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Title: **ECOLOGICAL RISK ASSESSMENT APPROACH FOR LOS ALAMOS NATIONAL LABORATORY**

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ECOLOGICAL RISK ASSESSMENT APPROACH

FOR LOS ALAMOS NATIONAL LABORATORY

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I. INTRODUCTION

The purpose of this document is to present the ecological risk assessment methodology that will be used to provide support to the Los Alamos National Laboratory (LANL) Environmental Restoration (ER) Project. The methodology that is presented is a work in progress. Although a framework for a risk assessment approach has been agreed to in principle with the regulators, the details of the methodology remain to be worked out. This version of the document presents the current status of the methodology. Subsequent versions will contain updates as consensus is reached on further details.

The regulatory drivers for ecological risk assessment are found in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Environmental Policy Act (NEPA), and the Resource Conservation and Recovery Act (RCRA). The fundamental directives established by these acts are to protect human health and the environment. The language requiring environmental protection varies from act to act, with the requirement being stated most strongly in CERCLA.

The process that is used to evaluate environmental impact is called "ecological risk assessment." Ecological risk assessment still is a young science, and formal protocols for its implementation are in the developmental stage. Both the Environmental Protection Agency (EPA) and the Department of Energy (DOE) have issued guidance documents addressing implementation of ecological risk assessment, but these guidance documents only provide a framework for an approach to be followed and do not provide specific methodology.. Appendices I and II of this document give a brief overview of relevant regulations and guidance.

At LANL, DOE's ER Program is being implemented under a RCRA Hazardous and Solid Waste Amendments (HSWA) permit that was issued by EPA Region 6 and currently is being overseen by the New Mexico Environment Department (NMED), which now has primacy. Although the language in RCRA requiring ecological risk assessment is not as strong as in CERCLA, LANL has committed to meeting the more rigorous CERCLA requirements during implementation of the LANL ER Project.

The approach for implementing ecological risk assessment at LANL is to perform assessments on "Ecological Exposure Units" (EEUs), which are ecological units defined on the basis of habitat type (e.g., piñon pine woodland or ponderosa pine savanna). Each EEU may contain several to many Potential Release Sites (PRSs). This approach does not directly integrate with human health risk assessments, which are performed on individual PRSs. Using the EEU approach, all of the PRSs within an EEU are evaluated cumulatively. The rationale for this approach is that ecological impacts occur within ecologically-defined boundaries that do not conform to PRS boundaries. The advantages of using EEUs as the basis for ecological risk assessment are that assessments performed in this manner are more scientifically defensible, focus remediation efforts on those sources that contribute to an unacceptable risk to the ecosystem, and are more cost effective. Performing an ecological risk assessment on an arbitrarily defined PRS is difficult to defend scientifically and is likely to result in biased and unnecessarily conservative results because of the assumptions that must be made. This can lead to unnecessary remediation requirements that may be avoided when the ecological risk assessment addresses a larger geographic area.

The requirement for ecological risk assessment in connection with Expedited Cleanup (EC) or Voluntary Correction Action (VCA) is addressed in the ER Project Accelerated Decision Logic. The objective when evaluating the ecological impact of an EC or VCA is to determine if the impact of the proposed remedial action is greater than the impact of leaving the contamination in place. The procedure that is followed in making this determination follows the same ecological risk assessment logic flow that is presented in this methodology document.

II. METHODOLOGY

The strategy for implementing the ecological risk assessment process at LANL is to do a preliminary risk screening assessment for each EEU based on the data that are immediately available. For some EEUs, this may be sufficient to reach a conclusion and preclude any further investigation. Other EEUs may require additional evaluation and/or data collection in order to perform a more detailed analysis. If the preliminary screening process for an EEU identifies PRSs within the EEU that do not contribute to ecological risk and do not need to be addressed further, this information may be combined with information from the human health risk assessment to propose the PRS for No Further Action (NFA). Under any circumstance, an Ecological RCRA Facility Investigation (ERFI) report will be written to close out the assessment process for an EEU when the ecological risk assessment for that EEU is complete.

Because ecological risk assessment is proceeding on a parallel track with human health risk assessment, the possibility exists that the conclusion of the ecological risk assessment is a recommendation for further remediation, even though remediation because of human health risk has been completed or is not required. However, even though remediation may have to be revisited at a site, the remediation requirements to address ecological concerns for an entire EEU should be less than the remediation that would be required if the ecological risk assessment was performed on a PRS-by-PRS basis.

Figure 1 shows the logic diagram for the LANL ecological risk assessment process. The overall approach is consistent with the EPA "*Framework for Ecological Risk Assessment*" (EPA 1992) and "*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*" (EPA 1994a). The more specific details of the protocol that is presented below are based on draft guidance received from EPA Region 6 (see Appendix III). In some cases, the guidance presented in Appendix III have been verbally modified by EPA Region 6, and the instances in which this has happened are so-indicated in the discussion.

Table 1 lists the tasks that are associated with implementation of the ecological risk assessment methodology shown in Figure 1. These tasks are subdivided according to whether they are associated with the screening process or with the baseline assessment. The tasks are described in more detail in subsequent paragraphs.

Task 1: Delineate Ecological Exposure Units.

Ecological Exposure Units are the ecologically-defined units within which ecological risk assessments will be conducted. At LANL, EEUs will be defined on the basis of habitat and topography according to EPA Region 6 guidance. The Laboratory is located on the Pajarito Plateau, which has an elevational gradient that drops from about 7500 feet to the north-northwest to about 6000 feet to the south-southeast. This elevational gradient results in vegetation zones that run roughly in a north-south direction on the plateau. The zones range from mixed conifer in the west through ponderosa pine and piñon-juniper to juniper grassland in the east. The plateau itself is dissected into several finger mesas by canyons that drain from the Jemez Mountains on the west to the Rio Grande on the east (see Figure 2). The intersections of the canyons that run from west-to-east with the vegetation zones that run north-to-south form somewhat of a checkerboard pattern that becomes the basis for defining EEUs. Within the canyons, the ecological setting is more complex as a result of (1) the extension of vegetation types along the north and south walls of the canyons because of edaphic conditions, and (2) because of the presence of riparian vegetation in the moist canyon bottoms. The boundaries of the EEUs will be coded into a Geographical Information System (GIS) so that detailed EEU maps can be prepared.

