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TECHNICAL WORKSHOP ON WIPP

COMPLIANCE ISSUES

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Carlsbad Area Office
TRU Waste Characterization Program

EPA Technical Workshop on WIPP Compliance Issues

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February 15, 1995

R95 0134

DOE/CAO Program has Established a TRU Waste Characterization Program that Will Support all WIPP Compliance Activities Associated with TRU Waste Disposal Standards

- Provides comparable DOE system-wide waste characterization data
- Utilizes the data quality objectives process (EPA QA/G4) to establish waste characterization data requirements for preparation of the RCRA permit application (40CFR § 264.13) RCRA no-migration variance petition (40CFR § 268.6) and enviromental radiation protection standards certification package (40CFR parts 191 and 194)
- Key DOE/CAO documents include Waste Characterization Program Plan, *WIPP TRU Waste Baseline Inventory Report* (WTWBIR) and TRU Waste Characterization Quality Assurance Program Plan
- Establishment of TRU Waste Characterization Interface Working Group

R95 0135

Waste Characterization Program Plan establishes high level planning strategies required to support the WIPP DDP and provides a program overview/summary

- Describes planning strategies required to integrate between the WIPP DDP and individual DOE site requirements and capabilities
- Describes relationship between documents related to waste characterization
- Provides a summary of waste characterization requirements detailed in the TRU Waste Characterization QAPP
- Provides how waste characterization programs will be implemented at DOE sites

R95 0136

WIPP TRU Waste Baseline Inventory Report establishes a methodology for grouping wastes of similar physical and chemical properties expected to behave similarly

- Provides a documented TRU waste inventory including chemical, radiological, and physical properties to be used in systems prioritization and performance assessment
- Developed from best available information and process knowledge
  - Mixed Waste Inventory Report (MWIR)
  - Integrated Data Base (IDB)
  - Nonradioactive Inventory Database (NID)
  - Site specific input
- Listing of all DOE sites included, along with current and future volume projections scaled to WIPP design basis

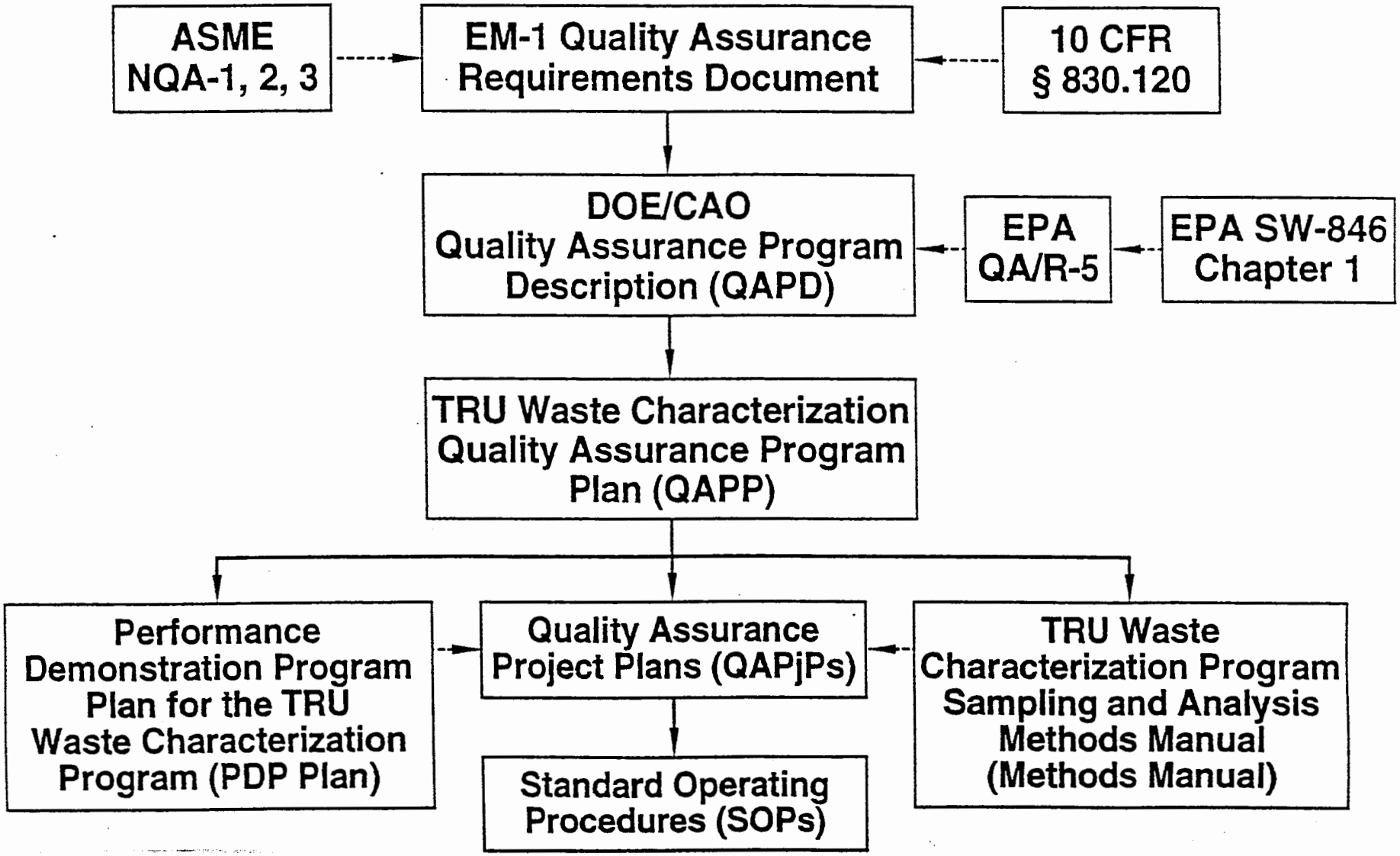
R95 0137

TRU Waste Characterization QAPP identifies the quality of data necessary and techniques designed to attain and ensure the required quality to meet objectives of the TRU Waste Characterization Program

- Establishes a single program to address waste characterization requirements associated with 40 CFA parts 264, 268, 270 and 191/194
- Utilizes a combination of process knowledge and non-intrusive and intrusive waste sampling
- Establishes a QA structure and records transmittal/ retention system that effectively utilizes WIPP and generator/storage site resources
- Utilizes performance based objectives

R95 0138

Program QA Document Hierarchy



R95 0139

The data quality objectives process as established in the EPA document, *Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process*, EPA QA/G-4 draft October 1993 has been utilized in the development of the TRU Waste Characterization QAPP

- DQO process was utilized when
  - Identified problems required additional information
  - Possibility that additional data may be required
- DQO process as applied to the Environmental Radiation Protection Standards
  - Waste characteristics identified not obtained from waste characterization activities
  - Performance assessment and systems prioritization supported by the *WIPP TRU Waste Baseline Inventory Report*; Enhanced Laboratory Program; Source Term Test Program; and other supporting activities

R95 0140

The data quality objectives process as established in the EPA document, *Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process*, EPA QA/G-4 draft October 1993 has been utilized in the development of the TRU Waste Characterization QAPP (Cont'd)

- DQO process as applied to the Resource Conservation and Recovery Act regulations
  - General waste analysis requirement
    - Listed waste determination
    - Characteristic waste determination
  - Land disposal restrictions
    - Hazardous constituent characterization
    - Repository performance
    - No-migration demonstration for health-based limits

R95 0141

Implementation of the requirements specified in the QAPP will result in data necessary to meet a number of objectives. TRU waste characterization techniques are determined based on required data.

- Assign Waste Matrix Code
  - Process knowledge
  - Radiography
  - Visual examination
- Estimate waste material parameters
  - Process knowledge
  - Radiography
  - Visual examination
- Determine radioisotopes and total alpha activity
  - Radioassay

R95 0142

Implementation of the requirements specified in the QAPP will result in data necessary to meet a number of objectives. TRU waste characterization techniques are determined based on required data. (Cont'd)

- Determine the container headspace concentration of volatile organic RCRA hazardous constituents and potentially flammable volatile organic compounds
  - Sample and analyze headspace gases
- Determine if a waste is listed under 40 CFA Part 261, Subpart D
  - Process knowledge
- Determine if a waste exhibits a toxicity characteristic under 40 CFR Part 261, Subpart C
  - Process knowledge - 5000 Series Waste Matrix Codes
  - Sampling and analysis - 3000 and 4000 Series Waste Matrix Codes

R95 0143

DOE's definition and use of "acceptable knowledge" is consistent with EPA's hazardous waste regulations and guidance provided in *Waste Analysis at Facilities that Generate, Treat, Store and Dispose of Hazardous Waste: A Guidance Manual* EPA 530-R-94-024

- TRU waste is generated from specific processes and activities associated with nuclear weapons fabrication which are well defined and controlled
  - Production of nuclear products
  - Plutonium recovery
  - Research and development
  - Decontamination and decommissioning
- DOE uses acceptable knowledge information, along with other waste characterization data, to provide definitive chemical and physical characterization of waste streams when:
  - Sampling and analysis is not necessary
  - It is not feasible to collect a representative sample

R95 0144

DOE's definition and use of "acceptable knowledge" is consistent with EPA's hazardous waste regulations and guidance provided in *Waste Analysis at Facilities that Generate, Treat, Store and Dispose of Hazardous Waste: A Guidance Manual* EPA 530-R-94-024 (Cont'd)

- DOE will verify adequacy of site-specific acceptable knowledge
  - Review site-specific sampling plans and compliance documents
  - Perform audits and assessment
- A small percentage (~2%) of the existing TRU waste is categorized as unknown
  - Existing records may not be adequate
  - Waste will be fully characterized prior to shipment

Use of performance based methods and objectives allows for site wide implementation and is consistent with EPA-OSWER guidance

- EPA SW-846 is a guidance manual with methods not tailored to WIPP specific waste streams
- QAPP specifies QA/QC criteria that will ensure data comparability
- QAPP requires that site specific methods be approved by DOE-CAO
- QAPP dictates the use of expert review teams for NDA techniques

R95 0146

All TRU waste will be characterized to demonstrate compliance with all final WIPP acceptance criteria derived from RCRA, environmental radiation protection standards, health and safety, and transportation

- Three approaches for WIPP acceptance of existing and future generated wastes have been established
  - Meet an acceptable waste envelop developed from WIPP performance assessment
  - Be treated to meet the established waste acceptance criteria
  - Be included in a future compliance package modification based on further analysis

R95 0147

Kate Trauth

Sandia National Laboratories

A Consideration of Passive Institutional Controls Consistent with 40 CFR 191

Kathleen M. Trauth
Sandia National Laboratories

EPA Technical Workshop
February 14, 1995

What has been the experience, to date, with the effectiveness of passive institutional controls (PICs)?

Specific information required

Specific purpose of the PICs

6342-346-0

Definition of PICs:

"...preserving knowledge about the location, design, and contents of a disposal system" (40 CFR 191.12)

Usage of PICs:

"Disposal sites shall...indicate the dangers of the wastes and their location." (40 CFR 191.14 (c))

"can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency" (40 CFR 191, Appendix C)

6342-347-0

To deter inadvertent human intrusion:

marker or record survival

marker or record understood and believed

If message understood and ignored, not inadvertent intrusion

Not in the scope of the regulation to consider human actions given knowledge of risks

6342-348-0

Inadvertent Intrusion as Focus

Inadvertent human intrusion is what is to be considered in performance assessments that are compared with 40 CFR 191 for compliance:

"Therefore, inadvertent and intermittent intrusion by exploratory drilling for resources (other than any provided by the disposal system itself) can be the most severe intrusion scenario assumed by the implementing agencies." (40 CFR 191, Appendix C)

Experience with PICs

Knowledge requirements relate to location, design, contents (dangers) of the repository

Resource information not required to be maintained by PICs

PICs information subsystem implemented when information available on contents/dangers, i.e., after disposal.

Therefore, there is no current requirement for a PIC system to be in place now, none exists, therefore, no experience with PICs for the WIPP as defined in 40 CFR 191.

How does one evaluate evidence and determine credit for the effectiveness of PICs in mitigating the likelihood of human intrusion?

Consistency with EPA assumptions in developing 40 CFR 191

Logic of making use of available information

6342-352-0

EPA directives from 40 CFR 191 and Guidance and Supplementary Information in the Federal Register:

"The implementing agencies should consider the effects of each particular disposal system's site, design, and passive institutional controls in judging the likelihood and consequences of such inadvertent exploratory drilling." (40 CFR 191, Appendix C)

"The Agency assumes that, as long as such passive institutional controls endure and are understood, they: (1) can be effective in deterring systematic or persistent exploitation of these disposal sites; and (2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency." (40 CFR 191, Appendix C)

6342-353-0

Need to Incorporate the impact of PICs:

"Not allowing passive institutional controls to be taken into account to some degree when estimating the consequences of inadvertent human intrusion could lead to less protective geologic media being selected for repository sites. ... If performance assessment had to assume that future societies will have no way to ever recognize and limit the consequences of inadvertent intrusion ..., the scenarios that would have to be studied would be more likely to eliminate salt media from consideration than other rock types. Yet this could rule out repositories that may provide the best isolation, compared to other alternatives, if less pessimistic assumptions about survival of knowledge were made." (50 FR 38080)

6342-354-0

"However, the Agency believes it is important that the assumptions used by the implementing agencies are compatible with those used by EPA in developing this rule. Otherwise, implementation of the disposal standards may have effects quite different than those anticipated by EPA." (50 FR 38074)

"In making these various predictions, it will be appropriate for the implementing agencies to make use of rather complex computational models, analytical theories, and prevalent expert judgment relevant to the numerical predictions." (40 CFR 191, Appendix C)

6342-355-0

EPA guidance:

PICs must be used in determining the likelihood of inadvertent human intrusion to be considered in performance assessments.

Expert judgment is an appropriate part of performance assessment, including determining the impact of PICs.

6342-356-0

Appropriateness of Using Expert Judgement

The human mind is the best tool for assimilating information and producing judgments

Expert judgment is a means to accomplish the above in a coherent fashion

- information collected for other purposes/disciplines
- data and information not available from lab experiments
- complex issue

6342-357-0

SNL WIPP Markers Panel

2 parallel teams from a variety of disciplines

Wide ranging disciplines can contribute lessons learned for survivability and interpretability

6342-358-0

Markers Panel Recommendations

Materials

Size

Multiple levels of message complexity

Multiple types of markers

Multiple marker components

Multiple communication methods

6342-359-0

Categories of Current Knowledge for Records

Media

Owning organizations

Information retrieval

What information to communicate

6342-360-0

Mechanics of Convening an Expert Panel

Convene with an established procedure

- SNL QA Procedure for Expert Panels

Procedure

- diversity in membership (disciplines and viewpoints)
- documentation

6342-361-0

Qualitative Evaluation of a PIC System

Review of documentation describing development

- contributions of appropriate disciplines?
- participation of qualified individuals in development?

6342-362-0

Quantitative Evaluation of PIC Systems

Performed by qualified individuals from appropriate disciplines

within constraints, e.g., "practicable", EPA assumptions

Regulatory review of record (process and supporting evidence)

6342-363-0

Uncertainty

40 CFR 191 is probabilistically based

Uncertainty is a part of the performance assessments

Cannot avoid the uncertainty associated with PIC

6342-364-0

In Summary

No experience with PICs for the WIPP as defined in 40 CFR 191, therefore no conclusions can be drawn for implementing PIC.

PICs must be considered in performance assessments consistent with 40 CFR 191 (and Guidance and Supplementary Information)

Use expert judgment to consider PICs (consistent with 40 CFR 191)

Information available to direct PIC efforts and support benefits

Regulatory review of record

Kai Erickson

Yale University

No Hard Copy - Refer To Transcript

Mikael Jensen

Swedish Radiation Protection Institute

- What type of information should be conserved?
- In what form?
- The quality of the information, as regards both type and form.
- The problems of future retrieval.

1 Laws, general information from and about the society

2 Performance assessment, the final safety analysis

3 Records of the operation including

The dose register, the waste database and the operational records.

4 The location of the repository

5 The design of the repository, its physical shape and barriers.

Expert judgements - Jurisprudence

Prohibitions have poor long term prognoses, but civil rights has a 1000 year long tradition.

Expert judgements - Archaeology

Neither decrees nor requests on rune stones are followed by modern archaeologists

Year	Event
410	Rome attacked by Alaric and the Goths. Rome sacked 5 times during the 5th century.
1308	The papacy transferred to Avignon. Documents were left behind and some destroyed during their later transfer to France.
1404	The Vatican Palace of the Pope Innocent VII were sacked by a mob.

1527 Rome sacked by imperial German troops.

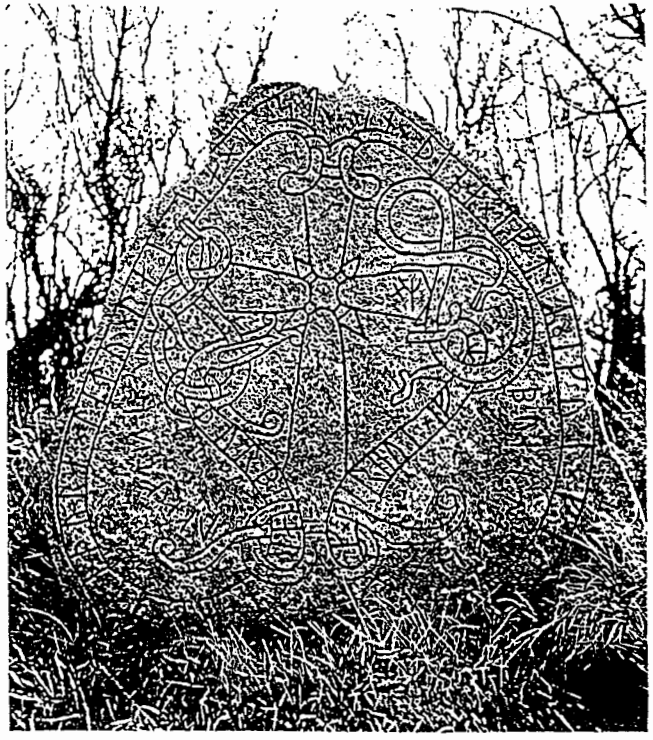
1810 Napoleon moved the archives, in 3239 chests, to Paris. One third was lost before they were brought back after the defeat of Napoleon. The last wagon train arrived in Rome 1917.

1870 The Italian army occupied Rome.

1940 Few losses during World War 2.

Sweden has the worlds largest number of markers in the form of rune stones, all around 1 000 years old.

Out of 3 000 stones, more than 10% have been completely lost over about 300 years, according to the Swedish Central Board of National Antiquity.



Mikael Jensen, Swed. Rad. Prot. Inst.
USEPA, 14-16 February, Washington, 1995.

Science theory

Carl Popper:

Knowledge as the archive content has a meaning and value in itself independent of external factors.

vs

Thomas Kuhn:

No record has a meaningful existence in its own right, it must always be related to the society around it.

A European and an American tradition

Archives vs Markers

Consider the hero's (John Wayne's) problems in "North to Alaska" on site and in the local land register.

Level	Content
1	Rudimentary information to promote a notion of caution. Example: a sign or symbol.
2	A warning message. One sentence.
3	Basic information about the repository. A short description, as on one sheet of paper.
4	Detailed information about the repository. A 100 page book.

Mikael Jensen, Swed. Rad. Prot. Inst.
USEPA, 14-16 February, Washington, 1995.

Generalization of the hierarchy from 1-7 (not only potential marker information)

5 The complete technical records of the repository: The archived information in at the responsible government agency.

6 Documented information about the repository from all sources in society.

7 All information in society relating to the repository.

OPTIMIZATION

The reasonable cost for an information system in terms of its capacity to deter intrusion an avoid doses to man.

An example

Probability of intrusion	Collective dose in sievert (Sv) (1 Sv=100 rem)	Risk per sievert	Protective effort (MUSD per death)	Total protective cost (MUSD)
0.1 *	40 *	0.05 *	2 =	0.4

Mikael Jensen, Swed. Rad. Prot. Inst.
USEPA, 14-16 February, Washington, 1995.

Hierarchy of disturbances for a repository

Dose	to	man	
Undisturbed repository	Disturbed		repository
	Inadvertent		Intentional
		Legal	Illegal

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Various modes of intrusion and consequences as a background for assessing information needs

	Society intrudes intentionally	Intentional illegal intrusion	Inadvertent Intrusion
Intruder	Is protected as deemed appropriate	May (or may not) protect himself	Cannot be assumed to be protected
Critical group	Is protected as above	Cannot be assumed to be protected	Cannot be assumed to be protected
World citizen	May be protected (by international conventions)	Cannot be assumed to be protected	Cannot be assumed to be protected

Mikael Jensen, Swed. Rad. Prot. Inst.
USEPA, 14-16 February, Washington, 1995.

- Tools for assessing human intrusion

Time period	0 - 50 (100)	100 - 1000	1000 - 10 000
Models based on natural science	1	1	2
Historical analogues	2	1	1
Philosophical Considerations	3	2	1

Tools for assessing the undisturbed repository's performance

Time period	0 - 1000	1000 - 10 000	10 000 - >100 000
Models based on natural science	1	1	2
Natural analogues	2	1	1
Philosophical Considerations	3	2	1

How do we "Evaluate evidence and determine credit"?

i)

Time period	0 - 50 (100)	100 - 1000	1000 - 10 000
Technique	A. Contemporary experience as a basis for statistical calculation	B= A and C	C. Scenario development and expert judgement
Prerequisite	Today's legal system	Given reference conditions	Given reference conditions

How do we "Evaluate evidence and determine credit"?

ii)

By assuming today's reasoning in a broad sense. "Exotic" future societies obviously cannot be excluded and should, in principle, be protected.

The reason we must exclude exotic societal formations from reference scenarios in our assessments, is simply that we cannot have knowledge about their (possibly exotic) needs.

A hypothesis:

1 There is no difference, in principle, between difficulties of prediction by social and natural sciences (future societies vs future earthquakes), but there is a difference of about a factor of 10 in the time scale, ~~but~~ ..

2 there is a dependence of the time periods for human intrusion, so that a repository best equipped to withstand inadvertent intrusion for 1000 years may also be best equipped for the next period (10 000 years). The same is not necessarily true for releases from the undisturbed repository, but it may be true if the periods are taken as i) 0-10,000 years and ii) 10,000 -100,000 years.

The state will influence markers and archives by its regulation:

- Access control, restrictions on land use
- The National Archives
- Marker location marked on maps, and
- Active measures such as remediation of markers.

The state's and waste management's roles are therefore not completely independent.

It is the role and responsibility of the state that provide arguments for a separate, or special, judgement of human intrusion, not the false idea that natural sciences always are better suited for prediction or projection than the social sciences.

HUMAN INTRUSION

Some Aspects of Regulation and Assessment of Future Human Actions at Radioactive Waste Disposal Sites

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ABSTRACT

A presentation in some detail of the problem of human intrusion is valuable. The issue is related to fundamental reasons why society disposes of the waste. If these questions are not addressed early in the licensing process, they are likely to turn up later as problems for both the waste management and the regulator.

Intrusion scenarios may include individuals who receive high doses, in excess of dose limits. This is a consequence of the strategy of waste isolation which cannot be rejected solely on the basis of the intruder's dose.

A logical presentation of the interdependence of some factors such as environmental consequences versus area restrictions makes it possible to describe this aspect of the licensing as a balanced decision.

An optimization study of the value of an information conservation system may be helpful in bringing into the open some important assumptions made in the human intrusion scenario. Some issues may be worthwhile to discuss: the problems of a large number of minor disturbances, of repeated intrusions and protection of a hypothetical drilling crew versus protection of the general public at risk as a result of the intrusion.

In licensing a repository with a life-time of thousands of years it is impossible to completely separate the responsibility of the waste management and the regulating system. However, it is the responsibility of the regulator to define its role in the process, where this could influence the environmental impact of the repository. This is also important in order to make the process as coherent and transparent as possible.

FUNDAMENTAL CONCEPTS.

In the political and technical discussion of high level waste (HLW) disposal, several fundamental concepts must be dealt with, such as the potential danger of plutonium in the hands of future groups of people, even future governments. The same plutonium, however, can also be seen as a value to groups in the future. Thus plutonium may be treated as a detriment in one analysis, and as an asset in a another. Still another and perhaps predominant view is that plutonium as all other radioactive material is toxic and for that reason should be kept separated from the biosphere.

Some of the fundamentals of radioactive waste disposal may not be possible for a regulating agency to define by itself without a dialogue with political decision-makers. If for instance it is considered important to restrict the use of plutonium not only geographically, which is the rationale behind the Non-Proliferation Treaty, but also to restrict access to plutonium for governments in a distant future, then very deep boreholes (VDH) might be the most important alternative of the deep geological disposal options simply because this option could make the waste most difficult to retrieve.

The considerations above are ultimately political in nature, and it must be up the regulator to determine what decisions are necessary so that the prerequisites for a coherent process of waste disposal are at hand.

It follows that it is not possible to avoid the sense of illusiveness felt by many about the idea of human intrusion, if some of the underlying concepts are not reexamined and given a stringent treatment.

It may therefore be necessary to have a set of fundamental, explicitly given, assumptions which defines society's motives for disposal of the waste. In defining these motives, a strategy should be presented that includes issues like the need for and the value of retrievability of the waste and repairability of the repository, including a description of the waste's potential future value or detriment as assessed by society today. Other concepts, mainly technical but also philosophical in nature can be expected to be decided upon by the regulator, and a few are presented below.

Waste Disposal Strategies and Protection Principles

For protection against toxic wastes, it is in principle possible to have two mutually excluding strategies exemplified by the expressions:

1 dilute and disperse, and

2 isolate and contain.

A complete radiation protection strategy also includes the three principles of Justification, Optimization and Dose Limitation. The first principle must be addressed already in the licensing process of the practice in which the waste is produced. Most often Optimization, the second principle above, leads to a choice of the second of the above mentioned strategies, isolation and containment in the form of a waste storage facility. The third radiation protection principle ensures the protection of single individuals in cases where the collective dose is deemed acceptable, but it is distributed in such a way that high doses are received by single individuals who may not receive all the benefits of the practice. According to ICRP, the principle of dose limitation should be regarded as a boundary condition to the process of optimization.

The principle "dilute and disperse" may seem provocative but releases to the environment may occur for various reasons:

- Unavoidable acceptable releases. Almost any practice which produces waste - as well as waste handling itself - includes releases of radioactive material to the environment. If the practice is deemed justified, the regulator defines the acceptable levels of releases. In this framework, however, releases are not always seen as a conscious waste disposal strategy.

- In some circumstances, and for some short-lived radionuclides, dispersion can in some cases (such as certain medical practices), be shown to yield the lowest collective and individual doses.

- In some cases releases of short-lived nuclides may not be the option which gives the lowest collective dose but may still be acceptable if i) the practice which causes the release has been considered justified and ii) if it can be shown that alternative disposal options would cost more than reasonable (in the eyes of the regulator).

High individual doses would be avoided if the first strategic view were taken and the toxic waste diluted and dispersed, for instance into the sea. This strategy is often rejected by society on grounds that is it unjustified or that it would represent an under-optimized alternative. In most countries, dispersion of radionuclides with half-lives of many years into the sea is not a realistic alternative.

In the environmental impact assessment of a radioactive waste repository design, the special case of intrusion into the repository, may present a possibility for high individual doses to individual, namely the intruder. However safe the repository is designed, intrusion can always be imagined, sometimes by considering simple practices such as drilling for water, sometimes by taking into account extremely improbable events.

The conclusion is therefore that when society, on grounds of justification or optimization, chooses the option of waste containment in the form of a storage, the hypothetical scenario of intrusion followed by doses to the intruder in excess of dose limits cannot be used as a constraint the same way as in normal standards for building X-ray facilities in hospitals or for determining release limitations for nuclear facilities where doses are continuously monitored. On the contrary, the high dose to the potential intruder flows directly from the strategy of waste isolation in a repository.

Intrusion or other human actions that may influence the performance of the waste repository must still be a part of the total safety assessment. But it follows from the above reasoning, that the threat of intrusion must be balanced against the probability of the intrusion in the regulation, since otherwise dilution would be the only remaining option.

SOME DEFINITIONS RELATED TO THE INTRUSION CONCEPT

In the absence of a definition of the human intrusion concept, almost any scenario leading to some radiation dose to man can be said to constitute a human intrusion or human action scenario which disturbes the repository. It is therefore worth while to establish a common international basis for definitions and judgement of human intrusion scenarios.

The following sections are dedicated to defining some necessary concepts for human actions at radioactive waste disposal sites. It is assumed that an extended analysis covering human intrusion is carried out in two steps:

- a first phase consisting of an assessment of the repository performance in the absence of intrusion.
- a second phase where human action disturbs or changes the outcome of the initial performance assessment.

It is assumed that performance assessment criteria exist for the first phase. The present task can therefore be described as finding criteria necessary to cover the additional, and separate, second phase. Human actions are seen as a broad concept, not restricted to human intrusion into the primary disposal. It may also include actions far from the disposal site, but close enough to influence the performance assessment. In some cases, like the Swedish repository for low and intermediate level waste, SFR, intrusion may be an important siting factor. This does not prevent that the analysis is made in two steps as mentioned above.

Definition of an Extended Repository Limit

Radioactive disposal concepts imply that the physical and chemical form of the radioactive waste, the repository design and technical barriers, in addition to natural barriers of the site, guarantee a sufficient protection to compensate for the dangers of the waste.

In this formulation, true for most repositories, part of the environment can be considered an integral part of the disposal concept. Sometimes, it may therefore be useful to define a spatial limit outside which human actions would not influence the outcome of a safety analysis. In theory, this limit is defined as a three-dimensional surface around the repository, where doses would be low enough to meet regulatory criteria for the undisturbed repository function. The limit of the extended repository cannot be expected to have the same meaning for all sites. Even for a specific site it may be difficult to define such a limit, but the concept may be useful as a theoretical reference in the discussion.

Restrictions

It should be observed that the range mentioned in the preceeding section coincides with the area, or volume, where society may impose restrictions on various forms of activities. Even if the assessment does not rely on such active constitutional restrictions, it can be assumed that some records will be kept in some form for all high level radioactive waste repositories. Keeping such information available can be seen as a passive form of institutional control.

The human intrusion assessment serves to improve the repository concept. When choices are made between different concepts, the total detriment to society should be considered including the detriment of the restrictions described above. Thus, the performance of a repository cannot be improved simply by including a larger part of the environment in the repository concept. Also information conservation through long periods of time implies a cost to society and must have a weight in the assessment of costs and benefits of various solutions of the total problem, involving both radiation protection and use of the land above the repository. Some problems of optimization of the protection is discussed in the next section.

OPTIMIZATION OF RADIATION PROTECTION FOR HUMAN INTRUSION

Optimization as an important, perhaps the most important, concept in radiation protection was suggested in ICRP 26 in 1977 and in ICRP 60 in 1991 (1). It was pointed out that keeping doses as low as reasonably achievable was a powerful tool in radiation protection and that dose limits were to be seen mainly as a limit for the optimization procedure. Governments were advised that, for the activities where uses of ionizing radiation were justified, regulations should ensure not only that dose limit rules were met, but also that efforts were made to reduce individual doses further below those limits.

Both regulator and waste management could benefit from optimization studies, not least because all the underlying concepts will come under scrutiny in the process of determining the inherent factors in the calculation, the numerical result of which may be of limited value compared to the process itself.

Optimization categories for nuclear repositories

It is pointed out in ICRP 46 (2) that optimization of protection is a broad concept in waste management and it can apply at four levels:

A. Comparison of design alternatives for a specific facility such as a waste repository.
B. Comparison of different disposal options for particular waste streams.
C. Comparison of different overall management systems for particular waste streams.
D. Comparison of complete waste management systems, including conditioning, storage, transport and disposal alternatives for a given source or practice.

The global view should never be forgotten, so that for instance doses from waste handling should be added to doses from the repository in a distant future in the optimization.

Optimization may be used to identify the most cost-effective operation and the best (undisturbed) repository. What is balanced in the optimization described here is a special case of A above: the cost of establishing an information conservation system against the potency of such a system to prevent doses to man by deterring inadvertent intrusion. In principle, other costs could enter the calculation, such as choosing a site for which a repository would cost more, but that has not been taken into account in this presentation.

In this case, actions by individuals or groups must be described as an element in the calculation. Such calculations are always problematic, but they are easier for a shallow land burial where analogues may exist (e.g. experiences from waste dumps). It is worth noting that, for a given repository, the optimization of the benefit from the information system may not have much in common with the protection optimization of the undisturbed repository itself. The difficulties are not necessarily less but they are different.

A NUMERICAL EXAMPLE OF AN OPTIMIZATION CALCULATION

In the following example, an optimization study of intrusion is described for a high-level waste repository. The calculation is meant as an illustrative numerical example of the calculation, and a demonstration of the uncertainties involved. The time span for the optimization may be assumed to be 10 000 years.

Probability of intrusion through loss of memory

Some estimates of the probability of intrusion has been given in work presently carried out by Sandia National Laboratories for the US Department of Energy's Waste Isolation Pilot Plant (WIPP) in New Mexico (3). Panels of experts have been asked to estimate the probability of inadvertent intrusion by future societies up to 10 000 years into the future. Some panelists have estimated the probability of intrusion to about 0.1 in 10 000 years. This is for a case where nothing denotes the location of the site. Another panel discussed to what extent information at the site (markers) could be a remedy for loss of knowledge. The effectiveness of markers, that is the ability to deter inadvertent intrusion, was believed by some panelists to be near 0.9 for 10 000 years and higher (0.99) for the first 1 000 years. With these estimates, and for the period 1 000 years the probability of intrusion can thus be calculated to be 0.1 * (1-0.99) = 0.001, for 10 000 years: 0.1 * (1-0.9) = 0.01.

In another site-specific study (4) regarding a repository in Boom clay at Mol, Belgium, the authors themselves assigned values to probabilities for loss of information, interest in drilling and a geometrical factor giving the probability of drillers hitting the repository. They combined these probabilities to arrive at a probability for inadvertent intrusion of less than 0.001 for 2 000 years after closure. In that work, probabilities are attributed to intrusion as far as 250 000 years into the future.

It is assumed, in the example below, that direct intrusion, in the absence of an information conservation system, has a probability of 0.1 over 10 000 years.

Individual and collective doses from intrusion scenarios

In a study of doses from inadvertent drilling intrusion into the repository, made for the Swedish Radiation Protection Institute (5), intrusion scenarios with high doses are presented for direct hits of a fuel waste canister followed by routine examination of cuttings in the field, and even higher doses for close inspection of samples in a laboratory (from inhalation as the sample is cut). No probability is given for either mode of intrusion, except that intrusion into a waste canister or its backfill material is considered "very low". Doses are received by one or a few members of the drilling crew and laboratory personnel.

The collective dose in the example is taken to be such that the probable outcome of each intrusion or disturbance is one case of fatal cancer (20 person-sievert) for the members of the intrusion (drilling) crew and that the damage done by the intrusion in terms of a dose received by a larger number of people does not exceed nine times this value, so that the total collective dose is taken to be 200 person-sievert.

There can be no strong rationale for this value for the collective dose as a consequence of the drilling scenario. But one line of argumentation could be that if the collective dose was higher, it would be very easily detected (from acute radiation effects in the crew) and knowledge about the repository would be reimposed upon society. Such a reimposed knowledge might limit the damage made by the intrusion to the intrusion crew.

The value 0.05 excess cancer deaths per person-sievert is assumed for simplicity. In a detailed calculation, different risk estimates should apply to members in a drilling crew and a whole city population with a different age distribution. The estimate of this value by international expert organizations such as UNSCEAR (United Nation's Scientific Committee on the Effects of Atomic Radiation) and ICRP has changed over the years, but the estimate has always been thought to lie within the interval 0.01 to 0.1 cancer death per person-sievert.

It is assumed, in the field of radiation protection, that efforts are made to lower the dose as long as such efforts are deemed cost-effective. This assumes that the practice has been approved by the proper authorities and that doses are below the relevant dose limits. The limit where dose reduction is regarded barely cost-effective may be given in USD per person-sievert (1 sievert = 100 rem). This limit is often taken to be about USD 100 000 per person-sievert, although both higher and lower values are employed in individual cases.

If the probability of death is 0.05 per person-sievert, a value can be obtained giving the reasonable cost of increased safety in terms of cost to be taken to save one life (on the average). This reference cost may the be used by individuals and society to direct safety measures where these are most cost-effective. A combination of the death risk of 0.05 per person-sievert and the marginal cost of USD 100 000 per sievert yields 100 000/0.05 = USD 2 000 000 per saved life.

The result: the cost of the information system

The result of the calculation presented in Table I is that if intrusion can be avoided by information conservation in some form, it would be worth USD 2 000 000 to establish such a system. It can be seen that if the intrusion probability is set to 1 rather than 0.1 in the above calculation the reasonable effort for information retention would rise to USD 20 000 000. The somewhat arbitrary values in the calculation are discussed in section 3.5.

Table I. The value of an information conservation system.

Probability of intrusion or disturbance (no information conservation effort)	Collective dose per scenario in sievert (Sv) (1 Sv=100 rem)	Risk per sievert (fatal cancer)	Protective effort (million USD per death)	Total protective cost (million USD)
0.1 * (multiplied by)	200 *	0.05 *	2	= 2

In view of the conceptual problems mentioned in the preceding sections, it must be kept in mind that the calculations are made assuming certain scenarios, and that maximum values of the doses are scenario specific. With such reservations, it is possible to infer some maximum

and minimum values for the product of intrusion probability and the collective dose (i.e. the expectation value of the collective dose as a result of intrusion). The maximum value for the first term is 1 and as mentioned earlier 200 sievert constitutes a possible maximum collective dose to the crew and to the public assuming 20 person-sievert to the crew members which is enough to give life-threatening health effects to all members in the crew if the dose is distributed evenly and with some certain deaths if the distribution is uneven.

The lower set of parameters could be 0.001 for intrusion and 10 sievert for the collective dose to the crew plus the exposed public. It is possible to postulate a lower bound for the collective dose by considering natural analogues, such as doses from radon in ground water from a drinking water well. A dose of one millisievert (0.001 sievert or 100 millirem) per person and year is not uncommon for small wells in Sweden, for example (which does not emanate primarily from drinking, but from inhalation of radon daughters brought to indoor air by other uses of water). It seems reasonable that the family's collective dose: 4 persons * 0.001 Sv/year * 50 years = 0.2 person-sievert can give an example of an intrusion with a collective dose which may only deserve moderate concern.

The lower bound given in Table II represents such a low cost that further calculation seems uninteresting, because in no case would the waste management hesitate to pay this amount if safety could be improved.

Table II. Estimated lower bound for intrusion risk and detriment in dose and money.

Probability of intrusion	Collective dose in sievert (Sv) (1 Sv=100 rem)	Risk per sievert	Protective effort (M USD per death)	Total protective cost (M USD)
0.001 *	10 *	0.05 *	2 *	= 0.001

Perhaps not even the upper bound given in Table III may seem completely prohibitive for such a large scale project as a high-level waste disposal.

Table III. The upper bound for intrusion risk and detriment in dose and money.

Probability of intrusion	Collective dose in sievert (Sv) (1 Sv=100 rem)	Risk per sievert	Protective effort (M USD per death)	Total protective cost (M USD)
1	200 *	0.05 *	2	20

For a repository in salt, such as the WIPP, there is no use of ground water by nearby cities. This may limit the collective dose. If 20 person-sievert to the crew members may be taken as a reference as mentioned earlier, perhaps 40 person-sievert can be taken as the collective dose as a result of a drilling intrusion followed by some additional exposure through some less efficient pathways. If the probability of intrusion is 0.1, the acceptable cost for the planned information conservation system (of markers) is given in Table IV.

Table IV. Detriment expressed in dose and money for a repository in salt.

Probability of intrusion	Collective dose in sievert (Sv) (1 Sv=100 rem)	Risk per sievert	Protective effort (M USD per death)	Total protective cost (M USD)
0.1 *	40 *	0.05 *	2	0.4

If only the crew's dose is considered, the result would be USD 200 000.

A calculation as presented here may be useful for a discussion of the parameters and the assumptions used in the exercise. It may also be valuable to discuss some side issues: should the collective dose to the public be the first concern rather than the dose to the intruders? It is possible that history repeats itself so that several intrusions occurs (followed by restoration) during the ten millennia?

REGULATING HUMAN INTRUSION

There is, in principle, two main methods to inform future societies about radioactive waste repositories:

- Marker systems (such as described in reference 6)
- Archives and other information systems

Markers are created to allow individuals in the future to receive information directly, whereas archives and other information in society must be carried from one generation to the next. This is discussed further in reference 7.

It is resonable to assume that the state must have some responsibility for ensuring the continued information content of the National (and other state) Archives, and it is likewise obvious that the waste management must be responsible for constructing the on-site marker system. It may therefore seem reasonable that the state in its regulation, directed towards the waste management, concentrates on the marker system.

However, the waste management must be responsible for collecting the information in the archives. The IAEA has started work recently in this area related to information conservation for LLW. The author has taken part in a consultant's meeting 25 - 29 April 1994 on "Maintenance of Records and Documents for Near Surface Waste Disposal Facilities". Later, the Agency started working on a similar document for HLW.

The state could influence the markers by its regulation in many other fields: the markers themselves could receive protection through both passive (location marked on maps) and active measures (remediation of markers). The state's and waste management's roles are therefore not completely independent.

It is for this reason, that a separate view of regulating human intrusion may be justified. It is sometime remarked that natural science is more suited for prediction or projection than the social sciences, and that, therefore, human intrusion must be treated differently. There is no scientific justification for such a generalization. It is the role and responsibility of the state that provide arguments for a separate, or special, judgement of human intrusion.

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2 ICRP, Publication 46, "Radiation Protection Principles for the Disposal of Solid Radioactive Waste", Vol. 15, No. 4, 1985.

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4 D'Alessandro, M. and Bonne, A., "Radioactive Waste Disposal into a Plastic Clay Formation", Harwood Academic Publishers GmbH, Switzerland, 1981.

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TECHNICAL WORKSHOP ON WASTE ISOLATION PILOT PLANT (WIPP) COMPLIANCE ISSUES

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U.S. Environmental Protection Agency
The Embassy Row Hotel
Washington, D.C.
February 14-16, 1995

TOPICS

- WHAT HAS THE EXPERIENCE BEEN, TO DATE, WITH THE EFFECTIVENESS OF PASSIVE INSTITUTIONAL CONTROLS?

- HOW TO EVALUATE EVIDENCE AND DETERMINE CREDIT FOR THE EFFECTIVENESS OF PASSIVE INSTITUTIONAL CONTROLS IN TERMS OF MITIGATING THE LIKELIHOOD OF HUMAN INTRUSION?

TOPIC #1
EFFECTIVENESS

- 40 CFR 191 FOCUSES ON DETERRING <u>INADVERTENT</u> INTRUSION

- COMPREHENSION VS. DETERRENCE

- THE QUESTION OF RESPONSIBILITY
  A Team's judgement that the intentional disregard of a message is beyond our purview. If the message survives, is understood, and is credible, the marking system has served its purpose. Any action that takes place after the message is understood is ADVERTENT and intentional.

- 40 CFR 194 preamble

EFFECTIVENESS
PAST INTRUSIONS

- SOUGHT-AFTER OBJECT OR GOAL OUTWEIGHED THE RISKS/CONSEQUENCES
  Tombs
  Temples
  Wealth/Goods/Commodities

- DEEP GEOLOGIC DISPOSAL VERSUS SHALLOW LAND BURIAL

EFFECTIVENESS
SURVIVAL

- ARCHAEOLOGY HAS MANY EXAMPLES OF WHAT HAS SURVIVED

- ARCHAEOLOGY ALSO HAS EXAMPLES OF WHAT <u>DOESN'T</u> SURVIVE

- USE THE INFORMATION ON WHAT HAS SURVIVED IN DESIGNING A MARKING SYSTEM OR EVALUATING DESIGNS

EFFECTIVENESS
COMPREHENSIBILITY

- "IT IS PREPOSTEROUS TO THINK THAT YOU CAN EVEN BEGIN TO KNOW WHAT HUMAN BEINGS WILL DO A CENTURY OR MILLENNIUM HENCE" (KAI ERIKSON)

- THE ARROW OF TIME (STEPHEN HAWKING)

- GIVE THE FUTURE THE TOOLS WITH WHICH TO RECONSTRUCT THE PAST

OBSERVATION

- TO MY KNOWLEDGE, THIS IS THE FIRST ATTEMPT TO COMMUNICATE WITH FUTURE GENERATIONS ON EARTH THAT ACCEPTS THE FACT THAT THE FUTURE MAY LOOK VERY DIFFERENT THAN THE PRESENT
- REGARDLESS OF OTHER CHANGES, INTEREST IN SELF-PRESERVATION IS LIKELY TO CONTINUE
- ANCIENT CIVILIZATIONS MANAGED TO COMMUNICATE WITH US EVEN WHEN THEY PRESUMED THE FUTURE WOULD LOOK VERY MUCH LIKE THEIR PRESENT
- THE MARKING SYSTEM MUST BE COMPREHENSIBLE TO TODAY'S GENERATION
- THERE IS NO BETTER BASIS FOR A MARKING SYSTEM DESIGN THAN TODAY'S CONDITIONS

TOPIC #2

- EVALUATE EVIDENCE
- DETERMINE CREDIT FOR EFFECTIVENESS
- EXPERT JUDGEMENT

DESIGN EVALUATION

- SYSTEM
  Does it have an integrated set of components that reinforce the reconstruction of knowledge about the site?

- REDUNDANCY

- 100-YEAR PERIOD OF ACTIVE, INSTITUTIONAL CONTROL?

- NATIONAL AND INTERNATIONAL ASPECTS

- TESTING FOR PHYSICAL AND NON-PHYSICAL COMPONENTS?

DESIGN EVALUATION
DOES THE DESIGN ADDRESS PROBLEMS WE ALREADY KNOW ABOUT?

- SAND DUNES
- ACID RAIN
- DRAINAGE
- EROSION
- MINIMAL MATERIAL INTERFACES

DESIGN EVALUATION
DOES THE DESIGN ADDRESS PROBLEMS WE ALREADY KNOW ABOUT?

- VANDALISM
  Placement of inscriptions
  Durability of material
  Low value of material
  Size of markers
  One piece constructions

- RECYCLING
  No metals
  Low value of material
  Shapes that are difficult to re-use

DESIGN EVALUATION
REDUNDANCY

- DOES IT DEFINE THE AREA OF INTEREST IN A MANNER SUCH THAT SOME PHYSICAL COMPONENTS CAN BE LOST YET THE ENTIRE PATTERN CAN BE RECOVERED?

- IS THE SPACING OF THE COMPONENTS SUCH THAT AN INDIVIDUAL CAN STAND AT ONE AND SEE AT LEAST TWO OTHER COMPONENTS IN THE SYSTEM? CAN THE INDIVIDUAL PERCEIVE THAT THE COMPONENTS DELINEATE AN AREA?

