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Date: December 1, 1998
Refer to: EM/ER:98-461

Mr. Ted Taylor, Program Manager
US Department of Energy
Los Alamos Area Office, MS A316
Los Alamos, NM 87545

SUBJECT: REVIEW OF DRAFT MDA CORE DOCUMENT

Enclosed please find the Draft MDA Core Document and the appendices. Please review this material at your earliest convenience and provide comments no later than December 18, 1998.

If you have any questions, please contact Diana Hollis at 665-8469 or Deba Daymon at 665-9021.

Sincerely,

Julie A. Canepa

Julie A. Canepa, Program Manager
Environmental Restoration

JC/SE/gt

Enclosure: (1) Draft MDA Core Document
(2) Appendices

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MDA Core Document

A Process for Expediting Corrective Actions at LANL MDAs

Draft for LANL and DOE Review

December 1, 1998

1.0 INTRODUCTION

The Los Alamos National Laboratory (LANL, the Laboratory) generated significant quantities of waste in accomplishing its original mission of nuclear weapons research and development. Much of this waste was disposed of on-site in what are referred to as Material Disposal Areas, or MDAs. Most MDAs are land disposals similar to municipal landfills, except for their contents. There are about two dozen MDAs located across the 43 square mile LANL complex, with variable inventories, including liquids, sludges, solids, organic chemicals, non-nuclear explosives residues, and metallic plutonium. While disposal of such wastes was not in conflict with contemporaneous practice, more protective regulations have since been enacted to ensure that such legacy waste will not pose unacceptable risks to human or ecological receptors, either now or in the future.

The U.S. Environmental Protection Agency (EPA) regulations affecting Solid Waste Management Units (SWMUs) are specified within the Hazardous and Solid Waste Amendments (HSWA) of the Resource Conservation and Recovery Act (RCRA). The LANL Environmental Restoration (ER) Project performs corrective actions at SWMUs in accordance with the HSWA Module of the LANL RCRA Permit, issued under the authority of the New Mexico Environment Department (NMED) under agreement with the EPA. The majority of LANL's MDAs are identified as SWMUs in the HSWA Module, as Table 1-1 shows. The ER Project is following EPA's "Advance Notification of Proposed Rulemaking, *Corrective Actions for Releases from Solid Waste Management Facilities at Hazardous Waste Management Facilities*" (hereafter referred to as "Subpart S") in implementing corrective actions at these MDAs. While ER Project personnel recognize that Subpart S has been neither finalized by the EPA nor adopted by the NMED, proposed Subpart S is the standard corrective action protocol implemented nationally.

This document establishes the process for selecting and evaluating corrective action alternatives for MDA SWMUs, invoking elements of RCRA Subpart S to expedite the process in a manner that is at once cost-effective, compliant with RCRA, technically defensible, and protective of human health and the environment.

The MDA Core Document process applied at a given MDA will result in information substantively equivalent to the requirements of the HSWA Module. In particular, the process will be responsive to Section Q, "Scope of Work for a RFI at Los Alamos National Laboratory," and Section R, "Scope of Work for a RCRA CMS at Los Alamos National Laboratory."

1.1 Regulatory Framework

Under proposed Subpart S to RCRA, corrective actions are performed to minimize present-day and future risks to human and ecological receptors. Decisions regarding corrective actions at LANL MDAs will be made under the assumption that the EPA standard target risk range elucidated in Subpart S applies:

> "EPA's risk reduction goal is to reduce the threat from carcinogenic contaminants such that, for any medium, the excess risk of cancer to an individual exposed over a lifetime generally falls within a range from 10^{-6}... to 10^{-4}. For non-carcinogens, the hazard index should generally not exceed one. Risk-based media cleanup standards are generally considered protective if they achieve a level of risk which falls within 10^{-6} and 10^{-4} risk range." [FR Vol. 61, No. 85, May 1, 1996; EPA 1996a]

MDA	TA Location	Disposal Unit Type	Potential Contaminant(s)	Listed in HSWA Module ?
A	21	Trenches	Radioactive, Hazardous	Yes
B	21	Trenches	Radioactive, Hazardous	Yes
C	51	Trench	Radioactive, Hazardous	Yes
D		Firing Chamber	Radioactive, Hazardous	Yes
E		Trench	Radioactive, Hazardous	Yes
F			Radioactive, Hazardous	Yes
G	54	Trenches, Shafts	Radioactive, Hazardous	No
H	54	Shafts	Radioactive, Hazardous	No
J	54	Trench, Shafts	Radioactive, Hazardous	Yes
K		Seepage Pits	Radioactive	Yes
L	54	Seepage Pits, Shafts	Hazardous	
N				
Q				
R				
S				
T	21	Seepage Pits, Shafts	Radioactive, Hazardous	Yes
U	21	Seepage Pits, Trenches	Radioactive, Hazardous	Yes
V	21	Seepage Pits, Trenches	Radioactive, Hazardous	Yes
W				
X				
Y				
Z				
AA				
AB	49	Firing Chambers	Radioactive, Hazardous	Yes
Airport Landfill		Trenches		

Table 1.1. [Title?]

The Subpart S risk-based performance objective of 1×10^{-4} to 1×10^{-6} is consistent with and conservative relative to the identified radiological performance objectives of 15 to 25 to 100 mrem/year (that is, an increased lifetime risk of 3×10^{-4} to 5×10^{-4} to 2×10^{-3}). The EPA guidance in OSWER No. 9200.4-18, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," states [EPA 1992]:

> "Cleanup should generally achieve a level of risk within the 10^{-4} to 10^{-6} carcinogenic risk range based on the reasonable maximum exposure for an individual. The cleanup levels to be specified include exposures from all potential pathways, and through all media (e.g., soil, ground water, surface water, sediment, air, structures, biota). As noted in previous policy, "the upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions.
>
> "If a dose assessment is conducted at the site then 15 millirem per year (mrem/yr) effective dose equivalent (EDE) should generally be the maximum dose limit for humans. This level equates to approximately 3×10^{-4} increased lifetime risk and is consistent with levels generally considered protective in other governmental actions, particularly regulations and guidance developed by EPA in other radiation control programs."

The 10^{-4} to 10^{-6} risk-based performance objective is also consistent with the 4 mrem/year radiological drinking water limit in the Clean Water regulations and the 10 mrem/year radiological air dose limit in the radionuclide NESHAPs regulations.

A risk-based standard is reasonable because MDAs containing hazardous, radioactive, and/or mixed waste are indistinguishable in terms of risk. The target risk range is compliant because it encompasses other potentially applicable regulatory standards, including the DOE standard for public radiation protection and the EPA Clean Water and Clean Air Acts. Most important, the use of a risk-based regulatory decision threshold is consistent with the *Risk-Based Decision Tree* included in the <u>New Mexico Environment Department Hazardous and Radioactive Materials Bureau RCRA Permits Management Program Document Requirement Guide</u> [October __, 1998; NMED 1998].

Consistent with the philosophy developed by EPA to expedite the corrective action process, the MDA Core Document proposes narrowing the remediation alternatives to a set that is considered practicable and protective for a given site. Data collection and analysis are then focused on decisions relating to the comparative evaluations of those feasible alternatives. In so doing, the MDA Core Document approach adheres to Subpart S:

> "[T]he earlier in the corrective action process potential remedies can be identified, the more effectively information gathering can be focused... For example, in situations where the contamination being addressed involves a large mixed fill landfill, the remedial alternatives will likely involve physical and institutional controls. These alternatives should be identified early, enabling the facility owner/operator to tailor (site characterization) toward collection of information necessary to support development of appropriate physical controls... EPA advises program implementors and facility owners/operators to focus corrective measures studies on realistic remedies and to tailor the scope and substance of studies to the extent, nature and complexity of releases and contamination at any given

> facility. For example, some potential remedies should not be considered because they are simply implausible"

Alternative corrective actions for MDAs must ensure acceptable risks to human and ecological receptors, now and in the future; specific points and times of compliance will be negotiated with the NMED to maximize efficiencies in risk reduction and risk management across the LANL complex. Present-day risks posed by MDAs are generally low because of institutional controls, and because contamination is buried below ground. Future risks may be larger if naturally-occurring hydrogeological processes or disruptive events disperse contamination. Future risks posed by MDAs are likely to remain low if contamination remains inaccessible to human or ecological receptors. Assurance of inaccessibility by human or ecological receptors can be accomplished by:

- removing some or all of the material within an MDA and disposing of the inventory elsewhere,
- stabilizing the contamination within the MDA,
- controlling access to the MDA, and/or
- monitoring of environmental media that may transport contamination away from the MDA.

Excavation and off-site disposal may be a practical alternative for only a small subset of MDAs that contain a small, shallow, homogeneous, and well-characterized inventory. Most MDAs contain large volumes of deeply-buried heterogeneous materials contaminated with a variety of constituents, making excavation difficult or impracticable and off-site disposal unlikely or impossible. For these MDAs, capping, administrative controls, and long-term monitoring are likely to be the optimal corrective action alternative. This approach is consistent with Subpart S:

> "EPA expects to use a combination of methods (e.g., treatment, engineering and institutional controls), as appropriate, to achieve protection of human health and the environment... [with] institutional controls such as land use restrictions primarily to supplement engineering controls..."

1.2 Technical Framework

In the traditional RCRA corrective action process, the RCRA Facility Investigation (RFI) applies information to characterize the nature and extent of any release(s) to air, groundwater, surface water, and soil; to evaluate the potential threat to human health and the environment; and to support corrective measures proposals. Once the SWMU and its associated potential environmental and human-health risks are characterized, a corrective measures study (CMS) is undertaken to evaluate alternative means of mitigating those risks. In tailoring this approach to MDAs with the objective of streamlining, the technical framework established in this document adopts the Subpart S philosophy:

> "EPA continues to emphasize that the components of corrective action should not be viewed as isolated steps in a linear process... In the Agency's experience, it is generally more efficient to focus data collection on information needed to support an appropriate, implementable remedy than to attempt to complete separate evaluations at each step...

[T]he earlier in the corrective action process potential remedies can be identified, the more effectively information gathering can be focused..."

For MDAs, the fact that contamination is in the subsurface and not readily accessible has important implications in terms of site characterization and identification of viable remediation alternatives. If not thoughtfully designed, sampling and analysis programs implemented to *determine the nature and extent of contamination* can be very costly, and not serve the purpose of mitigating potential risks. Traditional risk assessment considers the contaminant concentrations, exposure pathways, and consequences. The MDAs require similar considerations, but at time scales that extend 1,000 years into the future. A combination of modeling and site characterization data will be used to define contaminant nature and extent to the degree necessary to support well-defined decisions in the corrective action process.

The traditional CMS process may be streamlined by proposing a standard corrective action for MDAs— capping and long-term monitoring. Enduring protectiveness is demonstrated using site-specific fate and transport models, and by results of decades-long field studies conducted at LANL. A monitoring program will be deployed for each MDA to provide assurance that the selected remedy is effective. In addition to MDA-specific monitoring, Laboratory-wide monitoring will provide additional assurance that cumulative releases through a given environmental pathway will not exceed acceptable risk thresholds across the entire LANL complex.

Evaluation of the future risk posed by contaminants in the environment, and of the risk-reduction capability of alternative corrective actions, is accomplished using mathematical models that simulate processes that may affect contaminant mobility. These models calculate concentrations of contaminants in environmental media at various times and locations, which are in turn used to assess the risk to human or ecological receptors under assumed exposure scenarios. There are several generic computer models used at RCRA corrective-action sites to calculate contaminant fate and transport via surface- and groundwater, two examples being MODFLOW and HELP. These generic models are adequate for sites that are reasonably represented by simplifications inherent in the models. However, site-specific models may be required to more accurately simulate fate and transport in more unusual or complex natural settings.[†] The use of site-specific models is consistent with Subpart S:

> "Site-specific risk assessments conducted at RCRA facilities ... based on ... methods developed expressly for application at specific sites or types of sites could result in more valid and reliable characterizations of risks to human health and the environment."

Site-specific models will be used to inform corrective-action decisions for LANL MDAs, due to the complexity of the natural setting. The same models were used to simulate fate and transport of radiological contaminants at MDA G in support of the performance assessment and composite analysis, which is required to demonstrate compliance with Department of Energy (DOE) requirements at that site. The performance assessment and composite analysis are substantively equivalent to EPA risk assessments conducted in support of ER activities across the DOE complex, and ensure facility compliance with EPA standards for radiological protection of human health and the environment. The MDA G performance assessment and composite analysis are

[†] HELP is currently recognized as the EPA's landfill cover design code, and is adequate for most surface water balance calculations, but it does not address soil physics within a cover in a robust way. MODFLOW is widely used for groundwater transport calculations, and could conceivably be used to handle many aspects of the groundwater flow in the main aquifer, although the representation of complex stratigraphy is not the forte of this code.

substantively equivalent to the analyses required by the Nuclear Regulatory Commission to license low-level radioactive waste disposal sites under 10 CFR 61 (e.g., the Chem-Nuclear disposal facility in South Carolina). They are also similar to the analyses required by the EPA for licensing disposal facilities under 40 CFR 191 (e.g., WIPP facility in New Mexico).

1.3 Decision Framework

The regulatory and technical frameworks already discussed have been consolidated into a general decision framework that will be implemented on an MDA-specific basis to expeditiously complete the corrective action process. This decision framework is shown in Figure 1-1. The decision framework developed for the MDA Core Document is designed to provide a step-by-step process to ensure that a systematic and defensible approach is taken to address both current and future risk and to ensure that risk is and remains within acceptable limits. The decision process provides a basis for no further action, evaluation of the proposed standard remedy (capping and long-term monitoring), or removal of MDA contents.

The analysis is uses predefined decision rules developed through the EPA's Data Quality Objectives (DQO) process, and provides a documentable basis for each decision. It provides flexibility by allowing alternative considerations through contingency options, which will be considered if the proposed remedy fails to meet specific criteria and removal is impracticable because of cost, worker safety, or non-existent disposal capacity.

The initial step in the decision framework calls for the evaluation of the existing site data for the MDA of concern. A portion of these data enter into the regulatory analysis for a site, which ensures that all potentially applicable regulations in addition to Subpart S of RCRA are met.

Present-day and future risks posed by the MDA are evaluated following the regulatory analysis. If present-day risks exceed acceptable limits, stabilization of the site may be necessary. Should baseline future risks be acceptable, the site is maintained and monitored. If future risks to humans and the environment exceed acceptable limits, corrective action decsions for the MDA will be undertaken. In evaluating the proposed standard remedy of capping and monitoring, the MDA G analysis is used as a point of comparison or departure. Quantitative decision rules used to compare a particular MDA to MDA G, with efficiencies gained in using the existing MDA G analysis to inform decisions about similar MDAs, and only modeling other MDAs specifically as determined through the decision analysis.

1.4 Scope

As stated earlier, there are about two dozen MDAs at LANL. In general, these sites have waste disposed of or otherwise emplaced on or below the ground surface in excavated pits, trenches, shafts, or cavities. Most of those sites, including those with the largest inventories of radioactive or hazardous contaminants, are located on mesa tops. Even before environmental laws were enacted to ensure groundwater protection, these mesa-top locations were chosen based on knowledge of favorable hydrogeologic conditions, which were relied upon to preclude transport of contaminants by groundwater. Figure 1-2 shows the locations of the LANL MDAs; Appendix 1 includes fact sheets that describe the current state of knowledge of some of those MDAs.

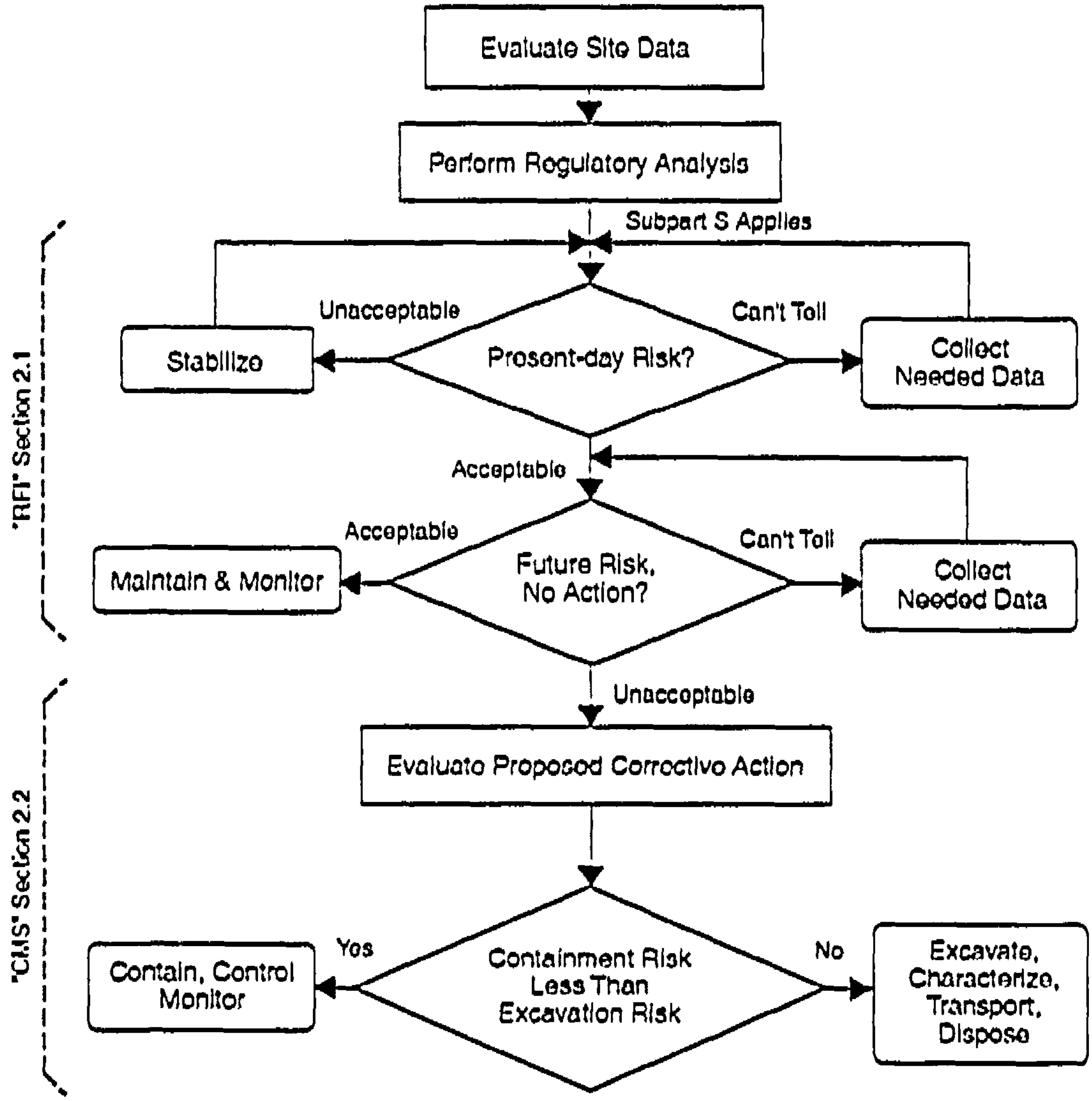

Figure 1-1. Generalized decision framework for streamlining the corrective action process for LANL MDAs

Section 2 of this document describes the expedited corrective action process in terms of focused RFI and streamlined CMS processes, as indicated in Figure 1-1. Section 3 discusses public involvement, and Section 4 presents the plan for implementing the MDA Core Document process at LANL MDAs. The level of detail in each section is optimized to ensure clarity of the description for a wide audience of interested readers. Each section is supplemented by one or more "Detail References," cited appropriately. Detail References are required for implementing the MDA Core Document decision framework, and are offered as information for more interested readers.

Material Disposal Areas of
Los Alamos National Laboratory

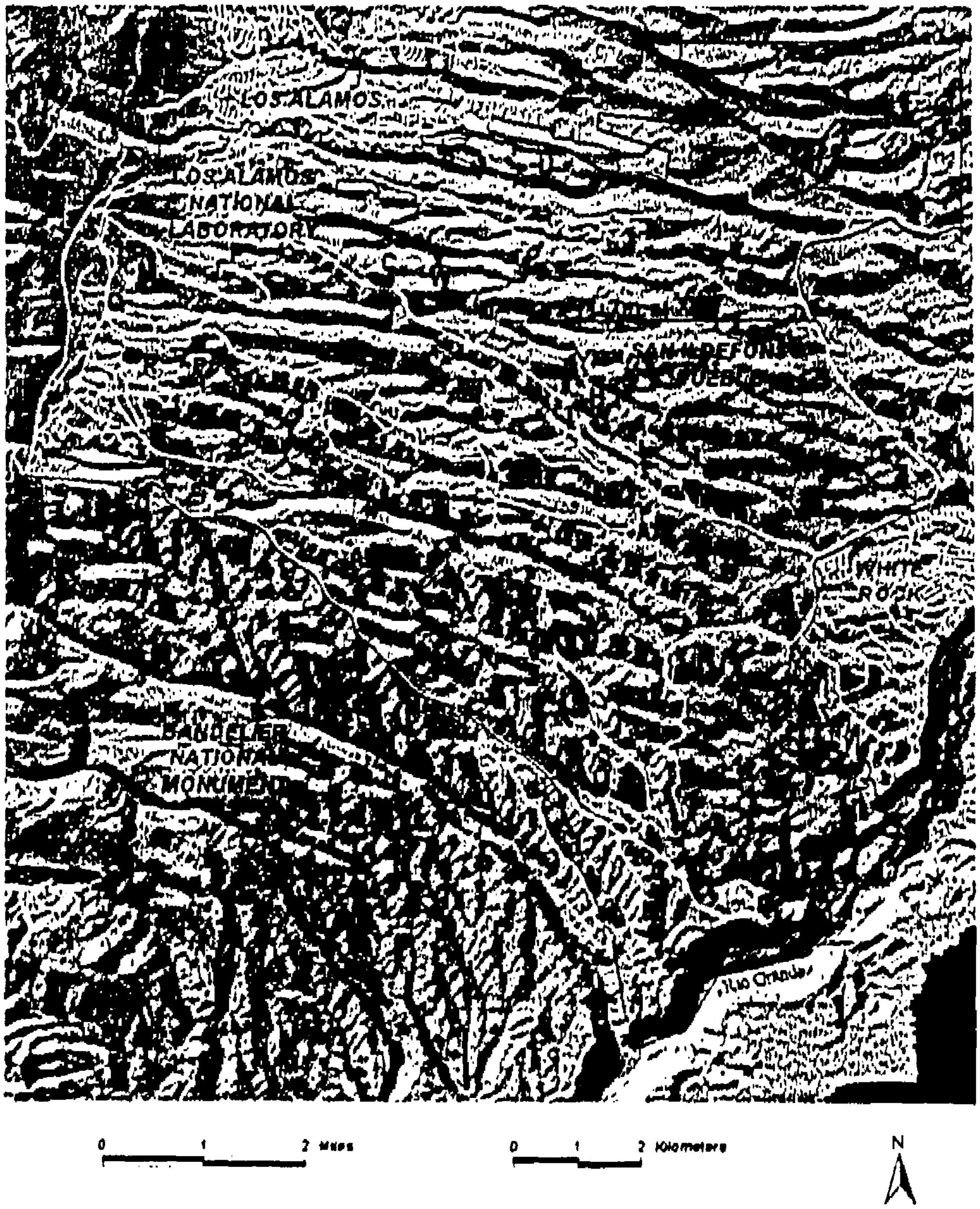

Figure 1-2. Location of LANL MDAs to be addressed according to the MDA core document decision framework

2.0 EXPEDITED RCRA CORRECTIVE ACTION PROCESS FOR MDAS

The purpose of RCRA corrective action is to minimize risks to human and ecological receptors due to contamination in the environment. The degree of risk from contamination in the environment depends upon:

- The nature of the contaminant,
- The extent of the contamination,
- The way that a receptor comes into contact with the contamination, and
- The toxicological or radiological effect that the contaminant has on the receptor

Toxicological and radiological effects can both be quantified in a risk context, which simplifies certain risk-based decisions for MDAs that contain both radioactive and toxic constituents. Assessing potential risks associated with a contaminated site requires understanding of each of the factors listed above. The goal of the RCRA Facilities Investigation (RFI) is to acquire data needed to ensure such an understanding. If the RFI determines that risk is unacceptable, then ways to minimize the risk must be evaluated. This is the purpose of the Corrective Measures Study (CMS). In general, risk can be minimized by

- removing some or all of the contamination, or
- controlling contact between contamination and receptor.

