNATIVE ID #35 (A & B)
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	48,815	162,552	236,513	88,797	6,405	543,082
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	48,815	1,235,557	236,513	467,839	6,405	
GRAND TOTAL								3,202,376

TABLE P-31

CH CENTRALIZED ALTERNATIVE ID #77 (A-D)
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Supercompaction	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	0	42,827	0	306,507
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	0	68,413	0	451,568
WIPP	0	0	64,032	162,552	236,513	192,869	90,325	6,405	752,697
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	64,032	1,235,557	236,513	192,869	469,368	6,405	
GRAND TOTAL									**3,411,991**

TABLE P-32

CH CENTRALIZED ALTERNATIVE ID #83
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	48,815	162,552	236,513	88,797	6,405	543,082
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	48,815	1,235,557	236,513	467,839	6,405	
GRAND TOTAL								3,202,376

TABLE P-33

CH CENTRALIZED ALTERNATIVE ID #94
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Enhanced Cement	Shred and Add Clay	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	0	14,123	0	165,997
BT	0	Portable	0	A	0	0	Portable	0	0
ETEC	0	Portable	0	A	0	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	0	42,827	0	306,507
LBL	0	Portable	0	A	0	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	0	14,123	0	166,096
MU	0	Portable	0	A	0	0	Portable	0	0
NTS	0	50,674	0	101,529	0	0	14,123	0	166,327
ORNL	0	35,343	0	101,819	0	0	10,831	0	147,993
PANTEX	0	Portable	0	A	0	0	Portable	0	0
PA	0	Portable	0	A	0	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	0	68,413	0	451,568
WIPP	0	0	66,658	162,599	498,895	708,036	115,157	6,405	1,557,749
PORTABLE	0	B	0	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	66,658	1,235,650	498,895	708,036	494,200	6,405	
GRAND TOTAL									4,217,091

TABLE P-34

CH CENTRALIZED ALTERNATIVE ID #111
COST SUMMARY
($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
AMES LAB	0	Portable	0	A	0	Portable	0	0
ANL-E	0	50,674	0	101,199	0	14,123	0	165,997
BT	0	Portable	0	A	0	Portable	0	0
ETEC	0	Portable	0	A	0	Portable	0	0
HANFORD	80,387	106,865	0	119,034	0	54,724	0	361,010
INEL/ANL-W	181,977	158,617	0	117,412	0	54,390	0	512,395
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	77,468	77,219	0	108,993	0	42,827	0	306,507
LBL	0	Portable	0	A	0	Portable	0	0
LLNL	0	35,343	0	101,543	0	10,831	0	147,717
MOUND	0	50,674	0	101,299	0	14,123	0	166,096
MU	0	Portable	0	A	0	Portable	0	0
NTS	0	50,674	0	101,529	0	14,123	0	166,327
ORNL	0	35,343	0	101,772	0	10,831	0	147,946
PANTEX	0	Portable	0	A	0	Portable	0	0
PA	0	Portable	0	A	0	Portable	0	0
RFETS	0	35,343	0	103,732	0	14,808	0	153,883
SNL/NM	0	Portable	0	A	0	Portable	0	0
SRS	104,703	161,960	0	116,492	0	68,413	0	451,568
WIPP	0	0	48,815	162,552	236,513	88,797	6,405	543,082
PORTABLE	0	B	0	0	0	79,848	0	79,848
Module Total	444,535	762,712	48,815	1,235,557	236,513	467,839	6,405	
GRAND TOTAL								3,202,376

TABLE P-35

DECENTRALIZED CONFIGURATION
CH ALTERNATIVE COST PER SITE
COST SUMMARY
($K)

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	170,847	170,847	170,847	285,494	170,847	170,847	170,847	170,847	170,847	310,767	170,847
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	513,712	659,484	600,952	921,904	513,712	513,712	513,712	659,484	513,712	1,029,337	513,712
INEL/ANL-W	693,385	827,859	772,196	837,927	693,385	693,385	693,385	827,859	693,385	1,264,140	693,385
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	451,057	548,034	508,155	784,392	451,057	451,057	451,057	548,034	451,057	797,317	451,057
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	288,556	314,822	303,610	367,879	288,556	288,556	288,556	314,822	288,556	383,473	288,556
MOUND	172,502	245,862	234,650	295,807	172,502	172,502	172,502	245,862	172,502	403,332	172,502
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	171,177	244,611	233,399	381,994	171,177	171,177	171,177	244,611	171,177	309,328	171,177
ORNL	288,786	315,125	303,913	450,441	288,786	288,786	288,786	315,125	288,786	383,836	288,786
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	285,810	317,515	313,444	567,272	285,810	285,810	285,810	317,515	285,810	413,958	285,810
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	461,273	655,350	596,665	993,469	461,273	461,273	461,273	655,350	461,273	1,006,183	461,273
WIPP	0	0	0	0	0	0	0	0	0	0	0
PORTABLE	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	0	79,848
GRAND TOTAL	3,576,954	4,379,357	4,117,678	5,966,427	3,576,954	3,576,954	3,576,954	4,379,357	3,576,954	6,301,672	3,576,954

TABLE P-36

REGIONALIZED CONFIGURATION
CH ALTERNATIVE COST PER SITE
COST SUMMARY
($K)

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	514,087	660,353	601,683	924,555	514,087	514,087	514,087	660,353	514,087	1,033,457	514,087
INEL/ANL-W	693,609	828,635	772,803	840,048	693,609	693,609	693,609	828,635	693,609	1,274,152	693,609
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	451,057	548,196	508,249	784,492	451,057	451,057	451,057	548,196	451,057	797,660	451,057
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717
MOUND	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327
ORNL	147,946	147,946	147,946	147,993	147,946	147,946	147,946	147,946	147,946	147,993	147,946
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	285,810	317,515	313,444	567,272	285,810	285,810	285,810	317,515	285,810	413,958	285,810
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	600,156	746,066	687,184	1,002,541	600,156	600,156	600,156	746,066	600,156	1,109,726	600,156
WIPP	0	0	0	0	0	0	0	0	0	0	0
PORTABLE	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848
GRAND TOTAL	3,418,650	3,974,696	3,757,294	4,992,885	3,418,650	3,418,650	3,418,650	3,974,696	3,418,650	5,502,932	3,418,650

TABLE P-37

CENTRALIZED CONFIGURATION
CH ALTERNATIVE COST PER SITE
COST SUMMARY
($K)

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997	165,997
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	361,010	361,010	361,010	361,010	361,010	361,010	361,010	361,010	361,010	361,010	361,010
INEL/ANL-W	512,395	512,395	512,395	512,395	512,395	512,395	512,395	512,395	512,395	512,395	512,395
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	306,507	306,507	306,507	306,507	306,507	306,507	306,507	306,507	306,507	306,507	306,507
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717	147,717
MOUND	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096	166,096
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327	166,327
ORNL	147,946	147,946	147,946	147,993	147,946	147,946	147,946	147,946	147,946	147,993	147,946
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	153,883	153,883	153,883	153,883	153,883	153,883	153,883	153,883	153,883	153,883	153,883
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	451,568	451,568	451,568	451,568	451,568	451,568	451,568	451,568	451,568	451,568	451,568
WIPP	543,082	752,697	670,039	1,300,797	543,082	543,082	543,082	752,697	543,082	1,557,749	543,082
PORTABLE	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848	79,848
GRAND TOTAL	3,202,376	3,411,991	3,329,333	3,960,139	3,202,376	3,202,376	3,202,376	3,411,991	3,202,376	4,217,091	3,202,376

TABLE P-38

DECENTRALIZED CONFIGURATION
CH COST PERCENT PER SITE

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	5	4	4	5	5	5	5	4	5	5	5
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	14	15	15	15	14	14	14	15	14	16	14
INEL/ANL-W	19	19	19	14	19	19	19	19	19	20	19
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	13	13	12	13	13	13	13	13	13	13	13
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	8	7	7	6	8	8	8	7	8	6	8
MOUND	5	6	6	5	5	5	5	6	5	6	5
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	5	6	6	6	5	5	5	6	5	5	5
ORNL	8	7	7	8	8	8	8	7	8	6	8
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	8	7	8	10	8	8	8	7	8	7	8
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	13	15	14	17	13	13	13	15	13	16	13
WIPP	0	0	0	0	0	0	0	0	0	0	0
PORTABLE	2	2	2	1	2	2	2	2	2	0	2
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-39

REGIONALIZED CONFIGURATION
CH COST PERCENT PER SITE

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	5	4	4	3	5	5	5	4	5	3	5
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	15	17	16	19	15	15	15	17	15	19	15
INEL/ANL-W	20	21	21	17	20	20	20	21	20	23	20
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	13	14	14	16	13	13	13	14	13	14	13
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	4	4	4	3	4	4	4	4	4	3	4
MOUND	5	4	4	3	5	5	5	4	5	3	5
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	5	4	4	3	5	5	5	4	5	3	5
ORNL	4	4	4	3	4	4	4	4	4	3	4
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	8	8	8	11	8	8	8	8	8	8	8
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	18	19	18	20	18	18	18	19	18	20	18
WIPP	0	0	0	0	0	0	0	0	0	0	0
PORTABLE	2	2	2	2	2	2	2	2	2	1	2
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-40

CENTRALIZED CONFIGURATION
CH COST PERCENT PER SITE

Site	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
AMES LAB	0	0	0	0	0	0	0	0	0	0	0
ANL-E	5	5	5	4	5	5	5	5	5	4	5
BT	0	0	0	0	0	0	0	0	0	0	0
ETEC	0	0	0	0	0	0	0	0	0	0	0
HANFORD	11	11	11	9	11	11	11	11	11	9	11
INEL/ANL-W	16	15	15	13	16	16	16	15	16	12	16
KAPL	0	0	0	0	0	0	0	0	0	0	0
LANL	10	9	9	8	10	10	10	9	10	7	10
LBL	0	0	0	0	0	0	0	0	0	0	0
LLNL	5	4	4	4	5	5	5	4	5	4	5
MOUND	5	5	5	4	5	5	5	5	5	4	5
MU	0	0	0	0	0	0	0	0	0	0	0
NTS	5	5	5	4	5	5	5	5	5	4	5
ORNL	5	4	4	4	5	5	5	4	5	4	5
PANTEX	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0
RFETS	5	5	5	4	5	5	5	5	5	4	5
SNL/NM	0	0	0	0	0	0	0	0	0	0	0
SRS	14	13	14	11	14	14	14	13	14	11	14
WIPP	17	22	20	33	17	17	17	22	17	37	17
PORTABLE	2	2	2	2	2	2	2	2	2	2	2
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-41

DECENTRALIZED CONFIGURATION
CH COST PERCENT PER MODULE

Module	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End	30	25	26	18	30	30	30	25	30	17	30
Retrieval	12	10	11	7	12	12	12	10	12	7	12
Waste Characterization	21	17	19	13	21	21	21	17	21	12	21
Maintenance	8	10	11	8	8	8	8	10	8	8	8
Grout	15	12	13	0	15	15	15	12	15	0	15
Supercompact	0	15	0	0	0	0	0	15	0	0	0
Shred & Compact	0	0	9	0	0	0	0	0	0	0	0
Plasma	0	0	0	46	0	0	0	0	0	0	0
Enhanced Cement	0	0	0	0	0	0	0	0	0	17	0
Shred & Add Clay	0	0	0	0	0	0	0	0	0	32	0
Certification & Shipping	11	9	10	6	11	11	11	9	11	6	11
Storage	2	1	2	1	2	2	2	1	2	1	2
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-42

REGIONALIZED CONFIGURATION
CH COST PERCENT PER MODULE

Module	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End	31	27	29	21	31	31	31	27	31	19	31
Retrieval	13	11	12	9	13	13	13	11	13	8	13
Waste Characterization	22	19	20	15	22	22	22	19	22	14	22
Maintenance	7	6	7	5	7	7	7	6	7	5	7
Grout	13	11	12	0	13	13	13	11	13	0	13
Supercompact	0	14	0	0	0	0	0	14	0	0	0
Shred & Compact	0	0	9	0	0	0	0	0	0	0	0
Plasma	0	0	0	41	0	0	0	0	0	0	0
Enhanced Cement	0	0	0	0	0	0	0	0	0	14	0
Shred & Add Clay	0	0	0	0	0	0	0	0	0	30	0
Certification & Shipping	12	10	11	8	12	12	12	10	12	8	12
Storage	2	1	1	1	2	2	2	1	2	1	2
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-43

CENTRALIZED CONFIGURATION
CH COST PERCENT PER MODULE

Module	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End	39	36	37	31	39	39	39	36	39	29	39
Retrieval	14	13	13	11	14	14	14	13	14	11	14
Waste Characterization	24	22	23	19	24	24	24	22	24	18	24
Maintenance	2	2	2	2	2	2	2	2	2	2	2
Grout	7	7	7	0	7	7	7	7	7	0	7
Supercompact	0	6	0	0	0	0	0	6	0	0	0
Shred & Compact	0	0	3	0	0	0	0	0	0	0	0
Plasma	0	0	0	25	0	0	0	0	0	0	0
Enhanced Cement	0	0	0	0	0	0	0	0	0	12	0
Shred & Add Clay	0	0	0	0	0	0	0	0	0	17	0
Certification & Shipping	15	14	14	12	15	15	15	14	15	12	15
Storage	0	0	0	0	0	0	0	0	0	0	0
Sum	100	100	100	100	100	100	100	100	100	100	100

TABLE P-44

DECENTRALIZED CONFIGURATION
CH COST PERCENT PER AREA OF PROCESSING

Area of Processing	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End Processing[1]	64	52	55	38	64	64	64	52	64	36	64
Treatment[2]	23	37	33	55	23	23	23	37	23	57	23
Back End Processing[3]	13	11	12	7	13	13	13	11	13	7	13
Sum	100	100	100	100	100	100	100	100	100	100	100

[1]Front End processing includes Front End, Retrieval, and Waste Characterization Modules.
[2]Treatment includes Maintenance and specific alternative treatment modules (e.g., Plasma, Grout, etc.).
[3]Back End processing includes Certification and Shipping and Storage Modules.

TABLE P-45

REGIONALIZED CONFIGURATION
CH COST PERCENT PER AREA OF PROCESSING

Area of Processing	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End Processing[1]	67	57	61	46	67	67	67	57	67	41	67
Treatment[2]	20	31	27	46	20	20	20	31	20	49	20
Back End Processing[3]	13	11	12	8	13	13	13	11	13	9	13
Sum	100	100	100	100	100	100	100	100	100	100	100

[1]Front End processing includes Front End, Retrieval, and Waste Characterization Modules.
[2]Treatment includes Maintenance and specific alternative treatment modules (e.g., Plasma, Grout, etc.).
[3]Back End processing includes Certification and Shipping and Storage Modules.

TABLE P-46

CENTRALIZED CONFIGURATION
CH COST PERCENT PER AREA OF PROCESSING

Area of Processing	Base Case	1	6	10	33	35 (a&b)	60	77 (a-d)	83	94 (a-f)	111
Front End Processing[1]	76	72	73	62	76	76	76	72	76	58	76
Treatment[2]	9	14	12	26	9	9	9	14	9	30	9
Back End Processing[3]	15	14	14	12	15	15	15	14	15	12	15
Sum	100	100	100	100	100	100	100	100	100	100	100

[1]Front End processing includes Front End, Retrieval, and Waste Characterization Modules.
[2]Treatment includes Maintenance and specific alternative treatment modules (e.g., Plasma, Grout, etc.).
[3]Back End processing includes Certification and Shipping and Storage Modules.

TABLE P-47

RH DECENTRALIZED BASELINE COST SUMMARY ($K)

Site	Retrieval	Waste Characterization	Maintenance	Front End	Grouting	Certification and Shipping	Storage	Site Total
BCLDP	0	Portable	0	A	0	Portable	0	0
BT	0	Portable	0	A	0	Portable	0	0
HANFORD	0	50,674	0	102,076	0	14,123	6,405	173,279
INEL/ANL-W	0	50,674	0	101,201	0	14,123	4,850	170,849
KAPL	0	Portable	0	A	0	Portable	0	0
LANL	34,458	50,674	0	101,272	0	14,123	6,405	206,932
ORNL	0	50,674	57,884	101,501	108,602	14,123	6,405	339,190
SRS	0	0	0	101,202	0	14,123	6,405	121,730
Portable	0	B	0	0	0	C	0	0
Module Total	34,458	202,697	57,884	507,251	108,602	70,617	30,471	
GRAND TOTAL								1,011,980

TABLE P-48

RH DECENTRALIZED BASELINE COST PERCENTAGE BY SITE

Site	Cost Percentage
BCLDP	0
BT	0
HANFORD	17
INEL/ANL-W	17
KAPL	0
LANL	20
ORNL	34
SRS	12
Sum	100

TABLE P-49

RH DECENTRALIZED BASELINE COST PER MODULE ($K)

Module	Cost
Front End	507,251
Retrieval	34,458
Waste Characterization	202,697
Maintenance	57,884
Grout	108,602
Certification & Shipping	70,617
Storage	30,471
GRAND TOTAL	1,011,980

TABLE P-50

RH DECENTRALIZED BASELINE COST PERCENTAGE PER MODULE

Module	Cost Percentage
Front End	50
Retrieval	3
Waste Characterization	20
Maintenance	6
Grout	11
Certification and Shipping	7
Storage	3
Sum	100

TABLE P-51

RH DECENTRALIZED BASELINE COST PERCENTAGE PER PROCESSING AREA

Processing Area	Cost Percentage
Front End Processing[1]	74
Treatment[2]	16
Back End Processing[3]	10
Sum	100

[1]Front End processing includes Front End, Retrieval, and Waste Characterization Modules.
[2]Treatment includes Maintenance and specific alternative treatment modules (e.g., Plasma, Grout, etc.).
[3]Back End processing includes Certification and Shipping and Storage Modules.

TABLE P-52

TRANSPORTATION COST GRAND TOTAL SUMMARY

	Number of Shipments	Total Miles Traveled	Fixed Costs($K)	Variable Costs($K)	Total Costs($K)
CH Centralized Baseline	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 1	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 6	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 10	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 33	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 35	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 60	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 77	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 83	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 94	17,662	47,388,994	163,550	446,272	609,822
CH Centralized Alternative 111	17,662	47,388,994	163,550	446,272	609,822
CH Regionalized Baseline	18,045	48,001,334	167,097	452,756	619,852
CH Regionalized Alternative 1	10,539	26,366,812	97,591	249,770	347,361
CH Regionalized Alternative 6	15,576	40,837,024	144,234	385,541	529,775
CH Regionalized Alternative 10	5,593	14,831,054	51,791	140,129	191,920
CH Regionalized Alternative 33	18,045	48,001,334	167,097	452,756	619,852
CH Regionalized Alternative 35	18,045	48,001,334	167,097	452,756	619,852
CH Regionalized Alternative 60	18,045	48,001,334	167,097	452,756	619,852
CH Regionalized Alternative 77	10,539	26,366,812	97,591	249,770	347,361
CH Regionalized Alternative 83	18,045	48,001,334	167,097	452,756	619,852
CH Regionalized Alternative 94	18,526	48,425,946	171,551	456,701	628,252
CH Regionalized Alternative 111	18,045	48,001,334	167,097	452,756	619,852
CH Decentralized Baseline	17,690	47,397,822	163,809	446,380	610,190
RH Decentralized Baseline	7,958	26,210,998	73,691	244,610	318,301
CH Decentralized Alternative 1	10,182	25,845,272	94,285	244,174	338,459
CH Decentralized Alternative 6	15,227	40,280,216	141,002	379,625	520,627
CH Decentralized Alternative 10	5,237	14,331,254	48,495	134,734	183,229
CH Decentralized Alternative 33	17,690	47,397,822	163,809	446,380	610,190
CH Decentralized Alternative 35	17,690	47,397,822	163,809	446,380	610,190
CH Decentralized Alternative 60	17,690	47,397,822	163,809	446,380	610,190
CH Decentralized Alternative 77	10,182	25,845,272	94,285	244,174	338,459
CH Decentralized Alternative 83	17,690	47,397,822	163,809	446,380	610,190
CH Decentralized Alternative 94	18,181	47,862,978	168,356	450,731	619,087
CH Decentralized Alternative 111	17,690	47,397,822	163,809	446,380	610,190

TABLE P-53

CH DECENTRALIZED BASELINE TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM2 ($/mile)	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	7	20,370	65	190	254
BT	MOUND	289	10.87	17	9,826	157	107	264
ETEC	NTS	375	10.87	2	1,500	19	16	35
HANFORD	WIPP	1,808	9.31	5,712	20,654,592	52,893	192,294	245,187
INEL/ANL-W	WIPP	1,392	9.31	4,974	13,847,616	46,059	128,921	174,981
KAPL	MOUND	694	10.87	1	1,388	9	15	24
LANL	WIPP	342	10.87	2,839	1,941,876	26,289	21,108	47,397
LBL	LLNL	75	19.65	1	150	9	3	12
LLNL	WIPP	1,452	9.31	137	397,848	1,269	3,704	4,973
MOUND	WIPP	1,557	9.31	47	146,358	435	1,363	1,798
MU	ANL-E	393	10.87	1	786	9	9	18
NTS	WIPP	1,214	9.31	68	165,104	630	1,537	2,167
ORNL	WIPP	1,521	9.31	120	365,040	1,111	3,399	4,510
PANTEX	LANL	335	10.87	1	670	9	7	17
PA	ORNL	317	10.87	1	634	9	7	16
RFETS	WIPP	704	10.87	931	1,310,848	8,621	14,249	22,870
SNL-NM	WIPP	104	19.65	3	624	28	12	40
SRS	WIPP	1,509	9.31	2,827	8,531,886	26,178	79,432	105,610
TOTAL				**17,690**	**47,397,822**	**163,809**	**446,380**	**610,190**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b

Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

TABLE P-54

CH DECENTRALIZED ALTERNATIVE ID #1
TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM2 ($/mile)	Volume (m3)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0	1	0	1	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	30	90	7	10	4	11,640	37	108	145
BT	MOUND	289	10.87	56	167	13	19	7	4,046	65	44	109
ETEC	NTS	375	10.87	3	9	1	2	1	750	9	8	17
HANFORD	WIPP	1,808	9.31	25,688	76,301	5,709	8,305	2,769	10,012,704	25,641	93,218	118,859
INEL/ANL-W	WIPP	1,392	9.31	33,295	98,896	7,399	10,764	3,588	9,988,992	33,225	92,998	126,222
KAPL	MOUND	694	10.87	1	3	1	1	1	1,388	9	15	24
LANL	WIPP	342	10.87	18,257	54,229	4,058	5,903	1,968	1,346,112	18,224	14,632	32,856
LBL	LLNL	75	19.65	2	7	1	1	1	150	9	3	12
LLNL	WIPP	1,452	9.31	601	1,784	134	195	65	188,760	602	1,757	2,359
MOUND	WIPP	1,557	9.31	259	770	58	84	28	87,192	259	812	1,071
MU	ANL-E	393	10.87	1	3	1	1	1	786	9	9	18
NTS	WIPP	1,214	9.31	217	646	49	71	24	58,272	222	543	765
ORNL	WIPP	1,521	9.31	467	1,389	104	152	51	155,142	472	1,444	1,917
PANTEX	LANL	335	10.87	0	1	0	1	1	670	9	7	17
PA	ORNL	317	10.87	2	7	1	1	1	634	9	7	16
RFETS	WIPP	704	10.87	6,061	18,003	1,347	1,960	654	920,832	6,056	10,009	16,065
SNL-NM	WIPP	104	19.65	6	18	2	3	1	208	9	4	13
SRS	WIPP	1,509	9.31	9,427	28,001	2,095	3,048	1,016	3,066,288	9,408	28,547	37,955
TOTAL								**10,182**	**25,845,272**	**94,285**	**244,174**	**338,459**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

TABLE P-55

CH DECENTRALIZED ALTERNATIVE ID #6
TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM2 ($/mile)	Volume (m3)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total
AMES	ANL-E	353	10.87	0	1	0	1	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	34	101	8	12	4	11,640	37	108	145
BT	MOUND	289	10.87	122	361	28	40	14	8,092	130	88	218
ETEC	NTS	375	10.87	7	20	2	3	1	750	9	8	17
HANFORD	WIPP	1,808	9.31	43,809	130,125	9,736	14,163	4,721	17,071,136	43,716	158,932	202,649
INEL/ANL-W	WIPP	1,392	9.31	42,186	125,304	9,375	13,638	4,546	12,656,064	42,096	117,828	159,924
KAPL	MOUND	694	10.87	2	6	1	1	1	1,388	9	15	24
LANL	WIPP	342	10.87	23,787	70,654	5,286	7,690	2,564	1,753,776	23,743	19,064	42,806
LBL	LLNL	75	19.65	5	15	2	3	1	150	9	3	12
LLNL	WIPP	1,452	9.31	1,037	3,082	231	336	112	325,248	1,037	3,028	4,065
MOUND	WIPP	1,557	9.31	549	1,631	122	178	60	186,840	556	1,739	2,295
MU	ANL-E	393	10.87	2	5	1	1	1	786	9	9	18
NTS	WIPP	1,214	9.31	472	1,403	105	153	51	123,828	472	1,153	1,625
ORNL	WIPP	1,521	9.31	883	2,625	197	286	96	292,032	889	2,719	3,608
PANTEX	LANL	335	10.87	0	2	0	1	1	670	9	7	17
PA	ORNL	317	10.87	2	7	1	1	1	634	9	7	16
RFETS	WIPP	704	10.87	7,830	23,259	1,741	2,532	844	1,188,352	7,815	12,917	20,733
SNL-NM	WIPP	104	19.65	13	39	3	5	2	416	19	8	27
SRS	WIPP	1,509	9.31	20,469	60,801	4,549	6,618	2,206	6,657,708	20,428	61,983	82,411
TOTAL								**15,227**	**40,280,216**	**141,002**	**379,625**	**520,627**

[1]Source: ORNL, 1993
2Source: INEL, 1994b
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

TABLE P-56

CH DECENTRALIZED ALTERNATIVE ID #10
TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM2 ($/mile)	Volume (m3)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0	1	0	1	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	11	33	3	4	2	5,820	19	54	73
BT	MOUND	289	10.87	53	157	12	18	6	3,468	56	38	93
ETEC	NTS	375	10.87	3	9	1	2	1	750	9	8	17
HANFORD	WIPP	1,808	9.31	15,934	47,331	3,541	5,152	1,718	6,212,288	15,909	57,836	73,745
INEL/ANL-W	WIPP	1,392	9.31	13,325	39,580	2,962	4,309	1,437	4,000,608	13,307	37,246	50,552
KAPL	MOUND	694	10.87	1	3	1	1	1	1,388	9	15	24
LANL	WIPP	342	10.87	6,979	20,730	1,551	2,257	753	515,052	6,973	5,599	12,571
LBL	LLNL	75	19.65	2	7	1	1	1	150	9	3	12
LLNL	WIPP	1,452	9.31	384	1,142	86	125	42	121,968	389	1,136	1,524
MOUND	WIPP	1,557	9.31	237	705	53	77	26	80,964	241	754	995
MU	ANL-E	393	10.87	1	3	1	1	1	786	9	9	18
NTS	WIPP	1,214	9.31	205	609	46	67	23	55,844	213	520	733
ORNL	WIPP	1,521	9.31	372	1,105	83	121	41	124,722	380	1,161	1,541
PANTEX	LANL	335	10.87	0	1	0	1	1	670	9	7	17
PA	ORNL	317	10.87	1	3	1	1	1	634	9	7	16
RFETS	WIPP	704	10.87	2,062	6,126	459	668	223	313,984	2,065	3,413	5,478
SNL-NM	WIPP	104	19.65	6	17	2	3	1	208	9	4	13
SRS	WIPP	1,509	9.31	8,888	26,401	1,976	2,874	958	2,891,244	8,871	26,917	35,789
TOTAL								**5,237**	**14,331,254**	**48,495**	**134,734**	**183,229**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b

Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

TABLE P-57

CH DECENTRALIZED ALTERNATIVE ID #33
TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM2 ($/mile)	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	7	20,370	65	190	254
BT	MOUND	289	10.87	17	9,826	157	107	264
ETEC	NTS	375	10.87	2	1,500	19	16	35
HANFORD	WIPP	1,808	9.31	5,712	20,654,592	52,893	192,294	245,187
INEL/ANL-W	WIPP	1,392	9.31	4,974	13,847,616	46,059	128,921	174,981
KAPL	MOUND	694	10.87	1	1,388	9	15	24
LANL	WIPP	342	10.87	2,839	1,941,876	26,289	21,108	47,397
LBL	LLNL	75	19.65	1	150	9	3	12
LLNL	WIPP	1,452	9.31	137	397,848	1,269	3,704	4,973
MOUND	WIPP	1,557	9.31	47	146,358	435	1,363	1,798
MU	ANL-E	393	10.87	1	786	9	9	18
NTS	WIPP	1,214	9.31	68	165,104	630	1,537	2,167
ORNL	WIPP	1,521	9.31	120	365,040	1,111	3,399	4,510
PANTEX	LANL	335	10.87	1	670	9	7	17
PA	ORNL	317	10.87	1	634	9	7	16
RFETS	WIPP	704	10.87	931	1,310,848	8,621	14,249	22,870
SNL-NM	WIPP	104	19.65	3	624	28	12	40
SRS	WIPP	1,509	9.31	2,827	8,531,886	26,178	79,432	105,610
TOTAL				**17,690**	**47,397,822**	**163,809**	**446,380**	**610,190**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b

Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

TABLE P-58

CH DECENTRALIZED ALTERNATIVE ID #35 (a & b) TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	1	706	9	8	17
ANL-E	WIPP	1,455	9.31	7	20,370	65	190	254
BT	MOUND	289	10.87	17	9,826	157	107	264
ETEC	NTS	375	10.87	2	1,500	19	16	35
HANFORD	WIPP	1,808	9.31	5,712	20,654,592	52,893	192,294	245,187
INEL/ANL-W	WIPP	1,392	9.31	4,974	13,847,616	46,059	128,921	174,981
KAPL	MOUND	694	10.87	1	1,388	9	15	24
LANL	WIPP	342	10.87	2,839	1,941,876	26,289	21,108	47,397
LBL	LLNL	75	19.65	1	150	9	3	12
LLNL	WIPP	1,452	9.31	137	397,848	1,269	3,704	4,973
MOUND	WIPP	1,557	9.31	47	146,358	435	1,363	1,798
MU	ANL-E	393	10.87	1	786	9	9	18
NTS	WIPP	1,214	9.31	68	165,104	630	1,537	2,167
ORNL	WIPP	1,521	9.31	120	365,040	1,111	3,399	4,510
PANTEX	LANL	335	10.87	1	670	9	7	17
PA	ORNL	317	10.87	1	634	9	7	16
RFETS	WIPP	704	10.87	931	1,310,848	8,621	14,249	22,870
SNL-NM	WIPP	104	19.65	3	624	28	12	40
SRS	WIPP	1,509	9.31	2,827	8,531,886	26,178	79,432	105,610
TOTAL				**17,690**	**47,397,822**	**163,809**	**446,380**	**610,190**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b

Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

Table P-59
CH Decentralized Alternative ID #77 (a-d)
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0.32	119.43	1	0	1	1	2	76.68	A	42	3	1	VOLUME	1	1	706	9	8	17
ANL-E	WIPP	1455	9.31	30.13	23311.75	90	7	10	4	145	160.93	B	35	15	5	MASS	5	15	14550	46	135	182
BT	MOUND	289	10.87	55.96	122052.74	167	13	19	7	322	453.62	XX	14	46	23	MASS	23	46	13294	213	145	357
ETEC	NTS	375	10.87	3.01	6466.58	9	1	2	1	18	446.44	XX	14	4	2	MASS	2	4	1500	19	16	35
HANFORD	WIPP	1808	9.31	25687.77	26934798.08	76301	5709	8305	2769	123499	218.10	D	21	11762	5881	MASS	5881	11762	21265696	54,458	197,984	252,442
INEL/ANL-W	WIPP	1392	9.31	33294.81	26952245.98	98896	7399	10764	3588	160072	168.38	C	28	11434	5717	MASS	5717	11434	15916128	52,939	148,179	201,119
KAPL	MOUND	694	10.87	0.84	1825.80	3	1	1	1	5	452.10	XX	14	2	1	VOLUME	1	1	1388	9	15	24
LANL	WIPP	342	10.87	18257.03	14114042.46	54229	4058	5903	1968	87775	160.80	B	35	7524	2508	MASS	2508	7524	1715472	23,224	18,647	41,871
LBL	LLNL	75	19.65	2.30	4996.08	7	1	1	1	14	452.10	XX	14	2	1	VOLUME	1	1	150	9	3	12
LLNL	WIPP	1452	9.31	600.54	545260.94	1784	134	195	65	2888	188.85	C	28	208	104	MASS	104	208	302016	963	2,812	3,775
MOUND	WIPP	1557	9.31	259.12	386958.46	770	58	84	28	1246	310.62	E	14	178	89	MASS	89	178	277146	824	2,580	3,404
MU	ANL-E	393	10.87	0.75	1626.80	3	1	1	1	5	452.10	XX	14	2	1	VOLUME	1	1	786	9	9	18
NTS	WIPP	1214	9.31	217.42	477750.02	646	49	71	24	1258	457.05	XX	14	180	90	MASS	90	180	218520	833	2,034	2,868
ORNL	WIPP	1521	9.31	467.33	859464.22	1389	104	152	51	2262	382.53	XX	14	324	162	MASS	162	324	492804	1,500	4,588	6,088
PANTEX	LANL	335	10.87	0.22	474.71	1	0	1	1	2	452.10	XX	14	2	1	VOLUME	1	1	670	9	7	17
PA	ORNL	317	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	634	9	7	16
RFP	WIPP	704	10.87	6060.69	5771670.13	18003	1347	1960	654	29138	198.08	C	28	2082	1041	MASS	1041	2082	1465728	9,640	15,932	25,572
SNL-NM	WIPP	104	19.65	5.99	13016.73	18	2	3	1	35	452.10	XX	14	6	3	MASS	3	6	624	28	12	40
SRS	WIPP	1509	9.31	9426.72	21122425.35	28001	2095	3048	1016	55586	466.06	XX	14	7942	3971	MASS	3971	7942	11984478	36,771	111,575	148,347
TOTAL																	19,602	41,711	53,672,290	181,515	504,689	686,204

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-60
CH Decentralized Alternative ID #83
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0.32	119.43	1	0	1	1	2	76.68	A	42	3	1	VOLUME	1	1	706	9	8	17
ANL-E	WIPP	1455	9.31	35.95	22938.06	107	8	12	4	173	132.73	A	42	15	5	MASS	5	15	14550	46	135	182
BT	MOUND	289	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	12716	204	138	342
ETEC	NTS	375	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	1500	19	16	35
HANFORD	WIPP	1808	9.31	54415.83	24828774.58	161632	12093	17592	5864	261615	94.91	A	42	18687	6229	MASS	6229	18687	22524064	57,681	209,699	267,380
INEL/ANL-W	WIPP	1392	9.31	47390.00	25850461.76	140763	10532	15321	5107	227837	113.46	A	42	16275	5425	MASS	5425	16275	15103200	50,236	140,611	190,846
KAPL	MOUND	694	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1388	9	15	24
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	LLNL	75	19.65	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	150	9	3	12
LLNL	WIPP	1452	9.31	1293.18	503804.65	3842	288	419	140	6218	81.03	A	42	447	149	MASS	149	447	432696	1,380	4,028	5,408
MOUND	WIPP	1557	9.31	718.35	352609.62	2134	160	233	78	3454	102.10	A	42	249	83	MASS	83	249	258462	769	2,406	3,175
MU	ANL-E	393	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	786	9	9	18
NTS	WIPP	1214	9.31	621.21	434318.20	1846	139	202	68	2987	145.42	B	35	258	86	MASS	86	258	208808	796	1,944	2,740
ORNL	WIPP	1521	9.31	1127.04	789272.40	3348	251	365	122	5419	145.66	B	35	465	155	MASS	155	465	471510	1,435	4,390	5,825
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	ORNL	317	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	634	9	7	16
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	WIPP	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	26933.46	19202207.74	80001	5986	8708	2903	129488	148.29	B	35	11100	3700	MASS	3700	11100	11166600	34,262	103,961	138,223
TOTAL																	19,974	59,913	53,744,480	184,959	505,929	690,888