Figure 1: Ecological Risk Assessment Methodology Flowchart

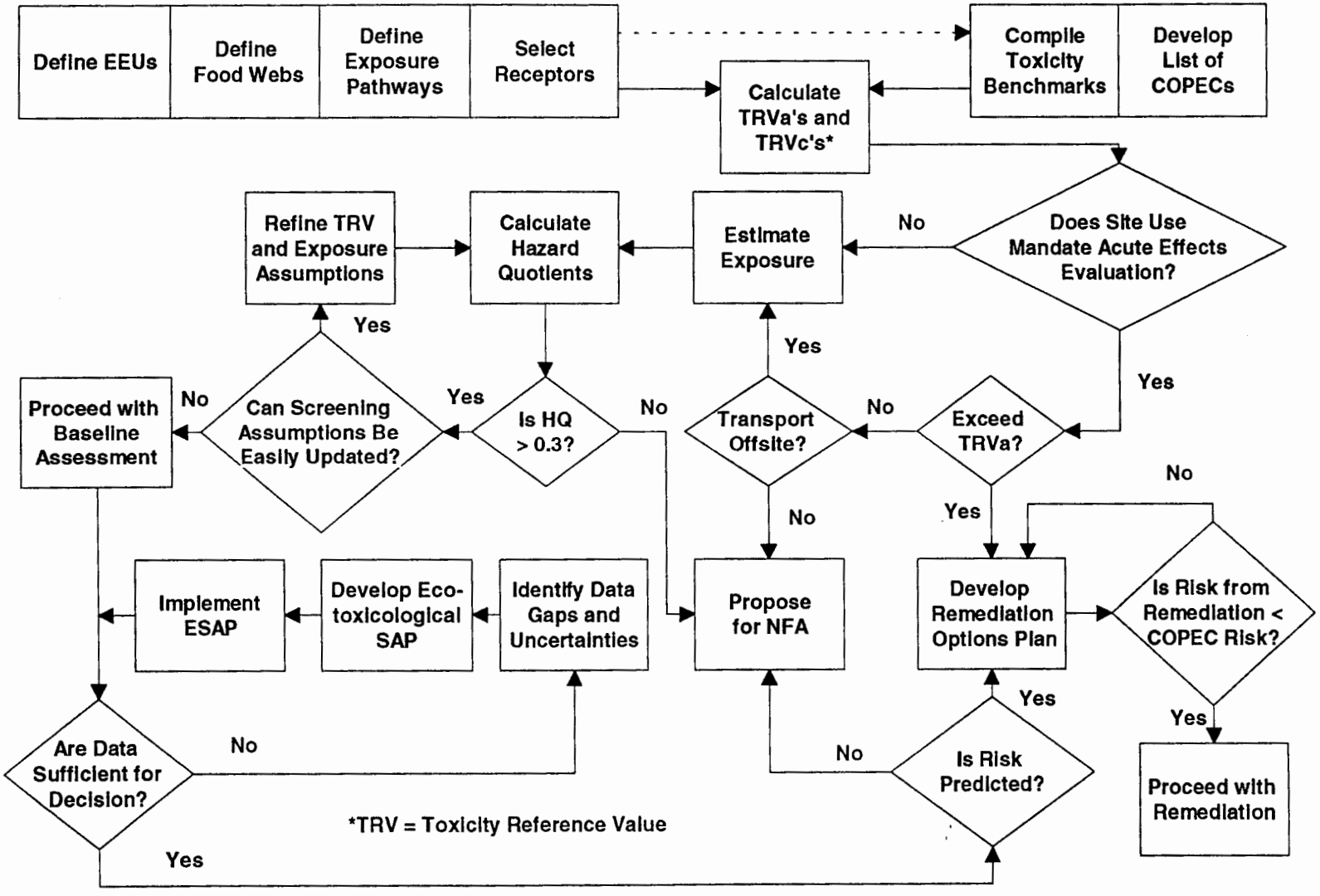


Table 1: Ecological Risk Assessment Tasks for LANL

Screening Tasks

1. Delineate Ecological Exposure Units (EEUs).
2. Develop preliminary Contaminant of Potential Ecological Concern (COPEC) lists.
3. Define food webs.
4. Define pathways of exposure.
5. Select receptors.
6. Compile toxicity data and benchmarks.
7. Calculate Toxicity Reference Values (TRVs).
8. Evaluate sources of contamination for acute or chronic exposure potential.
9. Calculate exposure or dose.
10. Calculate Hazard Quotients (HQs).
11. Identify EEUs where further assessment is required.

Baseline Assessment Tasks

12. Identify data gaps and uncertainties.
13. Develop and implement plans to address data gaps and uncertainties.
14. Perform baseline ecological risk assessments.
15. Write ecological RFI (ERFI) reports.

Figure 2: Canyons at Los Alamos

A subtask to this task is to delineate disturbed land use areas. Although EEUs are delineated primarily on the basis of habitat type, there may be different land use categories within the boundaries of an EEU. Highly disturbed land is a major concern. Sites that are located within highly disturbed areas are evaluated against acute Toxicity Reference Values (TRVs) rather than chronic TRVs because of the lower potential for biotic usage, as explained in Task 8.

Status: A proposal for creation of EEUs is being finalized for submission to the regulators. Major issues in this proposal are how to define "disturbed" land areas and how to deal with transition zones between disturbed land and undisturbed land.

Task 2: Develop preliminary Contaminant of Potential Ecological Concern (COPEC) lists.

Ultimately, the list of COPECs will be determined on the basis of those contaminants to which selected receptors are sensitive and for which complete pathways exist from source to receptor (see Task 4). However, the preliminary list of COPECs for a given EEU will be developed on the basis of several criteria, which include the following.

- Contaminants known to have been used or known to be present within the EEU.
- Contaminants to which receptors within the EEU are known to be sensitive.
- Contaminants identified as of concern during the human health risk assessment.
- Other factors, such as toxicity, persistence, exposure potential, bioavailability, and potential for food chain transfer.

As stated in the EPA Region 6 guidance (see Appendix III), background concentrations will not be used to screen out COPECs. Another important consideration to keep in mind is that contaminants that pose an ecological risk are not necessarily the same as those that pose a human health risk (and vice versa) because of differences in exposure pathways, sensitivities, receptor responses, and assessment endpoints.

At some point in the selection process subsequent to the preliminary screen, the risk manager and risk assessor may decide to reduce the list of COPECs to a priority list that will be carried forward into a baseline ecological risk assessment.

Status: A preliminary list of COPECs, based on the criteria listed above, has been developed for submission to the regulators. This preliminary COPEC list is shown in Table 2.

Task 3: Define food webs

Figure 3 is a diagram of a generic terrestrial food web. Using this generic food web as a basis, species lists that are available for LANL (Hinojosa 1996) will be used to generate specific food webs for the LANL EEUs. Definition of food webs is important because food webs are one of the bases for identifying trophic levels, appropriate receptors, and pathways of exposure. The abiotic aspects of the nutrient cycle (dashed lines in Figure 3) also are important because metallic contaminants and radionuclides move through the environment in the same manner as metallic inorganic nutrients, and the soil may act as a contaminant reservoir for them.