- MESSAGE LEVELS

- MODES OF COMMUNICATIONS
  Symbols
  Pictures
  Languages

MESSAGE LEVELS

- LEVEL I: RUDIMENTARY
  "Something man-made is here"

- LEVEL II: CAUTIONARY
  "Something man-made is here and it is dangerous"

- LEVEL III: BASIC INFORMATION
  Tells what, why, when, where, who, and how

- LEVEL IV: DETAILED INFORMATION

- MESSAGES LEVELS I THROUGH IV SHOULD APPEAR ON-SITE; MESSAGES WITH HIGHER LEVEL OF COMPLEXITY ARE MORE SUITABLE FOR OFF-SITE ARCHIVES

- MESSAGE LEVELS II AND III SHOULD APPEAR TOGETHER ON THE SAME COMPONENT

- MESSAGE LEVEL III SHOULD INDICATE THE EXISTENCE AND LOCATION OF MESSAGE LEVEL IV

SYMBOLS

- CULTURALLY-LEARNED
- CAN PLAY A ROLE IF PLACED IN CONTEXT
- RADIATION SYMBOL
  Iconically sound
  Internationally established
  In use for several decades

LANGUAGES

- MUST BE USED EVEN THOUGH IMMEDIATE INTELLIGIBILITY WILL BE LIMITED TO SEVERAL CENTURIES

- MUST USE SEVERAL LANGUAGES
  A Team recommended seven languages

- AT LEAST TWO LANGUAGES PER MESSAGE LEVEL II/III COMPONENT

- CRITERIA
  - In wide-spread use now
  - Local language necessary
  - No artificial languages

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Passive Institutional Control: Experience to Date

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Washington, D.C.
February 14, 1995

KEY POINTS

1) Experience with passive institutional controls.

- Records - many incorrect.
- Markers - some inaccurate, misunderstood, or non-enduring.
- Government ownership - of limited effectiveness.

KEY POINTS

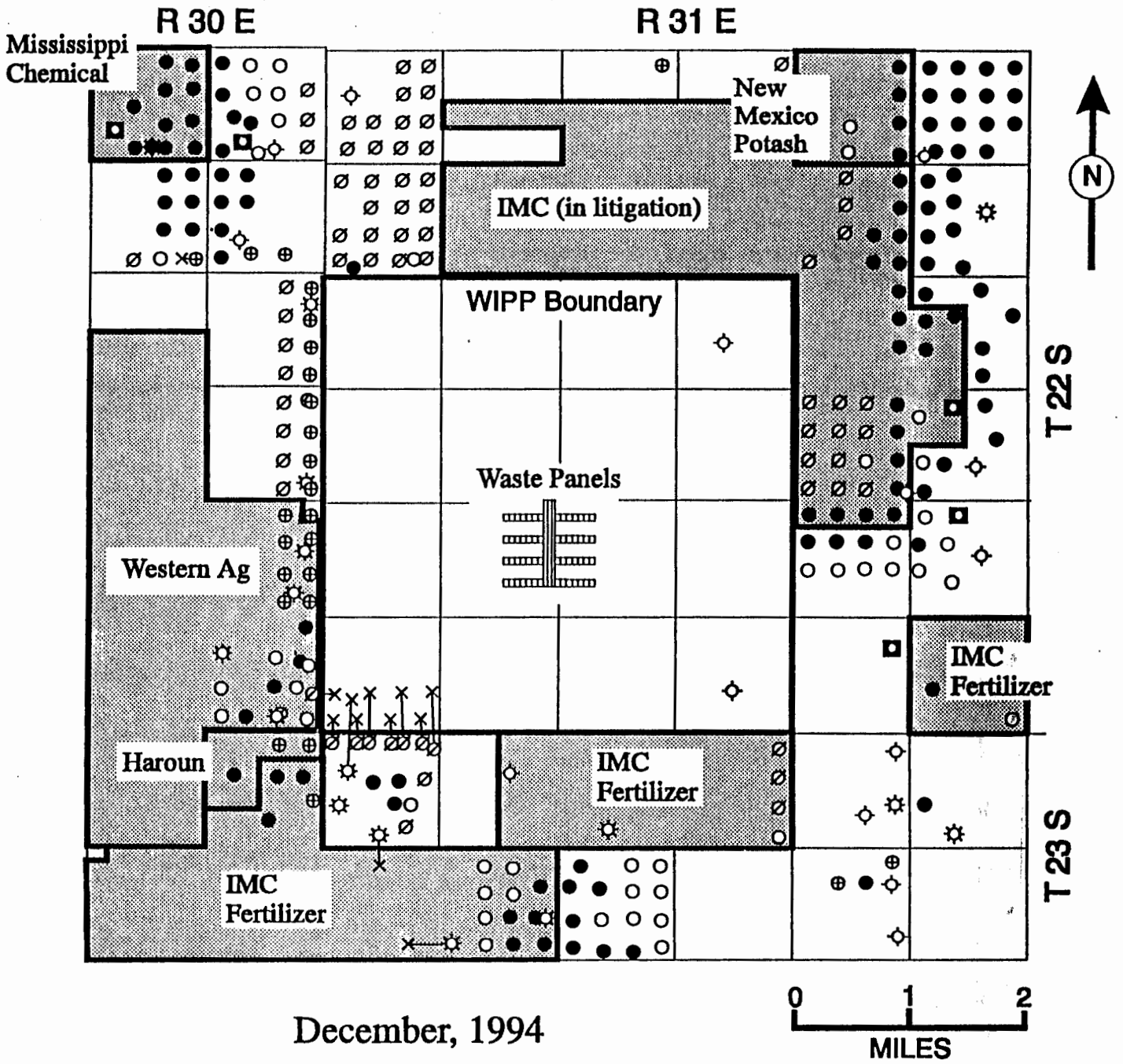
2) Before allowing credit for passive institutional control, EEG recommends that DOE demonstrate committment by publishing detailed plans addressing:

- The Assurance Requirements (40 CFR 191) including design of markers, records, engineered barriers, resource-rich area impacts.
- Requirements of the Criteria.
- DOE's experience with institutional controls.
- Impact of credit on the performance assessment.

EPA 40 CFR 191.14(e)

"Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites...."

With known natural resources, WIPP fails all three criteria, which emphasizes the importance of institutional control to deter human intrusion.



December, 1994

○	Location (Notice of Staking or pending Application to Drill)
⊕	Application approved
⌀	Application Denied or Cancelled
●	Producing Oil Well
☼	Producing Gas Well
✸	Combination Oil and Gas Well
◘	Water Injection or Salt Water Disposal Well
×	Bottom hole location of directionally drilled well
⌖	Abandoned (Permanent or Temporary)

1985 EPA 40 CFR 191.14

"Using extensive markers and records and avoiding resources when selecting disposal sites both serve to reduce the chances that people may inadvertently disrupt a disposal system because of incomplete understanding of its location, design, or hazards."

March 1990 DOE No-Migration Variance Petition, Section 6.3.2:	EEG Comments.
".... Oil and gas exploratory drilling requires permits from the state, and it is unlikely that prospective future well drillers would not be informed about the existence of WIPP.	Reliance on government regulation.
As an additional protective measure, the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future."	Failure of records.

26 Oct 90	DOE and BLM establish land management MOU.
29 Oct 90	Following DOE's request, BLM sends confirmation of valid leases to DOE.
31 Oct 90	EPA approves the DOE NMVP.
03 Nov 90	Albuquerque Journal uncovers forgotten leases.
16 Jan 91	DOE acknowledges and explains the mistake.

Bottom line - DOE and EPA did not consult public records.

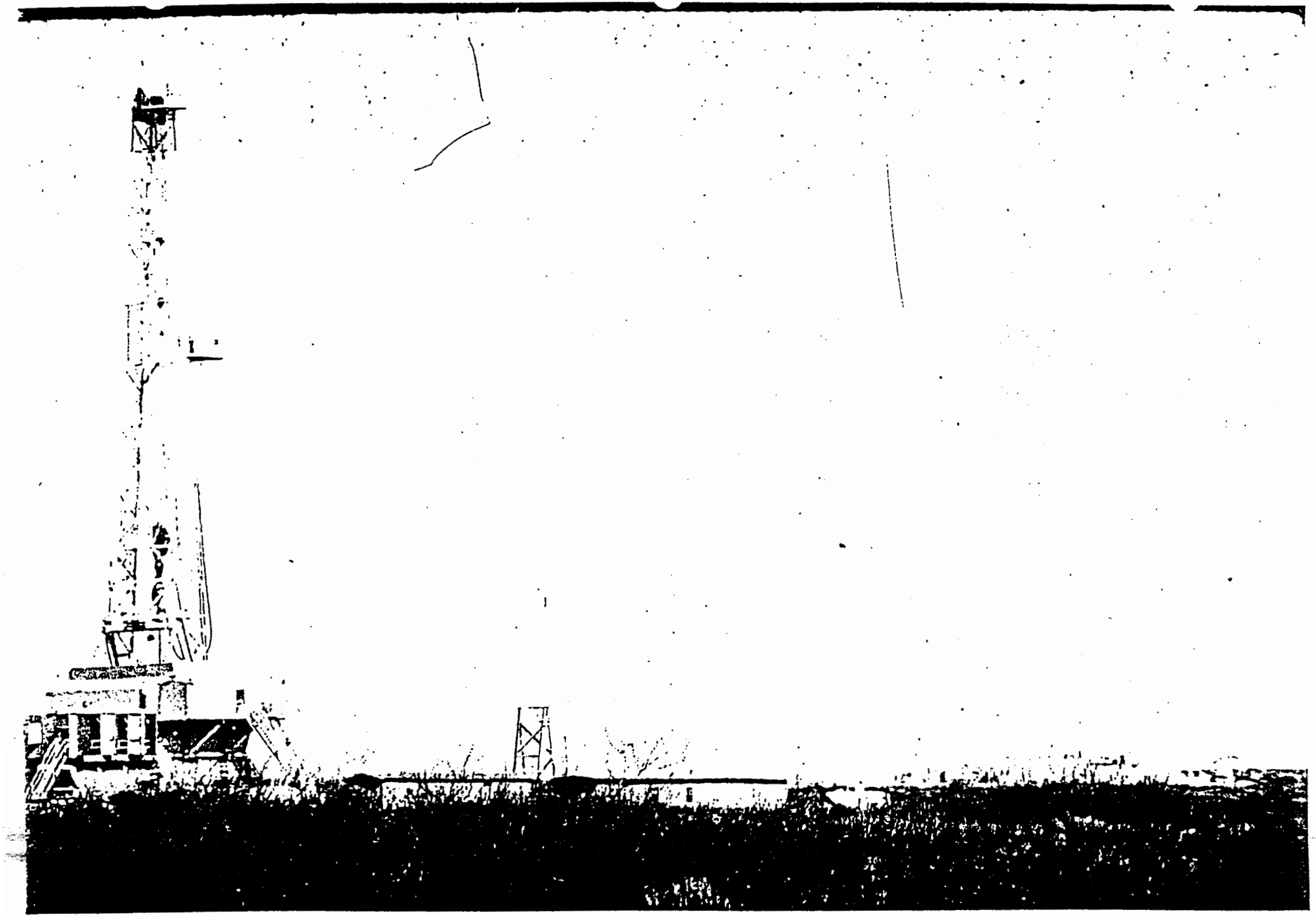
EEG-50 identifies key DOE Records that are incorrect, silent, or inconsistent.

- 1980 WIPP FEIS.
- 1990 WIPP FSAR.
- 1990 DOE No-Migration Variance Petition.
- Secretary of Energy Decision Plan.
- Implementation of Resource Disincentive Document.

DOE 1992 review of EEG-50 states:

"The controls that are crucial to protect the site from inadvertent exploration are BLM leasing procedures and lease records and the internal procedures of the BLM which require the DOE's review and comment for any permit application to drill within one mile of the WIPP site.

Adherence to policies governing resource extraction at the WIPP has been carefully maintained. Review of the BLM's interface with the DOE reveals numerous requests from the BLM for DOE comments regarding requests to drill in the area."



DOE/DOI 1990 MEMORANDUM OF UNDERSTANDING

"The BLM will notify the DOE of any requests for permits for resource recovery activities within one mile of the WIPP site boundary.... Drilling approval will be withheld until comments are received from the DOE."

Lapses in Institutional Control by DOE and BLM.

Satisfactory procedure.	3
BLM failed to request DOE review.	3
DOE failed to respond to BLM request.	9
BLM approved permits to drill before requesting DOE review.	5
BLM approved permits to drill before receiving DOE review.	5

Applications for Permit to Drill (APDs)

Period	Submitted	Properly Reviewed	Institutional Failure Rate
Oct 90 - Oct 92	25	3	88%
On March 9, 1993, EEG cautions DOE about lapse in MOU			
Apr 93 - Dec 94	55	50*	9%

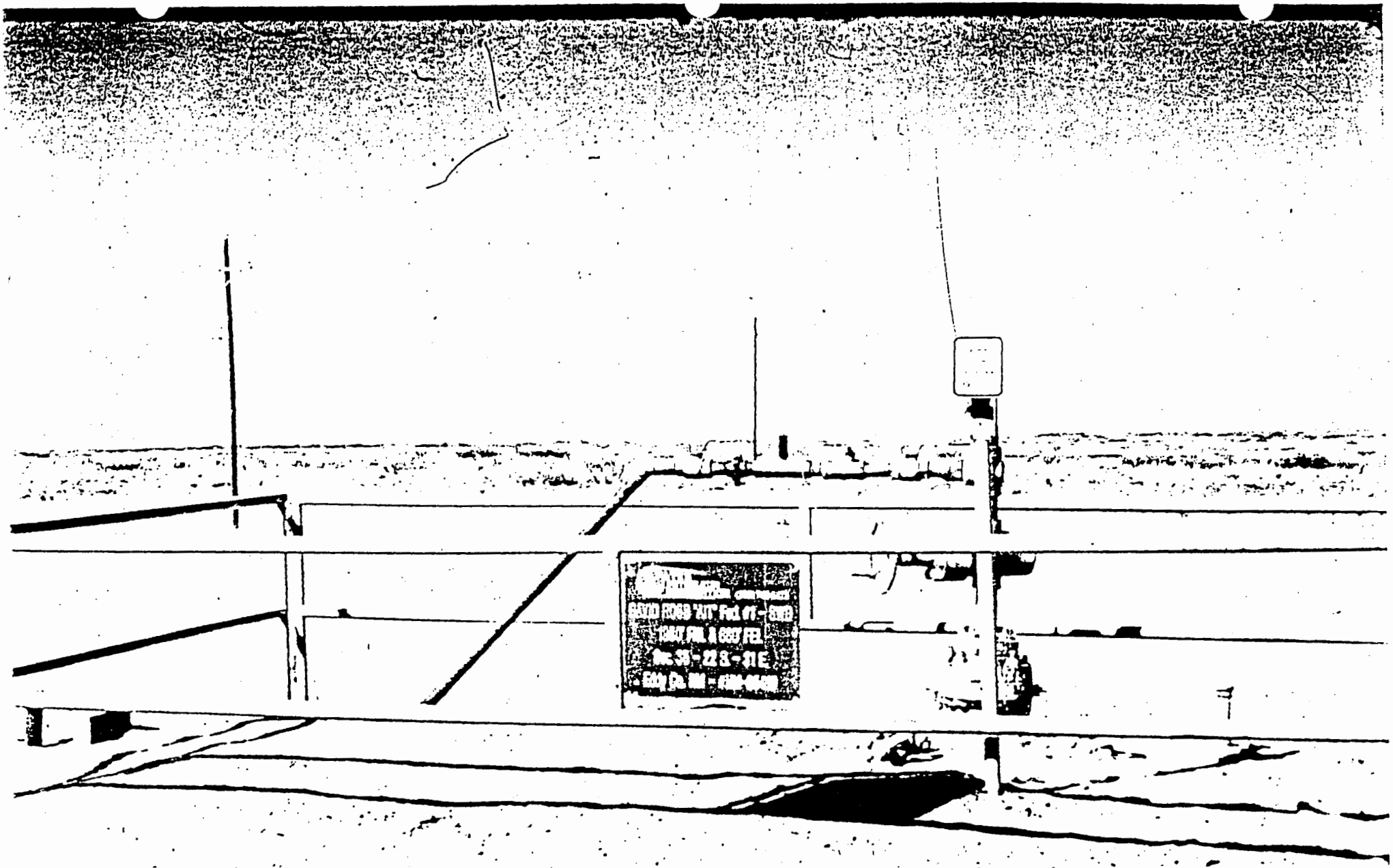
* Time until lapse in institutional control:
8 months (Dec 93), no DOE review for 4 APDs
4 months (May 94), no request from BLM for 1 APD

EPA 40 CFR 191, Appendix B, Guidance

The Agency assumes that as long as such passive institutional controls endure *and are understood*, they: (1) can be effective in deterring systematic or persistent exploitation of these disposal sites; and (2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency.

DOE 1993 letter summarizes experience with markers and records.

Barclay State #1	**Wrong location on sign.**
James Ranch Unit #4	**Wrong range on sign.**
James Ranch Unit #1	**Wrong township, section, and quadrants on sign.**
Federal 26 #4	**Wrong location on sign.**
Phillips James	**Crossover on a pipeline misidentified as a well.**

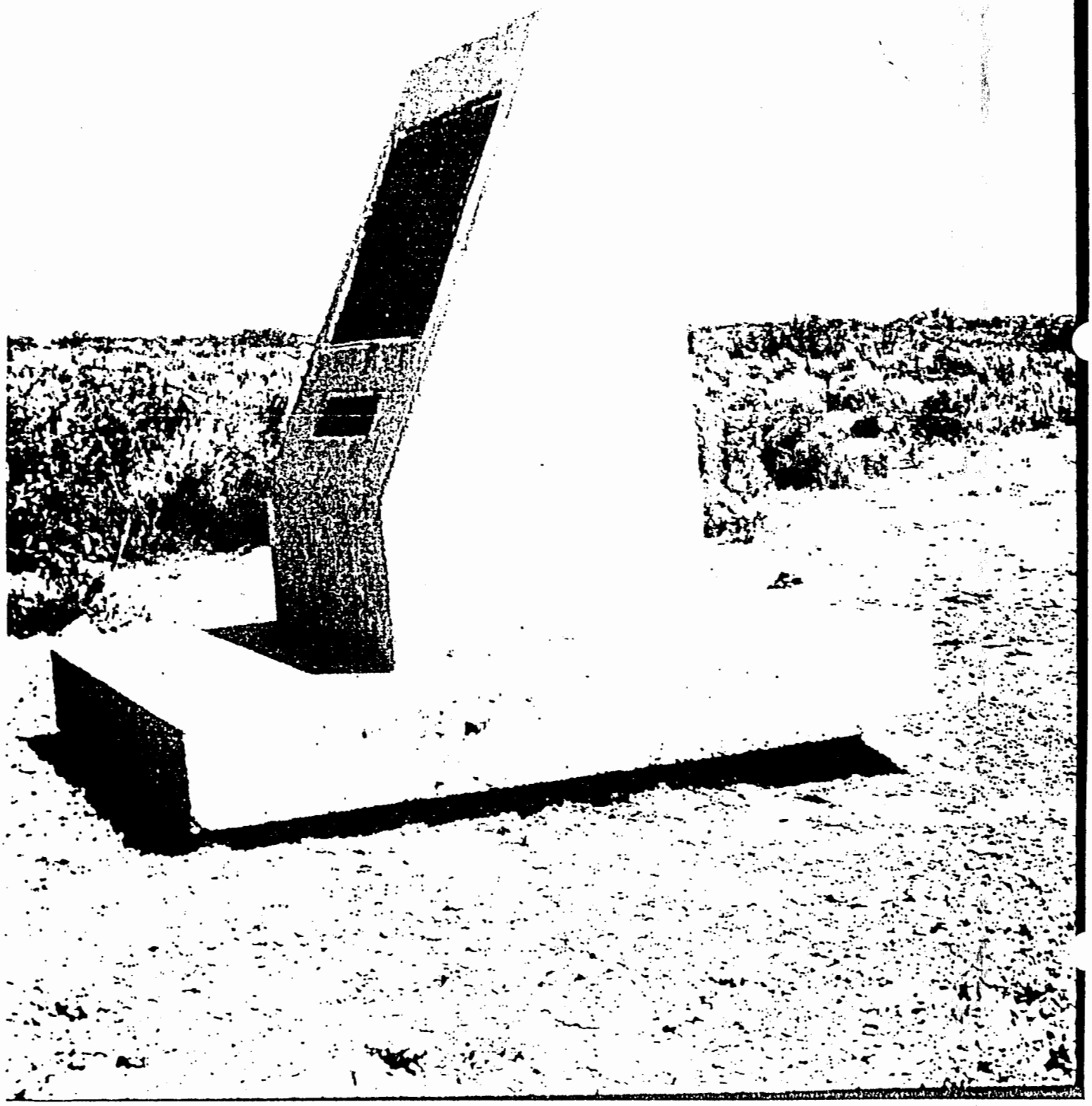


EPA 40 CFR 191, Appendix B, Guidance

".... controls endure"

Status of markers at two underground nuclear detonations.

Name	Location	Date	Yield
Gnome	Los Medaños, NM	10 Dec 61	3 kT
Shoal	Fourmile Canyon, NV	26 Oct 63	12 kT



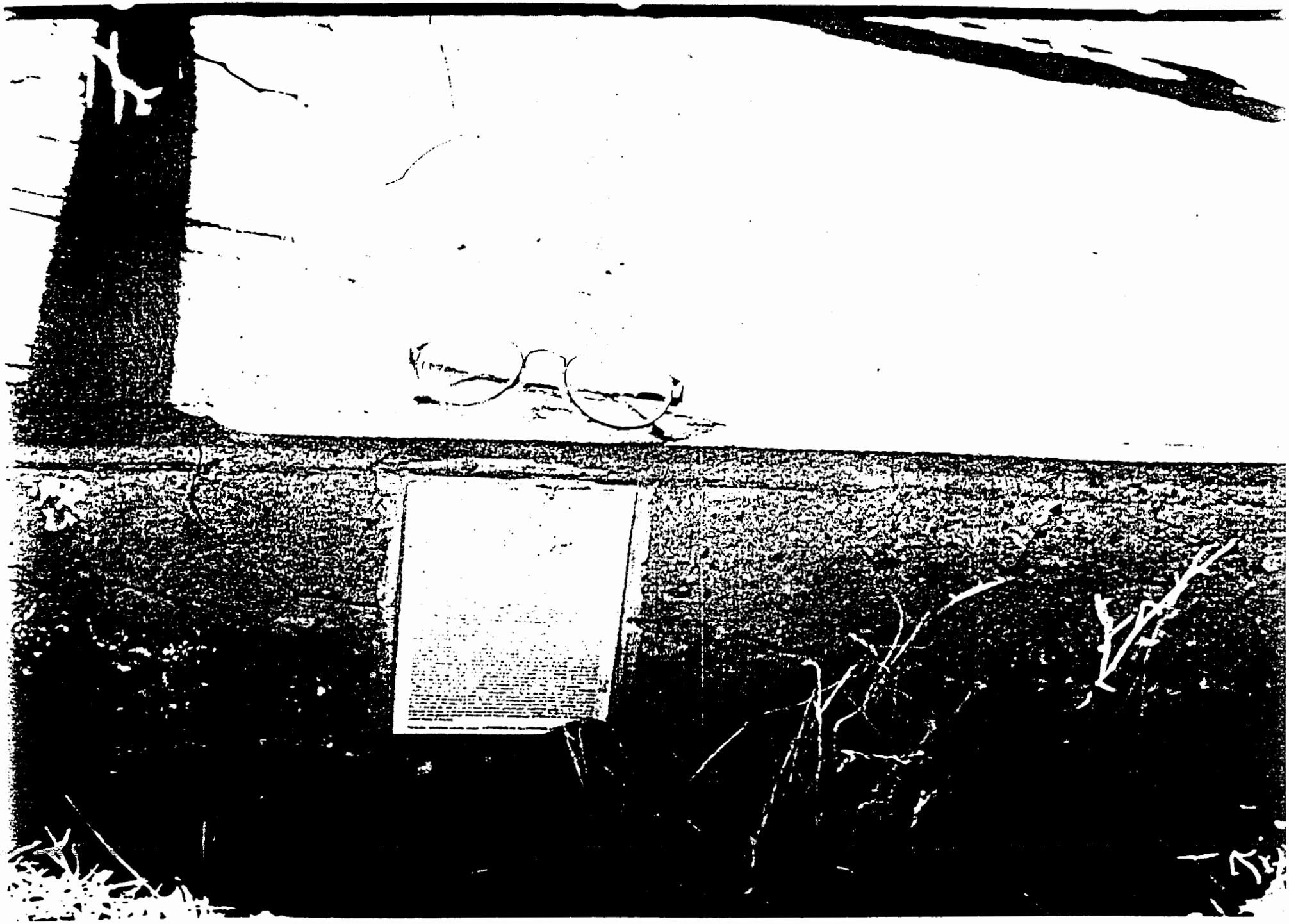
UNITED STATES ATOMIC ENERGY COMMISSION
DR. GLENN T. SEABORG, CHAIRMAN

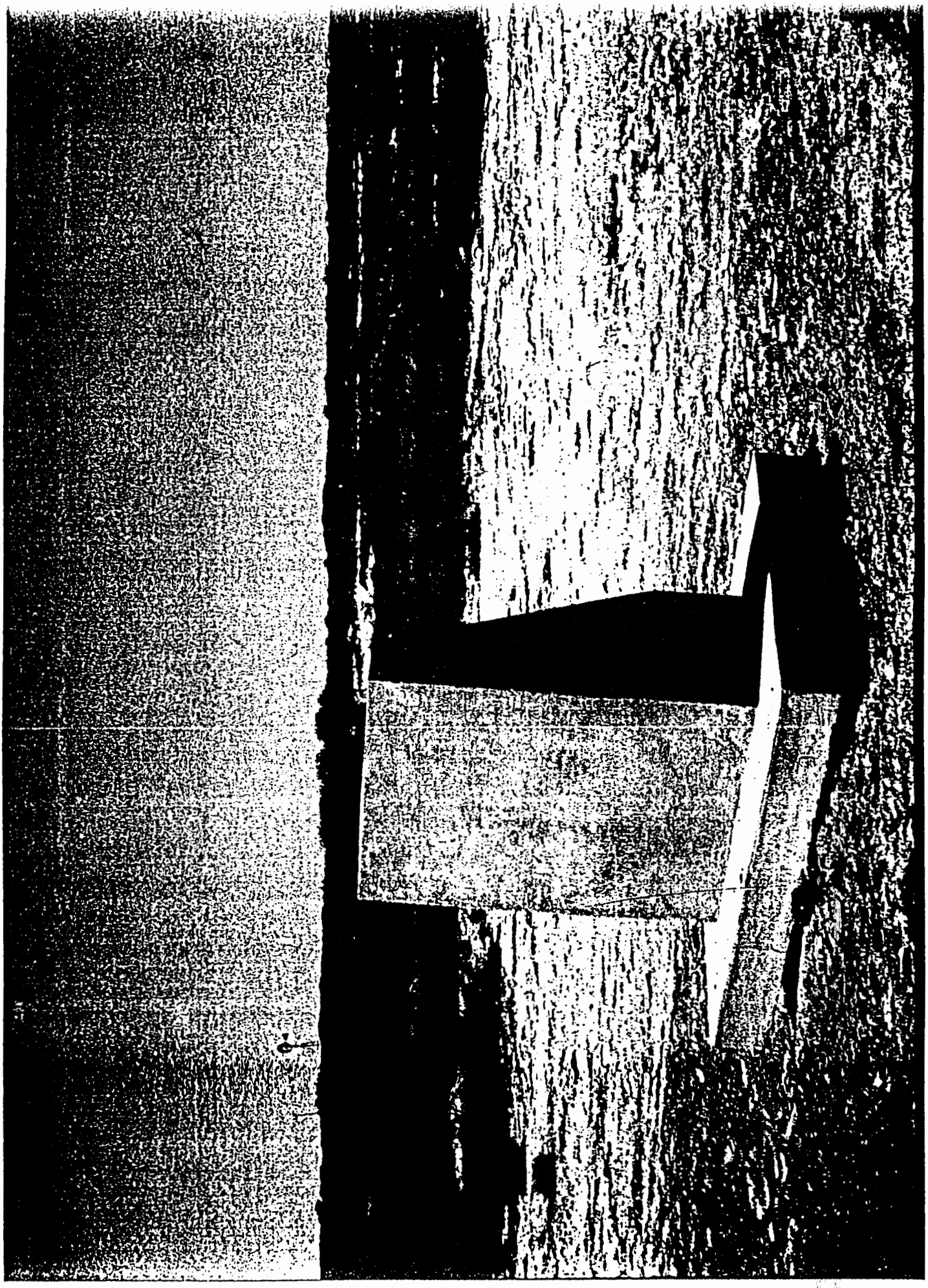
PROJECT GNOME

DECEMBER 10, 196[illegible]

THE FIRST NUCLEAR DETONATION IN THE PLOWSHARE PROGRAM TO DEVELOP PEACEFUL USES FOR NUCLEAR EXPLOSIVES WAS CONDUCTED BELOW THIS SPOT AT A DEPTH OF 1,216 FEET IN A STRATUM OF ROCK SALT. THE EXPLOSIVE EQUIVALENT TO 3.00 TONS OF TNT WAS DETONATED AT THE END OF A HORIZONTAL PASSAGE LEADING FROM A VERTICAL SHAFT LOCATED 1,116 FEET SOUTHWEST OF THIS POINT. AMONG THE MANY OBJECTIVES WAS THE PRODUCTION AND RECOVERY OF USEFUL RADIOACTIVE ISOTOPES, THE STUDY OF HEAT RECOVERY, THE CONDUCT OF NEUTRON PHYSICS EXPERIMENTS, AND THE PROVISION OF A SEISMIC SOURCE FOR GEOPHYSICAL STUDIES.

NO EXCAVATION AND/OR DRILLING IS PERMITTED TO PENETRATE SECTION 34, TOWNSHIP 23 SOUTH, RANGE 30 EAST, NEW MEXICO PRINCIPAL MERIDIAN AT ANY DEPTH BETWEEN THE SURFACE AND 1,500 FEET





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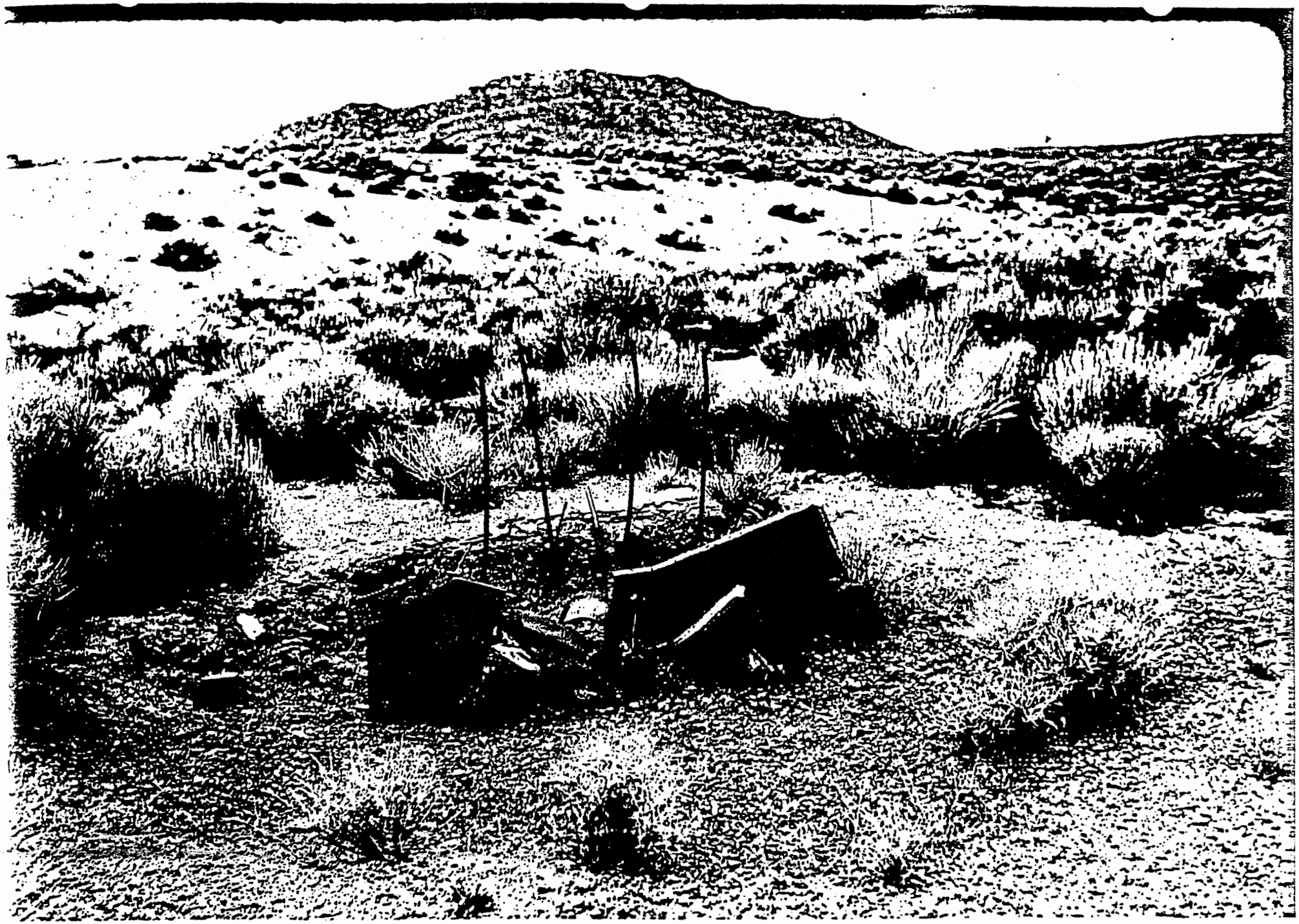

EEG Recommendations

1) Examine experience with passive institutional controls.

- Records - many incorrect.
- Markers - some inaccurate, misunderstood, or non-enduring.
- Government ownership - of limited effectiveness.

EEG Recommendations

2) Before allowing credit for passive institutional control, EEG recommends that DOE demonstrate committment by publishing detailed plans addressing:

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- Requirements of the Criteria.
- DOE's experience with institutional controls.
- Impact of credit on the performance assessment.

Jim Benetti

Environmental Protection Agency

Office of Radiation and Indoor Air

WASTE CHARACTERIZATION ISSUES

James Benetti

USEPA Office of Radiation and Indoor Air

Las Vegas, Nevada

February 16, 1995

Questions Which Influence Waste Characterization Issues

- What Waste Parameters are Important to Compliance?
- On What Scale of Analysis are They Used?
- What Data Quality is Necessary and at What Level of Detail to Demonstrate Compliance?

Process Knowledge

- Consists of Facts
- Used to Predict at Some Level of Detail (Drum, Batch, ..)
- Level of Detail not Yet Established
- Level of Detail May Affect Level of Verification Needed

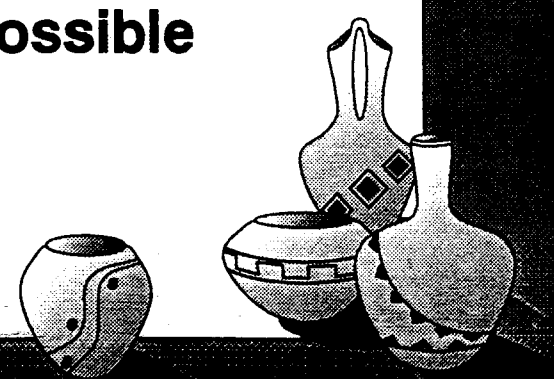
Verification of Process Knowledge

- Confirmation Through Documentation
- Confirmation Through Representative Measurements
- Confirmation of Process Inputs and Outputs
- Confirmation That Process was Controlled
- Could be Done in Context of QA Audits

Opinion:

If Data Quality Objectives were formulated by the end users of the waste characterization data in question, it might be possible to use limited process knowledge to predict quantities of interest well enough for their intended purpose and to use a grosser level of confirmation.

Without Data Quality Objectives, it will probably be necessary to default to a drum by drum prediction/verification scheme to assure that predictions are good enough for any possible intended purpose.

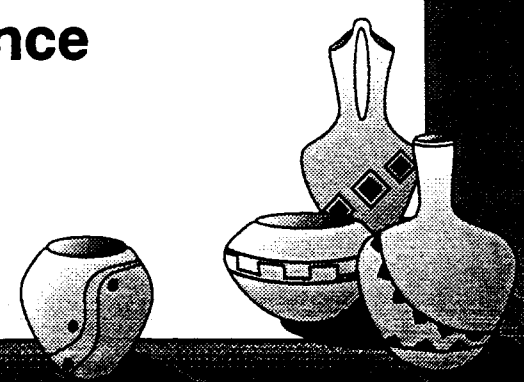


Capabilities and Limitations of Current Methods of Waste Characterization

Real Time Radiography: Able to verify content code, presence of free liquids, possibly to quantify cellulosics and metals. Limited value with unsegregated or supercompacted waste, requires Performance Demonstration for data comparability.

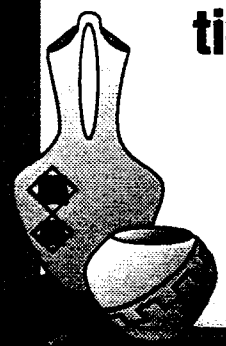
Capabilities and Limitations of Current Methods of Waste Characterization - *cont'd*

Radioassay: Able to quantify sums of odd/even fissiles and to infer or quantify ratios of fissiles and quantities of non–fissiles with supplementary methods. High (50%) uncertainty at low gram loadings, subject to interferences from drum contents, and requires Performance Demonstration for data comparability.



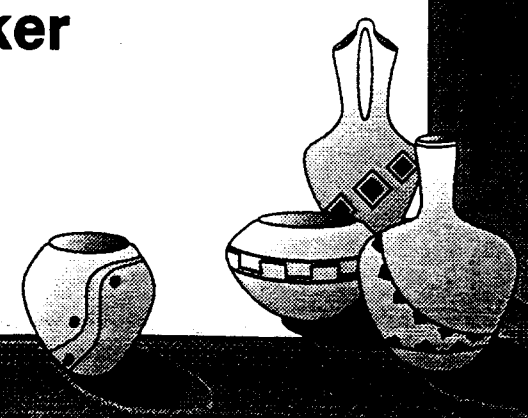
Capabilities and Limitations of Current Methods of Waste Characterization - *cont'd*

Headspace Sampling and Analysis:
Able to quantify relatively high concentrations of VOC's and flammable gases, data comparability established through PDP.
Uncertainty of relating headspace concentrations to those of inner layers of confinement.



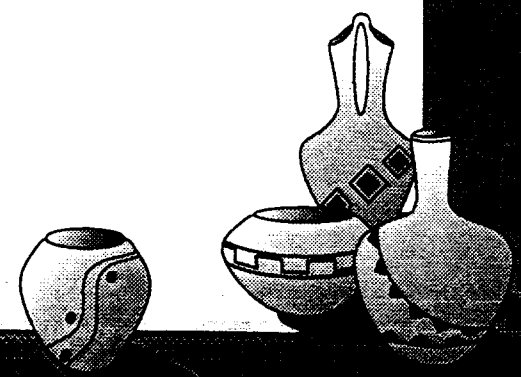
Capabilities and Limitations of Current Methods of Waste Characterization - *cont'd*

Solids Sampling and Analysis: Capable of extended precision and accuracy of analysis for virtually any contaminant. Representativeness of sample is difficult (limited to relatively homogeneous media), generates mixed waste, higher worker exposures, considerable cost.



Capabilities and Limitations of Current Methods of Waste Characterization - *cont'd*

Visual Examination: Capable of qualitative confirmation of contents, possible biased sampling schemes. Involves considerable worker exposure and cost and is very slow.



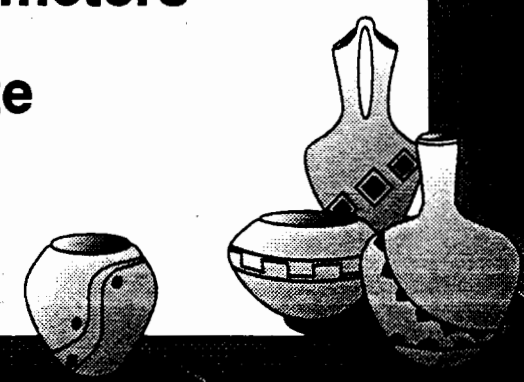
Capabilities and Limitations of Current Methods of Waste Characterization - *cont'd*

Use of Process Knowledge: Potential is great for characterization as generated. Current capabilities and limitations are unknown.

Estimates Versus Actual TRU Waste

Confidence Builders:

- Waste Acceptance Criteria – Audit Observations
- Future Waste – Demonstration of Control
- Qualification of Existing Waste Data
- Experimental Confirmation of Parameters
- Treatment or Repackaging of Waste



Barry Lesnik

Environmental Protection Agency

Office of Solid Waste

1BLWP14.95

REGULATORY ASPECTS OF RCRA ANALYSES

by Barry Lesnik

USEPA

Office of Solid Waste

Methods Section

401 M St., SW

Washington, DC 20460

WHAT IS RCRA?

RCRA is the Resource Conservation and Recovery Act of 1976 which regulates the management of hazardous waste under Subtitle C. Administration of the program has been passed down to the states via authorization of State Programs in most States.

RCRA HAZARDOUS WASTE

- Waste which exhibits one of the following characteristics:
  - Ignitablity (40 CFR §261.21)
  - Corrosivity (40 CFR §261.22)
  - Reactivity (40 CFR §261.23)
  - Toxicity (40 CFR §261.24)
- Listed Waste (40 CFR §261, Appendix VII)

WHAT IS SW-846?

Test Methods for Evaluating Solid Waste, or SW-846, is the compendium of analytical and test methods approved by EPA's Office of Solid Waste (OSW) for use in determining regulatory compliance under the Resource Conservation and Recovery Act (RCRA).

SW-846 functions primarily as a guidance document setting forth acceptable, although not required, methods to be implemented by the user, as appropriate, in responding to RCRA-related sampling and analysis requirements.

WHY DO WE DO RCRA ANALYSES?

- General Analytical Policy and Philosophy of RCRA Program
- Regulatory Drivers
- Applications where Use of SW-846 Methods Are Mandatory

GENERAL RCRA ANALYTICAL POLICY

- Analyses are performed on a site-specific basis.
- Intended use of the data to be generated must be determined in the project planning stage.
- Analyses performed under the RCRA Program are regulation driven.
  - Regulations specify what analytical data is needed, i.e., analytes of concern in the matrix of concern at the regulatory level of concern.
  - Regulations do not specify "how" the analyses will be performed.
- For most RCRA analyses "any reliable method" may be used (58 FR 46040).
- Develop cost effective analytical scheme.

WHY WE DO RCRA ANALYSES - REGULATORY DRIVERS

- Compliance with specific regulations under RCRA which include:
  - monitoring of leachates from hazardous waste landfills (Appendix IX),
  - determination of whether a waste is hazardous by characteristic,
  - compliance with boiler, incinerator, furnace (BIF) rules,
  - compliance with land disposal restrictions (LDRs),
  - permit compliance for surface impoundments, storage facilities, etc., and
  - corrective action.

MANDATORY APPLICATIONS OF SW-846 METHODS

- These applications where the use of SW-846 methods is mandatory can be grouped into the following five categories:
  - Determination of a Hazardous Waste Characteristic
  - Determination of Free Liquid (Method 9095)
  - Analyses associated with submission of Delisting Petition
  - Analyses associated with a Hazardous Waste Incinerator Trial Burn
  - Determination of air emissions from process equipment
- Specific regulatory citations are listed on the following slides

MANDATORY APPLICATIONS OF SW-846 METHODS (CONTD.)

- The RCRA applications listed in 40 **CFR** Parts 260 through 270 where the use of SW-846 methods is mandatory are the following:

  (1) § 260.22(d)(1)(i) - Submission of data in support of petitions to exclude a waste produced at a particular facility (i.e., delisting petitions);

  (2) § 261.22(a)(1) and (2) - Evaluation of waste against the corrosivity characteristic;

  (3) § 261.24(a) - Leaching procedure for evaluation of waste against the toxicity characteristic;

MANDATORY APPLICATIONS OF SW-846 METHODS (CONTD.)

(4) Section 261.35(b)(2)(iii)(A) - Testing rinsates from wood preserving cleaning processes;

(5) §§ 264.190(a), 264.314(c), 265.190(a), and 265.314(d) - Evaluation of waste to determine if free liquid is a component of the waste;

(6) 264.1034(d)(1)(iii) and 265.1034(d)(1)(iii) - Testing total organic concentration of air emission standards for process vents;

(7) 264.1063(d)(2) and 265.1063(d)(2) - Testing total organic concentration of air emission standards for equipment leaks;

MANDATORY APPLICATIONS OF SW-846 METHODS (CONTD.)

(8) Section 266.106(a) - Analysis in support of compliance with standards to control metals emissions from burning hazardous waste in boilers and industrial furnaces;

(9) § 266.112(b)(1) and (2)(i) - Certain analyses in support of exclusion from the definition of a hazardous waste of a residue which was derived from burning hazardous waste in boilers and industrial furnaces;

(10) § 268.32(i) - Evaluation of a waste to determine if it is a liquid for purposes of certain land disposal prohibitions;

(11) §§ 268.40(a), (b) and (f), 268.41(a), and 268.43(a) - Leaching procedure for evaluation of waste to determine compliance with Land Disposal treatment standards;

MANDATORY APPLICATIONS OF SW-846 METHODS (CONTD.)

(12) Section 268.7(a) - Leaching procedure for evaluation of a waste to determine if the waste is restricted from land disposal;

(13) §§ 270.19(c)(1)(iii) and (iv), and 270.62(b)(2)(i)(C) and (D) - Analysis and approximate quantification of the hazardous constituents identified in the waste prior to conducting a trial burn in support of an application for a hazardous waste incineration permit; and

(14) §§ 270.22(a)(2)(ii)(B) and 270.66(c)(2)(i) and (ii) - Analysis conducted in support of a destruction and removal efficiency (DRE) trial burn waiver for boilers and industrial furnaces burning low risk wastes, and analysis and approximate quantitation conducted for a trial burn in support of an application for a permit to burn hazardous waste in a boiler and industrial furnace.

MANDATORY APPLICATIONS OF SW-846 METHODS (CONTD.)

- Authorized States can also require use of SW-846 methods for any or all applications in their RCRA Programs.

- EPA Regions do not have the statutory authority to require the use of SW-846 methods for non-mandatory applications.

- Third Edition (September, 1986) as amended by Updates I (July, 1992), II (September, 1994), and IIA (August, 1993) methods are required to be used for mandatory applications.

WHAT IS AN "EPA-APPROVED" METHOD?

- "EPA-Approved" methods are a factor only when a particular application requires the use of SW-846 methods.

- General approval only when method promulgated via FRN

- Limited approvals
  - Regional approval
  - Site approval

USE OF DRAFT SW-846 METHODS

- Draft methods are methods that have passed Technical Workgroup review, but have not yet been promulgated by FRN.

- Since draft SW-846 methods fall into the "Any reliable method" category, they can be used in all applications for which the use of SW-846 methods is not mandatory and for which they are effective.

- Proposed Third Update methods will be distributed to SW-846 subscribers by GPO. (Scheduled for March or April, 1995)

- Fourth Update methods will be available from OSW Methods Section Office as they are completed.

FLEXIBILITY OF RCRA METHODS

- RCRA specifies "what" needs to be determined, and leaves the "how" up to the analyst.

- Monitoring requirements under RCRA Subtitle C specify only that the analyst must demonstrate that he can determine the analytes of concern in the matrix of concern at the regulatory level of concern.