The optimal corrective action depends upon the balance of many considerations on a site-specific basis, chief among these being

- the protectiveness of the corrective action,
- its technical practicality, and
- its cost.

For MDAs where inventory removal is shown to be imminently hazardous, impractical (e.g., no offsite disposal capacity), and/or cost-prohibitive, the optimal corrective measure will be controlling contact between inventory and human and ecological receptors. A combination of methods commensurate with the risks associated with a given site will be implemented, to include:

- Site stabilization and capping,
- Access control and institutional care,
- Long-term monitoring, and
- Contingency planning.

The final corrective action will ensure that risks to human and ecological receptors from all contaminants in the inventory, through all transport pathways and exposure routes, will be acceptable to the NMED and other stakeholder groups. Monitoring of environmental media will be implemented to ensure protectiveness and compliance, and to evaluate performance of the engineered controls (i.e., stabilization and capping). The point(s) of compliance and time(s) of compliance will be negotiated with NMED, with the objective of ensuring protectiveness on a scale that accounts for as many contaminants and receptors as possible, recognizing that nature will, in time, aggregated multiple contaminated sites along transport pathways. This approach is consistent with Subpart S:

> "EPA emphasizes that it expects facility owners/operators to develop and recommend remedies including proposed media cleanup levels, points of compliance and compliance time frames, that address the proposed threshold criteria and present an advantageous combination of the proposed balancing criteria."

2.1 Focused RCRA Facilities Investigations

The RFI is intended to ascertain the nature and extent of contamination and to gather information necessary to support selection and implementation of remediation strategies. According to proposed Subpart S:

> "Carefully designed and implemented RFIs are critical to accurately characterize the nature, extent, direction, rate, movement, and concentration of releases at a given facility... to determine potential risks to human health and the environment and support development and implementation of corrective measures should they prove necessary... In the Agency's experience, it is generally more efficient to focus data collection on information needed to support an appropriate, implementable remedy than to attempt to complete separate evaluations at each step... [T]he earlier in the corrective action process potential remedies can be identified, the more effectively information gathering can be focused... Site investigations and remedy implementation are often most successful when based on a conceptual site model... a three-dimensional picture of the conditions that conveys what is known or suspected about the sources, releases, and release mechanisms, contaminant fate and transport, exposure pathways and potential receptors... The conceptual site model may be used... to support risk-based decision-making and to aid in the identification and design of potential remedial alternatives." [EPA 1996a]

Consistent with this philosophy, the data collected at MDAs will be focused on:

- Bounding the nature, extent, direction, rate, movement, and concentration of releases at a given facility;
- Determining potential risks to human health and the environment; and
- Supporting design of an appropriate, implementable remedy.

2.1.1 General Conceptual Model for MDAs

Site investigations will be based on a conceptual site model, "a three-dimensional picture of the conditions that conveys what is known or suspected about the sources, releases, and release mechanisms, contaminant fate and transport, exposure pathways and potential receptors." The general conceptual model for MDAs is taken from the MDA G analysis, and is shown in Figure 2-1. This conceptual model is based on extensive data from various MDAs including MDA G, and extensive modeling done exclusively for MDA G. Although developed for MDA G, it is thought to be representative of most of LANL MDAs, which feature contaminated materials contained below the surface of the ground, within a mesa, flanked by canyons containing alluvial water. The sites are, in general, covered with an earthen, vegetated cap.

For a generic MDA with engineered disposal units and a simple cap, the diagram illustrates:

- The mesa-canyon topography; which has important effects on air, surface water, and subsurface contaminant transport, as well as on potential contaminant receptors.
- The geology, consisting of subsurface layers of various volcanic depositions (e.g., Units 2, 1vu, 1vc, and 1vg of the Tshirege Member of the Bandelier Tuff; the Otowi Member of the Bandelier Tuff; and the Cerros del Rio Basalts), which has variable physical and chemical features that dramatically affect subsurface contaminant transport.
- The hydrology, incorporating intermittent surface streams in adjacent canyons, liquid- and vapor-phase water moving through the subsurface within the rock matrix, within fractures in the rock, and along interfaces between layers, and from transpiration, all of which affect surface and subsurface transport of contaminants.

The solid arrows emanating from the mesa surface and vegetation represent the movement of water as a liquid (straight arrows) and as a vapor (serpentine arrows). Liquid water generally moves down into the mesa (i.e., infiltrates), while water vapor generally moves up through the mesa surface and out the mesa sides (i.e., evaporates), and up through vegetation (i.e., transpires).

The source terms illustrated in the general conceptual model for MDAs are indicated with straight and serpentine arrows around the disposal units. The straight arrows represent movement of leachate percolating through the disposal units. The serpentine arrows suggest releases of contamination into the air, either as gases or as dust particles. The actual source term for resuspended particulates involves processes that lead to surface contamination, including erosion and intrusion by plants and animals.

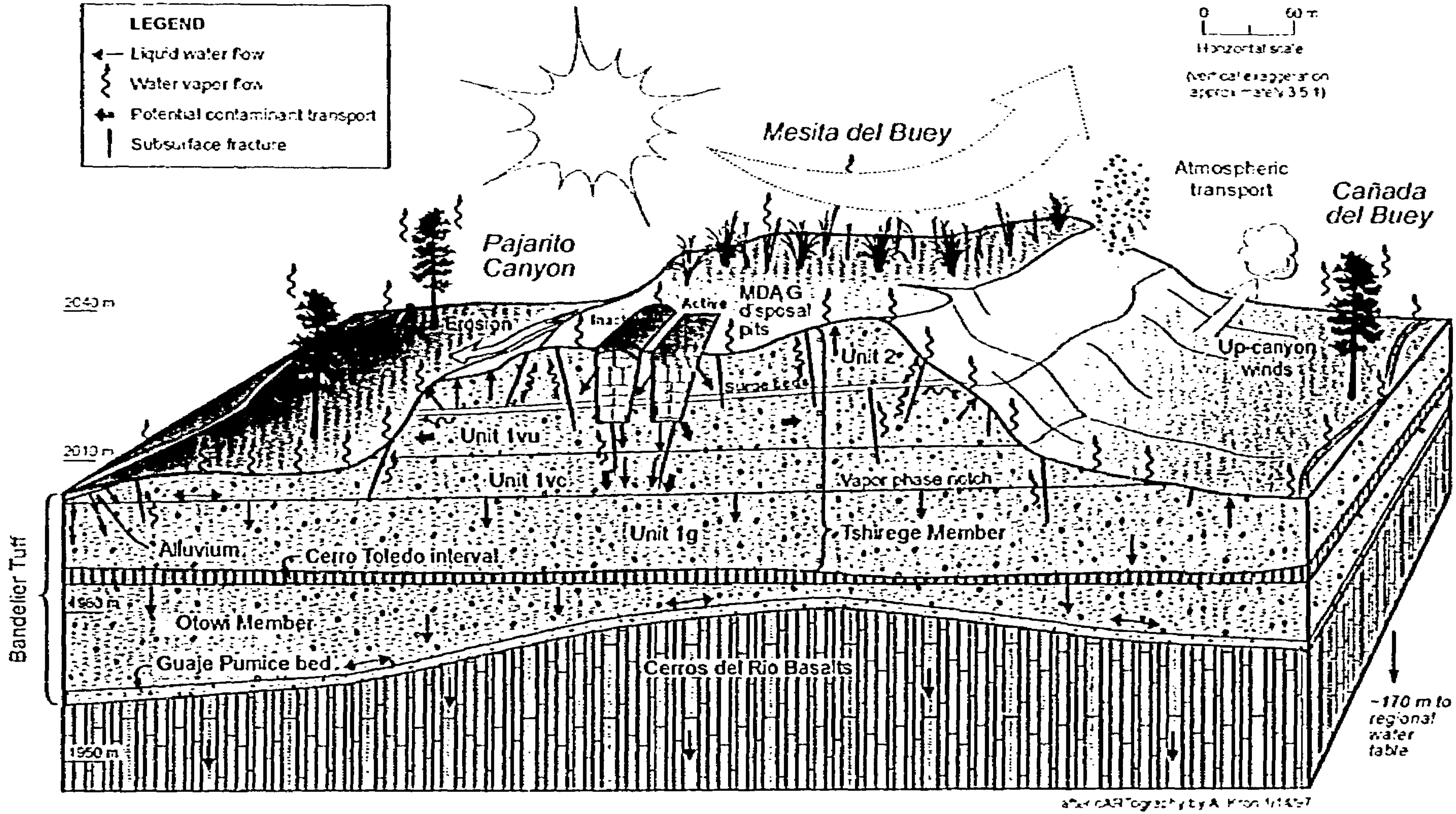

Figure 2-1. General conceptual model for MDAs

The exposure pathways combine a source release with air or water, which can transport contamination away from the disposal facility to locations where it might be accessed by human or ecological receptors. Contaminant transport is identified by open arrows on the figure:

- Leachate is transported through the rock beneath the disposal units toward the regional aquifer by gravity and other natural forces (e.g., vapor pressure, water pressure, etc.).
- Gas-phase releases and resuspended particulates are transported in air to downwind receptors.
- Surface contamination resulting from biotic translocation and erosion is transported off of the mesa by stormwater runoff.

Exposure pathways can combine one or more source terms and transport media. For example, contaminants in water (either below ground or on the surface) can be assimilated by plants; resuspended radioactivity in air can be deposited on plants; and contaminated surface soils can be splashed onto plants.

2.1.2 Nature and Extent

Guidance on what constitutes nature and extent is provided in Subpart S:

> "In delineating the nature and extent of contamination it may not be necessary to delineate to background concentrations in all cases. In some cases, information adequate to support cleanup decisions can be obtained through delineation to risk-based concentrations or other investigation endpoints."

In the corrective action process for MDAs, data, models, and Data Quality Objectives (DQOs) will be used to ensure that nature and extent of contamination have been bounded. (Decision rules, determined through the DQO process and evaluated with models and data, can be thought of as "other investigation endpoints" in the context of the previous excerpt from Subpart S.) Site-specific data will be used for each MDA. For a given MDA, data will be used to:

- Directly bound nature and extent of contamination,
- Indirectly bound nature and extent by comparison to conditions at another similar, but better characterized, MDA, or
- Indirectly bound nature and extent with fate and transport models.

2.1.3 Evaluating Present-Day Risk

The RFI process requires the evaluation of conditions at an MDA that pose an immediate risk to human health and the environment. When evaluating conditions at an MDA in the context of present-day risk, it is important that factors that may exacerbate future risk also be considered. The ER Project has procedures for evaluating imminent present-day risks, summarized in Detail Reference- Evaluating Present-Day Risks at MDAs. Should present-day risks or the potential for exacerbating future risks prove to be unacceptable, it may be necessary to initiate site stabilization. The rationale for site stabilization is provided in the EPA's stabilization initiative:

> "The goal of the Stabilization Initiative is to increase the rate of corrective actions by focusing on near-term activities to control or abate threats to human health and the environment and prevent or minimize the further spread of contamination... Controlling exposures or the migration of a release may stabilize a facility, but does not necessarily mean that a facility is completely cleaned up. At some stabilized facilities, contamination is still present and additional investigations or remediation may be required... Stabilization activities should be a component of, or at least consistent with, final remedies."

Stabilization of a site may be necessary if, for example, contaminant concentrations in surface soils pose imminent threat to persons working in the area. Alternatively, stabilization may be required if conditions at an MDA have a potential for increasing rates of contaminant release and environmental transport in the future. An accurate evaluation of conditions such as these require an understanding of site processes. As a point of departure, the general conceptual model described earlier in this section will be used to determine the need for stabilization on the basis of future contaminant transport potential. Regardless of the cause for a stabilization action, activities will be conducted in a manner that is consistent with the likely final remedy.

2.1.4 Evaluating Future Risk

The evaluation of future human or ecological risks associated with a given MDA is fundamentally different from the process used to estimate present day risks. Unlike the evaluation of present-day risks, future risks cannot be determined in "real time," using current conditions as an indicator. Instead, fate and transport models are used to estimate potential rates of contaminant release and transport from the disposal facility, and any subsequent impacts on human health and the environment. Projected risks to humans and the environment are compared to regulatory risk criteria, and used in the corrective action process to identify effective remediation strategies.

It is the intent of the Core Document approach to use the extensive analyses conducted for MDA G to evaluate risks posed by the LANL MDAs, without having to directly model each MDA. A quantitative decision analysis approach provides such efficiencies in the risk-assessment process without compromising the credibility of that process. The decision framework, shown in Figure 2-1, allows for comparisons of contaminant nature and extent, and transport pathways, as well as extrapolations of potential future risk by evaluating MDA-specific data in the context of data and modeling from MDA G.

The decision analysis uses quantitative decision rules, formulated through the EPA DQO process, to evaluate data from an MDA under consideration to

- Determine the applicability of the general conceptual model for MDAs, considering each transport/receptor pathway individually, and then
- Determine the adequacy of site-specific data to confidently extrapolate potential future risk at the MDA in question using the MDA G analysis.

The decision framework will be detailed later in this section, after a brief summary of the MDA G analysis upon which much of the decision analysis is based. The summary describes independent transport/receptor analyses undertaken at MDA G. For each transport/receptor pathway analysis, the summary describes the major assumptions, the final results, and the dominant uncertainties. All of this information is critical in the DQO application to develop decision rules for each decision node shown in Figure 2-2. An in-depth summary of that analysis is provided in Detail Reference-Summary of the MDA G Performance Assessment and Composite Analysis.

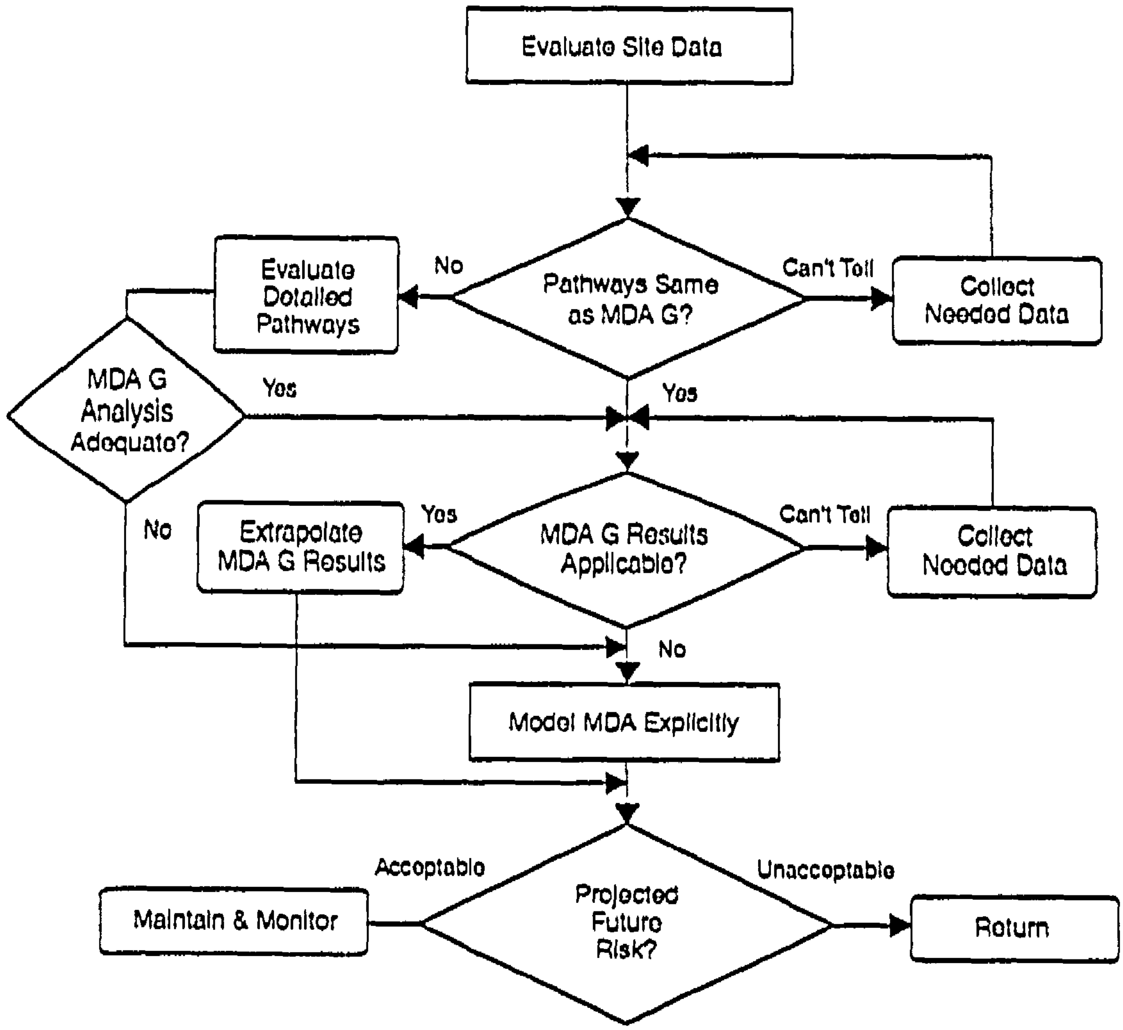

Figure 2-2. Decision framework for expedited corrective actions at MDAs

2.1.4.1 Groundwater Pathway Analysis

The groundwater pathway analysis considered in the MDA G analysis is based on the following sequence of events:

- Radionuclides are leached by water percolating through disposal units at MDA G;
- Leachate is transported vertically downward through the vadose zone to the regional aquifer, or laterally into semi-saturated alluvium in Pajarito Canyon, from which it is transported directly downward to the regional aquifer;

- Radionuclides are diluted and transported within the regional aquifer to locations downgradient of MDA G; and
- Individuals at offsite locations receive doses as a result of using contaminated water drawn from the regional aquifer for drinking, crop irrigation, and watering animals.

It is important to note that the groundwater pathway at MDA G appears to be incomplete, but was modeled for the sake of conservatism. The lateral transport mechanism to the sides of the mesa and into the alluvial system has no basis in reality, but was included as a conceptual fast-path of groundwater transport to the regional aquifer.

The maximum annual groundwater-pathway dose calculated during the 1,000-year compliance period in the MDA G CA was 1.2×10^{-5} mrem at the downgradient receptor location. Carbon-14 was responsible for most of this dose, with ^{99}Tc, and ^{129}I also contributing. Even when worst-case bounds on the uncertainties in the groundwater analysis were considered, doses were orders of magnitude below EPA's 4 mrem/yr threshold. The largest uncertainties in the groundwater pathway analysis were uncertainties in:

- the total inventory of non-sorbing, long-lived radionuclides,
- the infiltration rate through the disposal units
- the percolation rate of leachate through the vadose zone, and
- the factors affecting dilution in the regional aquifer.

2.1.4.2 Air Pathway Analysis

The air pathway analysis of MDA G is based on the following assumptions:

- Radionuclides are brought to the surface of MDA G by plants and animals penetrating into the disposed waste, and upward-diffusing gaseous radionuclides diffuse upward to the ground surface;
- Contaminated soils suspended in the air above the disposal facility and gaseous releases are transported to an offsite receptor by the prevailing winds;
- An individual receives doses from the inhalation of airborne particulates and gases, ingestion of contaminated food crops, and external radiation from airborne radionuclides and contaminated soils.

The resulting maximum air-pathway dose projected for the MDA G composite analysis was 5.5 mrem per year, at the point of maximum exposure in Canada del Buey. The radionuclides responsible for the vast majority of the air-pathway dose were actinides from the oldest waste. The model used for biotic translocation assumes a maximum burrowing depth of 2 m (6.6 ft) based on site-specific data, and assumes that burrowing animals readily excavate waste contaminated with actinides. This is conservative based on information indicating that the largest

amount of the plutonium-bearing waste in that portion of the inventory is dewatered sludge that is buried at depths of three meters or more.

The largest uncertainties in the air pathway analysis were associated with the following parameters:

- Animal burrow depth,
- Total actinide inventory and concentration, and
- Canyon channeling.

2.1.4.3 Surface Water Pathways Analysis

The surface water pathway analysis is based on the following assumptions:

- Radionuclides are brought to the surface of MDA G by plant uptake with plant roots growing into the waste and animals burrowing into the waste;
- Contaminated soils are transported from the mesa top to the floor of Pajarito Canyon by surface-water runoff;
- Mobile contaminants are transported vertically downward, in the alluvial deposits, to the regional aquifer; and
- An individual receives doses as a result of using contaminated water drawn from the regional aquifer for drinking, for crop irrigation, and for watering animals; and exposure to contaminated soils.

The maximum surface water pathways dose calculated during the 1,000-year compliance period of the composite analysis was 7.2×10^{-3} mrem/yr. The majority of the dose was attributed to inhalation of resuspended contaminated sediments and ingestion of vegetables contaminated with sediment (via rainsplash). Important radionuclides were ^{239}Pu, ^{108m}Ag, and ^{241}Am, brought to the surface of the disposal facility by burrowing animals. Assumptions about the distribution of actinides in the disposal units, discussed previously with respect to the air-pathway analysis, are expected to result in conservative dose projections for the surface water pathway. The primary uncertainties in the surface water pathways analysis are associated with the following parameters:

- Animal burrow depth,
- Total actinide inventory and concentration, and
- Sediment transport characteristics.

2.1.5 Using the MDA G Analysis in Evaluating Future Risk at other MDAs

The ability to use the MDA G performance assessment and composite analysis modeling framework for evaluating risks at other MDAs lies in the analogous hydrologic and geologic settings of the sites. Chief similarities are that the majority of the MDAs sit atop mesas like MDA G, and that the contamination of concern is disposed in excavated disposal units. The similar

setting and disposal characteristics are expected to allow direct application of the MDA G modeling results to most of the MDAs at LANL.