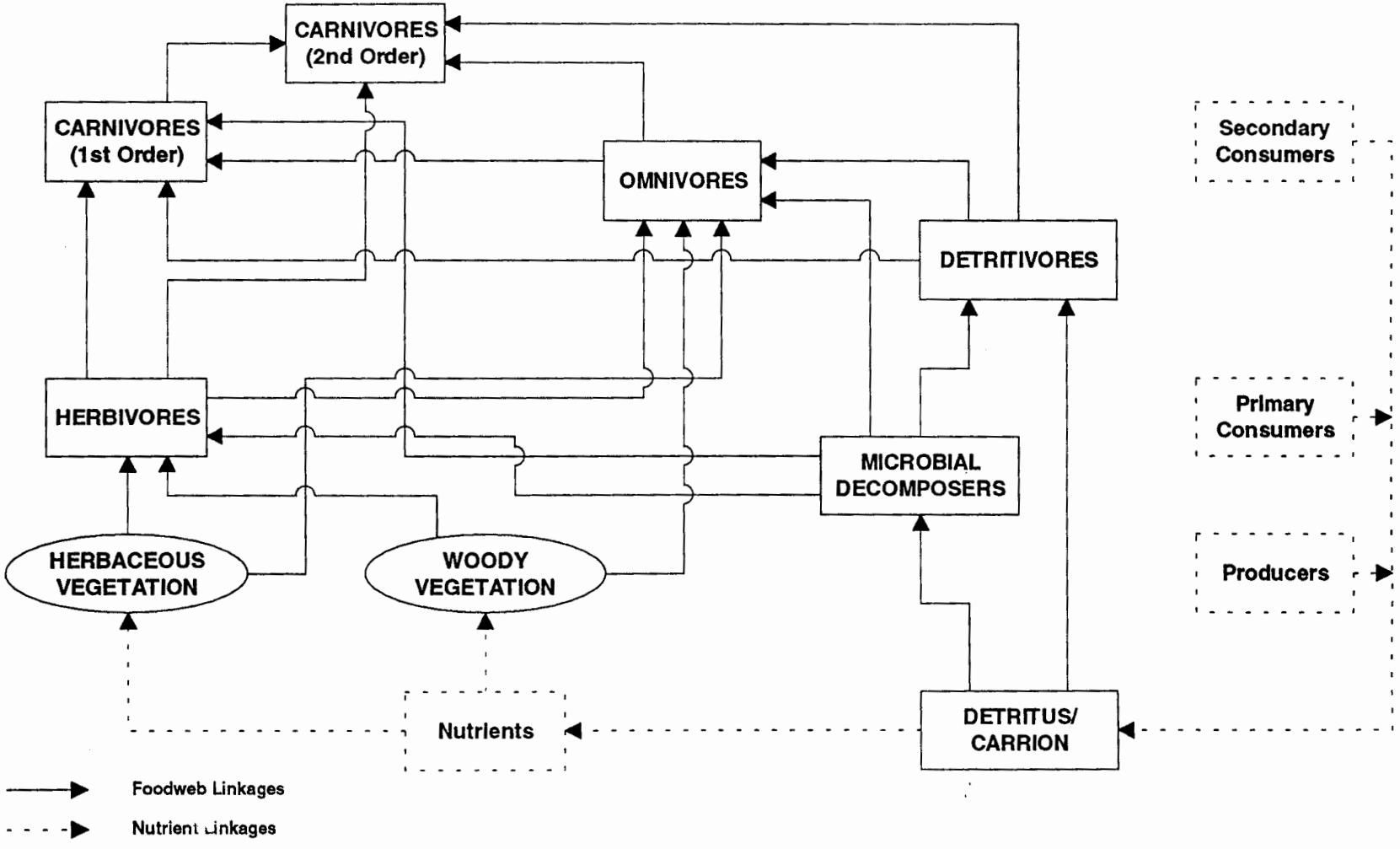
An analogous food web for aquatic systems will be used if appropriate.

Status: Comprehensive species lists for Los Alamos National Laboratory have only recently been compiled (Hinojosa 1996). The species in these lists are being subdivided into trophic levels in order to create food webs that will be the basis for selecting receptors in Task 5.

Table 2: Preliminary COPEC List for Screening

Analyte Suite	COPEC	Analyte Suite	COPEC
Inorganic	Silver (Ag)	VOC	TCE
Inorganic	Aluminum (Al)	VOC	TPH
Inorganic	Arsenic (As)	VOC	1,4-Dichlorobenzene
Inorganic	Barium (Ba)		
Inorganic	Beryllium (Be)	High Explosive	DNT
Inorganic	Cadmium (Cd)	High Explosive	HMX
Inorganic	Chromium (Cr)	High Explosive	RDX
Inorganic	Copper (Cu)	High Explosive	TNT
Inorganic	Lead (Pb)		
Inorganic	Manganese (Mn)	Radionuclide	Americium (Am)
Inorganic	Mercury (Hg)	Radionuclide	Cesium (Cs)
Inorganic	Nickel (Ni)	Radionuclide	Plutonium (Pu)
Inorganic	Thallium (Tl)	Radionuclide	Radium (Ra)
Inorganic	Uranium (U)	Radionuclide	Strontium (Sr)
Inorganic	Vanadium (V)	Radionuclide	Thorium (Th)
Inorganic	Zinc (Zn)	Radionuclide	Tritium (H^3)
		Radionuclide	Uranium (U)
SVOC	Anthracene		
SVOC	Phenanthrene	Pesticide	Aldrin
SVOC	Pyrene	Pesticide	Chlordane
SVOC	Benzo[a]pyrene	Pesticide	DDE
SVOC	PCBs	Pesticide	DDT
SVOC	TPH	Pesticide	Dieldrin
		Pesticide	Lindane

Figure 3: Generic Terrestrial Foodweb



Task 4: Define pathways of exposure

This task is an assessment of the fate and transport of contaminants. It identifies sources, release mechanisms, transport pathways, points of exposure, and mechanisms of exposure. In order to define pathways of exposure, a conceptual model of contaminant movement within the ecosystem must be developed. Figure 4 shows an example of such a conceptual model. Theoretically, a model of this type should be developed for each COPEC within each EEU. However, as many COPECs, habitat types, and receptors will be the same, a relatively small number of generic conceptual models may be sufficient.

Status: Generic pathways are known. Specific pathways will be evaluated when the receptors and COPECs are selected for each EEU.

Task 5: Select receptors

After exposure pathways have been identified, representative species must be selected to serve as receptors. Receptors must be selected to be protective of the ecosystem structure as a whole. The following criteria, which are relevant to the significance of adverse toxicological, biological, and ecological effects, must be considered in the selection of receptors.

- Sensitivity to concentrations of COPECs that are present.
- Relevance to integrity of ecosystem structure and function.
- Representation of exposure pathway target organisms.

An important question to keep in mind is how an assessment of the selected receptors as ecological endpoints will help determine the appropriate action to take at the site. The objective in selecting receptors is to select the minimum number of receptors that is necessary and sufficient to adequately assess the risk to the ecosystem. There may not necessarily be a receptor from each trophic compartment of the food web model. EPA Region 6 guidance is that receptors will be considered as populations rather than individuals. Because of the conservation assumptions built into all aspects of the screening process, Threatened or Endangered (T&E) Species are treated in the same manner as other species during the screening process.

Status: Selection of receptors awaits definition of food webs in Task 3.