- SW-846 methods may be modified to meet the requirements of specific applications whether their use is mandatory or not:

  - Disclaimer

  - Secs. 2.1.1. and 2.1.2 of Chapter Two

REGULATORY APPROVAL PROCESS FOR METHODS
WHY SW-846 METHODS MUST BE ISSUED AS REGULATIONS

- Per 40 CFR §260.11, SW-846 methods are incorporated by reference, rather than published in 40 CFR.

- Since SW-846 functions as a guidance document setting forth acceptable, although not required, methods to be implemented by the user, as appropriate, in responding to RCRA-related sampling and analysis requirements, why must SW-846 methods be issued as regulations?

- There are 14 specific sections in 40 CFR §260 to §270 where the use of SW-846 methods is required.

  - For trial burns and delisting petitions, any method in the manual may be used.

  - Therefore, all RCRA methods must be issued as regulations to allow for their use in the above 14 sections of the RCRA regulations.

OUTLINE OF EPA REGULATORY PROCESS FOR METHODS

- Technical Workgroup (Peer review)
- Preparation of Proposed Regulatory Package
  - Internal Agency Review Process
  - OMB Approval
  - EPA Administrator Signature
  - Proposed through FRN
- Public Comments on FRN
  - Response to Comments
- Preparation of Final Regulatory Package
  - Internal Agency Review Process
  - OMB Approval
  - EPA Administrator Signature
  - Promulgated through FRN

OUTLINE OF STREAMLINED EPA REGULATORY APPROVAL PROCESS FOR METHODS

- Technical Workgroup (Peer review)
- Preparation of Proposed Regulatory Package
  - Streamlined Internal Agency Review Process
  - EPA Assistant Administrator Signature
  - Proposed through FRN
- Public Comments on FRN
  - Response to Comments
- Preparation of Final Regulatory Package
  - Streamlined Internal Agency Review Process
  - EPA Assistant Administrator Signature
  - Promulgated through FRN

ORGANIZATION OF SW-846

- SW-846 is organized as a methods manual.
  - Minimizes redundancy in individual methods (Saves trees)
  - Organized into specific Functional Chapters.
- Currently consists of four volumes
  - Volume IA - Chapters 1, 2 and 3
  - Volume IB - Chapters 1 and 4
  - Volume IC - Chapters 1, 5, 6, 7 and 8
  - Volume II - Chapters 1, 9, 10, 11, 12 and 13

ORGANIZATION OF SW-846 (CONTD.)

CHAPTER	TOPIC
One	Quality Control
Two	Choosing the Correct Procedure
Three	Metallic Analytes
Four	Organic Analytes
Five	Miscellaneous Test Methods
Six	Properties

ORGANIZATION OF SW-846 (CONTD.)

CHAPTER	TOPIC
Seven	Characteristics-Introduction and Regulatory Definitions
Eight	Methods for Determining Characteristics
Nine	Sampling Plan
Ten	Sampling Methods
Eleven	Ground Water Monitoring
Twelve	Land Treatment Monitoring
Thirteen	Incineration

Robert H. Neill

Environmental Evaluation Group

ENVIRONMENTAL EVALUATION GROUP

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

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USEPA TECHNICAL WORKSHOP ON WIPP COMPLIANCE ISSUES

WASTE CHARACTERIZATION

Robert H. Neill

February 14-16, 1995

Washington, D.C.

Providing an independent technical analysis of the Waste Isolation Pilot Plant (WIPP), a federal transuranic nuclear waste repository.

PROPER CHARACTERIZATION OF EXISTING[a] AND TO BE GENERATED[b] RADIOACTIVE AND HAZARDOUS WASTE

- Assuring the accuracy of process knowledge or other methods of estimation.
- Determining what constitutes an acceptable sampling methodology.
- Identifying the technical limitations of technologies used.
- Assuring that characterization is consistent with waste emplaced.

[a] "Existing" means pre-compliance application.

[b] "To be generated" means post-compliance application.

NEED FOR WASTE CHARACTERIZATION

- **Transportation Risk Assessment**

  10 CFR 71
  49 CFR 173

- **Operational Risk Assessment**

  DOE Orders
  40 CFR 191 Subpart A
  29 CFR 1910

- **Long Term Disposal Risk Assessment**

  40 CFR 191, 194, 268, etc.

- **Non-regulatory oversight organizations have similar needs**

RELEVANT DATES FOR TRU WASTE CHARACTERIZATION

- **Before 1970** — Surface burial, meager records
- **1979** — WAC developed by DOE
- **1980** — EEG comments noted
  - ▲ Did not provide information on the methods to be used by waste generating facilities
    - A. In assaying or processing to determine compliance
    - B. Quality assurance
  - ▲ Omission of methods is a serious deficiency
  - ▲ Need inspection of the waste generating facility by an outside agency

RELEVANT DATES (cont.)

1987	RCRA requirements apply to DOE (by-product material not mixed waste)
1992	Congress assigns responsibility to determine compliance for long term disposal to EPA
1993	EPA issues Standards (40 CFR 191)
1996	EPA to publish 40 CFR 194 criteria

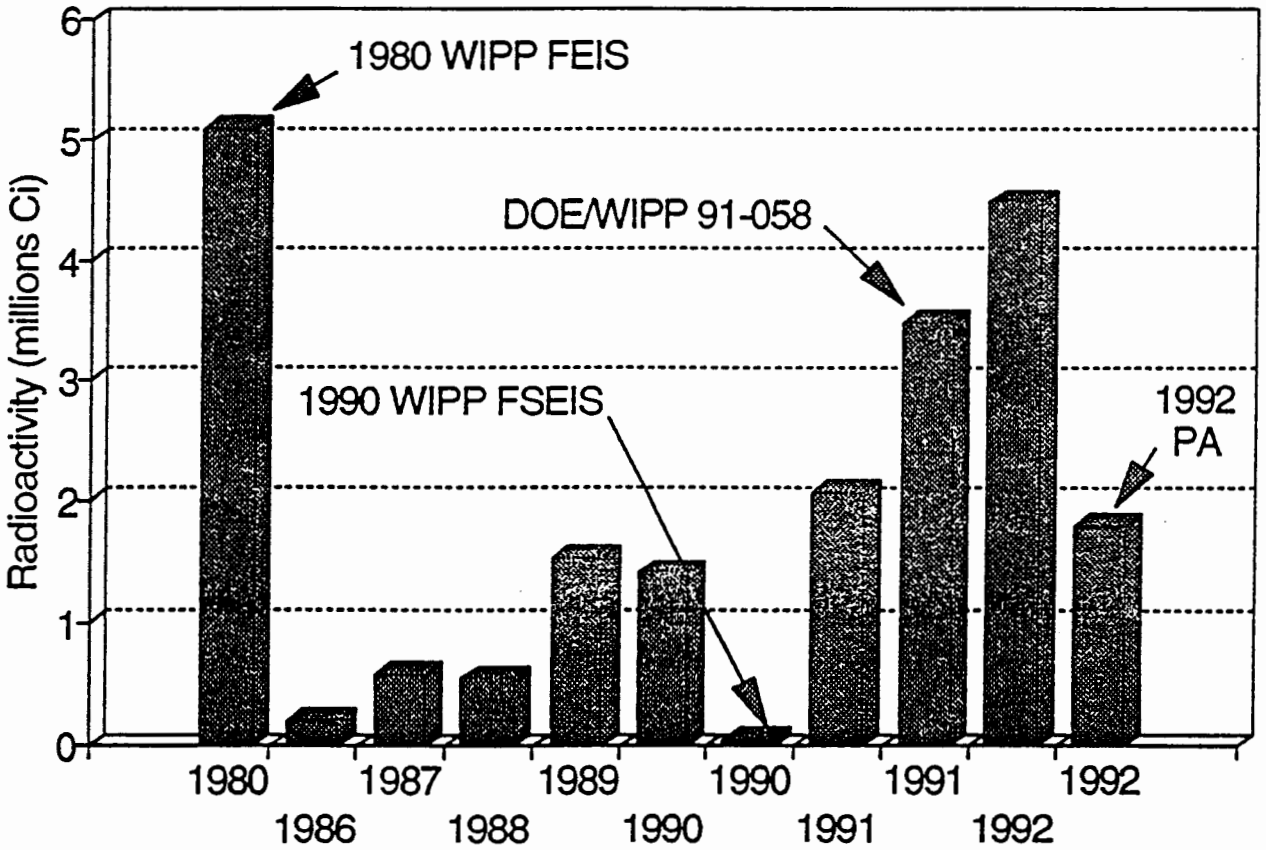
CHARACTERIZATION PROBLEMS FOR EXISTING WASTE

- Waste is heterogeneous.
- Old data don't inspire confidence.
- Criteria for acceptance at WIPP have changed resulting in need to recharacterize.
- Characteristics under disposal conditions needed (P, T, pH etc.)
- Solubility of waste.
- No clear definition of TRU Waste (Ex. in HLW tanks at Hanford defined as RH-TRU).
- Estimates of CH-TRU vary.
- Estimates of RH-TRU vary.
- If new data required to characterize waste, deadline for data is 3/96.

ESTIMATED DESIGN INVENTORY OF TRU WASTE (M Ci)

	CH-TRU	RH-TRU	Total
1991 P.A. (SAND 91-0893)	16.5	1.7	18.2
1992 P.A. (SAND 92-0700)	8.2	1.8	10

DOE Projected RH TRU Inventory for WIPP
(Taken from IDB except where specified)



CHARACTERIZATION PROBLEMS FOR TO BE GENERATED WASTE

- Various DOE documents state 40 to 70% of TRU waste doesn't exist.
- Other non weapons grade waste streams such as Pu-238 heat source waste may/may not qualify for WIPP.
- Characterizing WIPP site generated waste.
- Changing definition of RH-TRU waste not in place. (Piping in Hanford HLW tanks).
- Expected CH-TRU much less than repository design. Hence new forms may be defined as CH-TRU.

DOE REQUIREMENTS FOR CH-TRU WASTE PACKAGE INTEGRITY

1980	**10 Years after Emplacement**
1981	**15 Years after Emplacement**
1985	**15 Years after Emplacement**
1989	**20 Years from Certification**
1991	**All container life requirements deleted**

ASSURING ACCURACY OF PROCESS KNOWLEDGE* OR OTHER METHODS OF ESTIMATION

*

Sampling and analysis

Radioassay

Examination of waste generation documentation and associated records

Recommendations

Existing Waste

1. Require DOE to show validity of process knowledge to predict inventory.

2. Optimize sampling and analysis for information gained vs. worker exposures.

ASSURING ACCURACY (cont.)

3. EPA should require generators to participate in analytical cross-check radioassay program for actinide concentration and other key parameters such as VOC's.

4. Require peer review of old records.

5. Inventory non-compliance drum problems.

   LANL - Improper pH

   RFP - Excessive decay heat

   ORNL - Corrosion of steel

To Be Generated

1. EPA should specify detailed protocols and procedures for generators.

WHAT CONSTITUTES AN ACCEPTABLE SAMPLING METHODOLOGY?

- Existing Waste

1. Determine PA needs as to what is adequate for

   Drum
   Room
   Repository

2. Recognize waste is heterogeneous and not amenable to homogeneous type sampling.

3. Get DOE to establish uniform methodology amongst generators.

4. Define similar wastes to permit categories to be clearly established.

WHAT CONSTITUTES AN ACCEPTABLE SAMPLING METHODOLOGY? (cont.)

- **To Be Generated**

  Same as above

1. **Future waste forms may be different.**

2. **If buried TRU waste is exhumed for shipment to WIPP, what level of characterization would be required?**

IDENTIFYING THE TECHNICAL LIMITATIONS OF TECHNOLOGIES USED

Existing

1. Compare measurements of waste in boxes vs. drums.

2. Establish standardized procedures for all generating sites.

3. Output of DOE characterization study on performance should feed DOE engineered alternatives study.

4. Apply expert judgment.

ASSURING THAT CHARACTERIZATION IS CONSISTENT WITH WASTE EMPLACED

- Check records at generator sites prior to shipment.
- Unnecessary to establish system to confirm measurements at WIPP.

WIPP Library

ATTACHMENT TWO OF TWO

TO

ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL WORKSHOP ON WIPP

COMPLIANCE ISSUES

FEBRUARY 14 - 16, 1995

Jim Benetti

Environmental Protection Agency

Office of Radiation and Indoor Air

RECEIVED
APR 18 1995

QUALIFICATION OF EXISTING DATA

James Benetti

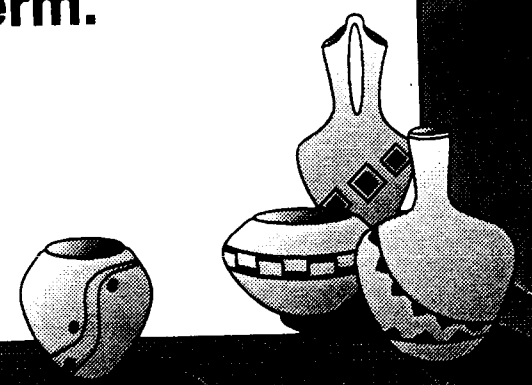
USEPA Office of Radiation and Indoor Air

Las Vegas, Nevada

February 16, 1995

Qualification of Existing Data

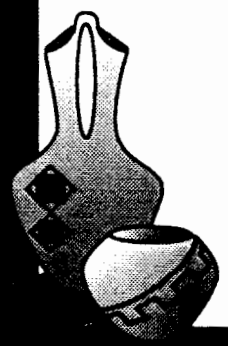
- Data collected prior to implementation of EPA acceptable QA program.
- Includes non–DOE generated data used to demonstrate compliance.
- DOE/Sandia have identified 40 records packages to be qualified in the near term.



DOE/Sandia Approach to QED

Assemble records packages of important studies
Evaluation by "Independent Review Team"

- Establish equivalent QA Program
- Conduct "technical assessment" to build confidence
- Summarize in "Statement of Condition"
- Alternative methods if not accepted

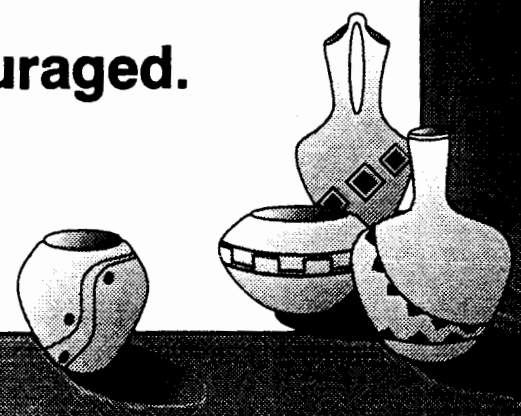


NUREG 1298

Data may be qualified by:

- Establishing an equivalent QA program
- Use of corroborating data.
- Use of peer review
- Use of confirmatory testing

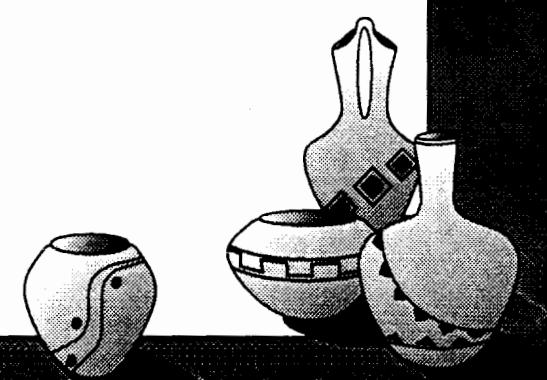
Combinations of the above are encouraged.



EPA Acceptance of QED

Has data been collected under a QA program equivalent in scope and implementation to ASME NQA–1–1989, ASME NQA–2a–1990 (part 2.7) and ASME NQA–3–1989?

Has data been qualified by an alternative method which can be approved by the Administrator for use at the WIPP?



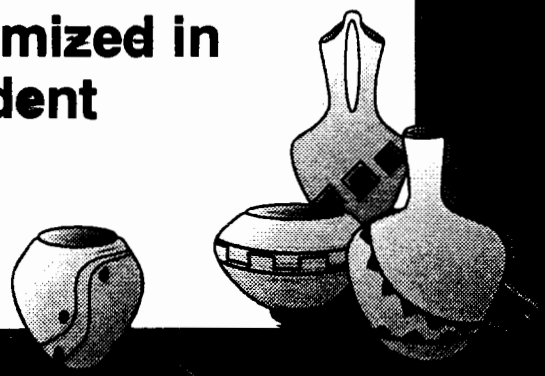
Issues in Qualification of Existing Data

What qualifications should corroborating data sets or methodology be required to have?

What degree of completeness of review or statistical analysis should be required of records packages to establish an equivalent QA program?

What degree of technical assessment of studies should be required in conjunction with the establishment of an equivalent QA program?

How should subjectivity and bias be minimized in the selection and functioning of Independent Review Teams?



Aldred Stevens

Sandia National Laboratories

Qualification of Existing Data

Aldred L. Stevens
Manager, WIPP Quality Assurance
Sandia National Laboratories

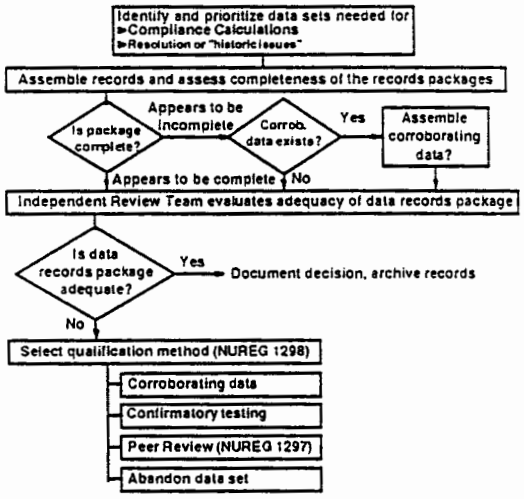
EPA Technical Workshop
on WIPP Compliance Issues
February 16, 1995
Washington, D.C.

Qualification of Existing Data

Using
SNL WIPP Project QA Procedure 20-3

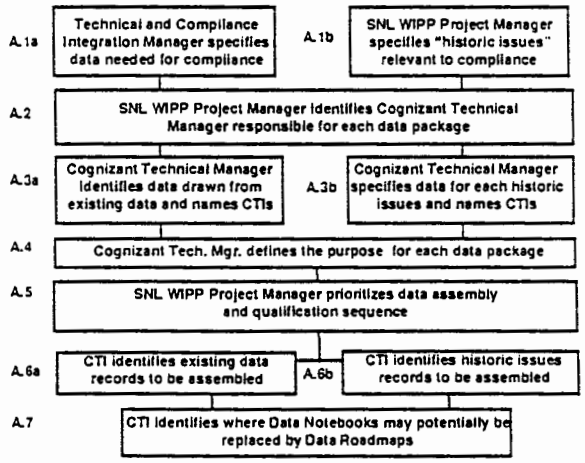
- Data Records Package Identification
- Records Package Assembly
- Independent Technical Review
- Data Remediation Process

Simplified Logic Diagram for QED Process



3

Data Package Identification



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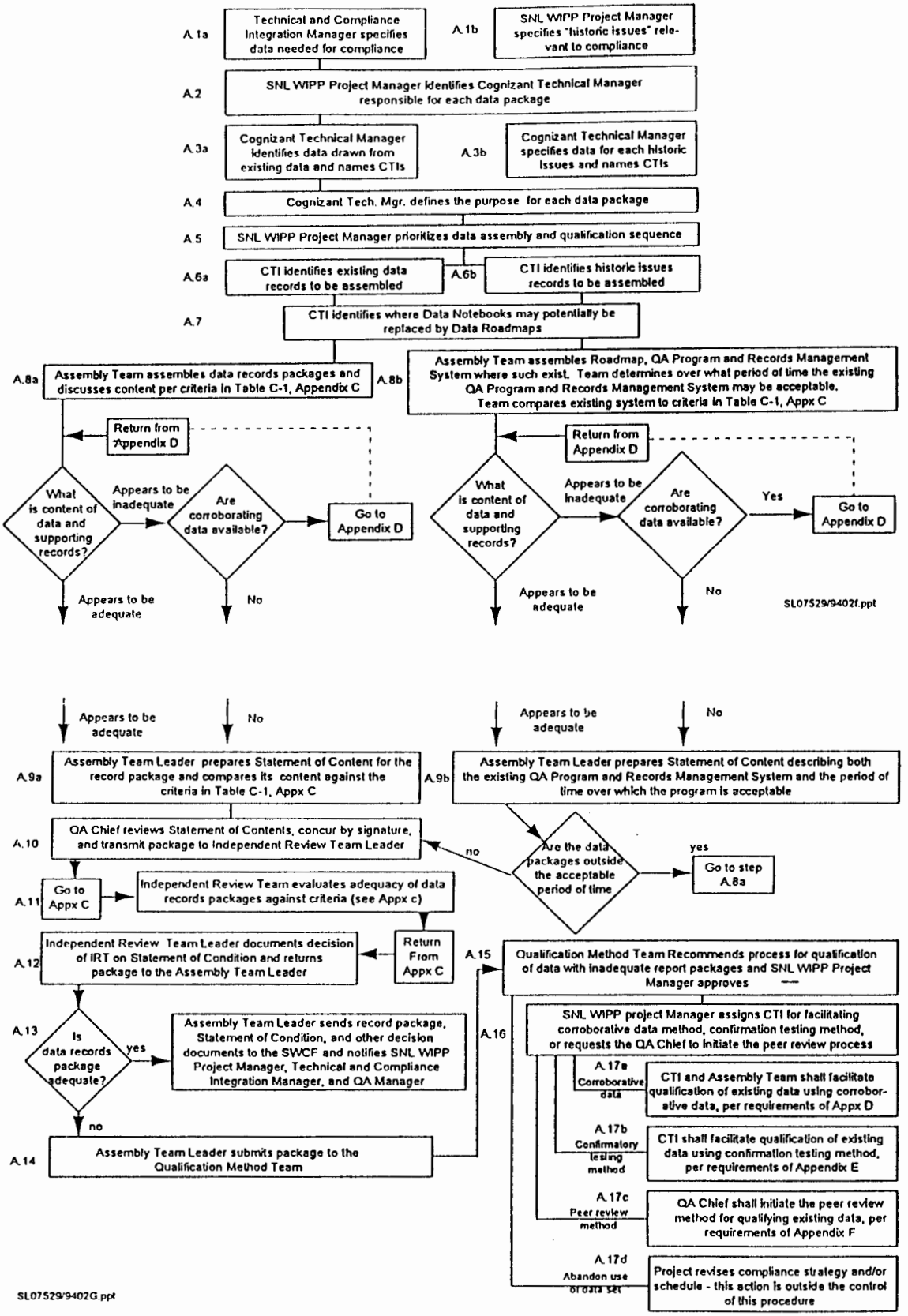

A.1a
Technical and Compliance Integration Manager specifies data needed for compliance
A.1b
SNL WIPP Project Manager specifies "historic issues" relevant to compliance
A.2
SNL WIPP Project Manager identifies Cognizant Technical Manager responsible for each data package
A.3a
Cognizant Technical Manager identifies data drawn from existing data and names CTIs
A.3b
Cognizant Technical Manager specifies data for each historic issues and names CTIs
A.4
Cognizant Tech. Mgr. defines the purpose for each data package
A.5
SNL WIPP Project Manager prioritizes data assembly and qualification sequence
A.6a
CTI identifies existing data records to be assembled
A.6b
CTI identifies historic issues records to be assembled
A.7
CTI identifies where Data Notebooks may potentially be replaced by Data Roadmaps
A.8a
Assembly Team assembles data records packages and discusses content per criteria in Table C-1, Appendix C
A.8b
Assembly Team assembles Roadmap, QA Program and Records Management System where such exist. Team determines over what period of time the existing QA Program and Records Management System may be acceptable. Team compares existing system to criteria in Table C-1, Appx C
Return from Appendix D
What is content of data and supporting records?
Appears to be inadequate
Are corroborating data available?
Go to Appendix D
Appears to be adequate
No
Return from Appendix D
What is content of data and supporting records?
Appears to be inadequate
Are corroborating data available?
Yes
Go to Appendix D
Appears to be adequate
No
SL07529/9402f.ppt
Appears to be adequate
No
Appears to be adequate
No
A.9a
Assembly Team Leader prepares Statement of Content for the record package and compares its content against the criteria in Table C-1, Appx C
A.9b
Assembly Team Leader prepares Statement of Content describing both the existing QA Program and Records Management System and the period of time over which the program is acceptable
A.10
QA Chief reviews Statement of Contents, concur by signature, and transmit package to Independent Review Team Leader
no
Are the data packages outside the acceptable period of time
yes
Go to step A.8a
A.11
Go to Appx C
Independent Review Team evaluates adequacy of data records packages against criteria (see Appx c)
A.12
Independent Review Team Leader documents decision of IRT on Statement of Condition and returns package to the Assembly Team Leader
Return From Appx C
A.15
Qualification Method Team Recommends process for qualification of data with inadequate report packages and SNL WIPP Project Manager approves
A.13
Is data records package adequate?
yes
Assembly Team Leader sends record package, Statement of Condition, and other decision documents to the SWCF and notifies SNL WIPP Project Manager, Technical and Compliance Integration Manager, and QA Manager
A.16
SNL WIPP project Manager assigns CTI for facilitating corroborative data method, confirmation testing method, or requests the QA Chief to initiate the peer review process
A.17a
Corroborative data
CTI and Assembly Team shall facilitate qualification of existing data using corroborative data, per requirements of Appx D
A.17b
Confirmatory testing method
CTI shall facilitate qualification of existing data using confirmation testing method, per requirements of Appendix E
A.17c
Peer review method
QA Chief shall initiate the peer review method for qualifying existing data, per requirements of Appendix F
A.17d
Abandon use of data set
Project revises compliance strategy and/or schedule - this action is outside the control of this procedure
no
A.14
Assembly Team Leader submits package to the Qualification Method Team
SL07529/9402G.ppt

Qualification of Existing Data Introduction

- QA Procedure 20-3 requires identification of *ALL* data needed for Compliance Calculations
  - "Existing Data" are subject to the process controlled by QAP 20-3
  - Data collected from current testing activities are subject to current QA program requirements
  - Data collected from "ongoing" testing activities, that span both existing and current work, will be identified and treated on a case-by-case basis

Basis for List of Data Needed for Compliance

- List includes all data needed for parameters supporting the models used in the Performance Assessment process
- Data sets are identified (Step A.1a) in the process of establishing the WIPP Project Technical Baseline, currently ongoing
- Data sets are subject to change as a result of the Systems Prioritization process currently in progress
- Prioritization of the assembly sequence (Step A.5) is responsive to parallel schedule activities

"Historic Issues" Relevant to Compliance

- Compliance Status Report, Chapter 6, identifies 40 issues
  - CSR indicates 20 issues are "resolved"
    - Objective is to assemble records packages to support this claim
  - Remaining 20 issues are identified as "open", and are being addressed as part of the compliance process

HISTORIC ISSUES

Identified in the Past, Many "Resolved" in the Past
Listed in Chapter 6 of the Compliance Status Report*

Section	Issue #	Short Title	Status
6.1.1		**Geological/Geochemical Compliance Issues**	
	A	1. Breccia Pipes	Resolved
	B	2. Borehole & Shaft Plugging	Open
	C	3. Brine Reservoirs	Open
	D	4. Brine Weeps & Seeps	Open
	E	5. Dissolution	Resolved
	F	6. Igneous Dikes	Resolved
	G	7. Karst	Resolved
	H	8. Natural Background Radiation	Resolved
	I	9. Paleoclimate & Climate Changes	Resolved
	J	10. Resources	Closed
	K	11. Salt Deformation	Resolved
	L	12. Seismic Activity	Resolved
	M	13. Specific Site Geological Characteristics	Resolved
	N	14. Subsidence	Open
	O	15. Tectonic Stability/Faulting	Resolved
	P	16. Culebra Radionuclide Retardation	Open
6.1.2		**Issues in Rock Mechanics**	
	A	17. Thermal Expansion	Resolved
	B1	18. Salt Creep Simulation -	Resolved
	B2	Constitutive Descriptions	Resolved
	C	19. Seal Performance	Open
6.1.3		**WIPP Hydrology**	
	A	20. Culebra Dolomite	Resolved
	B	21. Culebra Regional Flow model	Open
	C	22. Rustler Formation Water Recharge	Open
	D	23. Culebra Flow and Transport Model	Open
	E	24. Culebra Transmissivity Variations	Open
	F	25. Brine Content of Salado Evaporites	Open
	G	26. Effects of Gas Generation	Open
	H	27. Effects of Groundwater Below the Salado & Castile Formations	Resolved
6.1.4		**Performance Assessment**	
	A	28. CCDF Confidence Bounds	Open
	B	29. Scenario Construction	Resolved
	C	30. Complexity and Realism of PA Models	Resolved
	D	31. Uncertainty in Rad. Solub & Retardation	Open
	E	32. Human Intrusion	Resolved
	F	33. Climate Change	Open
	G	34. 2-Phase Flow & Gas Generation	Resolved
	H	35. Culebra Transmissivity	Open
	I	36. Displays of Uncertainty	Resolved
	J	37. Coupling of Models	Open
	K	38. Fracture Modeling	Open
	L	39. Confirm dequacy of 2-D Models	Open
	M	40. Events/Process Screening	Open

* Compliance Status Report for the WIPP, DOE/WIPP 94-019, Revision 0, March 1994
US DOE, Carlsbad Area Office, Carlsbad, NM

Records Packages for Historic Issues

- Records packages are being assembled for each "resolved" historic issue, and reviewed per QAP 20-3
- A summary report discusses the issue, identifies reference reports and records associated with the issue
- Priority for assembly of these packages follows that of the data records packages

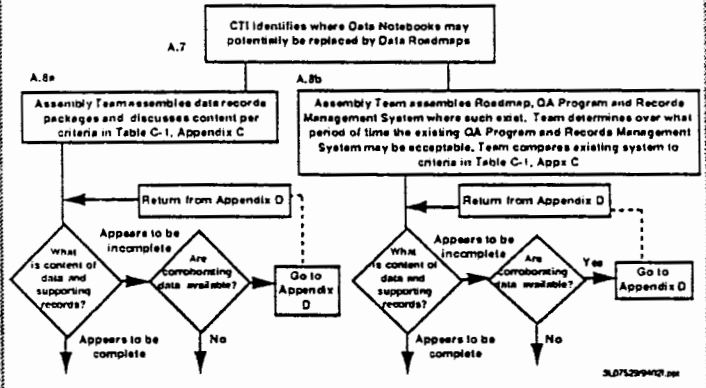
Records Package Assembly

- What is a Data Package?
- Types of packages and contents
- Approach to assembly
- Assembly process

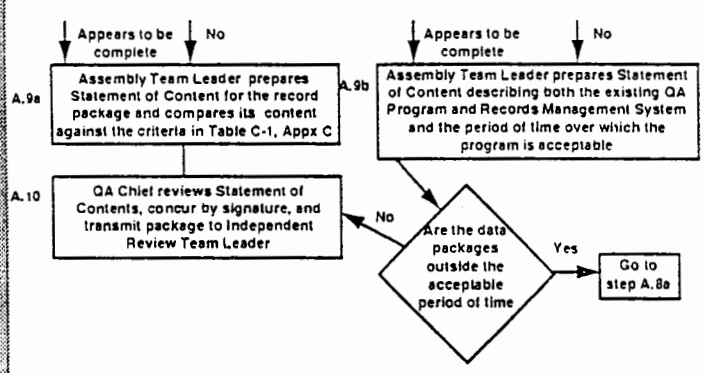
What Is a Data Package?

- A collection of information on a specific technical topic which will be used in the demonstration of compliance for WIPP

Records Package Assembly



Records Package Assembly (cont)



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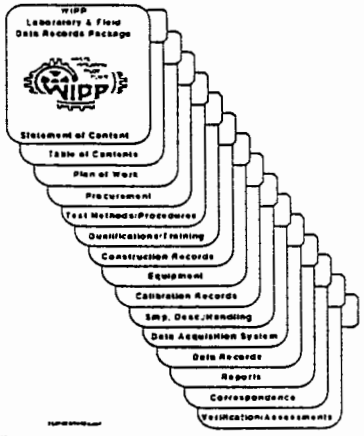
Types of Record Packages

- Notebooks
  - Used when data and records are scattered and not formally controlled, and not readily retrievable
  - Assembly of actual data and records into an integrated package
- Roadmaps
  - Used when records are formally controlled and easily retrieved
  - Utilizes a matrix pointing to where the records are stored

14

Table of Contents for a Data Package



Typical Contents of Data Packages

Section Title	Content
STATEMENT OF CONTENT	· Description of the Content of the Notebook per QAP 20-3, Table 1
TABLE OF CONTENTS	· What's in this notebook · Date, title/subject/activity, WBS#, responsible Cognizant Technical Individual or Principal Investigator (PI) who conducted or supervised the work, the Assembly Team Leader who directed the development of the Notebook, dates of testing,...
1 PLAN OF WORK	· What did we use to define/control the work to be performed?· Letters of direction, test plans, statements of work, work agreements,...
2 PROCUREMENT (By Reference)*	· Who performed the work?· What supplies, samples, equipment were purchased to support the work performed?· Information relating to costs should not appear in these notebooks.· Specifications pertaining to specialized equipment and services requested.

Typical Contents Of Data Packages (cont)

3 TEST METHODS/PROCEDURES	· QA or technical procedures used to perform work. (By reference after assuring the reference is correct, or hard copy).· Documents supporting how the testing was done.· Equipment operating instructions, test procedures, sample preparation procedures, etc...
4 QUALIFICATION/TRAINING RECORDS (By Reference)*	· Who did the work? Were they qualified?
5 CONSTRUCTION RECORDS (Generally for Field Experiments)	· Include records pertaining to mining, drilling, surveys,...
6 EQUIPMENT DESCRIPTION	· What test facility/fixture was used?· Include shop-requested and standard equipment, as well as data acquisition instrumentation used.· Supporting photos, drawings, serial numbers,...
7 CALIBRATION RECORDS	· What evidence exists to show that the instruments used during testing were calibrated?· Sandia Equipment Identification Numbers and Serial Numbers necessary to track the calibration records to the equipment.

Typical Contents Of Data Packages (cont)

8 SAMPLE DESCRIPTION/HANDLING · How were the samples taken/made and handled?· Sample custody, photos, logbooks, sample preparation records, shipment records,...

9 DATA ACQUISITION SYSTEM (By Reference)* · What software packages were used during data collection process?· If not on file in the records center, submit hard copy of software then reference or include in the notebook system.

10 DATA RECORDS · What is the raw data? What records accompany or support the raw data and where are these records located? · Verify the traceability of the data manipulation process from raw data to the reduced data tables, graphs in the final report.· What is the reduced data and how was it done? Written instructions or by reference to the Data Acquisition System section?· What is the final data and where is it located?· Lab notes, notebooks, calculations, lab sheets,...· Sort as possible by test identifier such as test date, solution number, sample used, etc...

Typical Contents Of Data Packages (cont)

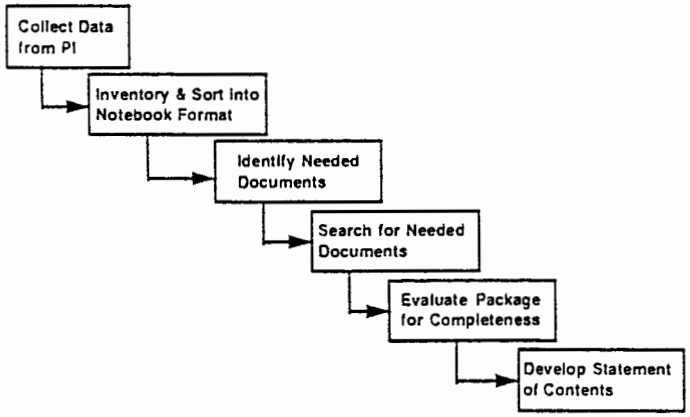
11 REPORTS (By Reference)* · SAND Reports, publications, etc. referenced in the SAND Reports or used to support or report the work performed.

12 CORRESPONDENCE · Are there any additional records of correspondence, interactions, etc. that provide further evidence of the quality of the data?· Include as appropriate, correspondence from day files, periodic status reports, memos, etc.

13 VERIFICATION & ASSESSMENTS · Include audits, nonconformance reports, corrective actions, overviews, independent assessments, peer reviews, etc. that provide further evidence of the quality of the data.

*These records are expected to be on file in the records center or readily available from reference sources.

Assembly Process



Guidelines For Assembly

- Assembly Teams consist of technical and quality assurance staff
- Technical staff provide knowledge of good scientific protocol
- Quality assurance staff identify types of QA records to support the data

Guidelines for Assembly (cont)

- Assembly Team locates data and records and assemble into records package
  - Team does not create data
- Assembly Team spot-verifies traceability from raw data to data report
  - Not full verification
  - Amount of verification depends upon data processing method

Simple Data Package

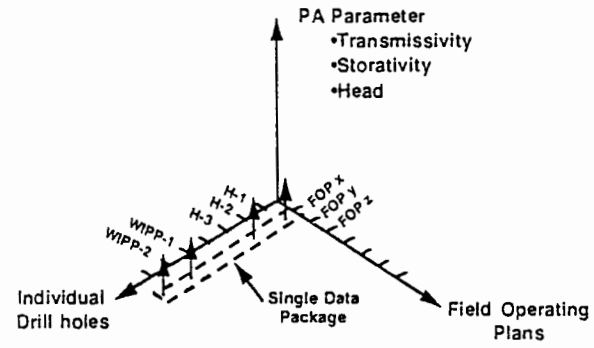
- Single crushed salt reconsolidation test series
- A few samples
- Single temperature
- Single confining pressure
- No follow-on permeability testing of consolidated samples

Objectives for Assembly

- Assemble all existing data (and associated records) needed for compliance
- Assemble packages for past or ongoing tests - not for tests conducted under updated QA Program
- Not to verify original test methods or equipment

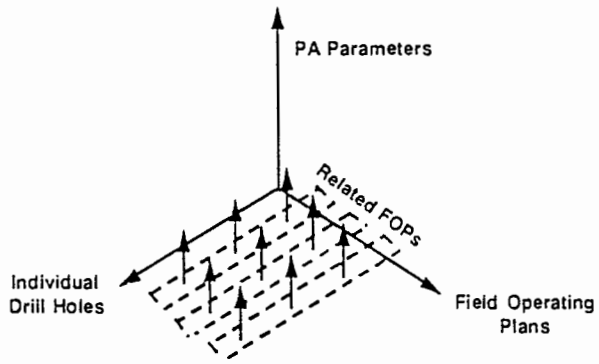
Complex Data Package

Review data for each FOP to assess accuracy of individual measurements, calibration, and validity



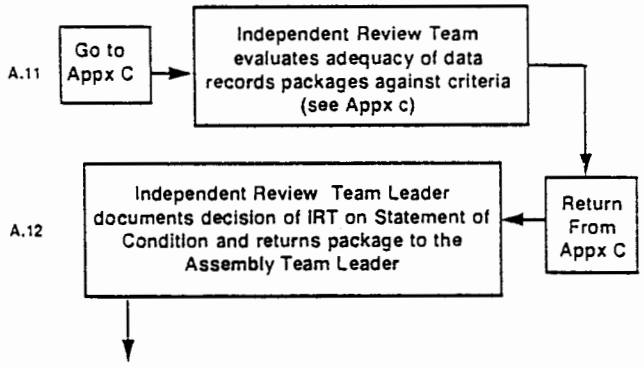
Grouped Data Packages

Integrated Review of related data to assess the conversion of individual data into conceptual model



Example of Roadmap Content

Procedure
Independent Technical Review



Independent Review Team (IRT) Goals

Review Sandia National Laboratories (SNL) WIPP Data Records Packages

- Appropriate scientific protocol
- Equivalent Quality Assurance Program Implementation to NQA-1, NQA-2 (Subpart 2.7), and NQA-3

Governing Documents

- NUREG-1298, Qualification of Existing Data for High Level Waste Repositories
- ASME NQA-1-1989 (1992 Addenda), QA Program Requirements for Nuclear Facilities
- ASME NQA-2a-1990, Part 2.7, Quality Assurance Requirements of Computer Software for Nuclear Facility Applications
- ASME NQA-3-1989, Quality Assurance Program Requirements for the Collection of Scientific and Technical Information for Site Characterization of High-Level Nuclear Waste Repositories

Governing Documents (Cont)

- SNL WIPP Quality Assurance Program Description
- SNL WIPP QAP 20-3, Qualification of Exiting Data
- WTAC IRT Desk Instruction IRT DI-1.0, Independent Review Team Qualifications, Selection and Roles
- WTAC IRT Desk Instruction IRT DI-2.0, Data Records Package Review Process
- CAO-94-1012, Quality Assurance Program Description

Approach for IRT

- Independent review of Data Records Packages
  - Review IRT candidates with SNL QA Chief to ensure qualification and independence
- Review of scientific methods, experimental processes, and reasonableness of data
- Review of QA Program, adequacy, and appropriateness
- Recommend limitations on use of the data
- Not 100% verification of data traceability nor validation of conclusions

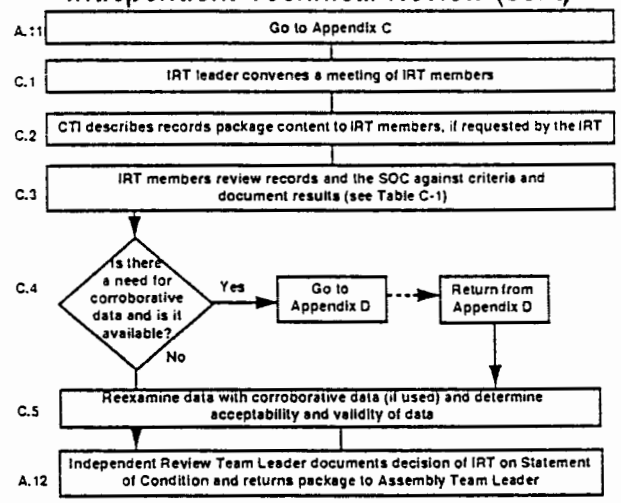
IRT Members

- One Quality Assurance expert
  - Bachelor's Degree
  - 10 years quality assessment experience
  - Working knowledge of governing documents
  - Certified Lead Auditor
- Two subject matter experts picked for specific expertise
  - Primarily Doctoral Degrees in subject matter

IRT Members (Cont)

- Use same reviewers for related packages when possible
- All formally trained to QAP 20-3 and Desk Instructions

Independent Technical Review (cont)



Procedure
WTAC IRT Desk Instructions

- Desk Instructions amplify the review process and requirements defined in SNL QAP 20-3
  - Purpose
  - Scope
  - References and definitions
  - Responsibilities
  - Procedure
  - Records
  - Attachments

WTAC IRT Desk Instructions

- WTAC IRT DI-1.0, Independent Review Team Qualifications, Selection and Roles
  - Establishes the responsibilities and methods employed in qualification and selection process of IRT members
- WTAC IRT Desk Instruction IRT DI-2.0, Data Records Package Review Process
  - Describes the process of IRT review of SNL Data Records Packages

Conduct of IRT

- Independence from Assembly Team
- Independence from Principal Investigator
- Conduct review over 1 to 2 week period
- Communicate results to Assembly Team and SNL QA Chief via Statement of Condition

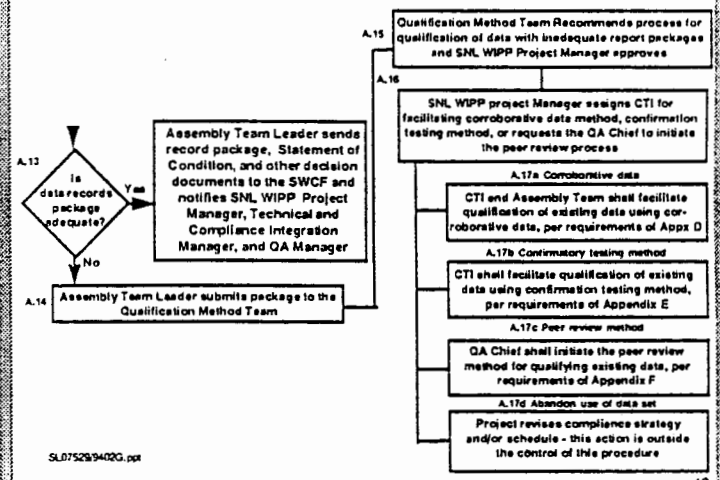
Review Process

- IRT Lead ensures team members are trained and training records are complete
- IRT reviews Data Records Package in accordance with QAP 20-3 and Desk Instruction DI-2.0
- IRT Lead facilitates consensus of IRT members
- IRT Lead prepares Statement of Condition (SOC)
- IRT Lead assembles and ensures completeness of QA records
- Data Records Package and SOC returned to SNL QA Chief

IRT Review Products Maintained as Quality Records

- Checklist and Comment sheets
- Statement of Condition
- IRT member training records

Data Remediation Process



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Qualification Method Team

- Goal - Recommend process for Data Remediation
- Members
  - Cognizant Technical Manager
  - Technical and Compliance Integration Manager
  - SNL WIPP Project manager
- Recommendation Options
  - Qualify using corroborative data
  - Qualify using confirmation testing
  - Qualify using Peer Review
  - Abandon data
    - Send to records center with statement that data not to be used for compliance and why

Qualification of Existing Data by Use of Corroborrative Data Process

- Approach - Compare the data set in question to Similar data generated under an approved QA plan, or generated by others for similar purposes, or generated using different procedures but obstaining similar results
- Corroborative data collected by Cognizant Technical Individual (CTI) supported by assembly team
- Analysis performed by CTI
- Completed analysis and supporting data returned to Independent Review Team for concurrence

Corroborative Data Review

D.1 CTI identifies corroborative data sources

D.2 CTI collects corroborative data and all known QA records on the data

D.3 CTI and Assembly Team analyzes data and QA records, assesses potential for use as corroborative data, and revises Statement of Content

D.4 CTI and Assembly Team forwards augmented data package and Statement of Content to the IRT (step C.4)

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What is Corroborative Data?

- *Basis* - NUREG-1298, Qualification of Existing Data for High-Level Nuclear Waste Repositories, February, 1988
- *Definition* - Existing data used to substantiate or suppport other existing data. Data from peer-reviewed journals can be used regardless of the extent of knowledge of the associated QA program. Data on geologic systems and parameters need not be identical to be corroborative.
- *Purpose* - Develop confidence that the lack of a specific QA program did not affect the validity of the results

What is Confirmatory Testing?