The decision framework that will guide the evaluation of future risks using the MDA G modeling results is illustrated in Figure 2-2. To begin the process, information about the MDA in question is collected and evaluated for regulatory classification according to the considerations elucidated in Detail Reference- Regulatory Analysis. Once it is determined that Subpart S is applicable, the site data are evaluated in the context of the general conceptual model for MDAs, and a determination is made whether this conceptual model is likely to conservatively bound fate and transport processes at the MDA of interest. This is done on a pathway-specific basis. If one or more pathways are judged to be conceptually similar at both sites, a more detailed comparison of the MDAs is undertaken.

Conversely, if the manner in which contaminants are expected to behave at the two MDAs differs significantly, MDA-specific modeling that departs from the MDA G analyses may be required.

Every MDA at LANL has undergone a RCRA Facilities Assessment, and most have undergone Phase 1 RFI. Thus, there is at least some information available for developing conceptual models for the MDAs. That said, all of the information required to develop an ideal conceptual model for any given pathway will rarely be available. This is especially true for MDAs that were active decades ago, when detailed disposal records were not maintained and therefore site characterization data were especially difficult to acquire. Limited data hampered modeling efforts at MDA G in conjunction with the performance assessment and composite analysis, and restricted use of truly realistic modeling simulations. This limitation was dealt with by modeling the site in a conservative manner. Modeling assumptions were used that are expected to overestimate contaminant releases and rates of environmental transport. This approach resulted in human dose projections that overstate expected exposures.

Collection of additional information about the MDA of concern may be necessary if the comparability of the site and MDA G conceptual models cannot be established. This information may come from several different sources. Given the similarity of the MDAs across the Laboratory, data from other MDAs or the MDA G analysis may be useful. Data from peer-reviewed literature may be appropriate, if the case can be made that site-specific data are not required. Theoretical calculations may form the basis for other data. For example, distribution coefficients for organic compounds may be calculated for tuff if the total organic carbon of the substrate is known. In other circumstances, the lack of data may be remedied by simple, cost-effective, bench-scale laboratory experiments. Finally, critical site-specific data for the MDA may be lacking and require that field investigations be conducted to obtain the information.

Given an MDA that is expected to function in a manner conceptually similar to MDA G, the detailed behavior of the two sites is compared, as indicated in Figure 2-2. While determining the applicability of the general MDA conceptual model may be somewhat subjective and based on expert judgment, the determination of whether existing models are adequate can be far more objective. This objectivity is provided by quantitative decision rules developed through a formal DQO evaluation of the sensitive parameters identified in the MDA G analysis, and a quantification of the acceptable uncertainties within those sensitive parameters.

The most sensitive parameters in each pathway/receptor analysis for MDA G were summarized previously in this section. In the language of DQOs, these are "Sensitive Parameters," and the options at the second and third decision diamonds on Figure 2-2— "MDA G Analysis Adequate?"

and "MDA G Results Applicable?"— are "Alternative Actions." Decision rules quantify "Action Levels," or thresholds that discriminate between alternative actions. Action levels have uncertainty tolerances associated with each alternative-action threshold that ensure decisions are made with a high degree of confidence.

With these decision rules, explicit data from a given MDA may compared to determine if the modeling results for MDA G can be directly applied to the MDA of concern. If the two sites compare favorably for one or more pathways, it may be possible to estimate the risks posed by the MDA of concern by directly scaling the MDA G modeling results. If, on the other hand, significant differences exist in the details of the two MDAs, it may be more prudent to conduct pathway modeling using the MDA G modeling methodology and MDA-specific input parameters. If additional information is needed to establish the comparability of MDA G and the MDA of interest, the sources of data discussed above may be consulted.

While the MDA G analysis is expected to apply to many of the LANL MDAs, a number of decisions will be needed to ascertain the degree to which this is true. Examples of the types of decisions that may be necessary to address within the framework of Figure 2-2 are:

- MDA T TA-21: Based on available information (see Fact Sheet, Appendix 1), MDA T is conservatively bounded by MDA G in most parameters affecting groundwater transport (e.g., shallower depth of disposal, higher position in the stratigraphic section of Bandelier Tuff, similar covers). However, there are two potentially significant differences that must be evaluated according to the decision analysis in Figure 2-2. First, the paleochannel that bisects the disposal trenches at MDA T is not present at MDA G. Decision: Is the "out and down" modeling of groundwater transport at MDA G sufficient to evaluate the potential effect that the paleochannel might have on groundwater transport? Second, the waste form at MDA T is a cement paste. Decision: Is the "surface contamination" modeling of the MDA G source term sufficient to represent the release rate of contamination in the cement paste at MDA T?

- MDA AB at TA-49: Based on available information (see Fact Sheet, Appendix 1), MDA AB is conservatively bounded by MDA G in several parameters affecting groundwater transport (e.g., higher stratigraphic position, no basalt, comparable inventory). However, the near-surface moisture content is much higher at MDA AB due in part to the presence of an asphalt cover. Decision: Is the steady-state moisture flux approximation in the MDA G model sufficient to represent the higher observed moisture content at MDA AB?

The application of the decision framework described above will indicate whether the potential future risks can be directly extrapolated from the MDA G modeling analysis. If extrapolation is possible and the extrapolated risks for the MDA of concern are within acceptable limits, no additional information should be required to support a final action for the MDA. Alternatively, if the extrapolated risks are unacceptable, actions may be taken to confirm the need for corrective action. Additional information about the site may be collected to improve the accuracy of the extrapolation process. Alternatively, the additional data may be used in conjunction with models specifically tailored to the MDA of concern to more accurately assess potential risks. Should projected risks remain at unacceptable levels, site remediation strategies will be evaluated.

The extrapolation of MDA G modeling results to estimate future risks at other MDAs may not be possible in some cases. If extrapolation fails due to lack of information about the MDA of interest, the collection of additional data may overcome the obstacle. Should extrapolation fail due to significant differences in fate, transport, and exposure pathways, then site-specific modeling may be required as well as additional data.

Consistent with DOE Order 5820.2A, the MDA G performance assessment and composite analysis focus on the potential risks posed by radioactive waste to human health and safety. The model framework, however, can be readily adapted to estimate risks associated with hazardous constituents found at many of the other MDAs. This adaptation will be completed before the decision framework shown in Figure 2-2 is applied at any other MDA. Ecological risk posed by waste disposed of at MDA G was not considered in the MDA analyses. The MDA G modeling will also be extended to address ecological risks posed by radioactive and hazardous contaminants.

The MDA G performance assessment and composite analysis are subject to errors introduced by uncertainties in the models and data used for the analyses. If these modeling analyses are used to estimate risks for other MDAs, then those MDA G uncertainties will affect those sites as well. Additional error may be introduced into the process because of uncertainties associated with the behavior of the subject MDAs. The potential impact of uncertainties must be considered when determining the applicability of the MDA G analyses to other MDAs and when extrapolating risks for the sites.

Two general approaches will be considered for addressing uncertainties associated with the use of MDA G modeling for risk estimation at other MDAs. The approach used will depend, in part, upon the magnitude of the risk posed by the MDAs being evaluated. If the risk posed by a given site is expected to be small, a deterministic, or bounding, approach to evaluating the impacts of uncertainty may be appropriate. In this approach, the assumptions and data used to model a site are chosen conservatively, to yield projected risks that can reasonably be expected to bound actual risks at the MDA. The result is to overstate the impact of the associated uncertainties, providing confidence that the MDA will perform at least as well as projected.

The deterministic approach to uncertainty analysis is best applied to sites that pose little risk to human health and the environment. This is because these sites will still be capable of complying with regulatory requirements despite the fact that the risks are overstated. Uncertainties associated with sites posing potentially significant risks will generally need to be evaluated using more sophisticated techniques. In recognition of this, probabilistic analyses will be used to evaluate the impact of uncertainties at some of the MDAs.

Probabilistic uncertainty analysis is generally used to address uncertainties inherent in the model-input parameters. Distributions describing the variability of the parameters are developed and propagated to yield distributions for model endpoints such as contaminant concentrations or risks. These model endpoint distributions can then be used to estimate the probabilities of the MDA exceeding pertinent regulatory criteria. The probabilistic analysis provides a more complete understanding of the actual uncertainties inherent in the modeling compared to the deterministic approach. However, such analyses generally require extensive information about the site. Depending upon how they are implemented, probabilistic analyses may cost considerably more to conduct.

As indicated in Figures 1-1 and 3-3, data are potentially needed at several steps in the MDA Core Document decision framework. Information may be needed to support RFI decisions related to

nature and extent of contamination, selection of appropriate remedial options within the context of the CMS, and the establishment and operation of long-term monitoring systems. Because data should be collected only if the information will significantly reduce the uncertainty in the decisions to be made (e.g., decisions about present-day or future risks, appropriate remedial options, and monitoring system configurations), a value-of-information analysis should be conducted.

Probabilistic uncertainty analysis, in conjunction with information about model sensitivities to parameter variations, provides insight into the importance of parameters relative to the decisions being made. As such, they lend themselves to value-of-information analysis. Deterministic analyses of uncertainty provide little information on the relative importance of parameters, limiting attempts to establish the value of collecting specific data. If a deterministic uncertainty analysis was performed for a site that exceeds regulatory thresholds, consideration should be given to the comparative costs of conducting a probabilistic analysis and taking action at the site.

2.2 Streamlined CMS Process

Steps in the CMS/CMI include the following:

- Identification of alternative corrective actions to minimize potential risks posed by contamination.
- Selection of the optimal corrective action to minimize potential risks posed by contamination.
- Implementation of the optimal corrective action.
- Monitoring the performance of the corrective action.
- Implementing contingencies as indicated by monitoring data.

If the RFI process determines that future risk at an MDA is unacceptable a CMS is undertaken to evaluate options for reducing risk. To simplify the regulatory and technical process, Subpart S advocates limiting the CMS to realistic options:

> "The CMS does not necessarily have to address all potential remedies for every corrective action. EPA advises program implementors and facility owners/operators to focus corrective measures studies on realistic remedies and to tailor the scope and substance of studies to the extent, nature and complexity of releases and contamination at any given facility. For example, some potential remedies should not be considered because they are simply implausible. "

This section describes the streamlined CMS process for MDAs shown to have an unacceptable future risk under the no action alternative. Two options are considered: containment with monitoring, and excavation. Containment with monitoring is presented as the proposed corrective action, based on the results of the MDA G composite analysis, and long-term field studies at LANL. Consistent with Subpart S, where effective remedies have been identified,

> "...the purpose of the CMS will be to confirm that the presumptive remedy is appropriate to facility-specific conditions..."

For sites where containment is determined to be inappropriate, excavation may be considered.

2.2.1 Low Risk Sites

At some MDAs, there is likely to be little present-day or future risk. These are candidates for the No Further Action alternative, and will not require corrective action to ensure protection of humans and the ecology. The treatment of these low risk sites will depend upon their ultimate disposition. Reclaimed sits will be evaluated using aesthetic and ecological standards used to guide the grading and landscaping necessary to promote site stability and a stable ecological assemblage. Where industrial or commercial use is contemplated, engineering issues, such as subsidence, will also be considered.

2.2.2 Presumptive Remedies: Identifying a Preferred Containment Alternative

The EPA's presumptive remedy approach is a key element of the streamlined CMS process. This section reviews the background on EPA's approach to presumptive remedies and presumptive remedy selection. Following this, the proposed LANL cover design and monitoring options are described.

2.2.2.1 Regulatory Background on Presumptive Remedies

Subpart S indicates that presumptive remedies are applicable to MDAs:

> "Presumptive remedies are preferred technologies for common categories of sites... The Agency expects that presumptive remedies will be used at all appropriate sites, including RCRA facilities, to help ensure consistency in remedy selection and implementation and to reduce the costs and time required to investigate and remediate similar types of sites."

The MDA Core Document proposes capping and monitoring as the remedy for LANL MDAs. This is a common approach at radioactive and hazardous waste sites. Subpart S provides guidance on possible options:

> "Attaining media cleanup standards does not necessarily entail removal or treatment of all contaminated material above specific constituent concentrations. Depending on the site-specific circumstances, remedies may attain media clean-up standards through... engineering and institutional controls. For example, in situations where waste is left in place... under a cap, media cleanup standards would be attained, in part, through long-term engineering and institutional controls."

In order to apply the capping and monitoring remedy to any given MDA, however, it must be shown to meet the following threshold and balancing criteria:

> "EPA established a two-phased evaluation for remedy selection. During the first phase, potential remedies are screened to see if they meet 'threshold criteria;' remedies which meet the threshold criteria are then evaluated using various 'balancing criteria' to identify the remedy that provides the best relative combination of attributes. The four threshold criteria are that all remedies must: (1) be protective of human health and the environment; (2) attain media cleanup standards; (3) control the source(s) of releases so as to reduce or eliminate, to the extent practicable, further releases...; and (4) comply with applicable standards for waste management. The five balancing criteria (are): (1) Long-term

reliability and effectiveness; (2) reduction in toxicity, mobility or volume of waste; (3) short-term effectiveness; (4) implementability; and (5) cost."

How these criteria are to be met is discussed Detail Reference- Alternative Cover Designs.

2.2.2.2 The Proposed Basic Cover Design for MDAs

The MDA Core Document approach proposes capping and monitoring as the corrective action for LANL MDAs. The proposed "baseline" cover design for LANL MDAs is a vegetated cover consisting of 10 cm of topsoil over 1.90 m of crushed tuff for a total of 2 m of rooting media. This will be placed over 30 to 45 cm of gravel, cobbles, or basalt, which serves as a barrier to burrowing animals. The cover will be seeded with a mixture of native species selected based on rooting depth, ease of establishment, and resistance to pests and disease. Cover thickness may be thicker on parts of MDA covers to assure adequate surface drainage. This straightforward design has been locally tested and similar designs have been tested elsewhere. The design is relatively easy to model, design, construct, and monitor. In addition, the value of simplicity and consistency in a cover design is hard to overstate in a system with a variety of contaminants and multiple exposure pathways. The cover design proposed here is based upon neither risk- nor performance-based standards established for LANL MDAs. The proposed design is similar to the MDA G interim design evaluated in the performance assessment and composite analysis. The design and its acceptability are based upon analogy to the MDA G modeling work and the level of risk reduction considered necessary for other LANL MDAs.

Based upon pilot studies at LANL, the MDA G composite analysis and cover evaluations at other sites, the proposed cover design appears to meet the threshold criteria discussed above. In the balancing criteria phase, the decision to proceed with the proposed corrective action will consider all technical, environmental, regulatory, political, and socioeconomic factors that might affect the determination of "appropriate" and "preferred" for a given MDA. Capping and monitoring will be analyzed on a site-specific basis to determine if it provides adequate performance.

While these standards are being clarified, several cover performance issues should be pursued to assure this cover or any final cover selected would meet defined standards. These include (1) water balance studies, (2) biota barrier performance studies, (3) root intrusion and uptake studies, (4) erosion studies, and (5) dry barrier studies focused on water removal from below the waste. These studies, in conjunction with post-construction performance monitoring and risk assessment, provide a basis for long term confidence in the final design. Further information is provided in Detail Reference- Alternative Cover Designs.

2.2.3 Monitoring Considerations

Multiple levels of monitoring are needed to assure that risks to public health and the environment remain low. *Site wide monitoring* covers potential releases through groundwater, surface water and sediments, and air across laboratory boundaries. *Facility monitoring* provides oversight to assure maintenance and proper operation of MDAs where waste remains in place. Maintenance, operation, and monitoring requirements are based upon regulations, and the contaminants, and transport pathways of concern. *Performance monitoring* provides more intensive information on the selected cover design to verify that the cover will provide long term protection. Site wide, facility, and performance monitoring all provide data and insight for demonstrating adequate risk reduction.

- Site-wide monitoring. Site-wide monitoring is designed to detect contaminant movement and contaminant release from the laboratory, regardless of where the contaminant was initially disposed. This monitoring includes on site groundwater monitoring, on site surface water monitoring, and on and off site air quality/radiation monitoring. A Laboratory-wide monitoring network already exists for air, and groundwater and surface-water monitoring programs are being designed.

- Facility monitoring. Facility monitoring is a part of operation and maintenance activities. Covers will be monitored for erosion, subsidence, loss of vegetation, and burrowing by animals and will be maintained, as necessary. Depending upon the nature of the waste, the site, and regulatory requirements, radiation or contaminant monitoring at the boundary of the facility may also be performed.

  Monitoring requirements will vary by facility. MDA G is an example of a complex site with many monitoring requirements. Facility monitoring at MDA G includes: air quality monitoring for radioactive elements; water quality monitoring for radioactive elements in sediment, NPDES storm waters, and alluvial waters; waste site monitoring for perimeter soil, wind-blown soil, mesa runoff, and transuranic waste; and biota monitoring of small mammals, vegetation, and of bees and honey. In general, the older MDAs are less complex from both a regulatory and technical viewpoint. Thus, monitoring at these sites will typically be a subset of MDA G activities.

- Performance monitoring. Performance monitoring is used to determine if the cover design selected performs up to design expectations. This type of monitoring is needed because the long-term behavior of any available cover or containment design can not be accurately predicted. Careful and intensive long term monitoring and evaluation of a test cover built explicitly to address performance concerns can provide information used to improve cover reliability. In a well-designed and nested monitoring program, performance monitoring activities will also track information obtained from site wide and facility monitoring efforts.

2.2.4 Comparing Containment and Excavation Alternatives

The protectiveness of capping and monitoring will be evaluated for an MDA based upon the considerations discussed in above. Before undertaking an analysis of options using the EPA criteria, it is wise to determine the practicability of the excavation option. Early identification of MDAs where either excavation or containment is impractical early in the risk-comparison process will save time and money.

Excavation may be deemed impractical when risks are too high to be acceptable. A very preliminary cost estimate for excavation of MDAs is two billion dollars. Excavation would require about 20,000 worker-years (e.g., 2,000 skilled and unskilled laborers for 10 years). If we treat this excavation as a standard construction or earth-moving effort, we would expect one or two fatalities and many more serious injuries on a project of this magnitude. Workers would also be

exposed to the additional risk of radioactive waste, high explosives, and chemicals. Under the proposed risk-based decision analysis, these very real tangible risks associated with excavation must be carefully weighed against the *hypothetical* risk of excess fatal cancer. The risk associated with containment is, by the definition of this study, one in one million (or 10^{-6}). This risk tradeoff, however, could also lead to higher overall costs where closure in place has lower risks but higher long-term monitoring costs.

2.2.5 Threshold and Balancing Criteria

Comparing excavation and containment options on the basis of threshold and balancing criteria, models will be used to demonstrate compliance for the containment option, because potential risks associated with containment and monitoring are generally expected to occur only in the distant future, and are, by definition, hypothetical. In contrast, risks associated with the excavation option must be considered in both the short- and long-term. Potential health risks to workers include both acute "actuarial" risks associated with excavation activities, and potential chronic effects due to exposures to hazardous and/or radiological contaminants. In addition, immediate habitat destruction and long-term effects is *expected* for the excavation option, whereas ecological impacts of containment and monitoring may be *hypothesized* to occur over a very long time frame.

Another fact that should be considered in comparing excavation and containment is this: newly excavated material must also be contained, and disposed of elsewhere. This excavated and contained material must meet the same performance standards that the material would have to meet under the proposed corrective action (i.e., performance assessment standards) if it was not excavated. Thus, excavation of a site where the capping and monitoring are shown to be protective, by definition *increases* risks over the containment option. It is this comprehensive risk assessment that should be compared to the containment option.

2.2.6 Alternatives to Excavation or Containment

'Simple' excavation or containment may not work at all MDAs. It is possible that some combination of excavation and containment might be appropriate and acceptable for particular MDA, and would be acceptable in terms of Subpart S:

> "EPA emphasizes that it expects facility owners/operators to develop and recommend remedies ... that address the proposed threshold criteria and present an advantageous combination of the proposed balancing criteria."

For example, if excavation of the entire inventory of an MDA is cost-prohibitive or technically impracticable, and if risk can be substantially reduced by removing a portion of the inventory, then partial excavation may be proposed. Other technologies may be considered if shown to be a more cost-effective solution than capping or excavation, or to provide a required level of risk reduction unachievable by the proposed remedy.

3.0 PUBLIC INVOLVEMENT PLAN

This section describes how members of the public will be involved in the process that moves LANL MDAs through the streamlined corrective action process. This plan includes performing the requirements for public involvement required by RCRA, and performing additional public involvement that goes beyond those regulatory requirements because the LANL ER Project

believes that public involvement is very important to successful corrective actions. Furthermore, the LANL ER Project recognizes that people from all over northern New Mexico are concerned and affected by LANL. Some of the primary reasons for public involvement include the following:

- Public involvement aids credibility in the cleanup process. When members of the public are involved in decision-making for the LANL ER Project, they can help assure that better long-term decisions are made and appropriate remedies are adopted.
- Better decisions are made if the public is involved early, frequently, and regularly.
- Continued public support in the cleanup process will help maintain congressional support for funding needed for cleanup.
- If people are not informed or involved in this process, they have reasons to doubt, criticize, or stop the process.

3.1 Compliance with Subpart S Requirements

The ER Project will comply with the applicable RCRA regulatory requirements regarding public participation and involvement. In implementing the MDA Core Document, the ER Project will incorporate the recommendations received by the EPA upon soliciting input from public interest groups on improving the corrective action program. These recommendations include:

- Tailoring the level of public participation to the level of community interest.
- Including opportunities for public participation throughout the cleanup process.
- Using risk goals and clearly defined cleanup standards to make cleanups more efficient.

3.2 Compliance with the LANL Permit

The ER Project will comply with the applicable requirements of Module VIII of LANL's Hazardous Waste Facility Permit regarding public participation and involvement.

3.3 Relationship to the Installation Work Plan (Site-Wide Work Plan)

The Laboratory's Installation Work Plan (IWP), or its equivalent Site-Wide Work Plan includes general requirements for public involvement in the ER process. The MDA Core Document will comply with the requirements of the IWP.

3.4 Educational Workshops

The ER Project recognizes that there is often a greater level of participation in decision making if stakeholders feel comfortable with their level of knowledge about a given MDA activity. In an effort to ensure that interested stakeholders have an opportunity to learn about technical,

regulatory, and/or site-specific issues regarding MDAs, the ER Project is committed to holding educational workshops. A workshop may be held if a need is identified by either stakeholders or ER Project personnel. If necessary, subject matter experts from outside the Laboratory will conduct the workshop.

4.0 IMPLEMENTATION PLAN

The MDA Core Document proposes a decision-analytical process for expediting decisions about remediation of LANL MDAs. It is anticipated that the time required for completing corrective actions at LANL MDAs will be dramatically contracted by the process presented in this document. A number of activities must be conducted before the process can be applied to all LANL MDAs. This section briefly summarizes the elements of the implementation plan for the MDA Core Document.

First, the MDA G analysis must be extended to include all contaminants in the MDA G inventory, in addition to the radioactive constituents. These include volatile organic compounds and heavy metals. Tasks to be accomplished include

- evaluating the adequacy of the existing source term and fate and transport analyses in terms of the applicability to hazardous contaminants known or suspected in the MDA G inventory,

- assessing the human-health and ecological risks associated with fate and transport of non-radiological contaminants in a manner that is consistent with the existing radiological dose assessment, and

- quantifying uncertainties in input parameters.