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-61
CH Decentralized Alternative ID #94
Transportation Costs

								VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Revised Volume (m^3)	Mass (kg)	Revised Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0.32	0.28	119.43	102.83	1	0	1	1	2	76.68	A	42	3	1	VOLUME	1	0	706	9	8	17
ANL-E	WIPP	1455	9.31	70.51	60.72	66143.70	56953.63	181	14	20	7	292	195.11	C	28	22	11	MASS	11	22	32010	102	298	400
BT	MOUND	289	10.87	159.90	137.68	261072.26	224798.62	409	31	45	15	662	339.61	E	14	96	48	MASS	48	96	27744	444	302	746
ETEC	NTS	375	10.87	8.61	7.41	13832.09	11910.25	23	2	3	1	36	334.23	E	14	6	3	MASS	3	6	2250	28	24	52
HANFORD	WIPP	1808	9.31	54420.36	46859.14	53326437.16	45917208.65	139186	10414	15149	5050	225285	203.82	C	28	16092	8046	MASS	8046	16092	29094336	74,506	270,868	345,374
INEL/ANL-W	WIPP	1392	9.31	68421.44	58914.90	56312806.14	48488648.54	174995	13093	19047	6349	283245	171.19	C	28	20232	10116	MASS	10116	20232	28162944	93,674	262,197	355,871
KAPL	MOUND	694	10.87	2.40	2.07	3905.40	3362.78	7	1	1	1	10	338.47	E	14	2	1	VOLUME	1	1	1388	9	15	24
LANL	WIPP	342	10.87	32641.55	28106.30	26855786.89	23124417.00	83465	6246	9087	3029	135127	171.13	C	28	9652	4826	MASS	4826	9652	3300984	44,689	35,882	80,570
LBL	LLNL	75	19.65	6.57	5.65	10686.68	9201.86	17	2	3	1	28	338.47	E	14	4	2	MASS	2	4	300	19	6	24
LLNL	WIPP	1452	9.31	1313.13	1130.68	1086694.76	935708.31	3359	252	366	122	5436	172.13	C	28	390	195	MASS	195	390	566280	1,806	5,272	7,078
MOUND	WIPP	1557	9.31	736.12	633.84	836930.14	720646.23	1883	141	205	69	3048	236.49	D	21	292	146	MASS	146	292	454644	1,352	4,233	5,585
MU	ANL-E	393	10.87	2.14	1.84	3479.75	2996.27	6	1	1	1	9	338.47	E	14	2	1	VOLUME	1	1	786	9	9	18
NTS	WIPP	1214	9.31	621.21	534.90	1021912.97	879927.36	1589	119	173	58	2572	342.17	E	14	368	184	MASS	184	368	446752	1,704	4,159	5,863
ORNL	WIPP	1521	9.31	1295.19	1115.23	1926718.19	1659018.03	3313	248	361	121	5362	309.42	E	14	766	383	MASS	383	766	1165086	3,547	10,847	14,394
PANTEX	LANL	335	10.87	0.62	0.54	1015.40	874.32	2	0	1	1	3	338.47	E	14	2	1	VOLUME	1	0	670	9	7	17
PA	ORNL	317	10.87	5.25	4.52	8367.75	7205.13	14	2	2	1	22	331.52	E	14	4	2	MASS	2	4	1268	19	14	32
RFP	WIPP	704	10.87	9148.83	7877.68	8458950.48	7283655.45	23400	1751	2547	849	37874	192.32	C	28	2706	1353	MASS	1353	2706	1905024	12,529	20,708	33,236
SNL-NM	WIPP	104	19.65	17.11	14.73	27842.94	23974.41	44	4	6	2	71	338.47	E	14	12	6	MASS	6	12	1248	56	25	80
SRS	WIPP	1509	9.31	26933.49	23191.32	45181150.31	38903636.11	68886	5154	7498	2500	111497	348.92	E	14	15930	7965	MASS	7965	15930	24038370	73,756	223,797	297,553
TOTAL																			**33,290**	**66,574**	**89,202,790**	**308,265**	**838,670**	**1,146,935**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Revised Mass and Volume Scaling Factor:0.861059

Table P-62
CH Decentralized Alternative ID #111
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-WayMileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	ANL-E	353	10.87	0.32	119.43	1	0	1	1	2	76.68	A	42	3	1	VOLUME	1	1	706	9	8	17
ANL-E	WIPP	1455	9.31	35.95	22938.06	107	8	12	4	173	132.73	A	42	15	5	MASS	5	15	14550	46	135	182
BT	MOUND	289	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	12716	204	138	342
ETEC	NTS	375	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	1500	19	16	35
HANFORD	WIPP	1808	9.31	54415.83	24828774.58	161632	12093	17592	5864	261615	94.91	A	42	18687	6229	MASS	6229	18687	22524064	57,681	209,699	267,380
INEL/ANL-W	WIPP	1392	9.31	47390.00	25850461.76	140763	10532	15321	5107	227837	113.46	A	42	16275	5425	MASS	5425	16275	15103200	50,236	140,611	190,846
KAPL	MOUND	694	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1388	9	15	24
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	LLNL	75	19.65	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	150	9	3	12
LLNL	WIPP	1452	9.31	1293.18	503804.65	3842	268	419	140	6218	81.03	A	42	447	149	MASS	149	447	432696	1,380	4,028	5,408
MOUND	WIPP	1557	9.31	718.35	352609.62	2134	160	233	78	3454	102.10	A	42	249	83	MASS	83	249	258462	769	2,406	3,175
MU	ANL-E	393	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	786	9	9	18
NTS	WIPP	1214	9.31	621.21	434318.20	1846	139	202	68	2987	145.42	B	35	258	86	MASS	86	258	208808	796	1,944	2,740
ORNL	WIPP	1521	9.31	1127.04	789272.40	3348	251	365	122	5419	145.66	B	35	465	155	MASS	155	465	471510	1,435	4,390	5,825
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	ORNL	317	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	634	9	7	16
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	WIPP	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	26933.46	19202207.74	80001	5986	8708	2903	129488	148.29	B	35	11100	3700	MASS	3700	11100	11166600	34,262	103,961	138,223
TOTAL																	**19,974**	**59,913**	**53,744,480**	**184,959**	**505,929**	**690,888**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-63
CH Regionalized Baseline
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55709.01	25332579.23	165473	12380	18010	6004	267832	94.58	A	42	19131	6377	MASS	6377	19131	23059232	59,051	214,681	273,732
INEL/ANL-W	WIPP	1392	9.31	48011.21	26284779.96	142608	10670	15522	5174	230824	113.87	A	42	16488	5496	MASS	5496	16488	15300864	50,893	142,451	193,344
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	28814.79	20367027.82	85589	6404	9316	3106	138533	147.02	B	35	11877	3959	MASS	3959	11877	11948262	36,660	111,238	147,899
TOTAL																	20,356	61,058	54,395,038	188,497	512,795	701,291

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-64
CH Regionalized Alternative ID #1
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	26288.31	27480059.02	78085	5842	8499	2833	126387	217.43	D	21	12038	6019	MASS	6019	12038	21764704	55,736	202,629	258,365
INEL/ANL-W	WIPP	1392	9.31	33512.23	27429996.01	99542	7448	10835	3612	161117	170.25	C	28	11510	5755	MASS	5755	11510	16021920	53,291	149,164	202,455
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	18257.03	14114042.46	54229	4058	5903	1968	87775	160.80	B	35	7524	2508	MASS	2508	7524	1715472	23,224	18,647	41,871
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	6060.69	5771670.13	18003	1347	1960	654	29138	198.08	C	28	2082	1041	MASS	1041	2082	1465728	9,640	15,932	25,572
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	10183.30	22392159.78	30248	2263	3293	1098	58927	457.37	XX	14	8420	4210	MASS	4210	8420	12705780	38,985	118,291	157,275
TOTAL																	19,948	42,809	54,214,868	184,718	510,549	695,268

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-65
CH Regionalized Alternative ID #6
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	44845.98	27480059.02	133206	9966	14498	4833	215606	127.46	A	42	15402	5134	MASS	5134	15402	18564544	47,541	172,836	220,377
INEL/ANL-W	WIPP	1392	9.31	42657.74	27429996.01	126707	9480	13791	4597	205086	133.75	A	42	14649	4883	MASS	4883	14649	13594272	45,217	126,563	171,779
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	23786.64	14114042.46	70654	5286	7690	2564	114359	123.42	A	42	8169	2723	MASS	2723	8169	1862532	25,215	20,246	45,461
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	7830.33	5771670.13	23259	1741	2532	844	37646	153.32	B	35	3228	1076	MASS	1076	3228	1515008	9,964	16,468	26,432
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	21935.47	22392159.78	65155	4875	7092	2364	105460	212.33	D	21	10044	5022	MASS	5022	10044	15156396	46,504	141,106	187,610
TOTAL																	**19,253**	**52,727**	**51,234,016**	**178,283**	**483,104**	**661,387**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-66
CH Regionalized Alternative ID #10
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	16318.82	22708067.71	48472	3627	5276	1759	78456	289.44	E	14	11208	5604	MASS	5604	11208	20264064	51,893	188,658	240,551
INEL/ANL-W	WIPP	1392	9.31	13530.24	21099392.64	40189	3007	4375	1459	65050	324.36	E	14	9294	4647	MASS	4647	9294	12937248	43,031	120,446	163,477
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	6979.09	9846783.71	20730	1551	2257	753	33554	293.47	E	14	4794	2397	MASS	2397	4794	1639548	22,196	17,822	40,018
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	786615.97	3342	250	364	122	5409	145.44	B	35	465	155	MASS	155	465	110980	1,435	1,206	2,642
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	2062.25	3151674.56	6126	459	668	223	9915	317.88	E	14	1418	709	MASS	709	1418	998272	6,565	10,851	17,417
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	9508.10	20366033.36	28242	2113	3074	1025	53595	445.53	XX	14	7658	3829	MASS	3829	7658	11555922	35,457	107,586	143,042
TOTAL																	**17,627**	**35,685**	**47,954,934**	**163,226**	**451,451**	**614,677**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg/drum for calculations. Use Shipment Configuration E.

Table P-67
CH Regionalized Alternative ID #33
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55709.01	25332579.23	165473	12380	18010	6004	267832	94.58	A	42	19131	6377	MASS	6377	19131	23059232	59,051	214,681	273,732
INEL/ANL-W	WIPP	1392	9.31	48011.21	26284779.96	142608	10670	15522	5174	230824	113.87	A	42	16488	5496	MASS	5496	16488	15300864	50,893	142,451	193,344
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	28814.79	20367027.82	85589	6404	9316	3106	138533	147.02	B	35	11877	3959	MASS	3959	11877	11948262	36,660	111,238	147,899
TOTAL																	20,356	61,058	54,395,038	188,497	512,795	701,291

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A – Maximum of 42 drums in three TRUPACT-II'S
B – Maximum of 35 drums in three TRUPACT-II's
C – Maximum of 28 drums in two TRUPACT-II's
D – Maximum of 21 drums in two TRUPACT-II's
E – Maximum of 14 drums in two TRUPACT-II's
XX – Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-68
CH Regionalized Alternative ID #35 (a&b)
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55709.01	25332579.23	165,473.00	12380	18010	6004	267832	94.58	A	42	19131	6377	MASS	6377	19131	23059232	59,051	214,681	273,732
INEL/ANL-W	WIPP	1392	9.31	48011.21	26284779.96	142608	10670	15522	5174	230824	113.87	A	42	16488	5496	MASS	5496	16488	15300864	50,893	142,451	193,344
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	28814.79	20367027.82	85589	6404	9316	3106	138533	147.02	B	35	11877	3959	MASS	3959	11877	11948262	36,660	111,238	147,899
TOTAL																	**20,356**	**61,058**	**54,395,038**	**188,497**	**512,795**	**701,291**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.

A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-69
CH Regionalized Alternative ID #77 (a-d)
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[1]	Maximum Number of TRUPACTs[1]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1,190.00	9.31	0.13	37.91	1.00	0.00	1.00	1.00	1.00	60.86	A	42.00	3.00	1.00	VOLUME	1.00	1.00	2,380.00	9.26	22.16	31.42
ANL-E	SRS	877.00	10.87	31.31	20,426.77	93.00	7.00	11.00	4.00	151.00	135.71	A	42.00	12.00	4.00	VOLUME	4.00	11.00	7,016.00	37.04	76.26	113.30
BT	SRS	686.00	10.87	159.90	110,957.04	475.00	36.00	52.00	18.00	769.00	144.34	B	35.00	66.00	22.00	MASS	22.00	66.00	30,184.00	203.72	328.10	531.82
ETEC	INEL/ANL-W	958.00	10.87	8.61	5,878.71	26.00	2.00	3.00	1.00	42.00	142.05	B	35.00	6.00	2.00	MASS	2.00	6.00	3,832.00	18.52	41.65	60.17
HANFORD	WIPP	1,808.00	9.31	26,288.31	27,480,059.02	78,085.00	5,842.00	8,499.00	2,833.00	126,387.00	217.43	D	21.00	12,038.00	6,019.00	MASS	6,019.00	12,038.00	21,764,704.00	55,735.94	202,629.39	258,365.33
INEL/ANL-W	WIPP	1,392.00	9.31	33,512.23	27,429,996.01	99,542.00	7,448.00	10,835.00	3,612.00	161,117.00	170.25	C	28.00	11,510.00	5,755.00	MASS	5,755.00	11,510.00	16,021,920.00	53,291.30	149,164.08	202,455.38
KAPL	SRS	949.00	10.87	2.40	1,659.81	8.00	1.00	2.00	1.00	12.00	143.85	B	35.00	3.00	1.00	VOLUME	1.00	2.00	1,898.00	9.26	20.63	29.89
LANL	WIPP	342.00	10.87	18,257.03	14,114,042.46	54,229.00	4,058.00	5,903.00	1,968.00	87,775.00	160.80	B	35.00	7,524.00	2,508.00	MASS	2,508.00	7,524.00	1,715,472.00	23,224.08	18,647.18	41,871.26
LBL	HANFORD	870.00	10.87	6.57	4,541.89	20.00	2.00	3.00	1.00	32.00	143.85	B	35.00	3.00	1.00	VOLUME	1.00	3.00	1,740.00	9.26	18.91	28.17
LLNL	HANFORD	890.00	10.87	1,158.04	445,343.02	3,440.00	258.00	375.00	125.00	5,568.00	79.99	A	42.00	399.00	133.00	MASS	133.00	399.00	236,740.00	1,231.58	2,573.36	3,804.94
MOUND	SRS	641.00	10.87	263.29	143,644.06	783.00	59.00	86.00	29.00	1,266.00	113.48	A	42.00	93.00	31.00	MASS	31.00	93.00	39,742.00	287.06	432.00	719.06
MU	SRS	863.00	10.87	2.14	1,478.91	7.00	1.00	1.00	1.00	11.00	143.85	B	35.00	3.00	1.00	VOLUME	1.00	1.00	1,726.00	9.26	18.76	28.02
NTS	INEL/ANL-W	713.00	10.87	612.60	428,439.49	1,820.00	137.00	199.00	67.00	2,946.00	145.47	B	35.00	255.00	85.00	MASS	85.00	255.00	121,210.00	787.10	1,317.55	2,104.65
ORNL	SRS	358.00	10.87	1,124.94	728,806.41	3,342.00	250.00	364.00	122.00	5,409.00	134.76	A	42.00	387.00	129.00	MASS	129.00	387.00	92,364.00	1,194.54	1,004.00	2,198.54
PANTEX	LANL	335.00	10.87	0.62	431.55	2.00	0.00	1.00	1.00	3.00	143.85	B	35.00	3.00	1.00	VOLUME	1.00	1.00	670.00	9.26	7.28	16.54
PA	SRS	569.00	10.87	2.10	2,656.43	7.00	1.00	1.00	1.00	11.00	263.11	E	14.00	2.00	1.00	VOLUME	1.00	1.00	1,138.00	9.26	12.37	21.63
RFP	WIPP	704.00	10.87	6,060.69	5,771,670.13	18,003.00	1,347.00	1,960.00	654.00	29,138.00	198.08	C	28.00	2,082.00	1,041.00	MASS	1,041.00	2,082.00	1,465,728.00	9,639.66	15,932.46	25,572.12
SNL-NM	LANL	104.00	19.65	17.11	11,833.39	51.00	4.00	6.00	2.00	83.00	143.85	B	35.00	9.00	3.00	MASS	3.00	9.00	624.00	27.78	12.26	40.04
SRS	WIPP	1,509.00	9.31	10,183.30	22,392,159.78	30,248.00	2,263.00	3,293.00	1,098.00	58,927.00	457.37	XX	14.00	8,420.00	4,210.00	MASS	4,210.00	8,420.00	12,705,780.00	38,984.60	118,290.81	157,275.41
													1,000.00									
TOTAL																	19,948.00	42,809.00	54,214,868.00	184,718.48	510,549.23	695,267.71

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.

A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-70
CH Regionalized Alternative ID #83
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55709.01	25332579.23	165473	12380	18010	6004	267832	94.58	A	42	19131	6377	MASS	6377	19131	23059232	59,051	214,681	273,732
INEL/ANL-W	WIPP	1392	9.31	48011.21	26284779.96	142608	10670	15522	5174	230824	113.87	A	42	16488	5496	MASS	5496	16488	15300864	50,893	142,451	193,344
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	28814.79	20367027.82	85589	6404	9316	3106	138533	147.02	B	35	11877	3959	MASS	3959	11877	11948262	36,660	111,238	147,899
TOTAL																	20,356	61,058	54,395,038	188,497	512,795	701,291

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.

A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-71
CH Regionalized Alternative ID #94
Transportation Costs

								VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Revised Volume (m^3)	Mass (kg)	Revised Mass (kg)	Number of Drums	Number of SWBs	NumberofTRUPACTs	NumberofShipments	Number of Drums	AverageDrumMass (kg)	Shipment Configuration[3]	MaximumDrumsper Shipment[3]	MaximumNumberof TRUPACTs[3]	NumberofShipments	Mass or Volume Limited?	Number of ShipmentsforCalcs	NumberofTRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	0.11	37.91	32.65	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	0	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	26.96	20426.77	17588.65	81	6	9	3	130	135.71	A	42	12	4	MASS	4	12	7016	37	76	113
BT	SRS	686	10.87	159.90	137.68	110957.04	95540.56	409	31	45	15	662	144.34	B	35	57	19	MASS	19	57	26068	176	283	459
ETEC	INEL/ANL-W	958	10.87	8.61	7.41	5878.71	5061.92	23	2	3	1	36	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55733.49	47989.82	54413131.92	46852916.96	142545	10665	15515	5172	230721	203.07	C	28	16482	8241	MASS	8241	16482	29799456	76,312	277,433	353,745
INEL/ANL-W	WIPP	1392	9.31	69042.65	59449.80	57334719.11	49368575.90	176584	13212	19220	6407	285817	172.73	C	28	20416	10208	MASS	10208	20416	28419072	94,526	264,582	359,108
KAPL	SRS	949	10.87	2.40	2.07	1659.81	1429.20	7	1	1	1	10	143.85	B	35	3	1	VOLUME	1	1	1898	9	21	30
LANL	WIPP	342	10.87	32641.55	28106.30	26855786.89	23124417.00	83485	6246	9087	3029	135127	171.13	C	28	9652	4826	MASS	4826	9652	3300984	44,689	35,882	80,570
LBL	HANFORD	870	10.87	6.57	5.65	4541.89	3910.84	17	2	3	1	28	143.85	B	35	3	1	VOLUME	3	2	5220	28	57	85
LLNL	HANFORD	890	10.87	1158.04	997.14	445343.02	383466.61	2962	222	323	108	4794	79.99	A	42	345	115	MASS	115	345	204700	1,065	2,225	3,290
MOUND	SRS	641	10.87	263.29	226.71	143644.06	123686.01	674	51	74	25	1090	113.48	A	42	78	26	MASS	26	78	33332	241	362	603
MU	SRS	863	10.87	2.14	1.84	1478.91	1273.43	6	1	1	1	9	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	527.48	428439.49	368911.68	1567	118	171	57	2536	145.47	B	35	219	73	MASS	73	219	104098	676	1,132	1,808
ORNL	SRS	358	10.87	1124.94	968.64	786615.97	677322.76	2878	216	314	105	4657	145.44	B	35	402	134	MASS	134	402	95944	1,241	1,043	2,284
PANTEX	LANL	335	10.87	0.62	0.54	431.55	371.59	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	0	670	9	7	17
PA	SRS	569	10.87	2.10	1.81	2656.43	2287.34	6	1	1	1	9	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	9148.83	7877.68	8458950.48	7283655.45	23400	1751	2547	849	37874	192.32	C	28	2706	1353	MASS	1353	2706	1905024	12,529	20,708	33,236
SNL-NM	LANL	104	19.65	17.11	14.73	11833.39	10189.25	44	4	6	2	71	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	29035.31	25001.11	48010942.34	41340254.00	74261	5556	8083	2695	120198	343.94	E	14	17172	8586	MASS	8586	17172	25912548	79,506	241,246	320,752
TOTAL																			**33,598**	**67,561**	**89,825,730**	**311,117**	**845,163**	**1,156,280**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.
A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's.
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.
Revised Mass and Volume Scaling Factor: 0.861059

Table P-72
CH Regionalized Alternative ID #111
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	NumberofTRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[2]	MaximumDrumsper Shipment[3]	MaximumNumberof TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of ShipmentsforCalcs	NumberofTRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	SRS	1190	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2380	9	22	31
ANL-E	SRS	877	10.87	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	7016	37	76	113
BT	SRS	686	10.87	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	30184	204	328	532
ETEC	INEL/ANL-W	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	55709.01	25332579.23	165473	12380	18010	6004	267832	94.58	A	42	19131	6377	MASS	6377	19131	23059232	59,051	214,681	273,732
INEL/ANL-W	WIPP	1392	9.31	48011.21	26284779.96	142608	10670	15522	5174	230824	113.87	A	42	16488	5496	MASS	5496	16488	15300864	50,893	142,451	193,344
KAPL	SRS	949	10.87	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	1898	9	21	30
LANL	WIPP	342	10.87	27023.49	13591943.62	80268	6006	8737	2913	129921	104.62	A	42	9282	3094	MASS	3094	9282	2116296	28,650	23,004	51,655
LBL	HANFORD	870	10.87	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	1740	9	19	28
LLNL	HANFORD	890	10.87	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	236740	1,232	2,573	3,805
MOUND	SRS	641	10.87	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	39742	287	432	719
MU	SRS	863	10.87	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	1726	9	19	28
NTS	INEL/ANL-W	713	10.87	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	121210	787	1,318	2,105
ORNL	SRS	358	10.87	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	92364	1,195	1,004	2,199
PANTEX	LANL	335	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	670	9	7	17
PA	SRS	569	10.87	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	1138	9	12	22
RFP	WIPP	704	10.87	8866.22	5587396.08	26336	1971	2867	956	42627	131.08	A	42	3045	1015	MASS	1015	3045	1429120	9,399	15,535	24,933
SNL-NM	LANL	104	19.65	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	624	28	12	40
SRS	WIPP	1509	9.31	28814.79	20367027.82	85589	6404	9316	3106	138533	147.02	B	35	11877	3959	MASS	3959	11877	11948262	36,660	111,238	147,899
TOTAL																	20,356	61,058	54,395,038	188,497	512,795	701,291

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.

A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

Table P-73
CH Centralized Baseline
Transportation Costs

						VOLUME LIMITING CALCULATIONS				MASS LIMITING CALCULATIONS												
Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Volume (m^3)	Mass (kg)	Number of Drums	Number of SWBs	Number of TRUPACTs	Number of Shipments	Number of Drums	Average Drum Mass (kg)	Shipment Configuration[3]	Maximum Drums per Shipment[3]	Maximum Number of TRUPACTs[3]	Number of Shipments	Mass or Volume Limited?	Number of Shipments for Calcs	Number of TRUPACTs for Calcs	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
AMES	WIPP	1255	9.31	0.13	37.91	1	0	1	1	1	60.86	A	42	3	1	VOLUME	1	1	2510	9	23	33
ANL-E	WIPP	1455	9.31	31.31	20426.77	93	7	11	4	151	135.71	A	42	12	4	VOLUME	4	11	11640	37	108	145
BT	WIPP	1803	9.31	159.90	110957.04	475	36	52	18	769	144.34	B	35	66	22	MASS	22	66	79332	204	739	942
ETEC	WIPP	958	10.87	8.61	5878.71	26	2	3	1	42	142.05	B	35	6	2	MASS	2	6	3832	19	42	60
HANFORD	WIPP	1808	9.31	48286.36	22258182.80	143425	10731	15611	5204	232146	95.88	A	42	16584	5528	MASS	5528	16584	19989248	51,189	186,100	237,289
INEL/ANL-W	WIPP	1392	9.31	40379.52	20665074.44	119940	8974	13055	4352	194133	106.45	A	42	13869	4623	MASS	4623	13869	12870432	42,809	119,824	162,633
KAPL	WIPP	2208	9.31	2.40	1659.81	8	1	2	1	12	143.85	B	35	3	1	VOLUME	1	2	4416	9	41	50
LANL	WIPP	342	10.87	21131.01	9834518.77	62766	4696	6832	2278	101592	96.80	A	42	7257	2419	MASS	2419	7257	1654596	22,400	17,985	40,385
LBL	WIPP	1522	9.31	6.57	4541.89	20	2	3	1	32	143.85	B	35	3	1	VOLUME	1	3	3044	9	28	38
LLNL	WIPP	1452	9.31	1158.04	445343.02	3440	258	375	125	5568	79.99	A	42	399	133	MASS	133	399	386232	1,232	3,596	4,827
MOUND	WIPP	1557	9.31	263.29	143644.06	783	59	86	29	1266	113.48	A	42	93	31	MASS	31	93	96534	287	899	1,186
MU	WIPP	1145	9.31	2.14	1478.91	7	1	1	1	11	143.85	B	35	3	1	VOLUME	1	1	2290	9	21	31
NTS	WIPP	1214	9.31	612.60	428439.49	1820	137	199	67	2946	145.47	B	35	255	85	MASS	85	255	206380	787	1,921	2,708
ORNL	WIPP	1521	9.31	1124.94	728806.41	3342	250	364	122	5409	134.76	A	42	387	129	MASS	129	387	392418	1,195	3,653	4,848
PANTEX	WIPP	443	10.87	0.62	431.55	2	0	1	1	3	143.85	B	35	3	1	VOLUME	1	1	886	9	10	19
PA	WIPP	1360	9.31	2.10	2656.43	7	1	1	1	11	263.11	E	14	2	1	VOLUME	1	1	2720	9	25	35
RFETS	WIPP	704	10.87	6249.25	3151674.56	18563	1389	2021	674	30045	104.90	A	42	2148	716	MASS	716	2148	1008128	6,630	10,958	17,589
SNL-NM	WIPP	311	10.87	17.11	11833.39	51	4	6	2	83	143.85	B	35	9	3	MASS	3	9	1866	28	20	48
SRS	WIPP	1509	9.31	26933.46	19202207.74	80001	5986	8708	2903	129488	148.29	B	35	11100	3700	MASS	3700	11100	11166600	34,262	103,961	138,223
TOTAL																	17,401	52,193	47,883,104	161,133	449,956	611,089

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b
[3]Source: Personal Communication with Phil Gregory
Notes:
This table presents the costs for transporting CH TRU waste by truck.
Volumes and masses represent total stored and project volumes and masses.
Volume and mass at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.
Shipment Configuration is dependent on the average drum mass.

A -- Maximum of 42 drums in three TRUPACT-II'S
B -- Maximum of 35 drums in three TRUPACT-II's
C -- Maximum of 28 drums in two TRUPACT-II's
D -- Maximum of 21 drums in two TRUPACT-II's
E -- Maximum of 14 drums in two TRUPACT-II's
XX -- Average drum mass exceeds expected upper limit. Average drum weight set at 380 kg./drum for calculations. Use Shipment Configuration E.

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Little or no scheduling information is available for processes similar to utilizing plasma melting to treat mixed TRU waste. The program evaluation review technique (PERT) was used to develop time estimates for critical plasma melting activities (see Section 1.3.2). The PERT techniques use multiple time estimates in order to take into account time variability. PERT time estimates were also developed for major activities that were assigned CPM durations to assure that the CPM estimates are reasonable.

Activity schedules and durations for possible scenarios are presented in Figures Q-1 through Q-5.

1.3.1 Critical Path Method

The critical path method (CPM) of scheduling involves developing a network model of the project by organizing the work to be accomplished into logical activities and linking activities to other activities in ways to illustrate their relationships (e.g., by defining the activities that must be accomplished before another can begin). The CPM technique involves using a single estimate for the time duration of an activity. This estimate is best based on historical information from similar projects. Time estimates were based on schedule information from a number of projects including: 1) the environmental restoration, waste management, and technology development programs at the Rocky Flats Environmental Technology Site (RFETS), 2) the RFETS Site Treatment Plan, 3) the Hanford High-Level Waste Tanks, and 4) the Pit 9 Comprehensive Demonstration at the Idaho National Engineering Laboratory.

In this analysis, Alternative 6 (shred and compact) was used as the basis for establishing baseline time estimates. The durations for major components (i.e., Design, Construction, and D&D) of other EAs were adjusted to account for the complexity and anticipated difficulty of implementing the different EAs, as shown below:

Alternative	Adjustment to Title I and Title II Design, Construction, and Internal D&D.
#6 Shred and compact	NA
Baseline	0%
#1 Supercompact	+12%
#94 Enhanced cement and shred/add clay	+10%

1.3.2Program Evaluation Review TechniqueTo determine appropriate times to accomplish major activities, three time estimates were developed, an optimistic estimate (T_o), a most probable estimate (T_m), and a pessimistic estimate (T_p). The time estimate used for the schedule analysis (T_e) was calculated by the following formula:

$$T_e = [T_o + T_m(4) + T_p]/6$$

Table Q-6 shows the preliminary PERT time estimates for Alternative #6 (Shred and Compact).

- **Design & Construction**—This includes the activities required for development of a detailed design and for facility construction. Construction could not begin until the RCRA permit modification is approved.

- **Procedures Development and Personnel Training**—DOE Order 5480.19, *Conduct of Operations* (DOE 1992b) requires that operations at DOE facilities be conducted in accordance with written and approved directives, plans, and/or procedures, and that personnel be adequately trained to perform their assigned tasks. The activities included in the schedule include the development of plans and procedures for equipment testing, data management, operations, and maintenance, and the training of personnel.

- **Equipment and Facility Testing**—All equipment and systems must be tested, both individually and in combination, to assure that they perform as planned and to assure that the facility will operate safely. Testing includes the performance of system operations (SO) tests and conduct of an Operational Readiness Review (ORR), as required by DOE Order 5480.31, *Startup and Restart of Nuclear Facilities* (DOE 1993).

- **Operations**—Operations includes the activities required for the retrieval, characterization, repackaging, treatment, certification, storage, and shipment of transuranic (TRU) waste. It was assumed that facilities would have an operating life of 20 years.

- **Decontamination and Decommissioning**—Decontamination and Decommissioning (D&D) includes deactivating the facilities after their operational lives have expired and decontaminating the facility equipment, structures, and surrounding areas so that the area can be safety used for another purpose.

1.2 SCHEDULING ASSUMPTIONS

In the process of developing the schedules for the various waste processing EAs, it was necessary to make many assumptions regarding the relationships between activities (e.g., which activities must be complete before another could begin). Tables Q-1 through Q-5 (see Attachment 1) present the assumptions used for each major element of each waste processing EA.

1.3 ACTIVITY DURATIONS

A key element to establishing schedules for waste processing EAs is to estimate the time required to accomplish each activity. For activities which are the same or similar to activities that have been accomplished as part of previous projects, estimating the duration of the activity based on historical performance information is appropriate. The critical path method (CPM) is best suited for this type of situation (see Section 1.3.1). Each of the waste processing EAs, with the exception of Alternative 10 (plasma melting), involves activities and processes that are well understood and for which historical data is available. Therefore, CPM was used to estimate the duration of these activities.

WASTE PROCESSING SCHEDULE ANALYSIS

1.0 INTRODUCTION

1.1 SCHEDULE DEVELOPMENT

The schedules for implementing the waste processing engineered alternatives (EA) were evaluated using PRIMAVERA, a commonly used computer application. Since the waste processing EAs include the construction of major capital facilities, it was assumed that these would be line item projects, as defined by DOE Order 4700.1, *Project Management System* (DOE 1992a). The schedules for these projects include activities required to take a project from initial conception through design, permitting, construction, operations, and final decontamination and decommissioning. These activities are grouped into the following summary-level activities:

- **Project Conception and Funding Request**—This includes preparing a preconceptual design, conducting laboratory scale and pilot scale testing (if required), and requesting and receiving approval for line item funding.

- **National Environmental Policy Act Process**—The National Environmental Policy Act (NEPA) requires that any major federal action be analyzed to provide decision makers information on the environmental impact of the proposed action. The level of analysis required for each action may vary depending on the potential impacts, but it was assumed that an Environmental Impact Statement (EIS) would be required for each of the waste processing EAs. Preparing an EIS includes preparing an Action Description Memorandum (ADM), scoping the analysis, preparing a draft and a final EIS, soliciting and responding to comments, and ultimately issuing a Record of Decision (ROD).

- **Other Permitting**—To demonstrate compliance with the Clean Air Act (CAA) and other federal and state regulations, several plans and regulatory documents must be prepared, including a Health and Safety Plan, Quality Assurance Program Plan (QAPP), Air Pollution Emission Notices (APENs), a determination that the project complies with National Emission Standards for Hazardous Air Pollutants (NESHAPS), and a Prevention of Significant Deterioration (PSD) permit.

- **Resource Conservation and Recovery Act Permitting**—The Resource Conservation and Recovery Act (RCRA) requires that any treatment/storage/disposal (TSD) facility for hazardous waste must operate under a RCRA permit. Most DOE facilities are already operating under a RCRA permit, so this section illustrates the required activities to modify an existing RCRA permit.

- **Safety Analysis Review**—DOE Order 5480.23, *Nuclear Safety Analysis Reports* (DOE 1994c) requires that safety analyses be developed that establish and evaluate the adequacy of the safety bases for nuclear facilities. The results of the safety analysis are documented in a Safety Analysis Report (SAR). A SAR is prepared in stages which include a Preliminary Safety Analysis Report (PSAR) and a Final Safety Analysis Report (FSAR).