- *Basis* - NUREG-1298, Qualification of Existing Data for High-Level Nuclear Waste Repositories, February, 1988
- *Definition* - Test conducted under an NQA-1, 2, 3 Quality Assurance Program
  - Conducted with similar procedures, test methods, and equipment on the original tests which generated the existing data
  - Conducted using different test methods and equipment but still investigating the parameters of interest
- *Purpose* - Develop confidence that the lack of a specific QA program did not affect the validity of the results

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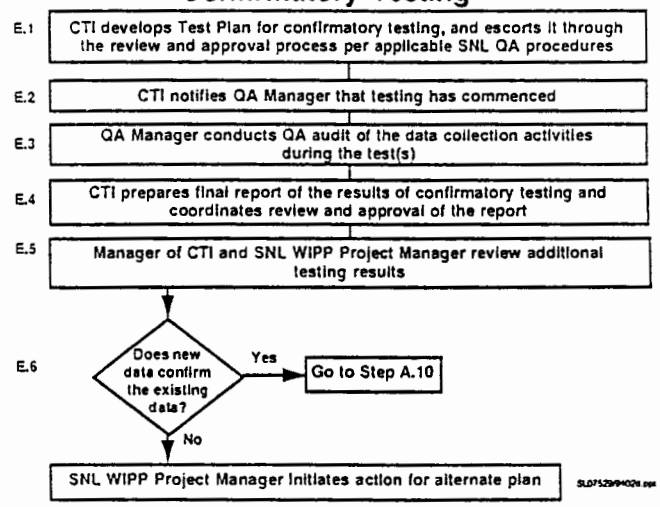
Confirmatory Testing



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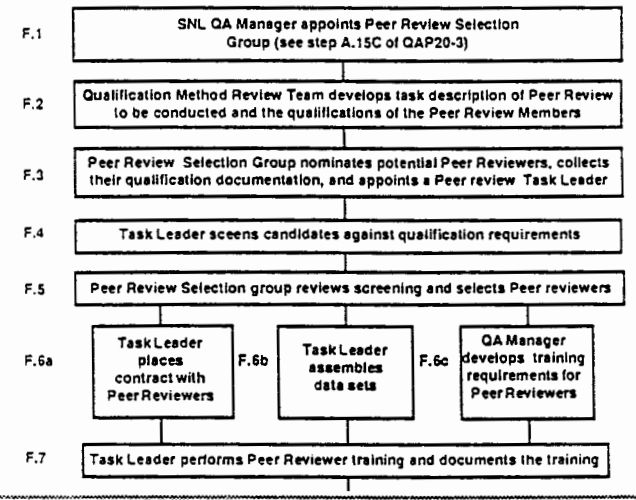
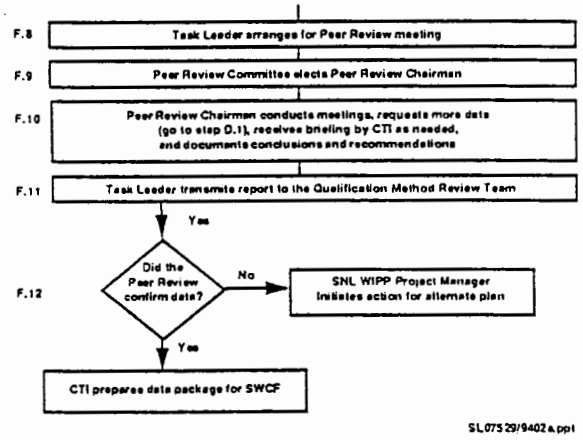
Qualification of Existing Data by Use of Confirmatory Testing Process

- Tests developed and performed by Cognizant Technical Individual based on guidance from Qualification Method Review Team
- Test results evaluated by Cognizant Technical Manager and SNL WIPP Project Manager to determine whether tests confirm existing data
- If confirmed, send to Independent Review Team
- Not confirmed, return to Qualification Method Review Team

Peer Review



Peer Review



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What is a Peer Review?

- *Basis* - NUREG-1297, Peer Review for High-Level Nuclear Waste Repositories, February, 1988
- *Definition* - A Peer has technical qualifications at least equivalent to that needed for the original work
  - Is independent of the original work
  - Was not involved as a participant, supervisor, technical reviewer, or advisor
  - Has sufficient freedom from funding considerations to assure impartial review

What is a Peer Review? (cont)

- A Peer Review - Confirms adequacy of work based on in-depth critique of
  - Assumptions
  - Calculations
  - Extrapolations
  - Alternative interpretations
  - Methodology
  - Acceptance criteria
  - Conclusions drawn in the original work

Qualification of Existing Data by Peer Review Process

- Qualification Method Review Team develops tasking and peer qualification standards
- Peers - nominated by group appointed by QA Chief and Independent Review Team Manager
  - Selected by Independent Review Team Manager
- Peer Review Chairman
  - Elected by Peer Review committee
  - Conducts meetings
  - requests more data
  - Receives briefing from Cognizant Technical Individual
  - Documents conclusions and recommendations

Qualification of Existing Data by Peer Review Process (cont)

- If Peer review confirms adequacy of data for intended use, assemble package and send to records
- If Peer review does not confirm data, return to Qualification Method Team

James E. Kennedy

Nuclear Regulatory Commission

Assuring the Quality of "Old" Data

EPA Technical Workshop
on WIPP Compliance Issues

February 16, 1995

James E. Kennedy
Division of Waste Management
U.S. Nuclear Regulatory Commission
(301)-415-6668

- Background--NRC's interest in "old data"
  - Many data previously collected at Yucca Mountain
  - QA programs variable
  - Qualified data needed in licensing

- Regulatory requirements for QA
  - Contained in Subpart G, 10 CFR Part 60
  - Based on nuclear power reactor criteria, "as applicable"
  - Science vs engineering debate

- Tradeoffs
  - Nature of site investigations and modeling
  - More data with less QA may be better than less data with more QA
  - Flexibility in application of QA needed

- GTP on Qualification of Existing Data
  - Recognizes less than full QA may be OK
  - Four ways
  - Subsequently adopted by ASME in NQA-3

Three Examples

1. The applicant calculated heat transfer rates from the spent fuel to the surrounding rock. Published data from handbooks were used for the thermal conductivity and density of the canister material, a metal alloy, in these calculations. Do these data need to be qualified?

2. The applicant made predictions of rainfall for the site, both the average value and the maximum expected, for calculations in performance assessment and for design purposes. Regional data for the last 75 years and collected by a Federal Agency were used. Similar data have been collected at hundreds of locations around the country and have been used in thousands of applications, from design of dams to specification of flood plains. Procedures and other information are available that describe how the data for the last 20 years were collected, but information is not available for data collected before then. Can these earlier data be qualified?

   Considerations

   - More data better for predicting rainfall amounts.
   - Experience of Federal agency and wide use of their data provides some confidence in the data.
   - Uncertainties of older data could be bounded.

3. The applicant measured rates of infiltration of water through a backfill material to be used in the repository. In order to obtain the required accuracy and sensitivity, scientists developed a state-of-the art procedure. In-situ tests at the site conducted were conducted in 1979 and some records are available. The applicant would like to use these data in performance assessments of the site. The infiltration rate through the backfill is important in predicting performance because it affects the amount of radioactive material that is dissolved from the waste and then transported to the environment.

   Considerations

   - Importance in predicting performance
   - State-of-the-art

   QA--Procedures, qualifications of personnel, records of data collection, calibration records, verification of data collection, other.

- Experience to Date
  - NRC review of DOE QED procedure
  - DOE--core samples, erosion, geophysical logs
  - Yucca Mountain Project is different from WIPP

- **Issues**
  - "...importance of the data in showing that the repository design meets the performance objectives..." [from NQA-3]
  - First order and second order QA issues
  - Qualification not just QA, not just technical
  - Thoroughness/thoughtfulness/adaptability

Patrick Kelly

Sanford Cohen & Associates, Inc.

Qualification of Existing WIPP Data

EPA Technical Workshop on
WIPP Compliance Issues
Washington, D.C.
February 16, 1995

Patrick Kelly
S. Cohen & Associates, Inc.
Contractor to U.S. Environmental Protection Agency
Office of Radiation and Indoor Air

DEFINITION OF EXISTING DATA
SNL QUALITY ASSURANCE PROCEDURE QAP 20-3
REVISION 1, 11-23-94

Data developed prior to the implementation of an NQA-1, 2, 3 QA program by SNL and its contractors, or data developed outside the SNL-WIPP program, such as by oil companies, national laboratories, universities, or data published in technical or scientific publications. Excludes accepted scientific facts, e.g., gravitational laws, density tables.

Qualification of Existing Data
Overview of Sandia National Laboratory
QAP 20-3, Revision 1, 11-23-94

Technical and Compliance Integration Manager

- Identifies Pertinent Parameters & Information

WIPP Project Manager

- Identifies Cognizant Technical Manager

Cognizant Technical Manager

- Identifies Needed Data

Cognizant Technical Individual

- Identifies Data and Other Records
- Designates Road Map or Notebook

Qualification of Existing Data
Overview of Sandia National Laboratory
QAP 20-3, Revision 1, 11-23-94

Assembly Team

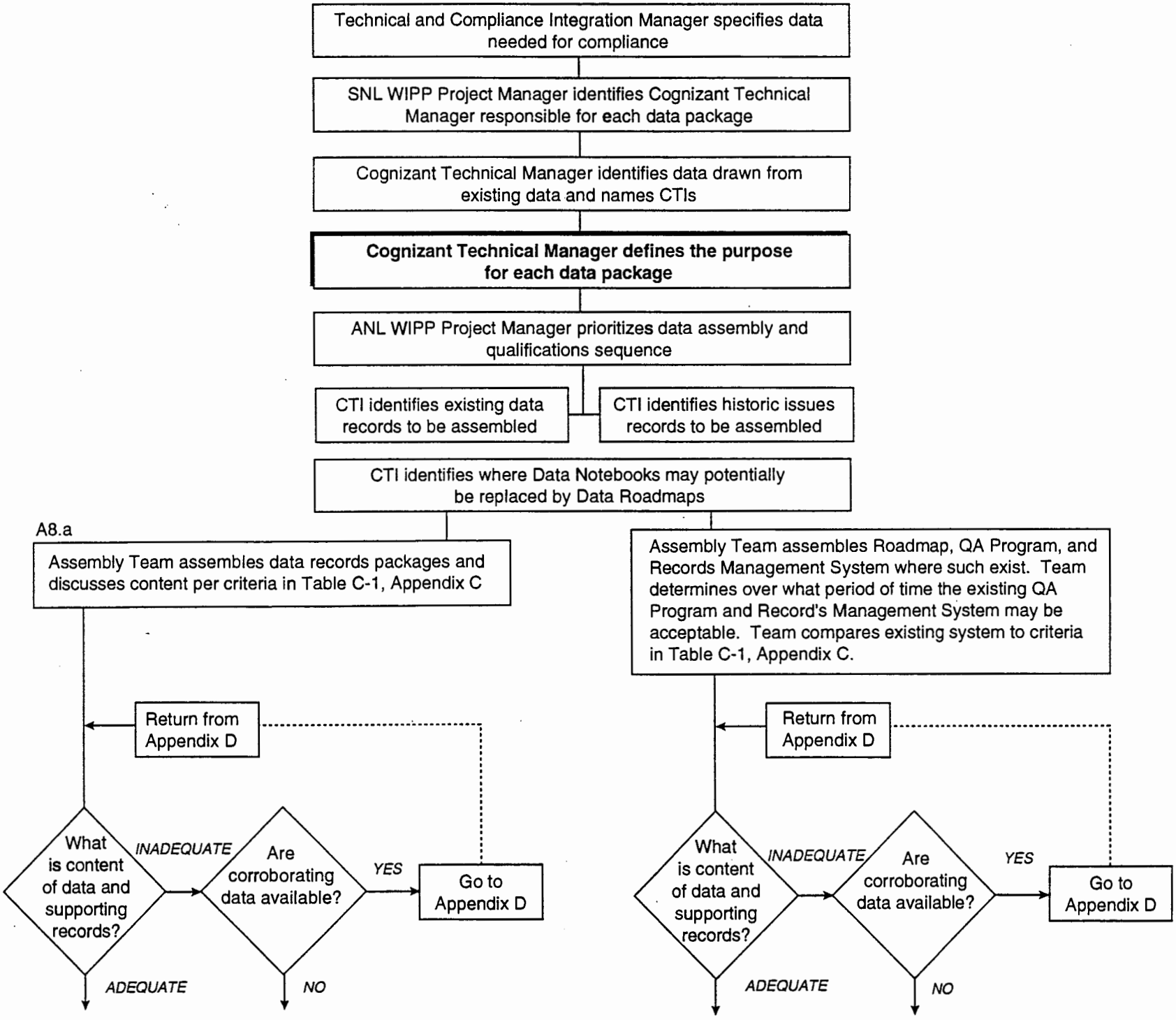
- Assembles Road Map or Notebook
- Provides Statement of Content

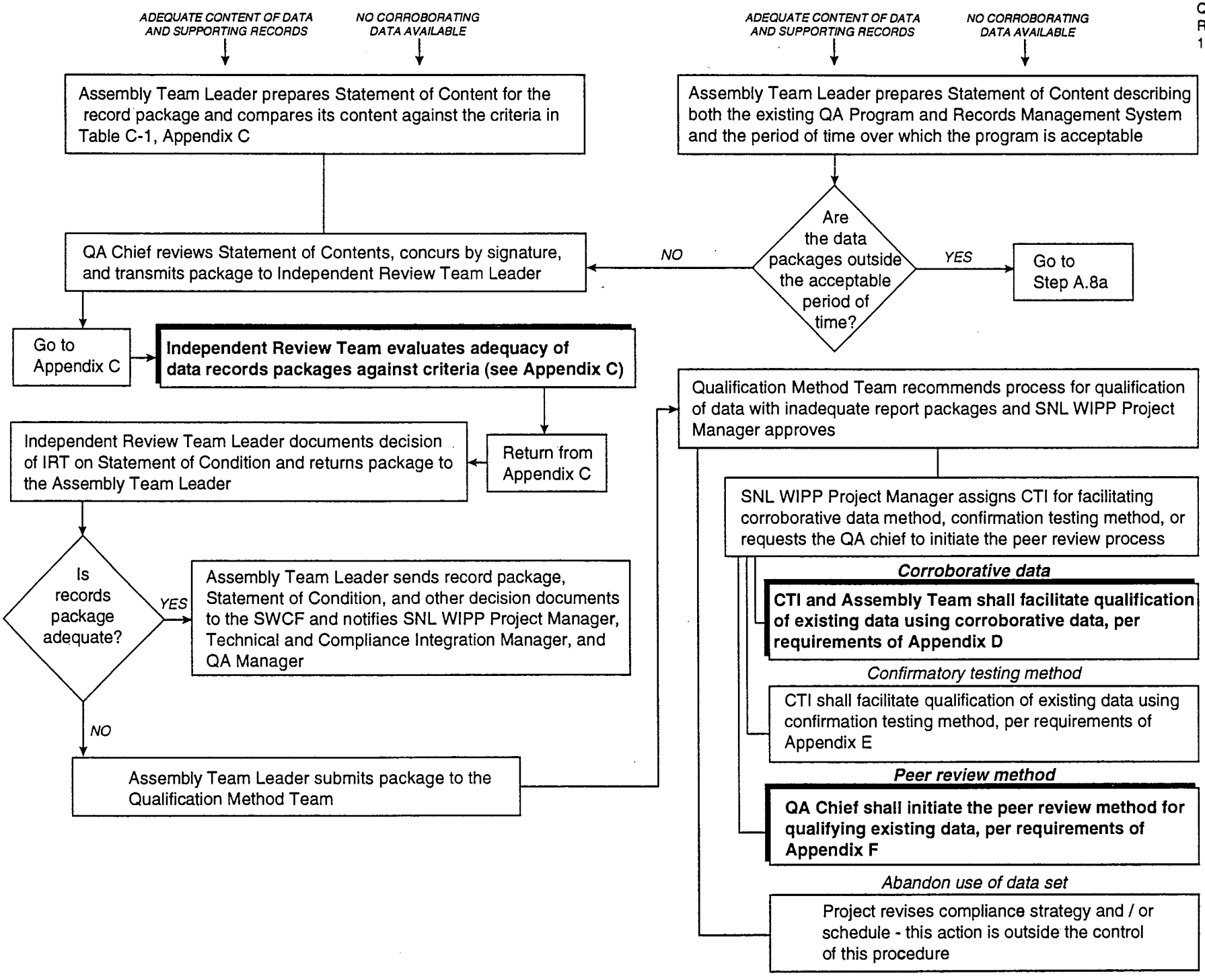
Independent Review Team

- Evaluates Records Package
- Provides Statement of Condition
- Accepts or Rejects Records Package

Qualification Method Team

- Recommends Qualification Process
  - Corroborating Data
  - Confirmatory Testing
  - Peer Review


Technical and Compliance Integration Manager specifies data needed for compliance
SNL WIPP Project Manager identifies Cognizant Technical Manager responsible for each data package
Cognizant Technical Manager identifies data drawn from existing data and names CTIs
Cognizant Technical Manager defines the purpose for each data package
ANL WIPP Project Manager prioritizes data assembly and qualifications sequence
CTI identifies existing data records to be assembled
CTI identifies historic issues records to be assembled
CTI identifies where Data Notebooks may potentially be replaced by Data Roadmaps
A8.a
Assembly Team assembles data records packages and discusses content per criteria in Table C-1, Appendix C
Return from Appendix D
What is content of data and supporting records?
INADEQUATE
Are corroborating data available?
YES
Go to Appendix D
ADEQUATE
NO
Assembly Team assembles Roadmap, QA Program, and Records Management System where such exist. Team determines over what period of time the existing QA Program and Record's Management System may be acceptable. Team compares existing system to criteria in Table C-1, Appendix C.
Return from Appendix D
What is content of data and supporting records?
INADEQUATE
Are corroborating data available?
YES
Go to Appendix D
ADEQUATE
NO


ADEQUATE CONTENT OF DATA AND SUPPORTING RECORDS
NO CORROBORATING DATA AVAILABLE
Assembly Team Leader prepares Statement of Content for the record package and compares its content against the criteria in Table C-1, Appendix C
QA Chief reviews Statement of Contents, concurs by signature, and transmits package to Independent Review Team Leader
Go to Appendix C
Independent Review Team evaluates adequacy of data records packages against criteria (see Appendix C)
Return from Appendix C
Independent Review Team Leader documents decision of IRT on Statement of Condition and returns package to the Assembly Team Leader
Is records package adequate?
YES
Assembly Team Leader sends record package, Statement of Condition, and other decision documents to the SWCF and notifies SNL WIPP Project Manager, Technical and Compliance Integration Manager, and QA Manager
NO
Assembly Team Leader submits package to the Qualification Method Team
ADEQUATE CONTENT OF DATA AND SUPPORTING RECORDS
NO CORROBORATING DATA AVAILABLE
Assembly Team Leader prepares Statement of Content describing both the existing QA Program and Records Management System and the period of time over which the program is acceptable
Are the data packages outside the acceptable period of time?
NO
YES
Go to Step A.8a
Qualification Method Team recommends process for qualification of data with inadequate report packages and SNL WIPP Project Manager approves
SNL WIPP Project Manager assigns CTI for facilitating corroborative data method, confirmation testing method, or requests the QA chief to initiate the peer review process
Corroborative data
CTI and Assembly Team shall facilitate qualification of existing data using corroborative data, per requirements of Appendix D
Confirmatory testing method
CTI shall facilitate qualification of existing data using confirmation testing method, per requirements of Appendix E
Peer review method
QA Chief shall initiate the peer review method for qualifying existing data, per requirements of Appendix F
Abandon use of data set
Project revises compliance strategy and / or schedule - this action is outside the control of this procedure

General Concerns Regarding QED Process

- Subjectivity
- Incorporation of Technical Assessment
- Completeness

Specific Concerns Regarding QED Process

Data Records Package

- Data Quality Objectives
- Definition of a Data Set

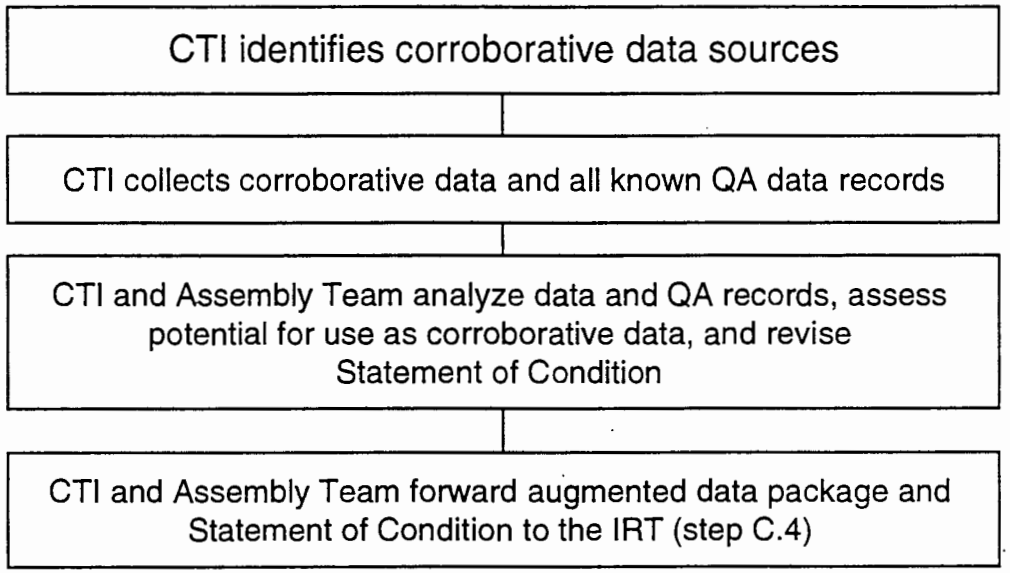
Corroborating Data

- Objectivity in Choosing Data
- Preponderance of Evidence
- Pedigree of Corroborating Data

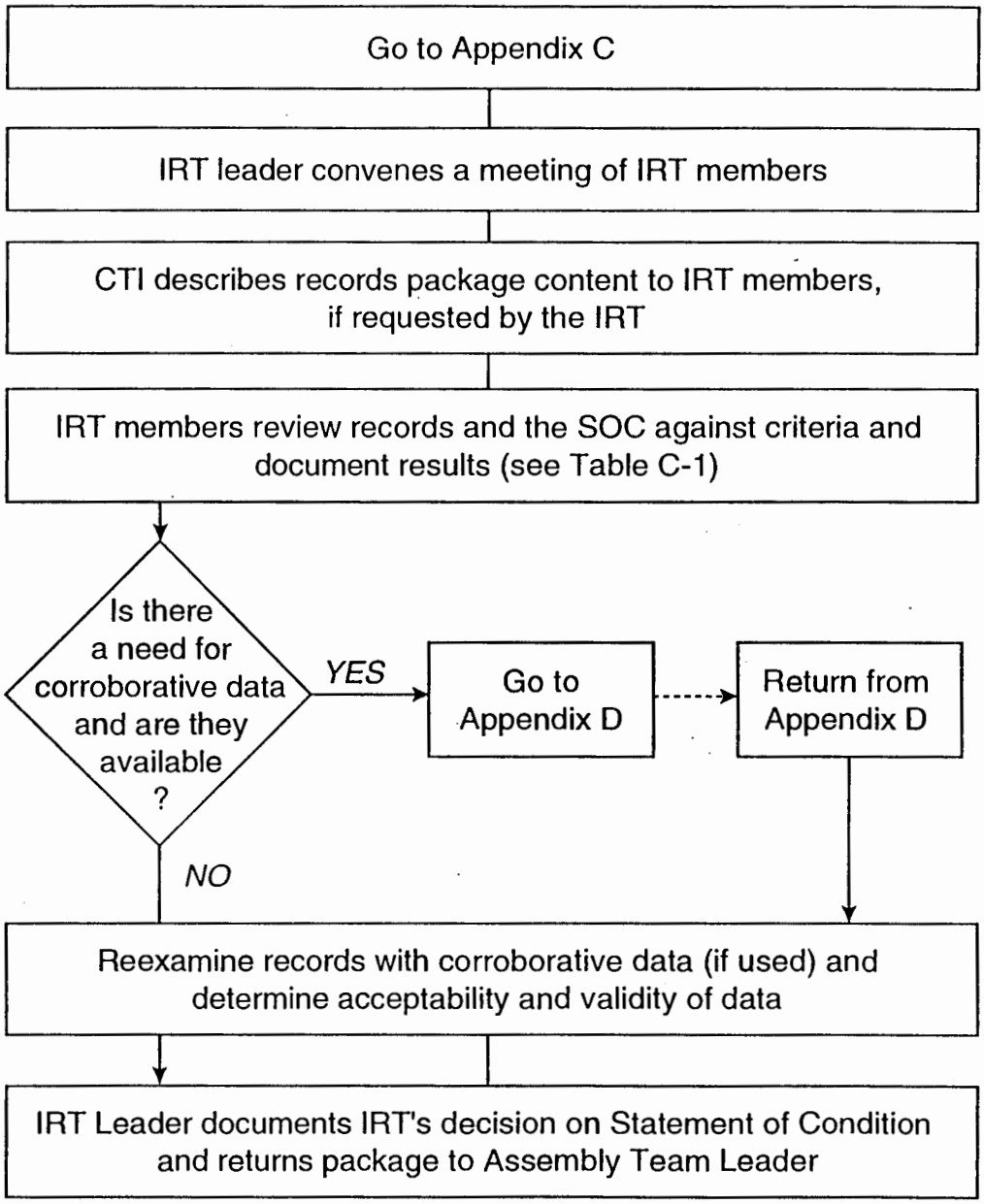
Peer Review

- Technical Qualifications
- Independence
- Objectivity

Logic Diagram for Corroborative Data Review



Logic Diagram for Independent Review Team (IRT) Actions



Lokesh Chaturvedi

Environmental Evaluation Group

ENVIRONMENTAL EVALUATION GROUP

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ASSURING THE QUALITY OF "OLD" DATA FOR WIPP

Lokesh Chaturvedi

Environmental Evaluation Group

EPA Technical Workshop on WIPP Compliance Issues

Washington D.C.

February 16, 1995

PLATITUDES AND PERSPECTIVES

- Quality assurance is everyone's business. QA documentation is assured by QA records.

- Absence of QA documentation does not reflect either positively or negatively on the scientific quality of data.

- Scientific quality of data is judged on the basis of corroboration by other investigators. QA procedures guard against sloppiness and fraud, and are needed in adversarial proceedings.

- A reputable investigator's data should be reviewed with an expectation to qualify. Disqualification should bear the burden of proof.

- A lack of records does not necessarily mean omission of specific activity. Often it simply displays a lack of attention to record-keeping in the midst of exciting lab or field work.

- Reviewers of old data should therefore be individuals who are familiar with the methods used to generate the data, and preferably have conducted similar studies themselves. The original PI should be an integral part of the review process whenever possible.

COMMENTS ON THE PROPOSED PROCEDURES

- NUREG-1298 outlines an adequate general approach to accomplish the objective of qualifying old data.

- The scheme set forth in the SNL QA procedures, QAP 20-3, and outlined in Appendix A of that document is appropriate and adequate for qualifying old data for preparing the compliance application for the WIPP.

- The QAP 20-3 scheme may be more easily applicable to laboratory data. Difficulties may arise in its application to field data, depending on the existing documentation.

- The choice of one of the three alternate procedures for inadequate data packages (QAP 20-3, Appendix A), i.e., corroboration, confirmation, or peer review, should be a carefully considered judgement based on feasibility, expense and time required.

- Peer review method may be the only method feasible for some old field data.

- The Independent Review Team (IRT) approach appears suitable for reviewing the adequacy of data record packages. However, if the peer review method is selected as a qualification method, then a rigorous NUREG-1297 procedure, open to monitoring by the EPA, should be followed.

COMMENTS ON SPECIFIC ISSUES RAISED BY EPA

- Q. Should a graded approach to the qualification of existing data (QED), such as prioritization of critical elements for weighing the importance of data packages be used?

  A. Yes. With 200 data packages containing data sets of varying importance, this would be the logical approach. The prioritization should be based on the sensitivity of data to performance assessment, and should be carried out with the concurrence of EPA.

- Q. By what means can the objectivity and independence of the IRT be maintained and what technical qualifications should be applied for team selection?

  A. To make the IRT requirements more rigorous than specified in the QAP 20-3 would be counter-productive. EPA's oversight and approval should ensure a fair process acceptable to EPA.

COMMENTS ON SPECIFIC EPA ISSUES (CONT)

- Q. By what means should the EPA evaluate the adequacy of technical reviews conducted by the IRT, or should EPA conduct independent technical reviews to assess the data quality?

  A. EPA should continue to participate in the QA process and conduct independent technical reviews on a fraction of the data packages (say, 25 out of 200) deemed most significant for performance assessment.

- Q. How should EPA evaluate the use of corroborating data, confirmatory testing, and/or peer review, or should EPA conduct independent testing and/or review?

  A. If the EPA maintains an effective oversight during the QED process, it should not be necessary to conduct independent testing. For some very critical data sets, independent review may be necessary.

A REMINDER

This discussion has addressed only the documentation of existing data. Other significant issues in the EPA approval of the DOE application for compliance will be in determining:

- the adequacy, interpretation, relevance, and use of the data;
- adequacy, accuracy, and pertinence of the conceptual and numerical models;
- need and relevance of the information derived through "expert judgement";
- accuracy of the calculations;
- and adequacy of conservatism in the process.

This presentation is not meant to address these issues.

Peter Swift

Sandia National Laboratories

Climate Change and Long-Term Performance Assessment for the Waste Isolation Pilot Plant

Peter Swift
Sandia National Laboratories
Albuquerque, NM

Presentation to EPA Technical Workshop
Washington, D.C., February 16, 1995

Three Questions

- Will climate change occur in 10,000 yr?
  - » yes
- Can we predict the time and amount of change with high confidence?
  - » no
- Can we incorporate our uncertainty about climate change into PA?
  - » yes

Characterizing Future Climate

- Present Climate at WIPP
- Paleoclimates
- Anthropogenic Effects

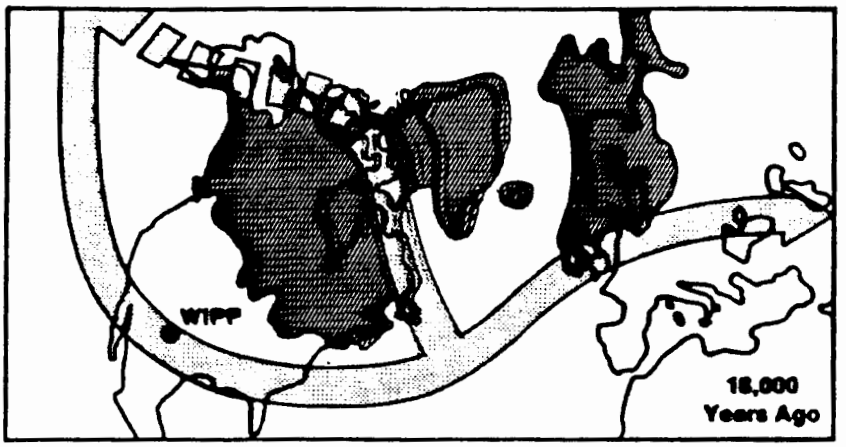
Present Climate at the WIPP

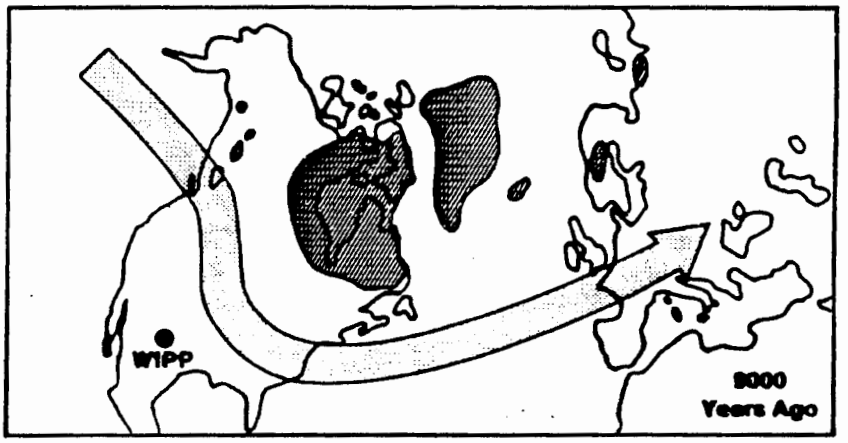
- Semi-Arid
  - » Ppt. approx. 30 cm/yr, variable
- Large Temperature Range
  - » 50 yr annual mean at Carlsbad is 17.1°C, mean daily high is 25.6°C, mean daily low is 6.3°C
- Monsoonal Climate
  - » Cool, dry winter; warm, moist summer

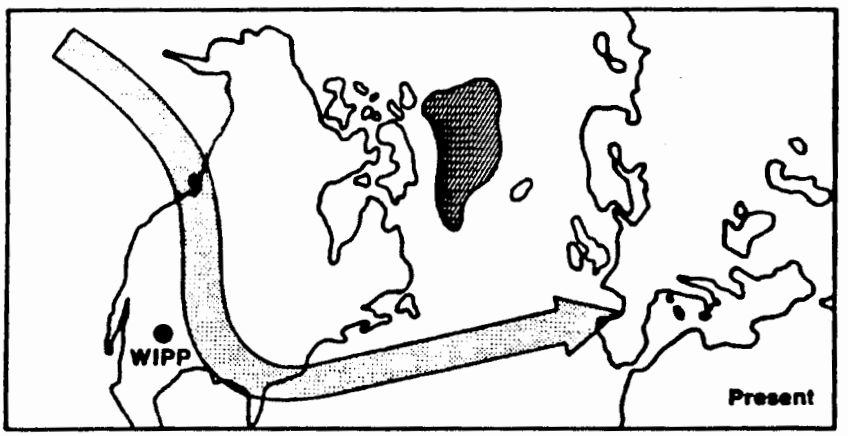
Paleoclimates

- Prior to 22,000 years ago
  - » Incomplete record shows alternations of wetter and drier climates throughout Pleistocene
- From 22,000 years ago to present
  - » Extensive data correlates well with glacial events

Modified from COHMAP Members, 1988





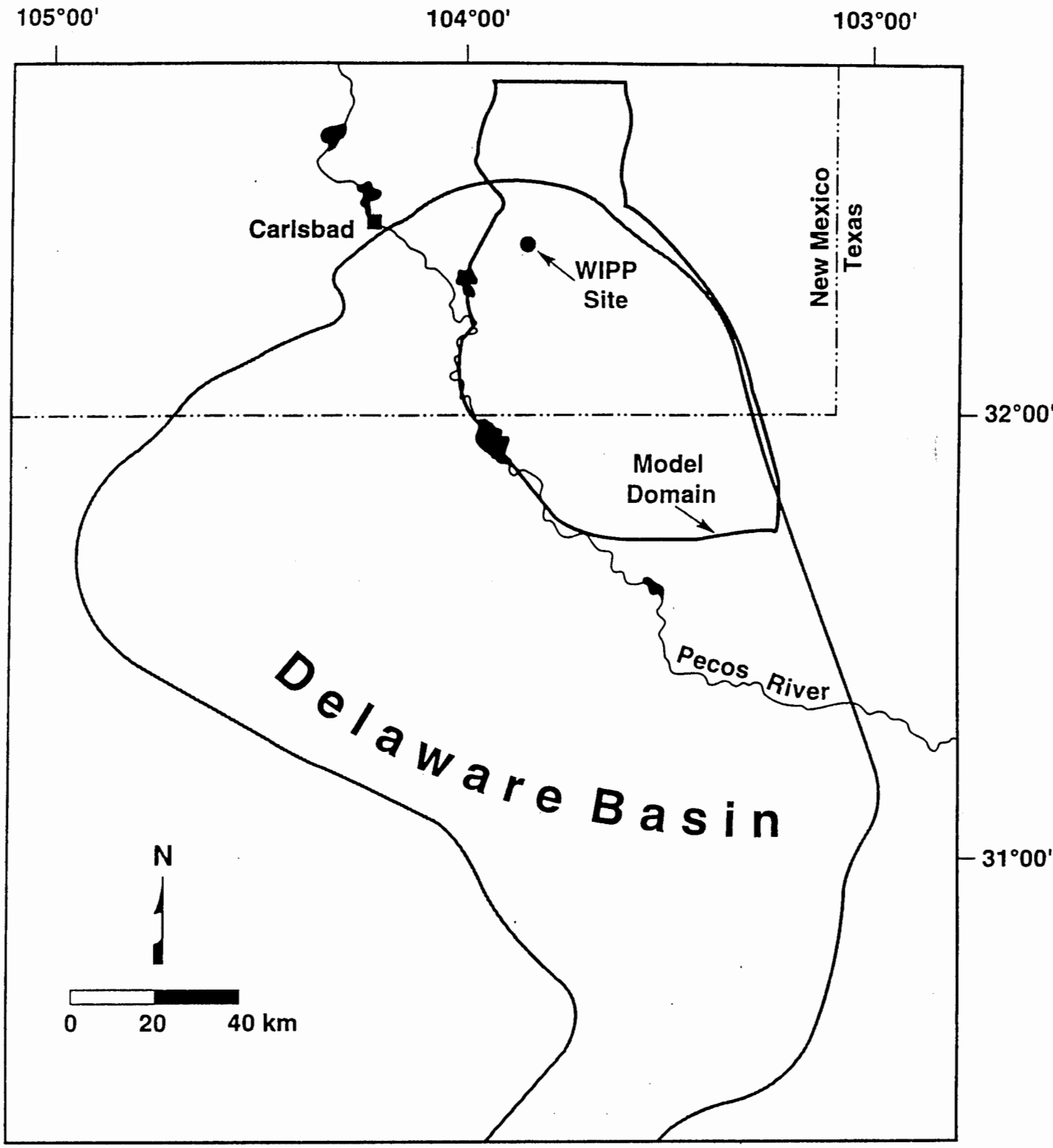


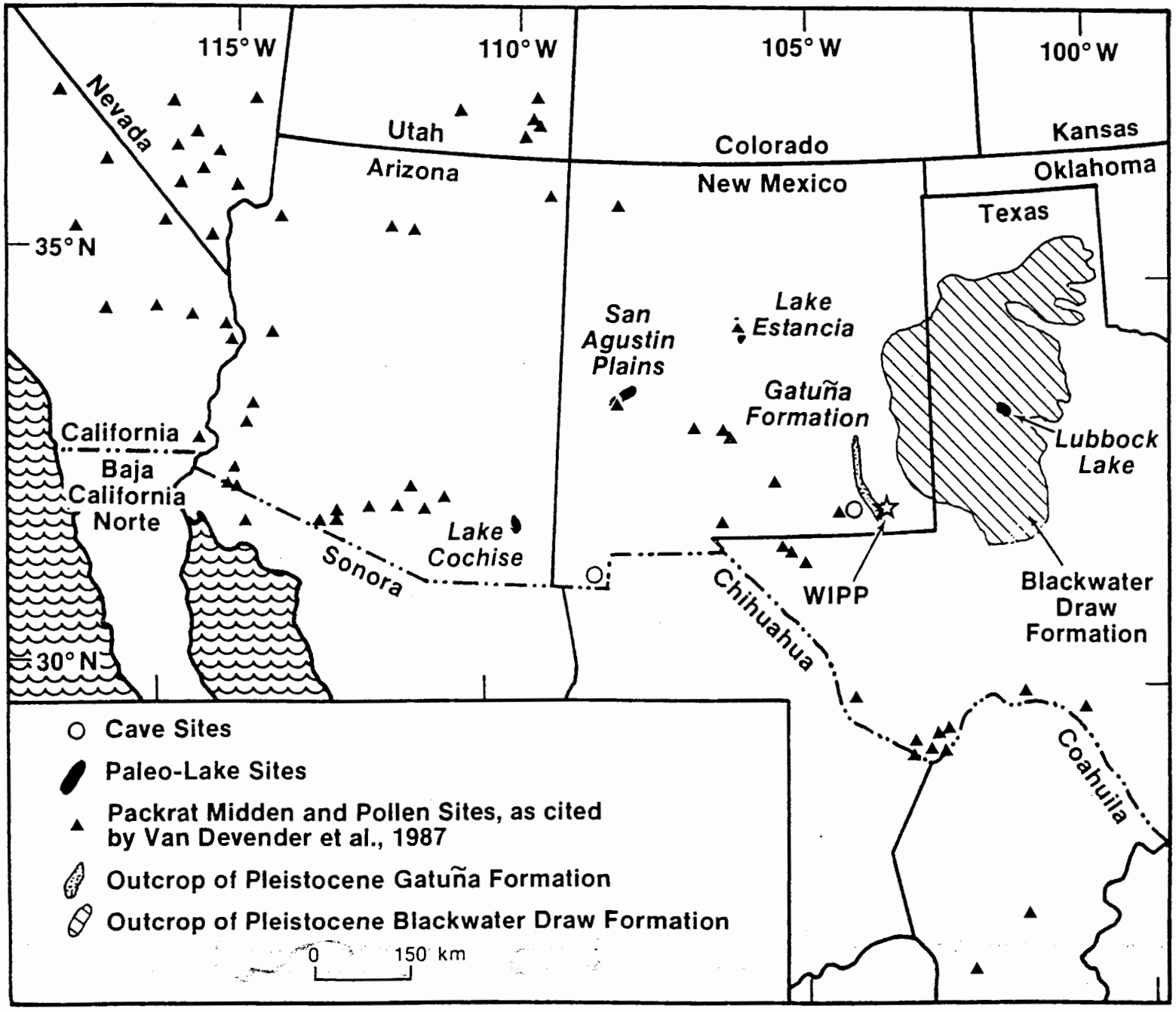
1629-0

Climate Change and PA

- Potential effect on groundwater flow
  - » WIPP is below the water table
  - » Potential releases involve saturated flow
- Other impacts of climate change
  - » Changes in infiltration rate from all causes may affect water table
  - » Human activities assumed like present
  - » Performance of surface facility

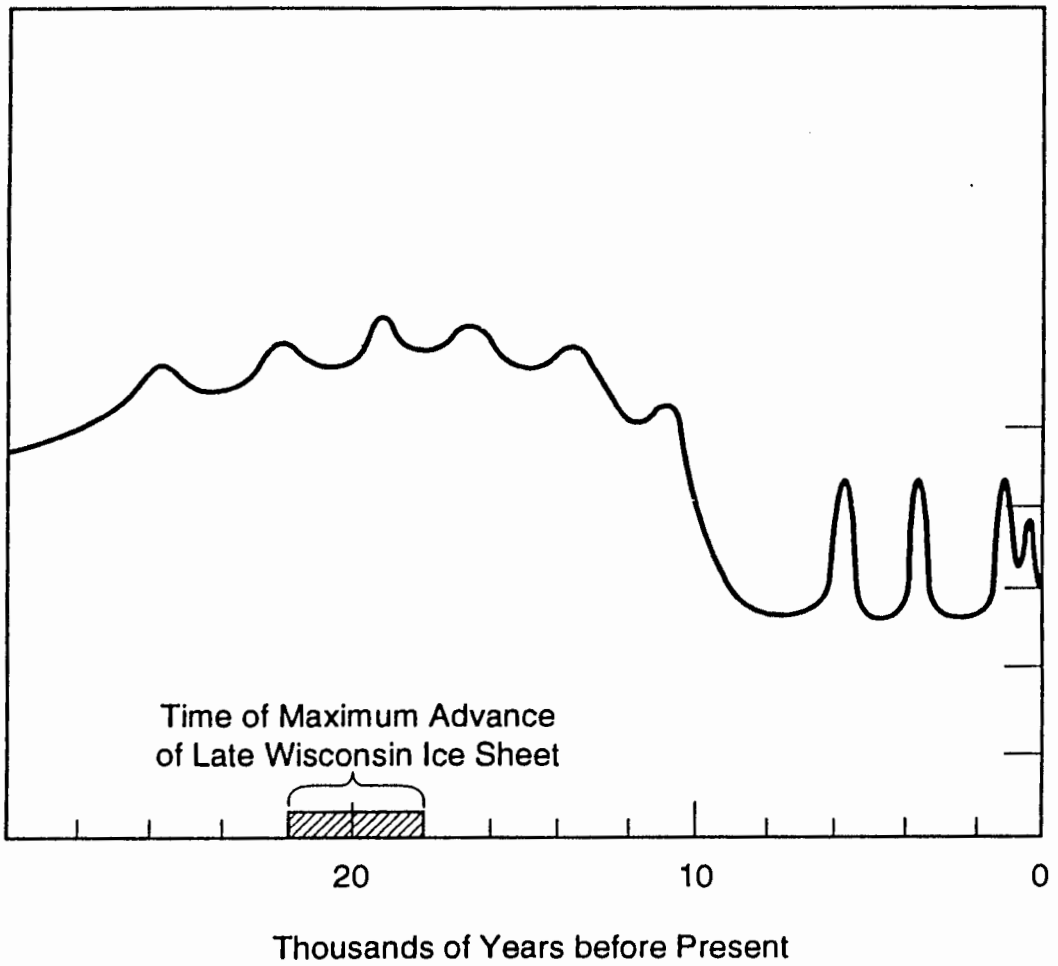
Regional 3-D Groundwater Flow Model Domain




115° W
110° W
105° W
100° W
35° N
30° N
Nevada
Utah
Arizona
Colorado
New Mexico
Kansas
Oklahoma
Texas
California
Baja California Norte
Sonora
Chihuahua
Coahuila
San Agustin Plains
Lake Estancia
Gatuña Formation
Lake Cochise
WIPP
Lubbock Lake
Blackwater Draw Formation
Cave Sites
Paleo-Lake Sites
Packrat Midden and Pollen Sites, as cited by Van Devender et al., 1987
Outcrop of Pleistocene Gatuña Formation
Outcrop of Pleistocene Blackwater Draw Formation
0
150 km

921-0

30,000 yr Precipitation History for WIPP



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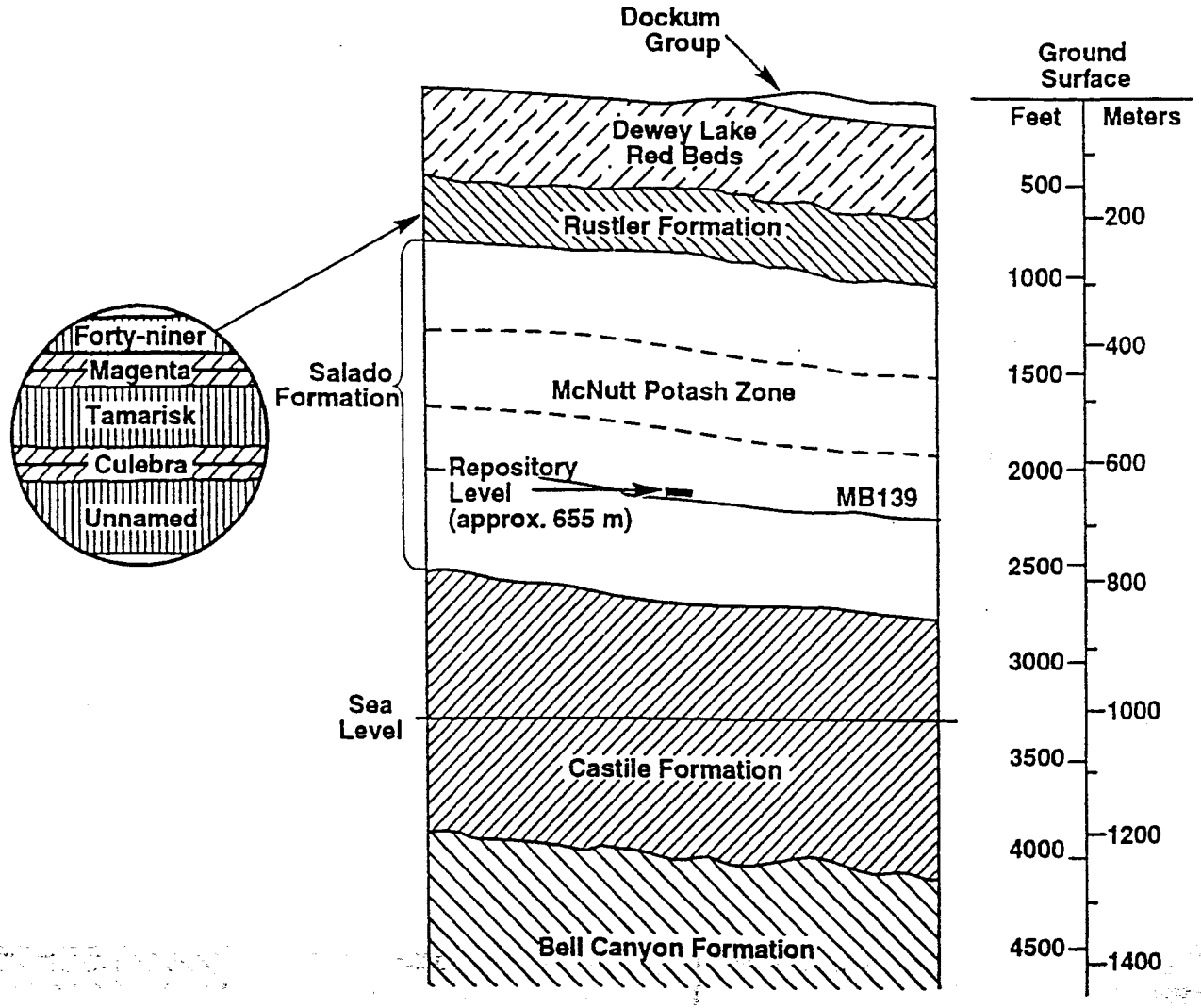
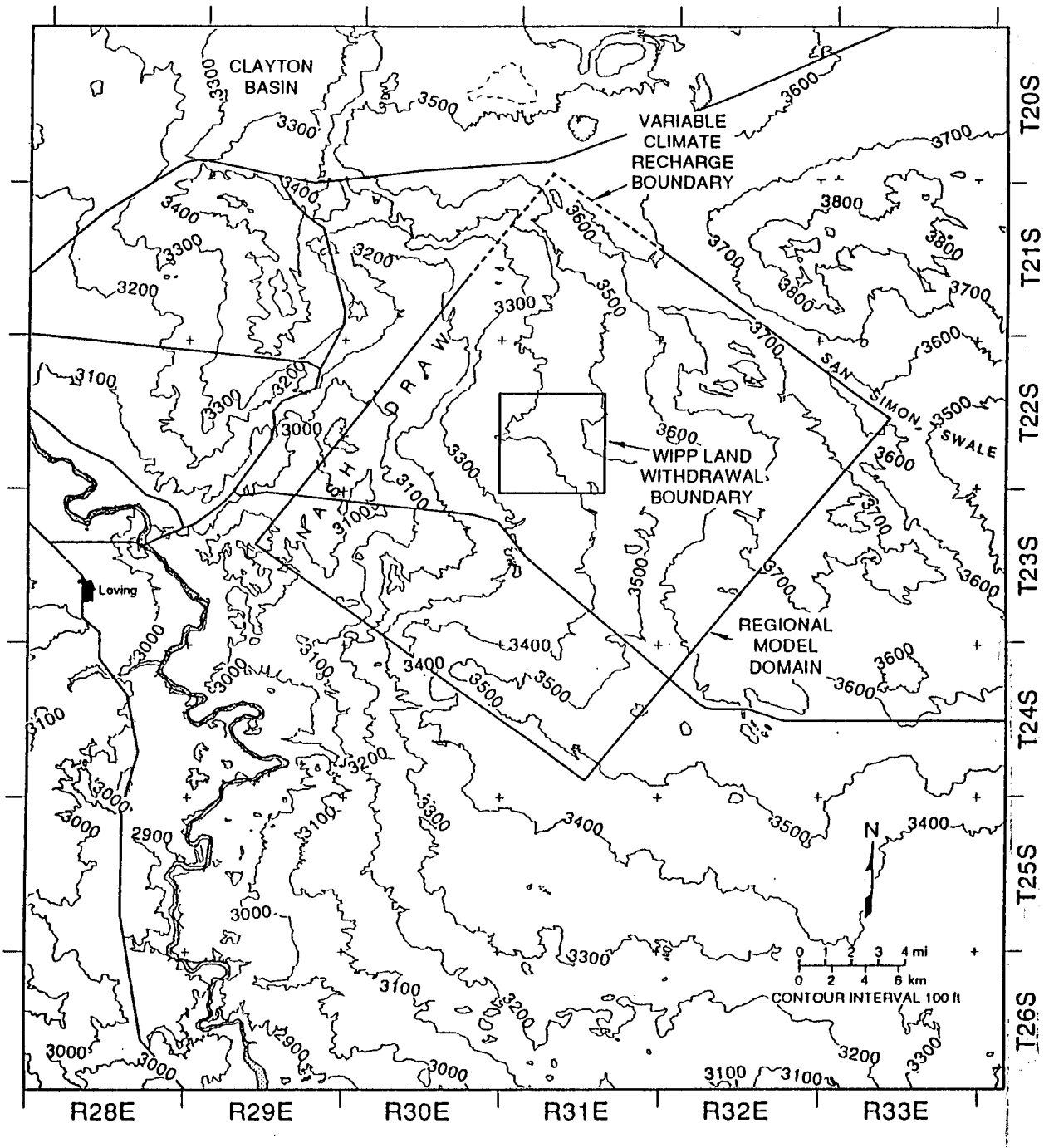
Generalized WIPP Stratigraphy



1623-0

Regional Domain for Groundwater Flow Modeling



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Conclusions

- Climate change may change groundwater flow direction and rate
- Changes in flow can be modeled, but uncertainty will remain
- Question for PA is “what effect does uncertainty have on performance?”