Once the MDA G modeling methodology has been extended to include hazardous contaminants and ecological risks, quantitative decision rules will be developed based on the cumulative MDA G risk-analysis results. This will require a detailed sensitivity and uncertainty analysis of the cumulative analysis. These activities will be conducted in Fiscal Year 1999.

After quantitative decision rules have been developed, they will be tested at MDA L, MDA J, and MDA H. These three MDAs are located near MDA G, and are expected to be well represented by the MDA G analysis. If the decision rules are useful in informing decisions in the corrective action process at the MDAs neighboring MDA G, the decision analysis will be considered valid for use at other MDAs. Testing and validation of the MDA Core Document approach will be accomplished in fiscal year 1999.

The sequence in which the MDAs are evaluated will be based on the risks posed by the sites and the costs associated with their remediation. A schedule for applying the MDA Core Document process at MDAs across the LANL complex will be developed following the validation of the approach.

The application of the MDA Core Document decision framework at a single MDA or a group of collocated MDAs will result in one of the following documents:

- A supplemental sampling and analysis plan to complete an existing data set, based on the data needs identified in the decision analysis, or
- A corrective action plan, describing the proposed corrective action and an implementation schedule.

REFERENCES

RCRA

LANL Permit

EPA 1996, Advance Notification of Proposed Rulemaking, "Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities," May 1, 1996

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LANL 1997, "Performance Assessment and Composite Analysis for LANL MDA G," LA-UR-97-85, March 1997

EPA 1993, "Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process, EPA QA/G-4, 1993

DOE 1988, "Radioactive Waste Management," Order 5820.2A, September 23, 1988

CONTAINMENT ALTERNATIVES

The overall goal of the ER Project is to reduce risks to human health and the environment to an acceptable level and in a cost-effective manner. Understanding engineering and environmental processes is key to closure in a cost-effective manner that minimizes risk and post-closure maintenance. The ER Project at Los Alamos is likely to leave waste in place at a significant proportion of its sites, but this option depends on demonstrating a clear understanding of environmental and engineering processes that affect risk and upon developing a high level of credibility with both the public and the regulatory community.

To this end, the processes that affect contaminant movement and closure options at LANL are discussed below, summarizing work done by the Laboratory addressing these questions. Next, closure options are considered, focusing on cover designs. Issue related to monitoring to ensure long-term containment are then discussed, along with a discussion information gaps on processes important for site closures at LANL. Finally, examples of cover designs used at other facilities are presented.

1 Processes affecting contaminant movement and closure

A great deal of information is available on landfill covers and performance. At Los Alamos, alone, the Environmental Science has performed studies and demonstrations on landfill covers and processes for approximately 20 years under the sponsorship of DOE, NRC, EPA, U.S. Air Force, and the U.S. Navy. These studies provide an extensive data set from which to design an engineered cap for a given MDA and assess future performance.

1.1 Surface Processes Pilot Studies

The *surface process pilot studies* have provided an understanding of physical processes, such as interflow, soil moisture, and water balance parameters (e.g., erosion, runoff, seepage) that can affect both surface cover design, contaminant transport, and long-term monitoring. *Engineering and ecological pilot studies* have examined processes on engineered covers and on undisturbed sites to provide the data needed to optimize a cover design in terms of both risk and cost.

1.1.1 Lateral Subsurface Flow

Lateral subsurface flow could result in lateral flow of water downslope through root channels in clayey soils. This flow would go downward into a zone excavated for waste disposal. Interflow has been shown to be an important flow mechanism in a number of other locations. If interflow occurs at an MDA, engineering controls would be needed. Pilot studies were undertaken to assess the importance of interflow.

The pilot studies data indicate that soils under ponderosa are prone to generate lateral subsurface flow and soils under pinon-juniper woodlands are not. Lateral subsurface flow volumes are largest when soils are saturated, either by spring snowmelt or by prolonged rainfall. When vertical flow of water through soil is restricted, as we believe it is by the soil/tuff interface, water is forced to move laterally. Lateral subsurface flow could be a mechanism for dissolved phase or colloidal contaminant transport away from an MDA. A result of the pilot study is that MDA's may require engineering controls to prevent interflow into the site. The Guidance on assessment of lateral subsurface flow at a given ER site is being developed.

1.1.2 Erosion

High erosion rates can redistribute contaminants and strip away landfill covers. An understanding of the factors causing rapid erosion is needed in evaluating remedial alternatives. Erosion rates are relatively low across much of the Pajarito Plateau, but some areas within pinyon-juniper (e.g., Bandelier Wilderness study site, which is representative of sites at LANL), are eroding rapidly. Such rapidly eroding areas, if contaminated at the surface, would represent a large potential for redistribution of contaminants on the Pajarito Plateau. Rapid erosion rates can also result in loss of soil from an engineered cover, and potential contaminant exposure. The ability to predict rates of landfill erosion over the long term is critical to devising effective remedies. Pilot study data on runoff and erosion assist in cover design.

1.1.3 Surface Runoff

Runoff data from the pilot study sites have shown that summer storms produce the highest peak flows and have the greatest potential for moving sediment (and any contaminants that may be present) to the stream channels, even though these storms generally last only a few hours. Small amounts of surface runoff can also be produced by snow melting over frozen soils. Surface runoff can redistribute contaminants on mesa tops and from mesas to canyons. The best protection from surface runoff is achieved by removal of surface contamination and construction of engineered covers over in-place closures.

1.1.4 Soil Moisture

Pilot study data quantify the variation of soil moisture, in time and space, in both natural systems and engineered covers. In the long term, engineered covers will behave more and more like the natural system. Thus, natural systems are studied to provide an understanding of long-term engineered system performance.

1.1.5 Biological Processes

Biological processes such as plant succession and animal intrusion will have direct and important effects on contaminant mobility and landfill stability, and these effects will increase through time.

1.1.5.1 Plant Succession

Plant succession occurs on landfill covers. At MDA B, 32 years after the site was closed, numerous native species had recolonized the waste site, including many ponderosa pine, the larger of which were 16-27 years old. On the integrated test plots 10 years after installation, integrated plots and conventional plots had substantially different plant covers and are progressing down distinct successional pathways. These data suggest that cover design has a significant impact on plant succession. Successional changes in vegetation are tied to water balance and erosion, and these changes directly affect our estimates of risk of groundwater contamination and risk from erosional loss of the waste cover. Changes in plant cover due to climate variability and/or changes, as occurred at the Bandelier site, could result in a drier climate and increased erosion.

1.1.5.2 Animal Intrusion

An animal intrusion barrier experiment conducted in 1981-1982 demonstrated that cobble, cobble/gravel and bentonite clay were equally effective in preventing pocket gopher intrusion with depth. A crushed tuff barrier (which is currently used at the MDAs), however was readily used for tunneling and offered little resistance to burrowing activity. Pocket gophers move tremendous amounts of soil, which affects plant species diversity, soil bulk density and interflow.

1.2 Modeling

Numerical modeling is one of the tools needed to predict long-term performance of surface covers. The surface processes pilot studies provide a high-quality, long-term data set for predicting long-term performance of in-place closures on the plateau. Pilot study data is being used to test the performance of the HELP and HYDRUS codes which can be used to evaluate landfill cover design performance. The ultimate result will be a more solid foundation for risk assessments. The pilot studies data are also being used to validate and parameterize runoff and erosion codes for application at other sites with surface contaminant transport issues. A bibliography of the studies discussed above is provided in Appendix BIBLIO. Much of the information collected in these studies is pertinent to process, risk, and cost. In addition to the MDAs, these studies are relevant to the former Los Alamos municipal sanitary landfill, and inactive firing sites.

2 Closure Options

There are two main options for closure of MDA's. The waste can either be removed or it can be left in place. If the waste is to be left in place, either the waste or the waste site will likely need stabilization. Waste site stabilization at low or no risk sites will involve relatively simple engineering controls for contouring and erosion control. Waste site stabilization at higher risk sites will be treated in a more complex fashion and will require a protective cover. A cover is a barrier against intrusion of water, plants, animals, and people into underlying wastes. Covers consist of one or more layers of soil, rock, geosynthetics, or other materials selected to minimize intrusion into underlying waste. Covers of widely varying design have been regularly used for site closures at uranium mill tailing sites, landfills, strip mines, and hazardous waste sites. It is likely that a formal evaluation of closure options will result in selection of a cover design for closure at many Los Alamos MDAs.

2.1 Standard Cover Design

The standard cover design will be 10 centimeters of topsoil over 190 centimeters of crushed tuff for a total of two meters of rooting media. This, in turn, will be placed over 30-45 centimeters of gravel or coarser material. The coarser material serves as a biota barrier. Because cover performance depends upon vegetation, plant species composition, rooting depth, establishment, and resistance to pests and disease are also considered.

2.2 Cover Design Conceptual Models

One of the major considerations in site closure is the method of covering or capping the waste material in place. When properly designed, these cover materials work as a system to limit percolation through the cover, to minimize erosion for long-term stabilization, and to prevent intrusion into the waste by animals and plants.

Covers can be divided into two major classes: (1) resistive and (2) capacitive. Resistive covers rely upon a low-permeability layer within the profile to reduce percolation to groundwater. Capacitive covers rely upon storing precipitation until remobilization by evaporation and transpiration.

2.2.1 Resistive Covers

The most common type of resistive cover uses a geosynthetic clay liner to supplement the evapotranspiration of the soil layer with a physical barrier to downward flow. This cover type has often been selected for landfills in climates with higher precipitation. At such sites, climate often precludes the use of a simple soil cover to limit percolation of moisture from precipitation events. Therefore, the geosynthetic clay alternative cover uses a very low-permeability layer (such as a GCL or flexible membrane line [FML]) to impede downward flow of moisture. The low-permeability layer increases water

storage in the overlying soil rooting layer so that the water can be consumed over a longer period of time by evapotranspiration.

Disadvantages of GCL or FML covers at Los Alamos include special cushioning requirements and a life expectancy less than that of the half-life of some of the radioactive waste to be covered. This concern lead to the exclusion of geosynthetic barriers at uranium mill tailing sites where long term cover viability was important because of the long halflife of uranium. Compacted clay alone has been used to impede water flow in resistive designs, but in semi-arid locations, plants usually treat a moist compacted clay as a source of plant available water. When plant roots grow into the clay, the clay desiccates, cracks and the permeability increases greatly.

2.2.2 Capacitive Covers

At Los Alamos in particular and at semi-arid sites in general, the potential evaporation greatly exceeds precipitation. In this climate, capacitive covers can store water in the soil. Evaporation and plant transpiration remove the water. This limits percolation of water through the underlying waste.

Advantages include the simplicity of the design, the similarity of the design to a natural soil profile in appearance and function. Thus, capacitive covers can take advantage of ecological processes for long term waste containment that resistive covers can not. Disadvantages of a capacitive cover approach include the possibility of climate change or a series of extremely wet years that could increase percolation enough to affect risk to the public. The relationship of percolation to risk is a component of the risk assessment study.

2.2.3 Vegetative Cover

A vegetative cover uses soil to store water when precipitation or snowmelt exceeds evapotranspiration. Knowledge and experience with the interactions of plants, soils, and climate is important in designing a reliable and effective vegetative cover design. A good design at Los Alamos will have a combination of water holding capacity, plant cover, and a rooting depth demonstrated to be capable of handling pulses of snowmelt. Thus, these designs will necessarily rely upon laboratory ecological and water balance studies.

2.2.4 Capillary barrier

A capillary barrier cover is designed to impede the downward movement of water in the cover through a contrast in permeability between an underlying coarse gravel layer and an overlying rooting medium of fine soil. During infiltration, water will accumulate in the overlying fine layer until the water potential

increases enough for a significant amount of water to enter the larger pores of the underlying coarse layer. If this system is sloped, water will preferentially flow laterally through the fine layer, and little vertical flow will occur. In unsaturated flow conditions, we have the initially counterintuitive condition where large (but, air-filled) pores are a barrier to water flow while small (water-filled) pores are important in water transport.

A practical concern with capillary barriers is their susceptibility to point failures. Small amounts of fine material that have filtered down or been moved by burrowing into the coarse layer can lead to focussed flow into the underlying waste. Subsidence is also a major concern for capillary barrier performance. If the underlying waste subsides, the overlying capillary barrier also subsides. This creates a condition where subsurface unsaturated flow is funneled to the point of maximum subsidence. This point of maximum subsidence occurs, of course, over consolidating or decaying waste.

2.2.5 Dry Barrier

The dry barrier cover system is similar to the capillary barrier cover in that fine soil layers are placed over coarser layers. A dry barrier cover, however, also uses subsurface airflow (driven by wind energy) through the coarse layer to continually dry the lower portion of the cover. A dry barrier cover system exploits the natural humidity gradients between the subsurface and ambient atmospheric air to dry the soil. The result is an increase water removal from the system.

Enhanced drying of the coarse layer increases water storage within the cover system. Thus, a large influx of water from events such as spring rains or snowmelts can be adsorbed and gradually removed by drying. Drying also reverses the water potential gradient, allowing water to move against gravity toward the dry barrier and away from underlying materials. In addition, drying reduces hydraulic conductivity: as water content is reduced, water films become discontinuous, and unsaturated hydraulic conductivity approaches zero. While dry barriers add an additional term for water removal in the water balance equation, a simpler vegetative cover can achieve similar results.

Dry barriers may be more useful as a component of a containment strategy. Evidence at several locations shows that natural air convection through fractured tuff at Los Alamos has resulted in subsurface drying. This appears to have hydraulically isolated waste disposal sites from the water table. When the water disappears, contaminant transport in water also disappears. Air drying in these systems depends upon mesa geology, permeability, fractures, temperature, wind direction, pressure fronts, and other factors. Drying can be augmented by wells, trenches, or covers designed to augment natural drying.

Our current understanding of subsurface dry barriers at Los Alamos is not yet complete enough to use this strategy for containment. However, the results from dry barrier investigations are very promising and should be pursued. Drying holds out the possibility of increasing the stability of the waste containment system over time and does not rely upon people or institutions to function.

2.2.6 LANL Vegetative Cover

The proposed standard cover design for LANL MDA sites is a vegetated cover consisting of 10 cm of topsoil over 1.90 meters of crushed tuff for a total of two meters of rooting media. This, in turn, will be placed over 30 to 45 centimeters of cobbles or coarse basalt that act as a biota barrier. Because cover performance depends upon vegetation, plant species composition, rooting depth, establishment, and resistance to pests and disease are also considered

The cover design proposed here is based upon neither risk- nor performance-based standards established for LANL MDAs. The proposed design is similar to the MDA G PA/CA design with a two meter thick crushed tuff cover propose for final closure of all MDA G disposal units. However, because neither risk-based nor performance-based standards are yet defined or agreed to for MDAs, the design is necessarily based upon analogy to the MDA Area G modeling work and the level of risk reduction required for other LANL MDAs.

While these standards are being clarified, several cover performance issues should be pursued to assure this cover or any final cover selected would meet defined standards. These include (1) water balance studies, (2) biota barrier performance studies, (3) root intrusion and uptake studies, and (4) dry barrier studies focussed on water removal from below the waste. These studies, in conjunction with post-construction performance monitoring, provide a basis for long term confidence in the final design. These issues are discussed in more detail in the monitoring section.

2.3 Contingencies

Some sites may require both a cover and additional containment or excavation measures. For example, the airport landfill (TA-73) has waste exposed on the canyon wall. This low risk site will require a combination of excavation and covering.

Some sites may be best remediated by a combination of excavation and stabilization.

Radioactive waste at Los Alamos potentially can be stabilized by in situ vitrification. Vitrification melts the waste-containing rock or soil into obsidian-like material. Vitrified material has generally desirable

properties with little risk of contaminant release. The technique, however, consumes vast quantities of electricity and can cause volitile contaminants to spread further during heating.

3 Monitoring

Multiple levels of monitoring are performed to assure that risks to public health and the environment remain low. *Site wide monitoring* covers potential releases through groundwater, surface water and sediments, and air across and beyond laboratory boundaries. *Facility monitoring* provides oversite to assure maintenance and proper operation of sites where waste remains in place. Individual facilities will also have monitoring requirements based upon regulations, contaminants, and pathways. *Performance monitoring* provides more intensive information on the selected cover design to verify that the cover will provide long term protection. Sitewide, facility, and performance monitoring all provide data and insight for demonstrating adequate risk reduction.

3.1 Site wide monitoring

Site wide monitoring is designed to detect contaminant movement and contaminant release from the laboratory, regardless of where the contaminant was initially disposed. This monitoring includes groundwater monitoring on site, surface water monitoring, and air quality/radiation monitoring both on and off site. A laboratory-wide monitoring network already exists for air quality monitoring and a groundwater monitoring program is being designed.

3.2 Facility monitoring

Facility monitoring is a part of operation and maintenance activities. Covers will be monitored for erosion, subsidence, loss of vegetation, and burrowing by animals and will be maintained, as necessary. Depending upon the nature of the waste, the site, and regulatory requirements, radiation or contaminant monitoring at the boundary of the facility will also be performed.

Monitoring requirements will vary by facility. Area G is an example of a complex site with many monitoring requirements. The Area G Closure Plan is currently in draft form and contains detailed monitoring requirements for the active waste disposal facility at Area G. Facility monitoring at Area G includes: air quality monitoring for radioactive elements; water quality monitoring radioactive elements in sediment, NPDES storm, and alluvial waters; waste site monitoring for perimeter soil, wind-blown soil, mesa runoff, and for transuranic waste; and biota monitoring of small mammals, vegetation, and of bees and honey. The older MDAs, as a group are less complex both regulatorily and technically. Thus, monitoring at other sites will typically be a subset of these activities.

3.3 Performance monitoring

Performance monitoring is used to determine if the cover design selected performs up to design expectations. This type of monitoring is needed because the long-term behavior of any available cover or containment design is not fully understood. Careful and intensive long term monitoring and evaluation of a test cover built explicitly to address performance concerns can improve cover reliability. The value of simplity and consistancy in cover design, where possible, is hard to overstate in a system with a variety of contaminants and multiple exposure pathways. What is learned at one site is useful for all sites.

3.4 Process Studies

Los Alamos National Laboratory has studied aspects of this basic design for nearly 20 years. There are, however, several key long-term concerns with this design. These concerns are outlined below.

3.4.1 Root intrusion

All feasible cover designs are prone to root intrusion. Roots have been shown to move dissolved contaminants, such as uranium or plutonium, from the subsurface to the surface (e.g., Klepper et al., 1979). A Los Alamos report by Foxx et al., 1984 documents rooting depths of various plant species at Los Alamos. While there is good reason to believe very little can move this way; performance monitoring is needed to test this assumption.

3.4.2 Water balance

Los Alamos is prone to winters with significant snow accumulation. Snowmelt in spring often occurs rapidly due to warm southwest winds. This, in turn, can lead to a large pulse of water entering a cover. If the cover can't hold enough water, water can percolate down through underlying waste. While the basic design appears thick enough, longer-term changes in the plant community or in soil composition may affect how snowmelt moves through a vegetated cover. These effects can be both positive and negative. This performance data has relatively small short-term value but is invaluable in assessing the overall performance of the laboratory-wide design approach. The laboratory already has a solid program doing water balance performance monitoring.

3.4.3 Biota barrier

A biota barrier is a layer in the cover designed to stop animals from digging through the cover into underlying wastes. Burrowing animals The animal of primary concern at Los Alamos is the gopher (Hakonson et al., 1982). The gopher burrows to approximately 5 feet in depth. The cover design will use about one foot of cobble sized materials under 5 feet of soil to prevent burrowing of gophers into underlying wastes However, performance monitoring is needed to assure that the barrier selected actually does prevent burrowing animals from increasing risk by burrowing and mobilizing waste.

Animals from ants to gophers to badgers have been a problem at other locations and performance monitoring will assure that, if the problem was not correctly assessed, it will be remedied.

3.4.4 Erosion

Most cover designs are susceptible to erosion and design allowances must be made. Erosion can result in exposure of waste at the surface in extreme cases or in reduced performance due to decreased thickness or perforation of protective layers in the cover. Good engineering models are available to estimate erosion and runoff from landfill covers. These models consider slope angles, lengths, vegetation, soil types, and climate

3.4.5 Subsurface Dry Barriers

Results from studies at Los Alamos suggest that it is plausible to prevent contaminant movement at some MDAs using air drying driven by natural forces (primarily barometric pumping and wind energy). Drying holds out the possibility of increasing the stability of the waste containment system over time and does not rely upon people or institutions to function. Exploitation of this passive long-term containment strategy may be valuable if risk assessment shows that (1) adequate risk reduction is not achievable with a cover and (2) that risk and cost associated with excavating a site also presents a large risk to workers and/or the public. Subsurface drying should continue to be studied as a passive low-cost and long-term measure for sites where additional risk reduction is needed for closure. Specific information needed includes (1) the extent of natural drying under a model system or an MDA of potential concern and (2) potential for augmentation of natural drying by augmentation using wells, trenches, or covers designed to augment natural drying.

4 Case Studies

Many sites have already selected or built covers over radioactive and mixed waste. Like Los Alamos, each of these sites has had complex technical and regulatory questions to resolve. Their accomplishments can simplify and speed our task. Below, we discuss the UMTRA program, individual UMTRA sites, and other sites with radioactive or hazardous wastes. Where possible, references and personal contacts have been given to aid the reader in understanding how agreement was reached on closure plans and cover designs.

Risk-Based Cover Designs for Uranium Mill Tailing: General UMTRA Background. In 1978, Congress passed Public Law 95-604, the Uranium Mill Tailings Radiation Control Act (UMTRCA), expressly finding that uranium mill tailings located at inactive (and active) mill sites may pose a potential health hazard to the public. Title I to the UMTRCA identified sites to be designated for remedial action.

The UMTRCA charged the EPA with the responsibility of promulgating remedial action standards for inactive mill sites. In developing the standards, the EPA determined that the potential for contamination of groundwater and surface water should be evaluated on a site-specific basis. On September 3, 1985, the U.S. Tenth Circuit Court of Appeals remanded the groundwater standards (40 CFR Part 192.2(a)(2)-(3)). In response to the Court's remand, the newly proposed EPA groundwater standards involve (1) protection of human health and the environment, (2) consideration of non-radiological as well as radiological hazards (3) consistence with the requirements of RCRA, and (4) general (not site-specific) standards applicable to all UMTRA (Uranium Mill Tailings Remedial Action) Project sites. The U.S. DOE was given the responsibility of selecting and executing a plan of remedial action that would satisfy the EPA standards and other applicable laws and regulations. The U.S. Nuclear Regulatory Commission (NRC) must concur with the DOE's remedial action plan. In order for the NRC to concur in each selection of remedial action, certain technical findings must be made leading to conclusion that the remedial action is consistent with the governing EPA standards for water resources protection in addition to other criteria. The NRC's technical position regarding technical findings is contained in the *Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailing Sites* (NRC, 1989). The DOE has a similar, parallel document entitled *Technical Approach Document* (DOE, 1989) that describes the general technical approaches and design criteria adopted by the DOE in order to implement remedial action plans and final designs that comply with the EPA standards. In both the NRC and DOE guidance documents, a standard procedure is described for groundwater resources protection, as an element of consideration in the overall design, which includes the following elements:

- Identifying and characterizing the source term in the mill tailings
- Proposing concentration limits for the source term constituents in groundwater within the uppermost aquifer beneath the disposal cell
- Identifying the point of compliance in the uppermost aquifer hydraulically downgradient of the disposal cell at which the concentration limits apply for post-closure monitoring
- Conducting a performance assessment of the proposed disposal cell design to determine compliance with the proposed concentration limits.