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APPENDIX Q
WASTE PROCESSING SCHEDULE ANALYSIS

TABLE P-77

WIPP WASTE EMPLACEMENT WORKOFF AND LABOR COST ESTIMATE

Engineered Alternative	Case	Number of CH shipments[1]	Number TRUPACT-IIs per day	Number of FTEs for operations[2]	Change in emplacement labor cost ($K)
Baseline, 33, 35(a,b), 83, 111	Decentralized	19,944	7.12	64	215,040
	Regionalized	19,944	7.12	64	215,040
	Centralized	17,401	6.21	64	215,040
1[3]	Decentralized	19,571	6.94	64	153,600
	Regionalized	19,548	6.93	64	153,600
	Centralized	17,401	8.70	64	153,600
6[3]	Decentralized	18,794	8.52	64	153,600
	Regionalized	18,838	8.58	64	153,600
	Centralized	17,401	8.70	64	188,160
10[3]	Decentralized	17,174	5.72	56	134,400
	Regionalized	17,186	5.80	56	134,400
	Centralized	17,401	8.70	64	153,600
77(a-d)[3]	Decentralized	19,571	6.94	64	153,600
	Regionalized	19,548	6.93	64	153,600
	Centralized	17,401	8.70	64	153,600
94(a-f)	Decentralized[3,4]	33,225	9.70	64	175,718
	Regionalized[3,4]	33,214	9.70	64	175,718
	Centralized	17,401	9.70	64	153,600

Notes.
[1] The number of shipments is for waste transported to the WIPP site.
[2] The number of FTEs is based on the crew directly involved in emplacement activities only.
[3] The number of TRUPACT-IIs and dollars for emplacement is based on a 25 year emplacement activity due to the lag in processing capability.
[4] The waste emplacement for this alternative exceeds the 25 year constraint by 3.6 years.

TABLE P-76

WIPP WASTE HANDLING COMPARATIVE COST IMPACTS

Alternative ID#	Cost Impacts ($K)[1]
1[2]	(61,440)
6[2]	(61,440)
10 (Decentralized, Regionalized)[2]	(80,640)
10 (Centralized)[2]	(61,440)
33	0
35(a-b)	0
77(a-d)[2]	(621,440)
83	0
94(a-f) (Decentralized, Regionalized)[2,3]	(39,322)
94(a-f) (Centralized)	(61,440)
111	0

Notes.
[1] Values in parentheses represent a reduction from the baseline costs.
[2] The emplacement of waste occurs during 25 years due to processing facility construction estimation of approximately 10 years.
[3] The waste handling for the WIPP occurs for approximately 28.6 years which exceeds the 35 year time constraint (10 year process facility start + 25 year emplacement).

TABLE P-75

BACKFILL EMPLACEMENT COST TOTALS SUMMARY

Alternative ID#	Capital Equipment	Design and Development	Operations and Maintenance	Total Cost[1] ($K)
33	1,007	302	43,114	55,527
35a	1,199	360	67,352	86,139
35b	1,200	360	67,352	86,141
77a	1,110	333	46,871	60,394
77b	760	228	24,052	31,299
77c	820	246	28,923	34,487
77d	805	241	27,669	35,894
83	981	294	41,241	53,146
94b	1,165	350	39,051	50,707
94c	1,418	425	61,025	78,536
94d	1,679	504	61,104	79,057
94e	1,037	311	32,462	42,262
94f	1,131	340	37,355	48,533
111	910	273	35,839	46,272

[1]Includes a 25% contingency factor.

TABLE P-74

RH DECENTRALIZED BASELINE TRANSPORTATION COSTS

Origin	Destination	One-Way Mileage[1]	CPLM[2] ($/mile)	Number of Shipments	Total Miles Traveled	Fixed Costs ($K)	Variable Costs ($K)	Total Costs ($K)
BATELLE	ORNL	409	10.87	123	100,614	1,139	1,094	2,233
BT	ORNL	607	10.87	3	3,642	28	40	67
HANFORD	WIPP	1,808	9.31	5,176	18,716,416	47,930	174,250	222,180
INEL/ANL-W	WIPP	1,392	9.31	109	303,456	1,009	2,825	3,835
KAPL	ORNL	884	10.87	57	100,776	528	1,095	1,623
LANL	WIPP	342	10.87	249	170,316	2,306	1,851	4,157
ORNL	WIPP	1,521	9.31	2,185	6,646,770	20,233	61,881	82,115
SRS	WIPP	1,509	9.31	56	169,008	519	1,573	2,092
TOTAL				**7,958**	**26,210,998**	**73,691**	**244,610**	**318,301**

[1]Source: ORNL, 1993
[2]Source: INEL, 1994b

Notes:
This table presents the costs for transporting CH TRU waste by truck.
Assume that shipments will be volume limited.
Volumes represent total stored and projected volumes.
Volume at sites that receive waste includes the waste received for treatment and/or interim storage from other sites.

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Act ID	Activity Description	Orig Dur	Early Start
WIPP TRU FACILITY			
05	WIPP TRU FACILITY	10,451*	14JUL88A
PROJECT CONCEPT/FUNDING REQUEST PROCESS			
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A
10	PRECONCEPTUAL DESIGN	250	14JUL88A
15	DECISION TO PROCEED	0	14JUL88A
20	DEVELOP & SUBMIT FUNDING REQUEST	248	14JUL88A
25	BENCH SCALE TESTING	640	17JUL89A
30	DETERMINE PROJECT FEASIBILITY	20	28JAN92A
35	PILOT SCALE	840	25FEB92A
40	DETERMINE PROJECT FEASIBILITY	90	01JUN95A
45	FUNDING REQUEST	60	09OCT95
50	DETERMINE LINE ITEM FUNDING	248	04JAN96
51	DESIGN CRITERIA COMPLETE	0	
55	PRIORITIZATION & SELECTION OF PROJECTS	60	23DEC96
60	GAIN FUNDING APPROVAL	248	19MAR97
65	OPERATIONAL REQUIREMENTS DOCUMENT	60	10MAR98
70	DESIGN INPUT & REVIEW/APPROVAL	20	27AUG98
NEPA PROCESS			
74	NEPA PROCESS	530*	04JAN96
75	PREPARE ENVIRONMENTAL CHECKLIST	60	04JAN96
80	NEPA COMPLIANCE COMMITTEE REVIEW	10	28MAR96
100	PREPARE ADM	60	11APR96
105	NEPA DETERMINATION DOE REVIEW ADM	30	08JUL96
165	PREPARE NOTICE OF INTENT	10	19AUG96
170	PUBLIC SCOPING	30	03SEP96
175	PREPARE IMPLEMENTATION PLAN	60	15OCT96
180	PREPARE DRAFT ENVIRONMENTAL IMPACT	120	10JAN97
185	DOE REVIEW DRAFT ENVIR. IMPACT	30	30JUN97
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97
195	STATE REVIEW & PUBLIC COMMENT PERIOD	60	12AUG97
200	REVIEW & FINALIZE ENV. IMPACT	60	05NOV97
205	ISSUE ROD	0	
OTHER PERMITTING			
434	MISCELLANEOUS PERMITTING	881*	10MAR98
440	HEALTH AND SAFETY PLAN	60	10MAR98
435	PREPARE QAPP FOR IMPLEMENTATION	60	10MAR98
460	PREPARE OPERATING QAPP	60	03JUN98
465	REVIEW/APPROVE IMPLEMENTATION PHASE	30	03JUN98
485	REVIEW AND APPROVE OPERATING QAPP	30	27AUG98
486	QAPP COMPLETE	0	
445	UPDATE/REVISE PROGRAM PLAN	60	10MAR98
470	DOE REVIEW PROGRAM PLAN	30	03JUN98
490	FINALIZE PROGRAM PLAN	30	16JUL98
450	APENs DETERMINATION	120	10MAR98
475	AGENCY REVIEWS APENs	60	27AUG98
495	FINALIZE APENs	40	20NOV98
451	APENs DETERMINATION COMPLETE	0	

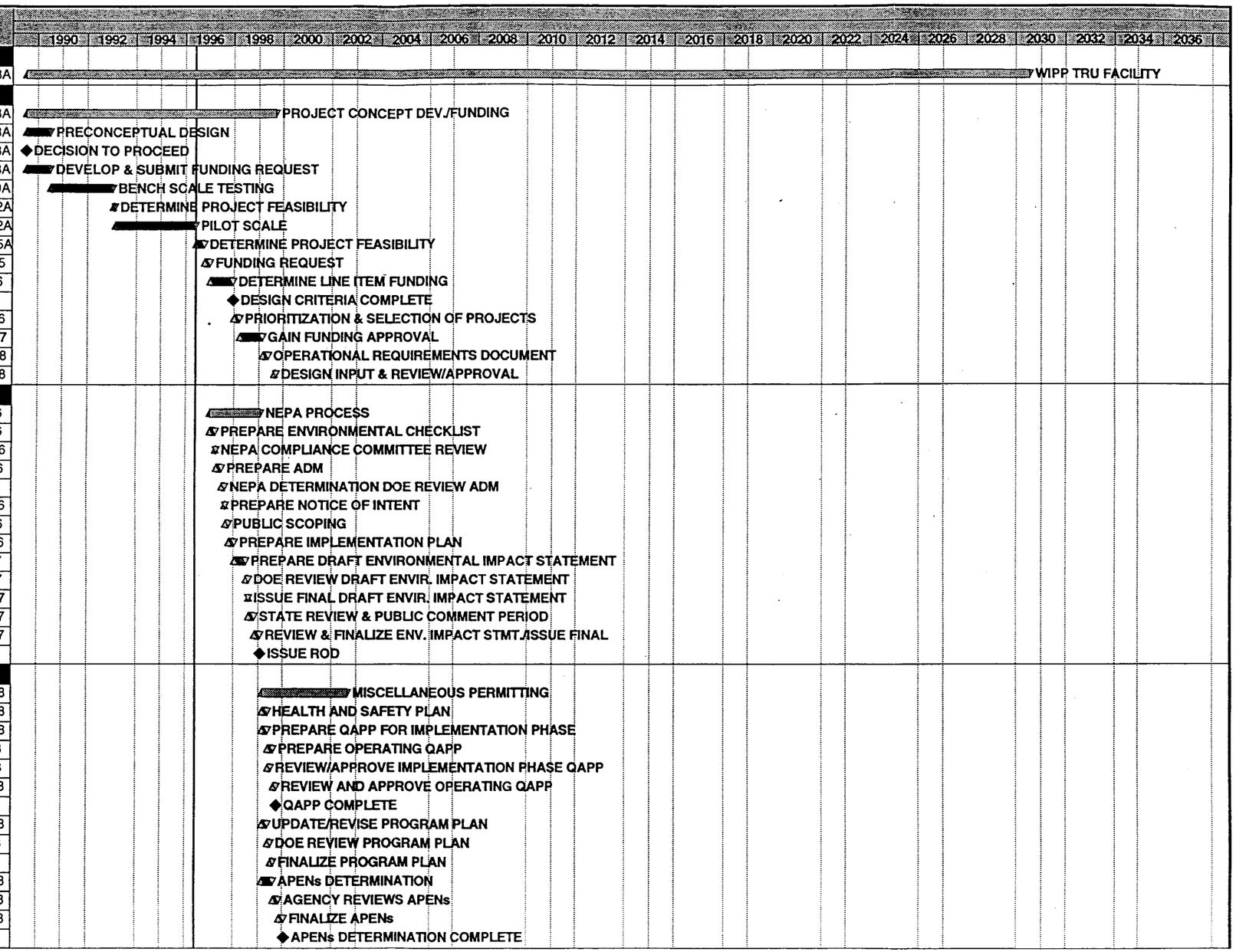

Figure Q-1a
Basecase Scenario

9/8/95

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Act ID	Activity Description	Orig Dur	Early Start
455	NESHAPS DETERMINATION	150	07SEP99
480	AGENCY REVIEWS NESHAPS	60	07APR00
500	FINALIZE NESHAPS	40	03JUL00
501	NESHAPS DETERMINATION COMPLETE	0	
502	PREPARE PSD PERMIT APPLICATION	250	07SEP99
503	PSD PERMIT REVIEW and APPROVAL	250	29AUG00
504	PSD PERMIT COMPLETE	0	
RCRA PERMITTING			
338	RCRA PERMITTING PROCESS	530*	29AUG00
339	BEGIN RCRA PERMIT MOD	0	29AUG00
380	PREPARE RCRA PERMIT MODIFICATION	140	29AUG00
385	DOE REVIEWS PERMIT MOD	30	19MAR01
390	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	90	30APR01
395	PUBLIC COMMENT PERIOD	60	06SEP01
400	PUBLIC HEARING	2	06SEP01
405	RESPOND TO COMMENTS & FINALIZE PERMIT	90	30NOV01
410	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	09APR02
430	PERMIT APPROVAL	0	
SAFETY ANALYSIS REVIEW			
209	SAFETY ANALYSIS REVIEW	550*	03JUN98
210	PREPARE HAZARD CLASSIFICATION	60	03JUN98
215	PSAR DEVELOPMENT	120	27AUG98
220	TSAR DEVELOPMENT	120	27AUG98
225	CRITICALITY SAFETY ASSESSMENT	120	27AUG98
230	ORC REVIEW	40	17FEB99
235	DOE REVIEW & APPROVE PSAR	40	14APR99
240	FSAR DEVELOPMENT	250	10JUN99
245	DOE REVIEW	40	02JUN00
DESIGN & CONSTRUCTION			
249	DESIGN & CONSTRUCTION	1,571*	25SEP98
250	BID/NEGOTIATE & AWARD DESIGN	90	25SEP98
260	PREPARE TITLE I DESIGN	151	03FEB99
265	PREPARE TITLE II DESIGN	375	07SEP99
270	LONG LEAD PROCUREMENT	210	07SEP99
266	TITLE II DESIGN COMPLETE	0	
275	PREPARE CONSTRUCTION PACKAGE	21	26FEB01
280	BID/NEGOTIATE & AWARD CONSTRUCTION	90	27MAR01
285	RCRA HOLD	0	
289	BEGIN CONSTRUCTION	0	27SEP02
290	CONSTRUCTION	450	27SEP02
291	CONSTRUCTON COMPLETE	0	
295	FINAL INSPECTIONS	10	02JUL04
300	TITLE III AS-BUILTS	90	19JUL04
PROCEDURES/TRAINING			
304	OPERATION PROCEDURES DEVELOPMENT &	180*	02JUL04
305	PREPARE S.O. TEST PLAN & PROCEDURES	60	02JUL04
310	DEVELOP DATA MANAGEMENT PROCEDURES	60	02JUL04
315	DEVELOP TECHNICAL PROCEDURES	60	02JUL04

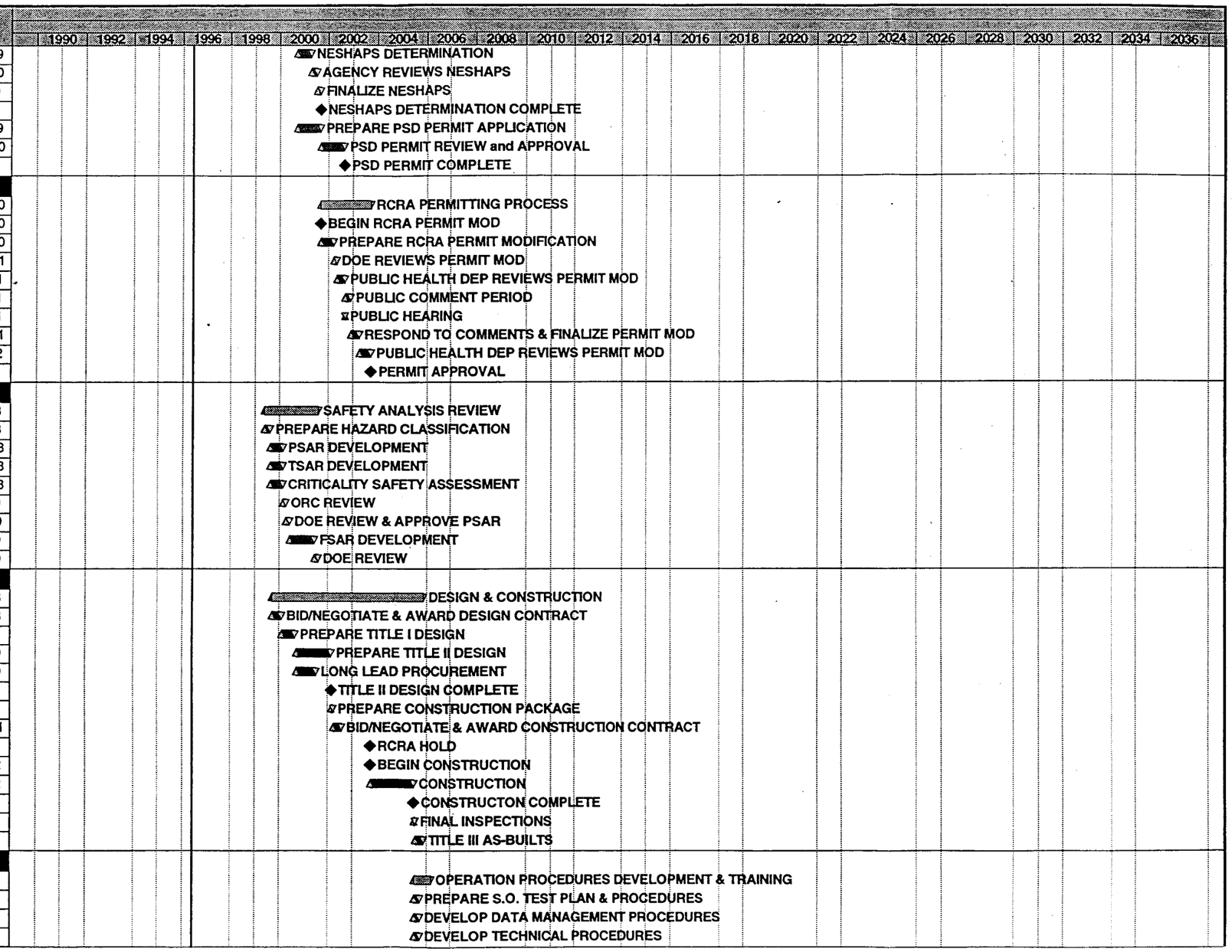

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Figure Q-1b
Basecase Scenario

Act ID	Activity Description	Orig Dur	Early Start
320	DEVELOP MAINTANENCE PROCEDURES	60	28SEP04
330	DEVELOP OPERATOR TRAINING PROGRAM	60	28SEP04
325	MAINTENANCE TRAINING	40	22DEC04
335	TRAIN OPERATORS	60	22DEC04
TESTING			
507	TESTING	460*	28SEP04
509	PERFORM S.O. TEST	120	28SEP04
510	ORR	160	18MAR05
520	PROCESS CONTROL PLAN	40	02NOV05
525	REVIEW AND APPROVAL OF ORR	140	02NOV05
530	ORR COMPLETE	0	
535	START-UP	40	22MAY06
OPERATIONS			
539	OPERATIONS	5,100*	19JUL06
545	BENEFICIAL OCCUPANCY	20	19JUL06
550	SYSTEM/OPERATOR CERTIFICATION	60	19JUL06
555	FINAL WASTE ANALYSIS/CERTIFICATION	20	19JUL06
560	IMPLEMENT SYSTEM USAGE	0	19JUL06
565	FACILITY ACCEPTANCE	0	12OCT06
570	FACILITY OPERATION	5,040	12OCT06
567	OPERATIONS COMPLETE	0	
D&D			
574	D&D	760*	22JUL26
575	FACILITY DEACTIVATION	120	22JUL26
580	ENGINEERING DESIGN	120	12JAN27
585	INTERNAL D&D OPERATIONS	220	30JUN27
590	STRUCTURAL D&D OPERATIONS	120	10MAY28
595	SUB-GRADE D&D OPERATIONS	120	30OCT28
600	VERIFICATION OF CLOSEOUT	60	19APR29

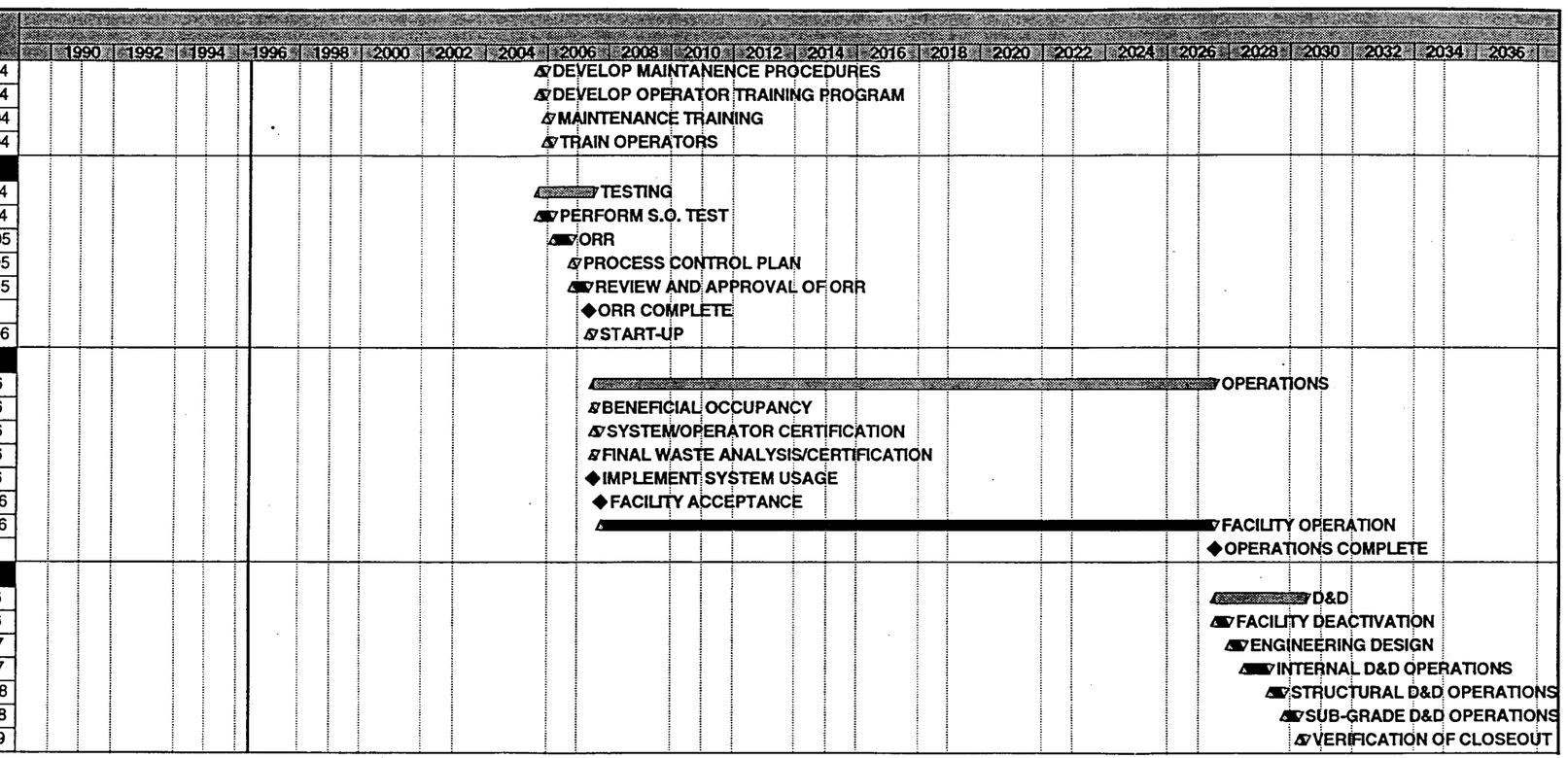

Figure Q-1c
Basecase Scenario

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Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,681*	14JUL88A	07JUN30
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
10	PRECONCEPTUAL DESIGN	250	14JUL88A	17JUL89A
15	DECISION TO PROCEED	0	14JUL88A	
20	DEVELOP & SUBMIT FUNDING REQUEST	248	14JUL88A	14JUL89A
25	BENCH SCALE TESTING	640	17JUL89A	27JAN92A
30	DETERMINE PROJECT FEASIBILITY	20	28JAN92A	24FEB92A
35	PILOT SCALE	840	25FEB92A	31MAY95A
40	DETERMINE PROJECT FEASIBILITY	90	01JUN95A	06OCT95
45	FUNDING REQUEST	60	09OCT95	03JAN96
50	DETERMINE LINE ITEM FUNDING	248	04JAN96	20DEC96
51	DESIGN CRITERIA COMPLETE	0		20DEC96
55	PRIORITIZATION & SELECTION OF PROJECTS	60	23DEC96	18MAR97
60	GAIN FUNDING APPROVAL	248	19MAR97	09MAR98
65	OPERATIONAL REQUIREMENTS DOCUMENT	60	10MAR98	02JUN98
70	DESIGN INPUT & REVIEW/APPROVAL	20	27AUG98	24SEP98
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
75	PREPARE ENVIRONMENTAL CHECKLIST	60	04JAN96	27MAR96
80	NEPA COMPLIANCE COMMITTEE REVIEW	10	28MAR96	10APR96
100	PREPARE ADM	60	11APR96	05JUL96
105	NEPA DETERMINATION DOE REVIEW ADM	30	08JUL96	16AUG96
165	PREPARE NOTICE OF INTENT	10	19AUG96	30AUG96
170	PUBLIC SCOPING	30	03SEP96	14OCT96
175	PREPARE IMPLEMENTATION PLAN	60	15OCT96	09JAN97
180	PREPARE DRAFT ENVIRONMENTAL IMPACT	120	10JAN97	27JUN97
185	DOE REVIEW DRAFT ENVIR. IMPACT	30	30JUN97	11AUG97
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
195	STATE REVIEW & PUBLIC COMMENT PERIOD	60	12AUG97	04NOV97
200	REVIEW & FINALIZE ENV. IMPACT	60	05NOV97	30JAN98
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	899*	10MAR98	17SEP01
440	HEALTH AND SAFETY PLAN	60	10MAR98	02JUN98
435	PREPARE QAPP FOR IMPLEMENTATION	60	10MAR98	02JUN98
460	PREPARE OPERATING QAPP	60	03JUN98	26AUG98
465	REVIEW/APPROVE IMPLEMENTATION PHASE	30	03JUN98	15JUL98
485	REVIEW AND APPROVE OPERATING QAPP	30	27AUG98	08OCT98
486	QAPP COMPLETE	0		08OCT98
445	UPDATE/REVISE PROGRAM PLAN	60	10MAR98	02JUN98
470	DOE REVIEW PROGRAM PLAN	30	03JUN98	15JUL98
490	FINALIZE PROGRAM PLAN	30	16JUL98	26AUG98
450	APENs DETERMINATION	120	10MAR98	26AUG98
475	AGENCY REVIEWS APENs	60	27AUG98	19NOV98
495	FINALIZE APENs	40	20NOV98	19JAN99
451	APENs DETERMINATION COMPLETE	0		19JAN99

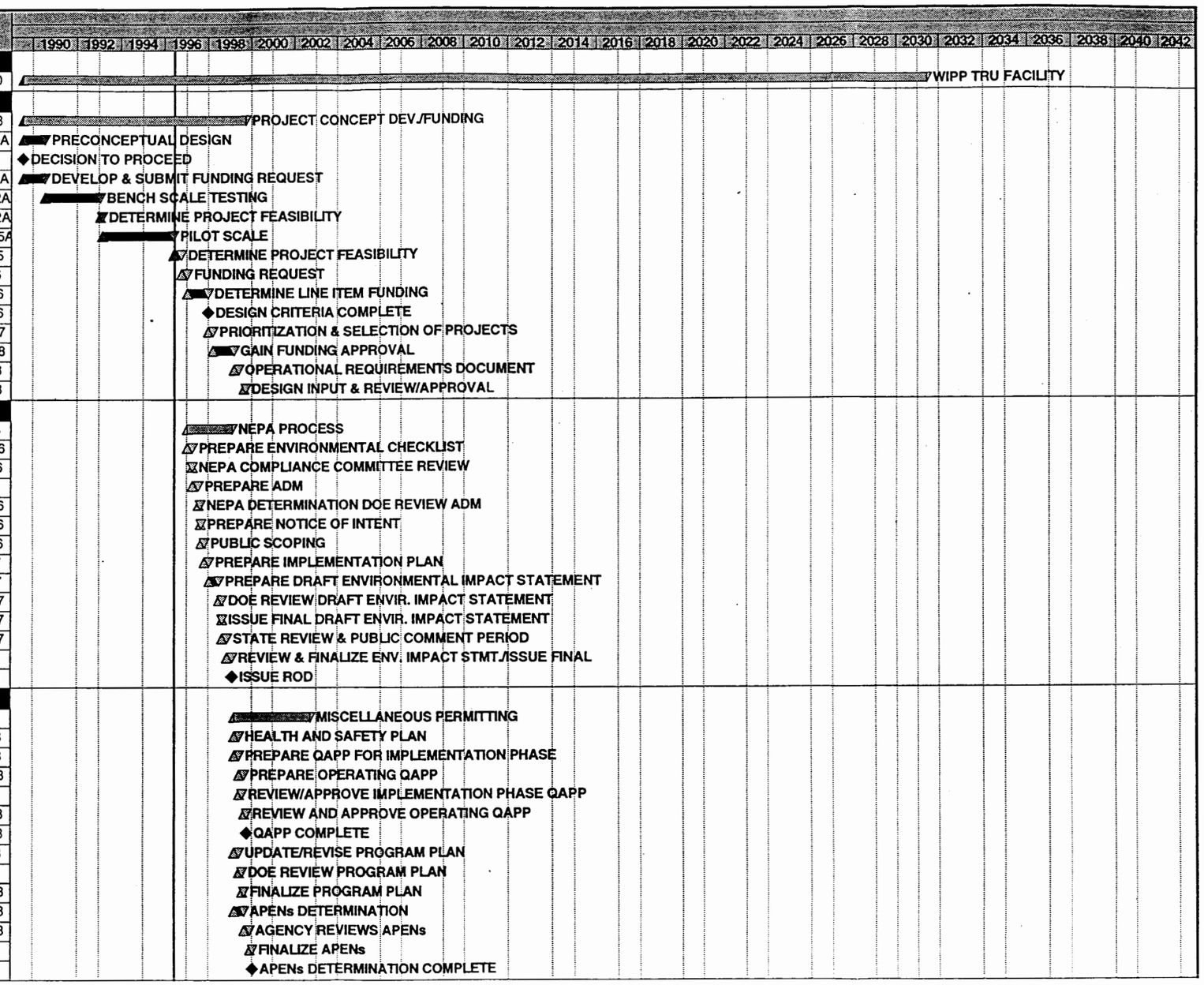

Figure Q-2a
Supercompaction Scenario

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96/3/6

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
455	NESHAPS DETERMINATION	150	01OCT99	02MAY00
480	AGENCY REVIEWS NESHAPS	60	03MAY00	27JUL00
500	FINALIZE NESHAPS	40	28JUL00	22SEP00
501	NESHAPS DETERMINATION COMPLETE	0		22SEP00
502	PREPARE PSD PERMIT APPLICATION	250	01OCT99	22SEP00
503	PSD PERMIT REVIEW and APPROVAL	250	25SEP00	17SEP01
504	PSD PERMIT COMPLETE	0		17SEP01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	28NOV00	26DEC02
339	BEGIN RCRA PERMIT MOD	0	28NOV00	
380	PREPARE RCRA PERMIT MODIFICATION	140	28NOV00	14JUN01
385	DOE REVIEWS PERMIT MOD	30	15JUN01	27JUL01
390	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	90	30JUL01	04DEC01
395	PUBLIC COMMENT PERIOD	60	05DEC01	28FEB02
400	PUBLIC HEARING	2	05DEC01	06DEC01
405	RESPOND TO COMMENTS & FINALIZE PERMIT	90	01MAR02	08JUL02
410	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	09JUL02	26DEC02
430	PERMIT APPROVAL	0		26DEC02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
210	PREPARE HAZARD CLASSIFICATION	60	03JUN98	26AUG98
215	PSAR DEVELOPMENT	120	27AUG98	16FEB99
220	TSAR DEVELOPMENT	120	27AUG98	16FEB99
225	CRITICALITY SAFETY ASSESSMENT	120	27AUG98	16FEB99
230	ORC REVIEW	40	17FEB99	13APR99
235	DOE REVIEW & APPROVE PSAR	40	14APR99	09JUN99
240	FSAR DEVELOPMENT	250	10JUN99	01JUN00
245	DOE REVIEW	40	02JUN00	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,744*	25SEP98	28JUL05
250	BID/NEGOTIATE & AWARD DESIGN	90	25SEP98	02FEB99
260	PREPARE TITLE I DESIGN	169	03FEB99	30SEP99
265	PREPARE TITLE II DESIGN	420	01OCT99	23MAY01
270	LONG LEAD PROCUREMENT	210	01OCT99	27JUL00
266	TITLE II DESIGN COMPLETE	0		23MAY01
275	PREPARE CONSTRUCTION PACKAGE	21	24MAY01	22JUN01
280	BID/NEGOTIATE & AWARD CONSTRUCTION	90	25JUN01	30OCT01
285	RCRA HOLD	0		26DEC02
289	BEGIN CONSTRUCTION	0	27DEC02	
290	CONSTRUCTION	560	27DEC02	08MAR05
291	CONSTRUCTION COMPLETE	0		08MAR05
295	FINAL INSPECTIONS	10	09MAR05	22MAR05
300	TITLE III AS-BUILTS	90	23MAR05	28JUL05
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	09MAR05	18NOV05
305	PREPARE S.O. TEST PLAN & PROCEDURES	60	09MAR05	01JUN05
310	DEVELOP DATA MANAGEMENT PROCEDURES	60	09MAR05	01JUN05
315	DEVELOP TECHNICAL PROCEDURES	60	09MAR05	01JUN05