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- Corbet, T. F., 1993. "Evolution of Patterns of Regional Groundwater Flow in Southeastern New Mexico; Response to Post-Pleistocene Changes in Climate," poster session at 1994 Annual Meeting of the Geological Society of America, Seattle, Washington, Oct. 24-27, 1994. Reproduced as Appendix A of Draft Position Paper, Non-Salado Fluid Flow and Transport, December 15, 1994. Albuquerque, NM: Sandia National Laboratories.
- Swift, P. N., B. L. Baker, K. Economy, J. W. Garner, J. C. Helton, and D. K. Rudeen, "Incorporating Long-Term Climate Change in Performance Assessment for the Waste Isolation Pilot Plant," in *Proceedings of the Thirty-Second Hanford Symposium on Health and the Environment. Regional Impacts of Global Climate Change: Assessing Change and Response at the Scales that Matter, October 19-21, 1993, Richland WA.* (Also published with the same title in February 1994 as SAND93-2266, Sandia National Laboratories, Albuquerque, NM).
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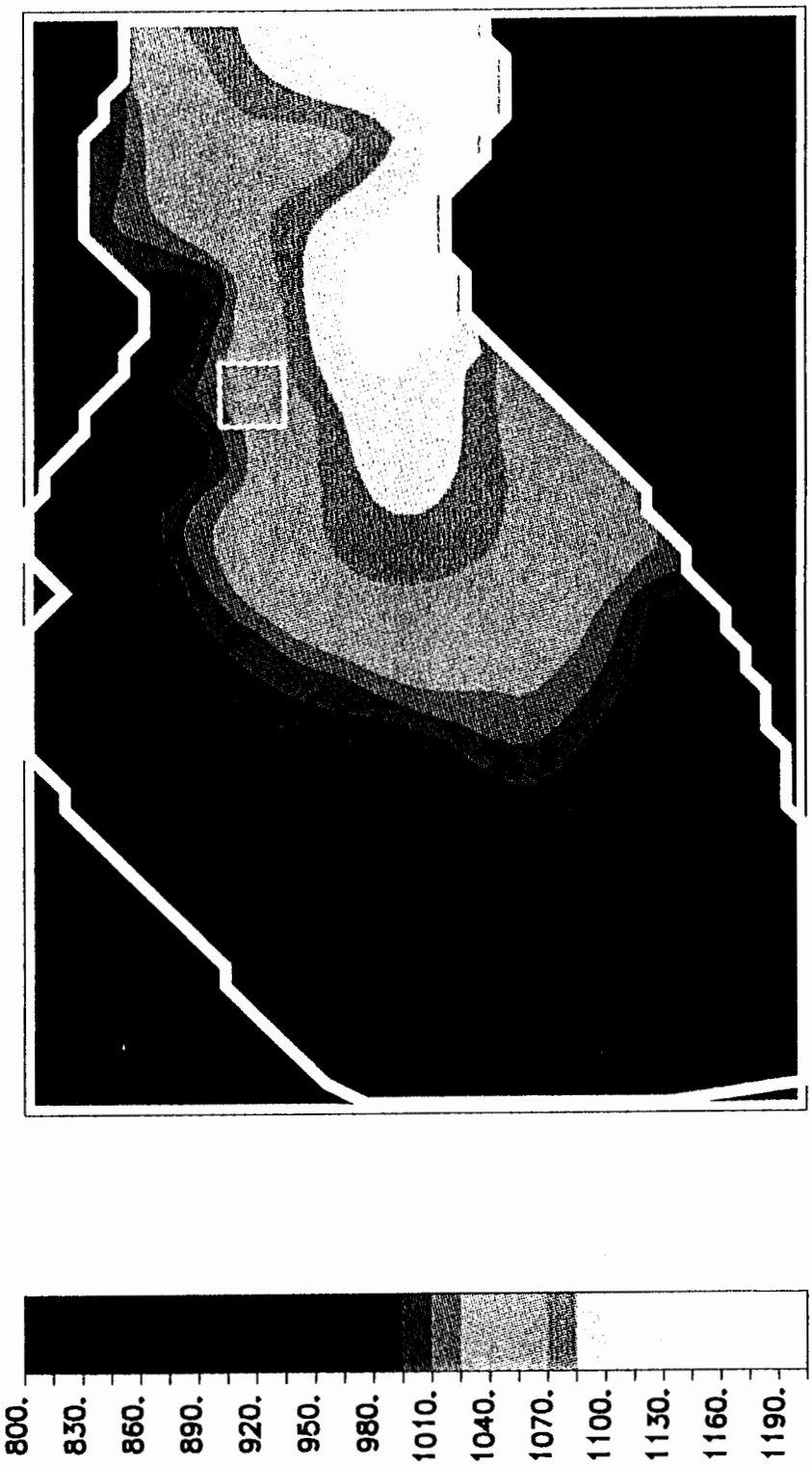


Figure 12

Steady-State Water Table (meters)
Maximum Potential Recharge = 0.1 cm/yr

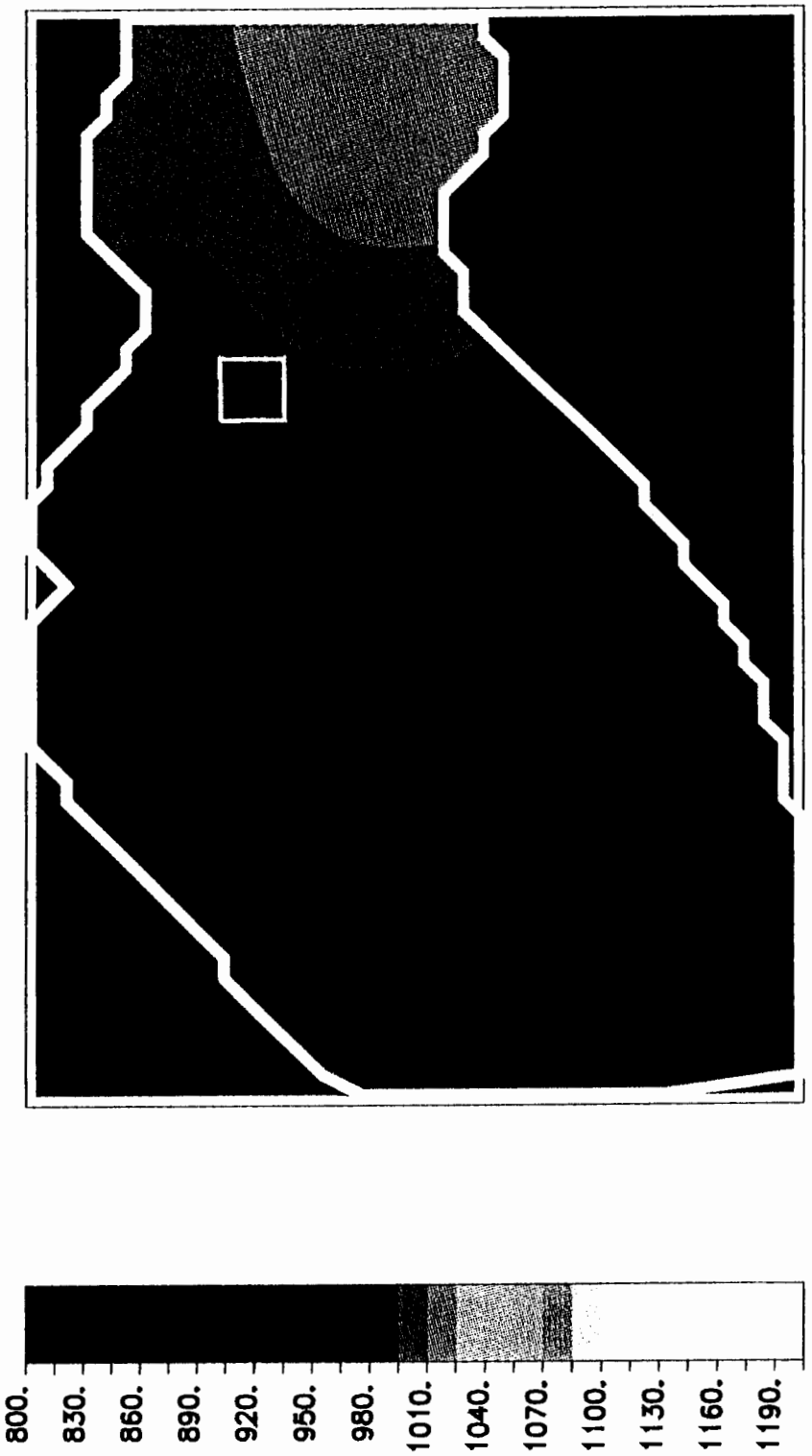


Figure 14

Steady-State Water Table (meters)
Maximum Potential Recharge = 0.01 cm/yr

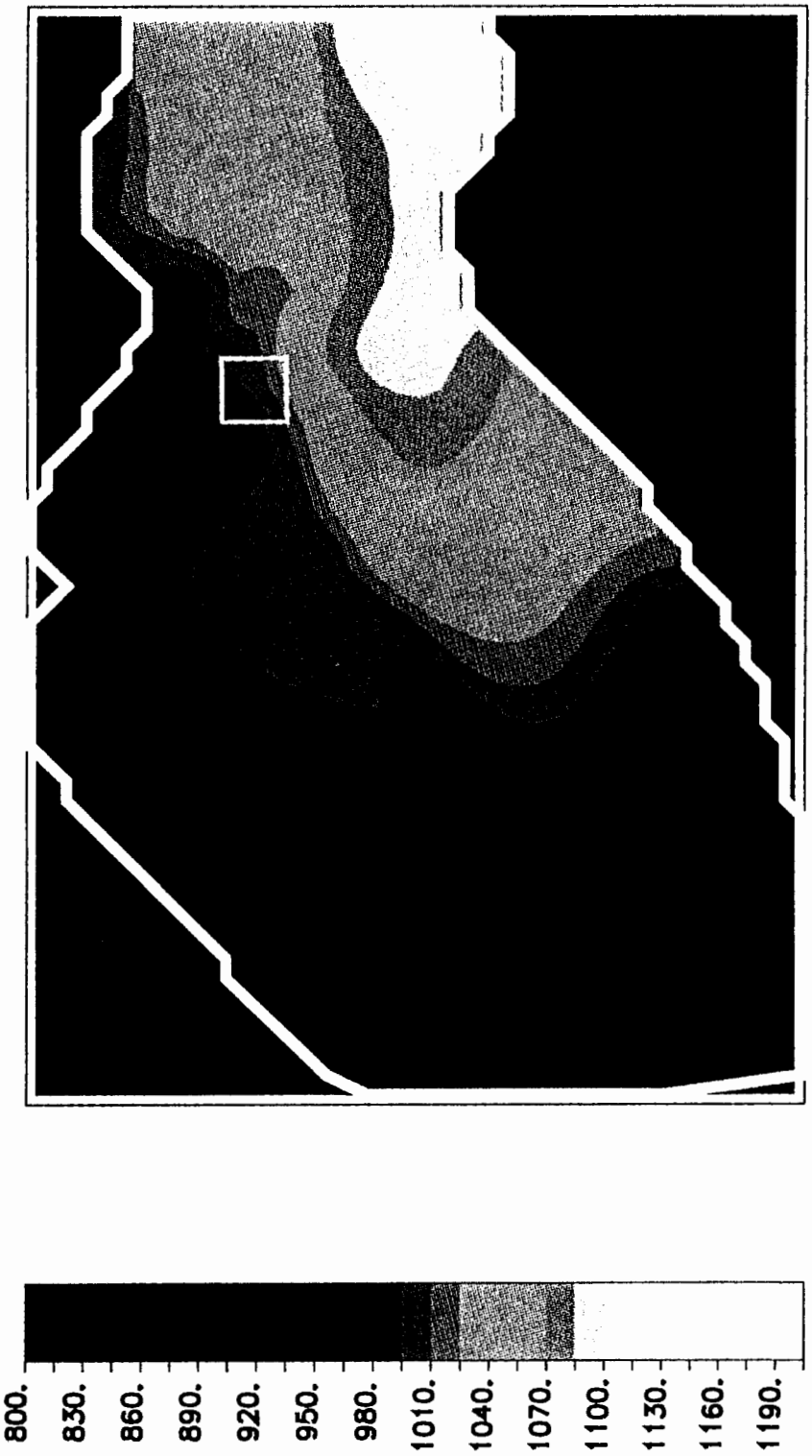


Figure 15

Steady-State Hydraulic Head in the Culebra (meters
Maximum Potential Recharge = 0.1 cm/yr

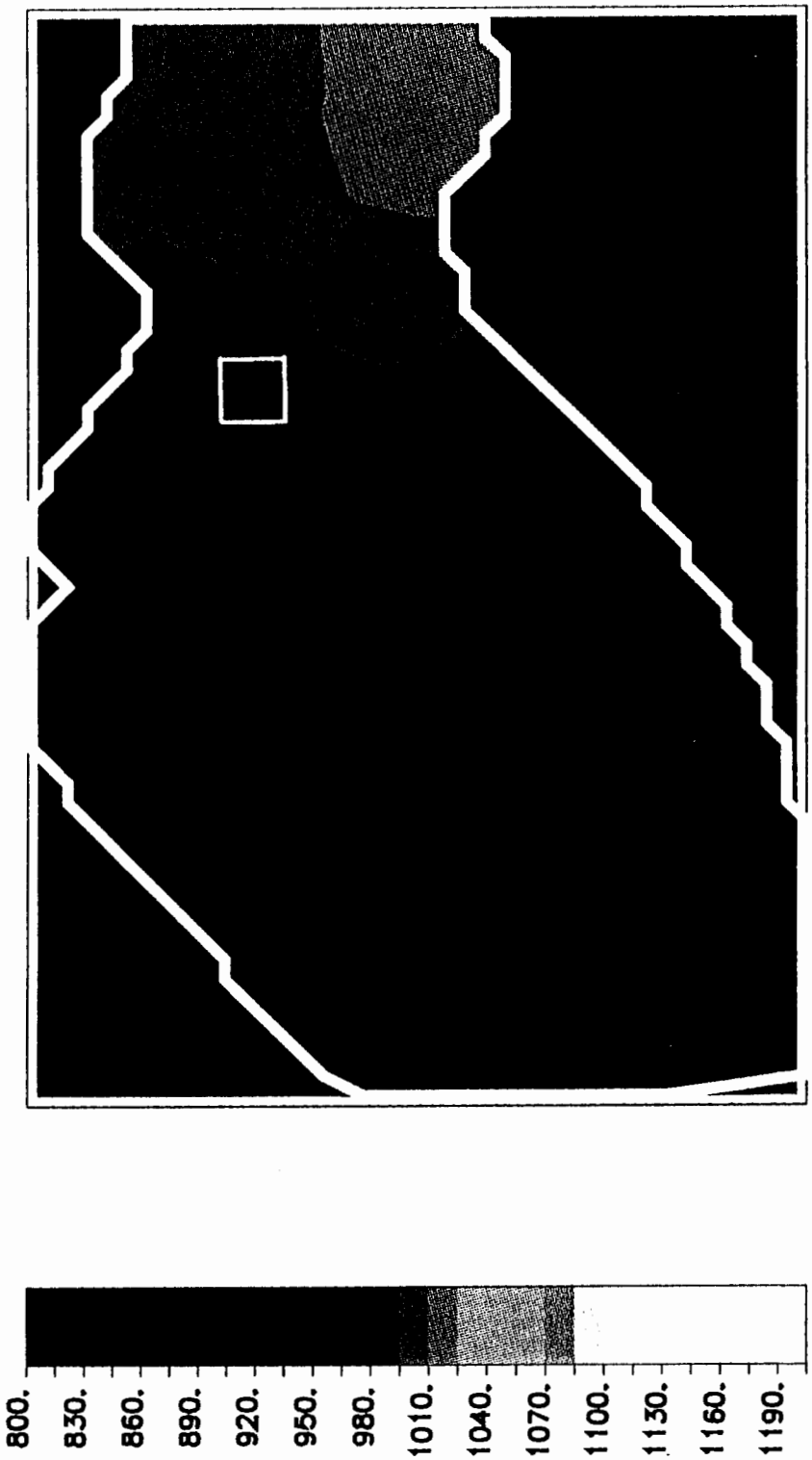


Figure 16

Steady-State Hydraulic Head in the Culebra (meters)
Maximum Potential Recharge = 0.01 cm/yr

Roger Anderson

University of New Mexico

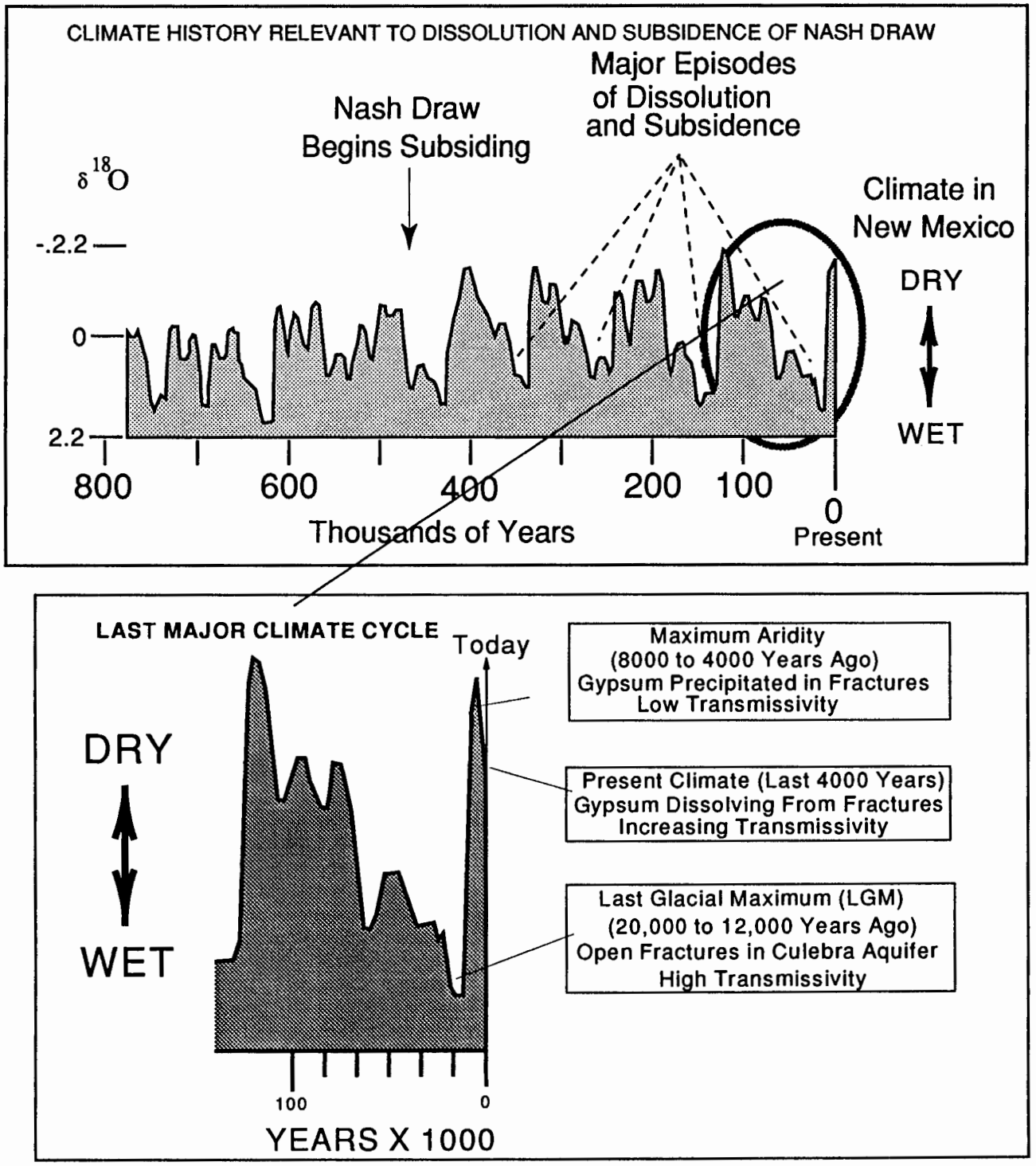
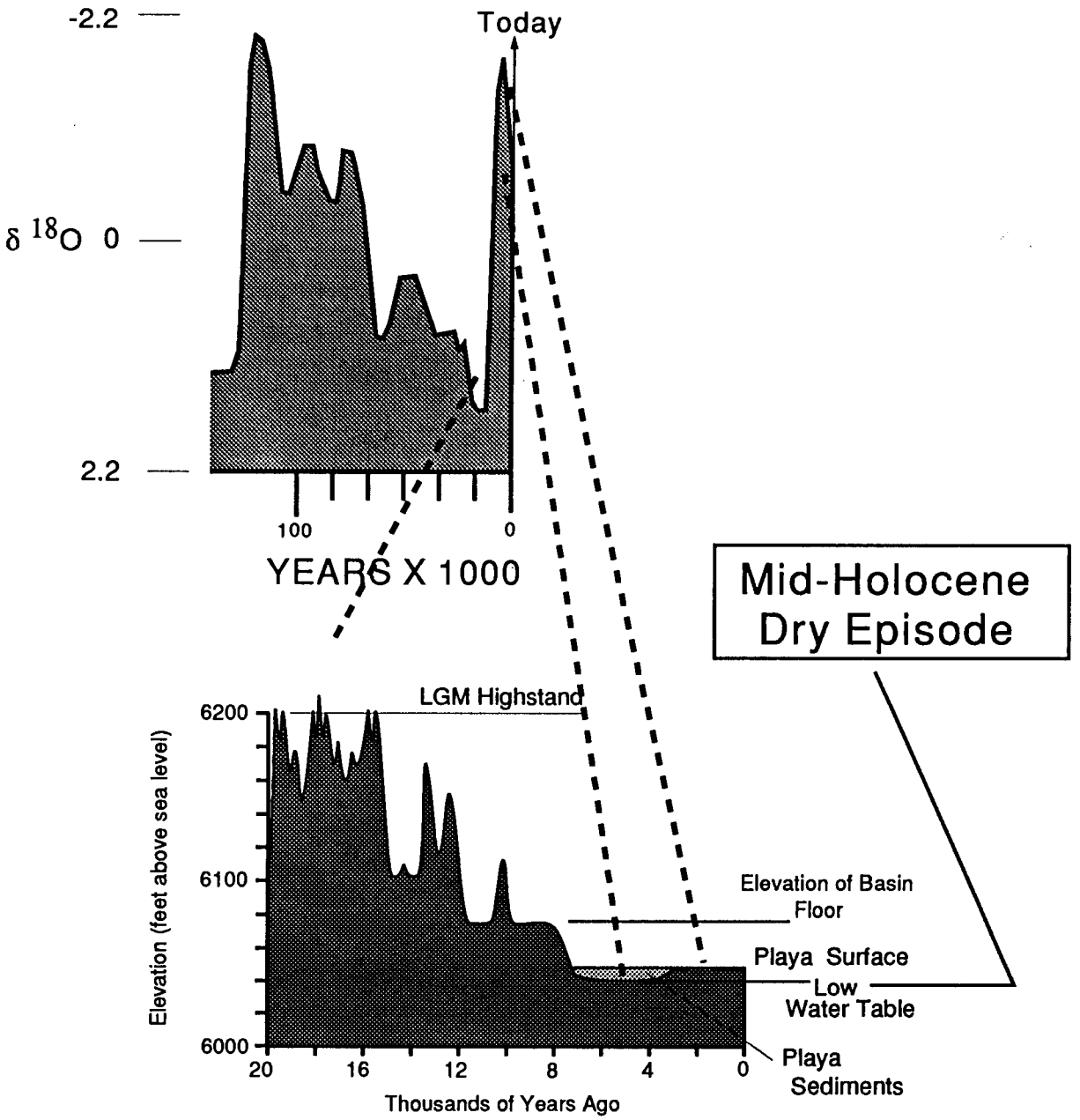
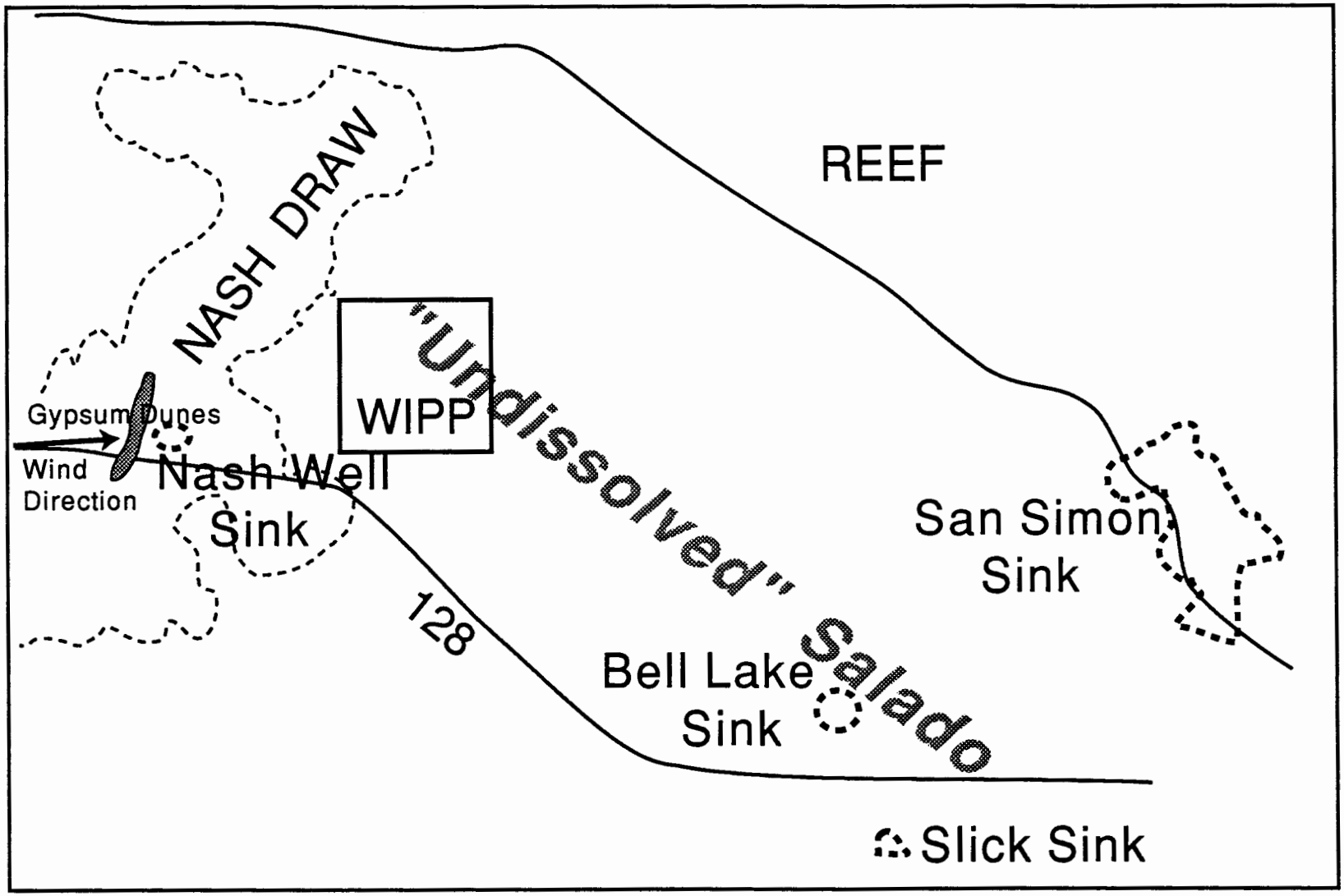
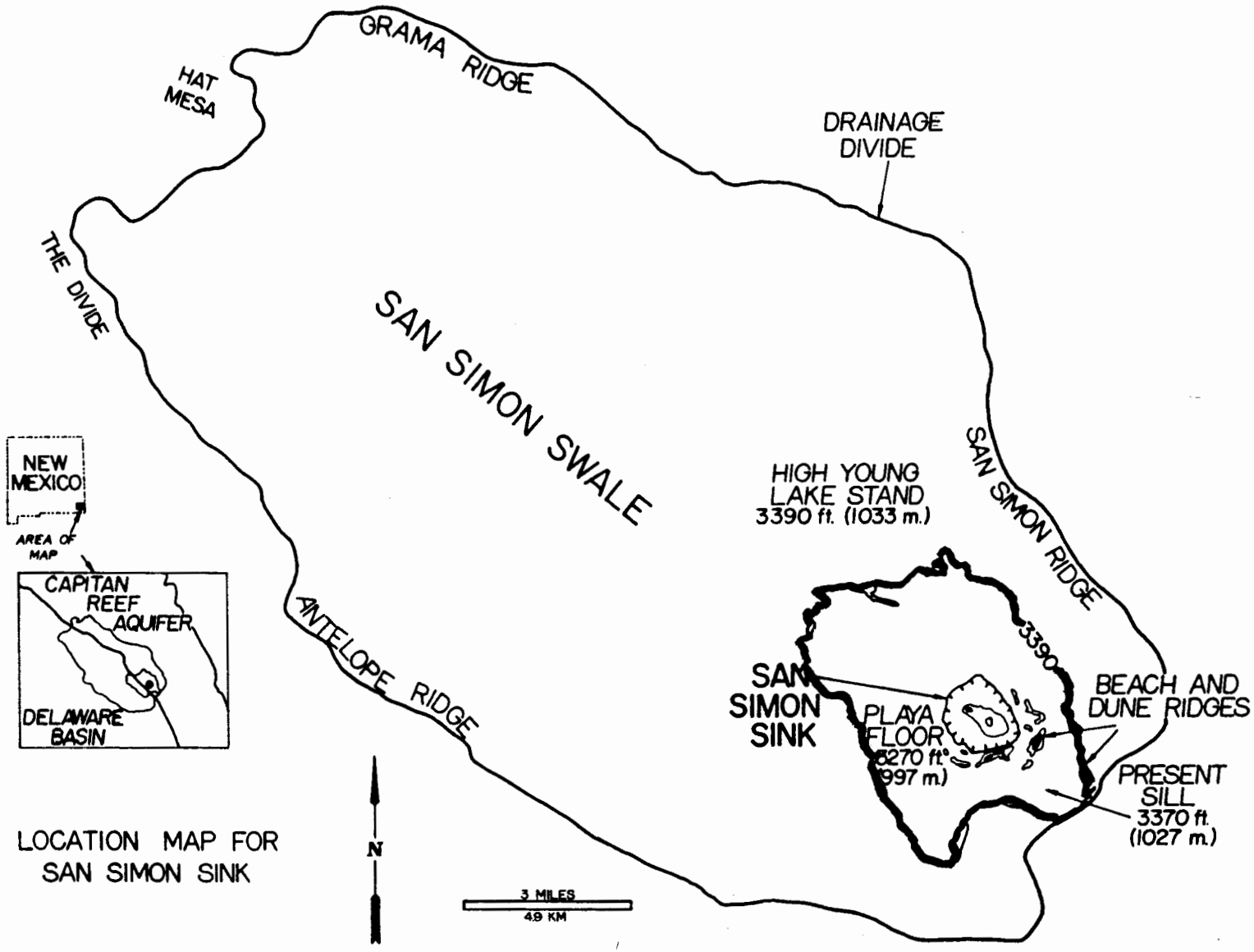


Fig. 3. Wet/dry climate cycles and their effect on the Rustler aquifer in the southern area of the WIPP site. Major climate cycles based on marine isotopic record (see Swift, 1992).

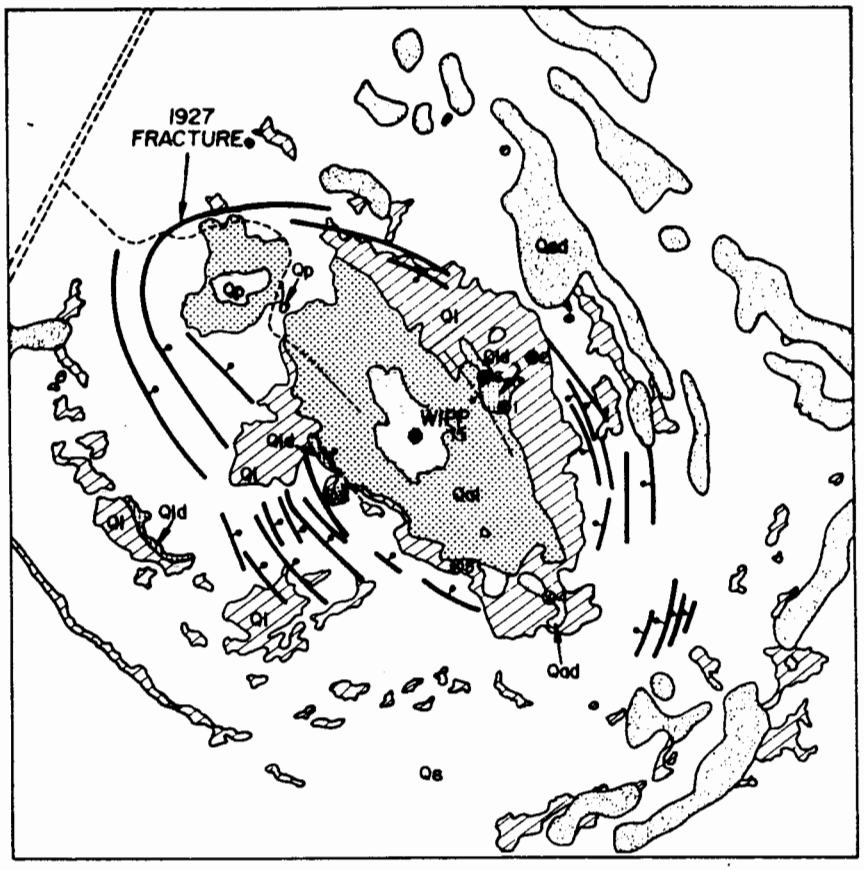

-2.2
Today
δ 18O 0
2.2
100
0
YEARS X 1000
Mid-Holocene
Dry Episode
LGM Highstand
6200
6100
6000
Elevation (feet above sea level)
Elevation of Basin
Floor
Playa Surface
Low
Water Table
Playa
Sediments
20
16
12
8
4
0
Thousands of Years Ago


REEF
NASH DRAW
"Undissolved" Salado
WIPP
Gypsum Dunes
Wind Direction
Nash Well Sink
128
San Simon Sink
Bell Lake Sink
Slick Sink



LOCATION MAP FOR SAN SIMON SINK

FIG. 2



N

6000 Feet

1829 Meters

San Simon Sink Surface Map

Qp — Playa

Qal — Alluvium

Ql — Lake Sediment-buff, grey, green fine stratified lacustrine sands

Qld — Qld-extent of pure laminated diatomite bed

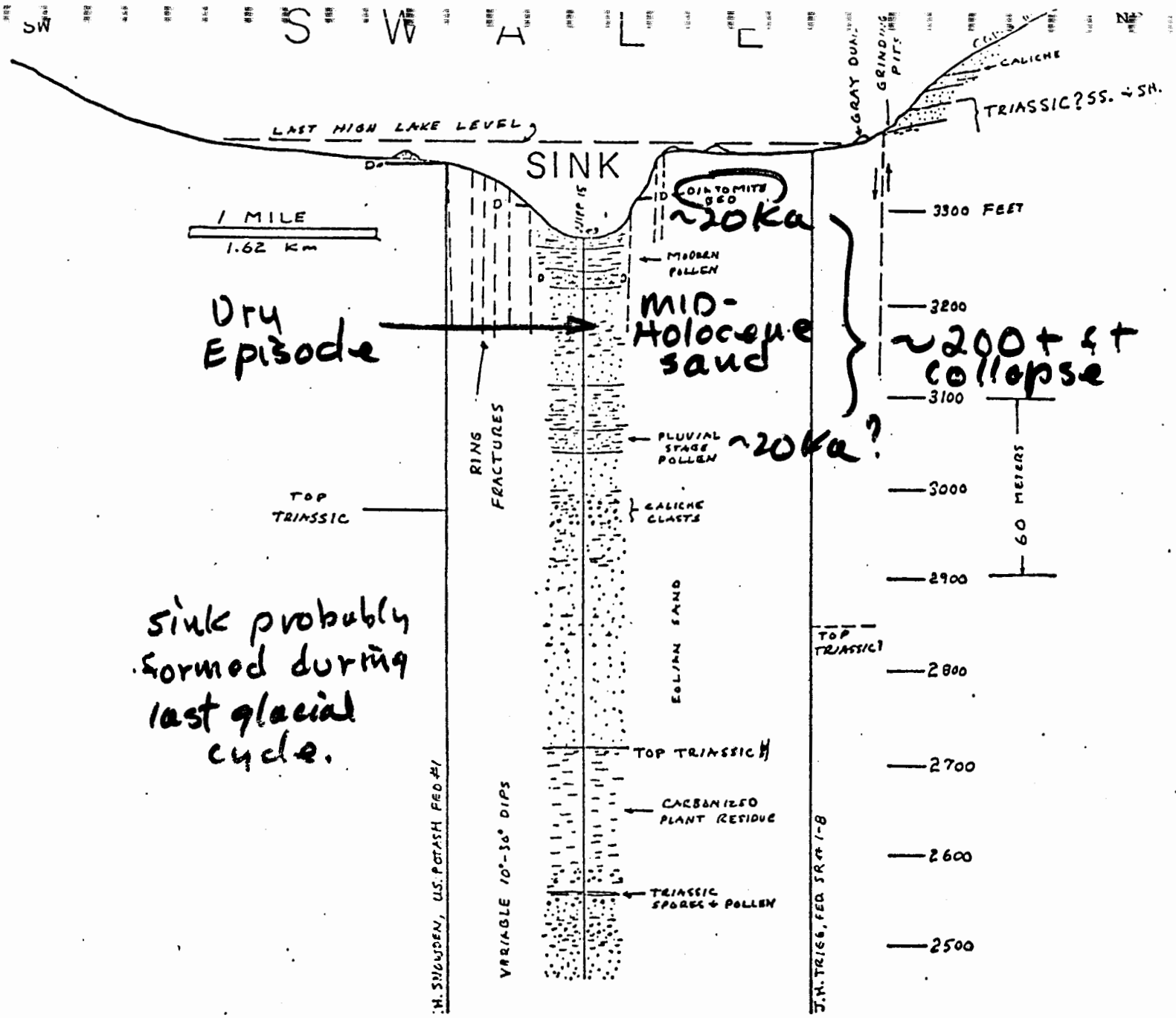
Qad — Active Dunes-white unconsolidated eolian sands

Qsd — Stabilized Dunes-vegetated brown eolian sands

Qs — Soil-sandy loam

Faults

Location of stratigraphic section



sink probably formed during last glacial cycle.

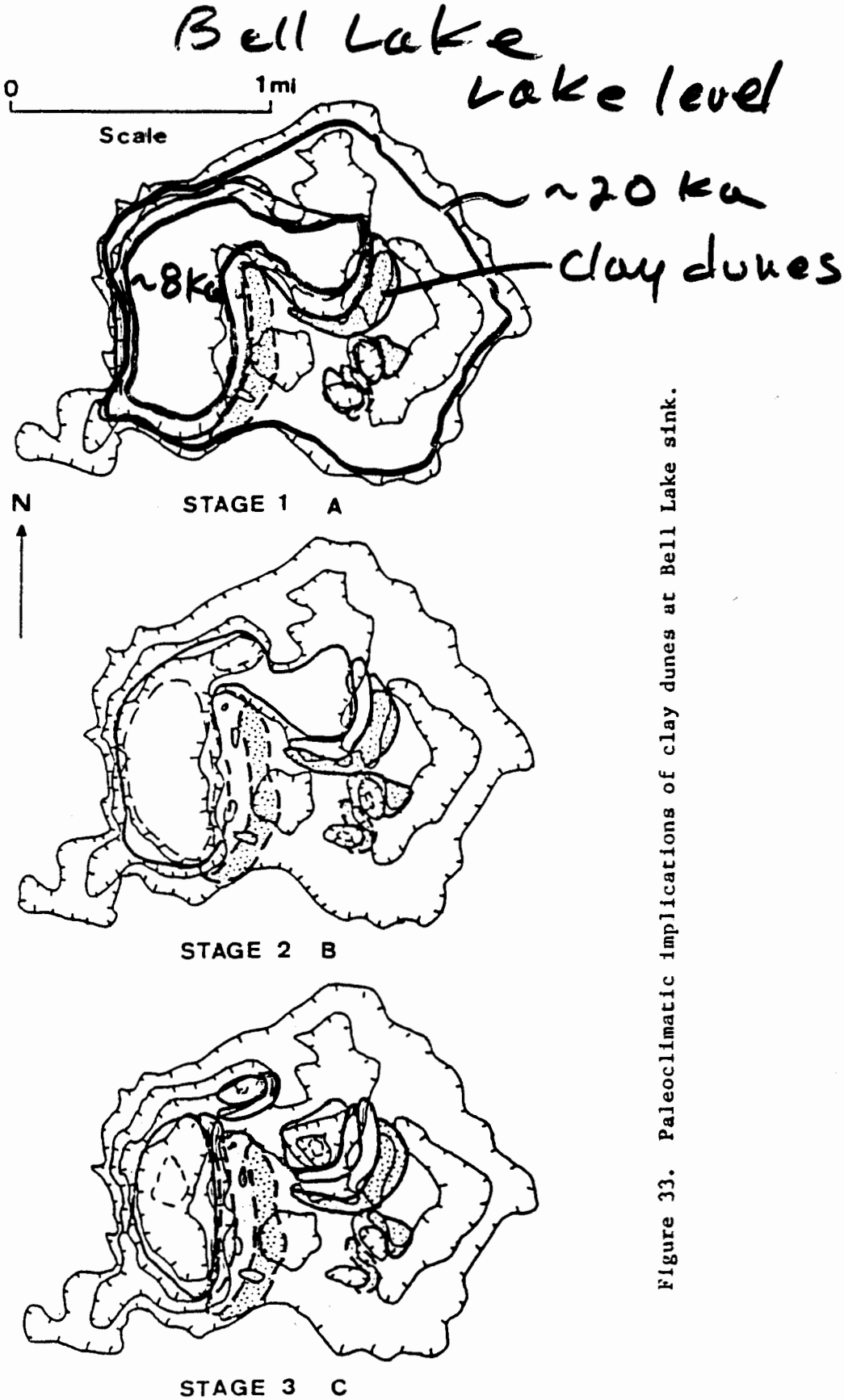


Figure 33. Paleoclimatic implications of clay dunes at Bell Lake sink.