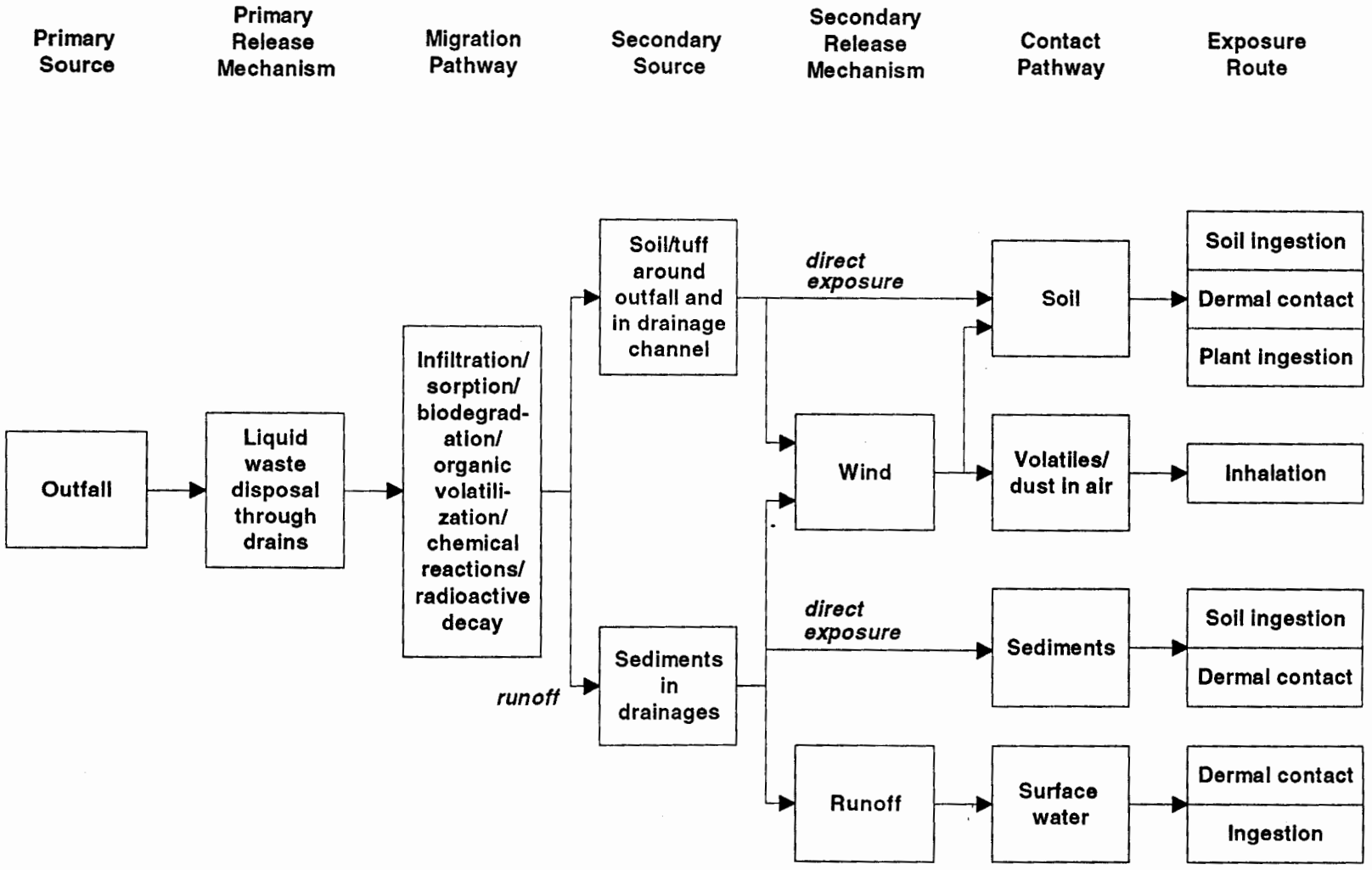
Task 6: Locate appropriate toxicological data

The primary databases recommended by EPA Region 6 are the EPA ECOTOX database and the Oak Ridge Screening Benchmark database. The EPA Region 6 guidance in Appendix III lists several other potential sources of toxicological data. These include the following:

- Literature values;
- Integrated Risk Information System (IRIS) database;
- Hazardous Substances Data Base (HSDB);
- Registry of Toxic Effects of Chemical Substances;
- Agency for Toxic Substances and Disease Registry; and
- U.S. Fish and Wildlife Service publications.

For radionuclides, International Atomic Energy Agency guidance (IAEA 1992) will be followed. This guidance states that "the level of safety required for the protection of all human individuals is thought likely to protect other species, although not necessarily individual members of those species." "If man is adequately protected, than other living things are also likely to be sufficiently protected." Thus, ecological risk assessment at LANL will not address radionuclides except in situations where no human health risk assessment has been performed.

Figure 4: Example Conceptual Model



Status: Toxicological data is being collected for receptors and COPECs that appear to be appropriate for the preliminary screening process.

Task 7. Calculate Screening Toxicity Reference Values (TRVs)

TRVs will be estimated for all of the receptors identified in Task 5. Although the draft guidance from EPA Region 6 reproduced in Appendix III indicates that the lowest literature ecotoxicological values should be used for screening, verbal guidance from EPA Region 6 is that receptor-specific ecotoxicological data may be used if the food webs for the EEUs are adequately described and appropriate receptors are selected.

The toxicity information required to estimate TRVs for metals and organics usually is presented in terms of dose expressed as mg/kg body weight/day. The formula for converting dose information to a TRV expresses TRV as a function of reference dose (RfD), body weight (BW), dietary food intake (I), and fraction of dietary food intake estimated as soil (FS). I.e.,

$$TRV_i = f(RfD_i, BW, I, FS)$$

where TRV_i is the TRV for toxicological effect "i", and RfD_i is the reference dose for that effect. TRVs may be calculated for various toxicological endpoints.

When calculating TRVs for use as screening references, the most conservative assumptions should be used. These include the following, based on the EPA Region 6 guidelines shown in Appendix III:

- Lowest ecotoxicological effect literature values;
- Maximum body weight for receptor;
- Maximum dietary intake for receptor; and
- Fraction of dietary food intake estimated as soil = 50%.

Current EPA Region 6 guidance is to use the geometric mean of the NOAEL and LOAEL as the RfD for calculating TRVs, which is an update to the information presented in Appendix III. This parameter is referred to as the Maximum Available Toxicity Concentration (MATC). If the information required to calculate the MATC is not available, the order of preference of use of other toxicological parameters is as follows.

(1) The lowest no observed adverse effects level (NOAEL).
(2) The lowest observed adverse effects level (LOAEL).
(3) The dose or concentration found to be lethal to 50% of the test organisms (LD50, LC50, EC50).

The NOAEL will be used as the RfD if it is the only information available. If LOAELs or LD50 values are used as RfDs, EPA Region 6 specifies the following uncertainty factors, which are the standard uncertainty factors used for these extrapolations.

If a NOAEL is used, the RfD = the NOAEL.

If a LOAEL is used, the RfD = the LOAEL x an uncertainty factor of 0.1.

If an LD50 is used, the RfD = the LD50 x an uncertainty factor of 0.01.

Ambient Water Quality Criteria (AWQC) can be used as RfDs for aquatic systems.

In many cases, toxicity information for the particular species of interest may not be available. When this happens, an extrapolation of data from another species may be required. If data are extrapolated within a class of animals (i.e., mammals to mammals or birds to birds), EPA Region 6 guidance is that no uncertainty factors need be incorporated. However, the standard uncertainty factor of 10 must be applied if data are extrapolated across classes of animals (i.e., mammals to birds).

TRVs will be calculated for application to specific land use scenarios. When undisturbed land areas are being considered, RfDs will be based on chronic toxicity studies. However, TRVs based on RfDs from acute toxicity studies will be used for highly disturbed areas. Acute TRV (TRV_a) values will be calculated using LD50 data as RfDs.

Status: TRVs will be calculated after receptors and COPECs have been selected and appropriate toxicological data are compiled.

Task 8: Classify potential sources of contamination for acute and chronic screening assessment exposure

At the screening level, potential sources of contamination are evaluated according to whether they are located in highly disturbed or undisturbed areas. Sources that are in highly disturbed areas or are at the periphery of highly disturbed areas are screened against acute TRVs. This is because, while fauna may visit these areas from time to time and occasionally may even forage or obtain drinking water there; extended usage of the area may not occur. The concern is whether the exposure or dose received as the result of a single visit would be sufficient to have an unacceptable impact on the receptor. Guidance from EPA Region 6 is that remediation is required if the acute TRV is exceeded.