As such, the design of the disposal cell, including the final cover design, is based upon risk to human health and the environment. The level of risk, with groundwater as the pathway, is a function of the proposed concentration limits at the point of compliance. Concentration limits for the identified hazardous constituents in the mill tailings can be proposed as either maximum concentration limits (MCLs),

background concentrations, or alternate concentration limits (ACLs). EPA in 40 CFR Part 192.02(a)(3) Table 1 identifies MCLs for a list of hazardous constituents that include elements, organic compounds, and radionuclides. The MCLs are based upon acceptable concentrations for a public drinking water supply. At sites where source constituents are identified in the tailings but are not included in the list of EPA hazardous constituents with established MCLs, or the concentrations of identified hazardous constituents exceed MCLs in the uppermost aquifer beneath the disposal site, then proposing background concentrations for those constituents may be applicable. Alternate concentrations may be proposed if the level of risk is acceptable and the concentration is as low as reasonably achievable.

Example 1: The Green River Site. The Green River inactive uranium mill site is in Grand County, Utah, and approximately one-mile southeast of the town of Green River. The tailings and other contaminated materials at the site were stabilized on site in a mostly below-grade disposal cell. The DOE complied with the disposal standard (40 CFR Part 192.02(a)(3)) by constructing a disposal cell that prevents any tailings leachate from mixing with groundwater within the mandated 200-year minimum design life of the cell. Placing the tailings in a cell, which is nearly 40 feet below existing grade, did this. The bottom six feet of the cell is filled with compacted, select clean buffer to retard movement of contaminants to groundwater from the overlying contaminated materials. Above the buffer layer are compacted wind-blown tailings and vicinity property materials (which are mixed with clean soils) and a layer of compacted tailings. The final cover system, constructed over the tailings, consists of (from bottom to top) 3 feet of compacted radon/infiltration barrier, 6 inches of clean filter bedding, and one foot of large rock for erosion protection.

The disposal cell was constructed in consideration of minimizing moisture flux and downward re-distribution of moisture in the cell to meet the mandated disposal standard. The disposal cell components were placed in a specific order to accomplish this, and were compacted in place at the calculated long-term moisture content (tailings at 5 percent volumetric and windblown at 13 percent by volume) that will result in an unsaturated moisture flux of between 1×10^{-8} and 1×10^{-9} centimeters per second (cm/s) per unit area. The radon/infiltration barrier was amended with 6 percent sodium bentonite and compacted to 100 percent of standard proctor density at optimum to 3 percent above optimum moisture content to achieve a saturated hydraulic conductivity of 2×10^{-8} cm/s.

Example 2: The Cannonsburg site _ UMTRA Title I

Site location: Washington County, PA

Site/Manufacturer: Cannonsburg site

Size/Type of facility: Original facility was 18.6 acres. Facility extracted radium from carnotite ore.

Contaminant/Media: Waste is in the form of tailings, rubble, building waste and near-surface contaminated soil. Radionuclide inventory contains ^{238}U, ^{232}Th, and ^{235}U, and radium.

GW conditions: Groundwater depths vary from 6-10 feet bgs, with infiltration and groundwater underflow being the sources. Hydraulic connection with Chartiers Creek, which bounds the site to the north, affects water levels, and acts as a sink for local groundwater.

Waste disposition: Approximately 85,000 yd^3 of material is contained in the encapsulation cell, most of which was excavated from the site.

Containment method: Shallow-land burial using a multi-layer liner and cap. Liner consists of a coarse sand capillary break (1 ft min), then compacted earth (2 ft min). Cover includes clayey soil (2 ft min), bentonite-clayey soil (1 ft min), pit run riprap (1.5 ft min), then topsoil, and vegetation (1 ft min). The cell slopes 2% minimum at the crown and 5-on-1 slope at the side.

Environ.Conditions: Site is located in the Appalachian Plateau physiographic province, with a median precipitation rate of 34.5 in/year.

EPA region: U.S. EPA, Region 3.

License status: Site work is completed. Facility currently holds a NRC-issued license.

References and/or contacts:

U.S. Dept. Energy. 1983. *Final remedial action plan for the stabilization of uranium mill tailings at Cannonsburg, PA sites.* DOE/UMTRA-1140.

Example 3: The Shieldalloy Metallurgical Corporation sites _ SDMP

Site location: Cambridge, OH

Site/Manufacturer: Shieldalloy Metallurgical Corp. site

Size/Type of facility: 52-ha site, containing ~600,000 tons of contaminated slag material. Facility manufactured metal alloys.

Contaminant/Media: Most of the waste is in the form of slag and soil, which was excavated and stored with the slag in two piles, the East and West slag piles. Parent radionuclides mostly include ^{238}U, ^{232}Th, and ^{235}U, contained in ferrocolumbian, ferrotitanium and ferrovanadium alloys.

GW conditions: Present at approximately 3 m bgs, unconfined, with an average thickness of 12 m. The groundwater is believed to be unaffected by the Shieldalloy site.

Waste disposition: On-site stabilization (SIP) of the existing East and West slag piles is the preferred alternative. Off-site contaminated material would not be excavated. Existing piles would be regraded, stabilized, and capped.

Containment method: Shallow-land burial using a multi-layer cap, including a clay cover (3 ft min), geotextile material, silty sand (1 ft min), topsoil and vegetation (9 in. min). Crushed stone (riprap) would be used as erosion protection at the toe of the disposal cell. Total area for the two cells would be 15.9 acres.

Environ. Conditions: Site is located in the Appalachian Plateau physiographic province, with a median precipitation rate of 36.9 in/year.

EPA region: Participating agencies include Ohio Env. Protect. Agency and U.S. NRC, which are cooperating on the RI/FS study, and the U.S. EPA, Region 5.

License status: Draft EIS was issued in July, 1996 (NUREG-1543). NRC is the licensing authority.

References and/or contacts: Mark Thaggart, NRC/PM
U.S. NRC. 1996. Draft Environmental Impact Statement. NUREG-1543. Washington, DC.
U.S. NRC. 1993. Site decommissioning management plan. NUREG-1444. Washington, DC.
PTI. 1995. Draft remedial investigation and feasibility study at the Shieldalloy Metallurgical Corp. Site in Cambridge, Ohio, PTI Environmental Services, Bellevue, WA.

Site location: Muskogee County, OK

Site/Manufacturer: Fansteel, Inc. site

Size/Type of facility: Entire facility is approximately 10 acres. Disposal cell has a proposed area of 6.4 acres.

Contaminant/Media: Waste is in the form of contaminated soil excavated from settling ponds (22,000 yd^3), and cement and additives (8,000 yd^3).

GW conditions: Minimum depth to groundwater is 10 feet below the base of the proposed containment cell. Flow is reported to be south and east, away from nearest resident. Some groundwater contamination could be present because the pond liners were known to have failed.

Waste disposition: All contaminated soil and building material will be mixed with cement, placed in layers, and compacted in the disposal cell.

Containment method: On-site construction of a disposal cell for shallow-land burial using a multi-layer cap. Liner consisting of compacted subgrade and geomembrane is being considered for the site. All material will be compacted in lifts not to exceed 1 foot. Cover includes recompacted soil material (1.5 ft min) obtained on site, gravel (0.5 ft min), sand layer (0.5 ft min), and finally riprap (layer thickness and rock size to be determined, though document indicated a 1 ft thickness for design purposes). 1.5 ft min), then topsoil and vegetation (1 ft min). The cell slopes 2% minimum at the crown and 5-on-1 slope at the side.

Environ.Conditions: Mean annual precipitation is 41.6 in/year.

EPA region: U.S. EPA, Region 6.

License status: Disposal site design is in progress and will require NRC-issued approval

References and/or contacts: Sam Nalliswami, NRC/PM
U.S. NRC. 1993. Site decommissioning management plan. NUREG-1444. Washington, DC.

Example 5: The Beatty, NV - LLW Disposal Facility

Site location: Amargosa Desert, 100 miles NW of Las Vegas, NV

Site/Manufacturer: Disposal facility only _ no manufacturing

Size/Type of facility: Entire facility is approximately 80 acres. LLW disposal area is 26.4 acres.

Contaminant/Media: Waste material as defined in 10 CFR 61

GW conditions: Groundwater is known to exist at 250 feet bgs. Three monitoring wells are used for the monitoring program: two downgradient and one upgradient of the site.

Waste disposition: All waste material is disposal in shallow trenches.

Containment method: On-site construction of a disposal cell for shallow-land burial using a multi-layer cap. Liner consisting of compacted subgrade and geomembrane is being considered for the site. All material will be compacted in lifts not to exceed 1 foot. Cover includes recompacted soil material (1.5 ft min) obtained on site, gravel (0.5 ft min), sand layer (0.5 ft min), and finally riprap (layer thickness and rock size to be determined, though document indicated a 1 ft thickness for design purposes). 1.5 ft min), then topsoil and vegetation (1 ft min). The cell slopes 2% minimum at the crown and 5-on-1 slope at the side.

Environ.Conditions: Mean annual precipitation is 4.75 in/year.

EPA region: U.S. EPA, Region 9.

License status: Disposal site is closed. Facility control was transferred to the State of Nevada on 12/30/97. Nevada, an agreement state, has accepted the property and will be responsible for long-term custodial care.

References and/or contacts:

Example 6: Sierra Blanca, Texas - LLW Disposal Facility

Site location: Sierra Blanca, Texas

Site/Manufacturer: Disposal facility only _ no manufacturing

Size/Type of facility:

Contaminant/Media: Low-level radioactive waste as defined by 10 CF 61.

GW conditions:

Waste disposition: All waste to be disposed using shallow-land burial.

Containment method: According to design documents, dated 12/93, proposed site will incorporate shallow-land burial method using bottom and sidewall liners, and a multi-layer cap. The proposed liner consists of compacted low-permeability material. Sidewall slopes will be constructed of the same low-K material. Cover design was selected based on the results of HELP model. Gravelly-sand backfill to be used around concrete canisters, then temporary soil cover (2 ft) during waste emplacement, additional compacted soil material (8 ft), asphaltic concrete (10 in), single layer of geosynthetic clay liner (clay sandwiched between layers of geosynthetic membrane), additional compacted soil material (4 ft), then vegetative top boundary.

Environ.Conditions: Mean annual precipitation is 30.99 in/year.

EPA region: U.S. EPA, Region 6.

License status: Disposal site is in the process of review by the Texas LLRW Disposal Authority.

References and/or contacts:

Example 7: Norwood PCBs site - EPA Superfund

Site Location: Norwood, MA

Site/Manufacturer: Norwood PCBs Site

Size/Type of Facility: Norwood PCBs Site covers approximately 26-acres, in which several industrial and commercial properties, parking areas and vacant lots are located. In 1979, 9 acres of this site was purchased by Grant Gear Works, Inc. to produce gears for industry, and the rest of the site was purchased by three individuals which further divided into seven lots.

Contaminant/Media: PCB contamination in soil and groundwater primarily due to the past practices of previous electrical equipment manufacturing businesses. These businesses were located in the building , now, owned by Grant Gear Works, Inc.

GW Conditions: Depth of the water table throughout the site is less then 10 feet. Shallow bedrock is highly fractured and exhibits a porous medium where groundwater and water table flows are in the same direction. Based on EPA_s investigation groundwater contamination was confined in the site.

Waste Disposition: 518 tons of soil which contained PCB concentration greater than 50 ppm was removed and disposed to a remote landfill.

Containment method: Grant Gear property and other soil and sediments which has PCB concentration exceeding 40 ppm were consolidated and a multi-layered barier(cap) will be constructed. Cap over the contamination will be minimum one foot in thickness and will be consist of at least 6 inch of both asphalt binding course and asphalt wearing surface. A geotextile fabric will be placed in between contaminated soil and cap. Contaminated Grant Gear Building slabs and foundation will also be covered by cap, but its design might be somewhat different depending on if there is any contaminated soil sediment backfill over the existing slabs. Although initially solvent extraction was chosen as a remediation method, U.S. EPA implemented a less costly method (asphalt cap) which saved the agency about $ 47.5 million.

Environ.Conditions: Geological units include outwash plain deposits and fill material which is predominantly sand and gravel. Mean annual precipitation is 39.8 in/year.

EPA Region: U.S. EPA, Region 1.

License Status:

Reference and/or contacts:

Example 8: New Bedford Harbor Cleanup Site - EPA Superfund

Site Location: Bristol County, MA

Site/Manufacturer: New Bedford Harbor Cleanup Site

Size/Type of Facility: New Bedford Site is an 18,000 acre urban tidal estuary with sediments contaminated with heavy metals and PCBs. PCBs were used by electrical capacitor manufacturers, the Aerovox facility and the Cornell-Dubilier facility from 1940 to 1978 and they were discharged into the harbor.

Contaminant/Media: This site was contaminated with PCBs and heavy metals notably cadmium, lead copper and chromium. Harbor was contaminated to varying degrees for at least 6 miles. High levels of PCBs were detected in the northern portion of Acusnet River Estuary, which was identified as _hot spot._

GW Conditions: n/a

Waste Disposition: Approximately 450,000 cubic yards of contaminated sediment will be dredged and isolated in four confined disposal facilities (CDF) constructed in shoreline. Drained water will be treated and returned to the harbor.

Containment method: After the contaminated sediments settles in the CDFs, an impermeable cover or cap will be constructed on top of CDFs.

Environ.Conditions: Mean annual precipitation is 39.8 in/year.

EPA Region: U.S. EPA, Region 1.

License Status:

Reference and/or contacts: Jim Brown, EPA/RPM (617) 573-5799

1 REGULATORY ANALYSIS FOR THE MDA CORE DOCUMENT

This Detail Reference will outline the primary hazardous and radioactive waste regulations that may impact future RFI and CMS activities for MDAs. It does not outline "secondary" regulations that may or may not impact such activities, (e.g., National Historic Preservation Act, Native American Graves Protection and Repatriation Act). The document entitled, "University of California Implementation Plan for the Evaluation of Applicable Regulations and Standards" (May 30, 1997, ERID 55989.1) includes a list of the major environmental requirements that the Laboratory's ER Project believes are applicable. (Note, however, that applicable regulations such as the final rule for PCB disposal, [6/29/98] are not included in this list.) The document was generated to satisfy the FY 97 Performance Measure in the U.C. Contract. (All MDA cleanup activities will comply with the applicable requirements included in this list.)

Please note that while the information contained in this summary is comprehensive, it should not be used as the sole basis for making regulatory determinations for a given MDA. MDA project personnel are required to work with representatives from the Regulatory Compliance Focus Area for regulatory determinations impacting MDAs.

2 ENVIRONMENTAL PROTECTION

2.1 10 CFR PART 1021, NATIONAL ENVIRONMENTAL POLICY ACT IMPLEMENTING PROCEDURES

The National Environmental Policy Act (NEPA) is codified for DOE in Title 10 CFR Part 1021. The general purpose of NEPA is to analyze any activity undertaken by the federal government that may affect the quality of the environment. Presumably, many of the activities undertaken pursuant to MDA cleanup would affect the quality of the environment.

There is an explicit reference to NEPA in the HSWA Module. It states that, "All work (information, reports, investigations, remediations, etc) required by this ModuleVIII will be deemed as "functionally equivalent" of an Environmental Impact Statement (EIS). Therefore, the requirements of the National Environmental Policy Act will not apply to work required by Module VIII...."

Despite the apparent certitude of the above statement, it is unclear whether all relevant regulatory agencies are in agreement with such an approach to NEPA requirements for ER Project activities. The ER Project is very interested in resolving this issue and in meeting the intent of any applicable and appropriate NEPA requirements.

In April 1998, DOE published a draft Site-Wide EIS for continued operations at the Laboratory. Although there is very little ER-related information discussed in the document, it does say that waste generation from future environmental restoration actions is estimated in the EIS, as are the risks associated with transport, treatment, storage and disposal of ER waste.

3 HAZARDOUS WASTE REGULATIONS

3.1 Resource Conservation and Recovery Act (RCRA)

RCRA is the authorizing statute for the regulation of solid and hazardous waste. Environmental restoration activities are subject to RCRA corrective action program requirements, also referred to as RCRA Subpart S. Certainly, the RFI/CMS process is conducted pursuant to Subpart S. RCRA contains additional requirements however, that may also impact MDA closure activities. For example, RCRA regulates the generation, transportation, treatment, storage, and disposal of hazardous and solid waste, the closure of active units, and the management of inactive units. MDA closures will comply with one of three RCRA closure scenarios, i.e., RCRA closure of permitted units; RCRA closure of interim status units; or closure conducted under the corrective action program, (Proposed Subpart S).

3.1.1 RCRA Closure of Regulated Units

3.1.1.1 Applicability

RCRA closure requirements apply to any unit, which has received a RCRA, permit. These requirements are found at 20 NMAC 4.1 Subpart V, 40 CFR 264 Subpart F and G, 20 NMAC 4.1 Subpart IX, and 40 CFR 270.1(c).

3.1.1.2 Performance Objectives

According to 40 CFR 264.111, closure must be completed in a manner that: (a) minimizes the need for further maintenance; (b) controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to ground or surface waters or to the atmosphere; and, (c) complies with the unit specific closure requirements of 40 CFR Part 264. These unit specific requirements include groundwater detection and compliance monitoring, landfill cap design and monitoring, and other closure activities. The applicable regulatory citations from 40 CFR Part 264 appear as Appendix _____.

3.1.1.3 Exposure Scenarios

Groundwater is the only "pathway" individually identified in Part 264. (264.92) However, as is stated above, one of the performance objectives for RCRA closure includes controlling releases to surface waters and to the atmosphere. The point of compliance (POC) for groundwater appears at 264.95. "The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." This location is specified in the facility permit.

Any unit closing under RCRA must also undertake corrective action under 264.101 for any releases of hazardous wastes or hazardous constituents. Proposed Subpart S was intended to provide the substance of the corrective action program under 264.101, but has not yet been finalized. Because of this, proposed Subpart S is used as guidance and contains specific direction on POCs for groundwater, air, surface water, and soils.

3.1.1.4 Compliance Period

The compliance period is the time during which the groundwater protection standard applies. It is, "the number of years equal to the active life of the waste management area (including any waste management activity prior to permitting, and the closure period.) [It] begins when the owner or operator initiates a compliance monitoring program meeting the requirements of 264.99," (which are described in Appendix ____).

3.1.1.5 Other considerations

Although not specifically noted in the RCRA closure regulations for permitted units, community involvement should be an integral part of the RCRA closure process. Stakeholders have an opportunity to comment on planned closure activities during the comment period for initial permit issuance. Moreover, if there are future permit modifications, the appropriate regulatory authority, (i.e., NMED) is required to provide an opportunity for public comment. The proposed revisions to the RCRA closure/postclosure provisions also include stakeholder involvement requirements. (59 FR 55778)

3.1.2 RCRA Closure of Interim Status Units

3.1.2.1 Applicability

Interim status applies to units that (1) were in existence on November 19, 1980 or on the effective date of the statutory or regulatory change that subjected the unit to a permit requirement, and 2) complied (or should have complied) with the requirements of Section 3005(e) of RCRA by being included in a permit application. For most units, the critical regulatory date is November 19, 1980. However, this date could differ depending the types of wastes managed and the dates upon which they were managed. Because the identification of hazardous waste was a phased activity, a unit managing only a later-identified waste would become subject to permit requirements on the date the hazardous waste designation was effective. As an example, a facility that managed only petroleum refinery waste would have been exempt from RCRA regulations until August 1992 when that was identified as a RCRA hazardous waste.

This same concept applies to mixed waste. Because the regulation of mixed waste in New Mexico started upon New Mexico's receipt of mixed waste authorization on July 25, 1990, a unit managing only mixed waste in New Mexico would qualify for interim status only if it was in existence, (i.e., operating or under construction) on July 25, 1990. (Please note that NMED may not agree with the July 25, 1990 date as the effective date for interim status for mixed waste units.)

Interim status may be granted to facilities in operation at the time they become regulated provided they submit a permit application by the deadline. Existing facilities for which an application was not filed, most MDAs for example, do not qualify for interim status.

If a unit was not in existence (i.e., stopped receiving waste) before it ever qualified for interim status, it is not an interim status unit and is not a permitted unit, but may be a solid waste management unit (SWMU) if the facility has a RCRA operating permit.

Closure/post-closure requirements for interim status facilities are contained in 20 NMAC 4.1 Subpart VI, and 40 CFR 265, Subparts F and G. In addition, 20 NMAC 4.1 Subpart IX and 40 CFR 270.1(c) require that any unit (including an interim status unit) that received wastes after July 26, 1982, and did not have closure certified by January 26, 1983 must obtain a post-closure

permit subjecting the unit to Part 264 requirements for groundwater monitoring and vadoze zone monitoring, post-closure care, and corrective action.

3.1.2.2 Performance Objectives

The performance objectives for interim status units are similar to those for permitted units. That is, close the facility in a manner that: "(a) minimizes the need for further maintenance, and (b) controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere, and (c) complies with the closure requirements of this subpart, including, but not limited to, the requirements of Sections 265. 197, 265.228, 265.258, 265.280, 265.310, 265.351, 265.381, 265.404, and 265.1102. The landfill-specific closure standards for interim status units are generally less rigorous than those for permitted units.

3.1.2.3 Exposure Scenarios

The exposure scenarios for interim status units (i.e., POCs and pathways) are substantively similar to those for permitted units. (See discussion above.)

3.1.2.4 Compliance Period

Section 265.113 states that within 90 days after receiving the final volume of hazardous waste...or within 90 days after approval of the closure plan, whichever is later, the owner or operator must treat, remove from the unit or facility, or dispose of on-site, all hazardous wastes in accordance with the approved closure plan.

3.1.3 Closure of Solid Waste Management Units under RCRA Proposed Subpart S

Note: Although most of Subpart S is still in proposed form, it is considered the controlling guidance for cleanup of solid waste management units. For simplicity, the word "proposed" is implied throughout the remainder of this section.

3.1.3.1 Applicability

A unit can be closed using Subpart S authorities if it is designated as a solid waste management unit (SWMU) on the facility permit, or if it meets the definition of a SWMU and is not undergoing RCRA closure. A SWMU is defined as "any discernable unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at or around a facility at which solid wastes have been routinely and systematically placed."

Facilities can be brought into the corrective action process when there is a release of hazardous waste or hazardous constituents; or when the facility is engaged in the permitting process.

3.1.3.2 Performance Objectives

The primary performance objective for the protection of human health is to control carcinogenic risk within the acceptable risk range of 10E-4 to 10E-6, with the point of departure at 10E-6.

Maximum contaminant levels (MCLs) must be considered in establishing cleanup levels if the pathway involves drinking water. For noncarcinogens, the hazard index should not exceed one. Although ecological risk is not discussed as explicitly as human health risk, it also is an implied goal of the corrective action process, (and one in which the NMED is taking an increased interest).