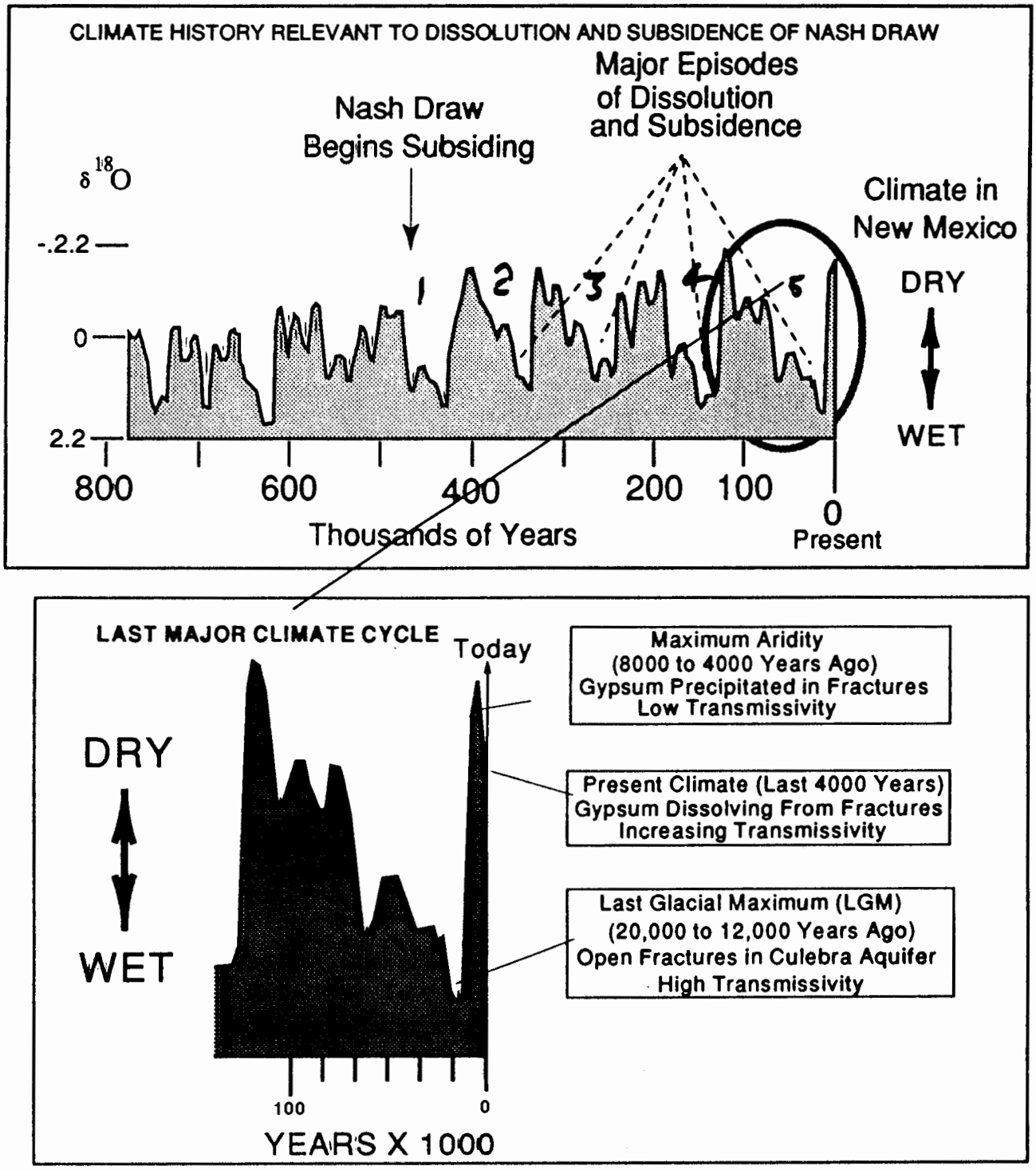


Fig. 3. Wet/dry climate cycles and their effect on the Rustler aquifer in the southern area of the WIPP site. Major climate cycles based on marine isotopic record (see Swift, 1992).

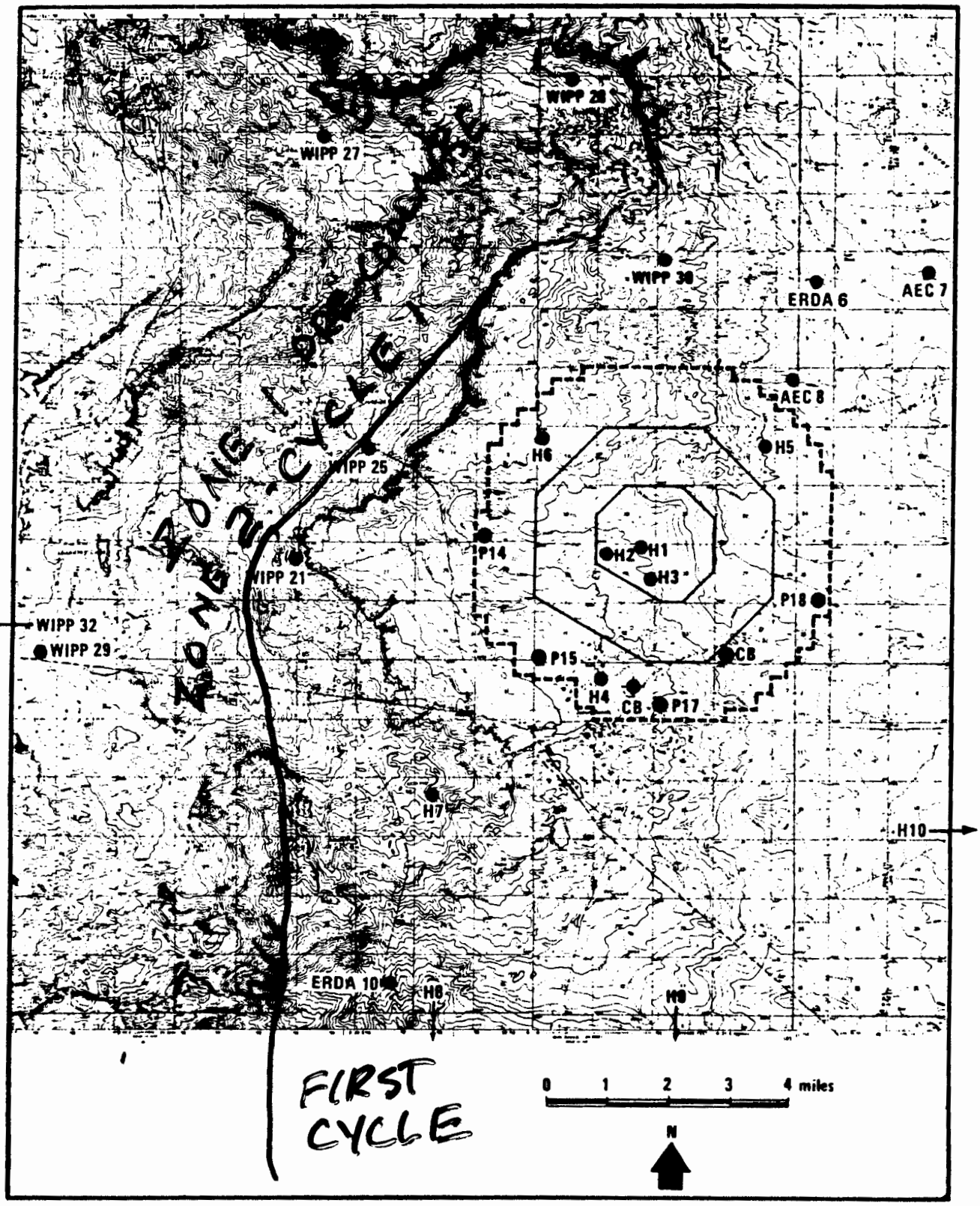


Figure 7-35. Location of drill holes used for hydrologic testing.

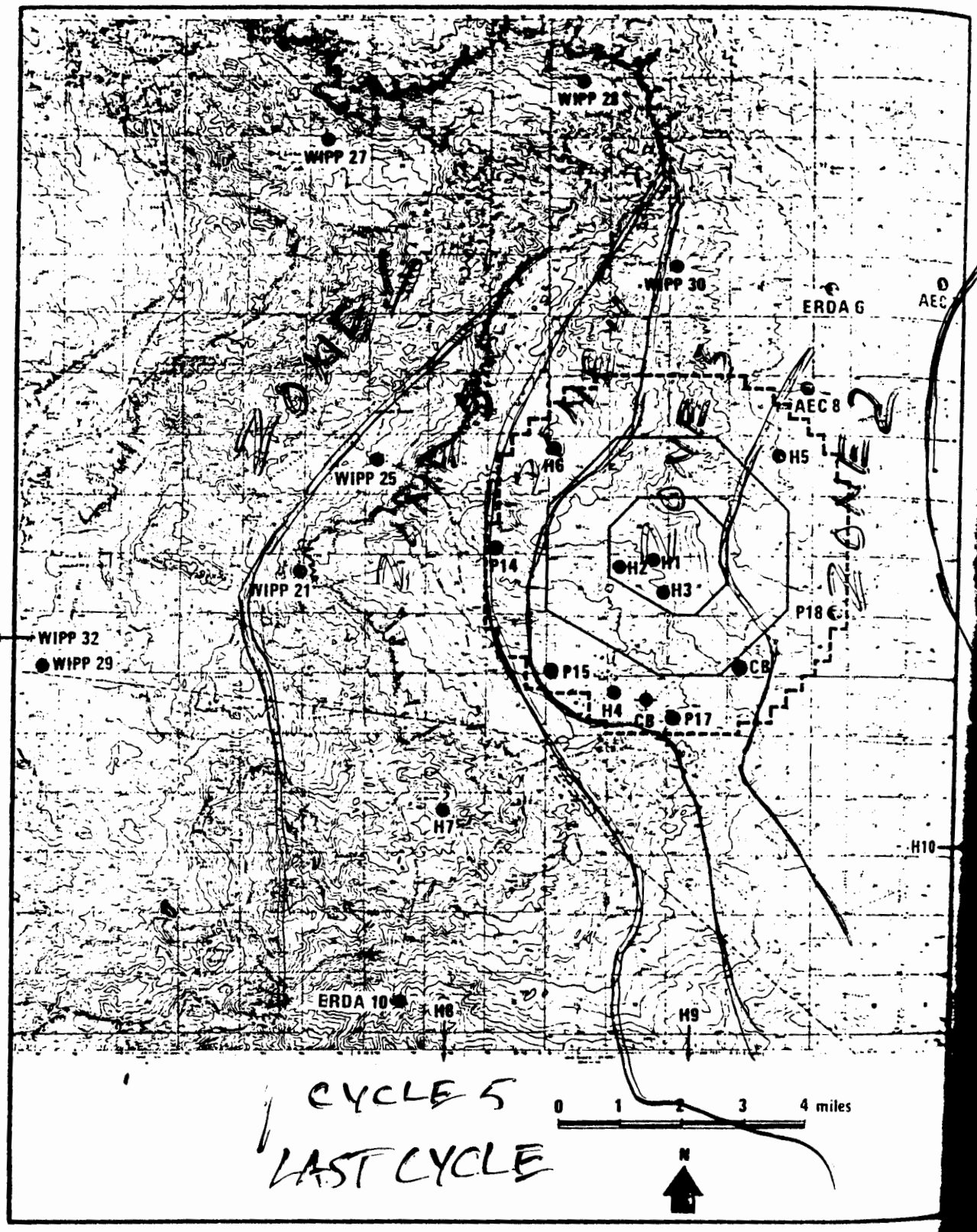


Figure 7-35. Location of drill holes used for hydrologic testing.

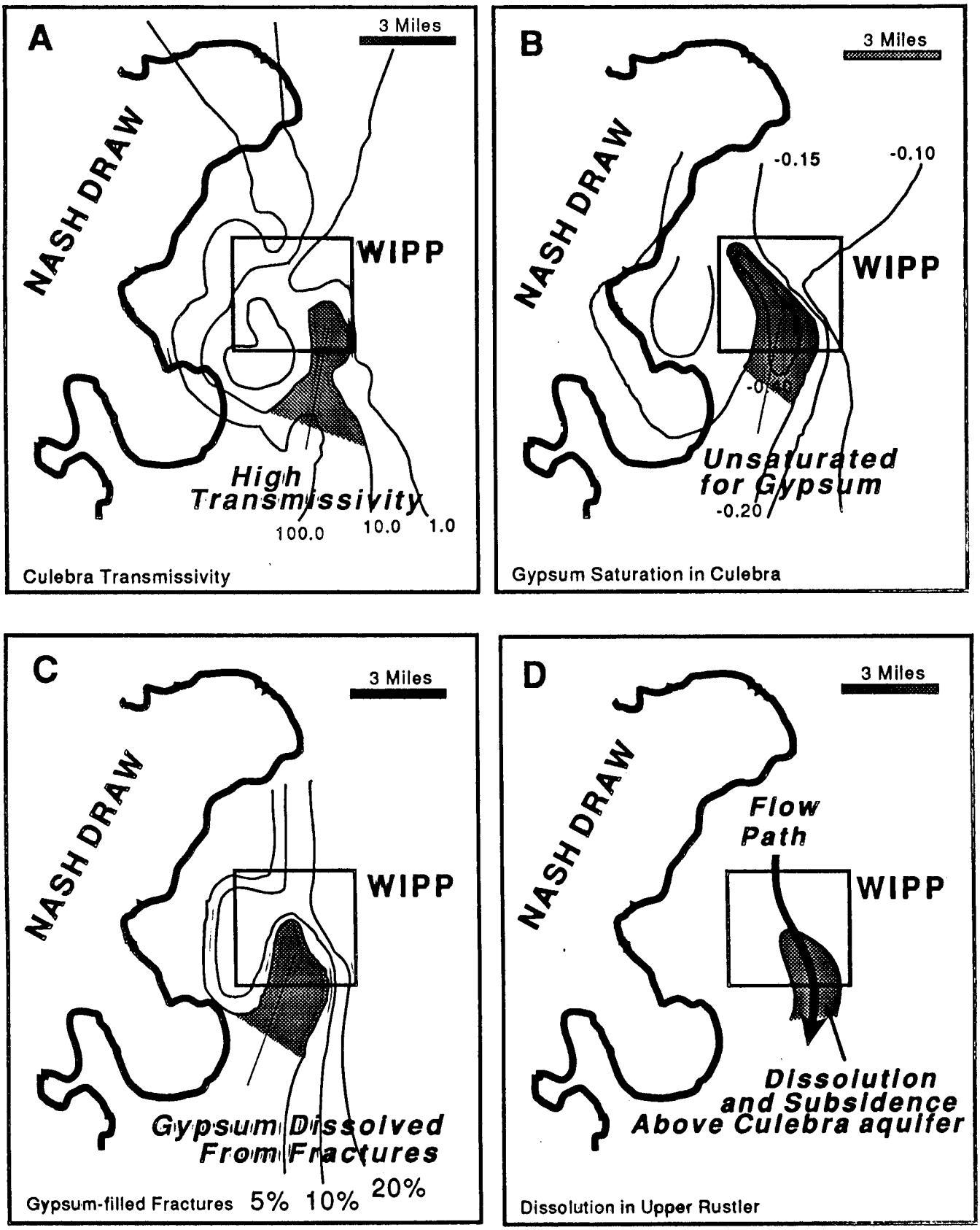


Fig. 2. Expression of active dissolution in the southern area of the WIPP site. Adapted from Beauheim and Holt (1990).

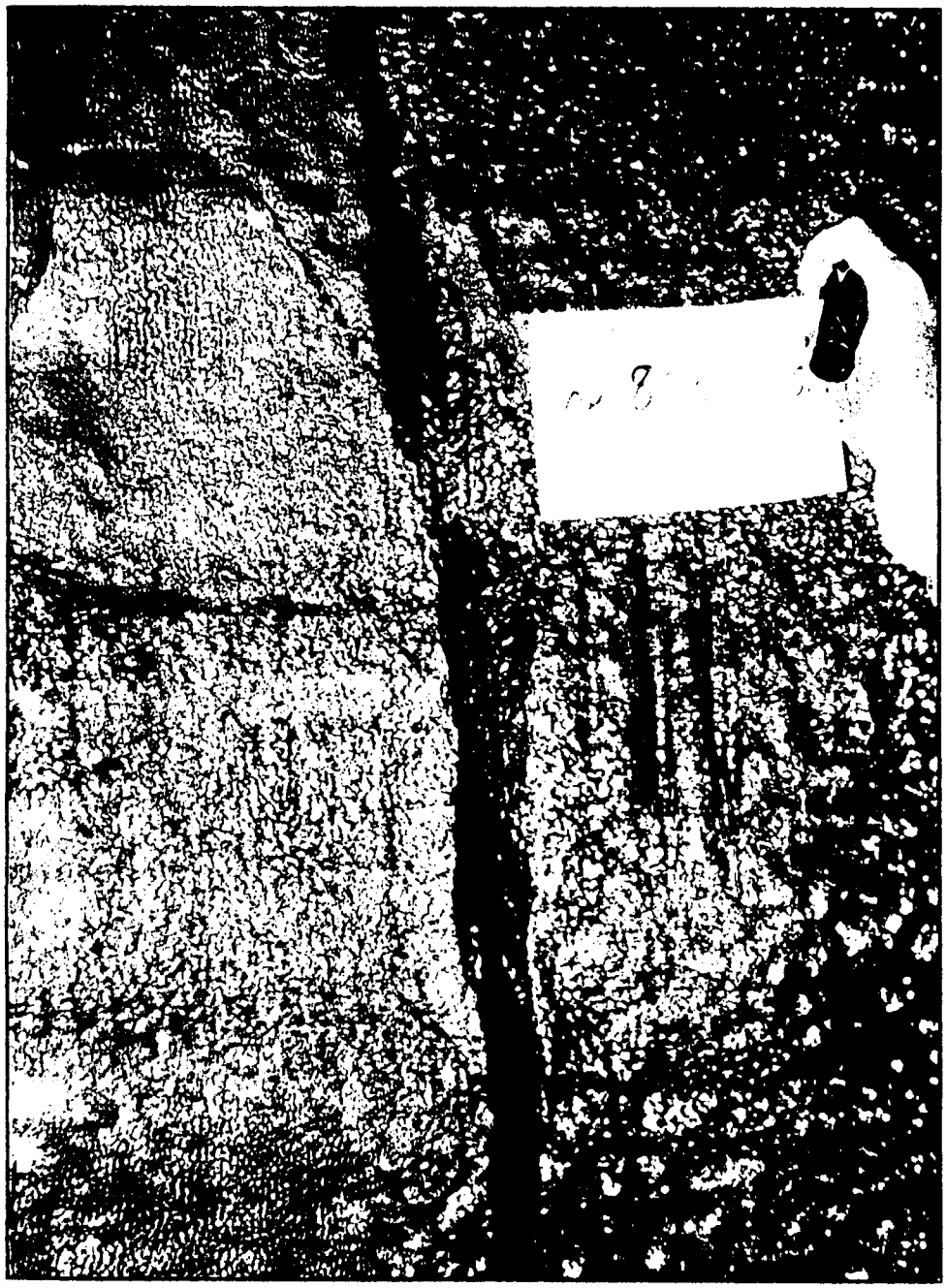


Figure 2. Fracture enlarged by groundwater flow and dissolution in unnamed lower member (anhydrite) of Rustler Formation. Fracture is in the wall of the main waste-handling shaft at the WIPP site (from Chaturvedi, L., and Channel, J. K., 1985).

Effects of Climatic Change on Stability of the WIPP Site

CONCLUSIONS

Timing of Dissolution

1 Nash Draw migrated eastward during the last 5 major glacial-interglacial cycles.

2 Active dissolution and eastward migration occurred mainly during the moist (glacial) phase of glacial-interglacial cycles when high recharge and the movement of undersaturated waters maintained a network of open fractures.

3 Dry interglacial climatic conditions were accompanied by greatly reduced recharge, lower hydraulic head, and by the filling of voids and fractures with gypsum cement.

4 The last major episode of dry climate and fracture filling occurred between ~8000 and ~4000 years ago.

5 Dissolution eastward of Nash Draw (San Simon Sink, Bell Lake Sink) appears to have occurred mainly during the last glacial cycle.

CONCLUSIONS

Localization of Dissolution

1 Localized dissolution and collapse within the undissolved area of the basin (Bell Lake Sink, Slick Sink) probably involves the Rustler aquifer and represents an early stage in a continuous process. Nash Draw represents a late stage.

2 A "finger" of dissolution and area of high transmissivity is working northward toward the center of the WIPP site from the southeastern lobe of Nash Draw.

3 The localized area of open fractures and high transmissivity which extends north to south across the WIPP site has resulted from the movement of undersaturated waters and dissolution of gypsum cement, probably since the end of the last major dry episode ~4000 years ago.

4 Gypsum cement in fractures probably will continue to dissolve within areas of high transmissivity under present climate conditions. The dissolution of cement from fractures can be expected to accelerate with an increase in precipitation, thereby changing the properties of the aquifer.

5 The high transmissivity typical of Zone 4 (Beauheim and Holt) probably will extend completely across the WIPP site during the moist phase of the next glacial-interglacial cycle.

CONCLUSIONS

Projection of Consequences

1 The 10,000-year period of institutional responsibility for transuranic waste disposal is based upon the reasonable assumption that a geological site, demonstrated to be stable for 10,000 years, will probably be stable for an even longer interval of time.

However, *this assumption is not valid for the WIPP site and the Rustler aquifer because of the known response, and rate of response to past changes in climate.* It is virtually certain that the present physical geometry and flow properties of the Rustler Aquifer above the repository will not survive the next moist glacial cycle.

2 Projections of consequences for 10,000 years, based on hydrologic models which increase only the rate of recharge and hydraulic head for the Rustler aquifer, will be inaccurate owing to the continuous removal of gypsum cement from fractures under present climate conditions and under projected increases in precipitation.

3 The Rustler aquifer will not be an effective barrier in breach scenarios after 10,000 years.

Recommendation

The 10,000-year period of institutional responsibility for the WIPP repository, because of the long half life of transuranic wastes, and because of the site's vulnerability to the effects of dissolution, should logically be extended through the next glacial cycle (~50,000-100,000 years).

Anderson to Lovejoy, Comments on CSR,DOE/WIPP 94-019; 14 July, 1994

"Deep Hydrology" Issues

6.1.1 A Breccia pipes (closed)
6.1.1 D Brine weeps and seeps (open)
6.1.1 E Dissolution (closed)

The report contains several inaccuracies about the distribution of breccia pipes and their relation to hydrology. Breccia pipes ***are*** found within the basin and they are ***not*** restricted to the area above the reef. The occurrence of a breccia pipe within the basin was reported by Anderson and Kirkland (1980) and a photograph of collapse breccia in that pipe was featured on the cover of the national journal which published the reviewed article. The abundant *limestone buttes* (castiles) that are exposed in Culberson County are another example of breccia pipes or chimneys within the basin. All of these vertically penetrating features have a small cross section and the statement that none occur in the vicinity of WIPP would require supporting evidence that the geophysical methods used to explore the WIPP site area were capable of identifying such features. Equally important as their occurrence within the basin, is a lack of understanding about how such collapse features formed and how they are related to the hydrology of the basin.

Other collapse structures found within the basin are Bell Lake Sink and Slick Sink, which occur east of the WIPP site and within an area of the basin where there is no evidence for regional dissolution. No one disputes that these are collapse structures but there is no information about the depth of these structures, about which geologic strata were dissolved to produce the collapse, or about the hydrologic conditions that caused the collapse. It is entirely conceivable, and in fact likely, that the collapse extends downward at least to the Rustler aquifer. The large diameter of Bell Lake Sink, a collapse structure which pre-dates the climate change of the last glacial maximum (LGM), and geochemical evidence for the upward movement of deep formation fluids (Hill, 1993), suggest that Bell Lake Sink is a deep structure. Some information on Bell Lake Sink is in a UNM MS thesis by R. Widdicombe, but the origin of this collapse feature, *within the basin*, has been largely ignored during the characterization of WIPP.

The implications of having a deep, localized collapse structure within the "undissolved" region of the Delaware Basin should not be

underestimated. For example, if the structure is rooted in the Rustler aquifer it would mean that fluids moving through the Rustler have produced localized dissolution and collapse well beyond advancing regional fronts of dissolution. Bell Lake Sink contains a high lake stand that probably reflects climate changes during the LGM. The possible renewal of localized collapse before or during the LGM has important implications for the local stability and hydrology of the site under a wetter climate regime and is therefore related to the "closed" issue of climate change. Climate issues are also related to the question of karst and surface hydrology, discussed later.

Still another question related to "deep" hydrology, is the character and origin of the west-to-east, upslope-to-downslope hydrologic communication that is known to exist within the body of Salado evaporites within the Delaware Basin. This hydrologic condition was recognized long ago by Hills (1968), evidence was presented by Anderson (1981, and in several reports to Sandia Laboratories), and EEG has confirmed the validity of the evidence. Possible consequences of having moist salt is the unexpectedly fast rate of salt creep and room closure (see issue 6.1.2 B.2) and increased brine seepage (see issue 6.1.3 F).

The repository is already built and it is too late to use information about this largely unknown hydrologic system for site selection. However, it is not too late to characterize the hydrology and to use this understanding in order to provide more reliable estimates of brine seepage and room closure, issues that are vital to PA. For the reasons cited above, I do not consider dissolution or "deep dissolution", breccia pipes, or brine weeps and seeps to be resolved issues.

"Surface Hydrology" Issues

The remaining issues are closely related to one another and to the larger issue of karst, which DOE claims is resolved.

6.1.1 G Karst
6.1.1 I Paleoclimate and climate change
6.1.3 A Focus on Culebra Dolomite
6.1.4 F Climate change

Karst

History of the Karst Issue

In 1975, after complex structures and a pressurized brine reservoir were encountered at the first WIPP site , the project moved westward to the Los Medaños site along the eastern margin of Nash Draw. Approximately half of the halite in the Rustler Formation was missing at this site (CSR Fig. 2-8). It soon became apparent that dissolution by near-surface ground waters had removed the halite along the eastern margin of Nash Draw (Fig. 1), which borders the WIPP site on the west. Nash Draw is one of the largest karstic dissolution structures with surface expression in North America. Geologic features and surface hydrology around the site clearly are expressions of the kinds of geomorphic features and groundwater flow regimes that geologists, world-wide, refer to as karst.

The issue of surface dissolution and karst was originally investigated to determine if rates of regional dissolution and erosion were sufficient to breach the repository. Although suberosion is too slow for a breach, dissolution does pose a threat to the Rustler aquifer. The CSR separates the issues of karst and dissolution and minimizes its use the term karst in describing the processes of dissolution at the site that effect the Rustler aquifer. The CSR uses the term karst for the deep dissolution troughs that occur in the central and southern part of the Delaware Basin and which contain thick sequences of early Pleistocene Gatuña Formation.

The CSR cites the absence of visible karstic surface features at the WIPP site as DOE's main reason for closing the issues of both karst and surface dissolution. The CSR acknowledges the importance of karst, were it to exist at the WIPP site, but closes the issue by stating that "...karst formation is not a process at the WIPP site which will result in significant compliance-related consequences."

The absence of visible karstic surface features such as sink holes, however, is <u>not</u> evidence that the Rustler aquifer is unaffected by dissolution. The moderate thickness of halite and gypsum strata in the Rustler Formation precludes the development of large, visible collapse structures at the surface until late stages of dissolution. In addition, a cover of dune sand at WIPP obscures any surface expression of smaller karst features such as swallow holes. As will be discussed, there is ample evidence that dissolution is an active process at the WIPP site and the issue of near-surface dissolution(karst) is critical to the effects of climate change on the performance of WIPP.

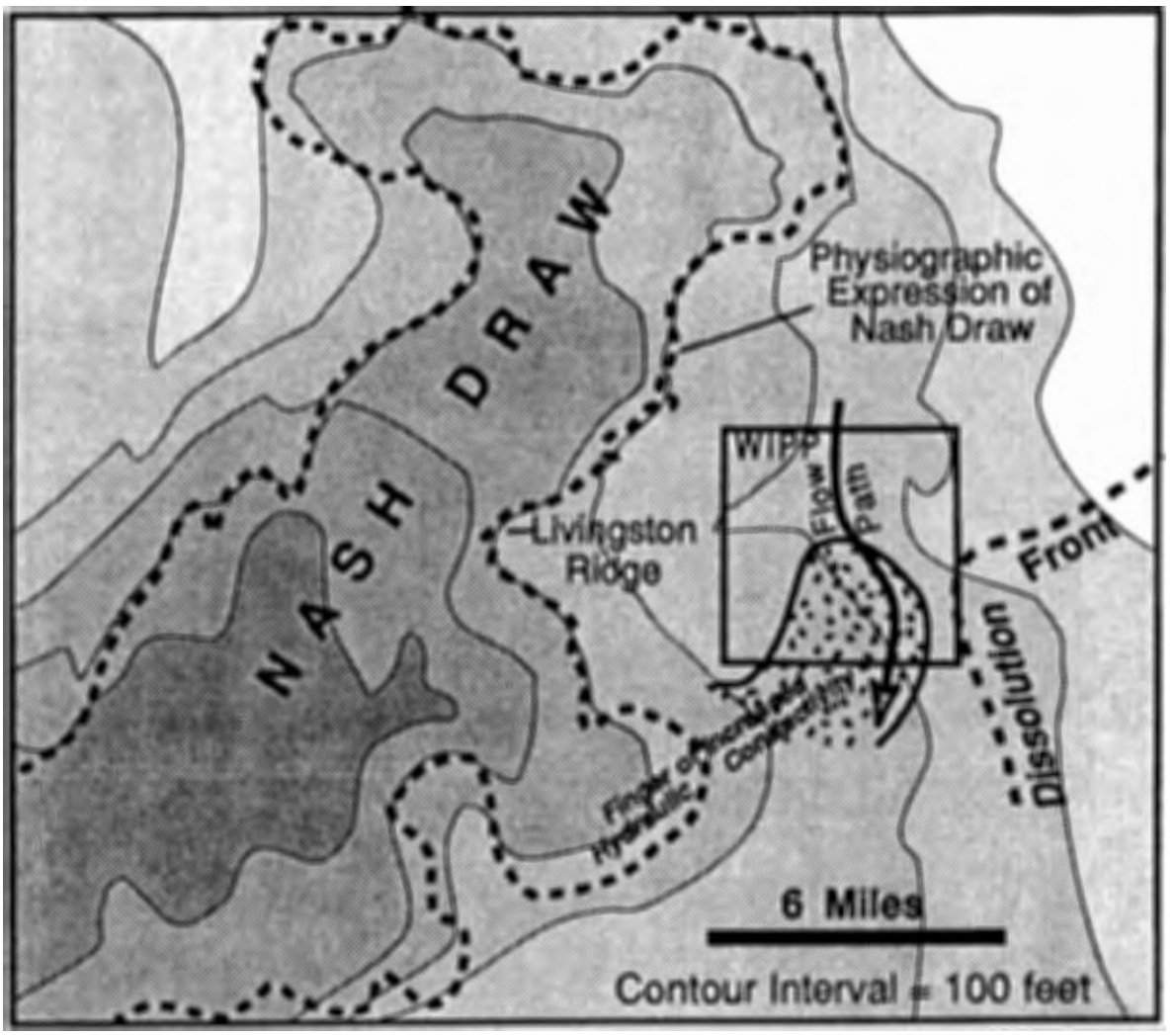


Fig. 1. Location of Nash Draw in relation to WIPP site.

Dissolution, beginning along the axis of Nash Draw, has moved about 10 miles eastward and over the WIPP site to the present position of the dissolution front. Dissolution moved eastward in a series of pulse-like episodes controlled by changes in climate (see Fig. 3).

Notice that the main flow path in the Rustler aquifer and the local area of increased hydraulic conductivity in the southern part of the WIPP site occur as a northward extension of the southeastern lobe of Nash Draw.

Subsiding and expanding topographic depressions, such as Nash Draw, are typical of karst regions and a karstic hydrology.

Age of Dissolution

Although the CSR makes little mention of the age of dissolution in the area of WIPP, other publications by DOE team members (e. g. Beauheim and Holt, 1990) make it clear that most of the dissolution, karst development, and associated fracturing of the Rustler aquifer is believed to have occurred in the Cenozoic. Nash Draw, for example, is considered to be a Cenozoic feature related to the ancestral Pecos drainage and to the deep dissolution troughs in the central area of the Delaware Basin (Beauheim and Holt, 1990). This estimate of the age of Nash Draw clearly is in error because the age of this structure has been adequately dated by tephrochronology as younger than 600,000 years (Bachman, 1974). The young age of Nash Draw is highly relevant because it offers a means for examining the effects of climate change on the progress of dissolution.

The young age of Nash Draw and its growth and development under regional hydrologic conditions that continue to the present day provide a basis for understanding and predicting future dissolution at the WIPP site. For example, Beauheim and Holt (1990) recognize that *"A high transmissivity 'finger' penetrates the southern border of the WIPP site."* This finger is a localized area of high transmissivity in the Culebra aquifer (Fig. 2A). This is the area where test wells that show rapid movement of tracers. It is also the area where groundwater is relatively fresh and unsaturated for gypsum (Fig. 2B), and where gypsum cement in Culebra fractures has been removed by dissolution (Fig. 2C). The "finger" is also the pathway for the most rapid flow in the Culebra and the local site for dissolution of halite above the Culebra (Fig. 2D). Examination of the location and orientation of this finger of high flow, fresher water, and dissolution effects, relative to the configuration of Nash Draw, shows it to be a northeastern extension of conditions that prevail within the southeastern lobe of Nash Draw.

Other geologic features and hydrologic conditions found in the finger and into the central area of the WIPP site are explainable as early stages in the process of karstic dissolution. For example, physical and photographic evidence taken from the main shaft at the center of the WIPP site reveals that fractures in soluble units below the Culebra have been enlarged by dissolution to form flow channels (see Fig. 2 in Chaturvedi and Channel, 1985). The fact that hydraulic conductivity varies by 6 orders of magnitude across the site, as well as the vertical movement of fluids through other stratigraphic units of the Rustler, are conditions that are consistent with karstic dissolution. Some wells in the finger, such as H-11, show high transmissivities and rapid movement of tracers, while other nearby wells

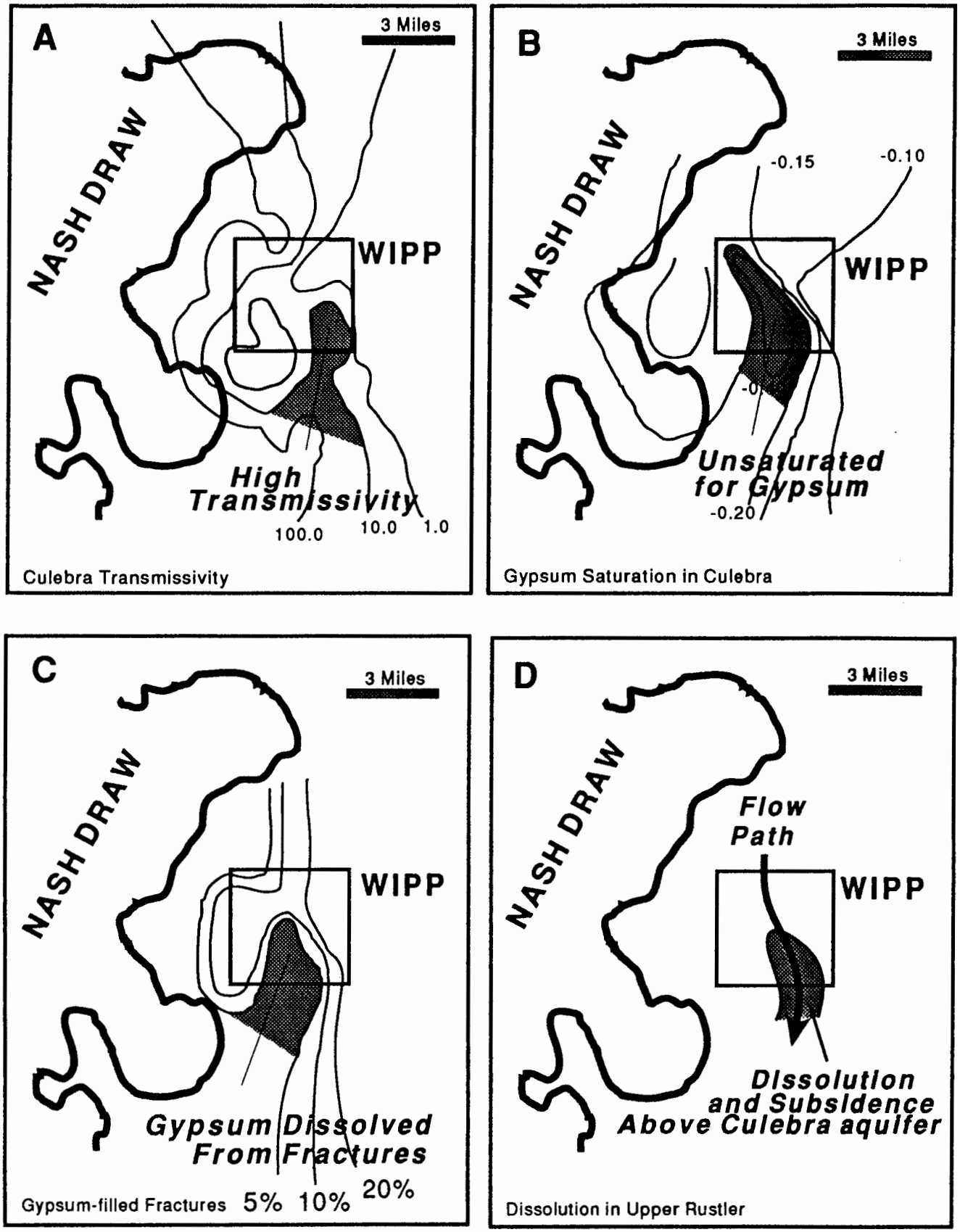


Fig. 2. Expression of active dissolution in the southern area of the WIPP site. Adapted from Beauheim and Holt (1990).

have very low transmissivities. This is precisely what one would expect to find under conditions of developing karstic dissolution.

Present models adopted for the WIPP PA assume only fracture flow in the Culebra, and as will be discussed, a correct understanding of the evidence for dissolution is necessary for the development of valid hydrologic models. In this regard, it is pertinent that a team of international experts, reviewing WIPP hydrologic models, has suggested the use of alternate "fracture channeling models" (see Beauheim and Davies, 1992), thereby acknowledging that the aquifer has developed flow channels and has adjusted to an early stage of karstic development.

Interpreting the "finger" as an advancing extension of the karst hydrology of Nash Draw follows logically from the young age of Nash Draw and from its history of eastward expansion and migration during past episodes of climate change. The response of Nash Draw and adjacent areas to the effects of climate change are critical to predicting the future performance of WIPP.

Climate Change

The CSR contains a meager summary of climate issues and gives conflicting statements, saying in one section that the issue of climate change is open and in another that the issue is closed (12-7 vs 12-24).

I have emphasized the issues of karst and dissolution because placing the WIPP in a region of developing karst carries with it profound implications for the stability of the site under conditions of variable climate. Problems related to site stability and hydrology are different in character and more acute in a region of soluble strata that continues to be affected by changes in climate.

A brief geologic history of Nash Draw illustrates the problem of long-term site stability. Nash Draw (Fig. 1) formed sometime after a thick surface-layer of soil carbonate (Mescalero "caliche") developed over the region of WIPP. The Mescalero unit is about 500,000 years old. The first stage of dissolution and subsidence was centered in the present axis of Nash Draw and during the last 500,000 years dissolution and subsidence has expanded laterally under a highly variable climate, creating the present topography and reaching the present edge of the regional dissolution front (Fig. 1). Today, the topographic or physiographic expression of Nash Draw resembles a very large dog bone (Fig. 1). In the southeastern corner of Nash Draw, dissolution and

subsidence have outflanked Livingston Ridge and the effects of dissolution have encroached upon the WIPP site from the south (Fig. 1).

Dissolution and eastward expansion of Nash Draw occurred mainly during a series of four strong perturbations in climate that occurred in the latter part of the Ice Age and Nash Draw migrated eastward during a series of dissolution episodes, each separated by dry intervals of lesser dissolution, such as the dry episode of the last 12,000 years (Fig. 3). The average amount of precipitation in New Mexico during these major climatic episodes is believed to have increased to more than double its present value. Precipitation during moist episodes also occurred in short pulse-like events of even greater precipitation (Allen and Anderson, 1992). The pulse-like character of these events may have increased the effectiveness of infiltration into karstic systems, thereby facilitating dissolution during moist episodes.

The finger of anomalous hydraulic conductivity in the southern part of the WIPP site, referred to earlier, is also the main flow path through the Culebra aquifer. One can anticipate that during the next major climate cycle of increased precipitation, dissolution will expand along the finger, advance northward, dissolve what remains of the halite in the Rustler Formation, and dissolve some fraction of the upper Salado at the interface between the Rustler and Salado salt (brine aquifer).

A precursor to the path that dissolution is expected to take in the future can be seen, as well, in the distribution of the secondary gypsum in fractures in the Culebra aquifer (CSR Fig. 2-12). To appreciate the significance of this pattern, and the importance of the effects of climate change, it is helpful to describe the process of re-solution of gypsum in stages, as follows, and as depicted in Fig. 3:

1. Creation of a system of open fractures in the Culebra aquifer during episodes of high flow prior to 12,000 years ago.

2. Plugging of the open-fracture network by precipitation of secondary gypsum in fractures during a period of reduced rainfall and infiltration, and low hydraulic head in the WIPP area. This warm dry climate episode occurred in the American Southwest about ~ 8000 to 4000 years ago.

3. Beginning about 4000 years ago, re-solution of secondary gypsum from fractures in the Culebra aquifer occurred after the regional climate changed from dry to the moderately moist conditions of the present day.

4. Development of a localized pattern of open fractures that corresponds, approximately, with the modern flow path through the Rustler aquifer (Figs. 1, 2, and see Fig. 26 in Beauheim and Holt, 1990).

The effects of the above climate-driven cycle of solution, deposition, and re-solution can be seen in the present-day pattern of open fractures in the Culebra (Fig. 2C, and see CSR Fig. 2-12). This localized pattern corresponds to the area of variable and high hydraulic conductivity, to the area of anomalous tracer tests, and to the main flow path (Fig. 2D).

DOE, as outlined by Swift (1992), has correctly identified a climate history for the WIPP area that is essentially as illustrated in Fig. 3. The CSR, however, does not link this history to dissolution and related changes in the Rustler Formation. The effect on dissolution by the moderate changes in climate that occurred during the last 10,000 years, as shown in stages 1-4 above and in Fig. 3, leads to several observations regarding the effects of larger changes in climate expected in the future.

1. *Adjustments of the Rustler aquifer to past changes in climate can be used as a predictor of patterns of dissolution and structural adjustments during future changes in climate.*

One can predict that the dissolution front will migrate further eastward and most if not all the remaining soluble beds will be removed from within the Rustler. More important for the performance of WIPP, however, will be the flanking movement of dissolution that extends from the southeastern lobe of Nash Draw. This route will bring active dissolution to the center of the WIPP site shortly after a major change in climate and before the remaining halite in the Rustler Formation is removed along the regional dissolution front.

2. *Changes in climate result in rapid adjustment of the aquifer to the altered climate state.*

Evidence for this observation is considered in later paragraphs.

3. ***Predictive models based on hydrologic data collected from the existing Rustler aquifer are valid only for the present climate state.***

Rapid adjustment of the aquifer due to dissolution and subsidence following a change in climate means that hydrologic models cannot accurately predict flow rates, retardation, and other measures of WIPP performance on the basis of modern hydrologic data. These adjustments range from dissolution of gypsum in existing fractures to the generation of additional fractures following the removal of soluble strata

Present hydrologic models alter climate input by changing values for hydraulic head in the Culebra aquifer. Such models assume no change in the condition of the aquifer and cannot be used to predict adjustments in the aquifer (e. g. fracturing and channelization) under different climatic conditions. A model that attempted to do so would have to consider so many unknown variables that output from the model would be of little or no value.

Inadequacy of Performance Assessment For Altered Climatic Conditions

The above observations indicate that *there is no adequate means for predicting the performance of WIPP under climatic conditions of increased moisture.* This conclusion is based on the fact that soluble material and strata adjust rapidly, through dissolution and then through subsidence and fracturing, to small increases in the supply of dissolving fluids. For example, a continuation of the increased moisture of the last 4000 years, relative to the dry interval between 8000 and 4000 years ago, will result in further dissolution of secondary gypsum from fractures in the Culebra Dolomite. With only a moderate increase in moisture and head, fractures in the Culebra will continue to widen and accommodate increased flow within a time frame of a few thousand years, thereby reducing the validity of a 10,000-year prediction based on tighter fractures. For even larger increases in moisture, as illustrated in Fig. 3, removal of soluble strata within and below the Rustler Formation will lead to further fracturing and channelized flow, making predictions even less reliable.

DOE, which has closed the issue of karst, probably will challenge the above conclusions on grounds that little or no dissolution, fracturing, or channelization of the aquifer is likely to occur during the next 10,000 years. However, such an argument cannot be based on the assumption that Nash

Draw and the associated fractures in the Rustler are old structures that developed largely during the Cenozoic or early Pleistocene.

Evidence for the on-going nature of dissolution is provided by the distribution of secondary gypsum in Culebra fractures and by the fact that the climate history of the Southwest constrains the time when re-solution and increases in transmissivity occurred (Fig. 3). Another line of evidence that helps date the pace of dissolution is the rate of migration and collapse of Nash Draw. Although Nash Draw grew to its present size during four or five major climate cycles over the last 500,000 years (Fig. 3), eastward migration was undoubtedly marked by episodes of rapid migration during wet intervals separated by cessation of dissolution and fracture filling during periods of dryness. Eastward migration means that most of the soluble materials removed from the Rustler Formation in the vicinity of WIPP were dissolved out during the last major wet climate episode (less than ~100,000 years, see Fig. 3).

Examination of this last major climate cycle at other localities in New Mexico shows that climate changed in a series of strong pulsations lasting no more than a few centuries and that these century-scale wet intervals were grouped into longer cycles of about 2000 years (Allen and Anderson, 1993). Even though the last major wet episode was sustained for more than 50,000 years, actual increases in moisture to double present values during this prolonged interval were much shorter, possibly representing as little as 10,000 years. We are left with the understanding that the time available for active dissolution and the development of karst, in the vicinity of the site, is within the same time frame as the time interval for which prediction is required.