If sources in a highly disturbed area do not exceed acute TRVs and there is no potential for transport offsite, the sources will be assumed to contribute little additional impact to effects of ongoing Laboratory operations and are candidates for NFA. Sources in highly disturbed areas that exceed acute TRVs must be evaluated for remediation.

Sources in undisturbed areas that do not exceed chronic TRVs are candidates for NFA. Sources in undisturbed areas that exceed chronic TRVs must be carried forward for further assessment.

Status: COPECs and receptors must be selected and TRVs calculated before potential contaminant sources can be evaluated.

Task 9: Calculate exposure or dose

Exposures are estimated for the selected receptors (see Task 5) using the pathways defined in the conceptual model (see Task 4). For the purposes of the screening assessment, exposures should be estimated using conservative assumptions (as for estimation of TRVs). The following assumptions are recommended by EPA Region 6 guidance.

- Maximum chemical concentrations should be used for each medium of exposure without regard for number of samples, statistical distribution of sample results, spatial distribution of samples, or location of maximum concentration relative to usable habitat.
- Bioavailability of 100% is assumed for all chemicals in all exposure media.
- The area use factor is assumed to be 100% (i.e., continuous use)..

- The most toxic chemical species of contaminants are assumed to be present.
- Soil or sediment consumption constitutes 50% of the diet for terrestrial receptors.
- Maximum ingestion rate is assumed.

The data on contaminant concentrations in environmental media used for calculating exposures for ecological risk assessment must be consistent with the data used for human health risk assessment. At LANL, the acceptable data to be used for the Environmental Restoration Project resides in the LANL ER Project FIMAD system. Ultimately, the data used for ecological risk assessments must be quality assured, validated, and entered into FIMAD.

The U.S. EPA publication entitled, "Wildlife Exposure Factors Handbook" (EPA 1993), contains much information relevant to calculating exposure or dose and is a useful reference. Other references will be consulted as required in order to estimate exposure.

Status: COPECs and receptors must be selected and pathways of exposure identified before exposure can be estimated.

Task 10: Calculate Hazard Quotients (HQs)

The Hazard Quotient (HQ) is defined as the ratio of exposure to an appropriate reference toxicity value. When used as a screening tool, the HQ is sometimes referred to as the Risk Ratio (RR) or Ecological Screening Quotient (ESQ, see Appendix III).

$$HQ = \frac{\text{Exposure}}{\text{TRV}}$$

When used for screening purposes, the exposure values and TRVs are calculated using conservative assumptions as explained in Tasks 7 and 9. The HQ then becomes the maximum exposure divided by the lowest screening reference value.

Status: HQs will be calculated after TRVs and exposures are determined.

Task 11: Identify EEUs where further assessment is required

When used as a conservative screening tool, EPA Region 6 guidance is that the critical value for the HQ is 0.3. If the HQ is less than or equal to 0.3, the site is considered to pose no ecological risk and can be excluded from further consideration. If the HQ is greater than 0.3, further ecological assessment is required. The HQ threshold is set at 0.3 to compensate for the lack of a screening requirement to sum HQs to produce a Hazard Index (HI), which is used to evaluate cumulative effects from multiple contaminants that have a common physiological effect. (I.e., HI = $\sum$HQ , but an evaluation of cumulative effects is not necessary because of the conservatism of the approach.)

If the HQ is greater than 0.3, the screening approach may be examined to determine if the use of less conservative assumptions is justified in order to better reflect specific site and/or receptor conditions. Assumptions that may be adjusted after review of additional data include the following.

- Statistical and spatial distributions of chemical concentrations may be used instead of maximum concentrations.

- Bioavailability may be less than 100%.
- The area use factor may be less than 100%.
- Chemical speciation may be taken into account.
- Soil or sediment may constitute less than 50% of the diet.
- Statistical distributions of receptor body weights and ingestion rates may be used.
- Higher ecotoxicological reference values may be justified.

Any use of less conservative assumptions must follow a standardized protocol that is approved by the regulators. If there is insufficient information to make a reliable assessment, or if the uncertainties associated with the assessment make the results unusable for management decisions, acquisition of additional data may be required. Decision criteria for when to acquire more data and how much data are enough must be established. This situation is addressed in Task 12.

Task 12: Identify data gaps and/or uncertainties

When the information that is available is insufficient for an adequate ecological risk assessment, it may be because (1) information is missing, or (2) there is too much uncertainty in the available information. There are a number of possible reasons why an assessment cannot be performed, which may include the following.

- Chemical site characterization data are lacking.
- Biotic characterization is inadequate.
- Physiological information on receptors is insufficient.
- Toxicological information is lacking.
- Exposure pathways are poorly defined.
- Etc.

Task 13: Develop and implement plans to address data gaps and uncertainties

Whatever data gaps and uncertainties are identified, the likely resolution of the issue is that more information must be collected. This could be accomplished through some combination of the following approaches.

- Further literature searches.
  Ecological or toxicological studies
  - > Field
  - > Greenhouse
  - > Laboratory
- Additional site characterization
  - > Chemical
  - > Biotic
- Modeling

Data may be collected either to support the screening process or to provide information for a baseline risk assessment. The intent of the data collection must be clearly understood, because data collected for one purpose may not be useful for the other. Either way, a tradeoff may be involved. Data collected to support the screening process may not be useful for a baseline assessment if the site cannot be NFAed on the basis of the screening assessment. Conversely, a decision to move directly to a baseline assessment if additional data must be collected may preclude a quick NFA, although the assessment may be more defensible in the long run.

An Ecological Sampling Analysis Plan (ESAP) must be developed to define the necessary work required to obtain the missing information. The Data Quality Objectives (DQO) approach (DOE 1996, EPA 1994b) should be used to guide the development of the plan so that objectives and milestones are clearly defined.

As shown in Figure 1, refining the information used for screening is an iterative process through which all possibilities for reaching a decision during the screening process should be examined before proceeding to a baseline assessment (see Figure 5, which is taken from the EPA 1995 *"Draft Proposed Guidelines for Ecological Risk Assessment"* [EPA 1995]).

Task 14: Perform baseline ecological risk assessments

The HQ approach to ecological risk assessment is generally used as a screening tool. When more sophisticated ecological risk assessment is required, a more thorough examination of ecosystem structure and function must be undertaken. There are a number of reasons why the HQ approach may be inadequate to evaluate ecological risk.

- The HQ evaluates harm to organisms in the environment as opposed to harm to the environment. An ecosystem may continue to be unhealthy even when chemical-specific criteria for individual species are met, because numerous indirect effects of chemicals are not considered by the HQ approach.

- HQs may tend to focus more on short-term issues rather than long-term sustainability. The goal of environmental protection should be to sustain variety and ecosystem function.