The relevant language from the Advanced Notice of Proposed Rulemaking (61 FR 19449) regarding human health risk is below. (A discussion of ecological risk appears later in this summary.)

"Consistent with the CERCLA program, in the RCRA corrective action program EPA intends to clean up sites in a manner consistent with available, protective, risk-based media cleanup standards (e.g., MCLs and state cleanup standards) or, when such standards do not exist, to clean up to protective media cleanup standards developed for the site in questions (e.g., through a site-specific risk assessment)....EPA's risk reduction goal is to reduce the threat from carcinogenic contaminants such that, for any medium, the excess risk of cancer to an individual exposed over a lifetime generally falls within a range from 10E-6 to 10E-4....For noncarcinogens the hazard index should generally not exceed one.

Given the diversity of the corrective action universe and the emphasis on consideration of site-specific conditions such as exposure, uncertainty, or technical limitations, the Agency expects that other risk reduction goals may be appropriate at many corrective action facilities...EPA endorses...an approach to remedy selection that allows a pragmatic and flexible evaluation of potential remedies at a facility while still protecting human health and the environment. This approach emphasizes the overall goal of 10E-6 as the point of departure..."

3.1.3.3 Exposure Scenarios

The original 1990 Subpart S proposed rule states the point of compliance as the "location or locations at which media cleanup levels are achieved." For air releases, the program has generally used the location of the person most exposed, or other specified point(s) of exposure closer to the source of the release. For surface water, the POC is the point at which releases could enter the surface water body; if sediments are affected by releases to surface water, a sediment POC is also established. POCs for soils are those which would ensure protection of human and environmental receptors against direct exposure while also considering cross-media transfer (e.g., via leaching, runoff, or airborne emissions). The POC for groundwater is set throughout the area of contaminated groundwater or, when waste is left in place, at and beyond the boundary of the waste management area encompassing the original source(s) of groundwater.

3.1.3.4 Compliance Period

The proposed language allows a considerable amount of flexibility regarding the compliance period. On one hand, the language states, "The compliance time frame is the time period and schedule according to which corrective actions are implemented." However, the proposed language also offers this option. "...due to complexities associated with contaminant occurrence in the subsurface and with groundwater remediation in general, the time needed to remediate groundwater at some sites cannot be accurately predicted. In these circumstances, the Agency recommends the use of performance measures or milestones monitored over time to track progress toward attaining remedial goals.

3.1.3.5 Other considerations

- Ecological Risk Assessment—EPA recently promulgated final regulations for conducting ecological risk assessments at Superfund sites. (63 FR 26846, EPA/630/R-95/002F April 1998) Ecological risk assessment will now be a standard activity and must be conducted as part of the PA/SI and/or the RI/FS at Superfund sites. The guidance requires that if there is a likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more "stressors," a full ecological risk assessment must be conducted. The ER Project will adopt EPA's Eco-Risk approach as described in these regulations.

- Technical Impracticability—The July 1990 proposed language includes information on technical impracticability. (55 FR 30830) It states that, "[T]he determination of technical impracticability [TI] involves a consideration of both engineering feasibility and reliability. Such a determination may be made, for example, in some cases where the nature of the waste and the hydrogeologic setting would either prevent installation of a groundwater pump and treat system, (or other effective cleanup technology) or limit the effectiveness of such a system...In other situations a determination...may be made when remediation may be technically possible, but the scale of operations required might be of such a magnitude and complexity that the alternative would be impracticable....The Agency believes that the concept of TI may in some cases also apply to situations in which use of available remedial technologies would create unacceptable risks to workers or surrounding populations..."

- Environmental Justice—According to the May 1996 Proposed Subpart S language, there are four main areas of environmental justice concerns: 1) stakeholder outreach during the rulemaking process; 2) public participation on a site-specific level during the corrective action process; 3) public participation in future land-use and associated remedial decisions; and 4) ensuring the continued effectiveness of institutional controls. As stated in the text, "the Agency remains committed to identifying and addressing environmental justice concerns and to expanding public participation in the corrective action process..."

- Monitored Natural Attenuation—The EPA Office of Solid Waste and Emergency Response issued an interim final Directive on December 1, 1997 entitled, "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites." The term "monitored natural attenuation" refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by other more active methods. Attenuation processes can include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

  The Directive contains the following key themes: EPA does not view monitored natural attention to be a "no action" remedy. It also should not be considered a "presumptive" or default remedy, but should be evaluated and compared to other viable remediation alternatives. The decision to implement monitored natural attention should include a comprehensive site characterization, risk assessment where appropriate, and measures to control sources. It should not be used where such an approach would result in significant contaminant migration or unacceptable impacts to receptors and other natural resources. Where monitored natural attenuation's ability to meet these expectations is uncertain and based predominantly

on predictive analyses, contingency measures should be incorporated into the remedy.

- Presumptive Remedies—After 15 years of conducting RI/FS activities in the Superfund program, EPA determined that there was a handful of site types that resulted in similar types of remedies. Some of these site types included municipal landfill sites and groundwater sites. To accommodate these sites, EPA developed several presumptive or "default" remedies that are designed, in part, to expedite the RI/FS scoping process by eliminating the need to perform the traditional identification and screening of alternatives. Instead, attention is focused on fulfilling data needs to support the presumptive remedy. Although the landfills in the ER Project are not municipal, the presumptive remedy framework may be of value in the MDA CMS process. (Info. Re: where to find presumptive remedy guidance will be added.)

3.2 Toxic Substances Control Act (TSCA)

TSCA addresses the manufacture, processing, distribution in commerce, use, cleanup, storage, and disposal of polychlorinated biphenyls (PCBs). PCBs have been used at the Laboratory during much of the facility's operating history, and as such, are present at many MDAs. The ER Project is compiling a policy regarding the evaluation and cleanup of PCBs in soil. The policy should be thoroughly reviewed by MDA project personnel who are attempting to properly manage PCB contamination. The policy is attached as Appendix ____. What follows is a very general summation of this policy.

3.2.1.1 Applicability

If a PRS "received" PCB contamination prior to May 4, 1987, such contamination must be investigated by the ER Project. Conversely, PCB spills that occurred on or after May 4, 1987 are excluded from the ER Project, but must be addressed by the Laboratory in compliance with EPA's TSCA Spill Cleanup Policy (40 CFR 761, Subpart G), promulgated on May 4, 1987.

April 18, 1978 is another important threshold date for the PCB program. Before this date, PCB disposal was not regulated. PCBs that were disposed of in a landfill prior to this date are not required to be excavated and disposed of in accordance with PCB regulations, unless EPA determines that the disposal presents an unreasonable risk of PCB exposure. The TSCA disposal requirements at 40 CFR 761.60 become applicable only when PCBs are removed from service for disposal. TSCA requirements for cleanup and disposal of remediation wastes are contained in 40 CFR 761.61. (Please consult Appendix ___to determine how the Laboratory's policy impacts cleanup decisions for PCBs disposed of before 4/18/78.)

Investigation and remediation of PRSs contaminated with PCBs is conducted pursuant to RCRA Proposed Subpart S, TSCA, Subpart D, Storage and Disposal, and Subpart G, PCB Spill Cleanup Policy. The ER Project's PCB policy, (Appendix ___) contains a matrix that describes in detail the specific regulatory authorities and what they require. Please note that EPA has primary authority over PCBs even when the cleanup occurs under another authority.

3.2.1.2 Performance Objectives

In general, cleanup levels will be 1 part per million for high occupancy areas and 25 ppm for low occupancy areas. (63 FR 35408) One ppm should be used as a point of departure for sites located in or affecting a watercourse. (Watercourse is defined by the Clean Water Act.)

Screening action levels are as follows: In soil, 1 ppm will be used as the ER Project human health/ecological risk SAL at sites under an industrial land use scenario. At sites under a residential or potential residential land use scenario, 1 ppm will be used.

3.2.1.3 Exposure Scenarios

According to federal regulations, the points of compliance and pathways for PCB contamination are often site-specific, and are based in part on the given PCB spill scenario, i.e., where the PCBs were "spilled" and in what quantity. The regulatory text (40 CFR 761) and the appropriate subject matter expert should be consulted to properly identify the requirements at a given MDA.

The pathways considered in the ER Project PCB policy include soil, surface water and groundwater, although the PCB regulations also discuss sewers, sewage treatment systems, public or private drinking water sources, animal grazing lands and vegetable gardens. The ER Project PCB policy also notes that when determining cleanup levels at PRSs located in sensitive habitats, ecological risk must be considered.

3.2.1.4 Compliance Period

The compliance period for PCB cleanup is taken from the federal PCB Spill Cleanup Policy. It states that no time limit on completion of the cleanup effort exists since the time required for completion will vary from case to case. However, EPA expects that decontamination will be achieved promptly in all cases and has stated its intent in 40 CFR 761.120 to consider promptness in determining whether the responsible party made good faith efforts to clean up the spill in accordance with the TSCA cleanup regulations. (40 CFR 761.125(c)(1)(6).

3.2.1.5 Other considerations

The EPA published its final PCB disposal regulations on June 29, 1998 to become effective August 28, 1998. The ER Project PCB policy must be compared to these regulations to ensure consistency with the new EPA regulations.

4 WATER REGULATIONS

4.1 Clean Water Act

The broad goal of the Clean Water Act is to protect the nation's waterways. This is done in part through the use of different types of permits such as the National Pollutant Discharge Elimination System (NPDES).

4.1.1.1 Applicability

The Laboratory has a NPDES Stormwater General Permit that includes requirements for Stormwater Pollution Prevention Plans, monitoring and best management practices (BMPs). In addition, Section's 401 and 404 of the CWA state that any soil disturbance in a water course or drainage requires a dredge and fill permit. For purposes of MDA activities, a "soil disturbance" can include drilling, sampling, moving waste, etc. Water courses and drainages are identified by an ESH-18 representative through the use of the ESH-ID process. The Laboratory also has requirements for spill prevention as stated in 40 CFR 112. The Spill Prevention Control &

Countermeasure (SPCC) plan outlines the responsibilities for secondary containment, inspections and spill response.

4.1.1.2 Performance Objectives

The proposed NPDES Multi-sector Stormwater General Permit references the use of cut-off concentrations for certain metals and other contaminants of concern found in a watercourse that can not be exceeded, (per 40 CFR Sections 122, 123). In addition, the Laboratory's Watershed Management Plan will establish a monitoring program to ensure compliance with those concentration limits.

4.1.1.3 Exposure Scenarios

The relevant pathways to be considered include arroyos, drainages, subdrainages, canyons, and watercourses. All of these should be considered waterways of the United States, and hence are all regulated. A majority of the Laboratory's "waterways" are ephemeral and/or intermittent. There is no consensus within the Laboratory as to what an appropriate point of compliance is for surface and storm water. Options include the Rio Grande, the Laboratory boundary, or each individual sampling point.

4.1.1.4 Compliance Period

According to the draft Watershed Management Plan, real-time monitoring results, 3-5 year trend analyses, and future modeling results will be used to indicate when the WQCC standards or the NPDES permit concentrations have been exceeded. If an exceedance has occurred, the source will be identified and BMPs will be implemented.

4.1.1.5 Other Considerations

According to the proposed NPDES Multi-sector Stormwater General Permit, the implementation of BMPs, including the rerouting of surface waters cannot negatively impact threatened or endangered species or archeological sites.

4.2 State Standards for Interstate and Intrastate Streams (20 NMAC 6.1 1/23/95)

4.2.1.1 Applicability

The purpose of these standards is to designate the uses for which the surface waters of the State of New Mexico shall be protected and to prescribe the water quality standards to sustain the designated uses. The standards are consistent with Section 101(a)(2) of the CWA which declares that "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983..." Agricultural, municipal, domestic, and industrial water supply are other essential uses of New Mexico's water; however, water contaminants resulting from these activities will not be permitted to lower the quality of streams below that which is required for recreation and maintenance of a fishery where practicable.

4.2.1.2 Performance Objectives

The document contains performance objectives regarding toxic substances, radioactivity, turbidity, salinity, and other water quality criteria. (The text of this section is included as Appendix ____.) In summary, the regulations state that surface waters shall be free of toxic substances. Regarding radioactivity, surface waters shall be maintained at the lowest practical level and may not exceed the standards set forth in the New Mexico Environmental Improvement Board Radiation Protection Regulations.

4.2.1.3 Exposure Scenarios

When a point or nonpoint source discharge creates a source of water which could be used by livestock and wildlife in non-classified, otherwise ephemeral waters of the State, those waters shall be protected for the uses of livestock watering and wildlife habitat. (The actual numeric standards are included in Appendix ____.)

4.2.1.4 Compliance Period

The WQCC references the compliance periods as specified in the facility's NPDES permit. The Laboratory's current permit period was from 1992-1997, and is operating on an extension. The new permit will be effective from 1998 to 2003.

4.3 Laboratory Requirements

There are a number of Laboratory requirements regarding the protection of water quality (e.g., surface water site assessments and the Watershed Management Plan); some of these requirements are currently evolving, while others have been standard protocol. Rather then summarize them here, it will be important for MDA project personnel to fully utilize the ESH-ID process, and to work closely with ESH-18 in order to implement the most current Laboratory requirements regarding water quality.

5 RADIOACTIVE MATERIAL REGULATIONS

The MDAs included in the Environmental Restoration Project (ER Project) that contain radioactive constituents are subject to radioactive material regulations issued as Orders by the Department of Energy (DOE). Also, they are subject to U.S. Environmental Protection Agency (EPA) regulations addressing radioactive airborne emissions and Clean Water Act regulations addressing radioactivity in the groundwater. There also exist draft Orders and various regulations for other entities (for example, Nuclear Regulatory Commission licensees) that the ER Project does not have to comply with but they do provide additional guidance and insight into future regulatory philosophy. These documents are discussed in this section.

The existing regulations considered to be applicable to the remediation of the ER Project Material Disposal Areas (MDAs) are presented in this section. The attempt has been made within this section to reflect all requirements that affect ER Project MDAs. As presented, it is consistent with current regulations. The section will be revised as needed to reflect changes in the applicable regulations.

5.1 DOE ORDERS

The Department of Energy regulates radioactive materials at DOE facilities through DOE Orders. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," is applicable to the remediation of radioactively contaminated MDAs by the ER Project. and DOE Order 5820.2A, "Radioactive Waste Management," would be applicable only if ER removes radioactive material from an MDA and disposes of the radioactive waste again onsite. The effective date of DOE Order 5820.2A is September 26, 1988. The Order does not apply to any DOE activities before that date.

5.1.1 DOE ORDER 5400.5

The DOE's overarching standard to protect the public from radiation is set by DOE Order 5400.5, "Radiation Protection of the Public and the Environment." Excerpts from the Order applicable to the ER Project include the following.

"6. OBJECTIVES.

a. Protecting the Public. It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess does to members of the public.

b. Protecting the Environment. In addition to providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to the extent practical."

Specific requirements of this Order are discussed separately here as the primary radioactive material regulations with which the ER Project must demonstrate compliance.

5.1.1.1 ALARA

5.1.1.1.1 Applicability

The ALARA requirements apply to the remediation of all MDAs at LANL that contain radioactive constituents. Order 5400.5 states:

"3. SCOPE. The provisions of this Order apply to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer."

5.1.1.1.2 Performance Objectives

"CHAPTER II, REQUIREMENTS FOR RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT"

"2. THE ALARA PROCESS. Field elements shall develop a program and shall require contractors to implement the ALARA Process for all DOE activities and facilities that cause public doses.

a. Considerations. ALARA requires judgment with respect to what is reasonably achievable. Factors that relate to societal, technological, economic, and other public policy considerations shall be evaluated to the extent practicable in making such judgments. Factors to be considered, at a minimum, shall include:

(1) The maximum dose to members of the public;

(2) The collective dose to the population;

(3) Alternative processes, such as alternative treatments of discharge streams, operating methods, or controls;

(4) Doses for each process alternative;

(5) Costs for each of the technological alternatives;

(6) Examination of the changes in cost among alternatives;

(7) Changes in societal impact associated with process alternatives, e.g., differential doses from various pathways.

b. Evaluations. A quantitative cost-benefit analysis (e.g., optimization) could be performed, given the results of the considerations noted in paragraph II.2a, above. However, the parameters needed to evaluate the cost-benefit analyses are difficult to quantify, and evaluations themselves can be expensive. Furthermore, the evaluations include many additional assumptions, judgments, and limitations that are often difficult to reflect as uncertainties in the analyses. Therefore, except for meeting requirements of the National Environmental Policy Act, qualitative analyses are acceptable, in most instances, for ALARA judgments, especially where potential doses are well below the dose limit. The bases for such judgments should be documented. More detailed analyses should be considered if the decisions might result in doses that approach the limit."

The Order requires that doses shall be As Low As Reasonably Achievable (ALARA) for all DOE activities and facilities that cause a dose to the public. This requirement is in addition to the requirement to limit doses to less than 100 mrem/year. Even if the projected doses are acceptable, additional efforts should be undertaken to reduce doses to ALARA levels. An ALARA analysis is an optimization: are there cost-effective actions that can be taken to reduce projected doses even further? The DOE Order does not place a monetary value on averted doses; however, NRC guidance for NRC-regulated facilities suggests the implementation of ALARA measures that cost less than $2,000 per person-rem of averted dose. Note that Order 5400.5 states:

"5. POLICY. It is the policy of DOE to implement legally applicable radiation protection standards and to consider and adopt, as appropriate, recommendations by authoritative organizations, e.g., the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). It is also the policy of DOE to adopt and implement standards generally consistent with those of the Nuclear Regulatory Commission (NRC) for DOE facilities and activities not subject to licensing authority."

5.1.1.1.3 Exposure Scenarios

Section II.6 of 5400.5 discusses demonstration of compliance with the dose limits. 6.b. (1) addresses modeling and pathways. It states:

"Modeling. Analytical models used for dose evaluations shall be appropriate for characteristics of emissions (e.g., gas, liquid, or particle; depositing or non-depositing; buoyant or non-buoyant); mode of release (e.g., stack or vent; crib or pond; surface water or sewer; continuous or

intermittent); environmental transport medium (e.g., air or water); and exposure pathway (e.g., inhalation; ingestion of food, water, or milk; direct radiation). ....". The point of compliance for this Order is the nearest publicly accessible location where a member of the public would receive the highest radiation dose from all the pathways combined.

5.1.1.1.4 Compliance Period

The time frame is not explicitly stated in the Order, however, for remediated sites with radioactivity left at the sites, a modeling period of 1000 years is generally acceptable.

5.1.1.2 All Sources

5.1.1.2.1 Applicability

The dose limit of 100 mrem/yr applies to the remediation of all MDAs at LANL that contain radioactive constituents. Order 5400.5 states:

"3. SCOPE. The provisions of this Order apply to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer."

5.1.1.2.2 Performance Objectives

DOE ORDER 5400.5, CHAPTER II states:

"1.a. DOE Public Dose Limit--All Exposure Modes, All DOE Sources of Radiation. Except as provided by II.la(4), the exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem (1 mSv). Dose evaluations should reflect realistic exposure conditions (see II.6b)."

"(3) Application. The public dose limits in paragraph II.la apply to doses from exposures to radiation sources from routine activities, including remedial actions..."

Chapter II of this order establishes a dose limit of 100 mrem per year (effective dose equivalent) to protect the public from radiation from all exposure modes from all routine DOE operations (including remedial actions). Under unusual circumstances, the DOE may allow higher dose limits (not to exceed 500 mrem for a year) as provided by section II 1 a. (4) of the Order. The higher dose limit must be temporary and requires coordination with the Program Office and written authorization from DOE/HQ/EH-1.

5.1.1.2.3 Exposure Scenarios

Section II.6 of 5400.5 discusses demonstration of compliance with the dose limits. 6.b. (1) addresses modeling and pathways. It states:

"Modeling. Analytical models used for dose evaluations shall be appropriate for characteristics of emissions (e.g., gas, liquid, or particle; depositing or non-depositing; buoyant or non-buoyant);

mode of release (e.g., stack or vent; crib or pond; surface water or sewer; continuous or intermittent); environmental transport medium (e.g., air or water); and exposure pathway (e.g., inhalation; ingestion of food, water, or milk; direct radiation). ....".

The point of compliance for this Order is the nearest publicly accessible location where a member of the public would receive the highest radiation dose from all the pathways combined.

5.1.1.2.4 Compliance Period

The time frame is not explicitly stated in the Order, however, for remediated sites with radioactivity left at the sites, a modeling period of 1000 years is generally acceptable.

5.1.1.3 Air Emissions

5.1.1.3.1 Applicability

The airborne emissions exposure limit of 10 mrem/yr applies to the remediation of all MDAs at LANL that contain radioactive constituents. Order 5400.5 states:

5.1.1.3.2 "3. SCOPE. The provisions of this Order apply to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer."

5.1.1.3.3 Performance Objectives

"DOE Order 5400.5, Chapter II states:

"b. Airborne Emissions Only, All DOE Sources of Radionuclides. To the extent required by the Clean Air Act, the exposure of members of the public to radioactive materials released to the atmosphere as a consequence of routine DOE activities shall not cause members of the public to receive, in a year, an effective dose equivalent greater than 10 mrem (0.1 mSv). ....
Title 40 CFR Part 61. The public dose limits as outlined in paragraph II.lb are established by EPA regulation 40 CFR Part 61, Subpart H, under the authority of the Clean Air Act. These limits apply offsite where the members of the public reside or abide.... "

5.1.1.3.4 Exposure Scenarios

The pathway used to demonstrate compliance with this standard is the air pathway or human inhalation pathway. The point of compliance for this regulation is determined by the Environment, Safety and Health Division 17 (ESH-17) of LANL. ESH-17 sums all ambient air exposures from operations at LANL and compliance is presently demonstrated as total LANL air emissions exposure to a member of the public is less than 10 mrem per year. At the present time (ESH-17), is responsible for LANL's compliance with this regulation and the compliance reporting.

5.1.1.3.5 Compliance Period

The time frame for demonstrating compliance with this regulation is implied in section 61.90, "The provisions of this subpart apply to operations at any facility owned or operated by the Department of Energy that emits any radionuclide other than radon-222 and radon-220 into the air,..." This standard applies as long as DOE owns or operates a facility. Therefore, this standard applies to an MDA as long as DOE owns the MDA.

5.1.1.3.6 Additional Considerations

In order for LANL to be in compliance with this regulation, an air emissions source term should be calculated for each MDA during clean-up operations and as far into the future as it is assumed that DOE will retain control of the site. The default time period is 1000 years. The air emissions source term for each MDA would be incorporated by ESH-17 into the radioactive NESHAPS compliance model for LANL.

5.1.1.4 Groundwater

5.1.1.4.1 Applicability

The groundwater exposure limit of 4 mrem/yr applies to the remediation of all MDAs at LANL that contain radioactive constituents. Order 5400.5 states:

"3. SCOPE. The provisions of this Order apply to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer."

5.1.1.4.2 Performance Objectives

DOE Order 5400.5, Chapter II states:

"c. Drinking Water Pathway Only, All DOE Sources or Radionuclides. It is the policy of DOE to provide a level of protection for persons consuming water from a public drinking water supply operated by the DOE, either directly or through a DOE contractor, that is equivalent to that provided to the public by the public community drinking water standards of 40 CFR Part 141. These systems shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year. Combined radium-226 and radium-228 shall not exceed 5×10^{-9} uCi/ml and gross alpha activity (including radium-226 but excluding radon and uranium) shall not exceed 1.5×10^{-8} uCi/ml."