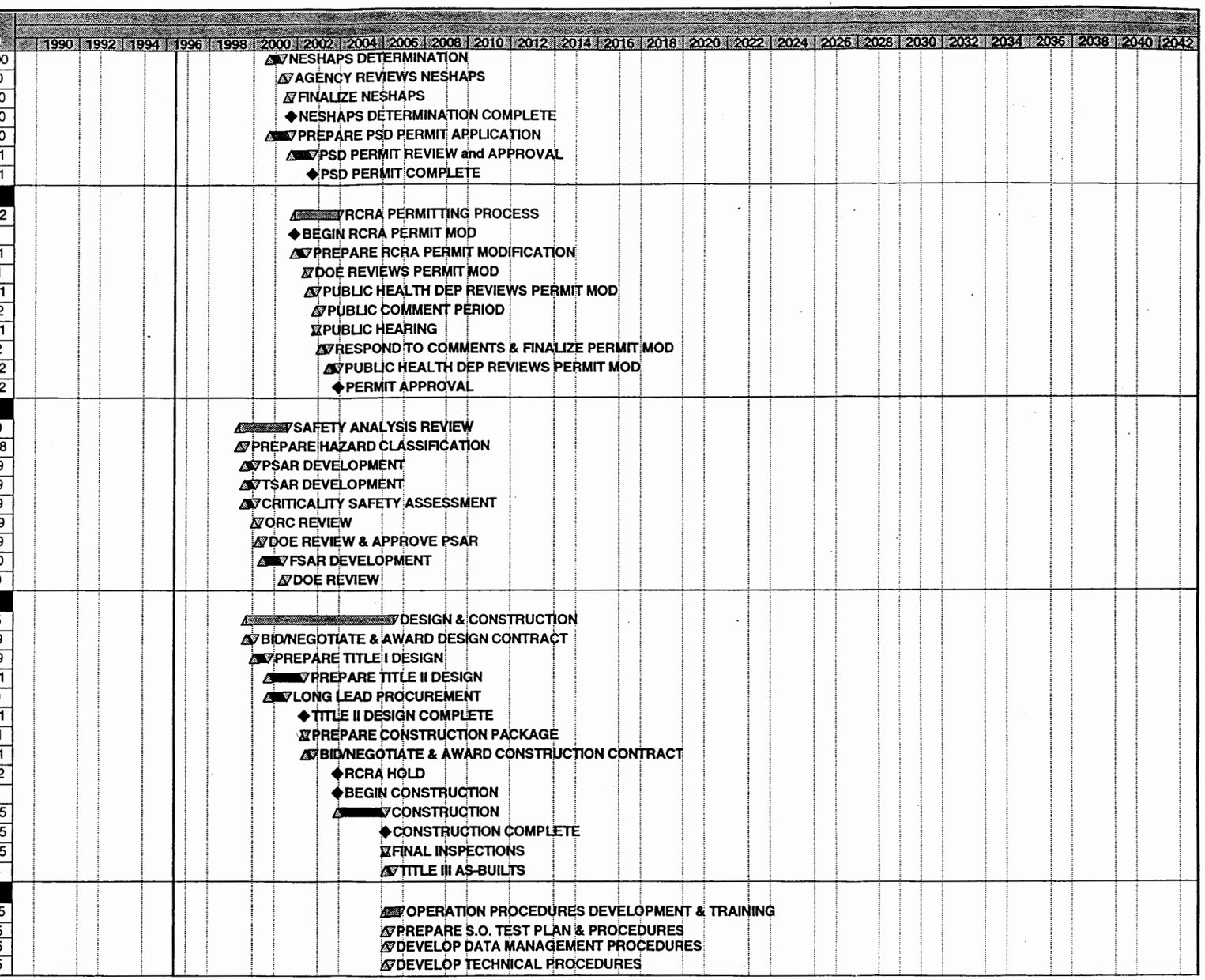

Figure Q-2b
Supercompaction Scenario

763435.01.00.00.00/zc B10
9/6/95

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
320	DEVELOP MAINTENANCE PROCEDURES	60	02JUN05	25AUG05
330	DEVELOP OPERATOR TRAINING PROGRAM	60	02JUN05	25AUG05
325	MAINTENANCE TRAINING	40	26AUG05	21OCT05
335	TRAIN OPERATORS	60	26AUG05	18NOV05
TESTING				
507	TESTING	460*	02JUN05	22MAR07
509	PERFORM S.O. TEST	120	02JUN05	18NOV05
510	ORR	160	21NOV05	07JUL06
520	PROCESS CONTROL PLAN	40	10JUL06	01SEP06
525	REVIEW AND APPROVAL OF ORR	140	10JUL06	25JAN07
530	ORR COMPLETE	0		25JAN07
535	START-UP	40	26JAN07	22MAR07
OPERATIONS				
539	OPERATIONS	5,100*	23MAR07	25MAR27
545	BENEFICIAL OCCUPANCY	20	23MAR07	19APR07
550	SYSTEM/OPERATOR CERTIFICATION	60	23MAR07	15JUN07
555	FINAL WASTE ANALYSIS/CERTIFICATION	20	23MAR07	19APR07
560	IMPLEMENT SYSTEM USAGE	0	23MAR07	
565	FACILITY ACCEPTANCE	0	18JUN07	
570	FACILITY OPERATION	5,040	18JUN07	25MAR27
567	OPERATIONS COMPLETE	0		25MAR27
D&D				
574	D&D	817*	26MAR27	07JUN30
575	FACILITY DEACTIVATION	120	26MAR27	14SEP27
580	ENGINEERING DESIGN	120	15SEP27	03MAR28
585	INTERNAL D&D OPERATIONS	277	06MAR28	04APR29
590	STRUCTURAL D&D OPERATIONS	120	05APR29	24SEP29
595	SUB-GRADE D&D OPERATIONS	120	25SEP29	14MAR30
600	VERIFICATION OF CLOSEOUT	60	15MAR30	07JUN30

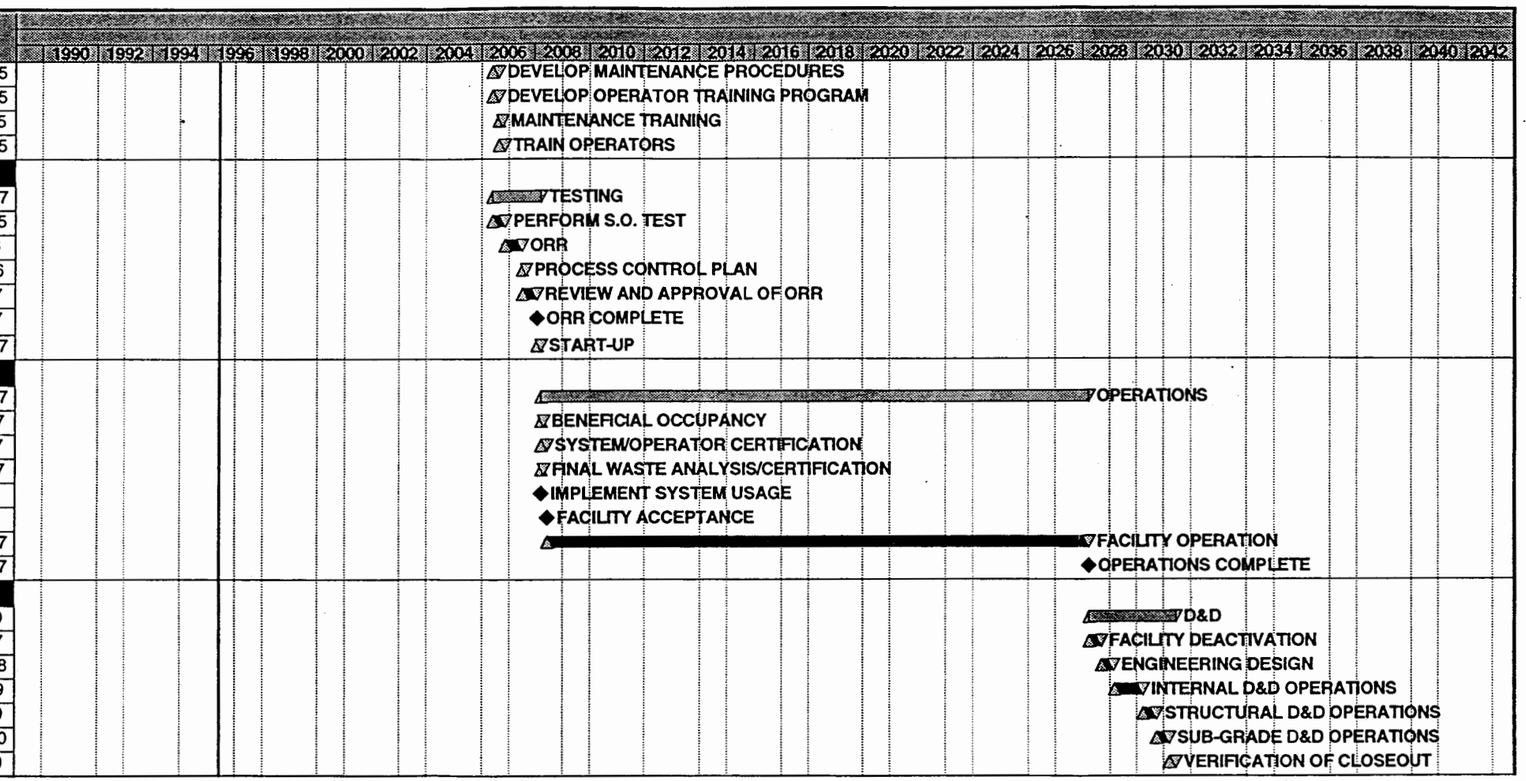

Figure Q-2c
Supercompaction Scenario

763gc 01.00.00.00/zc B11
9/8/95

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,529*	14JUL88A	01NOV29
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
10	PRECONCEPTUAL DESIGN	250	14JUL88A	17JUL89A
15	DECISION TO PROCEED	0	14JUL88A	
20	DEVELOP & SUBMIT FUNDING REQUEST	248	14JUL88A	14JUL89A
25	BENCH SCALE TESTING	640	17JUL89A	27JAN92A
30	DETERMINE PROJECT FEASIBILITY	20	28JAN92A	24FEB92A
35	PILOT SCALE	840	25FEB92A	31MAY95A
40	DETERMINE PROJECT FEASIBILITY	90	01JUN95A	06OCT95
45	FUNDING REQUEST	60	09OCT95	03JAN96
50	DETERMINE LINE ITEM FUNDING	248	04JAN96	20DEC96
51	DESIGN CRITERIA COMPLETE	0		20DEC96
55	PRIORITIZATION & SELECTION OF PROJECTS	60	23DEC96	18MAR97
60	GAIN FUNDING APPROVAL	248	19MAR97	09MAR98
65	OPERATIONAL REQUIREMENTS DOCUMENT	60	10MAR98	02JUN98
70	DESIGN INPUT & REVIEW/APPROVAL	20	27AUG98	24SEP98
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
75	PREPARE ENVIRONMENTAL CHECKLIST	60	04JAN96	27MAR96
80	NEPA COMPLIANCE COMMITTEE REVIEW	10	28MAR96	10APR96
100	PREPARE ADM	60	11APR96	05JUL96
105	NEPA DETERMINATION DOE REVIEW ADM	30	08JUL96	16AUG96
165	PREPARE NOTICE OF INTENT	10	19AUG96	30AUG96
170	PUBLIC SCOPING	30	03SEP96	14OCT96
175	PREPARE IMPLEMENTATION PLAN	60	15OCT96	09JAN97
180	PREPARE DRAFT ENVIRONMENTAL IMPACT	120	10JAN97	27JUN97
185	DOE REVIEW DRAFT ENVIR. IMPACT	30	30JUN97	11AUG97
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
195	STATE REVIEW & PUBLIC COMMENT PERIOD	60	12AUG97	04NOV97
200	REVIEW & FINALIZE ENV. IMPACT	60	05NOV97	30JAN98
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	881*	10MAR98	21AUG01
440	HEALTH AND SAFETY PLAN	60	10MAR98	02JUN98
435	PREPARE QAPP FOR IMPLEMENTATION	60	10MAR98	02JUN98
460	PREPARE OPERATING QAPP	60	03JUN98	26AUG98
465	REVIEW/APPROVE IMPLEMENTATION PHASE	30	03JUN98	15JUL98
485	REVIEW AND APPROVE OPERATING QAPP	30	27AUG98	08OCT98
486	QAPP COMPLETE	0		08OCT98
445	UPDATE/REVISE PROGRAM PLAN	60	10MAR98	02JUN98
470	DOE REVIEW PROGRAM PLAN	30	03JUN98	15JUL98
490	FINALIZE PROGRAM PLAN	30	16JUL98	26AUG98
450	APENs DETERMINATION	120	10MAR98	26AUG98
475	AGENCY REVIEWS APENs	60	27AUG98	19NOV98
495	FINALIZE APENs	40	20NOV98	19JAN99
451	APENs DETERMINATION COMPLETE	0		19JAN99

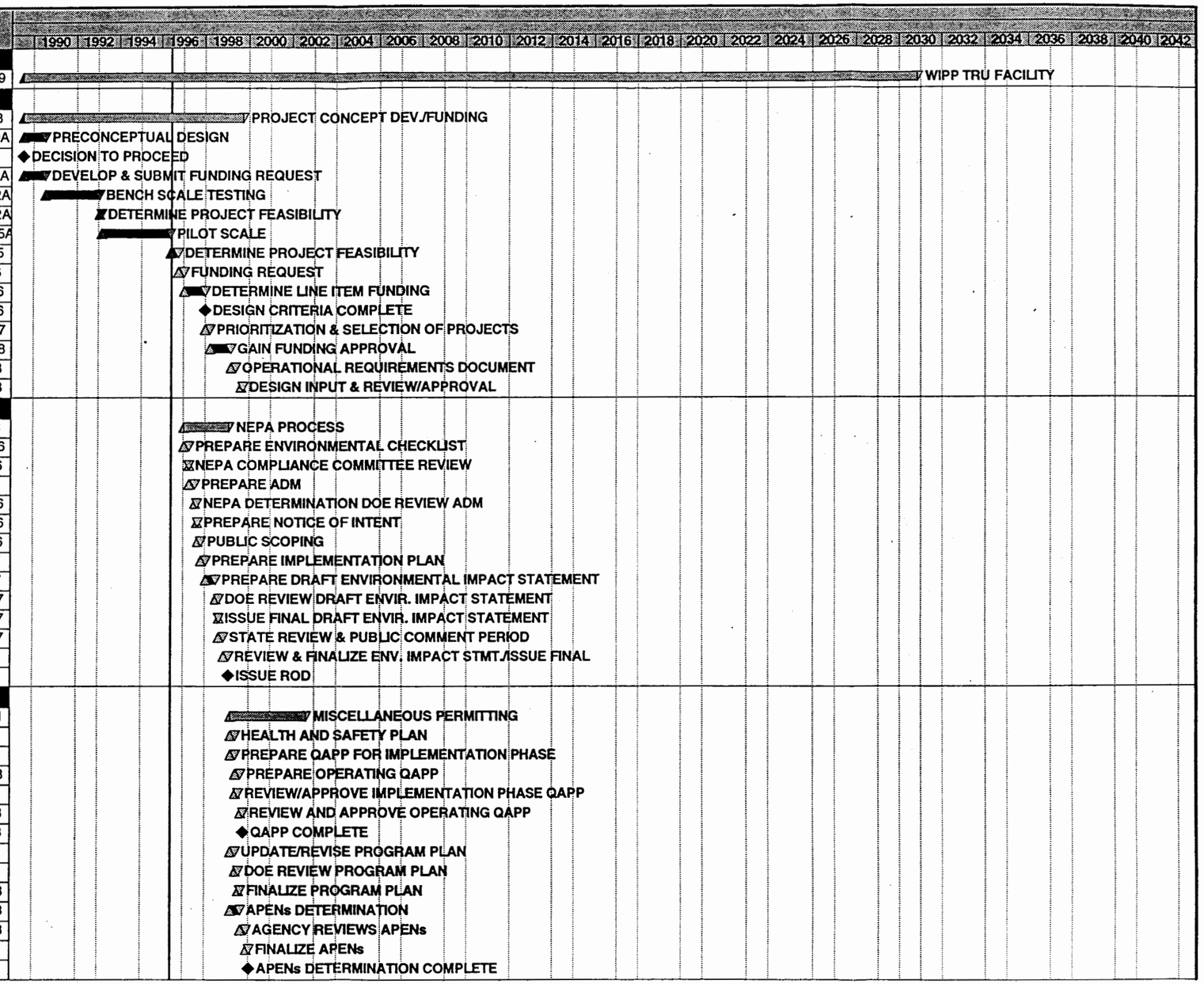

Figure Q-3a
Shred & Compact Scenario

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
455	NESHAPS DETERMINATION	150	07SEP99	06APR00
480	AGENCY REVIEWS NESHAPS	60	07APR00	30JUN00
500	FINALIZE NESHAPS	40	03JUL00	28AUG00
501	NESHAPS DETERMINATION COMPLETE	0		28AUG00
502	PREPARE PSD PERMIT APPLICATION	250	07SEP99	28AUG00
503	PSD PERMIT REVIEW and APPROVAL	250	29AUG00	21AUG01
504	PSD PERMIT COMPLETE	0		21AUG01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	29AUG00	26SEP02
339	BEGIN RCRA PERMIT MOD	0	29AUG00	
380	PREPARE RCRA PERMIT MODIFICATION	140	29AUG00	16MAR01
385	DOE REVIEWS PERMIT MOD	30	19MAR01	27APR01
390	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	90	30APR01	05SEP01
395	PUBLIC COMMENT PERIOD	60	06SEP01	29NOV01
400	PUBLIC HEARING	2	06SEP01	07SEP01
405	RESPOND TO COMMENTS & FINALIZE PERMIT	90	30NOV01	08APR02
410	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	09APR02	26SEP02
430	PERMIT APPROVAL	0		26SEP02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
210	PREPARE HAZARD CLASSIFICATION	60	03JUN98	26AUG98
215	PSAR DEVELOPMENT	120	27AUG98	16FEB99
220	TSAR DEVELOPMENT	120	27AUG98	16FEB99
225	CRITICALITY SAFETY ASSESSMENT	120	27AUG98	16FEB99
230	ORC REVIEW	40	17FEB99	13APR99
235	DOE REVIEW & APPROVE PSAR	40	14APR99	09JUN99
240	FSAR DEVELOPMENT	250	10JUN99	01JUN00
245	DOE REVIEW	40	02JUN00	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,621*	25SEP98	03FEB05
250	BID/NEGOTIATE & AWARD DESIGN	90	25SEP98	02FEB99
260	PREPARE TITLE I DESIGN	151	03FEB99	03SEP99
265	PREPARE TITLE II DESIGN	375	07SEP99	23FEB01
270	LONG LEAD PROCUREMENT	210	07SEP99	30JUN00
266	TITLE II DESIGN COMPLETE	0		23FEB01
275	PREPARE CONSTRUCTION PACKAGE	21	26FEB01	26MAR01
280	BID/NEGOTIATE & AWARD CONSTRUCTION	90	27MAR01	01AUG01
285	RCRA HOLD	0		26SEP02
289	BEGIN CONSTRUCTION	0	27SEP02	
290	CONSTRUCTION	500	27SEP02	13SEP04
291	CONSTRUCTION COMPLETE	0		13SEP04
295	FINAL INSPECTIONS	10	14SEP04	27SEP04
300	TITLE III AS-BUILTS	90	28SEP04	03FEB05
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	14SEP04	26MAY05
305	PREPARE S.O. TEST PLAN & PROCEDURES	60	14SEP04	07DEC04
310	DEVELOP DATA MANAGEMENT PROCEDURES	60	14SEP04	07DEC04
315	DEVELOP TECHNICAL PROCEDURES	60	14SEP04	07DEC04
320	DEVELOP MAINTENANCE PROCEDURES	60	08DEC04	03MAR05

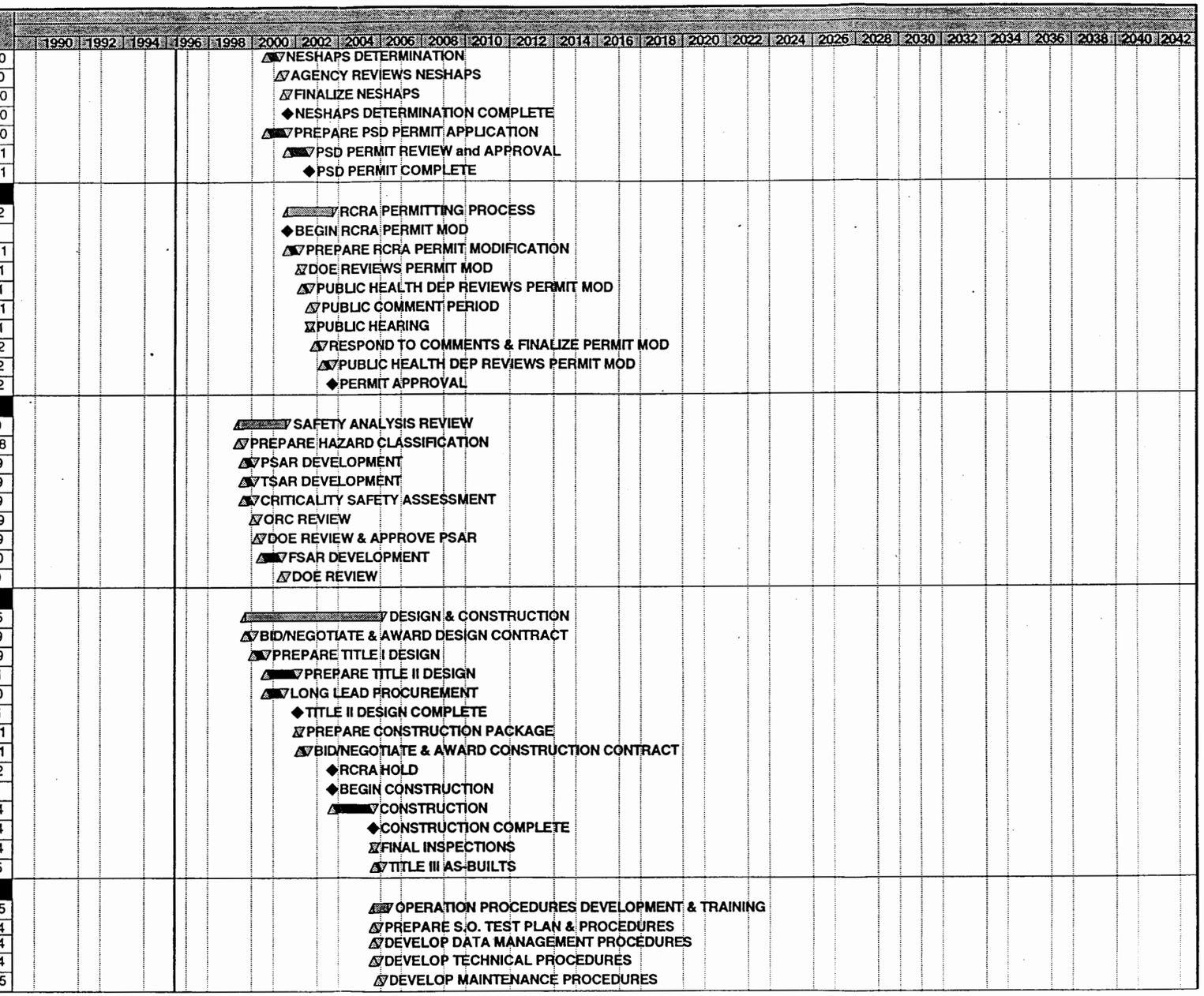

Figure Q-3b
Shred & Compact Scenario

763435.01.00.00.00/zc B13
9/8/95

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
330	DEVELOP OPERATOR TRAINING PROGRAM	60	08DEC04	03MAR05
325	MAINTENANCE TRAINING	40	04MAR05	28APR05
335	TRAIN OPERATORS	60	04MAR05	26MAY05
TESTING				
507	TESTING	460*	08DEC04	27SEP06
509	PERFORM S.O. TEST	120	08DEC04	26MAY05
510	ORR	160	27MAY05	13JAN06
520	PROCESS CONTROL PLAN	40	16JAN06	10MAR06
525	REVIEW AND APPROVAL OF ORR	140	16JAN06	01AUG06
530	ORR COMPLETE	0		01AUG06
535	START-UP	40	02AUG06	27SEP06
OPERATIONS				
539	OPERATIONS	5,100*	28SEP06	30SEP26
545	BENEFICIAL OCCUPANCY	20	28SEP06	25OCT06
550	SYSTEM/OPERATOR CERTIFICATION	60	28SEP06	21DEC06
555	FINAL WASTE ANALYSIS/CERTIFICATION	20	28SEP06	25OCT06
560	IMPLEMENT SYSTEM USAGE	0	28SEP06	
565	FACILITY ACCEPTANCE	0	22DEC06	
570	FACILITY OPERATION	5,040	22DEC06	30SEP26
567	OPERATIONS COMPLETE	0		30SEP26
D&D				
574	D&D	788*	01OCT26	01NOV29
575	FACILITY DEACTIVATION	120	01OCT26	22MAR27
580	ENGINEERING DESIGN	120	23MAR27	09SEP27
585	INTERNAL D&D OPERATIONS	248	10SEP27	29AUG28
590	STRUCTURAL D&D OPERATIONS	120	30AUG28	19FEB29
595	SUB-GRADE D&D OPERATIONS	120	20FEB29	08AUG29
600	VERIFICATION OF CLOSEOUT	60	09AUG29	01NOV29

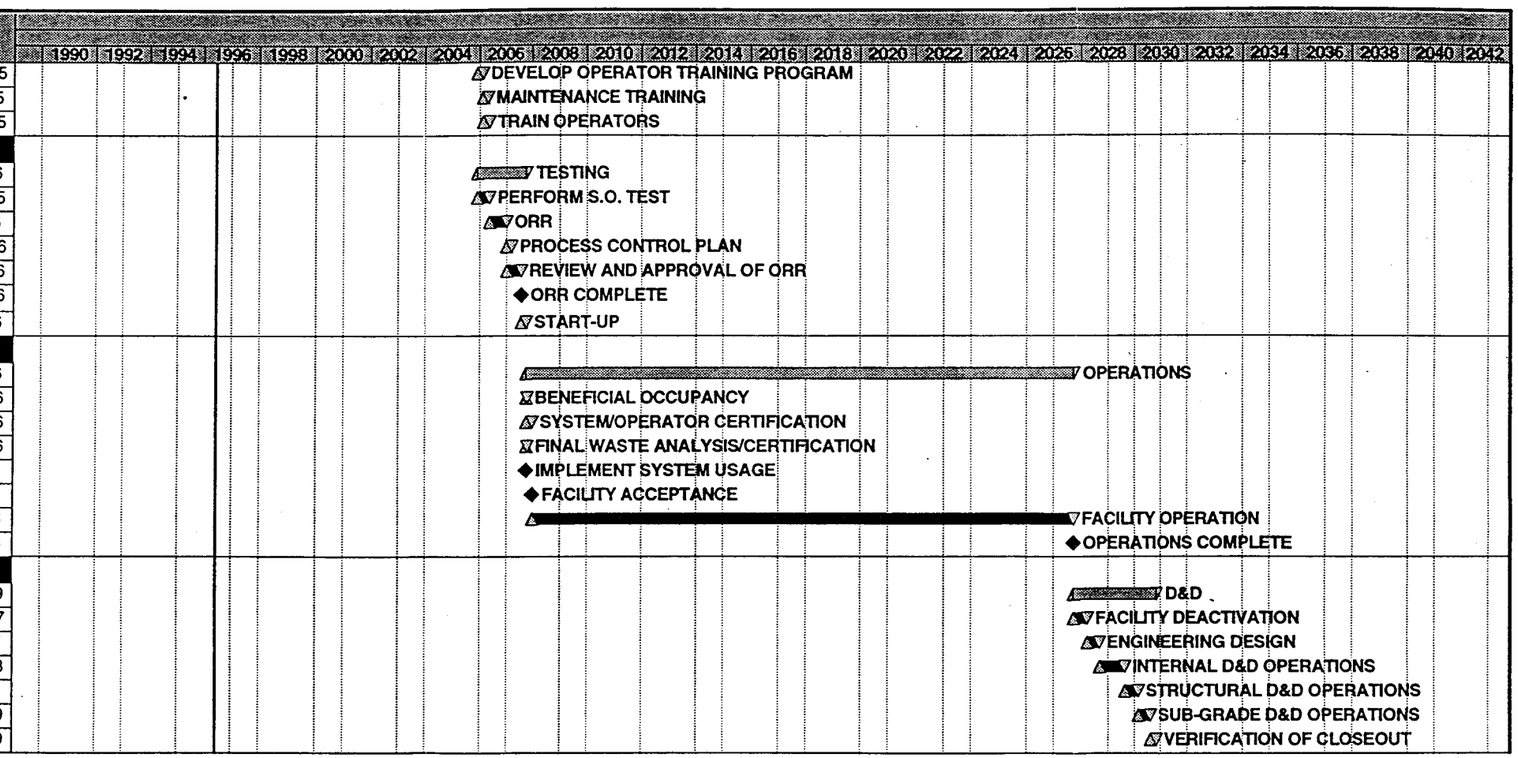

Figure Q-3c
Shred & Compact Scenario

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,903*	14JUL88A	22APR31
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
10	PRECONCEPTUAL DESIGN	250	14JUL88A	17JUL89A
15	DECISION TO PROCEED	0	14JUL88A	
20	DEVELOP & SUBMIT FUNDING REQUEST	248	14JUL88A	14JUL89A
25	BENCH SCALE TESTING	640	17JUL89A	27JAN92A
30	DETERMINE PROJECT FEASIBILITY	20	28JAN92A	24FEB92A
35	PILOT SCALE	840	25FEB92A	31MAY95A
40	DETERMINE PROJECT FEASIBILITY	90	01JUN95A	06OCT95
45	FUNDING REQUEST	60	09OCT95	03JAN96
50	DETERMINE LINE ITEM FUNDING	248	04JAN96	20DEC96
51	DESIGN CRITERIA COMPLETE	0		20DEC96
55	PRIORITIZATION & SELECTION OF PROJECTS	60	23DEC96	18MAR97
60	GAIN FUNDING APPROVAL	248	19MAR97	09MAR98
65	OPERATIONAL REQUIREMENTS DOCUMENT	60	10MAR98	02JUN98
70	DESIGN INPUT & REVIEW/APPROVAL	20	27AUG98	24SEP98
NEPA PROCESS				
74	NEPA PROCESS	680*	04JAN96	01SEP98
75	PREPARE ENVIRONMENTAL CHECKLIST	60	04JAN96	27MAR96
80	NEPA COMPLIANCE COMMITTEE REVIEW	10	28MAR96	10APR96
100	PREPARE ADM	60	11APR96	05JUL96
105	NEPA DETERMINATION DOE REVIEW ADM	30	08JUL96	16AUG96
165	PREPARE NOTICE OF INTENT	10	19AUG96	30AUG96
170	PUBLIC SCOPING	30	03SEP96	14OCT96
175	PREPARE IMPLEMENTATION PLAN	60	15OCT96	09JAN97
180	PREPARE DRAFT ENVIRONMENTAL IMPACT	240	10JAN97	17DEC97
185	DOE REVIEW DRAFT ENVIR. IMPACT	60	18DEC97	13MAR98
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	16MAR98	13MAR98
195	STATE REVIEW & PUBLIC COMMENT PERIOD	60	16MAR98	08JUN98
200	REVIEW & FINALIZE ENV. IMPACT	60	09JUN98	01SEP98
205	ISSUE ROD	0		01SEP98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	1,138*	10MAR98	23AUG02
440	HEALTH AND SAFETY PLAN	60	10MAR98	02JUN98
435	PREPARE QAPP FOR IMPLEMENTATION	60	10MAR98	02JUN98
460	PREPARE OPERATING QAPP	60	03JUN98	26AUG98
465	REVIEW/APPROVE IMPLEMENTATION PHASE	30	03JUN98	15JUL98
485	REVIEW AND APPROVE OPERATING QAPP	30	27AUG98	08OCT98
486	QAPP COMPLETE	0		08OCT98
445	UPDATE/REVISE PROGRAM PLAN	60	10MAR98	02JUN98
470	DOE REVIEW PROGRAM PLAN	30	03JUN98	15JUL98
490	FINALIZE PROGRAM PLAN	30	16JUL98	26AUG98
450	APENs DETERMINATION	240	10MAR98	16FEB99
475	AGENCY REVIEWS APENs	90	17FEB99	23JUN99
495	FINALIZE APENs	80	24JUN99	15OCT99
451	APENs DETERMINATION COMPLETE	0		15OCT99

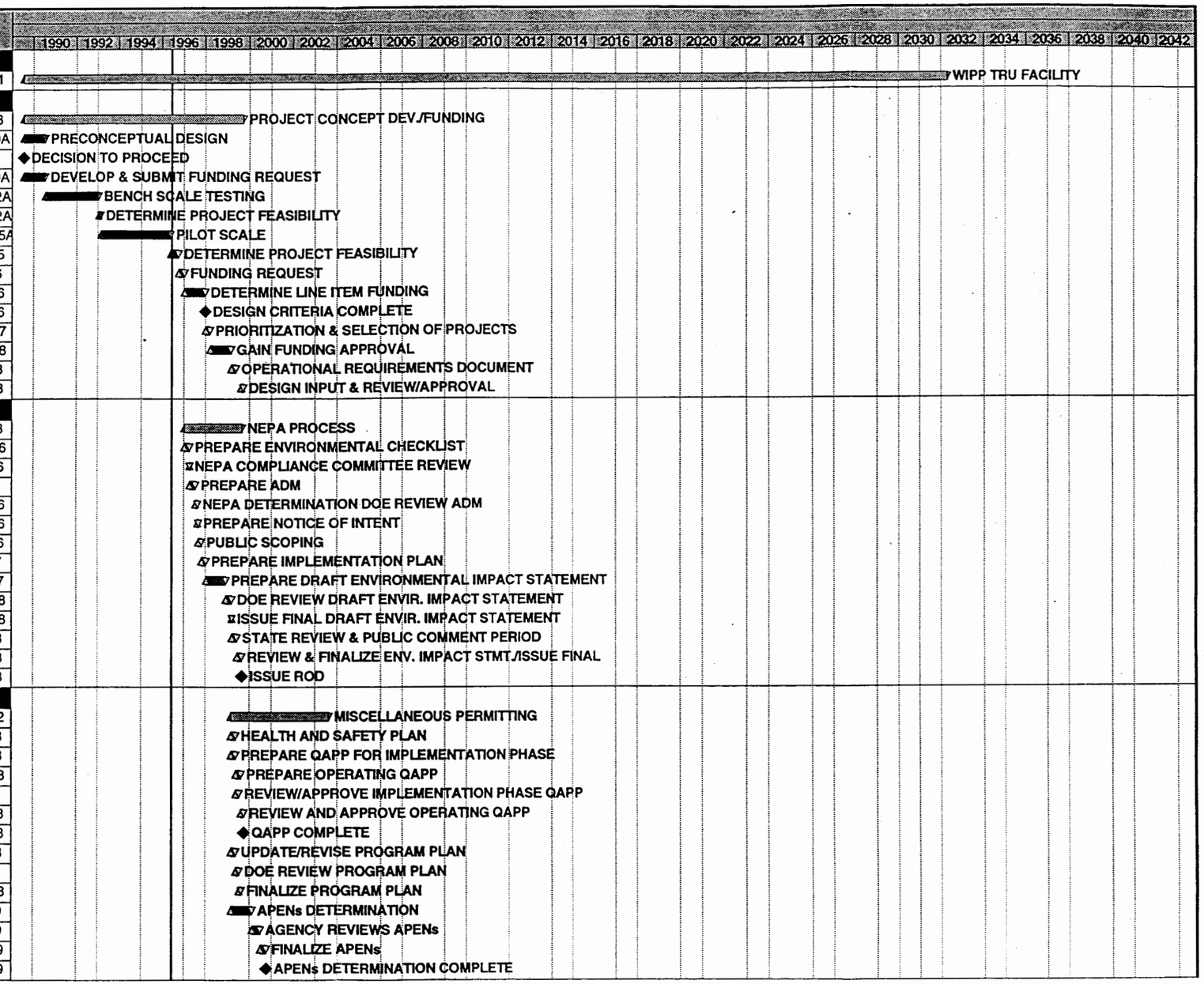

Figure Q-4a
Plasma Scenario

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
455	NESHAPS DETERMINATION	300	28OCT99	02JAN01
480	AGENCY REVIEWS NESHAPS	90	03JAN01	08MAY01
500	FINALIZE NESHAPS	80	09MAY01	30AUG01
501	NESHAPS DETERMINATION COMPLETE	0		30AUG01
502	PREPARE PSD PERMIT APPLICATION	250	28OCT99	19OCT00
503	PSD PERMIT REVIEW and APPROVAL	250	31AUG01	23AUG02
504	PSD PERMIT COMPLETE	0		23AUG02
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	700*	22SEP00	20JUN03
339	BEGIN RCRA PERMIT MOD	0	22SEP00	
380	PREPARE RCRA PERMIT MODIFICATION	250	22SEP00	14SEP01
385	DOE REVIEWS PERMIT MOD	60	17SEP01	10DEC01
390	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	11DEC01	30MAY02
395	PUBLIC COMMENT PERIOD	60	31MAY02	23AUG02
400	PUBLIC HEARING	2	31MAY02	03JUN02
405	RESPOND TO COMMENTS & FINALIZE PERMIT	90	26AUG02	02JAN03
410	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	03JAN03	20JUN03
430	PERMIT APPROVAL	0		20JUN03
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
210	PREPARE HAZARD CLASSIFICATION	60	03JUN98	26AUG98
215	PSAR DEVELOPMENT	120	27AUG98	16FEB99
220	TSAR DEVELOPMENT	120	27AUG98	16FEB99
225	CRITICALITY SAFETY ASSESSMENT	120	27AUG98	16FEB99
230	ORC REVIEW	40	17FEB99	13APR99
235	DOE REVIEW & APPROVE PSAR	40	14APR99	09JUN99
240	FSAR DEVELOPMENT	250	10JUN99	01JUN00
245	DOE REVIEW	40	02JUN00	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,933*	25SEP98	25APR06
250	BID/NEGOTIATE & AWARD DESIGN	90	25SEP98	02FEB99
260	PREPARE TITLE I DESIGN	188	03FEB99	27OCT99
265	PREPARE TITLE II DESIGN	468	28OCT99	28AUG01
270	LONG LEAD PROCUREMENT	350	28OCT99	13MAR01
266	TITLE II DESIGN COMPLETE	0		28AUG01
275	PREPARE CONSTRUCTION PACKAGE	60	31AUG01	26NOV01
280	BID/NEGOTIATE & AWARD CONSTRUCTION	120	27NOV01	15MAY02
285	RCRA HOLD	0		20JUN03
289	BEGIN CONSTRUCTION	0	23JUN03	
290	CONSTRUCTION	625	23JUN03	02DEC05
291	CONSTRUCTION COMPLETE	0		02DEC05
295	FINAL INSPECTIONS	10	05DEC05	16DEC05
300	TITLE III AS-BUILTS	90	19DEC05	25APR06
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	05DEC05	17AUG06
305	PREPARE S.O. TEST PLAN & PROCEDURES	60	05DEC05	28FEB06
310	DEVELOP DATA MANAGEMENT PROCEDURES	60	05DEC05	28FEB06
315	DEVELOP TECHNICAL PROCEDURES	60	05DEC05	28FEB06
320	DEVELOP MAINTENANCE PROCEDURES	60	01MAR06	23MAY06