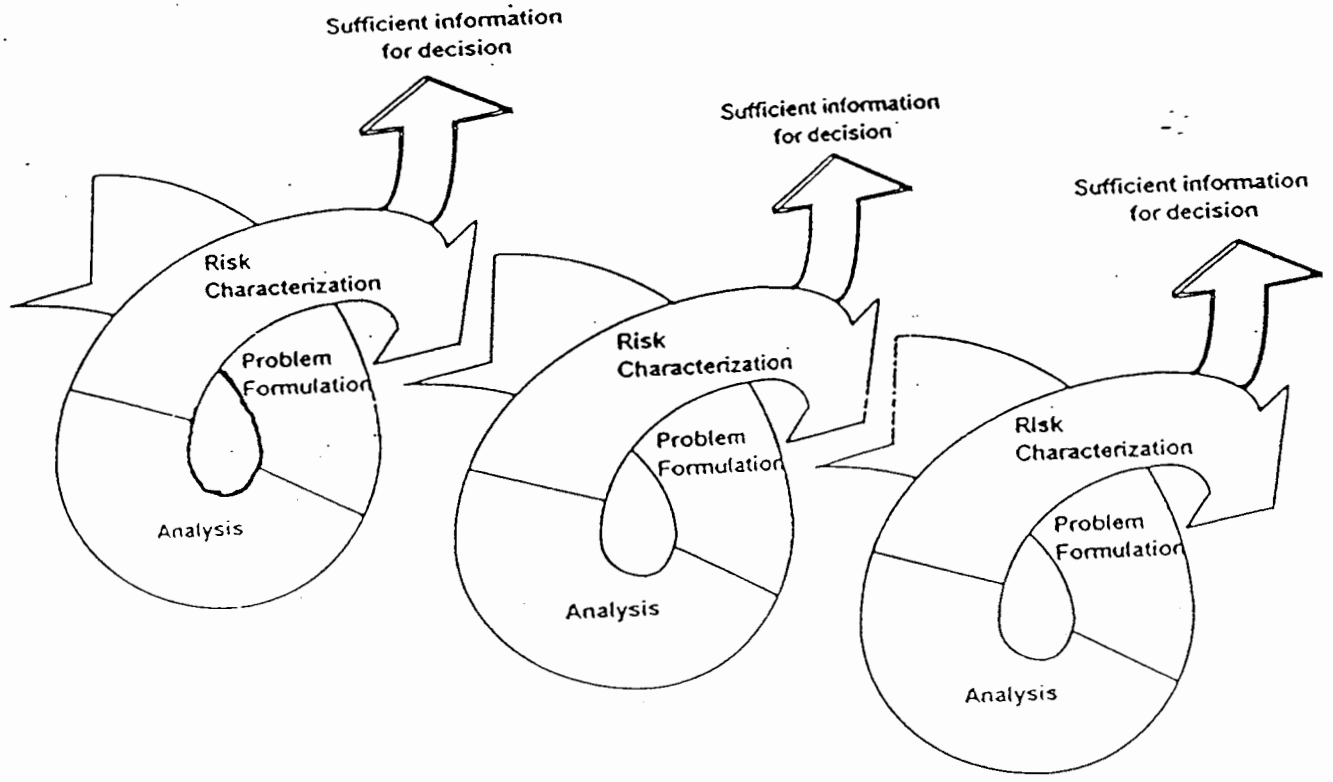
- A comprehensive prediction of the ecological contribution of a given species to ecosystem integrity is not always possible. (The HQ approach can be misleading because it masks the uncertainty involved when attempting to comprehensively predict the ecological contribution that a given species has on ecosystem integrity).

Thus, when performing a baseline risk assessment, a much broader spectrum of indicators of environmental health and ecosystem structure and function must be evaluated. These could include one or a combination of the following:

- Diversity indices,
- Status of Threatened and Endangered Species,
- Age class distributions
- Growth and productivity
- Population viability (morbidity and mortality),
- Reproductive index (fecundity),
- Physiological status and development,
- Tissue contaminant concentrations,
- Biomarkers,
- Water balance,
- Decomposition rates,
- Soil phytotoxicity values,
- Etc.

The appropriate combination of studies and indicators should be identified through application of the DQO process to the management goals determined by the risk assessor and risk manager. A factor that always must be taken into consideration is natural variability: how can adverse effects be distinguished from normal fluctuations in measurable parameters.

Figure 5: The Iterative Nature of Ecological Risk Assessment



As previously indicated for the screening assessment process, the baseline assessment process is an iterative process as shown in Figure 5.

Task 15: Complete Ecological RCRA Facility Investigation (ERFI) reports.

An ecological RFI report must be prepared for each EEU for the purpose of documenting the results of the risk assessment for that EEU. For those EEUs for which the screening approach shows that there is no ecological risk, the ERFI report will recommend the entire EEU for No Further Action (NFA). For EEUs for which baseline assessment is required, the ERFI report will recommend the preparation of an Ecological Sampling Analysis Plan to acquire the information needed to complete a baseline assessment. If the preliminary screening process for an EEU identifies PRSs within the EEU that do not contribute to ecological risk and do not need to be addressed further, this information may be combined with information from the human health risk assessment to propose those PRSs for No Further Action (NFA).

The ERFI report is intended primarily to present information relevant to the ecological risk assessment that has been performed. It is not intended to duplicate information that already has been presented in the human health RFI and, consequently, will not reiterate general background information, QA/QC data, etc.

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APPENDIX I

REGULATORY REQUIREMENTS FOR ECOLOGICAL RISK ASSESSMENT

The three major environmental laws that are applicable to Los Alamos National Laboratory and that have some requirement for ecological risk assessment are the Comprehensive Environmental Response, Compensation, and Liability Act; the National Environmental Policy Act; and the Resource Conservation and Recovery Act. In addition, several Department of Energy (DOE) Orders provide important guidance relevant to ecological risk assessment.

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was passed in 1980. Its primary focus is on the cleanup of hazardous waste sites. As part of the process of cleaning up these sites, CERCLA mandates the protection of human health and the environment. As originally written, the primary emphasis was on protection of human health, with a secondary emphasis on protection of the environment and insofar as such protection was necessary in order to prevent subsequent human health effects. Over time, the interpretation of the CERCLA requirements for environmental protection was broadened to encompass long-term ecological health because of the realization that human health implications of environmental damage may not always be immediately apparent. This interpretation was strengthened with the passage of the Superfund Amendments Reauthorization Act (SARA) in 1986.

SARA also mandates a further requirement for environmental protection by requiring compliance with all federal and many state environmental laws and regulations. Such laws and regulations are commonly referred to as Applicable or Relevant and Appropriate Regulations (ARARs). Examples of ARARs for Los Alamos National Laboratory are the Endangered Species Act, the wetlands protection provisions of the Clean Water Act and relevant Executive Orders, and New Mexico State laws regarding state-protected plants and animals.

Finally, CERCLA contains the requirement for recovery of damages resulting from injury to natural resources, which is commonly referred to as Natural Resource Damage Assessment (NRDA). NRDA is a powerful driver for ecological risk assessment. It is specifically mandated by CERCLA, and ecological risk assessment is imperative for an adequate assessment of natural resource injury.

Thus, the three basic CERCLA requirements for ecological protection are:

- protection of the environment,
- compliance with appropriate and relevant environmental regulations, and
- reparation for damage to natural resources.

The Environmental Protection Agency (EPA) was required to develop regulations for implementing CERCLA requirements, and these regulations are codified in the National Contingency Plan that is found at 40 CFR 300. However, although CERCLA and the National Contingency Plan both contain requirements for ecological risk assessment, there is no identification of methodologies or protocols to be used to fulfill these requirements.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) was passed in 1969 and was signed into law in 1970. Its purpose is to ensure that any major federal action with potential environmental effects

is evaluated for every significant aspect of the environmental impact of the proposed action and that the public is informed of the results of the impact analysis. NEPA is referred to as a "procedural" law. That is, it doesn't mandate any particular result. It simply prescribes a process for preventing uninformed decisions. The NEPA impact analysis process must address the following issues:

- the environmental impact of the proposed action;
- unavoidable adverse effects associated with the proposed action;
- alternatives to the proposed action; and
- irreversible and irretrievable commitments of resources.