The 4 mrem per year standard for the drinking water pathway is a further specification of the 100 mrem per year dose standard for all pathways (i.e., doses from DOE-operated water supplies cannot contribute more than 4 mrem of the 100 mrem per year, all pathways, total dose). Furthermore, DOE-operated water supplies must meet safe drinking water standards (MCLs) under 40 CFR 141.

5.1.1.4.3 Exposure Scenarios

The point of compliance for these performance objectives is the nearest member of the public to the MDA site that may consume water from a potentially contaminated public drinking water supply. The exposure pathways for this section of the Order are the groundwater pathway and any additional pathways that have a reasonable potential to impact a public drinking water supply.

5.1.1.4.4 Compliance Period

The time frame is not explicitly stated in the Order, however, for remediated sites with radioactivity left at the sites, a modeling period of 1000 years is generally acceptable.

5.1.1.4.5 Additional Considerations re: DOE Order 5400.5

In addition to setting a 100-mrem per year, all sources, all pathways dose standard, and the 4 mrem/year drinking water standard, DOE Order 5400.5 states that DOE must *also* comply with legally applicable requirements (e.g., 40 CFR Parts 61, 191, and 192 and 10 CFR Parts 60 and 72), including administrative and procedural requirements." (Section II 1., *emphasis added*)

Chapter IV of DOE Order 5400.5 addresses *the release of real property having residual radioactive materials, not for in-situ closure.* The requirements of the Order apply only to the release of materials with surface contamination, and no guidance is available for release of material that has been contaminated in depth, such as activated material or smelted contaminated metals (Section II 5. c. (6)). Importantly, DOE Order 5400.5 does not address characterization requirements – for example, the types of instruments to use and the number of measurements to be taken.

Chapter IV of DOE Order 5400.5 presents radiological protection requirements and guidelines for cleanup of residual radioactive material and management of the resulting wastes and release of property. Chapter IV sets requirements for the different options for residual radioactive material: (1) unrestricted release; (2) storage; and (3) long-term management (i.e., disposal).

The footnotes associated with Figure IV-1 offer recommendations for addressing "hot spots" and removable material. Section IV 4. a. states that "Residual Radionuclides in Soil... Guidelines... shall be derived from the basic dose limits (100 mrem per year) by means of an environmental pathway analysis using specific property data. Residual concentrations of radioactive material in soil are defined as those in excess of background concentrations averaged over an area of 100 m^2." Finally, Section IV 6. d. (2) states that the long-term management (i.e., disposal) of radioactive materials that are not mill tailings shall be in accordance with DOE Order 5820.2A, as applicable.

Chapter IV also provides examples of specific situations that warrant DOE use of supplemental standards and exceptions:

i. Where remedial actions would pose a clear and present risk of injury to workers or members of the public, not withstanding reasonable measures to avoid or reduce risk.

ii. Where remedial actions, even after all reasonable mitigative measures have been taken, would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near the affected properties now or in the future. A clear excess of environmental harm is harm that is grossly disproportionate to health benefits that may be reasonably anticipated.

iii. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and where residual material does not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a property should be considered in evaluating this risk. (Section IV 7. C).

5.1.2 DOE ORDER 5820.2A

The primary document that contains guidance concerning radioactive waste disposal site closure is DOE Order 5820.2A, "Radioactive Waste Management." The effective date of this Order is September 26, 1988.

5.1.2.1 Applicability

Chapter III of this order specifically states it applies to:

"DOE-low-level waste that has not been disposed of prior to issuance of this Order,"

that is, September 26, 1988. At LANL, this Order is only applicable to the radioactive waste disposed at MDA G after September 26, 1988, and any other LANL MDA where low-level waste was disposed after September 26, 1988. Chapter III, "Management of Low-Level Waste," would only apply to additional MDAs if, in the course of remediation at an MDA, radioactive material is removed from the MDA and disposed onsite at LANL. Chapter II, "Management of Transuranic Waste," would only be applicable if ER excavates radioactive waste and the waste meets the definition of TRU in 5820.2A. The sections of 5820.2A that would be the most likely to be applicable are discussed here.

5.1.2.2 Performance Objectives

Order 5820.2A, Chapter III states:

"3. REQUIREMENTS.

a. Performance Objectives. DOE-low-level waste that has not been disposed of prior to issuance of this Order shall be managed on the schedule developed in the Implementation Plan (See page 7, paragraph 10) to accomplish the following:

(1) Protect public health and safety in accordance with standards specified in applicable EH orders and other DOE Orders.

(2) Assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground, water, soil, plants and animals results in and effective dose equivalent that does not exceed 25 mrem/yr to any member of the public. Releases to she atmosphere shall meet the requirements of 40 CFR 61. Reasonable effort should be made to maintain releases of radioactivity in effluents to

the general environment as low as is reasonably achievable.

(3) Assure that the committed effective dose equivalents received by individuals who inadvertently may intrude into the facility after the loss of active institutional control (100 years) will not exceed 100 mrem/yr for continuous exposure or 500 mrem for a single acute exposure.

(4) Protect ground water resources, consistent with Federal, State and local requirements.

5.1.2.3 Exposure Scenarios

The exposure scenarios are stated in the performance objectives and further defined in 5820.2A guidance documents. The pathways specified in the Order include uptakes by a member of the public from surface water, ground, water, soil, plants and animals, and from the air. Points of compliance are on-site for the inadvertent intruder and the nearest publicly accessible location where a member of the public would receive the highest radiation dose from all the pathways combined for the rural land use scenario.

5.1.2.4 Compliance Period

The time frame is not explicitly stated in the Order, however, the DOE guidance document, "Draft Interim Performance Assessment and Composite Analysis Review Guidance Manual," recommends a compliance period of 1,000 years. DOE published this guidance in 1998.

5.1.2.4.1 Performance Assessment

The requirement for a performance assessment applies only to low-level waste as specified in 5820.2A:

"DOE-low-level waste that has not been disposed of prior to issuance of this Order," that is, September 26, 1988. At LANL, this means certain waste at MDA G and any other LANL MDA where low-level waste was disposed after September 26, 1988. A Performance Assessment and a Composite Analysis have been completed and conditionally approved by DOE for MDA G.

5.1.3 DOE ORDER 6430.1A

Another DOE document that impacts the remediation of ER Project MDAs is 6430.1A, "General Design Criteria.". This directive provides the minimally acceptable criteria for facility design and those criteria are reprinted here:

> "Section 1324-5.3 [Radioactive Solid Waste Facilities: Special Design Features: Low-level Waste Disposal Facility Confinement]
> Low-level solid waste that is disposed in the ground shall be confined by a site-specific system of barriers that may include, but not necessarily be limited to, waste form, waste packaging, and the geologic setting.

When site permeability characteristics do not provide the required confinement capabilities, the confinement system shall be augmented by the following:

- Constructing low permeability walls around the low-level waste
- Lining the walls and bottom of the excavated area with low permeability material
- Other suitable methods for reducing permeability

Means shall be provided to minimize contact of emplaced low-level waste with water. Active water control measures shall not be required following permanent closure. Typical requirements for water control are as follows:

- Placing a layer of highly permeable material (e.g. sand, gravel) beneath the low-level waste to channel any percolating water to a sump
- Mounding the soil surface to facilitate water runoff
- Use of a suitable low-permeability cover material (e.g. clay) over the disposal area to prevent contact of the waste by infiltrating rainwater. This cover material shall be protected by a layer of overburden (e.g. sand, gravel, topsoil).
- A site diversion system for surface water runoff during operation of the facility. (This system shall not be required following permanent site closure.)
- Temporary protective covers (e.g. tarpaulin) before the completion of the natural in-place soil barrier over the low-level waste.
- Revegetation of the overburden layer.
- Other suitable and reliable means for minimizing water contact with low-level waste.

Section 1324-6.4
The natural geologic setting composes the tertiary confinement system.

The tertiary confinement system shall function during the normal operations, anticipated operational occurrences, and the DBAs it is required to withstand. It shall be capable of performing its necessary functions following a DBE.

The tertiary confinement shall remain functional following DBAs and the severe natural phenomena postulated for the facility site. In addition, the tertiary confinement system shall meet the following performance objectives:

- Following permanent closure, ongoing site maintenance shall not be needed.
- In the absence of unplanned natural processes or humans contact with a low-level waste disposal facility, calculated contaminant levels in groundwater at the site boundary shall not exceed the maximum contaminant levels established in 40 CFR 141.
- In the event of human-induced activities following permanent closure, or reasonably foreseeable but unplanned natural processes, the guidelines of Section 1300-1.4.2, Accidental Releases, shall not be violated. Institutional controls may be relied on for a limited time following closure to preclude reclamation activities at a low-level waste disposal site. For the purposes of calculation, these controls shall not be relied on for more than 100 years following permanent closure."

5.1.3.1 Applicability

This Order is applicable to every MDA remediation that includes any designed features, such as a cover system.

5.1.3.2 Performance Objectives

The performance objectives for groundwater are stated in the Order: "In the absence of unplanned natural processes or humans contact with a low-level waste disposal facility, calculated contaminant levels in groundwater at the site boundary shall not exceed the maximum contaminant levels established in 40 CFR 141." For inadvertent intruder exposure, the objectives are: "In the event of human-induced activities following permanent closure, or reasonably foreseeable but unplanned natural processes, the guidelines of Section 1300-1.4.2, Accidental Releases, shall not be violated. Institutional controls may be relied on for a limited time following closure to preclude reclamation activities at a low-level waste disposal site. For the purposes of calculation, these controls shall not be relied on for more than 100 years following permanent closure."

5.1.3.3 Exposure Scenarios

Exposure scenarios include the human intruder scenario and the groundwater pathway. The points of compliance are on-site for the human intruder and at the site boundary for the groundwater.

5.1.3.4 Compliance Period

The compliance period can include taking credit for institutional controls for no longer than 100 years. The time frame is not explicitly stated in the Order, however, for remediated sites with radioactivity left at the sites, a modeling period of 1000 years is generally acceptable.

5.2 CODE OF FEDERAL REGULATIONS

The remediation of LANL MDAs must also comply with the applicable regulatory requirement of 40 CFR Part 61, Subpart H, and 40 CFR Part 141. The EPA promulgated these regulations.

5.2.1 40 CFR PART 61, SUBPART H

Title 40 CFR Part 61, Subpart H, "National Emission Standard for Radionuclide Emissions from Department of Energy (DOE) Facilities," regulates radionuclide air emissions from DOE facilities.

5.2.1.1 Applicability

The sections of Subpart H applicable to remediation of LANL MDAs are reprinted here for completeness. They have already been discussed under the requirements of DOE Order 5400.5.

"Sec. 61.90 Designation of facilities.

The provisions of this subpart apply to operations at any facility owned or operated by the Department of Energy that emits any radionuclide other than radon-222 and radon-220 into the air, except that this subpart does not apply to disposal at facilities subject to 40 CFR part 191, subpart B or 40 CFR part 192."

"Sec. 61.92 Standard.

Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr."

"Sec. 61.94 Compliance and reporting.

(a) Compliance with this standard shall be determined by calculating the highest effective dose equivalent to any member of the public at any offsite point where there is a residence, school, business or office. The owners or operators of each facility shall submit an annual report to both EPA headquarters and the appropriate regional office by June 30 which includes the results of the monitoring as recorded in DOE's Effluent Information System and the dose calculations required by Sec. 61.93(a) for the previous calendar year.

(b) In addition to the requirements of paragraph (a) of this section, an annual report shall include the following information:

(1) The name and location of the facility.

(2) A list of the radioactive materials used at the facility.

(3) A description of the handling and processing that the radioactive materials undergo at the facility.

(4) A list of the stacks or vents or other points where radioactive materials are released to the atmosphere.

(5) A description of the effluent controls that are used on each stack, vent, or other release point and an estimate of the efficiency of each control device.

(6) Distances from the points of release to the nearest residence, school, business or office and the nearest farms producing vegetables, milk, and meat.

(7) The values used for all other user-supplied input parameters for the computer models (e.g., meteorological data) and the source of these data.

(8) A brief description of all construction and modifications which were completed in the calendar year for which the report is prepared, but for which the requirement to apply for approval to construct or modify was waived under Sec. 61.96 and associated documentation developed by DOE to support the waiver. EPA reserves the right to require that DOE send to EPA all the information that normally would be required in an application to construct or modify, following receipt of the description and supporting documentation."

5.2.1.2 Compliance Period

The time frame for demonstrating compliance with this regulation is implied in section 61.90, "The provisions of this subpart apply to operations at any facility owned or operated by the Department of Energy that emits any radionuclide other than radon-222 and radon-220 into the air,..." This standard applies as long as DOE owns or operates a facility. Therefore, this standard applies to an MDA as long as DOE owns the MDA.

5.2.1.3 Additional Considerations

In order for LANL to be in compliance with this regulation, an air emissions source term should be calculated for each MDA during clean-up operations and as far into the future as it is assumed that DOE will retain control of the site. The default time period is 1000 years.

5.2.2 40 CFR 141, NATIONAL INTERIM PRIMARY DRINKING WATER REGULATION (Safe Drinking Water Act)

Potential radiological doses from drinking water are addressed in Section II 1. d. of DOE Order 5400.5, which requires that doses from DOE water supply systems shall not exceed 4 mrem per year. This is consistent with the comparable requirement in 40 CFR 141. The 4 mrem per year standard for the drinking water pathway is in addition to the 100 mrem per year dose standard for all pathways (i.e., doses from DOE-operated water supplies cannot contribute more than 4 mrem of the 100 mrem per year, all pathways, total dose). Furthermore, DOE-operated water supplies must meet safe drinking water standards under 40 CFR 141, the MCLs.

gencies and persons consulted."

5.2.3 Potential Guidance Documents

Several additional documents exist that could provide useful guidance for the remediation of ER Project MDAs contaminated with radioactive material. These documents are summarized here in the guidance portion of this section. The ER Project is not required to comply with these documents but they are presented here because they provide useful insight into possible future regulatory requirements and also present the current regulatory philosophy of the Nuclear Regulatory Commission (NRC). These documents include Draft DOE Order 435.1, NRC performance objectives for risk assessments of commercial LLW disposal facilities in 10 CFR Part 61, 10 CFR Section 20.1401, "Radiological Criteria for License Termination," and working draft regulations of the EPA, 40 CFR Part 196.

5.2.4 DRAFT DOE ORDER 435.1

In 1997, DOE published a new draft order, DOE Order 435.1, "Radioactive Waste Management." If Order 435.1 were finalized, it would replace DOE Order 5820.2A.

5.2.4.1 Applicability

This Order would only apply if, in the course of remediation at an MDA, radioactive material were removed from the MDA and disposed onsite at LANL. As stated in the draft Order:

"3. APPLICABILITY.

a. DOE Elements. Except for the exclusions cited, this Order applies to all DOE elements."

"c. Exclusions. This Order does not apply to:

....

(5) Activities other than storage, treatment, or disposal of radioactive waste, related to the decontamination and decommissioning of Department of Energy facilities."

5.2.4.2 Performance Objectives

The performance objectives are explicitly stated in Chapter IV of the Radioactive Waste Management Manual, DOE M 435.1, referenced in the draft Order:

"(a) Performance Objectives. Low-level waste shall be disposed to meet the following performance objectives:

1. Dose to a member of the public shall not exceed 25 mrem in a year total effective dose equivalent from all exposure pathways, excluding the dose from radon and its progeny in air.

2. Dose via the air pathway shall not exceed 10 mrem in a year total effective dose equivalent, excluding the dose from radon and its progeny.

3. Release of radon shall be less than an average flux of 20 pCi/m2/s at the surface of the disposal facility. Alternatively, for waste similar to uranium or thorium mill tailings, a limit of 5 pCi/1 of air at the edge of a 100 meter buffer zone may be applied.

4. Water resources shall be protected consistent with applicable Federal, state and local requirements."

5.2.4.3 Exposure Scenarios

The performance assessment and therefore exposure scenario guidance in Chapter IV of the Radioactive Waste Management Manual, DOE M 435.1, referenced in the draft Order are given below:

"(d) Performance Assessment. A site-specific radiological performance assessment shall be prepared and maintained for DOE low-level waste disposal facilities which received waste after September 26, 1988. The performance assessment shall calculate potential doses to hypothetical future members of the public and potential releases from the facility to provide a reasonable expectation that the performance objectives will not be exceeded over a period of 1,000 years after facility closure.

1. The performance assessment shall include an estimate of the maximum projected dose, flux, or concentration and the time of the maximum, in the sensitivity/uncertainty analysis.

2. Unless noted otherwise in section 3.C.(4)(a) of this chapter, the point of compliance shall correspond to the point of highest projected dose or concentration beyond a 100 meter buffer zone surrounding the disposed waste. A larger or smaller buffer zone may be used provided adequate justification is provided.

3. DOE shall control the land on which low-level waste is disposed until the land can be released in accordance with requirements of DOE O 5400.5, Radiation Protection of the Public and the Environment (or 10 CFR 834, when promulgated). However, the performance assessment shall normally assume a period of active institutional control of 100 years. Periods longer then 100 years may be assumed given adequate justification is provided.

4. Analyses performed to estimate results versus the performance objectives in 3.C.(4)(a) of this chapter and the intruder performance measures in 3.C.(4)(e) of this chapter shall be based on reasonable activities of a typical group of individuals performing activities consistent with regional construction practices and living habits.

5. Performance assessments shall address reasonably foreseeable processes (e.g., precipitation, erosion, subsidence, biotic intrusion) that might disrupt barriers against release and transport of radioactive materials.

6. Performance assessments shall use standard adult dose conversion factors.

7. Projected releases to the environment shall be as low as reasonably achievable.

(e) Intruder Analyses. For purposes of establishing limits on the concentration of radionuclides that may be disposed of near-surface, the performance assessment shall include an assessment of impacts calculated for a hypothetical person assumed to inadvertently intrude into the low-level waste disposal facility. For intruder analyses, institutional controls shall be assumed to be effective in deterring intrusion for at least 100 years following closure. The intruder analyses shall use performance measures of 100 mrem in a year total effective dose equivalent for chronic exposure and 500 mrem total effective dose equivalent for acute exposure.

(f) Composite Analysis. For disposal facilities which received waste after September 26, 1988, a site-specific radiological composite analysis shall be prepared and maintained to provide a reasonable expectation that requirements for the protection of the public will not be exceeded. A composite analysis accounts for all sources of radioactive material that may be left at the DOE site and may interact with the disposal facility, contributing to the dose projected to a hypothetical member of the public from the existing or future disposal facilities."

5.2.4.4 Compliance Period

The time frame is explicitly stated in Chapter IV of the Radioactive Waste Management Manual, DOE M 435.1, referenced in the draft Order:

"The performance assessment shall calculate potential doses from the facility to provide a reasonable expectation that the performance objectives will not be exceeded over a period of 1,000 years."

5.2.5 10 CFR PART 61

In 1982 the NRC promulgated 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." These regulations are comprehensive for the siting, design, licensing, operation and closure of a LLW disposal facility. DOE Order 5400.5 states:

"5. POLICY. It is the policy of DOE to implement legally applicable radiation protection standards and to consider and adopt, as appropriate, recommendations by authoritative organizations, e.g., the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). It is also the policy of DOE to adopt and implement standards generally consistent with those of the Nuclear Regulatory Commission (NRC) for DOE facilities and activities not subject to licensing authority."

Based on this policy, the NRC regulations relevant to LLW disposal and thus potential MDA remediation guidance are discussed here.

5.2.5.1 Applicability

The following sections of 10 CFR 61, which include both performance objectives and specifics on site closure, can be considered good guidelines for remediation of ER Project MDAs, but DOE is not required to comply with them.

5.2.5.2 Performance Objectives and Exposure Scenarios

The four performance objectives and specified exposure scenarios are:

"§ 61.41 Protection of the general population from releases of radioactivity.
Concentrations of radioactive material which may be release to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.

§ 61.42 Protection of individuals from inadvertent intrusion.
Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.

§ 61.43 Protection of individuals during operations.
Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by § 61.41 of this part. Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

§ 61.44 Stability of the disposal after closure.
The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required."

5.2.5.3 Compliance Period

The time frame is not explicitly stated in Part 61; however, a modeling period of 1000 years is generally acceptable.

5.2.5.4 Additional Considerations

The following subsections of § 61.52 address various aspects of site closure that could be used as guidance for ER Project MDAs:

"(a)(2) Wastes designated as Class C pursuant to § 61.55, must be disposed of so that the top of the waste is a minimum of 5 meters below the top surface of the cover or must be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for a[t] least 500 years."

"(a)(6) Waste must be placed and covered in a manner that limits the radiation dose rate at the surface of the cover to levels that at a minimum will permit the licensee to comply with all provisions of and §§ 20.1301 and 20.1302 of this chapter at the time the license is transferred pursuant to § 61.30 of this part.

(a)(7) The boundaries and locations of each disposal unit (e.g. trenches) must be accurately located and mapped by means of a land survey. Near-surface disposal units must be marked in such a way that the boundaries of each unit can be easily defined. Three permanent survey marker control points, referenced to United States Geological Survey (USGS) or National Geodetic Survey (NGS) survey control stations, must be established on the site to facilitate surveys. The USGS or NGS control stations must provide horizontal and vertical controls as checked against USGS or NGS record files.

(a)(8) A buffer zone of land must be maintained between any buried waste and the disposal site boundary and beneath the disposed waste. The buffer zone shall be of adequate dimensions to carry our environmental monitoring activities specified in § 61.53(d) of this part and take mitigative measures if needed.

(a)(9) Closure and stabilization measures as set forth in the approved site closure plan must be carried out as each disposal unit (e.g. trench) is filled and covered."

5.2.6 10 CFR 20.1401

Title 10 CFR Section 20.1401, "Radiological Criteria for License Termination," was promulgated by the NRC. This regulation became effective on August 20, 1997. However, licensees could defer rule implementation until August 20, 1998. DOE facilities do not have to comply with this regulation; however, it does provide the ER Project with some insight on the current NRC position for the decommissioning of facilities.

5.2.6.1 Applicability

The rule states it applicability:

"10 CFR 20.1401(a) General provisions and scope.

The criteria in this subpart apply to the decommissioning of facilities licensed under parts 30, 40, 50, 60, 61, 70, and 72 of this chapter, as well as other facilities subject to the Commission's jurisdiction under the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974, as amended. For high-level and low-level waste disposal facilities (10 CFR parts 60 and 61), the criteria apply only to ancillary surface facilities that support radioactive waste disposal activities."

5.2.6.2 Performance Objectives, Exposure Scenarios and Compliance Period

The performance objectives and exposure scenarios specified for the decommissioning of NRC-licensed facilities are as follows:

"10 CFR 20.1401(d)

When calculating total effective dose equivalent (TEDE) to the average member of the critical group the licensee shall determine the peak annual TEDE dose expected within the first 1000 years after decommissioning.

Critical Group means the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances."

"20.1402 Radiological criteria for unrestricted use.

A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal."