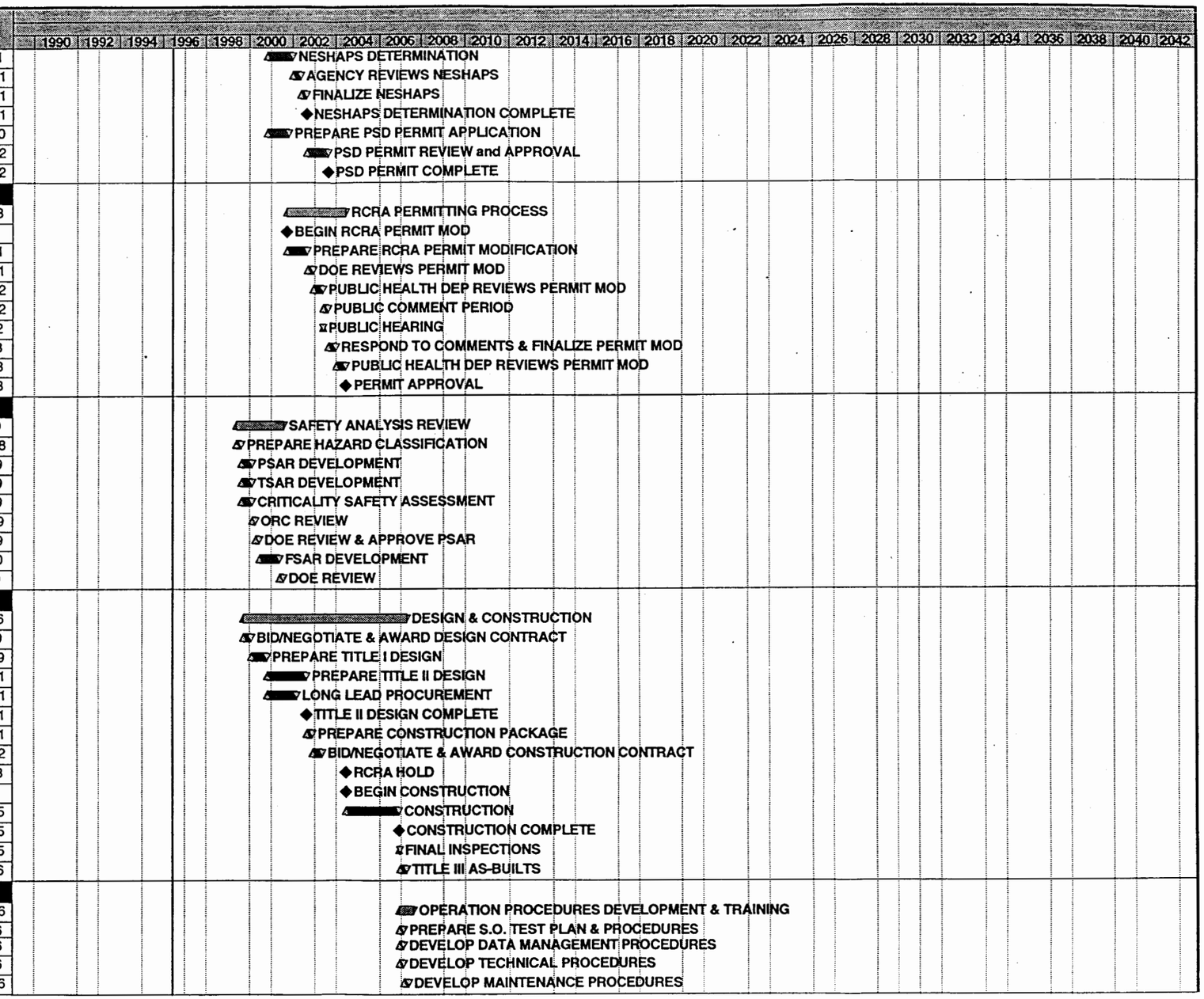

Figure Q-4b
Plasma Scenario

763435.0#-70.00/zc B17

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
330	DEVELOP OPERATOR TRAINING PROGRAM	60	01MAR06	23MAY06
325	MAINTENANCE TRAINING	40	24MAY06	20JUL06
335	TRAIN OPERATORS	60	24MAY06	17AUG06
TESTING				
507	TESTING	460*	01MAR06	18DEC07
509	PERFORM S.O. TEST	120	01MAR06	17AUG06
510	ORR	160	18AUG06	04APR07
520	PROCESS CONTROL PLAN	40	05APR07	31MAY07
525	REVIEW AND APPROVAL OF ORR	140	05APR07	22OCT07
530	ORR COMPLETE	0		22OCT07
535	START-UP	40	23OCT07	18DEC07
OPERATIONS				
539	OPERATIONS	5,100*	19DEC07	21DEC27
545	BENEFICIAL OCCUPANCY	20	19DEC07	17JAN08
550	SYSTEM/OPERATOR CERTIFICATION	60	19DEC07	13MAR08
555	FINAL WASTE ANALYSIS/CERTIFICATION	20	19DEC07	17JAN08
560	IMPLEMENT SYSTEM USAGE	0	19DEC07	
565	FACILITY ACCEPTANCE	0	14MAR08	
570	FACILITY OPERATION	5,040	14MAR08	21DEC27
567	OPERATIONS COMPLETE	0		21DEC27
D&D				
574	D&D	850*	22DEC27	22APR31
575	FACILITY DEACTIVATION	120	22DEC27	09JUN28
580	ENGINEERING DESIGN	120	12JUN28	29NOV28
585	INTERNAL D&D OPERATIONS	310	30NOV28	18FEB30
590	STRUCTURAL D&D OPERATIONS	120	19FEB30	07AUG30
595	SUB-GRADE D&D OPERATIONS	120	08AUG30	28JAN31
600	VERIFICATION OF CLOSEOUT	60	29JAN31	22APR31

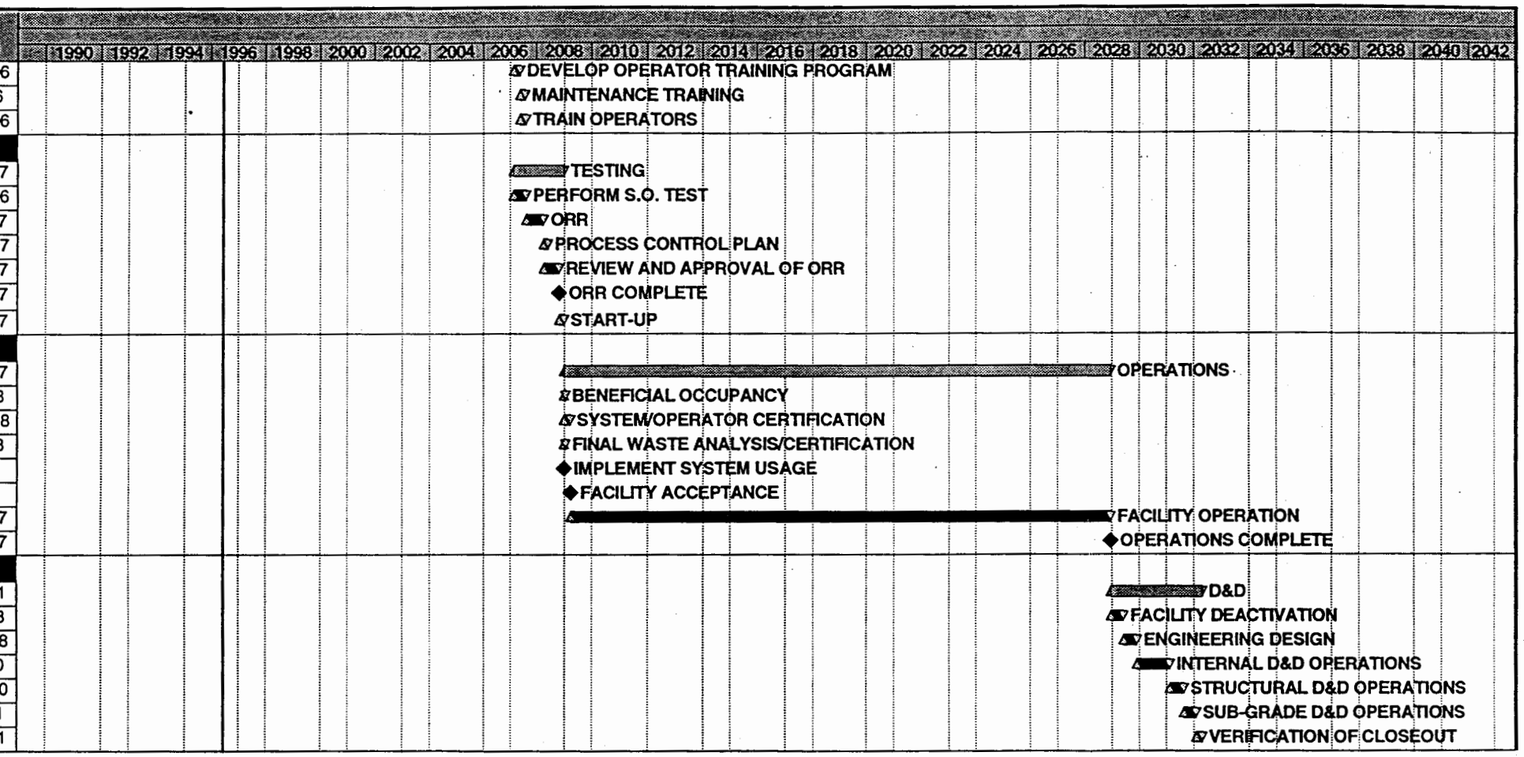

Figure Q-4c
Plasma Scenario

Act ID	Activity Description	Orig Dur	Early Start	Early Finish
WIPP TRU FACILITY				
05	WIPP TRU FACILITY	10,618*	14JUL88A	11MAR30
PROJECT CONCEPT/FUNDING REQUEST PROCESS				
09	PROJECT CONCEPT DEV./FUNDING	2,600*	14JUL88A	24SEP98
10	PRECONCEPTUAL DESIGN	250	14JUL88A	17JUL89A
15	DECISION TO PROCEED	0	14JUL88A	
20	DEVELOP & SUBMIT FUNDING REQUEST	248	14JUL88A	14JUL89A
25	BENCH SCALE TESTING	640	17JUL89A	27JAN92A
30	DETERMINE PROJECT FEASIBILITY	20	28JAN92A	24FEB92A
35	PILOT SCALE	840	25FEB92A	31MAY95A
40	DETERMINE PROJECT FEASIBILITY	90	01JUN95A	06OCT95
45	FUNDING REQUEST	60	09OCT95	03JAN96
50	DETERMINE LINE ITEM FUNDING	248	04JAN96	20DEC96
51	DESIGN CRITERIA COMPLETE	0		20DEC96
55	PRIORITIZATION & SELECTION OF PROJECTS	60	23DEC96	18MAR97
60	GAIN FUNDING APPROVAL	248	19MAR97	09MAR98
65	OPERATIONAL REQUIREMENTS DOCUMENT	60	10MAR98	02JUN98
70	DESIGN INPUT & REVIEW/APPROVAL	20	27AUG98	24SEP98
NEPA PROCESS				
74	NEPA PROCESS	530*	04JAN96	30JAN98
75	PREPARE ENVIRONMENTAL CHECKLIST	60	04JAN96	27MAR96
80	NEPA COMPLIANCE COMMITTEE REVIEW	10	28MAR96	10APR96
100	PREPARE ADM	60	11APR96	05JUL96
105	NEPA DETERMINATION DOE REVIEW ADM	30	08JUL96	16AUG96
165	PREPARE NOTICE OF INTENT	10	19AUG96	30AUG96
170	PUBLIC SCOPING	30	03SEP96	14OCT96
175	PREPARE IMPLEMENTATION PLAN	60	15OCT96	09JAN97
180	PREPARE DRAFT ENVIRONMENTAL IMPACT	120	10JAN97	27JUN97
185	DOE REVIEW DRAFT ENVIR. IMPACT	30	30JUN97	11AUG97
190	ISSUE FINAL DRAFT ENVIR. IMPACT	0	12AUG97	11AUG97
195	STATE REVIEW & PUBLIC COMMENT PERIOD	60	12AUG97	04NOV97
200	REVIEW & FINALIZE ENV. IMPACT	60	05NOV97	30JAN98
205	ISSUE ROD	0		30JAN98
OTHER PERMITTING				
434	MISCELLANEOUS PERMITTING	896*	10MAR98	12SEP01
440	HEALTH AND SAFETY PLAN	60	10MAR98	02JUN98
435	PREPARE QAPP FOR IMPLEMENTATION	60	10MAR98	02JUN98
460	PREPARE OPERATING QAPP	60	03JUN98	26AUG98
465	REVIEW/APPROVE IMPLEMENTATION PHASE	30	03JUN98	15JUL98
485	REVIEW AND APPROVE OPERATING QAPP	30	27AUG98	08OCT98
486	QAPP COMPLETE	0		08OCT98
445	UPDATE/REVISE PROGRAM PLAN	60	10MAR98	02JUN98
470	DOE REVIEW PROGRAM PLAN	30	03JUN98	15JUL98
490	FINALIZE PROGRAM PLAN	30	16JUL98	26AUG98
450	APENs DETERMINATION	120	10MAR98	26AUG98
475	AGENCY REVIEWS APENs	60	27AUG98	19NOV98
495	FINALIZE APENs	40	20NOV98	19JAN99
451	APENs DETERMINATION COMPLETE	0		19JAN99

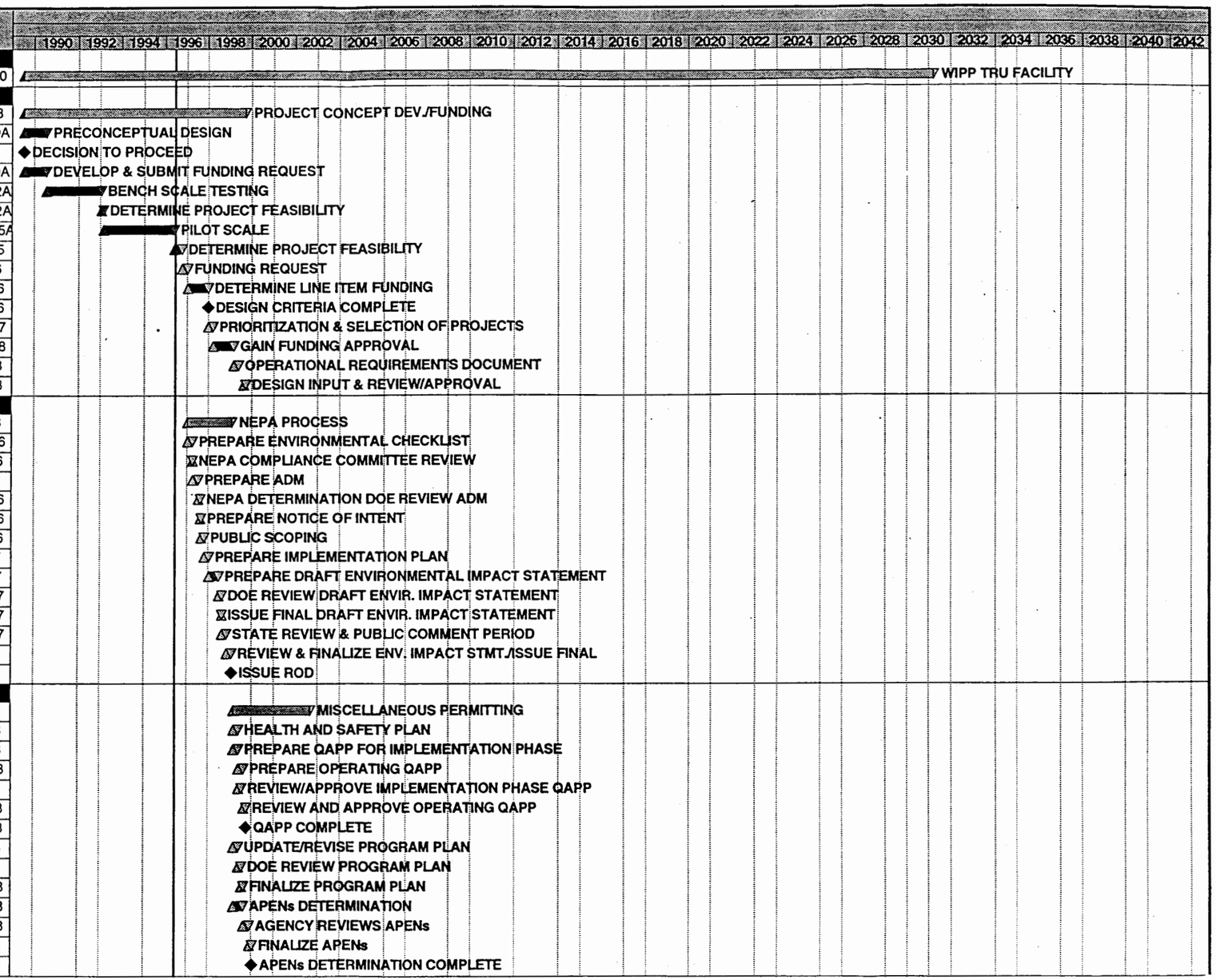

Figure Q-5a
Cementation/Shred/
Add Clay Scenario

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Act ID	Activity Description	Orig Dur	Early Start	Early Finish
455	NESHAPS DETERMINATION	150	28SEP99	27APR00
480	AGENCY REVIEWS NESHAPS	60	28APR00	24JUL00
500	FINALIZE NESHAPS	40	25JUL00	19SEP00
501	NESHAPS DETERMINATION COMPLETE	0		19SEP00
502	PREPARE PSD PERMIT APPLICATION	250	28SEP99	19SEP00
503	PSD PERMIT REVIEW and APPROVAL	250	20SEP00	12SEP01
504	PSD PERMIT COMPLETE	0		12SEP01
RCRA PERMITTING				
338	RCRA PERMITTING PROCESS	530*	20SEP00	17OCT02
339	BEGIN RCRA PERMIT MOD	0	20SEP00	
380	PREPARE RCRA PERMIT MODIFICATION	140	20SEP00	06APR01
385	DOE REVIEWS PERMIT MOD	30	09APR01	18MAY01
390	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	90	21MAY01	26SEP01
395	PUBLIC COMMENT PERIOD	60	27SEP01	20DEC01
400	PUBLIC HEARING	2	27SEP01	28SEP01
405	RESPOND TO COMMENTS & FINALIZE PERMIT	90	21DEC01	29APR02
410	PUBLIC HEALTH DEP REVIEWS PERMIT MOD	120	30APR02	17OCT02
430	PERMIT APPROVAL	0		17OCT02
SAFETY ANALYSIS REVIEW				
209	SAFETY ANALYSIS REVIEW	550*	03JUN98	28JUL00
210	PREPARE HAZARD CLASSIFICATION	60	03JUN98	26AUG98
215	PSAR DEVELOPMENT	120	27AUG98	16FEB99
220	TSAR DEVELOPMENT	120	27AUG98	16FEB99
225	CRITICALITY SAFETY ASSESSMENT	120	27AUG98	16FEB99
230	ORC REVIEW	40	17FEB99	13APR99
235	DOE REVIEW & APPROVE PSAR	40	14APR99	09JUN99
240	FSAR DEVELOPMENT	250	10JUN99	01JUN00
245	DOE REVIEW	40	02JUN00	28JUL00
DESIGN & CONSTRUCTION				
249	DESIGN & CONSTRUCTION	1,686*	25SEP98	05MAY05
250	BID/NEGOTIATE & AWARD DESIGN	90	25SEP98	02FEB99
260	PREPARE TITLE I DESIGN	166	03FEB99	27SEP99
265	PREPARE TITLE II DESIGN	412	28SEP99	08MAY01
270	LONG LEAD PROCUREMENT	210	28SEP99	24JUL00
266	TITLE II DESIGN COMPLETE	0		08MAY01
275	PREPARE CONSTRUCTION PACKAGE	21	09MAY01	07JUN01
280	BID/NEGOTIATE & AWARD CONSTRUCTION	90	08JUN01	15OCT01
285	RCRA HOLD	0		17OCT02
289	BEGIN CONSTRUCTION	0	18OCT02	
290	CONSTRUCTION	550	18OCT02	14DEC04
291	CONSTRUCTION COMPLETE	0		14DEC04
295	FINAL INSPECTIONS	10	15DEC04	29DEC04
300	TITLE III AS-BUILTS	90	30DEC04	05MAY05
PROCEDURES/TRAINING				
304	OPERATION PROCEDURES DEVELOPMENT &	180*	15DEC04	29AUG05
305	PREPARE S.O. TEST PLAN & PROCEDURES	60	15DEC04	10MAR05
310	DEVELOP DATA MANAGEMENT PROCEDURES	60	15DEC04	10MAR05
315	DEVELOP TECHNICAL PROCEDURES	60	15DEC04	10MAR05
320	DEVELOP MAINTENANCE PROCEDURES	60	11MAR05	03JUN05

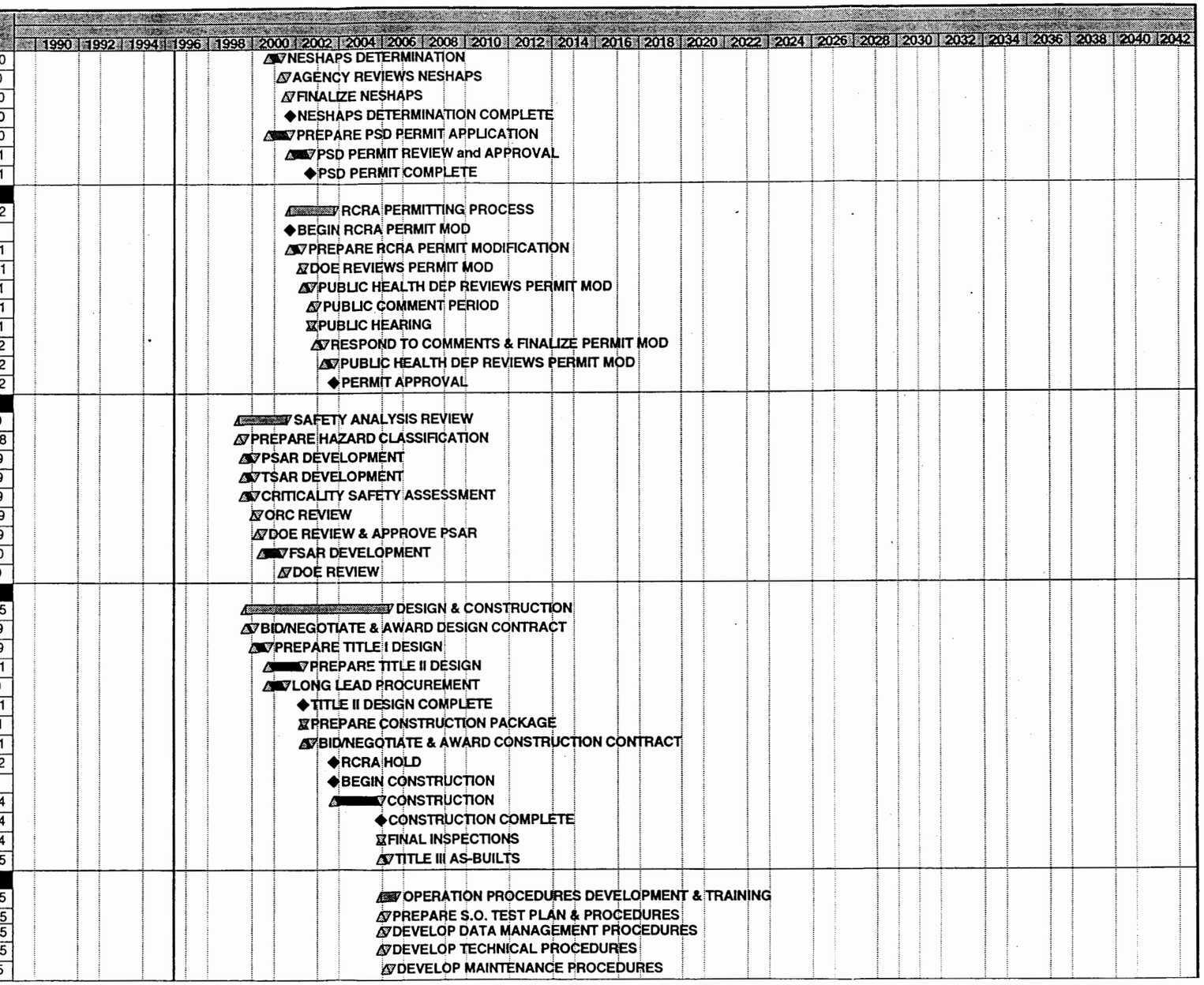

Figure Q-5b
Cementation/Shred/
Add Clay Scenario

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Act ID	Activity Description	Orig Dur	Early Start	Early Finish
330	DEVELOP OPERATOR TRAINING PROGRAM	60	11MAR05	03JUN05
325	MAINTENANCE TRAINING	40	06JUN05	01AUG05
335	TRAIN OPERATORS	60	06JUN05	29AUG05
TESTING				
507	TESTING	460*	11MAR05	29DEC06
509	PERFORM S.O. TEST	120	11MAR05	29AUG05
510	ORR	160	30AUG05	14APR06
520	PROCESS CONTROL PLAN	40	17APR06	12JUN06
525	REVIEW AND APPROVAL OF ORR	140	17APR06	01NOV06
530	ORR COMPLETE	0		01NOV06
535	START-UP	40	02NOV06	29DEC06
OPERATIONS				
539	OPERATIONS	5,100*	02JAN07	04JAN27
545	BENEFICIAL OCCUPANCY	20	02JAN07	29JAN07
550	SYSTEM/OPERATOR CERTIFICATION	60	02JAN07	26MAR07
555	FINAL WASTE ANALYSIS/CERTIFICATION	20	02JAN07	29JAN07
560	IMPLEMENT SYSTEM USAGE	0	02JAN07	
565	FACILITY ACCEPTANCE	0	27MAR07	
570	FACILITY OPERATION	5,040	27MAR07	04JAN27
567	OPERATIONS COMPLETE	0		04JAN27
D&D				
574	D&D	812*	05JAN27	11MAR30
575	FACILITY DEACTIVATION	120	05JAN27	22JUN27
580	ENGINEERING DESIGN	120	23JUN27	10DEC27
585	INTERNAL D&D OPERATIONS	272	13DEC27	05JAN29
590	STRUCTURAL D&D OPERATIONS	120	08JAN29	25JUN29
595	SUB-GRADE D&D OPERATIONS	120	26JUN29	13DEC29
600	VERIFICATION OF CLOSEOUT	60	14DEC29	11MAR30

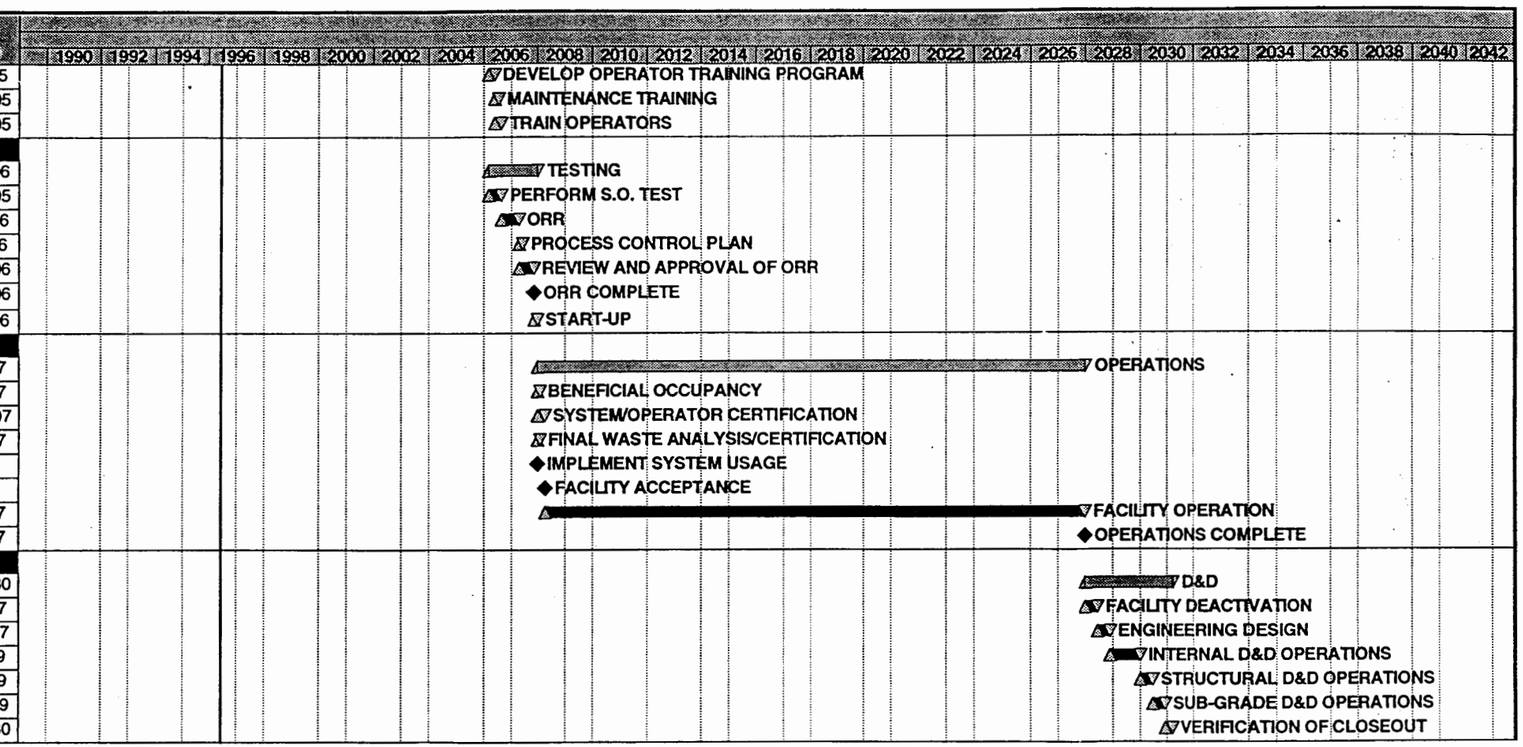

Figure Q-5c
Cementation/Shred/
Add Clay Scenario

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TABLE Q-6

PRELIMINARY PERT TIME ESTIMATES FOR ALTERNATIVE #6
(Time in Years)

Major Activity	T_o	T_m	T_p	T_e	T_e (days)
Preliminary Safety Analysis Report	.890	1.00	2.25	1.19	298
Final Safety Analysis Report	1.420	2.000	4.440	2.310	578
Title I Design	.375	.500	1.250	.604	151
Title II Design	.738	.860	1.810	.998	250
Construction	.910	1.000	2.160	1.178	295
NEPA Documentation	1.781	2.120	7.632	2.982	746
PSD Permit Preparation	.840	1.000	2.250	1.182	295
PSD Permit Approval	.335	.830	2.330	.996	249
NESHAPs	.750	1.000	2.500	1.208	302
RCRA Permit Preparation	.269	.320	.720	.378	95
ORR	1.840	1.840	4.287	2.248	562

The time estimates for Alternative #10 (Plasma Melting) were adjusted from the values given in Table Q-6 by the following:

Activity	Adjustment
Title I and Title II Design	+25%
Construction	+25%
D&D	+25%
RCRA Permit & NEPA	+100%

1.4DETAILED SCHEDULESAttachment 2 shows the detailed schedules for the waste processing EAs.