There are no particular methodologies identified for conducting the environmental impact analysis. This is left to the discretion of the implementing agency, as long as opposing views that are reasonably presented are included. The impact analyses conducted under NEPA frequently are rather qualitative in nature. Most importantly, there is no requirement that the most environmentally-protective alternative be selected, although in Section 101(b) the law enumerates six goals related to resource usage and environmental preservation that the selected alternative is supposed to best fulfill. Nevertheless, the only real requirement is that the environmental impacts associated with the alternatives are identified.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) was passed in 1976 and amended in 1984 with the passage of the Hazardous and Solid Waste Amendments (HSWA). Although the language in RCRA isn't as strong as in CERCLA, RCRA does have requirements for human health and ecological risk assessment. These are primarily associated with the provisions for safe management of hazardous waste during its treatment, storage, and disposal, particularly in connection with the investigation of potentially contaminated sites.

Department of Energy Orders

Several Department of Energy (DOE) Orders have provisions relevant to protection of the environment. DOE Order 5400.1 addresses the general protection of the environment and explicitly states that DOE policy is to conduct operations at its facilities in compliance with both the spirit and letter of environmental laws, regulations, and applicable standards. DOE Order 5480.23 on Safety Analysis Reports (SARs) specifies that SARs will include information regarding protection of the environment from accidental releases. Specifically, a stated goal of an SAR is to ensure comprehensive risk management of safety and environmental hazards posed by facilities and operations. Finally, in DOE Order 5480.4, DOE voluntarily commits itself to environmental statutes to which it is not specifically subject by law.

APPENDIX II

GUIDANCE FOR ECOLOGICAL RISK ASSESSMENT

Environmental Protection Agency Guidance Documents

"Draft Proposed Guidelines for Ecological Risk Assessment"

This document was issued by EPA in October of 1995 and became generally available in the late November time frame. It will supersede the 1992 framework document when it is officially released by EPA. The present draft is being circulated for review and comment.

The information presented in the 1995 draft is an update to the 1992 "*Framework for Ecological Risk Assessment.*" The guidance is greatly expanded; however, specific methodologies or protocols are not provided. The information that is presented is more in the nature of the theoretical basis that should be used in approaching the ecological risk assessment process.

"Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments"

This document supersedes the 1989 RAGS II guidance. It was published by EPA in 1994 and outlines the so-called "8-step" process for implementing the "*EPA Framework for Ecological Risk Assessment.*" However, while the steps outlined in this document provide more elaborate guidance for the implementation of the EPA framework, the document still does not identify any specific methodologies or protocols. The 8 steps that make up the process are the following:

Step 1: Preliminary Problem Formulation and Ecological Effects Evaluation

Step 2: Preliminary Exposure Estimate and Risk Calculation

Step 3: Problem Formulation: Assessment Endpoint Selection and Testable Hypotheses

Step 4: Problem Formulation: Conceptual Model, Measurement Endpoint Selection, and Study Design

Step 5: Site Assessment for Sampling Feasibility

Step 6: Site Investigation

Step 7: Risk Characterization

Step 8: Risk Management

"Managing Ecological Risks at EPA: Issues and Recommendations for Progress"

This document, which was published in 1994, is an enumeration of concerns that were identified during the development of the EPA framework. Although it does not specify methodologies, it does identify issues that must be addressed during methodology development.

"Role of the Ecological Risk Assessment in the Baseline Risk Assessment"

This 8/12/94 letter from Elliott Laws, then Assistant Administrator of EPA's Office of Solid Waste and Emergency Response, to EPA Directors of Waste Management and Environmental Services Divisions, specifically states, "I also want to make it clear that an ecological risk assessment (ERA) will be conducted during the Remedial Investigation (RI) at all Superfund sites." The letter goes on to state that the purpose of conducting the ERA is to:

1. identify and characterize the current and potential threats to the environment from a hazardous substance release,

2. evaluate the ecological impacts of alternative remediation strategies, and

3. establish cleanup levels in the selected remedy that will protect those natural resources at risk.

"Framework for Ecological Risk Assessment"

When EPA published this document in 1992, it was widely accepted as the long-awaited guidance for conducting ecological risk assessments. However, as the title states, it provides only the framework within which to conduct an assessment and does not identify specific methodologies or protocols. The framework presented in the document breaks the ecological risk assessment process into three phases.

Problem Formulation: This phase is essentially the definition of the problem, including identification of contaminants of concern, receptors, assessment endpoints, conceptual models, etc.

Analysis: This phase is further subdivided into 1) exposure assessment and 2) toxicity assessment. The first involves pathway analysis to determine potential receptor exposure, and the second involves selection of appropriate and relevant ecotoxicological data for comparison.

Risk Characterization: In this phase, the results of the exposure assessment and the toxicity assessment from the Analysis Phase are integrated and compared in order to make some kind of a statement about the risk to the receptors selected during the Problem Formulation Phase.

This framework has been the driver for developing ecological risk assessment approaches since its appearance in 1992, but no methodologies for implementing the phases of the framework have been issued by EPA or have been generally accepted. In October of 1995, EPA issued "*Draft Proposed Guidelines for Ecological Risk Assessment.*" When these new guidelines appear in final form, they will supersede the 1992 framework document. Numerous ecological risk assessment guidance documents have been issued by EPA and DOE. These documents are reviewed in Appendix II.

"Risk Assessment Guidance for Superfund Volume II: Environmental Evaluation Manual"

The interim final version of this guidance manual, referred to as RAGS II, was published by EPA in 1989. It was supposed to provide guidance for ecological risk assessment under CERCLA, but the guidance was only general and did not identify specific methodologies. It has since been superseded by the 1994 EPA document entitled "*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments.*"

Department Of Energy Guidance Documents

"Ecological Risk Assessment for Comprehensive Environmental Response, Compensation, and Liability Act Sites on Federal Facilities: An Introductory Guide for Facility Managers"

This document was prepared for DOE in 1994 by Oak Ridge National Laboratory. As stated in the introduction to this document, it is a very brief description of ecological risk assessment, the EPA framework, and its relation to the CERCLA Environmental Remediation process.

"Building Consensus through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program"

This report was published by the National Research Council of the National Academy of Sciences in 1994. It is the result of a review of the DOE's Environmental Remediation Program that was requested by Thomas P. Grumbly, who was then DOE Assistant Secretary for Environmental Restoration and Waste Management. The review was conducted during a "Workshop to Review Risk Management in DOE's Environmental Remediation Program" that was held in Washington, DC in November of 1993. The important conclusions of the workshop were:

1. that risk assessment by a credible agency is imperative for direction of Environmental Remediation Program activities, and

2. that communication of the results of the risk assessment to the public is equally as important.

The workshop and program review was not intended to address risk assessment methodologies, but the importance of conducting risk assessments was emphasized. Indirectly, this document has driven much of the risk assessment activity that has subsequently ensued.

"Integrating Natural Resource Damage Assessment and Environmental Restoration Activities at DOE Facilities"

This document was prepared for DOE in 1993 by Martin Marietta Energy Systems, Inc. Although it originally was developed as a guidance document, it was never issued as such. Instead, it was published as an information document to be used in integrating NRDA with Environmental Restoration activities. It does not discuss ecological risk assessment *per se*; but it does emphasize the importance of NRDA, which, as previously pointed out, depends on ecological risk assessment for evaluation of natural resource injury.