Predictions of future flow in the Rustler under conditions of a doubling of moisture, given the short time frame of dissolution and aquifer adjustment, must deal with the problem of an altered aquifer. For example, assume that a dramatic increase in precipitation occurred 2000 years from now, a real possibility if one examines Fig. 3. Under such conditions a lag between increased precipitation/infiltration and dissolution of nearly 8000 years would be required for a prediction to be valid for 10,000 years. The evidence from the rate of migration of Nash Draw, and from the re-solution of secondary gypsum in fractures, indicates no such lag.

The question of lag effects and how soon dissolution and subsidence will follow a shift in climate depends upon the pathways and rates of infiltration from the ground surface to the Rustler and brine aquifers. Extensive dune cover over the site area has obscured any surface expression of rapid infiltration (e.g. sinkholes and swallow holes). However, a sinkhole and a test well east of Nash Draw and near the western edge of the site (WIPP

33) testify to rapid infiltration. Halite is dissolved from the strata that lie above the finger of high transmissivity, undersaturation, and rapid flow in the Culebra (Fig. 2D). Where did the brine from this dissolved salt go, if not downward and into the Culebra aquifer? Where was the source of dissolving waters? South of the finger is an unexplained decrease in total dissolved solids that provides a strong clue as to how the hydrologic system must work.

The CSR leaves the question of surface recharge of the Rustler aquifer open, stating that "recharge areas and rates remain unidentified" (CSR, p. 6-20). Even after making this unequivocal statement, the CSR concludes, remarkably, that the issues of karst and dissolution are resolved and will not have... "compliance related consequences."

An Important Question

The inability to obtain meaningful predictions of performance over the next 10,000 years raises the question of the proper interval of time for which waste isolation must be assured with acceptable consequences. A 10,000-year period of institutional responsibility was promulgated for radioactive waste disposal on grounds that predictions made beyond that period would be increasingly unreliable. It was argued that if a site could be shown to be stable for 10,000- years, then it was likely that the site would be stable for a much longer interval. Although such an argument might be valid for many geologic sites, it is not valid for the WIPP because of its history of dissolution and the certainty that changes in climate will disrupt the Rustler aquifer.

For a radionuclide such as plutonium (half life of 24,000 years) a realistic period of isolation would be at least 100,000 years. If one examines the regularity of major episodes of past climate change (Fig. 3) and considers WIPP in this context, then the Rustler aquifer would have to survive at least one complete major climate cycle. Given the previous history of Nash Draw, the soluble beds in the Rustler would be completely removed during the next major cycle and the question of retardation of radionuclide transport in the Rustler aquifer would become moot.

A Logical Question

If the existence of karst at WIPP precludes the use of predictive models for performance assessment for the next 10,000 years, how is it that the WIPP project moved forward to its advanced stage of development without recognizing so fatal a flaw?

The answer lies in WIPP history and in an examination of institutional commitments to WIPP as a disposal site. When the first WIPP site had to be abandoned, the one remaining site in New Mexico, Los Medaños, came with

several problems. One problem was proximity to potash, petroleum and other resources. For example, producing oil wells nearly encircle the WIPP site. The pattern of well spacing indicates that WIPP sits above a major oil discovery, a fact already known by 1990. The record shows that DOE officials knowingly failed to inform experts about petroleum exploration and production at the site, even though producing oil rigs were in clear view of the WIPP facility (Silva, 1994). This episode illustrates the determination of institutions to complete the WIPP mission in the face of adverse information, but, more importantly, it shows the ineffectiveness of institutional controls and the certainty that the WIPP site is a target for Human intrusion.

The other problem was that about half of the salt in the Rustler aquifer was missing. At that time the reasons for a thin Rustler were not well understood and it was believed that karstic conditions were confined to Nash Draw. Investigators were concerned with travel time for fluids in the Rustler aquifer under existing climatic conditions and profound changes in climate were considered to be mainly a feature of the high latitudes associated with glaciation.

When evidence began to emerge, before WIPP was constructed, that karstic conditions were more widespread than anticipated, this information was ignored, leaving us, today, with consequences made greater by changes in climate. This means that the effects of human intrusion may not only be amplified by the pressurized brine reservoir that is reported to occur beneath the WIPP repository, it will not be possible to predict the consequences of this compounded scenario owing to unknown responses to climate change.

The institutional track record for characterizing WIPP and for considering possible consequences warns us to be certain about having reliable predictions of performance. Therefore, specific recommendations are in order.

Recommendations

1. The discovery of petroleum resources under WIPP, and a greatly increased potential for multiple breaches of the repository, relate directly to climate issues as they effect the performance of the Rustler aquifer. The issue of resources needs to be reexamined, with all the facts on the table.

2. Previous assumptions about the age of Karst are in error, with karst development and dissolution in the site area younger and more extensive than acknowledged. There needs to be a concerted effort to determine the extent of dissolution by means of further exploration.

3. It is acknowledged in the CSR that neither the area nor the rate of recharge of the Rustler aquifer are known. Explanations for Rustler flow, recharge, and geochemistry that draw upon conjectural models of past recharge under changed climatic conditions must be replaced by actual data about the specific areas where recharge is occurring today and about rates of recharge.

4. The Rustler aquifer is progressing through stages of dissolution which may make it impossible to assure predictions of performance within the selected 10,000-year time frame. Further exploration should be directed at determining not only the extent but the history of dissolution within the context of past changes in climate

In the absence of a resolution of key issues related to climate (see recommendations 2, 3, and 4), one must conclude that present hydrologic models are not adequate for performance assessment and that the WIPP project will be unable to demonstrate compliance with EPA requirements for waste isolation.

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14 July, 1994

Fred Phillips

New Mexico Technical Institute

THE PALEOHYDROLOGICAL RECORD OF MAJOR CLIMATE CHANGE IN THE WESTERN UNITED STATES

by

Fred M. Phillips

New Mexico Tech

Socorro

Glacial-Interglacial Climate Change

Global evidence

Regional Evidence

Rapid Climate Change

Ice-core evidence

Evidence from southwestern U.S.

Searles Lake

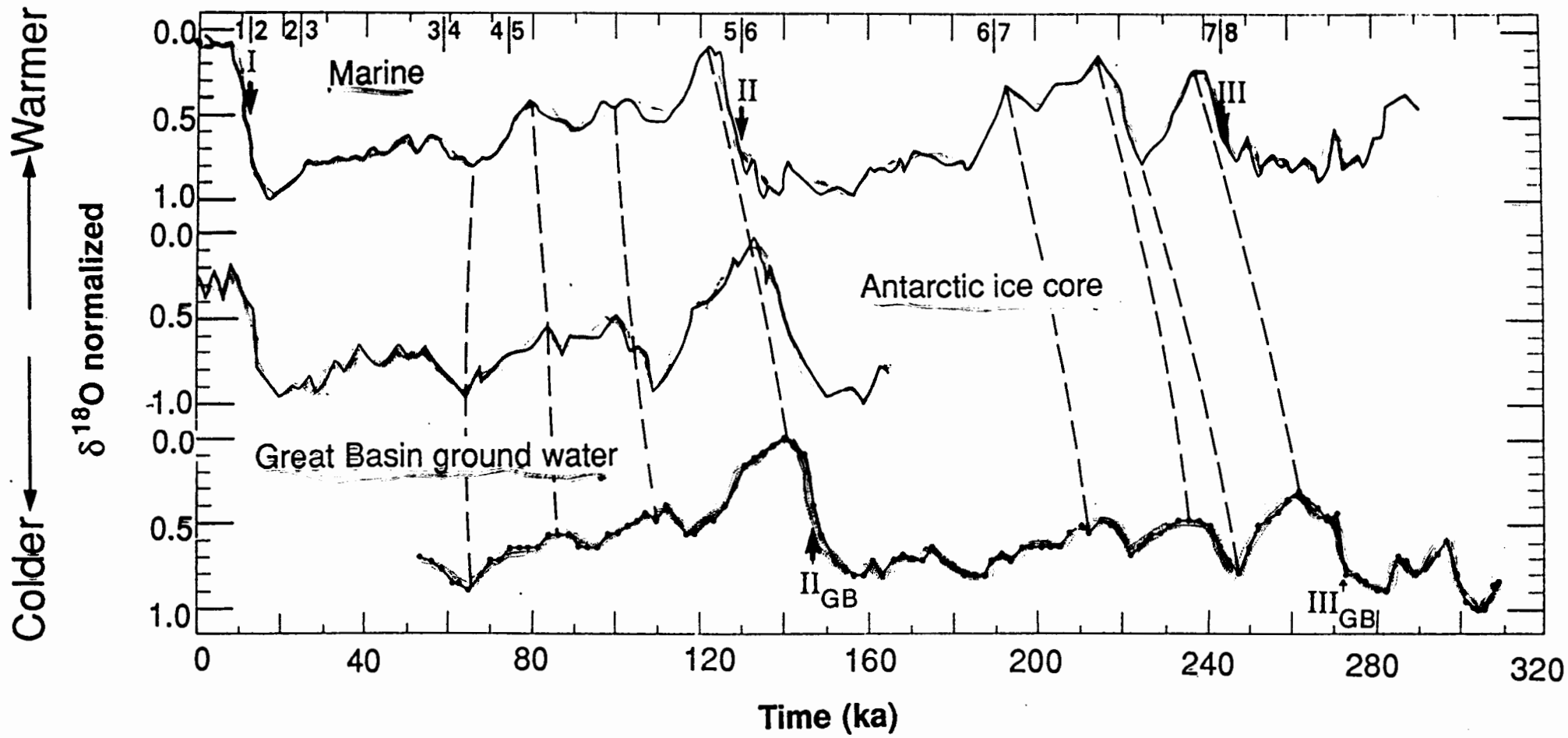
San Agustín Lake

Effects on Groundwater Recharge

Evidence from San Juan Basin groundwater

Evidence from vadose-zone chloride profiles

Timing of Recharge at the WIPP Site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Antarctic ice core
Great Basin ground water
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III
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IIIGB
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4|5
5|6
6|7
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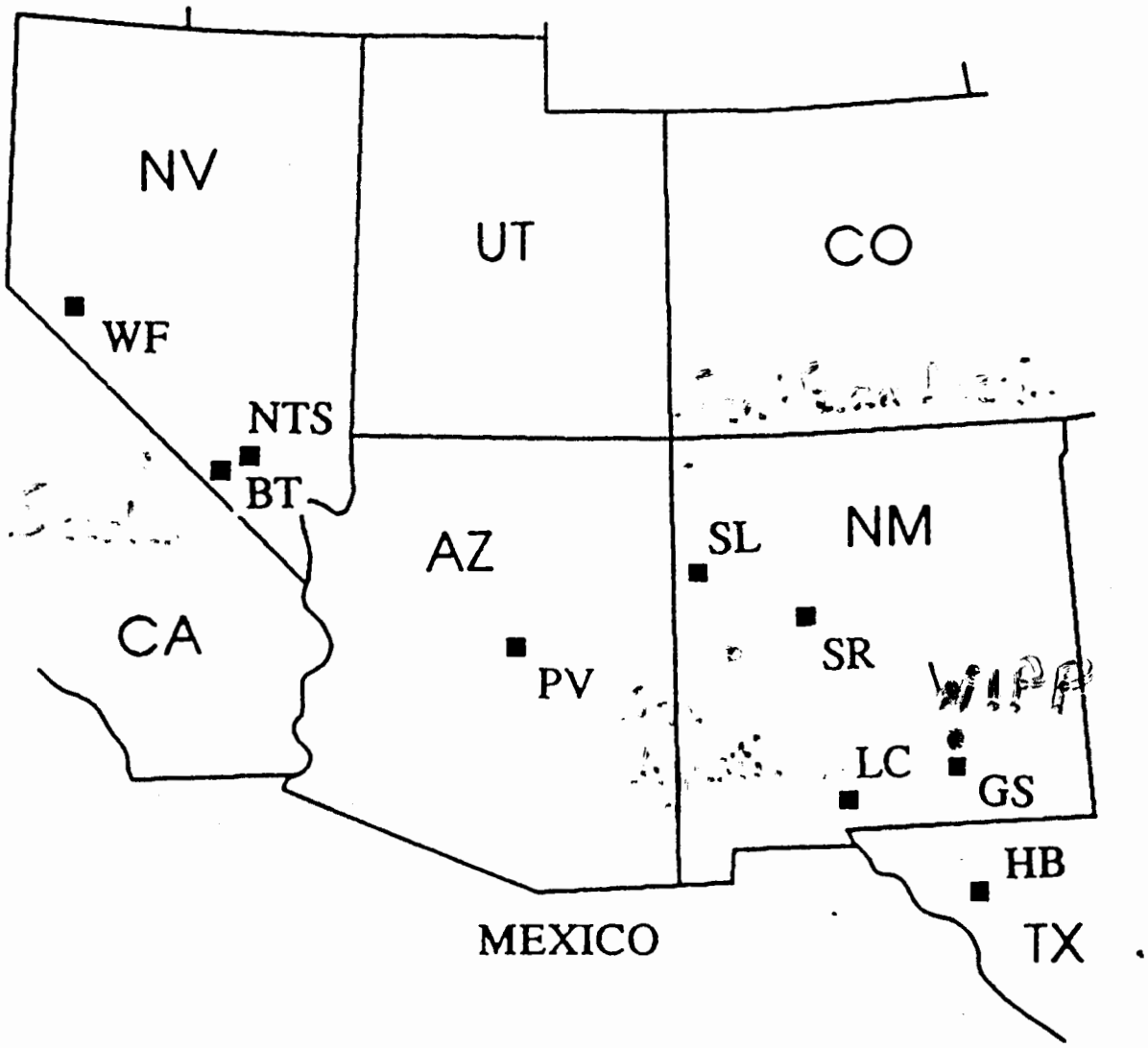
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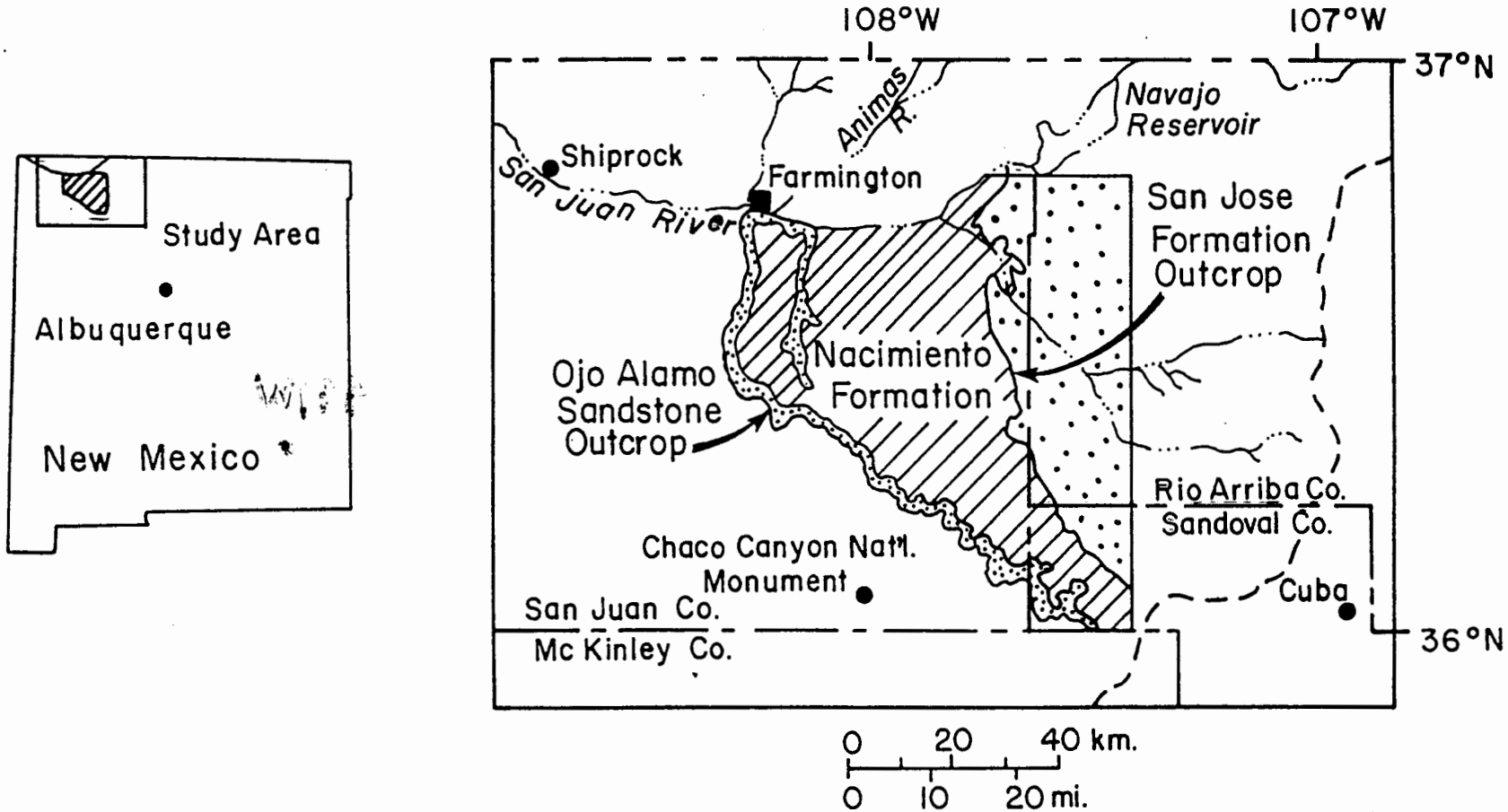
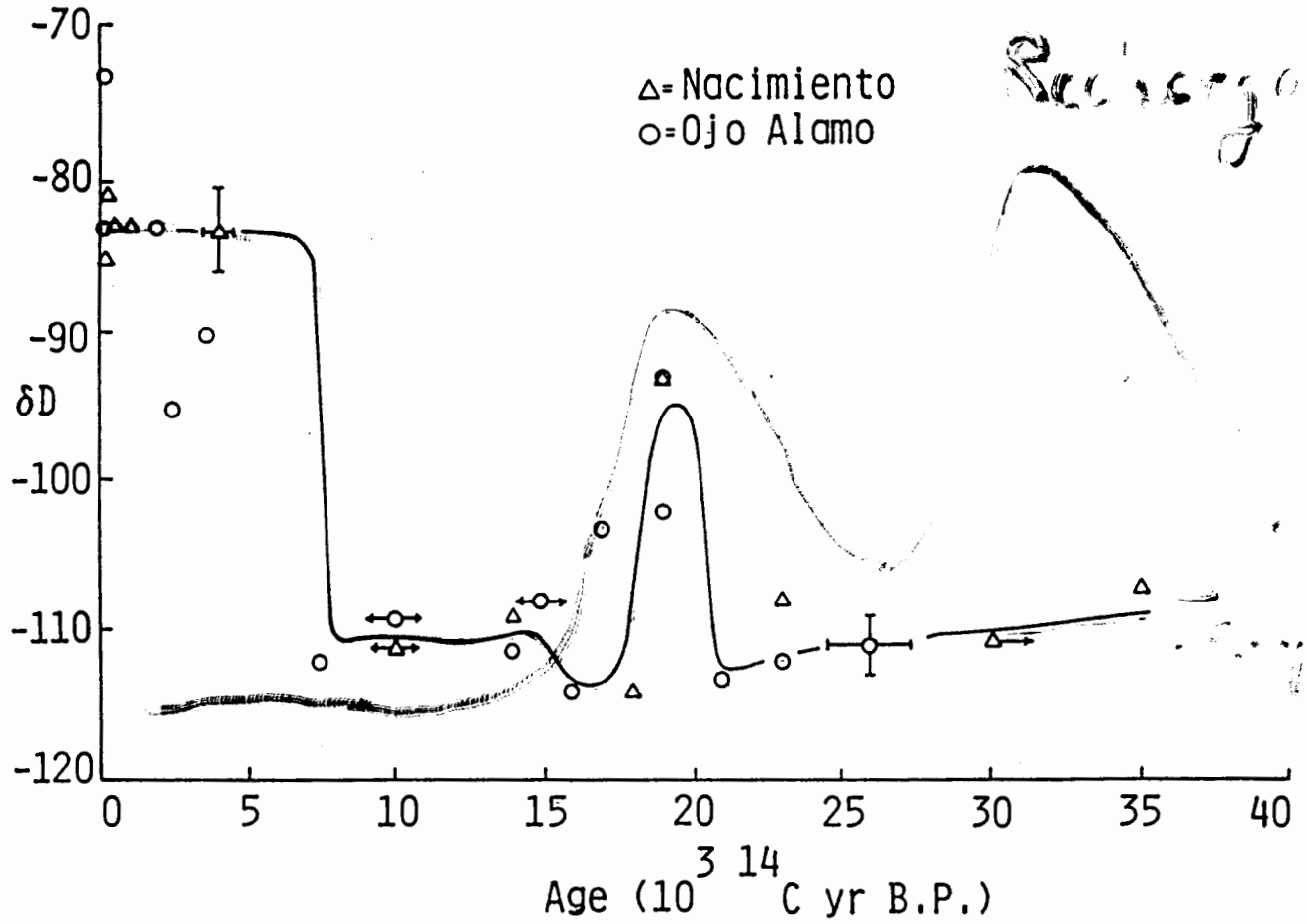


FIG. 1. Location of the study area.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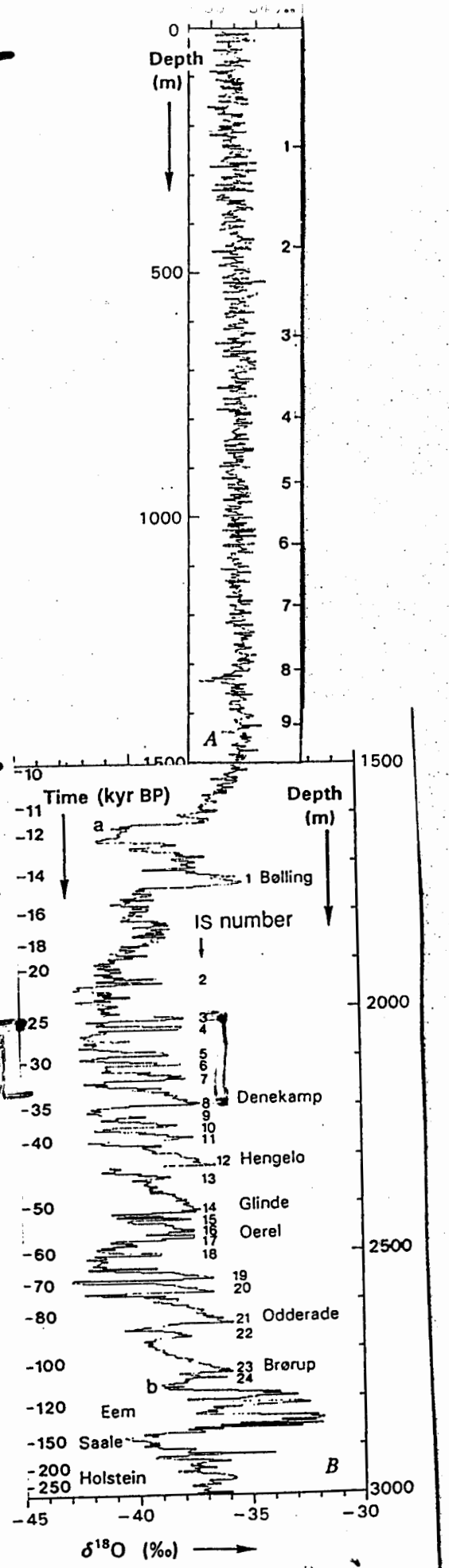
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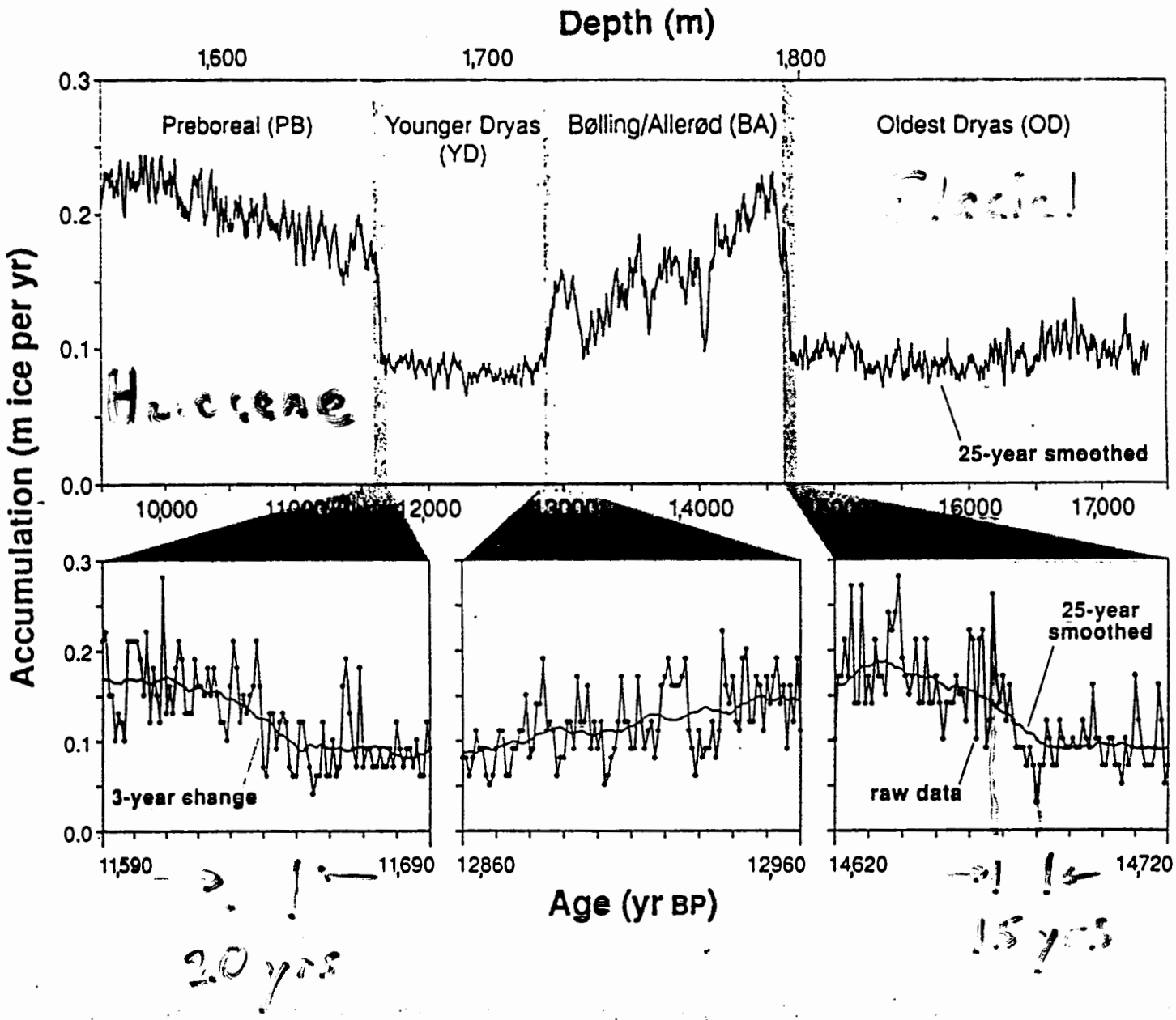
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Bølling/Allerød (BA)
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Glacial
Holocene
25-year smoothed
Accumulation (m ice per yr)
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0.2
0.1
0.0
10,000
12,000
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16,000
17,000
3-year change
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12,860
12,960
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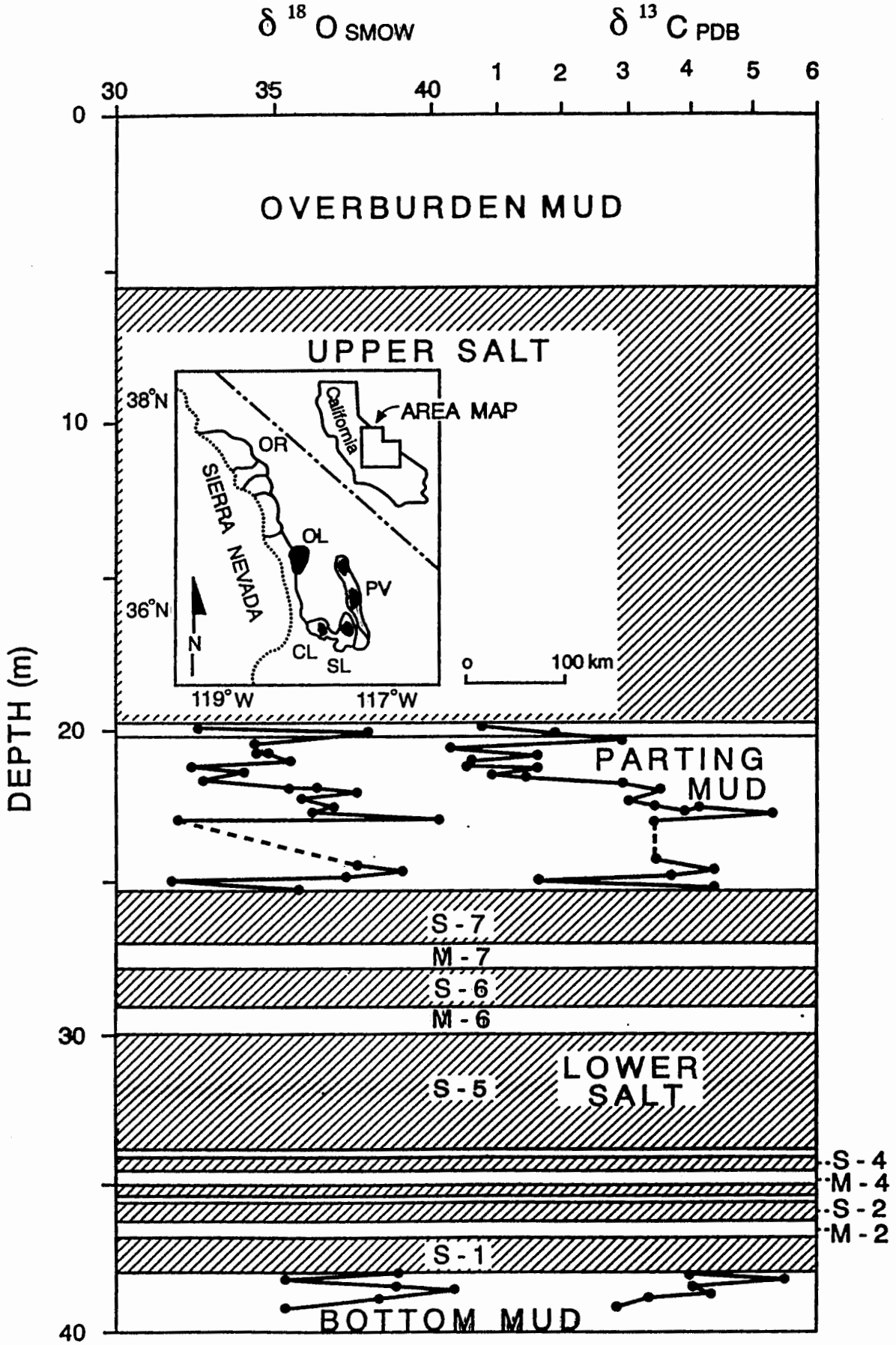
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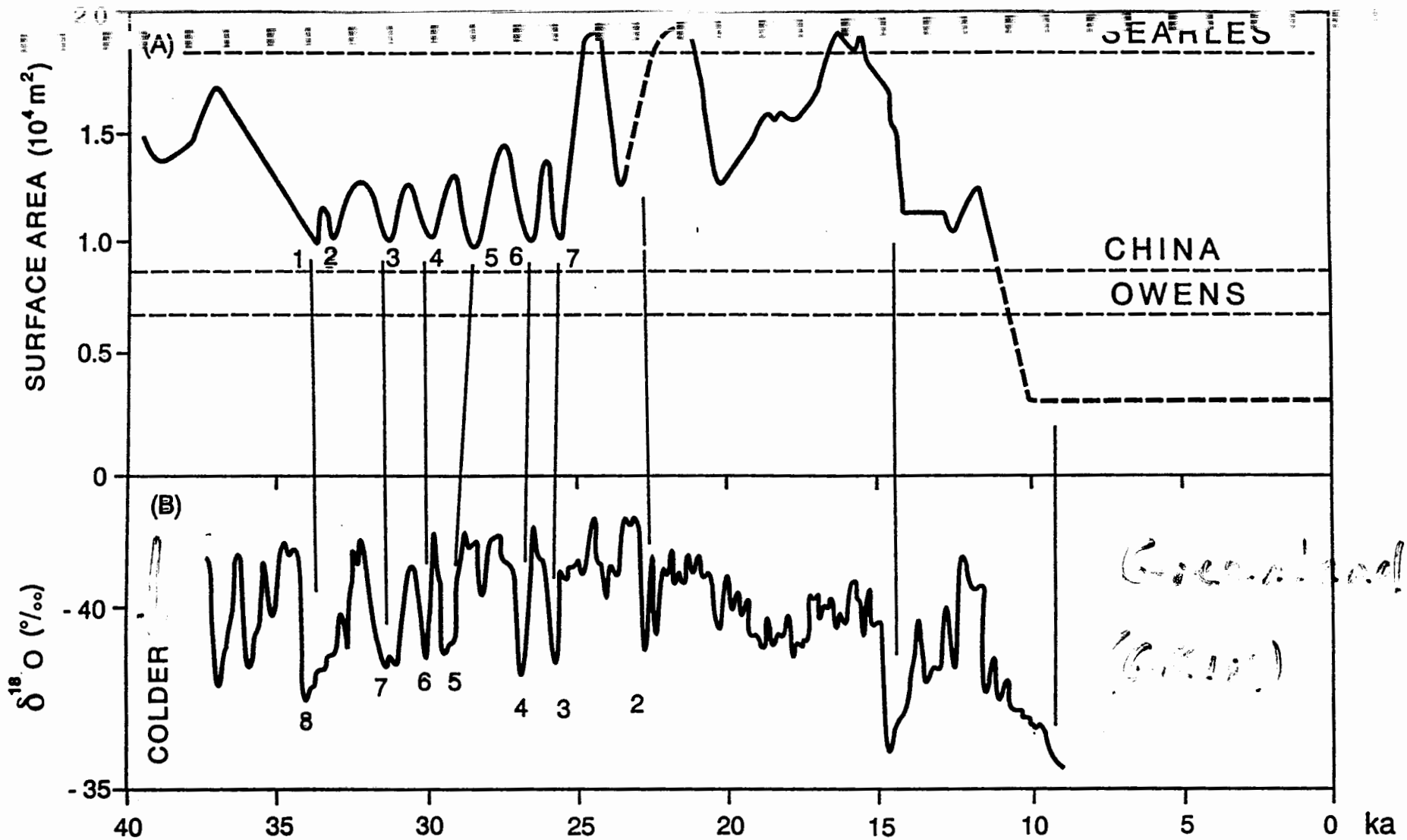


GEOLOGY, December 1994

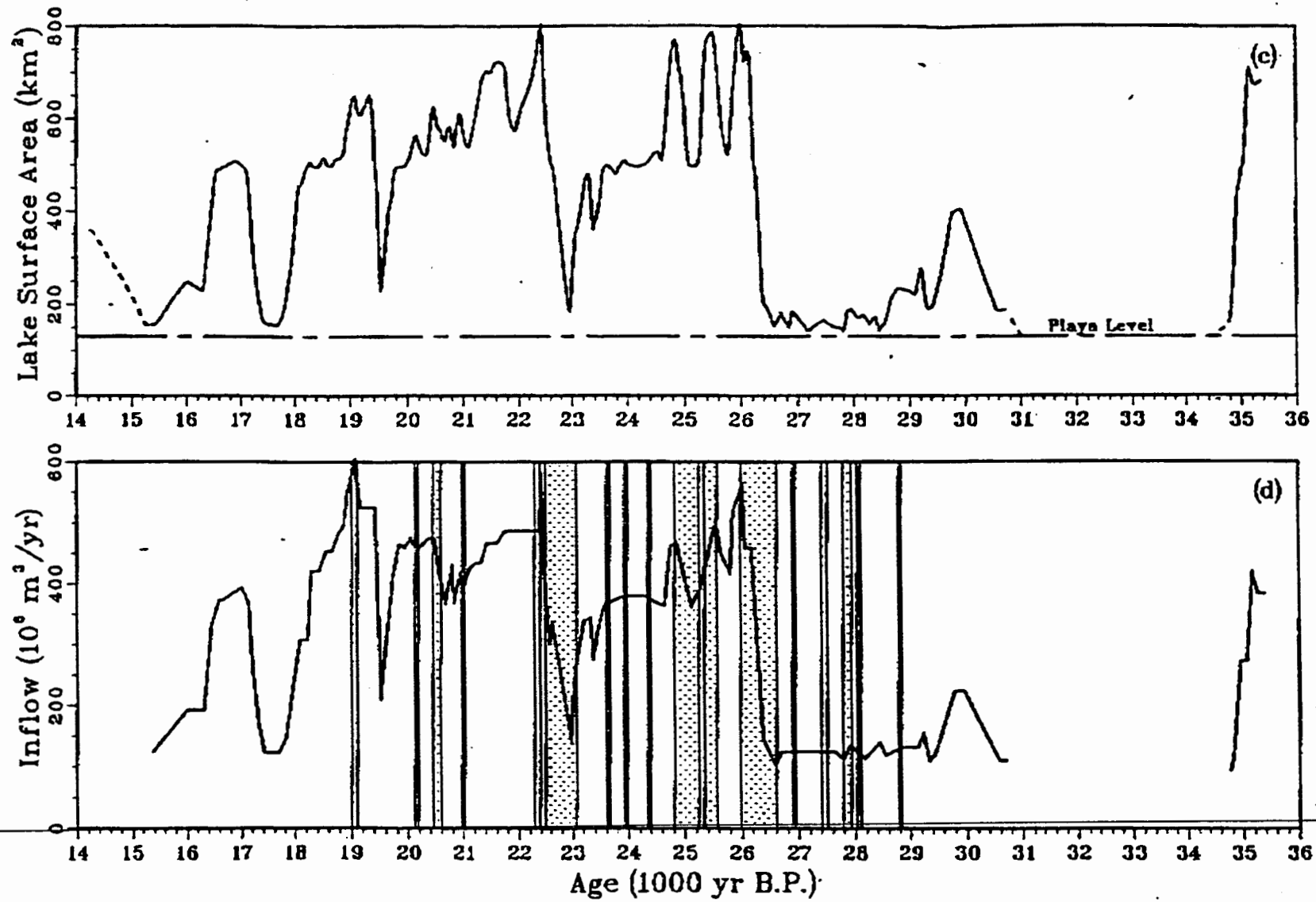
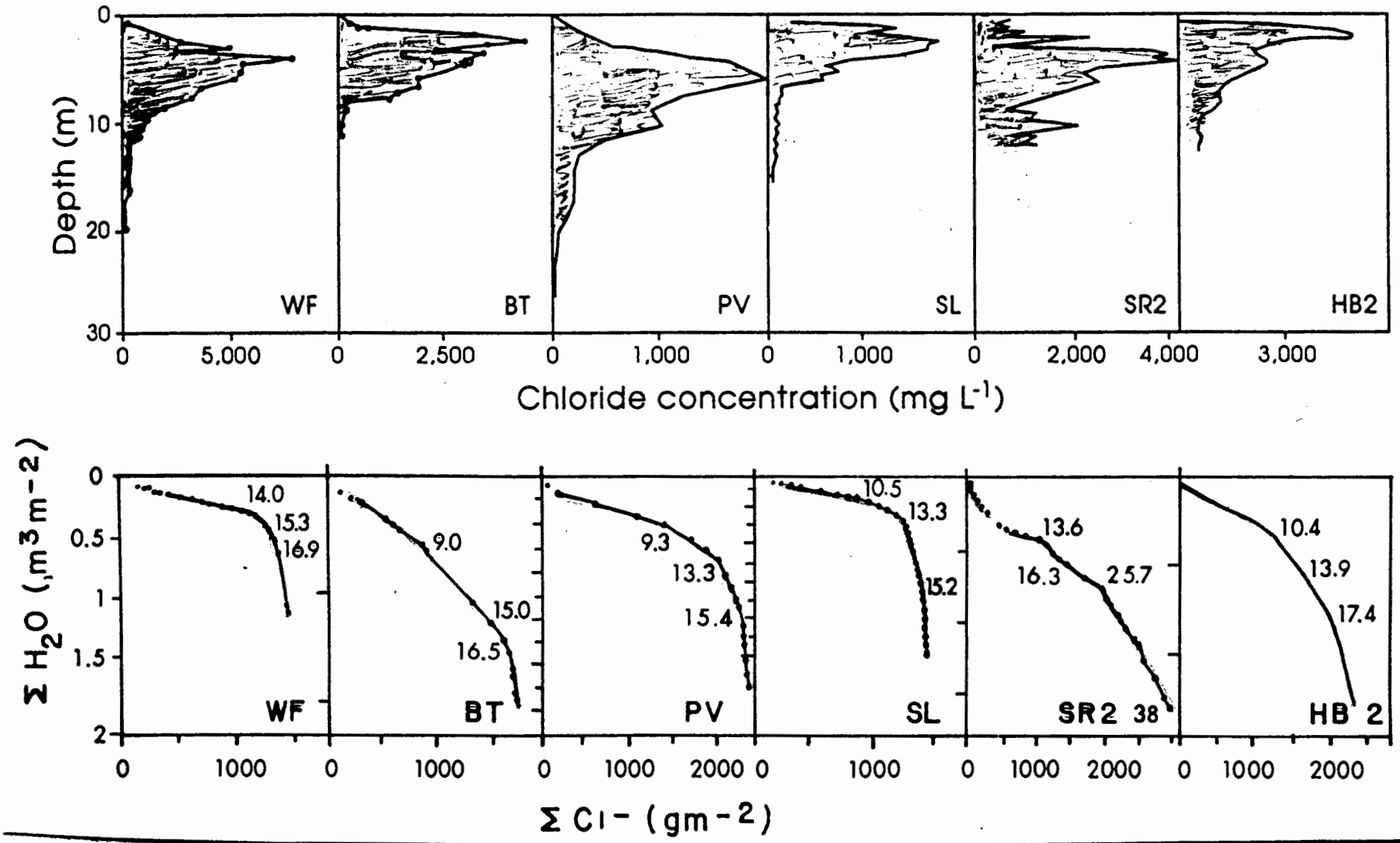
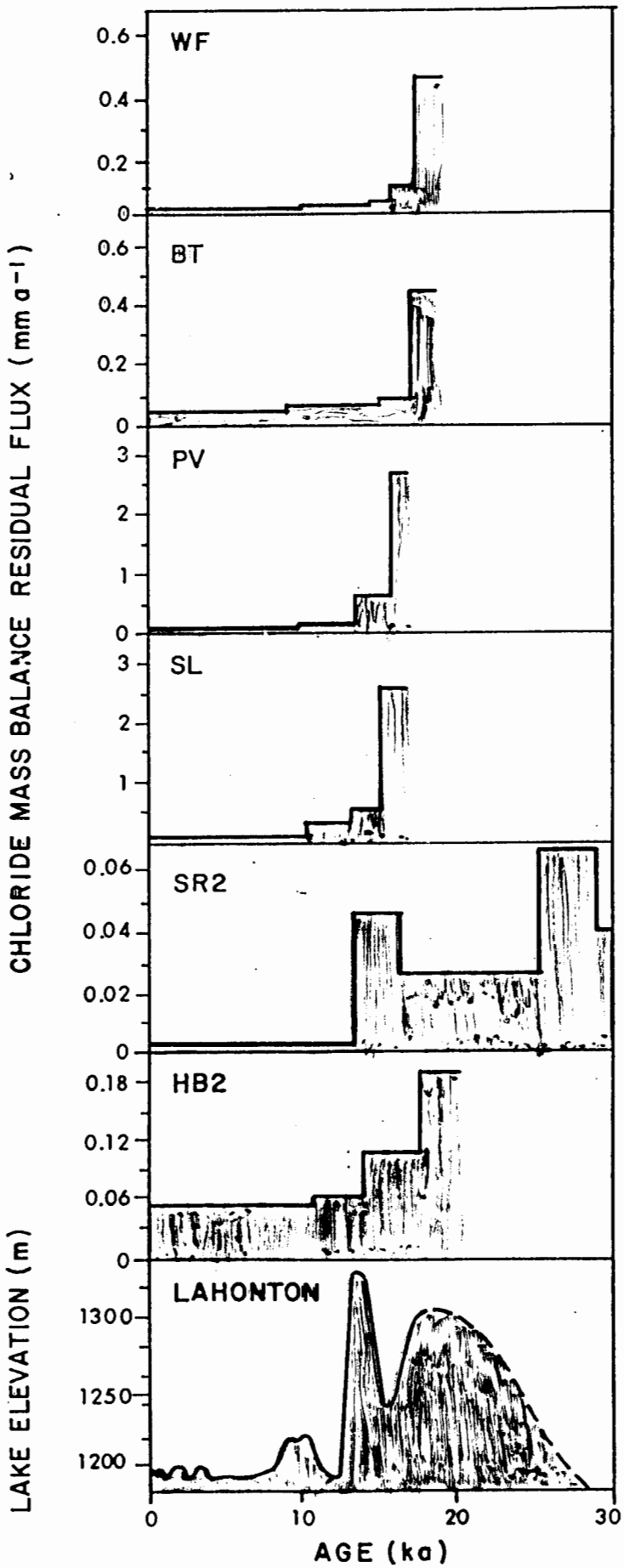
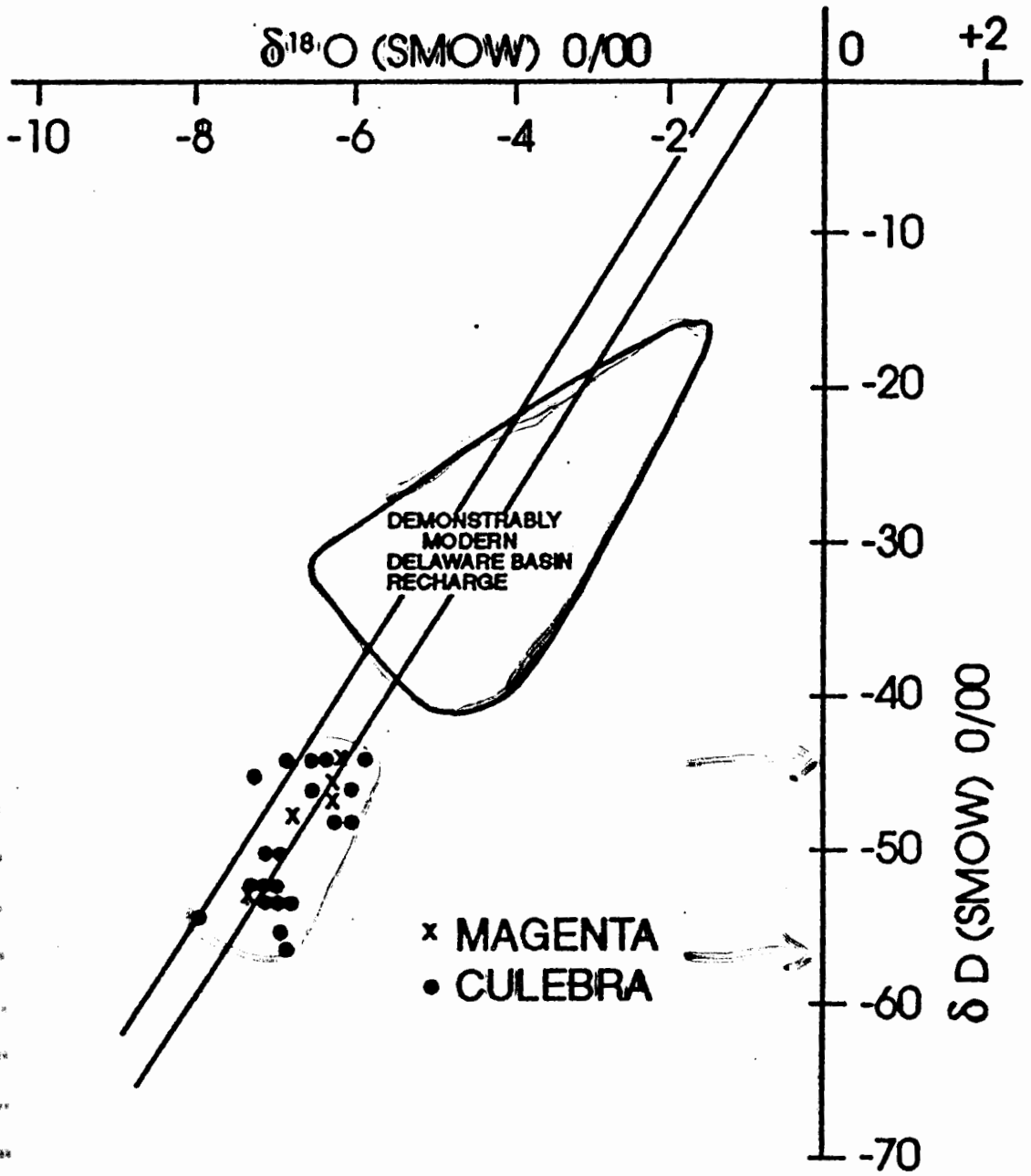