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APPENDIX Q

ATTACHMENT 1

SCHEDULING ASSUMPTIONS FOR WASTE PROCESSING ENGINEERED ALTERNATIVES

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APPENDIX Q

ATTACHMENT 1
SCHEDULING ASSUMPTIONS FOR WASTE PROCESSING ENGINEERED ALTERNATIVES

This attachment presents the assumptions used in developing the detailed schedules for each of the waste processing EAs. The assumptions are organized into tables, where each table presents the assumptions used for a specific alternative, as shown:

TABLE	ALTERNATIVE
Q-1	Baseline
Q-2	#1 Supercompact
Q-3	#6 Shred & Compact
Q-4	#10 Plasma Melting
Q-5	#94 Enhanced Cement/Shred & Clay

TABLE Q-1

Schedule Assumptions
Baseline Case

09 PROJECT CONCEPT DEVELOPMENT/FUNDING

Assumptions:

1. Funding request submitted after demo-scale will drive NEPA activities

2. Funding approval after project prioritization will drive other permitting and RCRA activities

3. Project requests line item funding

74 NEPA PROCESS

Assumptions:

1. EIS will be required resulting in a ROD

2. NEPA must be complete prior to Title I Design

209 SAFETY ANALYSIS REVIEW

Assumptions:

1. Preparation of the operational requirement document initiates the SAR process

2. PSAR must be completed prior to construction

3. FSAR must be completed prior to ORR

249 DESIGN AND CONSTRUCTION

Assumptions:

1. Facility is a concrete/steel structure

2. Facility retrieves, characterizes, treats to WIPP WAL, stores, and ships waste

338 RCRA PERMITTING PROCESS

Assumptions:

1. Facility requires a RCRA permit modification

2. Permit required prior to construction

434 MISCELLANEOUS PERMITTING

Assumptions:

1. A H&S Plan is required prior to construction

2. Current program plan will require updating

3. APENS will be determined

4. NESHAPS will be determined prior to design

5. A QAPP is required prior to construction

6. PSD permit required

539 OPERATIONS

Assumptions:

1. Facility will operate for 20 years

574 D&D

Assumptions:

1. Facility will undergo decontamination and decommissioning after its 20 year operation period

TABLE Q-2

Schedule Assumptions
Alternative #1—Supercompaction

09 PROJECT CONCEPT DEVELOPMENT/FUNDING

Assumptions:

1. Funding request submitted after demo-scale will drive NEPA activities
2. Funding approval after project prioritization will drive other permitting and RCRA activities
3. Project requests line item funding

74 NEPA PROCESS

Assumptions:

1. EIS will be required resulting in a ROD
2. NEPA must be complete prior to Title I Design

209 SAFETY ANALYSIS REVIEW

Assumptions:

1. Preparation of the operational requirement document initiates the SAR process
2. PSAR must be completed prior to construction
3. FSAR must be completed prior to construction of ORR

249 DESIGN AND CONSTRUCTION

Assumptions:

1. Facility is a concrete/steel structure
2. In addition to baseline functions, facility receives drums and supercompacts solid organic and solid inorganic waste
3. Title II design complete prior to RCRA permit application submittal

338 RCRA PERMITTING PROCESS

Assumptions:

1. Facility requires a RCRA permit modification

2. Permit required prior to construction

434 MISCELLANEOUS PERMITTING

Assumptions:

1. A H&S Plan is required prior to construction

2. Current program plan will require updating

3. APENS will be determined

4. NESHAPS will be determined

5. A QAPP is required prior to design

6. PSD permit required prior to construction

539 OPERATIONS

Assumptions:

1. Facility will operate for 20 years

574 D&D

Assumptions:

1. Facility will undergo decontamination and decommissioning after its 20 year operation period

TABLE Q-3

Schedule Assumptions
Alternative #6—Shred and Compact

09 PROJECT CONCEPT DEVELOPMENT/FUNDING

Assumptions:

1. Funding request submitted after demo-scale will drive NEPA activities

2. Funding approval after project prioritization will drive other permitting and RCRA activities

3. Project requests line item funding

74 NEPA PROCESS

Assumptions:

1. EIS will be required resulting in a ROD

2. NEPA must be complete prior to Title I Design

209 SAFETY ANALYSIS REVIEW

Assumptions:

1. Preparation of the operational requirement document initiates the SAR process

2. PSAR must be completed prior to construction

3. FSAR must be completed prior to ORR

249 DESIGN AND CONSTRUCTION

Assumptions:

1. Facility is a concrete/steel structure

2. In addition to baseline functions, facility receives drums, shreds and compacts contents, and repacks for disposal

3. Title II design complete prior to RCRA permit application submittal

338 RCRA PERMITTING PROCESS

Assumptions:

1. Facility requires a RCRA permit modification

2. Permit required prior to construction

434 MISCELLANEOUS PERMITTING

Assumptions:

1. A H&S Plan is required prior to construction

2. Current program plan will require updating

3. APENS will be determined

4. NESHAPS will be determined

5. A QAPP is required prior to design

6. PSD permit required prior to construction

539 OPERATIONS

Assumptions:

1. Facility will operate for 20 years

574 D&D

Assumptions:

1. Facility will undergo decontamination and decommissioning after its 20 year operation period

TABLE Q-4

Schedule Assumptions
Alternative #10—Plasma Melting

09 PROJECT CONCEPT DEVELOPMENT/FUNDING

Assumptions:

1. Funding request submitted after demo-scale will drive NEPA activities
2. Funding approval after project prioritization will drive other permitting and RCRA activities
3. Project requests line item funding

74 NEPA PROCESS

Assumptions:

1. EIS will be required resulting in a ROD
2. NEPA must be complete prior to Title I Design

209 SAFETY ANALYSIS REVIEW

Assumptions:

1. Preparation of the operational requirement document initiates the SAR process
2. PSAR must be completed prior to construction
3. FSAR must be completed prior to ORR

249 DESIGN AND CONSTRUCTION

Assumptions:

1. Facility is a concrete/steel structure
2. In addition to baseline functioning, facility houses a plasma arc furnace
3. Title II design complete prior to RCRA permit application submittal

338 RCRA PERMITTING PROCESS

Assumptions:

1. Facility requires a RCRA permit modification

2. Permit required prior to construction

434 MISCELLANEOUS PERMITTING

Assumptions:

1. A H&S Plan is required prior to construction

2. Current program plan will require updating

3. APENS will be determined

4. NESHAPS will be determined

5. A QAPP is required prior to design

6. PSD permit required prior to construction

539 OPERATIONS

Assumptions:

1. Facility will operate for 20 years

574 D&D

Assumptions:

1. Facility will undergo decontamination and decommissioning after its 20 year operation period

TABLE Q-5

Schedule Assumptions
Alternative #94—Enhanced Cementation/Shred and Add Clay

09 PROJECT CONCEPT DEVELOPMENT/FUNDING

Assumptions:

1. Funding request submitted after demo-scale will drive NEPA activities

2. Funding approval after project prioritization will drive other permitting and RCRA activities

3. Project requests line item funding

74 NEPA PROCESS

Assumptions:

1. EIS will be required resulting in a ROD

2. NEPA must be complete prior to Title I Design

209 SAFETY ANALYSIS REVIEW

Assumptions:

1. Preparation of the operational requirement document initiates the SAR process

2. PSAR must be completed prior to construction

3. FSAR must be completed prior to ORR

249 DESIGN AND CONSTRUCTION

Assumptions:

1. Facility is a concrete/steel structure

2. In addition to baseline functions, facility receives drums, shreds contents, and adds clay. Enhanced cementation will be used for sludges.

3. Title II design complete prior to RCRA permit application submittal

338 RCRA PERMITTING PROCESS

Assumptions:

1. Facility requires a RCRA permit modification

2. Permit required prior to construction

434 MISCELLANEOUS PERMITTING

Assumptions:

1. A H&S Plan is required prior to construction

2. Current program plan will require updating

3. APENS will be determined

4. NESHAPS will be determined

5. A QAPP is required prior to design

6. PSD permit required prior to construction

539 OPERATIONS

Assumptions:

1. Facility will operate for 20 years

574 D&D

Assumptions:

1. Facility will undergo decontamination and decommissioning after its 20 year operation period

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APPENDIX Q

ATTACHMENT 2
DETAILED SCHEDULES FOR WASTE PROCESSING ENGINEERED ALTERNATIVES

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APPENDIX Q

ATTACHMENT 2
DETAILED SCHEDULES FOR WASTE PROCESSING ENGINEERED ALTERNATIVES

this attachment presents detailed schedules for the waste processing EAs. The schedule for each alternative is presented in a separate figure, as shown below:

FIGURE	ALTERNATIVE
Q-1	Baseline
Q-2	#1 Supercompact
Q-3	#6 Shred & Compact
Q-4	#10 Plasma Melting
Q-5	#94 Enhanced Cement/Shred & Clay

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APPENDIX R
IMPACT ON OTHER WASTE DISPOSAL PROGRAMS

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IMPACT ON OTHER WASTE DISPOSAL PROGRAMS

This appendix presents the detailed methodology used to evaluate Factor 8. Backup data that were used to calculate the results of this factor analysis are also included.

Data from four TRU waste cementation treatment processes at Rocky Flats were analyzed, and the low-level secondary waste stream volumes were summed for each treatment process. The data analyzed for this factor came from the Rocky Flats Waste Stream and Residue Identification and Characterization report (WSRIC), version 5.0. The following treatment processes were reviewed:

Building 774: Organic and Sludge Immobilization System (OASIS)
Building 774: Miscellaneous Waste Handling
Building 774: Precipitation/Filtration
Building 374: Sludge Solidification

Tables R-1 through R-4 present summaries of secondary waste generation for these processes, all of which involve cementation of TRU waste and occur in gloveboxes. It was assumed that the Rocky Flats data would generally be representative of TRU waste cementation processes at any DOE facility. Several other assumptions were made in assembling and compiling the data:

- All secondary waste characterized as "transuranic (TRU) or low level (LL)" was assumed to be LL, to estimate conservatively the potential impacts on the LL waste program. Likewise, waste characterized as "(TRU mixed (TRUM) or low level mixed (LLM)" was assumed to be LLM, and waste characterized as "LLM or hazardous (HAZ)" was assumed to be LLM.

- Several waste streams listed generation rates as "variable" or "insufficient data." Generation rates for these waste streams were estimated based on other similar processes and wastes. The assumptions used are documented in the tables.

- Most generation rates were provided on a volume basis. Those that were presented on a mass basis were converted to volume basis using assumed densities based on other Rocky Flats data and the Baseline Inventory Report. Assumed densities are included in the tables.

Other TRU waste treatment processes at Rocky Flats that parallel treatment options being evaluated in this study, such as the supercompactor, did not have secondary waste estimates provided in the WSRIC report. Because other data were not readily available, it was assumed that the other waste treatments being evaluated (with the exception of plasma melting) generate similar volumes of secondary low-level waste as the cementation process, on a waste input basis.

The four waste generation rates, calculated as volume of low-level secondary waste generated per volume of cemented (output) waste, were then averaged. This average was 0.3 drums of secondary waste generated per drum of output cemented waste. The percents of the total secondary waste generated as low level waste (LLW) and low level mixed waste (LLMW) were also averaged for the four treatment processes. Table R-5 presents a summary of the secondary

1

TABLE R-1

BUILDING 774 OASIS PROCESS
SUMMARY OF SECONDARY WASTE GENERATION

Waste Description	Generation Rate[1]	Assumptions	Waste Category
Solidified oil	600 drums/yr		TRUM or LLM
Leaded glovebox gloves	1 drum/yr		TRUM or LLM
Glovebox filters	4 drums/yr		TRUM or LLM
Line metal	4 drums/yr		TRUM or LLM
Nonline wet combustibles	240 drums/yr		LLM or HAZ
Line wet combustibles	50 drums/yr		TRUM or LLM
Nonline metal	Insufficient data *4 drums/yr*	same as line metal	LLW or nonradioactive
Plastic (PPE)	25 lb/yr *0.1 drum/yr*	combustible drum wt = 212 lb	TRUM or LLM
Dry combustibles	Variable *30 drums/yr*	5% of solidified oil output	LLW

[1]Italic indicates assumed or calculated generation rate.

1

TABLE R-2

BUILDING 774 MISCELLANEOUS WASTE-HANDLING PROCESS SUMMARY OF SECONDARY WASTE GENERATION

Waste Description	Generation Rate[1]	Assumptions	Waste Category
Solidified lab waste, nonhazardous	14,000 lb/yr *22 drums/yr*	640 lb/drum (Rocky Flats data)	TRU or LLW
Solidified lab waste, hazardous	Variable *22 drums/yr*	Same as nonhazardous	TRUM or LLM
Leaded glovebox gloves	50 lb/yr *0.2 drum/yr*	300 lb/drum	TRUM or LLM
Glovebox HEPA filters	500 lb/yr *6.3 drums/yr*	79 lb/drum (WTWBIR)	TRU or LLW
Light metal, hazardous	Variable *0.3 drums/yr*	0.6% of total solidified lab waste, same as OASIS	TRUM or LLM
Light metal, nonhazardous	Variable *0.3 drums/yr*	0.6% of total solidified lab waste, same as OASIS	LLW
Dry combustibles	Variable *2.2 drums/yr*	5% of total solidified lab waste	TRU or LLW
Cement	Variable *0 drums/yr*	Minimal generation	TRU or LLW
Line plastic (empty bottles)	Insufficient data *2.2 drums/yr*	5% of total solidified lab waste	TRU or LLW

[1]Italic indicates assumed or calculated generation rate.

1

TABLE R-3

BUILDING 774 PRECIPITATION/FILTRATION PROCESS SUMMARY OF SECONDARY WASTE GENERATION

Waste Description	Generation Rate[1]	Assumptions	Waste Category
Cemented sludge	456,000 lb/yr *912 drums/yr*	500 lb/drum (Rocky Flats data)	TRUM or LLM
Line wet combustibles	Insufficient data *46 drums/yr*	5% of cemented sludge	TRUM or LLM
Leaded glovebox gloves	2 drums/yr		TRUM or LLM
Light metal, nonhazardous	3 drums/yr		TRU or LLW
Plenum prefilters	24 to 72 filters/yr *24 drums/yr*	Avg 48 filters/yr 2 filters/drum	LLW
Oil (lube)	4 gal/yr *0.07 drums/yr*		TRUM or LLM
Nonline dry combustibles	50 drums/yr		LLW
Filtrate	Insufficient data *0 drums/yr*	Recycled in process	TRUM or LLM
Glovebox filters	1-2 drums/yr *1.5 drums/yr*	Average	TRU or LLW
Nonline wet combustibles	Variable *46 drums/yr*	5% of cemented sludge	LLW
Light metal, hazardous	3 drums/yr		TRUM or LLM
Plastic (PPE)	25 lb/yr *0.1 drum/yr*	Combustible drum wt = 212 lb	TRUM or LLM

[1]Italic indicates assumed or calculated generation rate.

1

TABLE R-4

BUILDING 374 SLUDGE SOLIDIFICATION PROCESS SUMMARY OF SECONDARY WASTE GENERATION

Waste Description	Generation Rate[1]	Assumptions	Waste Category
Solidified bypass sludge	5-10 drums/month *90 drums/yr*	Average	TRUM or LLM
Process liquid waste (filtrate)	Variable *0 drums/yr*	Recycled in process	TRUM or LLM
Process liquid waste (supernatant)	Variable *0 drums/yr*	Recycled in process	TRUM or LLM
Wet combustibles	11 gal/month *2.4 drums/yr*		TRUM or LLM
Dry combustibles	11 gal/month *2.4 drums/yr*		TRUM or LLM
Plastic, hazardous	11 gal/month *2.4 drums/yr*		TRUM or LLM
Light metal, hazardous	11 gal/month *2.4 drums/yr*		TRUM or LLM
Absolute drybox filters	Variable *1.5 drums/yr*	Same as 774 precip/filtration (glovebox filters)	TRU or LLW
Light metal, nonhazardous	11 gal/month *2.4 drums/yr*		LLW
Dry combustibles, nonhazardous	11 gal/month *2.4 drums/yr*		LLW
Plastic, nonhazardous	11 gal/month *2.4 drums/yr*		LLW
Insulation, nonhazardous	11 gal/yr *0.2 drums/yr*		LLW
Insulation, hazardous	11 gal/yr *0.2 drums/yr*		TRUM or LLM
Glass, nonhazardous	11 gal/yr *0.2 drums/yr*		LLW
Hypalon glovebox gloves	Variable *0 drum/yr*	Minimal generation	TRU or LLW

[1]Italic indicates assumed or calculated generation rate.

1

TABLE R-5

WASTE GENERATION RATE SUMMARY

Process	Secondary Waste Generation (drums waste per drum solidified output)	Percentage of LL secondary waste	Percentage of LLM secondary waste
OASIS	0.56	10	90
Misc. Waste Handling	0.26	96	4
Precip/filtration	0.19	71	29
Sludge solidification	0.21	48	52
Averages	0.30	56	44

waste generation and percentages of LLW and LLMW for the four processes. The percentages of LLW and LLMW varied greatly, so an average of approximately 50 percent LLW and 50 percent LLMW was used in the analysis, instead of the calculated averages of 56 percent LLW and 44 percent LLMW.

Because data were not available for other treatment processes, it was assumed that the other waste treatments being evaluated (with the exception of plasma melting) generate similar volumes of secondary low-level waste as the cementation process, on a waste input basis. To convert the cementation data from an output basis to an input basis, the volume increase factor for cementation of 1:2.5 was used (refer to Table 3-73). This waste input basis factor, calculated to be 0.75 drums of secondary waste per drum of input waste, was then applied to each treatment process to calculate the volume of secondary low-level waste generated.

For the plasma melting process, the secondary low-level waste generation was assumed to be zero because the treatment process is designed such that secondary waste is fed back through the plasma melter. The volume reduction achieved in the plasma process for typical secondary wastes such as personal protective equipment, filters, and combustibles, is very high, so the volume of secondary wastes generated from the treatment process will be negligible. However, secondary waste will still be generated in the waste characterization step.

The waste characterization step is shown in the process flow diagrams in Section 3.7.2.1.1. The waste characterization module, as defined in the EMPEIS, includes opening and sorting drum contents, collecting waste samples, and repackaging, if necessary, to remove and stabilize noncompliant waste. This operation, which occurs in a glovebox, is assumed to generate secondary low-level waste at the same rate (input basis) as the treatment processes. The secondary waste generated was calculated only for the portion of the waste inventory that passes through the waste characterization step (assumed to be 30 percent of stored waste and 10 percent of projected waste, as discussed in Section 3.7.2.1.1). Secondary waste generated from waste characterization is the same for the baseline and all engineered alternatives (EA).

Table R-6 shows secondary waste volumes broken down by characterization and treatment steps. The calculated secondary waste generation rates shown in this table were then used to determine impacts on the DOE low-level programs. The calculated generation rates of LLW and LLMW for each EA were compared to current and projected total DOE inventories of LLW and LLMW to determine impact in terms of percentage increase over current levels for each EA. Data for total DOE waste inventories and projections for LLW and LLMW were obtained from the IDB and the MWIR, respectively.

Tables R-7 through R-9 show the secondary waste volumes by site for each configuration and EA. When combined with site-specific waste inventory and generation data, this data could be used to determine impacts on the low-level waste program at each site. A site-specific analysis was outside the scope of this report. Data in these tables were derived from the scaled volumes of sludges, solid organics, and solid inorganics that were used as inputs in the EA cost analysis.

Backup documentation attached to this appendix includes the WSRIC process descriptions for the four processes analyzed and pertinent sections of the IDB.

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TABLE R-6

SECONDARY WASTE VOLUMES
(cubic meters)

	Secondary Waste Generated (m^3)		
Alternative	Waste Char.	Treatment	Total
Baseline	21,848	10,881	32,729
1	21,848	96,192	118,040
6	21,848	96,192	118,040
10	21,848	0	21,848
94	21,848	109,777	131,625

1

TABLE R-7

TOTAL SECONDARY WASTE GENERATED
DECENTRALIZED ALTERNATIVES
CUBIC METERS

Site	Baseline	1	6	10	94
AMES LAB	0	0	0	0	0
ANL-E	8	15	15	7	32
BT	12	12	12	12	12
ETEC	1	1	1	1	1
HANFORD	7,932	41,079	41,079	4,867	41,082
INEL/ANL-W	12,590	28,853	28,853	9,084	39,369
KAPL	1	1	1	1	1
LANL	6,200	16,315	16,315	3,263	19,124
LBL	1	1	1	1	1
LLNL	185	984	984	120	994
MOUND	59	373	373	59	378
MU	0	0	0	0	0
NTS	138	604	604	138	604
ORNL	202	963	963	202	1,047
PANTEX	0	0	0	0	0
PA	0	0	0	0	0
RFP	1,937	5,174	5,174	628	5,315
SNL/NM	2	2	2	2	2
SRS	3,462	23,662	23,662	3,462	23,662
WIPP	0	0	0	0	0
TOTAL	32,729	118,040	118,040	21,848	131,625

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TABLE R-8

TOTAL SECONDARY WASTE GENERATED
REGIONALIZED ALTERNATIVES
CUBIC METERS

Site	Baseline	1	6	10	94
AMES LAB	0	0	0	0	0
ANL-E	7	7	7	7	7
BT	12	12	12	12	12
ETEC	1	1	1	1	1
HANFORD	7,996	41,943	41,943	4,867	41,955
INEL/ANL-W	12,590	29,319	29,319	9,084	39,835
KAPL	1	1	1	1	1
LANL	6,200	16,315	16,315	3,263	19,124
LBL	1	1	1	1	1
LLNL	120	120	120	120	120
MOUND	59	59	59	59	59
MU	0	0	0	0	0
NTS	138	138	138	138	138
ORNL	202	202	202	202	202
PANTEX	0	0	0	0	0
PA	0	0	0	0	0
RFP	1,937	5,174	5,174	628	5,315
SNL/NM	2	2	2	2	2
SRS	3,464	24,745	24,745	3,462	24,856
WIPP	0	0	0	0	0
TOTAL	32,729	118,040	118,040	21,848	131,629

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TABLE R-9

TOTAL SECONDARY WASTE GENERATED
CENTRALIZED ALTERNATIVES
CUBIC METERS

Site	Baseline	1	6	10	94
AMES LAB	0	0	0	0	0
ANL-E	7	7	7	7	7
BT	12	12	12	12	12
ETEC	1	1	1	1	1
HANFORD	4,867	4,867	4,867	4,867	4,867
INEL/ANL-W	9,084	9,084	9,084	9,084	9,084
KAPL	1	1	1	1	1
LANL	3,263	3,263	3,263	3,263	3,263
LBL	1	1	1	1	1
LLNL	120	120	120	120	120
MOUND	59	59	59	59	59
MU	0	0	0	0	0
NTS	138	138	138	138	138
ORNL	202	202	202	202	202
PANTEX	0	0	0	0	0
PA	0	0	0	0	0
RFP	628	628	628	628	628
SNL/NM	2	2	2	2	2
SRS	3,462	3,462	3,462	3,462	3,462
WIPP	10,881	96,192	96,192	0	109,781
TOTAL	32,729	118,040	118,040	21,848	131,629

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ATTACHMENT 1

INTEGRATED DATA BASE REPORT—1993: U.S. SPENT NUCLEAR FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS

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DOE/RW-0006, Rev. 10

December 1994

Integrated Data Base Report—1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics

Prepared for

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Office of Environmental Management
Washington, D.C. 20585

Prepared by

Oak Ridge National Laboratory
Managed by Martin Marietta Energy Systems, Inc., for the
U.S. Department of Energy under contract DE-AC05-84OR21400

Table 4.2. Historical and projected volume, radioactivity, and thermal power of buried DOE LLW[a]

End of calendar year	Volume (10^3 m^3)		Radioactivity (10^3 Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative[b]	Annual	Cumulative
1990	60.0	2,759	545	13,516	2,013	17,844
1991	53.6	2,812	717	13,277	2,788	18,220
1992	48.3	2,860	1,078	13,401	4,947	20,741
1993	50.5	2,911	894	13,147	3,263	20,398
1994	44.2	2,955	756	12,993	3,073	21,143
1995	44.2	2,999	756	12,906	3,073	22,066
1996	69.3	3,068	757	12,847	3,076	23,009
1997	117.2	3,186	759	12,807	3,080	23,928
1998	131.3	3,317	777	12,796	3,122	24,849
1999	146.2	3,463	769	12,785	3,103	25,708
2000	116.7	3,579	763	12,775	3,089	26,510
2001	131.3	3,710	756	12,765	3,073	27,260
2002	131.3	3,841	759	12,764	3,081	27,983
2003	132.6	3,975	764	12,775	3,091	28,687
2004	44.2	4,019	756	12,780	3,073	29,342
2005	131.3	4,150	756	12,792	3,073	29,974
2006	131.2	4,281	761	12,815	3,084	30,596
2007	88.0	4,368	757	12,838	3,076	31,188
2008	88.0	4,457	756	12,864	3,073	31,757
2009	87.7	4,545	756	12,894	3,073	32,309
2010	57.5	4,602	756	12,927	3,073	32,842
2011	64.3	4,666	756	12,963	3,073	33,359
2012	85.3	4,750	757	13,004	3,074	33,866
2013	131.3	4,885	763	13,055	3,088	34,374
2014	95.9	4,979	758	13,102	3,078	34,858
2015	87.7	5,063	756	13,150	3,073	35,322
2016	131.3	5,197	756	13,199	3,073	35,774
2017	131.3	5,331	756	13,251	3,073	36,216
2018	131.3	5,455	756	13,305	3,073	36,648
2019	87.7	5,550	756	13,358	3,073	37,067
2020	87.7	5,634	756	13,416	3,074	37,480
2021	44.2	5,678	756	13,472	3,073	37,879
2022	44.2	5,722	756	13,531	3,073	38,270
2023	44.2	5,766	756	13,590	3,073	38,652
2024	44.2	5,811	756	13,649	3,073	39,025
2025	44.2	5,855	756	13,709	3,073	39,390
2026	44.2	5,899	756	13,770	3,073	39,748
2027	44.2	5,943	756	13,832	3,073	40,098
2028	44.2	5,987	756	13,893	3,073	40,440
2029	44.2	6,031	756	13,955	3,073	40,775
2030	44.2	6,076	756	14,017	3,073	41,104

[a]Summation of values in Tables 4.16 (buried DOE LLW, except SRS saltstone) and 4.17 (LLW saltstone at SRS).

[b]The radioactivity added each year for each waste type is decayed as described in the footnotes of Tables 4.16 and 4.17.

Table 4.6. Summary of physical characteristics for LLW at DOE sites[a]

Waste type	Physical characteristic[b]	Volume, m^3			Activity, Ci		
		1993	Cumulative[c]	1994 (projected)	1993	Total gross[d]	1994 (projected)
Generated on-site	Biological	285	e	317	2,608	e	6,343
	Contaminated equipment	3,531	e	3,347	665,714	e	846,445
	Decontamination debris	4,814	e	5,870	704	e	986
	Dry solids	18,611	e	16,256	76,312	e	87,642
	Solidified sludge	745	e	843	1,657	e	3,673
	Other	13,429	e	7,742	4,168	e	5,235
	Total	41,415	e	34,375	751,163	e	950,324
Stored	Biological	167	939	200	1,361	13,441	3,806
	Contaminated equipment	852	42,248	1,986	109,538	877,888	267,317
	Decontamination debris	2,021	9,164	2,909	607	1,180	852
	Dry solids	4,338	46,332	4,429	20,046	680,334	36,518
	Solidified sludge	639	26,081	738	1,657	1,665	3,583
	Other	6,964	30,902	3,342	213,564	294,664	92,215
	Total	14,981	155,666	13,604	346,773	1,869,172	404,291
Buried	Biological	117	f	122	1,247	f	2,537
	Contaminated equipment	8,783	f	6,324	104,780	f	170,480
	Decontamination debris	7,313	f	10,292	193	f	213
	Dry solids	27,663	f	24,200	785,388	f	579,902
	Solidified sludge	106	f	197	2	f	90
	Other	6,481	f	3,049	2,670	f	2,884
	Total	50,463	2,911,177	44,184	894,280	45,286,174	756,106

[a]Based on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

[b]Physical characteristics: (1) biological (sewage sludge, animal carcasses, excreta, etc.); (2) contaminated equipment (components, maintenance wastes, etc.); (3) decontamination debris (wastes resulting from decontamination and decommissioning efforts, construction debris, etc.); (4) dry solids (normal plant wastes, blotting paper, combustible materials, etc.); (5) solidified sludge (any wastes solidified from a process sludge such as evaporator bottoms solidification, solidification of precipitated salts, etc.); and (6) other (materials which are outside of the above categories).

[c]From beginning of operations through 1993.

[d]Sum of annual additions without decay.

[e]Not applicable [i.e., generation is taken to be an intensive quantity (amount/year) and is not additive; whereas stored and buried are extensive quantities (amounts) and are additive].

[f]Information not available.

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ATTACHMENT 2

TREATMENT PROCESSES

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3.0 PROCESS 374-3: SLUDGE SOLIDIFICATION

The Sludge Solidification Process, located in Rooms 2804, 3803, and 4805, immobilizes radioactive and hazardous materials from decontamination-precipitation, and neutralization for shipment off site. The slurry waste to be solidified in this process is fed to Tanks D-824 A and B from the clarifier bottoms (Tanks D-815, D-819, and D-823) of the Radioactive Decontamination Process, from Tank D-808 of the Acid Neutralization Process, and acid descaling waste from Tank D-845. Equipment used in this process includes various tanks, conveyors, and drum vacuum filters. Figure 3.1 shows the inputs, process flow, and outputs associated with the Sludge Solidification process.

The Sludge Solidification Process contains an associated subprocess comprised of a vent scrubber system. This system collects and neutralizes fumes from chemical preparation area tanks; waste receiving tanks; reactor, flocculator, and clarifier tanks; the sludge dryer; and GB 118 and GB 120 for the Sludge Solidification Process. The fumes from these areas pass through a variable throat venturi where they contact a basic solution injected through sets of nozzles. A short elbow connects the venturi to the gas absorber, which has eight nozzles below a demister pad. Gases are pulled through the system by one of the two blowers. The scrubbing solution contains parallel pumps which switch automatically when a low liquid flow is detected by a sensor. The solution is cooled in the heat exchanges. A portion of the scrubbing solution is drawn off periodically to maintain proper Ph and solids concentration and is transferred to Tanks D-811 A or B. A level controller in the scrubber sump operates a valve used to replenish the liquid with process water. A manual valve in the caustic supply line allows personnel to replenish the caustic materials when necessary. The scrubber pulls a slight vacuum on the tanks and gloveboxes, which is controlled by the pressure drop across the scrubber, set at 600 millimeters absolute pressure. The scrubber vents to the Building 374 filter plenums, which contain two sets of HEPA filters.

Supernatant from Tanks D-824 A and B (at A, Figure 3.1) is decanted to Tank D-812 in the Radioactive Decontamination Process. The slurry from these tanks is pumped to the rotary drum vacuum filter, FL-802 A (at B, Figure 3.1), which is inside a large glovebox (GB 120). The filter drum is coated with a mixture of diatomite and either water or filtrate; this mixture is prepared in Tank D-848 (at C, Figure 3.1). The slurry is fed into the filter pan, and the filtrate is drawn through the precoat by a vacuum, leaving a sludge of precipitated solids on the surface of the filter media. An advancing blade continuously removes the sludge and a thin layer of precoat. Tanks D-825 A or B (at D, Figure 3.1) collect the filtrate from the rotary drum filter for transfer to the Radioactive Decontamination Process. Two mist tanks are associated with the vacuum pumps on the rotary drum filter. The tanks may receive some filtrate, which is discharged to Sump Tank D-852 (Figure 2.1A).

The sludge is solidified using either the sludge dryer system or the bypass system. In the sludge dryer system, the sludge is dried in a dryer (at E, Figure 3.1). The sludge from the vacuum filters is fed to the dryer feed hopper by a drop chute. The sludge is then conveyed through the dryer in heated flights. The dried sludge overflows directly into the conveying system of the direct cementation sludge hopper. In the direct cementation procedure (at F, Figure 3.1), dried sludge, cement, and water are metered by a computer and mixed using a paddle mixer to produce a cemented waste product. The cement is transferred pneumatically to a cement hopper from outside storage. The sludge, cement, and water are deposited in a 55-gallon drum and allowed to solidify. Filter FL-802B supports the direct cementation, which is not currently in operation.

The bypass system (FL-802A) transfers wet sludge directly from the vacuum filter to a 55-gallon drum via a conveyor system (at G, Figure 3.1). Cement and diatomaceous earth are metered into the drum with the sludge to absorb liquids. Various combustibles, glass (from lights and glassware), metals (from tools and pipes, etc.), plastics, and gloves are used in general cleanup and maintenance of the system.

Cemented drummed solids are put in a 90-day drum storage area WMU 379 or WMU 2005 before being sent to Real Time Radiography (RTR), and storage for eventual off-site storage. Filtrate is stored in Tanks D-804 A, B, C and D (Figure 2.1A) and Tank D-811 for eventual treatment in the Radioactive Decontamination Process. Exhaust fumes are passed to the vent scrubber system and are vented to the building filter plenum. Most hazardous wastes are collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to the drum assay counter, RTR, then stored for eventual off-site storage. Nonhazardous wastes are collected in 55-gallon drums in Room 3801 or 3810. Sealed containers are sent to the drum assay counters, to RTR, and then to storage for eventual off-site storage.

Filters are assayed at a drum counter and taken to Size Reduction in Building 776. Process Table 374-3 presents the outputs associated with the Sludge Solidification Process and provides their dispositions and hazardous character.

AutoCAD 12, File Name: 374-3 05/04/95

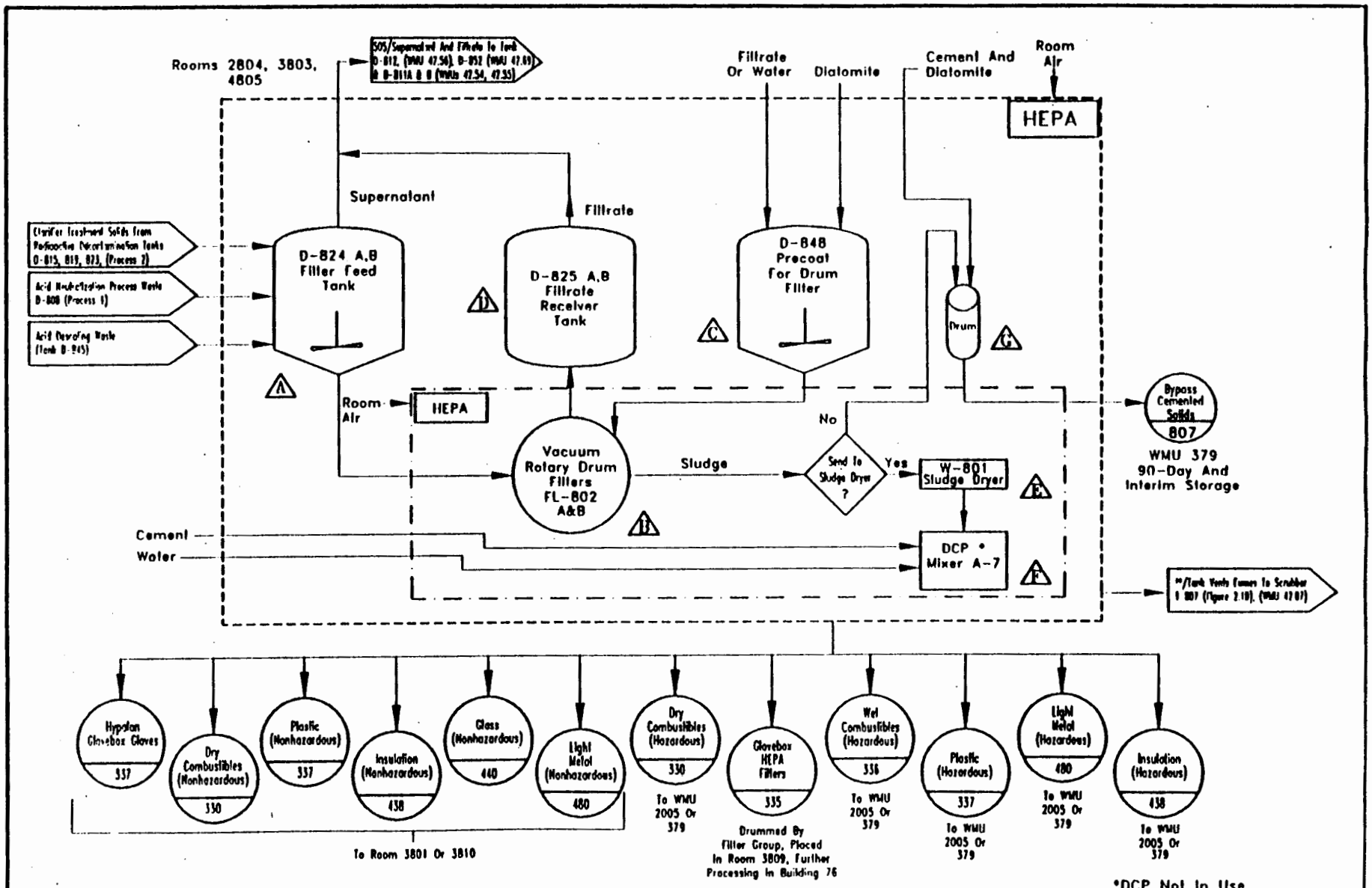

FIGURE 3.1

Rocky Flats Environmental Technology Site Waste Stream & Residue Identification & Characterization	BUILDING 374/PROCESS 3 SLUDGE SOLIDIFICATION	Task	By	Date
		Designed	J. Johnson	11/25/92
		Drawn	B. Crawford	05/04/95
		Checked	J. Joyce	05/04/95

PROCESS 374-3 SLUDGE SOLIDIFICATION

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-2	807	BS	00	NA	Solidified Bypass Sludge, Building 374 RCRA Reg. Chemical Constituents: DCP Bypass Sludge Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F001, F002, F003, F005, F006, F007, F009, F039

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Code
374-3-3	505	HC96	00	3A	Process Liquid Waste (Filtrate) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Leachate Non-RCRA Reg. Chemical Constituents: None	WMU 42.54 WMU 42.55 WMU 42.56 WMU 42.69 WMU 42.81 WMU 42.82	Yes	Yes	Yes	Waste	F001 F002 F00[illegible] F00[illegible] F00[illegible] F00[illegible] F00[illegible] F03[illegible]

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-4	505	HC96	00	3A	Process Liquid Waste (Supernatant) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Leachate Non-RCRA Reg. Chemical Constituents: None	WMU 42.54 WMU 42.55 WMU 42.56 WMU 42.69	Yes	Yes	Yes	Waste	F001, F002, F003, F005, F006, F007, F009, F039

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EP/ Cod
374-3-6	336	HC	00	NA	Combustibles, Wet RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F00 F00 F00 F00 F00 F00 F00 F0

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-7	330	HC	00	NA	Combustibles, Dry (Hazardous) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F001, F002, F003, F005, F006, F007, F009, F039

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Cod
374-3-8	337	HC	00	NA	Plastic (Hazardous)(Teflon, PVC, Poly, Etc) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F00 F00 F00 F00 F00 F00 F00 F03

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-10	480	HC96	00	NA	Light Metal (Hazardous) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Leachate Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F001, F002, F003, F005, F006, F007, F009, F039

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Code
374-3-11	303	00	00	NA	Absolute Drybox Filters(Not Acid Contaminated) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3809	Yes	No	No	Waste	
374-3-13	480	00	00	NA	Light Metal (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-15	330	00	00	NA	Combustibles, Dry (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	
374-3-16	337	00	00	NA	Plastic (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Code
374-3-17	438	00	00	NA	Insulation (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
374-3-18	438	HC	00	NA	Insulation (Hazardous) RCRA Reg. Chemical Constituents: Arsenic, Carbon Tetrachloride, Chlorinated Fluorocarbons, Methylene Chloride, Tetrachloroethylene, Trichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloro, 1,2,2-Trifluoroethane, Toluene, Cadmium, Chromium, Lead, Selenium, Silver; Can Also Contain Acids, Bases, Beryllium, Barium, Denatured Alcohol, Diamond Paste, Ethylene Glycol, Isopropanol, Mercury, Methanol, Mariko, Nickel, Oakite, Penetrate Oil, Spent Emulsifier, Spent Developer, Spent X-ray Developer/Starter And Trim Sol Non-RCRA Reg. Chemical Constituents: None	WMU 379 WMU 2005	Yes	Yes	Yes	Waste	F001, F002, F003, F005, F006, F007, F009, F039

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Cod
374-3-19	440	00	00	NA	Glass (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	
374-3-21	337	00	00	NA	Hypalon Glovebox Gloves RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 3801 Or 3810	Yes	No	No	Waste	

Process Number: 374-3-2 **Title:** SLUDGE SOLIDIFICATION
IDC: 807 **Description:** Solidified Bypass Sludge, Building 374

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Cemented solids from the bypass system are a mixture of wet sludge, cement, and diatomaceous earth that have been placed into 55-gallon drums. The wet sludge consists of solids that have been precipitated from process waste water and separated from filtrate water by a vacuum drum filter. The cement and diatomaceous earth are metered into the drum with the wet sludge to absorb free liquids.