"Ecological Risk Assessment Guidelines for Preparation of Remedial Investigation/Feasibility Study Work Plans"

This document was prepared for DOE in 1993 by Argonne National Laboratory. Its purpose is to provide instructions for preparing ecological work plans to complement Remedial Investigation/Feasibility Study (RI/FS) work plans. The idea was to provide guidance on how to develop an ecological risk assessment work plan and how to integrate it with the RI/FS process. The guidance is presented as a series of steps to be followed. However, as in the policy framework reviewed in the previous paragraph, the discussion in this document focuses on generic approaches and relevant considerations without identifying specific methodologies.

"Policy Framework and Implementation Plan for Using Ecological Risk Assessment at DOE Facilities"

This document was prepared for DOE in 1993 by the Pacific Northwest Laboratory. Its purpose is "to propose a policy framework and an implementation plan for using ecological risk assessment to support environmental management decisions at DOE facilities." It emphasizes the use of an integrated approach to ecological risk assessment. However, while it addresses the integration of ecological risk assessment with other activities and discusses considerations pertinent to developing methodological approaches, no specific methodologies are identified.

Other Guidance

The American Society for Testing and Materials (ASTM) is developing guidelines for most aspects of implementing ecological risk assessments, ranging from selection of receptors and endpoints to sampling methodologies and validation of data. At the present time, all of these guidelines are in various stages of preparation and review. They differ widely in scope and detail, depending on who is developing a particular guideline. Some are quite detailed and offer specific methodologies, while others are more general and simply reiterate the general approaches found in the EPA framework document.

APPENDIX III

EPA REGION 6 SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR ECOLOGICAL RISK ASSESSMENT (draft)

There are two major purposes for the screening procedure. One is to determine if there is a need to go forward with an ecological risk assessment. The second is to focus the ecological risk assessment by identifying those chemicals most likely to present a risk to ecological receptors exposed to chemicals in abiotic media within specific habitats. The screening values generated by this procedure are conservative and results are not to be used to define cleanup levels.

The conservative nature of the screening procedure is illustrated by the following summary of assumptions forming the basis for the procedure.

1) Maximum concentrations of chemicals in each medium without regard for the number of samples, statistical distribution of the analytical results, spatial distribution of the analytical results, spatial distribution of samples, or location of maximum concentration relative to usable environmental habitats will be used to generate screening values.

2) The lowest ecotoxicological literature values regardless of whether the test species (and its most sensitive life stage) are expected to occur in the vicinity of the site being evaluated will be used to generate screening values.

3) Naturally-occurring background concentrations will not be considered in establishing screening levels and will be dealt with separately.

4) Maximum concentrations of ground water contaminants will be screened without regard for dilution or attenuation between the sampling well location and the exposure point (e.g. surface water/ground water interface).

5) Chemicals will be screened without consideration of specific receptor populations or organisms at a particular level within a food chain.

6) Bioavailability of 100% is assumed for all chemicals in all exposure media.

7) The area use factor is assumed to be 100% -- home range of potentially exposed biota is assumed to coincide with the area having the maximum concentrations of chemicals, and migratory patterns of exposed biota are not considered.

8) The date of sample collection and analysis (i.e. the ability of data to represent current conditions) is not considered.

9) There is an assumption that soil or sediment constitutes 50% of the diet for terrestrial receptors, given that soil ingestion can range from less than 2% (some small birds and small mammals) to essentially all of the diet (earthworms).

10) The most toxic species of metals are assumed present, regardless of which species are most likely to predominate in the natural environment.

11) The most conservative exposure parameters (e.g. body weight, ingestion rate, % diet) will be used in calculating the screening quotients.

Calculation of ESQs

Ecological Screening Quotients (ESQs) are calculated using the maximum concentrations detected in media at a site (or half the detection limit if not detected) divided by the lowest screening reference values available for that chemical.

ESQ = maximum media concentration/lowest screening reference value

or

ESQ = maximum dose/lowest screening reference value

All chemicals of potential concern (COPCs) that bioaccumulate or bioconcentrate will be retained regardless of their ESQ. Organic COPCs with log Kow's greater than 3 should be retained as potentially bioaccumulative. All inorganic COPCs that have whole-body BCFs greater than 40 (EPA Regional Clean Water Act (304[A]) criteria charts) should be retained as potentially able to bioaccumulate.

If the ESQ is greater than 1, the chemical should be retained as a COPC for that media.

If the ESQ is less than 1 and the chemical does not tend to bioaccumulate or bioconcentrate, it should not be retained as a COPC.

If a chemical is detected in at least one medium, but was not an analyte in the remaining media, it should be considered not sampled and be retained for further evaluation.

If the chemical detection limit is not lower than the screening reference value, the chemical should be retained for further evaluation.

If ecotoxicological data for a specific chemical cannot be found in the literature, the chemical should be retained for further evaluation.

Screening Reference Values

Screening reference values are estimated from literature toxicity values compiled from several sources. Literature toxicity data should cover all receptor groups potentially exposed to all media of concern. For example, an aquatic habitat should include a search of fish, aquatic invertebrate, aquatic plant, water bird, aquatic reptile, and aquatic and semi-aquatic mammal databases. Primary sources for these values include:

- Federal Ambient Water Quality Criteria
- State Water Quality Standards
- ECOTOX Database, which includes: Aquire (fish and amphibian database), Terretox (mammal, bird, and reptile database), and Phytotox (plant database)
- Hazardous Substances Database (HSDB)
- Registry of Toxic Effects of Chemical Substances (RTECS)
- Agency for Toxic Substances and Disease Registry (ATSDR)
- Integrated Risk Information System (IRIS)
- National Status and Trends Program Approach (Long and Morgan; NOAA)
- Guidelines for Protection of Sediment Quality in Ontario
- Eisler publications by USFWS
- Oil and Hazardous Materials - Technical Assistance Data System (OHM TADS)

- Wildlife Exposure Factors Handbook for exposure parameters
- Other State or Provincial guidelines
- The general literature

Literature toxicity values selected for the screening reference values in order of preference are: 1) the lowest No Observed Adverse Effects Level (NOAEL) or No Observed Effects Level (NOEL), 2) the Lowest Observed Adverse Effects Level (LOAEL) or Lowest Observed Effects Level (LOEL), or 3) the dose or concentration that was found to be lethal to 50% of the test organisms (LD50), LC50), or EC50). If a NOAEL value is not available for a chemical, it can be estimated for use in generating the screening reference value by applying an uncertainty factor of 10 for the lowest LOAEL or 100 for the lowest acute value (LD50, LC50, EC50) found. If toxicity values are not available for the habitat of interest (e.g. aquatic, terrestrial), toxicity results from other habitats may not be used, and the chemical should be retained for further evaluation.

Toxicity information expressed in terms of dose (e.g. mg of chemical/kg body weight/day) can be converted to dietary concentrations (mg/kg) for use as a screening reference value using the following formula.

dietary conc. = dose/food ingestion rate x soil ingestion rate

Dose is the estimated contaminant intake (e.g. mg/kg-day) obtained from the literature or estimated by the following equation.

dose (mg/kg-day) = diet (mg/kg) x ingestion rate (kg/day) x 1/bodyweight (kg)

Uncertainty

The ecological screening procedure was developed as a conservative approach to eliminate COPCs. The conservative assumptions listed above can be examined and adjusted to better reflect site- and receptor-specific conditions in subsequent phases of the ecological risk assessment procedure.