FIGURE 50. Results of numerical modeling for Lake San Agustin: (a) simulated surface area history and (b) inflow history and *L. platyforma* biostratigraphy

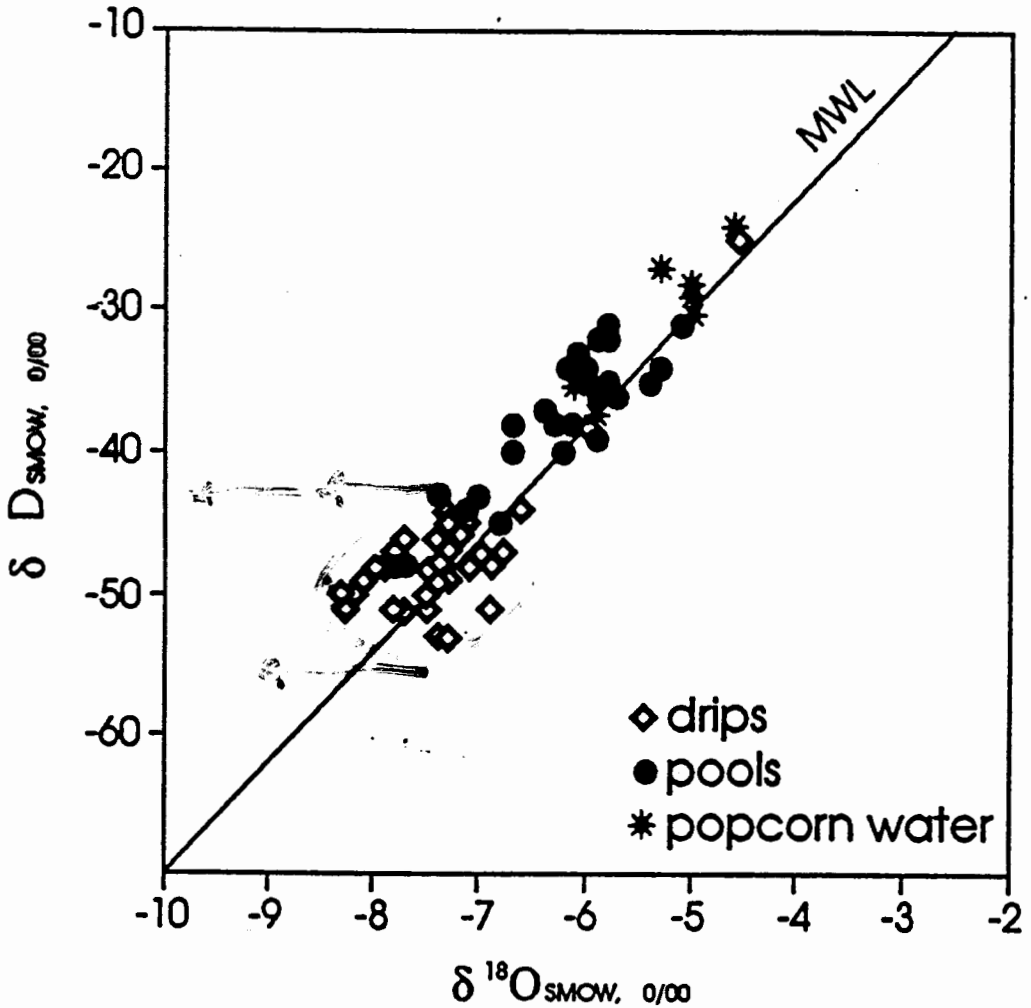

Depth (m)
0
10
20
30
WF
BT
PV
SL
SR2
HB2
0
5,000
0
2,500
0
1,000
0
1,000
0
2,000
4,000
3,000
Chloride concentration (mg L-1)
Σ H2O (m3m-2)
0
0.5
1
1.5
2
14.0
15.3
16.9
9.0
15.0
16.5
9.3
13.3
15.4
10.5
13.3
15.2
13.6
16.3
25.7
10.4
13.9
17.4
0
1000
0
1000
0
1000
2000
0
1000
0
1000
2000
0
1000
2000
Σ Cl- (gm-2)

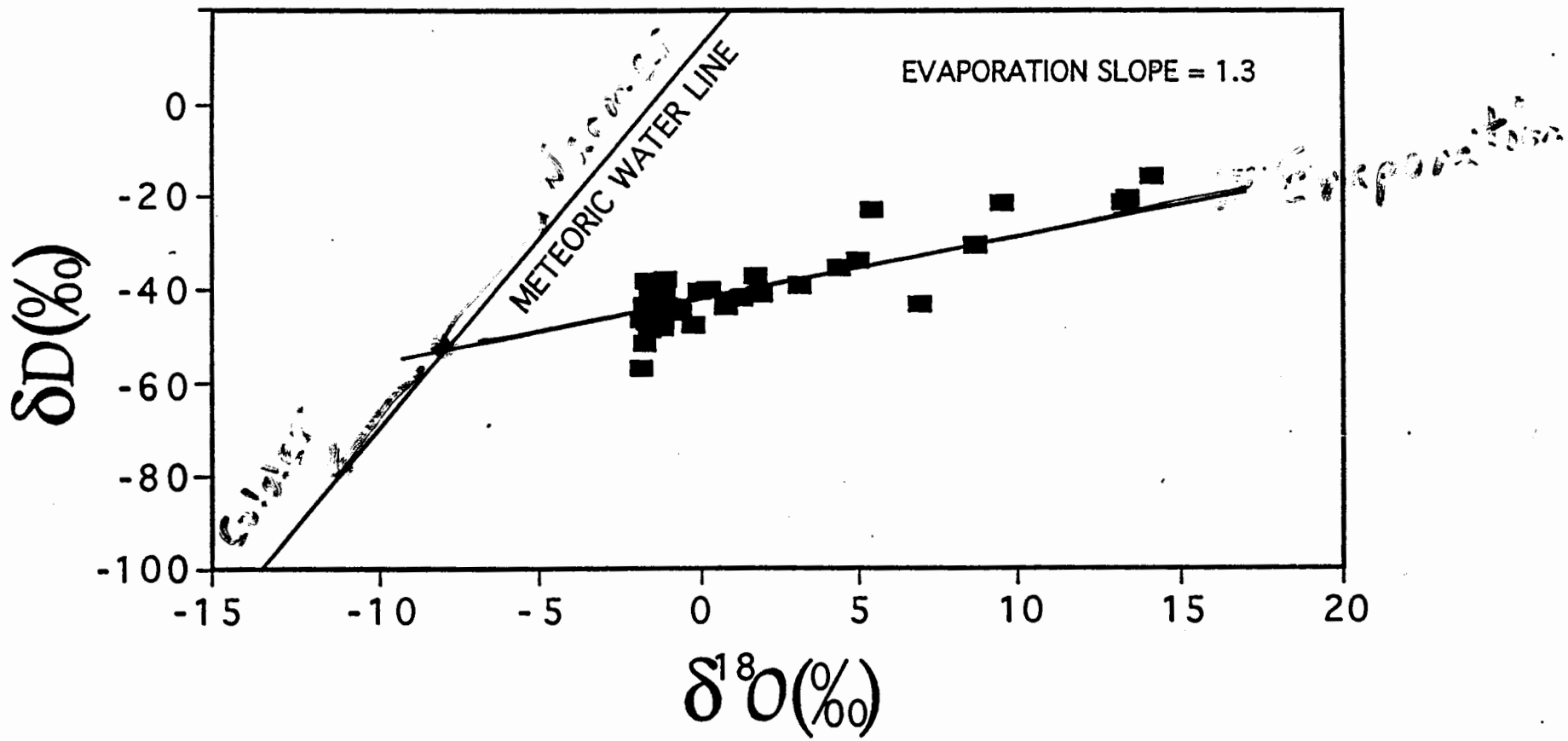

WF
BT
PV
SL
SR2
HB2
LAHONTON
CHLORIDE MASS BALANCE RESIDUAL FLUX (mm a⁻¹)
LAKE ELEVATION (m)
AGE (ka)
0.6
0.4
0.2
0
3
2
1
0.06
0.04
0.02
0.18
0.12
1300
1250
1200
10
20
30

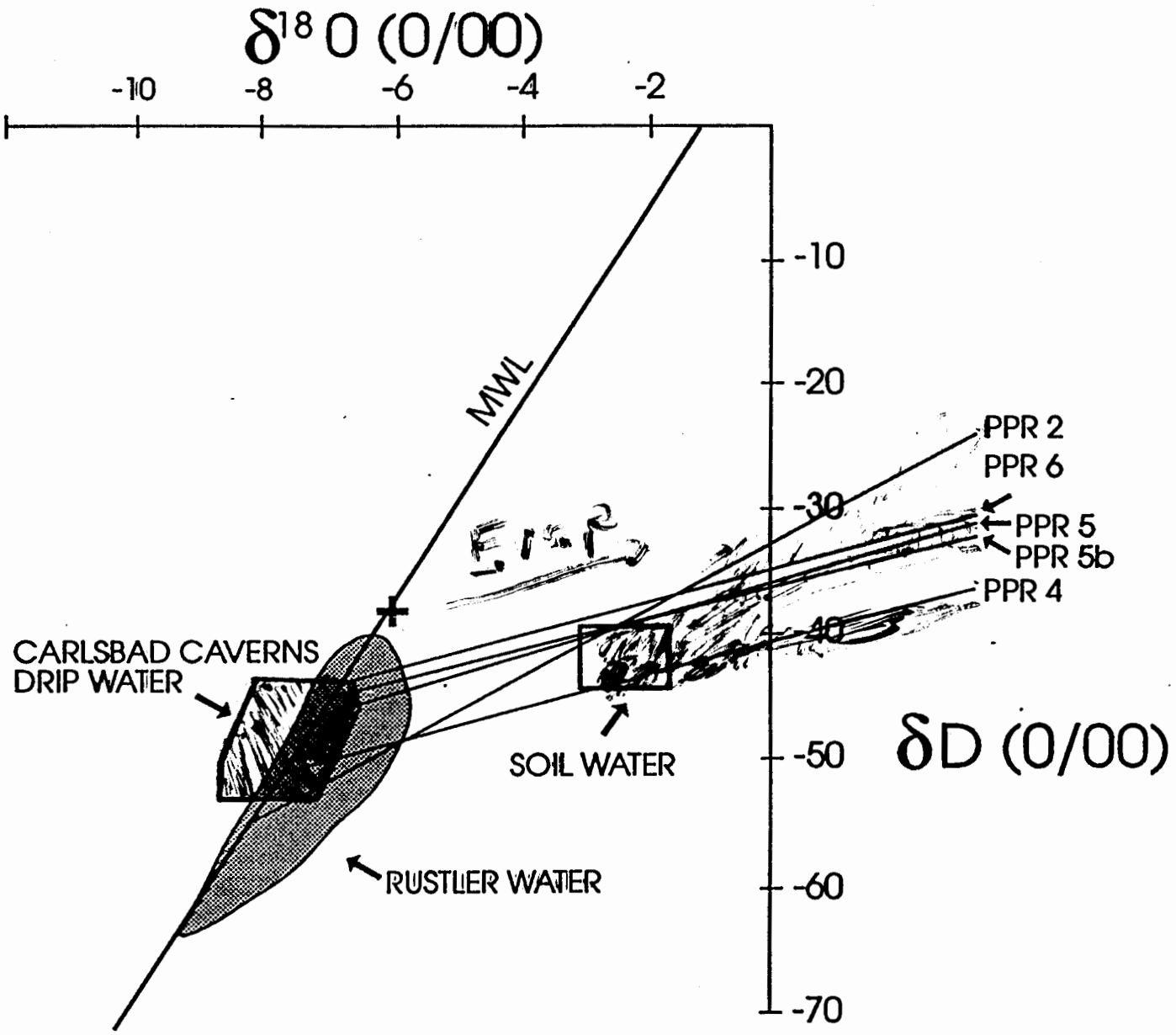


(Modified from Lambert and Harvey, 1987)

Cathedral Cavern




EVAPORATION SLOPE = 1.3
METEORIC WATER LINE
δD(‰)
δ18O(‰)
0
-20
-40
-60
-80
-100
-15
-10
-5
0
5
10
15
20


δ18 O (0/00)
-10
-8
-6
-4
-2
-10
-20
-30
-40
-50
-60
-70
δD (0/00)
MWL
PPR 2
PPR 6
PPR 5
PPR 5b
PPR 4
CARLSBAD CAVERNS
DRIP WATER
SOIL WATER
RUSTLER WATER

CONCLUSIONS

For most of the past 100,000 years the climate has been wetter and less stable than the past 10,000 years.

There is evidence in the southwestern U.S. for major climate fluctuations on the time scale of a few hundred years.

Wetter climates of the past probably increased groundwater recharge by an order of magnitude, or more.

The stable isotope composition of soil water at the WIPP Site indicates that groundwater at the site could have been derived from modern precipitation, but not by recharge through the soil.

Norman Eisenberg

Nuclear Regulatory Commission

THE TREATMENT AND EFFECT OF CLIMATE CHANGE ON REPOSITORY PERFORMANCE

Presented at the

EPA Technical Workshop on WIPP Compliance Issues

February 14–16, 1995

By

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PRESENTATION OUTLINE

BACKGROUND

- NRC Performance Assessment Approach
- Treatment of Scenarios in Iterative Performance Assessment—Phase 2

MODELING CLIMATE CHANGE

- Analytical
- Expert Elicitation

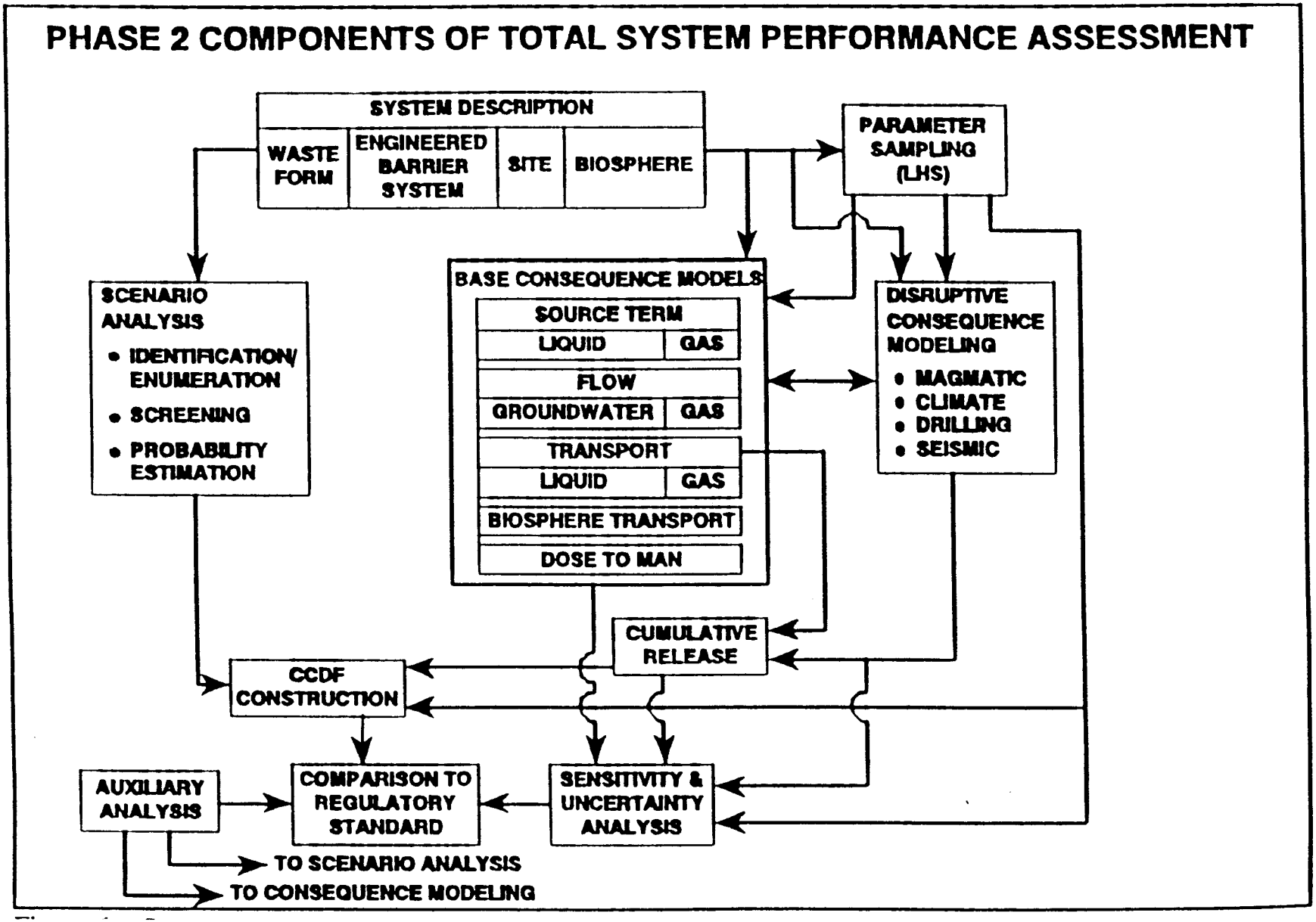
THE EFFECTS OF CLIMATE CHANGE

- Changes in Groundwater Recharge
- Changes in Groundwater Flow Pattern and Water Table Height
- Changes on the Total Complimentary Cumulative Distribution Function (CCDF) for Normalized Release

FINDINGS

OBSERVATIONS

NRC PERFORMANCE ASSESSMENT APPROACH



TREATMENT OF SCENARIOS IN ITERATIVE PERFORMANCE ASSESSMENT—PHASE 2

- The Events and Processes Considered (After Screening) Are:

  (i) Climate Change (C)

  (ii) Seismic Activity Affecting the Repository (S)

  (iii) Human Intrusion Via Drilling (D)

  (iv) Magmatic Activity Affecting the Repository (V)

- Scenario Probabilities Are Assigned Based on the Probabilities of Events and Processes Occurring or Not Occurring in the Next 10,000 Years

- The Scenario Classes Table is Constructed

SCENARIO CLASSES TABLE

		$P(\overline{V}) \approx 0.97$		$P(V) \approx 0.03$		
		$P(\overline{D}) = 2.3 \times 10^{-7}$	$P(D) = 0.99999977$	$P(\overline{D}) = 2.3 \times 10^{-7}$	$P(D) = 0.99999977$	SUM
$P(\overline{C}) = 0.356$	$P(\overline{S}) = 4.5 \times 10^{-5}$	$\overline{C}\,\overline{S}\,\overline{D}\,\overline{V}$ 3.6×10^{-12}	$\overline{C}\,\overline{S}\,D\,\overline{V}$ 1.6×10^{-5}	$\overline{C}\,\overline{S}\,\overline{D}\,V$ 1.1×10^{-13}	$\overline{C}\,\overline{S}\,D\,V$ 4.8×10^{-7}	1.6×10^{-5}
	$P(S) = 0.999955$	$\overline{C}\,S\,\overline{D}\,\overline{V}$ 7.9×10^{-8}	$\overline{C}\,S\,D\,\overline{V}$ 0.3492	$\overline{C}\,S\,\overline{D}\,V$ 2.5×10^{-9}	$\overline{C}\,S\,D\,V$ 0.0108	0.36
$P(C) = 0.644$	$P(\overline{S}) = 4.5 \times 10^{-5}$	$C\,\overline{S}\,\overline{D}\,\overline{V}$ 6.4×10^{-12}	$C\,\overline{S}\,D\,\overline{V}$ 2.9×10^{-5}	$C\,\overline{S}\,\overline{D}\,V$ 2.0×10^{-13}	$C\,\overline{S}\,D\,V$ 8.6×10^{-7}	2.9×10^{-5}
	$P(S) = 0.999955$	$C\,S\,\overline{D}\,\overline{V}$ 1.4×10^{-7}	$C\,S\,D\,\overline{V}$ 0.6208	$C\,S\,\overline{D}\,V$ 4.4×10^{-9}	$C\,S\,D\,V$ 0.0192	0.64
SUM		2.2×10^{-7}	0.96997	6.9×10^{-9}	0.0300	1.00

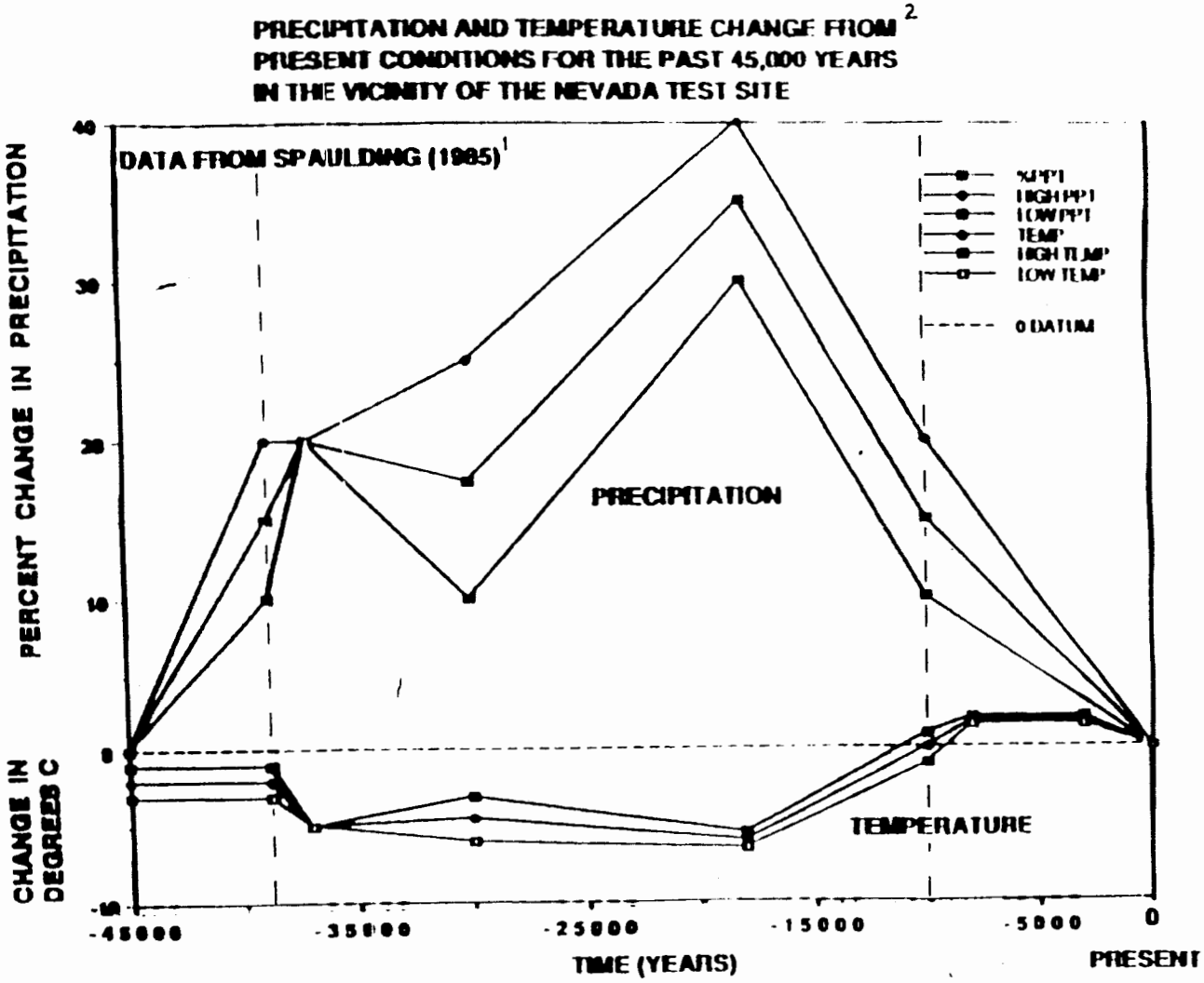
Note — The probabilities listed in the Scenario Classes Table are for Yucca Mountain, NV.

MODELING CLIMATE CHANGE

ANALYTICAL

- Present Day Average Annual Precipitation ~150 mm/yr at Yucca Mountain
- A "Climate Change" is Considered to be
  - (i) A Change in Average Annual Precipitation of Magnitude > 15 percent from Current Conditions, or
  - (ii) A Change in Average Annual Temperature of Magnitude > 2 °C from Current Conditions
- Only Cooler/Wetter "Climate Change" and "No Climate Change" Possibilities Were Considered
- Probabilities for "Climate Change" and "No Climate Change" in the 10,000 Year Post Closure Period Considered are Estimated from Climate Conditions Interpreted from the Geologic Record for the 45,000 Years Before Present (YBP)

MODELING CLIMATE CHANGE



[1] "Vegetation and Climates of the Last 45,000 years in the Vicinity of the Nevada Test Site, South-Central Nevada," US Geological Survey Professional Paper 1329, p.55, 1985.

[2] Estimates From Plant Microfossils Contained in Radioncarbon Dated Remains of Packrat Middens.

MODELING CLIMATE CHANGE

- From the Previous Figure, "Cooler/Wetter" Conditions Existed from 39,000 YBP to 10,000 YBP

- From these Dates it is Estimated that

  — The Probability of A "Climate Change" Occurring in the Next 10,000 Years

  $$= \frac{(39{,}000-10{,}000)\ \text{YR}}{45{,}000\ \text{YR}} = 0.644$$

  — The Probability of "No Climate Change" Occurring in the Next 10,000 Years

  $= 1 - 0.644 = 0.356$

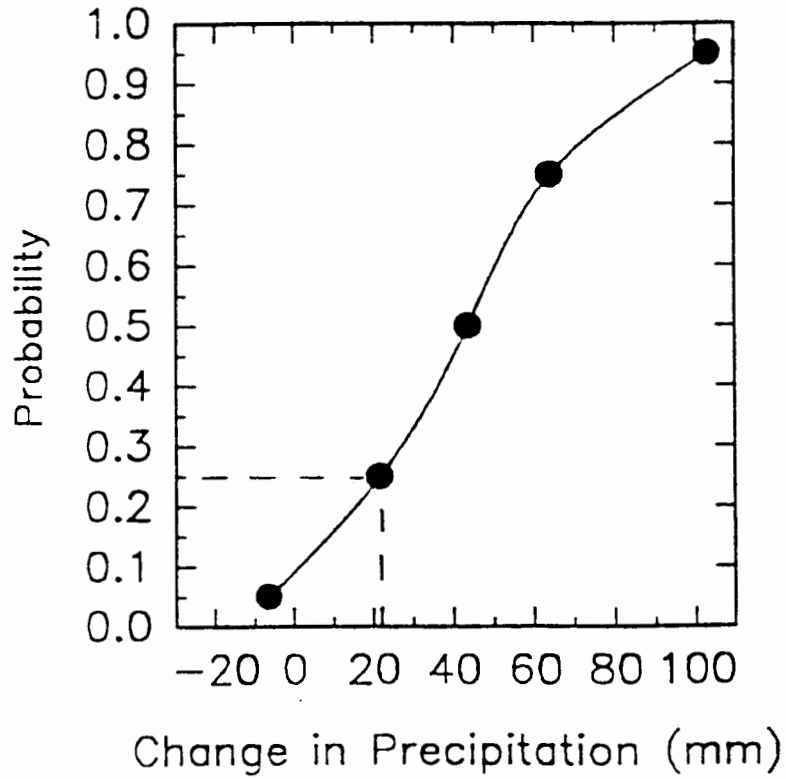
MODELING CLIMATE CHANGE

EXPERT ELICITATION

- A Panel of Five Climate Experts Was Assembled in a Systematic Fashion (NUREG-5411)
- All Experts Were Consistent in Predicting a Relatively Small Median Temperature Change (No More than Plus or Minus 2 °C)
- Precipitation Predictions Were More Varied
  - One Expert Predicted a Doubling of Precipitation for the 10,000 Years After Present (YAP)
    [Corresponding to an Average Annual Precipitation ≤ 300 mm/yr]
  - Three Experts Predicted 30 to 40 percent Increases
    [Corresponding to an Average Annual Precipitation of ≤ 195–210 mm/yr]
  - One Expert Predicted a 15 percent Decrease
    [Corresponding to an Average Annual Precipitation of ≤ 128 mm/yr]

MODELING CLIMATE CHANGE

EXPERT ELICITATION



- The Consensus Opinion (An Equally Weighted Average of Individual Opinions) for the Probability of "No Climate Change" in the 10,000 Years AP ≈ 0.25
- This Consensus Result Approximately Agrees with the Analytical Result of 0.344 Presented Earlier

SIGNIFICANCE OF DOMINANT CLIMATE CONTROLS AS RATED BY ELICITED EXPERTS IN IPA PHASE 2.5

CLIMATE CONTROL	+100 YEARS	+1000 YEARS	+5,000 YEARS	+10,000 YEARS
RAIN SHADOW EFFECT	1 (5)†	1 (5)	1 (5)	1 (5)
ANTHROPOGENIC FORCING	2 (5)	2 (5)	2 (3)	2 (2)
ATMOSPHERIC MOVEMENT	3 (5)		3 (2)	
MILANKOVITCH ORBITAL CLIMATE VARIATIONS		3 (5)	2 (2) 3 (3)	2 (3)

† RANK (NUMBER OF EXPERTS)

OTHER CLIMATE CONTROLS INDICATED AS IMPORTANT: SHIFTING OF MID-LATITUDE (CYCLONIC) STORM BELTS, INCREASED MOISTURE AVAILABILITY, MERIDIONAL FLOW, ICE SHEETS, WESTERLY WIND BELT MIGRATION

THE EFFECTS OF CLIMATE CHANGE

CHANGES IN GROUNDWATER RECHARGE

- For Periods of Dry Climate (i.e., "No Climate Change") the Groundwater Recharge Rate Was Loguniformly Distributed from 0.1 mm/yr to 5.0 mm/yr for Flow and Transport Calculations in the Total Performance Assessment (TPA) Code

- For Periods of Wet (or Pluvial) Climate (i.e., "Climate Change") the Groundwater Recharge Rate Was Loguniformly Distributed from 5.0 mm/yr to 10.0 mm/yr for Flow and Transport Calculations in the TPA Code

THE EFFECTS OF CLIMATE CHANGE

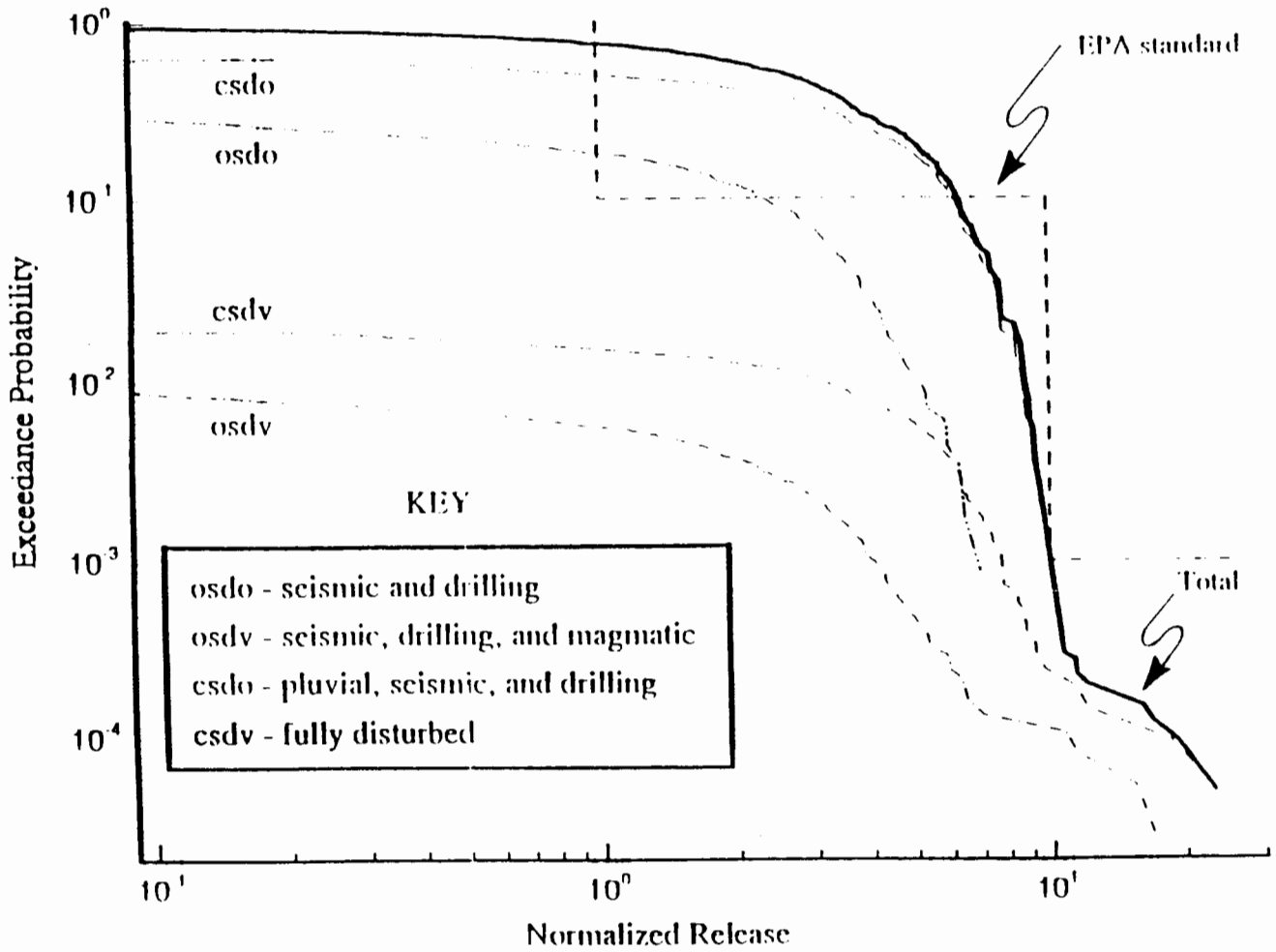
CHANGES IN GROUNDWATER FLOW PATTERN AND WATER TABLE HEIGHT

- For Pluvial Conditions, it is possible for the Recharge Rate to Exceed the Saturated Conductivity of the Pore Matrix
  - For Such Conditions, a Transition to Fracture Flow is Assumed
  - This Can Drastically Affect Repository Performance by Affecting Water Transport Through the Repository
- For Pluvial Conditions, There is the Potential for a Rise in the Height of the Water Table
  - This Could Affect Repository Performance By Changing the Transport Time
  - For NRC IPA-2 Calculations, A Water Table Rise of 100 m Was Used

THE EFFECTS OF CLIMATE CHANGE

- Climate Change Coupled With Other Events Can Also Have Dramatic Effects on the Height of the Water Table
  - In a Regional Analysis of the 200 km by 200 km Area Centered Around YM (NUREG/CR-5890) It Was Found that by Increasing the Recharge at Higher Elevations by a Factor of 20, the Water Table Rose 87 m
  - In this Same Regional Analysis, It Was Found that by Breaking the Existing Flow Barrier to the North of YM Through Geologic Activity, the Height of the Water Table Rose 275 m
  - If These Two Events Occurred Simultaneously, the Rise in the Height of the Water Table Could Potentially be Much Greater than 275 m

THE EFFECTS OF CLIMATE CHANGE



DISCLAIMER - DEMONSTRATION PLOT ONLY. DOES NOT REPRESENT EXPECTED REPOSITORY PERFORMANCE.

FINDINGS

- For the Case of Yucca Mountain, "Climate Change" Appears to Have the Potential to Significantly Impact Repository Performance
- The Numbers Presented Throughout this Presentation are for Yucca Mountain, NV
- Although the Numbers (e.g., Probability for a "Climate Change") for the WIPP Site Would be Different, the Methodology Would Be Similar

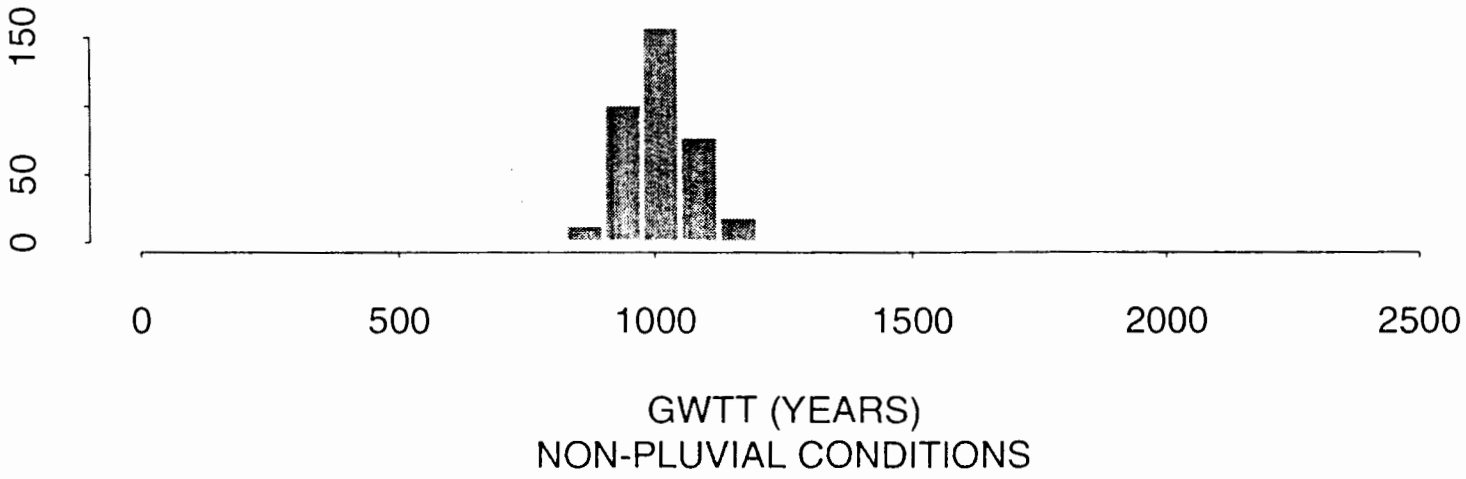
OBSERVATIONS

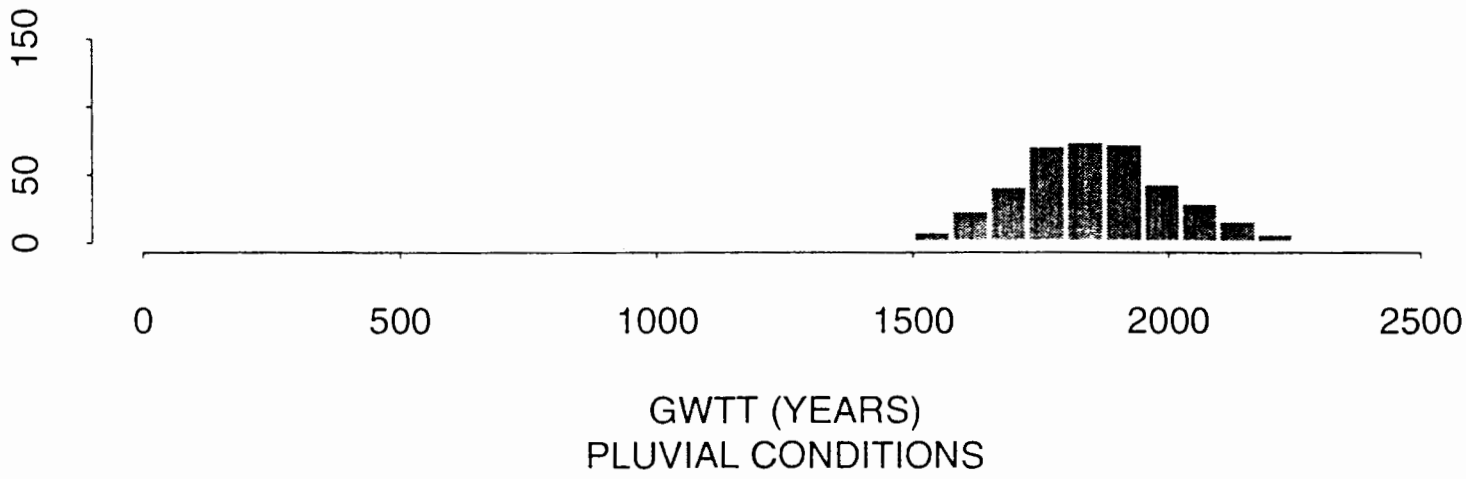
- Climate Change Can Potentially Affect Several Subsystems in a Repository, Without a Systematic, Comprehensive Analysis, It May Be Difficult to Determine the Overall Effect on Repository Performance

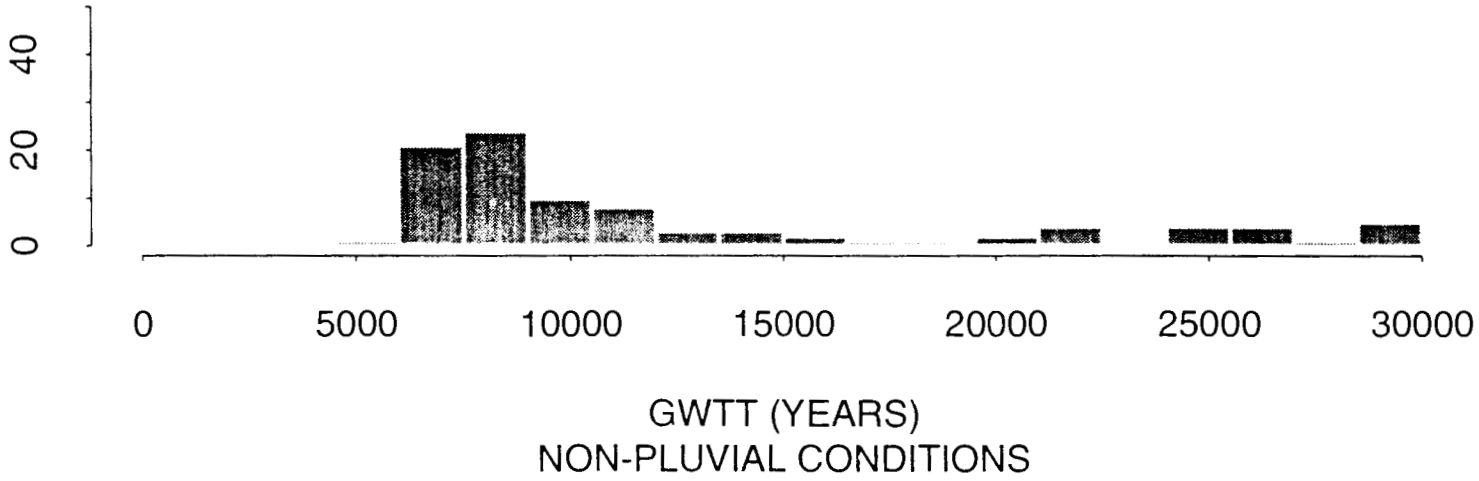
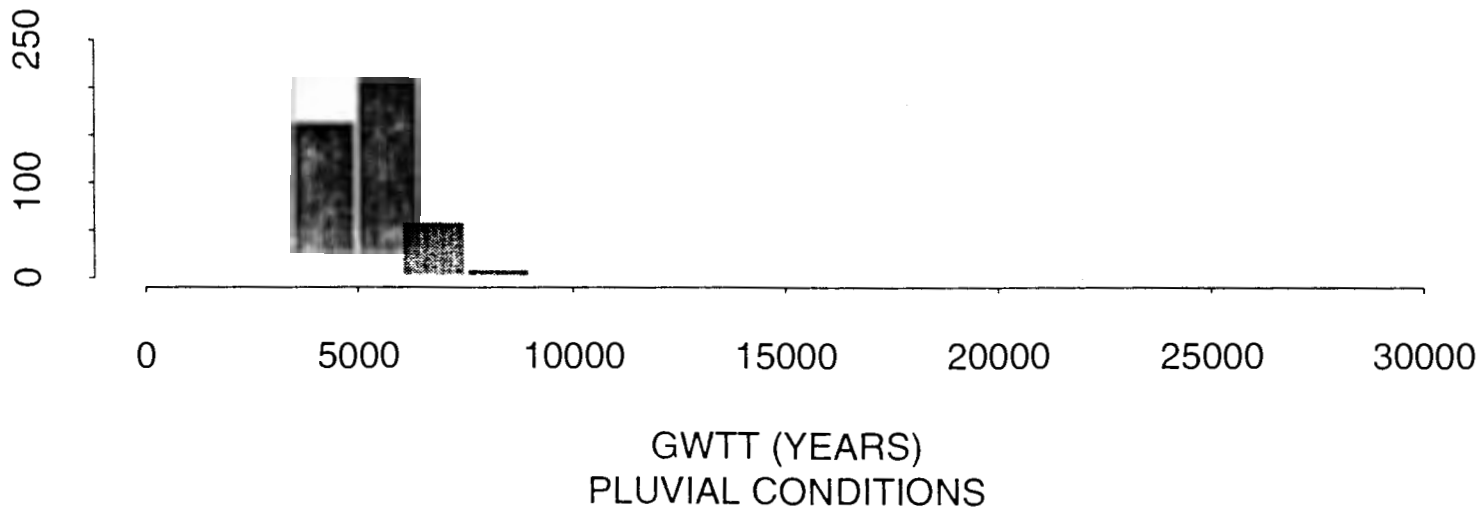
- Since Many Other "Common Cause" Inputs Could Influence Repository Performance, and Some of These Could Have a Synergistic Effect with Climate Change, One Should Not Assume that the Influence of Climate Change Alone on the Undisturbed System Adequately Describes the Influence of Climate Change

GROUNDWATER TRAVEL TIME DISTRIBUTIONS

REGION = 1 FORM = SHORT





GROUNDWATER TRAVEL TIME DISTRIBUTIONS

REGION = 4 FORM = SHORT