How the Output is Generated:
Solids Filtered From Slurry

Generation Rate:
5-10, 55-Gallon Drums Monthly

How the Output is Managed:
Cemented solids from the bypass system are brought to a 90-day area WMU 379 or WMU 2005 for storage until sample results are received. Based upon sample results, the containers are taken to WMU 19 if TRU mixed or WMU 24 if LLM.

Chemicals/Contaminants in or on the Output:
Building 374 Process Waste Stream

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output is an F-listed waste because it is derived from the treatment of F-listed wastes. Therefore, this output may be a mixed, transuranic or low-level waste.

Process Number: 374-3-3 **Title:** SLUDGE SOLIDIFICATION
IDC: 505 **Description:** Process Liquid Waste (Filtrate)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Filtrate from the vacuum filter is the liquid that is separated from precipitated solids by the FL-802 A and B vacuum drum filters. This filtrate is recycled through the filtrate receiver tank, and eventually mixed with Output 374-3-4, supernatant.

How the Output is Generated:
Generated During The Process

Generation Rate:
Combined With Item 4

How the Output is Managed:
Filtrate may be collected in Tank D-812 (WMU 42.56), Tanks D825 A and B (WMUs 42.81, 42.82), Tank D-852 (WMU 42.69), and Tanks D-811 A and B (WMUs 42.54 and 42.55) for treatment in the Radioactive Decontamination Process.

Chemicals/Contaminants in or on the Output:
Building 374 Process Waste

Characterization Rationale:
This output consists of liquids which are nonline generated in a Radioactive Materials Management Area. According to process knowledge, this output may contain F-listed spent solvents, electroplating wastes, and multi-source leachate. This output may be a mixed, transuranic or low-level waste.

Process Number: 374-3-4 **Title:** SLUDGE SOLIDIFICATION
IDC: 505 **Description:** Process Liquid Waste (Supernatant)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Supernatant from Tanks D-824 A and B (filter feed tanks) is the decanted liquid from tanks that receive clarifier solids from the Radioactive Decontamination Process.

How the Output is Generated:
Decant Solution

Generation Rate:
Variable

How the Output is Managed:
Supernatant from Tanks D-824 A and B (Filter Feed Tanks) is collected in the feed tank D-812, for the Radioactive Decontamination Process (WMU 42.56), Tank D-852 (WMU 42.69) and Tanks D-811 A and B (WMUs 42.54, 42.55).

Chemicals/Contaminants in or on the Output:
Building 374 Process Waste

Characterization Rationale:
This output consists of liquids which are nonline generated in a Radioactive Materials Management Area. According to process knowledge, this output may contain F-listed spent solvents, electroplating wastes, and multi-source leachate. This output may be a mixed, transuranic or low-level waste.

Process Number: 374-3-6 **Title:** SLUDGE SOLIDIFICATION
IDC: 336 **Description:** Combustibles, Wet

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Wet Combustibles Such As Kimwipes, Surgeon's Gloves And Tyveks Which Have Come In Contact With Waste From The Sludge Solidification Process

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Process And Routine Maintenance

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Combustibles are collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to the drum assay counters, RTR, and then storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
Waste From The Sludge Solidification Process

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output is contaminated with F-listed spent solvents, electroplating wastes, and multi-source leachate. This output is nonline generated in a Radioactive Materials Management Area and may be a mixed, transuranic or low-level waste.

Process Number: 374-3-7 **Title:** SLUDGE SOLIDIFICATION
IDC: 330 **Description:** Combustibles, Dry (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Dry Combustibles Such As Surgeon's Gloves, Kimwipes, Tyveks, And Wood That Have Been Contaminated With Waste From The Sludge Solidification Process

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Area And Routine Maintenance

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Dry combustibles are collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to the drum assay counters, RTR, and then storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
Waste From The Radioactive Decontamination Process

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output is contaminated with F-listed spent solvents, electroplating wastes, and multi-source leachate. This output is nonline generated in a Radioactive Materials Management Area and may be a mixed, transuranic or low-level waste.

Process Number: 374-3-8 **Title:** SLUDGE SOLIDIFICATION
IDC: 337 **Description:** Plastic (Hazardous)(Teflon, PVC, Poly, Etc)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Plastic (PVC, Teflon, Polyethylene) Wastes Such As Sample Vials, Bottles, Sheets Of Plastic, Bags, Santa Claus Booties, Oak Ridge Booties, And Pump Box Plexiglass

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Area, Replacement Of Pump Box Plexiglas And Routine Repair Of Equipment

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Plastic waste is collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to the drum assay counters, RTR, and then storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
Waste From The Sludge Solidification Process

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output is contaminated with F-listed spent solvents, electroplating wastes, and multi-source leachate. This output is nonline generated in a Radioactive Materials Management Area and may be a mixed, transuranic or low-level waste.

Process Number: 374-3-10 **Title:** SLUDGE SOLIDIFICATION
IDC: 480 **Description:** Light Metal (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated

- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials

- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Light metal wastes include carbon steel, stainless steel, aluminum, copper, and steel alloys that are part of the equipment for the sludge solidification process.

How the Output is Generated:
Replacement And Repair Of Equipment Contaminated With Sludge Solidification Waste

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Light metal wastes are collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to the drum assay counter, RTR, and storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
Sludge Solidification Wastes

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output is contaminated with F-listed spent solvents, electroplating wastes, and multi-source leachate. This output is generated in a Radioactive Materials Management Area and may be a mixed, transuranic or low-level waste.

Process Number: 374-3-11 **Title:** SLUDGE SOLIDIFICATION
IDC: 303 **Description:** Absolute Drybox Filters(Not Acid Contaminated)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Glovebox HEPA filters are used as room air intake filters only. The filters are used to remove particulates from incoming air. Glovebox HEPA filters are not changed unless air pressure is below .25 inches of water.

How the Output is Generated:
During Routine Scheduled Filter Replacement

Generation Rate:
Variable

How the Output is Managed:
The filters are packed in 55-gallon drums by the Filter Group, then placed in Room 3809 for staging before being sent to the drum assay counter, RTR, and then Size Reduction in Building 776.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is therefore characterized as a TRU or low-level, nonhazardous waste.

Process Number: 374-3-13 **Title:** SLUDGE SOLIDIFICATION
IDC: 480 **Description:** Light Metal (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Light metal wastes include carbon steel, stainless steel, aluminum, copper, and steel alloys that are part of the equipment not contaminated with waste from the sludge solidification process.

How the Output is Generated:
Cleanup Of The Sludge Solidification Process And Some Routine Maintenance

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Nonhazardous light metal is collected in Room 3801 or 3810. Sealed containers are sent to the drum assay counters, RTR, and then storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is therefore characterized as a low-level, nonhazardous waste.

Process Number: 374-3-15 **Title:** SLUDGE SOLIDIFICATION
IDC: 330 **Description:** Combustibles, Dry (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Dry Combustibles Such As Kimwipes, Surgeon's Gloves, Tyveks, And Paper Products That Are Not Contaminated In The Sludge Solidification Process

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Area And Some Routine Maintenance

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Nonhazardous dry combustibles are collected in Room 3801 or 3810. Sealed containers are sent to the drum assay counter, RTR, and then storage for eventual offsite storage.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is therefore characterized as a low-level, nonhazardous waste.

Process Number: 374-3-16 **Title:** SLUDGE SOLIDIFICATION
IDC: 337 **Description:** Plastic (Nonhazardous)

- ☐ RCRA Hazardous
- ■ RCRA Nonhazardous
- ☐ By Analytical Data
- ■ By Process Knowledge
- ☐ LDR Regulated
- ■ Not LDR Regulated
- ☐ Product
- ☐ High Content Residue
- ☐ Low Content Residue
- ☐ Transuranic
- ■ Low-Level
- ☐ Nonradioactive
- ☐ Source/Special Nuclear Materials
- ☐ Fuel Blending
- ☐ Uncontained Gas
- ☐ RCRA Sample
- ☐ Recyclable Material
- ☐ Recycled/Reused
- ☐ TSCA Reg. Waste
- ☐ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Plastic (PVC, Teflon, Polyethylene) Wastes Such As Sample Vials, Bottles, Plastic Sheets, Santa Claus Booties, Oak Ridge Booties, Rain Suits, Bags, And Pump Box Plexiglas That Have Not Come In Contact With The Sludge Solidification Process Waste

How the Output is Generated:
Cleanup Activities In The Process Area And Routine Maintenance

Generation Rate:
11 Gallons Monthly

How the Output is Managed:
Nonhazardous plastic is collected in Room 3801 or 3810. Sealed containers are sent to drum assay counter, RTR, and storage pending offsite storage.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is therefore characterized as a low-level, nonhazardous waste.

Process Number: 374-3-17 **Title:** SLUDGE SOLIDIFICATION
IDC: 438 **Description:** Insulation (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Insulation Scrap Waste That Is New Or Has Not Been In Contact With Waste From The Sludge Solidification Process

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Area And Routine Maintenance Of Equipment

Generation Rate:
11 Gallons Yearly

How the Output is Managed:
Nonhazardous insulation is collected in Room 3801 or 3810. Sealed containers are sent to the drum assay counter, RTR, and storage pending offsite storage.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is there characterized as a low-level, nonhazardous waste.

Process Number: 374-3-18 **Title:** SLUDGE SOLIDIFICATION
IDC: 438 **Description:** Insulation (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes:
F001, F002, F003, F005, F006, F007, F009, F039

Description (Material, Type, Size, Color, etc.):
Insulation That Has Come In Contact With The Liquids From The Sludge Solidification Process

How the Output is Generated:
Cleanup Activities In The Sludge Solidification Area And Routine Maintenance Of Equipment

Generation Rate:
11 Gallons Yearly

How the Output is Managed:
Insulation is collected in a 90-day area, WMU 379 or WMU 2005. Sealed containers are sent to drum assay counter, RTR, then storage pending offsite storage.

Chemicals/Contaminants in or on the Output:
Process Liquid From The Sludge Solidification Process

Characterization Rationale:
This output is characterized using information, based on the same IDC, contained in the Backlog Baseline Book. This output contains listed spent solvents, electroplating wastes, and multi-source leachate. This output is generated in a Radioactive Materials Management Area and may be a mixed, transuranic or low-level waste.

Process Number: 374-3-19 **Title:** SLUDGE SOLIDIFICATION
IDC: 440 **Description:** Glass (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Glass Waste Such As Jars, Sample Vials, Beakers, And Assorted Laboratory Glassware That Has Not Come In Contact With Waste From The Sludge Solidification Process Waste

How the Output is Generated:
Through Breakage And During Routine Process Operations

Generation Rate:
11 Gallons Yearly

How the Output is Managed:
Nonhazardous glass is collected in Room 3801 or 3810. Sealed containers are sent to drum assay counter, RTR, and storage pending offsite storage.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. This output is nonline generated in a Radioactive Materials Management Area and is therefore characterized as a low-level, nonhazardous waste.

Process Number: 374-3-21 **Title:** SLUDGE SOLIDIFICATION
IDC: 337 **Description:** Hypalon Glovebox Gloves

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Hypalon glovebox gloves are used for handling process contaminated equipment or materials within a glovebox that encloses the conveyer vacuum drum filter, and cementation process.

How the Output is Generated:
Hypalon glovebox gloves are generated when gloves deteriorate or are scheduled for change.

Generation Rate:
Variable

How the Output is Managed:
Hypalon glovebox gloves are collected in a 55-gallon drum in either Room 3801 Or 3810.

Chemicals/Contaminants in or on the Output:
Incidental Contact With Sludge Solidification Waste

Characterization Rationale:
This output is line generated in a Radioactive Materials Management Area. According to process knowledge, this output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. Therefore, this output may be a nonhazardous, transuranic or low-level waste.

4.0 PROCESS 774-04: PRECIPITATION/FILTRATION

The Precipitation/Filtration Process treats aqueous waste in two stages; removing radioactive contaminants from the waste and solidifying the material as transuranic mixed waste. Building 774 receives transuranic aqueous wastes from production facilities in Building 771. The precipitation process uses various holding tanks, pumps, controllers, valves, heat exchangers, and numerous filters. Figure 4.1 shows the inputs, process flow, and outputs associated with the Precipitation/Filtration Process.

Transfer tanks accumulate the aqueous waste in Building 771. These tanks are sampled for plutonium, americium, and uranium. If the measured levels are below the economic discard limit (EDL) and the nuclear material safety limit (NMSL), the tank contents are transferred into the Building 774 treatment processes.

Sludge from Tank C-1 gravity flows to Tank T-9 (at A, Figure 4.1). Silver recovery effluent and sludge from various tanks in the Basic Liquid Waste Process—Second Stage are pumped to Tank 40 (at B, Figure 4.1). The waste from Tank 40 and Tanks 4L, 4R, and 12 in the Neutralization Process are pumped to Tank 210A (at C, Figure 4.1). Sludge from Tanks T-9 and 210A are then sent to a precoated rotary drum vacuum filter (at D, Figure 4.1) which separates out the solids. The resultant wet sludge is solidified with a mixture of cement and diatomaceous earth at the rotary drum vacuum filter glovebox.

The slurry waste stream is pulled through the filter pad by a vacuum inside the rotating filter drum. A thin layer of filter pad plus solid contaminants from the slurry is continuously scraped from the outside of the filter. The sludge is collected in a 55-gallon drum which contains a rigid polyethylene liner and an inner PVC liner. A Portland cement/diatomite mixture is added to the drum along with the sludge as it collects in the drum. The cement/diatomite is added to the glovebox via a hopper and screw feeder mounted on the outside of the glovebox. The filtrate is recycled back into the first stage precipitation process described in the Basic Liquid Waste Process—First Stage. Gloves, Oil Dri, Kimwipes, towels, and paper coveralls are used for general room cleanup and materials handling. Oil, HEPA filters, valves, pumps, and lines are used for system maintenance.

The resultant solidified sludge is placed in 55-gallon drums and handled as a low-level or transuranic mixed waste; these drums are taken to Room 241. Excess filtrate separated from the solids in the vacuum filter is piped to Tanks 1RF or 1A, to be handled as part of Process 2, Basic Liquid Waste—First Stage. Exhaust air is passed to the building filter plenum system and then to the atmosphere. Nonline dry combustibles, nonline wet combustibles, glovebox gloves, nonhazardous light metal, plenum prefilters, and glovebox filters are put in the appropriate 55-gallon drums. Waste oil is placed in one-gallon plastic jugs and line wet combustibles are placed in 55-gallon drums and sent to the storage unit in Room 241. Hazardous light metal is placed in the appropriate 55-gallon drum. Waste plastic is collected in Room 241, Unit 73. Process Table 774-4 presents the outputs associated with the Precipitation/Filtration process and provides their dispositions and hazardous character.

AutoCAD 12, File Name: 774-4 12/12/94

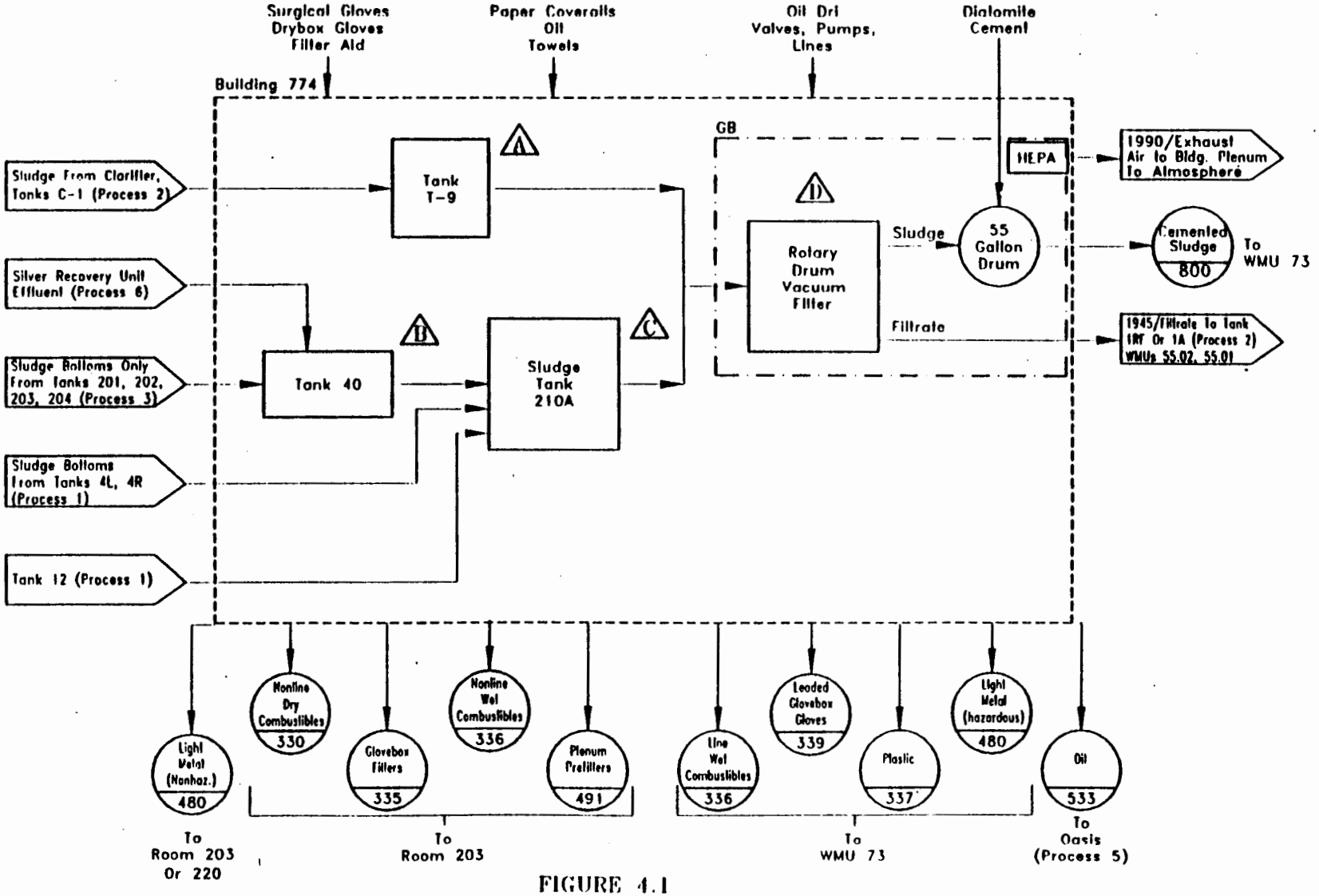

FIGURE 4.1

Rocky Flats Environmental Technology Site Waste Stream & Residue Identification & Characterization	BUILDING 774/PROCESS 4 PRECIPITATION/FILTRATION	Task	By	Date
		Designed	C. Wood	04/23/90
		Drawn	C.B. Grilli	07/14/90
		Checked	T. Horton	12/12/94

PROCESS 774-4 PRECIPITATION/FILTRATION

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-1	800	1236	00	NA	Cemented Sludge RCRA Reg. Chemical Constituents: Chromium Silver Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D007, D011
774-4-3	336	1236	00	NA	Line Wet Combustibles RCRA Reg. Chemical Constituents: Chromium Silver Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D007, D011

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-4	110	24	00	NA	Leaded Glovebox Gloves RCRA Reg. Chemical Constituents: Lead Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D008
774-4-5	480	00	00	NA	Light Metal (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	Room 203 Or In A Crate In Room 220	YES	NO	NO	DBC	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-6	491	00	00	NA	Plenum Prefilters RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	Room 203	YES	NO	NO	Waste	
774-4-7	533	G436	32	4A	Oil RCRA Reg. Chemical Constituents: Corrosive Liquids And Chromium Metal Silver Non-RCRA Reg. Chemical Constituents: Oil (Used)	1-Gallon Plastic Jug WMU 73	YES	YES	YES	Waste	D002, D007, D011

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-8	330	00	00	NA	Nonline Dry Combustibles RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	Room 203	YES	NO	NO	Waste	
774-4-9	1945	G436	00	1A	Filtrate RCRA Reg. Chemical Constituents: Corrosive Liquids And Chromium Metal Silver Non-RCRA Reg. Chemical Constituents: None	WMU 55.01 WMU 55.02	YES	YES	YES	Waste	D002, D007, D011

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-10	335	00	05	NA	Glovebox Filters RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: Base	Drum, Room 203	YES	NO	NO	DBC	
774-4-11	336	00	0205	NA	Nonline Wet Combustibles RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: Acid - General Base	55-Gallon Drum, Room 203	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-4-13	480	1236	00	NA	Light Metal (Hazardous) RCRA Reg. Chemical Constituents: Chromium Silver Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D007 D011
774-4-14	337	1236	00	NA	Plastic RCRA Reg. Chemical Constituents: Chromium Silver Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D007 D011

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-1 **Title:** PRECIPITATION/FILTRATION
IDC: 800 **Description:** Cemented Sludge

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D007, D011

Description (Material, Type, Size, Color, etc.):
Tank Sludge Mixed With Cement And Placed In Plastic Lined 55-Gallon Drums

How the Output is Generated:
Results Of Building 771 Waste Treatment

Generation Rate:
456,000 Pounds Yearly

How the Output is Managed:
The sludge is collected in WMU 73. The drums are sampled then sent to Real Time Radiography (RTR) in Building 664 and eventually will be shipped offsite for disposal.

Chemicals/Contaminants in or on the Output:
Basic Waste

Characterization Rationale:
This cemented sludge is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, it also exhibits the characteristic of toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-3 **Title:** PRECIPITATION/FILTRATION
IDC: 336 **Description:** Line Wet Combustibles

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D007, D011

Description (Material, Type, Size, Color, etc.):
Wet Combustibles Include Kimwipes, Rags, And Paper Cloth, And Plastic, These Materials Are Pu Contaminated

How the Output is Generated:
During General Room Cleanup And Materials Handling

Generation Rate:
Insufficient Data

How the Output is Managed:
Line wet combustibles are collected in 55-gallon drums, Room 241, WMU 73, and transferred to the drum counter and RTR.

Chemicals/Contaminants in or on the Output:
Waste, Acids, Or Other Liquids

Characterization Rationale:
These line wet combustibles are line generated in a Radioactive Materials Management Area and are always generated as TRU or low-level waste. According to process knowledge, this output also exhibits the characteristic of toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

Process Number: 774-4-4 **Title:** PRECIPITATION/FILTRATION
IDC: 339 **Description:** Leaded Glovebox Gloves

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- ■ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D008

Description (Material, Type, Size, Color, etc.):
Leaded glovebox gloves are used for handling plutonium contaminated equipment. The gloves typically contain up to 50% weight lead.

How the Output is Generated:
These gloves are replaced on a periodic or as-needed basis.

Generation Rate:
2 Drums Yearly

How the Output is Managed:
Glovebox gloves are collected in 55-gallon drums, WMU 73, Room 241, and transferred to the drum counter and RTR.

Chemicals/Contaminants in or on the Output:
Lead

Characterization Rationale:
These leaded glovebox gloves are line generated in a Radioactive Materials Management Area and are always generated as TRU or low-level waste. According to process knowledge, and supported by analytical data (G910049, 93G0191), the gloves also exhibit the characteristics of toxicity for lead. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-5 **Title:** PRECIPITATION/FILTRATION
IDC: 480 **Description:** Light Metal (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated

- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials

- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Pumps, Valves, Pipes And Other Materials Require Periodic Replacement

How the Output is Generated:
Replacement Of Pumps, Valves, Pipes And Other Materials

Generation Rate:
3 Drums Yearly

How the Output is Managed:
These materials are collected in 55-gallon drums, in Room 203 or in a crate in room 220, and transferred to the drum counter and RTR.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
This light metal is line generated in a Radioactive Materials Management Area and is always a transuranic or low-level waste. According to process knowledge, the output has no contact with the RCRA hazardous materials used in this process. Therefore, this output can be a nonhazardous, transuranic or low-level waste. The level of radioactivity will be determined by assay of each collection container.

Process Number: 774-4-6 **Title:** PRECIPITATION/FILTRATION
IDC: 491 **Description:** Plenum Prefilters

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Air plenum HEPA prefilters are used in areas with high dust particulate loading in order not to overload building air plenum filters.

How the Output is Generated:
During Plenum Prefilters Replacement

Generation Rate:
24 To 72 Filters Yearly

How the Output is Managed:
Used plenum prefilters are collected and placed in filter 55 gallon drums in Room 203.

Chemicals/Contaminants in or on the Output:
Process Particulates (Building Dust)

Characterization Rationale:
These plenum prefilters are nonline generated in a Radioactive Materials Management Area and can be a low-level waste. According to process knowledge, the output has no contact with the RCRA hazardous materials used in the process. Therefore, it can be a nonhazardous, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-7 **Title:** PRECIPITATION/FILTRATION
IDC: 533 **Description:** Oil

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D002, D007, D011

Description (Material, Type, Size, Color, etc.):
Small amounts of oil are used by equipment in the Precipitation Process area.

How the Output is Generated:
During Equipment Lubrication

Generation Rate:
4 Gallons Yearly

How the Output is Managed:
Oil is collected in one-gallon plastic jugs and transferred to the OASIS.

Chemicals/Contaminants in or on the Output:
Used Oil

Characterization Rationale:
This oil is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, this output also exhibits the characteristics of corrosivity and toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-8 **Title:** PRECIPITATION/FILTRATION
IDC: 330 **Description:** Nonline Dry Combustibles

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Nonline dry combustibles result from the Precipitation/Filtration Process.

How the Output is Generated:
During General Room Cleanup And Materials Handling

Generation Rate:
50 Drums Yearly

How the Output is Managed:
These materials are collected in 55-gallon drums in Room 203, and sent to Room 241.

Chemicals/Contaminants in or on the Output:
Cement And Diatomite

Characterization Rationale:
This output is nonline generated in a Radioactive Materials Management Area, and is known by the generator to always be low-level waste. According to process knowledge, no RCRA hazardous constituents are used in this process, and the output contains no RCRA hazardous constituents, and exhibits no RCRA hazardous characteristics. It is designated as low-level, nonhazardous waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-9 **Title:** PRECIPITATION/FILTRATION
IDC: 1945 **Description:** Filtrate

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D002, D007, D011

Description (Material, Type, Size, Color, etc.):
The filtrate liquid is the liquid remaining after filtering to remove waste sludge contamination. The filtrate liquid material is recycled back into the first stage Precipitation Process.

How the Output is Generated:
During Waste Sludge Contamination Removal

Generation Rate:
Insufficient Data

How the Output is Managed:
Filtrate is collected in WMU 55.01 and 55.02 and transferred to WMU 55.07.

Chemicals/Contaminants in or on the Output:
Basic Liquid

Characterization Rationale:
This filtrate is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, this output also exhibits the characteristics of corrosivity and toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

Process Number: 774-4-10 **Title:** PRECIPITATION/FILTRATION
IDC: 335 **Description:** Glovebox Filters

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Air within gloveboxes is vented through high efficiency particulate air filters to remove potential particulate contamination.

How the Output is Generated:
During Glovebox Filters Replacement

Generation Rate:
1-2 Drums Yearly

How the Output is Managed:
Filters are collected in 55-gallon drums, Room 203 and transferred to the drum counter and RTR.

Chemicals/Contaminants in or on the Output:
Process Particulates

Characterization Rationale:
These glovebox filters are a solid form waste contaminated with basic liquid. Although this basic liquid is known to be corrosive under RCRA, it cannot exhibit the characteristic in this case because the waste form is not liquid. Therefore, the output can be a nonhazardous, transuranic or low-level waste, and the level of radioactivity will be determined by assay of each collection container. This output is generated in a Radioactive Materials Management Area.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-11 **Title:** PRECIPITATION/FILTRATION
IDC: 336 **Description:** Nonline Wet Combustibles

- ☐ RCRA Hazardous
- ■ RCRA Nonhazardous
- ☐ By Analytical Data
- ■ By Process Knowledge
- ☐ LDR Regulated
- ■ Not LDR Regulated
- ☐ Product
- ☐ High Content Residue
- ☐ Low Content Residue
- ☐ Transuranic
- ■ Low-Level
- ☐ Nonradioactive
- ☐ Source/Special Nuclear Materials
- ☐ Fuel Blending
- ☐ Uncontained Gas
- ☐ RCRA Sample
- ☐ Recyclable Material
- ☐ Recycled/Reused
- ☐ TSCA Reg. Waste
- ☐ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Nonline Wet Combustibles Include Gloves, Kimwipes, Towels, And Paper Coveralls

How the Output is Generated:
During General Room Cleanup And Materials Handling

Generation Rate:
Variable

How the Output is Managed:
Placed In A 55-Gallon Drum In Room 203, And Sent To Room 241

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
These nonline wet combustibles are a solid form waste contaminated with acids and bases. Although these acids and bases are known to be corrosive liquid under RCRA, they cannot exhibit the characteristic in this case because the waste form is not liquid. This output is generated in a Radioactive Materials Management Area and can be a nonhazardous, low-level waste.

Process Number: 774-4-13 **Title:** PRECIPITATION/FILTRATION
IDC: 480 **Description:** Light Metal (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D007, D011

Description (Material, Type, Size, Color, etc.):
Pumps, valves, pipes and other materials require periodic replacement. Contaminated spent parts constitute line light metal.

How the Output is Generated:
Replacement Of Pumps, Valves, Pipes And Other Materials

Generation Rate:
3 Drums Yearly

How the Output is Managed:
These materials are collected in 55-gallon drums, WMU 73, Room 241 and transferred to the drum counter and RTR.

Chemicals/Contaminants in or on the Output:
Corrosive Sludge From Process

Characterization Rationale:
This light metal is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, this output also exhibits the characteristic of toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-4-14 **Title:** PRECIPITATION/FILTRATION
IDC: 337 **Description:** Plastic

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated

- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials

- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D007, D011

Description (Material, Type, Size, Color, etc.):
Supplied Air Suits, Gloves, Booties

How the Output is Generated:
During Routine Process Operations

Generation Rate:
25 Pounds Yearly

How the Output is Managed:
Placed In A 55-Gallon Drum, Room 241, WMU 73

Chemicals/Contaminants in or on the Output:
Solvents

Characterization Rationale:
This plastic is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, the output also exhibits the characteristic of toxicity for chromium and silver. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

5.0 PROCESS 774-05: OASIS

The Organic and Sludge Immobilization System (OASIS) Process accepts waste oils from any building at the Rocky Flats Environmental Technology Site which contain transuranic material, combines the waste with emulsifier, Envirostone and accelerator, and solidifies the mixture for transport in drums. The waste oil primarily comes from Buildings 707, 776, and 777. The OASIS process uses various holding tanks, pumps, controllers, valves, and mixers. Figure 5.1 shows the inputs, process flow, and outputs associated with the OASIS Process.

Waste oil being transferred from Buildings 707, 776, and 777 is stored in Tanks T-13 and T-14 (at A, Figure 5.1). A third tank, T-374A, has been used in the past to store feed to this system; however, this tank has been tagged out, and there are no plans for future use. From Tanks T-13 and T-14, the waste oil is pumped to the OASIS mixer (at B, Figure 5.1). The pump is enclosed in a small glovebox. Waste oil, water, emulsifier, Envirostone, and accelerator (to speed up the setting process) are mixed in a 55-gallon drum attached to the bottom of the glovebox. The waste is then sampled for plutonium, americium, and uranium. After the mixture has set, the drum is moved to Room 241 for storage. Surgical gloves, Kimwipes, tape, plastic, paper, and coveralls are used for general room cleanup and materials handling.

After a sufficient number of drums have accumulated in Room 241, (including waste drums not associated with the OASIS process), the waste is sent to RTR. Glovebox exhaust is discharged to the main HEPA filter plenum in Room 341. In addition to the solidified waste oil, outputs from the OASIS process include glovebox filters and metal. These wastes are put in the appropriate 55-gallon drums or crates in Rooms 203 or 220, then sent to Building 371 or 776 for counting. Leaded glovebox gloves are collected in a drum in Unit 73. Line and nonline-generated combustibles such as tape, plastic, Kimwipes, paper, and contaminated coveralls are generated throughout the building, collected in a 55-gallon drum, and placed in Rooms 210 or 203. Plastic is accumulated in Unit 73. Sanitary trash (packaging waste) is placed in a dumpster adjacent to the powder shed. Process Table 774-5 presents the outputs associated with OASIS and provides their dispositions and hazardous character.

AutoCAD 12, File Name: 774-5 12/12/94

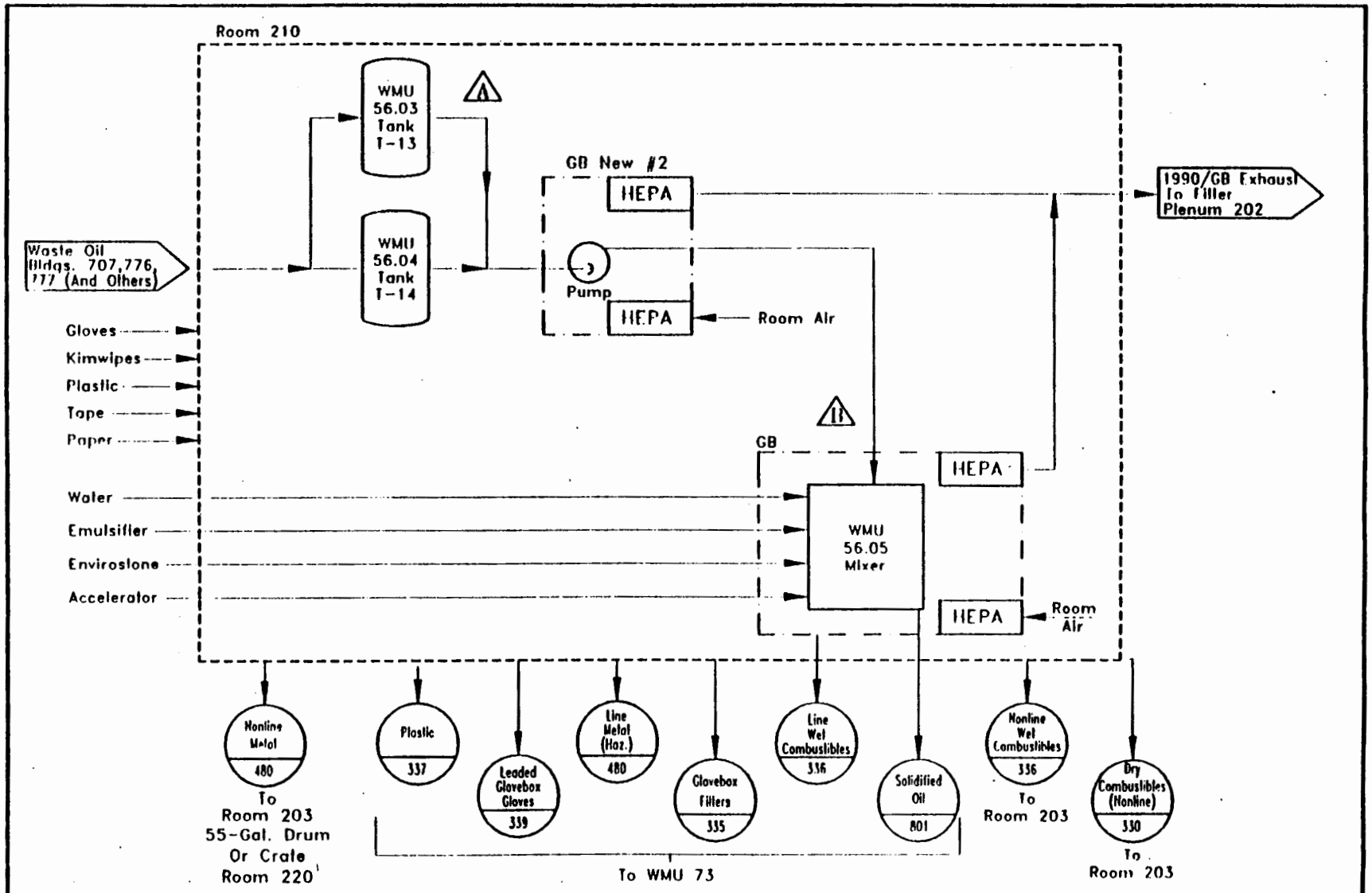

FIGURE 5.1

Rocky Flats Environmental Technology Site Waste Stream & Residue Identification & Characterization	BUILDING 774/PROCESS 5 OASIS	Task		Date
		Designed	D. Gelston	04/19/90
		Drawn	J.D. Sikora	07/19/90
		Checked	T. Horton	12/12/94

PROCESS 774-5 OASIS

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-5-1	801	B1	32	NA	Solidified Oil RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001, F002

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-5-2	339	J7	32	NA	Leaded Glovebox Gloves RCRA Reg. Chemical Constituents: OASIS Liquid/Solidified Liquid Containing Oil, Freon TF, Carbon Tetrachloride And 1,1,1-Trichloroethane Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	D008, F001, F002
774-5-3	335	B1	32	NA	Glovebox Filters RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001, F002

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Code
774-5-4	480	B1	32	NA	Line Metal (Hazardous) RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001 F002
774-5-6	336	B1	32	NA	Nonline Wet Combustibles RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001 F002

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-5-7	336	B1	32	NA	Line Wet Combustibles RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001, F002
774-5-11	480	00	00	NA	Nonline Metal RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Code
774-5-12	337	B1	32	NA	Plastic RCRA Reg. Chemical Constituents: Freon TF, Carbon Tetrachloride, 1,1,1-Trichloroethane, Lead, Chromium, Cadmium Non-RCRA Reg. Chemical Constituents: Oil (Used)	WMU 73	YES	YES	YES	Waste	F001 F002
774-5-13	330	00	00	NA	Dry Combustibles RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum	YES	NO	NO	Waste	

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-1 **Title:** OASIS
IDC: 801 **Description:** Solidified Oil

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated

- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials

- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
Oils from Buildings 707, 776, and 777 (as well as other buildings) are transferred by pipeline to Tanks T-13 and T-14 and are solidified during the process.

How the Output is Generated:
During OASIS Process

Generation Rate:
600 Drums Yearly

How the Output is Managed:
Solidified oil is collected in 55-gallon drums and stored in Room 241, WMU 73.

Chemicals/Contaminants in or on the Output:
Oil, Emulsifier, Envirostone, And Accelerator

Characterization Rationale:
This solidified oil is nonline generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, this output contains spent halogenated solvents and therefore the output meets the definition of an F-listed waste. It also exhibits the characteristic of toxicity for carbon tetrachloride. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-2 **Title:** OASIS
IDC: 339 **Description:** Leaded Glovebox Gloves

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- ■ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D008, F001, F002

Description (Material, Type, Size, Color, etc.):
Leaded gloves are used in gloveboxes to handle plutonium contaminated material.

How the Output is Generated:
During Materials Handling For OASIS Process

Generation Rate:
1 Drum Yearly

How the Output is Managed:
Gloves are collected in drums in Room 241, WMU 73.

Chemicals/Contaminants in or on the Output:
Lead

Characterization Rationale:
These leaded glovebox gloves are line generated in a Radioactive Materials Management Area and are never generated as a residue. According to process knowledge, and supported by analytical data (G910049, 93G0191), this output contains lead and exhibits the characteristic of toxicity. The gloves contain Freon TF, carbon tetrachloride, and 1,1,1-trichloroethane, which means the output also meets the definition of an F-listed waste. Therefore, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-3 **Title:** OASIS
IDC: 335 **Description:** Glovebox Filters

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
High efficiency particulate air filters remove particulates from air exhausted from the glovebox.

How the Output is Generated:
During Filter Replacement

Generation Rate:
4 Drums Yearly

How the Output is Managed:
The used filters are collected in 55-gallon drums (WMU 73) in Room 241.

Chemicals/Contaminants in or on the Output:
Process Particulates

Characterization Rationale:
These glovebox filters are line generated in a Radioactive Materials Management Area and are always generated as TRU or low-level waste. Using information, based on the same IDC, contained in the Backlog Baseline Book (10/21/94), the output contains spent halogenated solvents wastes and therefore the output meets the definition of an F-listed waste. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-4 **Title:** OASIS
IDC: 480 **Description:** Line Metal (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
Metal includes light metal scraps from glovebox operations and maintenance activities.

How the Output is Generated:
During General Room/Process Maintenance Activities

Generation Rate:
4 Drums Yearly

How the Output is Managed:
Light metal scraps are collected in 55-gallon drums (WMU 73) in Room 241, if generated in the line.

Chemicals/Contaminants in or on the Output:
Oil, Emulsifier, Envirostone, And Accelerator

Characterization Rationale:
This line metal is line generated in a Radioactive Materials Management Area and is always generated as TRU or low-level waste. According to process knowledge, the output contains spent halogenated solvents and therefore the output meets the definition of an F-listed waste. It also exhibits the characteristic of toxicity for carbon tetrachloride. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-6 **Title:** OASIS
IDC: 336 **Description:** Nonline Wet Combustibles

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- □ Transuranic
- ■ Low-Level
- ■ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
Nonline generated soft waste includes Kimwipes, tape and other materials generated throughout the building.

How the Output is Generated:
During General Cleanup And Working In Glovebox

Generation Rate:
240 Drums Yearly

How the Output is Managed:
Nonline generated soft waste is collected in 55-gallon drums in Room 203.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
These nonline wet combustibles are nonline generated in a Radioactive Materials Management Area, and are always generated as nonradioactive or low-level waste. According to process knowledge, this output contains spent halogenated solvents and therefore the output meets the definition of an F-listed waste. Consequently, this output is a mixed, low-level or nonradioactive, hazardous waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-7 **Title:** OASIS
IDC: 336 **Description:** Line Wet Combustibles

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
Line generated soft waste includes Kimwipes, tape, and other materials generated within the glovebox.

How the Output is Generated:
During OASIS Process And Cleanup

Generation Rate:
50 Drums Yearly

How the Output is Managed:
Line generated soft waste is collected in 55-gallon drums (WMU 73) in Room 241.

Chemicals/Contaminants in or on the Output:
Oil, Emulsifier, Envirostone, And Accelerator

Characterization Rationale:
These line wet combustibles are line generated in a Radioactive Materials Management Area, and are always generated as TRU or low-level waste. According to process knowledge, the output contains spent halogenated solvents and therefore the output meets the definition of an F-listed waste. Consequently, this output is a mixed, transuranic or mixed, low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-11 **Title:** OASIS
IDC: 480 **Description:** Nonline Metal

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated

- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▪ Nonradioactive
- ▫ Source/Special Nuclear Materials

- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Nonline Generated Metal

How the Output is Generated:
During Routine Room/Process Maintenance Operations

Generation Rate:
Insufficient Data

How the Output is Managed:
Collected In 55-Gallon Drum In Room 203

Chemicals/Contaminants in or on the Output:
Unknown

Characterization Rationale:
This nonline metal is nonline generated in a Radioactive Materials Management Area and can be a low-level or nonradioactive waste. According to process knowledge, the output has no contact with the RCRA hazardous materials used in the process. Therefore, it can be a nonhazardous, low-level or a nonradioactive waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-12 **Title:** OASIS
IDC: 337 **Description:** Plastic

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: F001, F002

Description (Material, Type, Size, Color, etc.):
Supplied Air Suits, Gloves, Booties

How the Output is Generated:
During Routine Process Operations

Generation Rate:
25 Pounds Yearly

How the Output is Managed:
Placed In A 55-Gallon Drum, WMU 73

Chemicals/Contaminants in or on the Output:
Oasis, Solvents

Characterization Rationale:
This plastic is line generated in a Radioactive Materials Management Area, and is always generated as TRU or low-level waste. According to process knowledge, the output contains spent halogenated solvents and therefore the output meets the definition of an F-listed waste. Consequently, this output is a mixed, transuranic or mixed, low-level waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-5-13 **Title:** OASIS
IDC: 330 **Description:** Dry Combustibles

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Kimwipes, Rags, Dry Combustibles

How the Output is Generated:
During Routine Operations

Generation Rate:
Variable

How the Output is Managed:
Placed In A 55-Gallon Drum In Room 203

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
This output is nonline generated in a Radioactive Materials Management Area, and is known by the generator to always be low-level waste. According to process knowledge, no RCRA hazardous constituents are used in this process, and the output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. It is designated as low-level, nonhazardous waste.

9.0 PROCESS 774-09: MISCELLANEOUS WASTE HANDLING

The cementation of aqueous waste is carried out during the Miscellaneous Waste Handling process. Waste is primarily generated through processes in Buildings 559, 771, and 371. Aqueous waste containing complexing agents detrimental to the radioactive decontamination process and containing certain radioactive isotopes or hazardous chemicals undesirable in the regular waste system are entered into the solidification process. The bulk of these wastes are received as package shipments. Figure 9.1 shows the inputs, process flow, and outputs to be associated with the Miscellaneous Waste Handling Process.

Specially prepared waste shipping drums, containing a mixture of Portland cement and an absorbent material, are attached by O-ring drum liner to the solidification glovebox, No. 4. All waste are basic before placement in the drums.

Packaged waste received in plastic bottles are entered via bag-in operations into the glovebox. The bottles containing acid waste are emptied by vacuum into receiver and neutralizer Tank T-7, adjacent to the glovebox. Sodium hydroxide reagent is added until the color indicator shows the contents of the tank to be basic. The neutralized waste is then drained by gravity back into the glovebox. There, a connecting hose directs the waste into the prepared drum. A maximum of 80 liters of basic waste solution can be added to the prepared drum. Solutions are verified basic by checking with pH paper. The cement chemically reacts with the waste solution to form a solid.

Basic bottled waste enters the glovebox to be poured directly into the prepared drum. The empty bottles are discarded into a shipping drum attached to the glovebox. Highly concentrated chloride wastes received from Building 771 Recovery Operations by pipeline into Tank 7 are neutralized (as described earlier) and drained into the prepared drum(s).

The filled shipping drums are separated from the glovebox by the standard bag cut procedure. This generates line plastic, cemented solids, glovebox gloves, dry combustibles and glovebox HEPA filters. The 55-gallon sludge drums containing cemented solids from the Unit 57 glovebox are taken to Room 241, then to the RTR unit to determine if there are any free liquids present. These drums are then stored as transuranic-mixed waste or straight TRU drums. Glovebox HEPA filters are placed in the appropriate 55-gallon drum in Rooms 203 or 241. Plastic bottles are also placed in a 55-gallon drum in Room 203. Light metal (hazardous) is placed in WMU 73, light metal (non hazardous) is placed in a 55-gallon drum, or crate and sent to room 203 or 220. Glovebox gloves are placed in a storage area. Dry combustibles are also sent to Room 203. Glovebox exhaust is vented through the building filter plenum. Process Table 774-9 presents the outputs associated with the Miscellaneous Waste Handling Process and provides their dispositions and hazardous character.

AutoCAD 12, File Name: 774-9 03/14/95

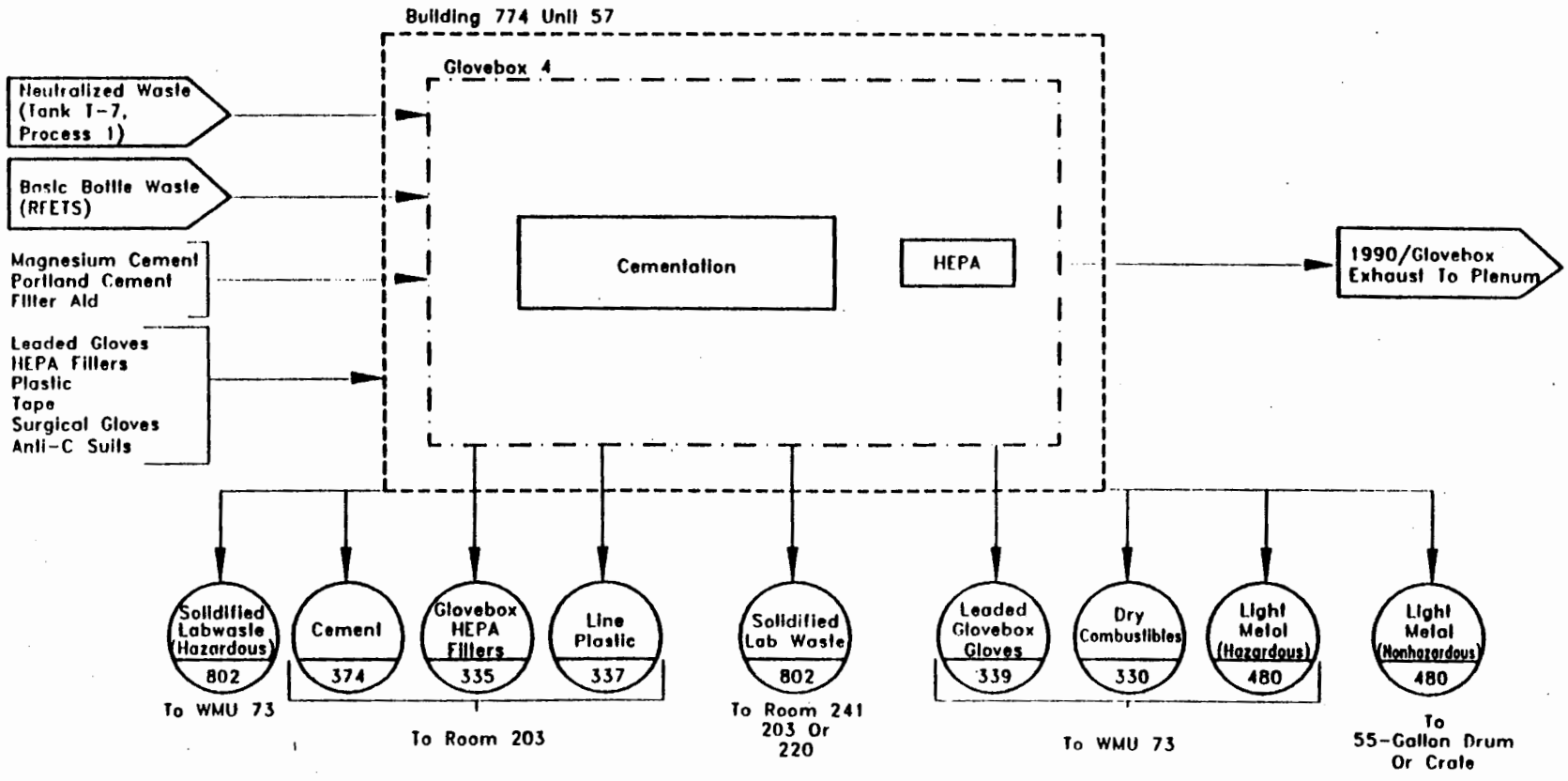

FIGURE 9.1

Rocky Flats Environmental Technology Site Waste Stream & Residue Identification & Characterization	BUILDING 774/PROCESS 9 MISCELLANEOUS WASTE HANDLING	Task	By	Date
		Designed	J. Johnson	08/07/92
		Drawn	B. Crawford	03/14/95
		Checked	J. Joyce	03/14/95

PROCESS 774-9 MISCELLANEOUS WASTE HANDLING

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-9-1	335	00	00	NA	Glovebox HEPA Filters RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 203	YES	NO	NO	Waste	
774-9-2	337	00	0205	NA	Line Plastic RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: Acid - General Base	55-Gallon Drum, Room 203	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-9-3	339	24	00	NA	Leaded Glovebox Gloves RCRA Reg. Chemical Constituents: Lead Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum WMU 73	YES	YES	YES	Waste	D008
774-9-4	802	00	00	NA	Solidified Lab Waste (Unit 57) Nonhazardous RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-9-6	330	00	00	NA	Dry Combustibles RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum, Room 203	YES	NO	NO	Waste	
774-9-8	374	00	00	NA	Cement RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-9-9	480	1236	00	NA	Light Metal (Hazardous) RCRA Reg. Chemical Constituents: Chromium Silver Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	D007, D011
774-9-10	480	00	00	NA	Light Metal (Nonhazardous) RCRA Reg. Chemical Constituents: None Non-RCRA Reg. Chemical Constituents: None	55-Gallon Drum Or Crate In Room 203 Or 220	YES	NO	NO	Waste	

Process Number	IDC/ WFC Number	CCCs RCRA Reg. Const.	CCCs Non-RCRA Reg. Const.	Comp. Codes	Description RCRA Reg. Chemical Constituents: Non-RCRA Reg. Chemical Constituents:	Collection	Solid Waste	RCRA Hazardous Waste	RCRA-Land Disposal Restricted (Part 268)	Output Category	EPA Codes
774-9-11	802	??	00	NA	Solidified Lab Waste (Unit 57)(Hazardous) RCRA Reg. Chemical Constituents: Constituents vary and will be determined on a case-by-case basis. Non-RCRA Reg. Chemical Constituents: None	WMU 73	YES	YES	YES	Waste	See Rational

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-1 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 335 **Description:** Glovebox HEPA Filters

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Glovebox HEPA filters are inlet and outlet filters associated with Glovebox Unit 57.

How the Output is Generated:
During Waste Solidification Routine Operations

Generation Rate:
500 Pounds Yearly

How the Output is Managed:
Glovebox filters are placed in 55-gallon drums in Rooms 203 or 241.

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
These HEPA filters are line generated but are always a transuranic or low-level waste. According to process knowledge, the output has no contact with the RCRA hazardous materials used in this process. Therefore, this output can be a nonhazardous, transuranic or low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-2 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 337 **Description:** Line Plastic

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Bottles Which Formerly Contained Basic Or Acid Waste Or Spent Halogenated Solvents

How the Output is Generated:
When Bottles Are Emptied Into Tank T-7 Or Into Glovebox

Generation Rate:
Insufficient Data

How the Output is Managed:
Empty Bottles Are Placed In A 55-Gallon Drum In Room 203

Chemicals/Contaminants in or on the Output:
Traces Of Basic, Acid Waste Solution, Or Spent Halogenated Solvents

Characterization Rationale:
This line plastic is a solid form waste contaminated with bases and acids. Although these liquids are known to be corrosive under RCRA, they cannot exhibit the characteristic in this case because the waste form is not liquid. The output is line generated in a Radioactive Materials Management Area and can, therefore, be a nonhazardous, TRU or low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-3 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 339 **Description:** Leaded Glovebox Gloves

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- ■ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D008

Description (Material, Type, Size, Color, etc.):
Leaded glovebox gloves are used to protect operating personnel.

How the Output is Generated:
During Cementation Of Neutralized Waste Solutions

Generation Rate:
50 Pounds Yearly

How the Output is Managed:
Placed In A 55-Gallon Drum WMU 73, Room 241

Chemicals/Contaminants in or on the Output:
Lead

Characterization Rationale:
These leaded glovebox gloves are line generated in a Radioactive Materials Management Area and are never generated as a residue. According to process knowledge, and supported by analytical data (G910049, 93G0191), this output contains lead and exhibits the characteristic of toxicity. They are therefore, a mixed, transuranic or mixed, low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-4 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 802 **Description:** Solidified Lab Waste (Unit 57) Nonhazardous

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▪ By Analytical Data
- ▫ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Magnesium And Portland Cement, Solidified Sludge

How the Output is Generated:
Produced During Treatment Of Aqueous Waste

Generation Rate:
14000 Pounds Yearly

How the Output is Managed:
Placed In 55-Gallon Drums, Sent To Room 241, Then To RTR To Determine Presence Of Free Liquids

Chemicals/Contaminants in or on the Output:
Aqueous Waste, Magnesium Cement, And Filter Aid

Characterization Rationale:
This solidified lab waste is characterized as nonhazardous per analytical data, sample numbers 94S0227, 94S0228, and 94S0229. This output is line generated in a Radioactive Materials Management Area and can be a low-level or transuranic waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-6 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 330 **Description:** Dry Combustibles

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Dry Combustibles

How the Output is Generated:
During Routine Process Cleanup Operations

Generation Rate:
Variable

How the Output is Managed:
Collected In A 55-Gallon Drum In Room 203

Chemicals/Contaminants in or on the Output:
Neutralized Acid/Base Waste, Reagents

Characterization Rationale:
These dry combustibles are nonline generated in a Radioactive Materials Management Area and are always generated as low-level or nonradioactive waste. According to process knowledge, the output has no contact with the RCRA hazardous materials used in this process. Therefore, this output can be a nonhazardous, transuranic or low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-8 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 374 **Description:** Cement

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▪ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Cement

How the Output is Generated:
During Solidification Process

Generation Rate:
Variable

How the Output is Managed:
Placed In A 55-Gallon Drum, Then Sent To Room 203

Chemicals/Contaminants in or on the Output:
Cement

Characterization Rationale:
This output is line generated in a Radioactive Materials Management Area, but is never generated as a residue. According to process knowledge, no RCRA hazardous constituents are used in this process, and the output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. Therefore, the output can be a nonhazardous, transuranic or low-level waste. The level of radioactivity will be determined by assay of each collection container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-9 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 480 **Description:** Light Metal (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- □ By Analytical Data
- ■ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: D007, D011

Description (Material, Type, Size, Color, etc.):
Light Metal

How the Output is Generated:
During Routine Operations

Generation Rate:
Variable

How the Output is Managed:
Placed In WMU 73

Chemicals/Contaminants in or on the Output:
Chromium And Silver

Characterization Rationale:
This light metal is line generated in a Radioactive Materials Management Area and is generated as TRU or low level waste. According to process knowledge, the output also exhibits the characteristic of toxicity for chromium and silver. The output is characterized as a mixed, TRU or mixed, low-level waste. The level of radioactivity will be determined by assay of each container.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-10 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 480 **Description:** Light Metal (Nonhazardous)

- ▫ RCRA Hazardous
- ▪ RCRA Nonhazardous
- ▫ By Analytical Data
- ▪ By Process Knowledge
- ▫ LDR Regulated
- ▪ Not LDR Regulated
- ▫ Product
- ▫ High Content Residue
- ▫ Low Content Residue
- ▫ Transuranic
- ▪ Low-Level
- ▫ Nonradioactive
- ▫ Source/Special Nuclear Materials
- ▫ Fuel Blending
- ▫ Uncontained Gas
- ▫ RCRA Sample
- ▫ Recyclable Material
- ▫ Recycled/Reused
- ▫ TSCA Reg. Waste
- ▫ Evaluated in Another Process

EPA Codes:

Description (Material, Type, Size, Color, etc.):
Light Metal

How the Output is Generated:
During Routine Operations

Generation Rate:
Variable

How the Output is Managed:
Placed In A 55-Gallon Drum Or Crate And Stored In Room 203 Or In 220

Chemicals/Contaminants in or on the Output:
None

Characterization Rationale:
This output is nonline generated in a Radioactive Materials Management Area, and is known by the generator to always be low-level waste. According to process knowledge, no RCRA hazardous constituents are used in this process, and the output contains no RCRA hazardous constituents and exhibits no RCRA hazardous characteristics. It is designated as low-level, nonhazardous waste.

WASTE STREAM AND RESIDUE DESCRIPTION AND CHARACTERIZATION

Process Number: 774-9-11 **Title:** MISCELLANEOUS WASTE HANDLING
IDC: 802 **Description:** Solidified Lab Waste (Unit 57) (Hazardous)

- ■ RCRA Hazardous
- □ RCRA Nonhazardous
- ■ By Analytical Data
- □ By Process Knowledge
- ■ LDR Regulated
- □ Not LDR Regulated
- □ Product
- □ High Content Residue
- □ Low Content Residue
- ■ Transuranic
- ■ Low-Level
- □ Nonradioactive
- □ Source/Special Nuclear Materials
- □ Fuel Blending
- □ Uncontained Gas
- □ RCRA Sample
- □ Recyclable Material
- □ Recycled/Reused
- □ TSCA Reg. Waste
- □ Evaluated in Another Process

EPA Codes: See Rationale

Description (Material, Type, Size, Color, etc.):
Magnesium And Portland Cement - Solidified Sludge

How the Output is Generated:
Produced During Treatment Of Aqueous Waste

Generation Rate:
Variable

How the Output is Managed:
Placed In 55-Gallon Drums, In Room 241, 203, 220

Chemicals/Contaminants in or on the Output:
Aqueous Waste

Characterization Rationale:
This solidified lab waste is characterized as hazardous. The EPA codes have not been identified because the chemicals involved in this process vary considerably in composition and characteristics; therefore, the appropriate codes will be assigned on a case-by-case basis, depending on analytical data. The chemical constituent code (??) is to be replaced by the actual numeric or alphanumeric constituent code on the drum traveler. This output is line generated in a Radioactive Materials Management Area and can be a low level or TRU, mixed waste.

APPENDIX S
FACTOR SPECIFIC QUALITY ASSURANCE

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FACTOR SPECIFIC QUALITY ASSURANCE

1.0 INTRODUCTION

Within the eight factors there were specific quality assurance measure taken. Some factors used computer codes while many used manual calculation and estimates to analyze the Engineered Alternatives (EAs). The following section describes Quality Assurance (QA) measure used within most of the factors.

1.1 TRANSPORTATION FACTOR

1.1.1 Computer Codes

All codes used for the transportation risk were developed under applicable QA standards. Previous verification has been performed on all models used in this analysis.

- RADTRAN—RADTRAN was developed by Sandia National Laboratories (SNL). The code has been continuously updated and subjected to SNL's QA procedures and standards. The code is accepted by the U.S. Department of Energy (DOE) for transportation use in estimating radiological risks.

- HIGHWAY—HIGHWAY was developed by Oak Ridge National Laboratory (ORNL). The code is continuously updated and subjected to ORNL's QA procedures and standards. The code is accepted by DOE for use in estimating routes, mileage, and fraction of travel in population zones.

- MICROSHIELD—MICROSHIELD was developed by Grove Engineering. The code meets American National Standards Institute standards and QA requirements.

1.1.2 Reporting

All transportation analysis results presented in the transportation risk section were double checked by independent review. The text was technically edited and subjected to a peer review.

1.2 IMPACT ON UNCERTAINTY IN COMPLIANCE ASSESSMENT

During the performance of the technical analysis, control of quality was maintained by verification and review of the work in progress. These reviews were performed at various stages of the work to assure that all aspects of the work affecting project quality requirements have been properly considered. Calculations, input data, report sections, and drawings were checked and verified during these reviews.

The computer codes developed for this factor were documented and validated in accordance with a defined QA procedure and includes the specification requirements, design and development information flowcharts, source code and sample data, and verification records documenting the test plan and results.

1.3 COST AND SCHEDULE FACTOR

1.3.1 Mass and Volumes

This section describes the quality assurance procedures used for the calculation of transuranic (TRU) waste preprocessed masses and volumes and final postprocessed masses and volumes.

1.3.2 Calculation of Initial Masses and Volumes

An electronic copy of the Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (WTWBIR), which is a reference DOE document, was used as the basis for determining the preprocessing masses and volumes. The WTWBIR data were imported into spreadsheets and manipulated to calculate the masses and volumes. These spreadsheets are subject to the following peer review:

- Transcription checkpoints were performed for data entered manually.
- Data sorts were spot-checked to ensure no loss of data during the sorting operation.
- Manual calculations were performed on random samples of data to verify spreadsheet calculations.

Records were generated that show the spreadsheet was verified, the date of the review, the reviewer, results, and corrective action (if required). The text of the Waste Inventory Appendix (Appendix O) was subject to peer reviews and technical editing.

1.3.3 Calculation of Final masses and Volumes

Computer programs were developed to determine final masses and volumes for the baseline and each alternative in each configuration, based on scaled initial masses and volumes. The computer code was reviewed against process flow diagrams to ensure proper logic. Manual calculations were performed to demonstrate the capability of the computer program to produce valid results. Manual calculations were used to test the overall computer program results additionally, tests were performed at several intermediate stages to verify proper working of individual modules. Tests were not performed to verify 100% of the results, but rather for each program. At least one result was tested for each logic branch in the program.

The computer programs were not installed on any other computer nor were significant hardware or operational systems configuration changes made. Therefore, no in-use tests were performed.

Records were generated that show the program tested, the date of the test, the tester, testing results, and corrective actions (if required).

1.3.4 Cost Calculations

This section describes the quality assurance procedures for calculation of process, transportation and backfill costs.

Information regarding the current DOE-TRU waste process capability was gathered from the Environmental Management Programmatic Environmental Impact Statement, Preliminary Draft Site Treatment Plan Database and the Preliminary Draft National TRU Program TRU Waste Management Program and consolidated in a single matrix. The resulting matrix was compared to the initial sources and checked for transcription errors, incorrect information, or missing information.

Costing data were gathered from an electronic copy of the Waste Management Facility Cost Information for Transuranic Waste. Cost data were charted and curve fitted into a spreadsheet. The trendlines were specified as either linear or polynomial, dependent on the resulting R^2 value. The trendline was qualified when R^2 rounded to 0.999 for the curve. These trendlines and their resulting equations were spot checked for their precision using visual observation and manual calculations.

These equations were used to develop programs that determine cost on the basis of mass or volume throughput. The computer code was reviewed against the equations obtained from the curve fitting and the processing schemes of the decentralized, regionalized, and centralized configurations to ensure proper logic was used. Manual calculations were performed to demonstrate the capability of the computer program to produce valid results.

The resulting costs for this study were spot checked to assure the appropriate cost programs were run for the appropriate masses or volume throughput. Spreadsheet links were checked to assure the correct costs were displayed in tables placed in this report.

The computer programs were not installed on any other computer nor were significant hardware or operating system configuration changes made; therefore no in-use tests were performed.

Records were generated that show the program tested, the date of the test, the tester, testing results, and corrective action (if required). All of the resulting tables, figures, and text for processing costing were subjected to peer review and technical editing.

1.3.5 Calculation of Transportation Costs

Costing information for transportation was obtained from the Waste Management Facility Cost Information for Transportation of Radioactive and Hazardous Materials. The primary information gathered, specific to the calculations, was the cost per loaded mile and the fixed cost equation. Mileage between the sites was obtained using HIGHWAY 3.3. This mileage was peer reviewed and checked for accuracy and is consistent with the mileage used in the transportation risk section of this report. The number of shipments was calculated based on the calculated waste output masses and volumes. Both the fixed costs and the variable costs were based on round trips in shipping. Manual calculations were performed to assure the performance of the spreadsheet calculations at each intermediate calculation step, up to and including, the final costs.

These manual calculations were archived as quality records.

1.3.6 Schedule Calculations

This section describes the quality assurance procedures for ensuring accurate schedule.

A preliminary baseline schedule scenario logic diagram was generated and subjected to a peer review to ensure that the flow of activities was accurate. Following this review, a Project Evaluation and Review Technique analysis was performed to verify the durations used were within acceptable limits. The start and finish dates were calculated using computer scheduling software then verified with manual calculations. All changes to the schedule were tracked using schedule-generated revision control and maintaining a computer backup of all schedule information. Upon completion, the schedules were peer reviewed again.

1.4 IMPACT ON OTHER DISPOSAL SYSTEMS FACTOR

Calculations based in Rocky Flats secondary waste data were peer reviewed, all the data summaries were checked against the original Rocky Flats Waste Stream and Residue Identification and Characterization reports, and 100% of the calculations were manually checked. The calculations for secondary waste generated for each EA were based on spreadsheets used for the cost analysis that had previously been through QA (see QA discussion for cost analysis). The new spreadsheets generated for this factor were checked for accuracy and logic. The final calculations to determine impacts on DOE low-level waste programs were based on referenceable information in the Integrated Data Base and Mixed Waste Inventory Report and 100% of these calculations were manually checked.

APPENDIX T
REFERENCES TO APPENDICES

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