5.2.7 PRELIMINARY STAFF WORKING DRAFT 40 CFR PART 196

Title 40 CFR 196, "Environmental Protection Agency Radiation Site Cleanup Regulation," is a working draft provided for discussion purposes only. It was issued in June, 1994. It addresses radiological site cleanup of DOE facilities for unrestricted releases. The draft regulation does not contain exactly the same performance objectives as NRC's 20 CFR 1402 (above). This EPA regulation specifies 15 mrem/yr versus 25 mrem/yr in the NRC regulation. This discrepancy is currently under discussion between the EPA and NRC.

5.2.7.1 Applicability

The working draft states that the regulations would be applicable to DOE facilities:

"196.01 Applicability

This part applies to:
(a) Sites under the control of a Federal Agency....."

5.2.7.2 Performance Objectives, Exposure Scenarios, and Compliance Period

The working draft contains the following specific language addressing performance objectives, exposure scenarios, and compliance period:

"196.04 Standards

(a) Remediation of sites shall be conducted to provide a reasonable expectation that, for 1,000 years after completion of the remedial action, radionuclide concentrations in excess of natural background levels shall not exceed those amounts that could cause any member of the public to receive, through all potential pathways under a residential land use scenario, an annual committed effective dose of 15 mrem/yr (0.15 mSv/yr).

(b) Compliance with 196.04(a) shall remove from the implementing agency any further responsibility under this part for the management of radioactive material on the site.

(c) In the event that remediation of a site will not meet the conditions of 196.04(a), the implementing agency shall:

(1) remediate the site to provide a reasonable expectation that, for 1,000 years after completion of the remedial action, radionuclide concentrations in excess of natural background levels shall not exceed those concentrations that could cause any member of the public to receive, through all potential pathways under the conditions of the selected active control measures, an annual committed effective dose of 15 mrem/yr (0.14 mSv/yr); and

(2) remediate the site to provide a reasonable expectation that, for 1,000 years after completion of the remedial action in the absence of active control measures, radionuclide concentrations in excess of natural background levels on the site shall not exceed those amounts that could cause any member of the public to receive, through all potential pathways under the conditions of residential land use, an annual committed effective dose that is less than 75 mrem/yr (0.75mSv).

(d) All existing and future structures on sites shall meet the guidelines of the U.S. EPA Radon Program."

DETERMINING MDA G PERFORMANCE ASSESSMENT AND COMPOSITE ANALYSIS APPLICABILITY TO RISK ASSESSMENTS FOR OTHER MDAS

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1. INTRODUCTION

The applicability of the Material Disposal Area (MDA) G Performance Assessment (PA) and Composite Analysis (CA) to other MDAs depends upon the manner in which the MDA G analyses were conducted and the waste, facility, and site characteristics for the MDAs of concern. Insofar as the characteristics of the MDAs vary across the Laboratory, specific criteria for evaluating the applicability of the MDA G analyses cannot be provided until the existing knowledge about the MDAs has been evaluated. However, the general approach that will be used to assess MDA G analysis applicability has been developed and is presented below.

The process for evaluating the applicability of the MDA G PA and CA to the other MDAs involves four steps:

- *Characterization of the MDA of interest*
- *Development of the conceptual model for the MDA of interest*
- *Comparison of the MDA conceptual model with the conceptual model for MDA G*
- *Comparison of detailed behavior of the MDA of interest and MDA G*

In the first step, all existing information about the MDA is collected and used to characterize the site. As part of this step, it will be necessary to determine if the information is adequate for completing the remaining steps of the process. If it appears the information is relatively complete, the development of a conceptual model for the MDA is undertaken. If it is clear at this stage of the process that additional information will be required to develop a conceptual model for the MDA, steps for collecting the necessary data are outlined.

Once the conceptual model for the MDA of interest has been developed it is compared to the conceptual model used to conduct the MDA G PA and CA. The purpose of this comparison is to determine if the two MDAs are expected to function similarly with respect to contaminant release, transport, and exposure pathways. If one or more pathways are expected to apply to both sites, it may be possible to apply the MDA G PA and CA to the MDA under consideration. Conversely, if the manner in which waste constituents are expected to behave at the two MDAs differs significantly, modeling analyses different than those conducted for MDA G may be required.

Given an MDA that is expected to function in a manner conceptually similar to MDA G, the detailed behavior of the two sites is compared. Here, specific waste, facility, and site characteristics for the two sites are compared to determine if the modeling results for MDA G can be readily applied to the MDA of concern. If the two sites compare favorably for one or more pathways, it may be possible to estimate the risks posed by the MDA of concern by directly scaling the MDA G

modeling results. If, on the other hand, significant differences exist in the details of the two MDAs, it may be more prudent to conduct pathway modeling using the MDA G modeling methodology and MDA-specific input parameters.

The process for determining the suitability of the MDA G PA and CA to other MDAs has been briefly described above. The steps in this process are considered in more detail in the following sections. Section 2 discusses characterization of the MDA of interest and considerations that go into the collection of additional data. Section 3 addresses the development of the conceptual model for this site. The conceptual model and aspects of the detailed modeling that went into the MDA G PA and CA are presented in Section 4. Using the information in those sections, Section 5 discusses the process of comparing the MDA of interest and MDA G.

2. MDA CHARACTERIZATION

The first step in determining if the MDA G PA and CA can be used to reliably address another MDA is to characterize the MDA of concern. Characterization starts by assembling the information that currently exists about the MDA of concern. If this information is incomplete or not of sufficient quality, additional data about the site may need to be collected. Section 2.1 addresses the types of information needed to characterize the MDA in question. Section 2.2 discusses sources of additional information for the MDAs and some of the steps involved in collecting data.

2.1 MDA CHARACTERIZATION DATA REQUIREMENTS

The types of information required to characterize the MDA of concern are listed in Table 2-1. The majority of these data needs describes the waste disposed at the MDA, the waste disposal units or configuration, and the environmental setting of the site. Information listed near the end of the table provides much of the information required to define patterns of human activity and the potential for exposure to waste constituents. This information generally tends to be based on regulations governing waste disposal and cleanup.

The parameters listed in Table 2-1 are not expected to include all data needs for all sites. Conversely, much less information may be required for some MDAs. The parameters listed in the table are provided as a general example of the types of information required for developing site specific conceptual models and using the MDA G PA and CA for evaluating the risks posed by the MDA in question. In all cases, the information collection and evaluation process should be guided by professional judgement and insight into the MDA of concern.

MDA characterization will rely on available information about the site to the extent possible. Consequently, the first step in the process is to assemble all available information that is pertinent to an MDA site. These data may be divided into several categories, depending upon the aspect of the MDA they address. These categories include:

- Waste inventory data
- Source release data

TABLE 2-1 TYPES OF INFORMATION REQUIRED FOR MDA CHARACTERIZATION.

~~Input~~ Info Used in MDA G Model

Information Category	Parameter or Data Required
Physical Setting and Characteristics	~~Location coordinates~~
	Height of mesa
	Distance from disposal units to mesa edge
	Distance from mesa top to canyon floor

	Slope of mesa top and sides ~~Soil types at MDA.~~
Disposal Unit Information	Type(s) of disposal unit(s) (e.g., pits or trenches, shafts, surface disposal, seepage pits or trenches, other) Disposal unit dimensions and configuration (e.g., length, width, and depth of units; waste layer thickness; cover thickness; thickness of backfill layers; unit spacing; ~~liner configuration)~~ Cover characteristics (e.g., composition and engineered features) Disposal unit fill characteristics
Available Contaminant Release and Plume Information	Anecdotal evidence Documented releases Plume delineation data
Geologic and Hydrologic Characteristics	Stratigraphy and topography Permeabilities and hydraulic conductivities Unsaturated characteristic curve data Porosities Bulk densities In-situ moisture contents and/or capillary pressures Fracture dimensions and geometries ~~Air permeabilities~~ ~~Evidence of interflow~~ Infiltration rates — Moisture profiles Surface features (e.g., ponded water and asphalt pads) ~~Potential for "dry barriers" (e.g., surge beds, pumice layers, and vapor-phase notch)~~
Inventory and Source Term Data	Contaminant-specific inventories (i.e., radionuclides, volatile and semi-volatile organic compounds, metals, PCBs, pesticides, non-hazardous constituents, etc.) Contaminant-specific concentrations Waste volumes

Table 2-1 Continued. Types of information required for MDA characterization

Information Category	Parameter or Data Required
	Disposal history (i.e., period over which waste was disposed, temporal patterns of disposal, etc.) Phase of disposed waste (i.e., solid or liquid) Form of solid waste (e.g., surface-contaminated waste, soils, concrete, sludges, activated metal) Descriptions of containers used for waste disposal Expected or observed modes of source release (e.g., volatilization, surface rinse or wash, sorption controlled release and solubility-limited release)

Geochemistry	Distribution coefficients ~~Diffusion coefficients~~ Contaminant volatility ~~Information about reactive chemistry (e.g., chemical reactions, changes in sorption characteristics, colloid formation, precipitation, presence of ligands or other complexants)~~ ~~Oxidation/reduction conditions~~ Pore water chemistry ~~Eh, pH, temperature, and total organic carbon~~ Associated mineralogy Solubility limits ~~Potential for cation-anion competition~~ ~~Potential for buffering by waste form~~
Meteorology	Precipitation data Diurnal and nocturnal windrose data Potential evaporation
Ecology	Description of dominant communities at and surrounding MDA Lists of fauna and flora Threatened and endangered species
Land Use Information	Current land use at and surrounding the MDA Anticipated land use at and surrounding the MDA

Inventory data are used in the development of the Source Release Conceptual Model which, when implemented, will project rates of contaminant release from the MDA in question. This information will include all inventory records that can be used to understand the nature and quantities (i.e., radionuclide activities, chemical concentrations, and waste volumes) of radionuclides and hazardous chemicals that have been placed in the disposal facility. Other data needed for the Source Release Conceptual Model include the physical and chemical characteristics of the waste buried at the MDA, information about containers used for packaging waste for disposal, and the amount of water available for interaction with the waste. Water infiltration data may be required for "as-is" conditions and for situations in which covers are placed over the disposal site. Information from the RFI characterization of an MDA site that addresses the nature and extent of contamination at the site may play an important role in the information collection process, especially for sites that received large quantities of liquid waste.

Environmental transport data are used to describe the processes through which waste contaminants may be transported to locations that are accessible to humans and ecological receptors. This information should address the geologic setting of the site, geochemical data, climatic information, ecological characteristics of the MDA, disposal unit information, and windrose

diagrams. Sources of these data may include MDA Work Plans, ESH yearly reports, geologic background studies, RFI Phase I reports, and special projects reports. The conceptual models developed using this information will be used to estimate rates of contaminant transport to exposure locations, constituent concentrations in environmental media, and rates of uptake by humans and ecological receptors.

The regulatory or policy information aids in the definition of the scope of the human health and ecological risk assessments. They define such things as expected patterns of future land use, the risk endpoints and criteria which must be met, and the times over which compliance with specific risk endpoints must be demonstrated. This information forms the basis for defining exposure scenarios and estimating specific risks for different receptors.

2.2 MDA DATA SOURCES AND COLLECTION

A portion of the data required to characterize the MDA of concern are expected to already exist in records documenting site operations, other data may have been collected through site-specific studies and routine monitoring. On the other hand, some of the information required for MDA characterization may not be available. This information may be able to be estimated using data that are not specific to the MDA, in other cases the lack of adequate data may require that formal data collection activities be undertaken. Some of the considerations that go into finding suitable sources of information are discussed below.

In some cases, data for other MDAs at the Laboratory may be deemed suitable for use at the MDA of concern. For example, limited information on a given parameter may exist for the MDA of concern. While this information is, in and of itself, inadequate for MDA characterization, it may be appropriate to assume that the site is similar to another MDA for which adequate information is available. In this case, data from the other MDA may be used to initially evaluate this aspect of the MDA in question. In another case, a parameter may not be expected to change significantly across the Laboratory. In this situation, data collected from another site may be suitable for use at the MDA of concern.

If it is appropriate to use data from other sites to characterize the MDA of concern, special consideration should be given to the data used to conduct the MDA G PA and CA. If the MDA G analysis data are appropriate for use, the process of determining if the MDA G PA and CA can be applied to the MDA of concern will be greatly facilitated.

There may be several instances where data used in the MDA G PA and CA could be applied to other MDAs. For example, the radionuclide distribution coefficients used in the MDA G analyses

for the Bandelier Tuff are based on site-specific data for those tuffs at Los Alamos National Laboratory (LANL) and for tuffs at Yucca Mountain. It is assumed that these data will not change significantly across the Laboratory. Therefore, this information could be applied to other MDAs. Many of the distribution coefficients may also be suitable for RCRA metals included in the MDA inventory, as a given element could be assumed to have the same distribution coefficient whether it is radioactive or not.

Another example of data (or assumptions) that may be transferred directly from the MDA G PA and CA concerns the presence of oxidizing conditions in the vadose zone of the Bandelier tuff. If similar conditions are expected for the MDA of concern, then similar geochemical interactions may be projected to occur. Similarly, if it is expected that matrix flow is the driving force for fluid transport in the tuff (as opposed to fracture flow for example), then the parameter values used to describe this flow for the MDA G PA may be applicable to the MDA in question. As a final example, if chemical analyses of pore water are unavailable for the MDA of concern, it may be decided that the data included in the MDA G PA and CA are appropriate for use.

In all likelihood, some of the information needed for MDA characterization will not be available. If the use of data from the MDA G PA and CA or other MDAs is not appropriate for describing the MDA in question, then collection of information from other sources will be necessary. Data from peer-reviewed literature may be appropriate, if the case can be made that site-specific data are not required. Theoretical calculations may form the basis for other data. For example, distribution coefficients for organic compounds may be calculated for tuff if the total organic carbon of the substrate is known. In other circumstances, the lack of data may be remedied by simple, cost effective, bench scale laboratory experiments. Finally, critical site-specific data for the MDA may be lacking and require that field investigations be conducted to obtain the information.

The types and quantities of waste placed in the MDAs are poorly or incompletely documented for many of the sites. Consequently, the collection of inventory data is expected to prove especially difficult. Short of sampling the disposal sites, the use of process knowledge may provide help with this aspect of the characterization process. This concept entails determining the lineage of the waste if the actual waste characteristics are not known. By tracking the lineage back to the waste generator, it may be possible to determine the process by which the waste was generated, the nature of the material produced in the process line, and whether any other chemicals were added during the process. Formal records of the methods and assumptions used in the application of process knowledge are kept to document the inventory adopted.

It is reasonable to assume that new information about many MDAs will have to be collected to complete MDA characterization. If this is the case, the data collection process should be defined to ensure that the quantity and quality of data collected are adequate to support defensible decision making. The process should also minimize collection of unnecessary, duplicative, and overly precise information. The U.S. Environmental Protection Agency (EPA) has developed the Data Quality Objective (DQO) Process (EPA, 1994) to aid in identifying cost-effective approaches for collecting data that are to be used in regulatory decision making and compliance demonstration.

The DQO Process is based on the scientific method, and provides a systematic procedure for defining criteria that data collection activities should satisfy. Specifically, the process defines when and where samples should be collected, how many samples should be collected, and the tolerable level of decision errors for the study. The DQO Process consists of seven steps, including:

- State the Problem to be Studied
- Identify the Decision(s)
- Identify the Inputs to the Decision(s)
- Define the Study Boundaries
- Develop a Decision Rule
- Specify Tolerable Limits on Decision Errors
- Optimize the Data Collection Design

This process should be used in the planning stages of any study that requires data collection, before the collection activities begin. The reader is referred to the EPA guidance document for detailed discussions on each of these steps (EPA, 1994).

3. CONCEPTUAL MODELS FOR MDAS OF CONCERN

The information collected for the MDA of concern is used to develop a conceptual model of the site, an example of which is shown in Figure 3-1. The conceptual model is a qualitative description of the site and how it functions. It addresses how waste contaminants may be released from the disposal site, migrate to locations accessible to human and ecological receptors, and result in exposures to the receptors. When implemented using mathematical models, it provides the basis for projecting rates of contaminant movement in the environment and, ultimately, potential risks to receptors.

The conceptual model for the MDA of concern must describe the site in a manner adequate to account for all potentially important modes of contaminant release, transport, and exposure. While the conceptual model will be specific to the MDA in question, several general considerations are expected to apply to most, if not all, of the MDAs. The following sections discuss these aspects as they apply to the contaminant inventory, source release, environmental transport, and exposure assessment.

3.1 INVENTORY

The inventory specifies the quantities and nature of waste disposed in the MDAs, and is the primary determinant of the risks posed to human and ecological receptors. In many cases, development of the inventory relies on the evaluation of past disposal records and requires little, if any, development of conceptual models. In other cases, however, historic disposal records are unavailable or inadequate for complete characterization of the disposed waste. In these cases, some aspects of the inventory may need to be estimated using models or a series of assumptions. Regardless of how the inventory is derived, certain types of information are required for evaluation of the MDA. The nature of this information is discussed in the following paragraphs.

The inventory should provide the information about the waste that is necessary to estimate rates of contaminant release from the MDA of concern. In general, this information will include the radioactive and chemical constituents that were disposed of at the MDA of concern, the quantities in which they were disposed, the physical and chemical characteristics of the contaminated waste, the characteristics of any containers used for waste disposal, and an indication of how the waste was placed in the disposal units over time. Depending upon the level of information available for the MDA, several different approaches may be necessary to obtain this information.

FIGURE 3-1. SITE CONCEPTUAL MODEL FOR MDAS

Waste contaminant identities may be provided in disposal records for the MDA, may be estimated from knowledge about the sources of the waste placed in the MDA and knowledge of operations at those facilities (e.g., process knowledge), or may be determined through routine monitoring and characterization of the disposal site. The available information should be collected and assimilated to derive a master list of the known contaminants at the site, along with an indication of the sources of information used to develop the list. It should be noted if there is reason to believe that contaminants in addition to those indicated in the available information were disposed of at the MDA.

The risks posed by the contaminants in a given MDA will be proportional to the quantities disposed of at the site. These quantities may be expressed as radionuclide activities and chemical masses or volumes in the MDA disposal records. If such records do not exist, or are incomplete, the best indicator of constituent quantities may be measured concentrations in the disposal units and in plumes extending from the units. These concentrations may be listed directly in the MDA inventory or used in conjunction with information about plume extent to back-calculate as-disposed inventories.

If little or no information exists about the specific constituents placed in a given MDA, the best available descriptions of the types of waste disposed need to be provided. The waste must be characterized to determine if it is hazardous, radioactive, or non-hazardous, or a combination of the three components. Chemical wastes should be identified with respect to the type of compound (e.g., volatile and semi-volatile organic compounds, polychlorinated biphenyls (PCBs), metals, and pesticides), the concentration of each compound, and the volume of each waste type. The presence of listed or characteristic wastes should be noted, along with estimates of quantities. Lacking radionuclide-specific identities, radioactive waste should be characterized in terms of the type of radiation emitted (e.g., alpha, beta, and gamma) and the total activity.

The physical and chemical forms of the waste disposed in the MDA of concern have significant effects on projected rates of contaminant release. The physical form of the waste (e.g., trash, contaminated soils, concrete, scrap metal, glass, oil, and irradiation sources) should be determined to the level of detail permitted by the available data. Chemical forms of radionuclides and chemicals in the waste (e.g., elemental, metallic, oxidized, or complexed) should also be tracked for use in source term modeling.

Containers used to dispose of the waste may prevent contaminant releases while they are intact. Consequently, the types and characteristics of the containers used should be determined to the

extent possible. Chief among the characteristics of interest is the expected lifetime of the packages, factors that may compromise container longevity should be noted as appropriate.

The manner in which waste was disposed at the MDA of concern may significantly affect how the units perform in the future. Consider, for example, the subsidence potential of the disposal units. Experience at MDA G has indicated that little potential for subsidence exists if unpackaged waste is placed in the disposal units and compacted with heavy equipment. A much greater potential for subsidence will exist if incompletely filled containers of waste are stacked in the units and no efforts are taken to fill void spaces within and between containers. Subsidence potential may be heightened still if large quantities of liquid waste are discharged to the disposal units. The conceptual model of the MDA should account for key operational practices such as this.

The temporal pattern of disposal at the MDA is of interest for two reasons. The time at which disposal began signals the time at which releases from the disposal units could first take place. If the period over which disposal occurred was great, actual inventories of short-lived radionuclides or chemicals that undergo rapid degradation could be much smaller than the as-disposed quantities suggest. Depletion of the inventory over time is an important modeling consideration that can only be tracked if there is information about the history of disposal operations.

The temporal pattern of disposal must also be known in order to understand the potential for contaminant transformations that give rise to hazardous constituents that were not initially present in the MDA. Several radionuclides are parents of one or more daughter products which may play an important role in the long-term performance of the MDA. Similarly, many hazardous chemicals degrade with age or by radiolysis to form new contaminants that are also hazardous and that may pose a risk to human health and safety, and the environment.

3.2 SOURCE RELEASE MODELING

The conceptual model for source release uses the inventory, disposal unit information, and site characteristics to identify the processes through which radionuclides and chemicals may be released to the environment. Releases from MDAs at LANL may occur through a variety of mechanisms. In general, the more significant of these are expected to include leaching, gaseous releases through the surface of the MDA, and exposure of the waste due to biointrusion, erosion, or cliff retreat. Some of the considerations that go into conceptualizing these processes are discussed below.

The rate at which leaching of waste contaminants occurs depends upon several factors including the physical and chemical forms of the waste, the amount of water percolating through the waste,

the chemical characteristics of the infiltrating water, and the long-term performance of containers used to dispose of the waste. The physical and chemical form of the waste may effectively limit releases to water percolating through the disposal units or may be such that all contamination is readily available for leaching. As an example, consider bulk-contaminated concrete. The physical form of the waste will tend to limit the accessibility of most of the contamination to water due to the low permeability of the concrete. Furthermore, the highly alkaline material will tend to bind a number of waste contaminants. On the other hand, releases from surface-contaminated glass will tend to be relatively rapid because water can freely contact all contamination and the constituents are not bound by the glass matrix.

The Source Release Conceptual Model should address the expected modes of release for the different waste forms in the inventory. If a wide variety of physical and chemical waste forms exist at the MDA, it may be reasonable to group waste forms that are expected to exhibit similar release behaviors, thereby reducing the complexity of the Source Release Conceptual Model. Such groupings should be based on an understanding of the different waste forms and should be conservative in nature. All assumptions made in grouping waste forms should be explicitly documented and justified.

The rate of leaching will be proportional to the amount of water percolating through the disposed waste. The water infiltration rate will, in turn, depend upon the amounts and patterns of precipitation at the site, the species of plants and degree of plant coverage occurring at the site, and the characteristics of the cover placed over the disposal units. Once water contacts the waste, rates of leaching will be strongly affected by the geochemical properties of the water and the chemical characteristics of the waste. The conceptual model of the MDA should take all of these factors into account.

The Source Release Conceptual Model should also account for the effects of waste containers on contaminant release, as appropriate. Releases may be effectively prevented as long as containers remain intact, while releases from unpackaged waste may begin immediately upon disposal. Over time, containers will deteriorate and no longer be capable of isolating the waste from water percolating through the disposal units. Releases of any contaminants remaining in the packages may begin at this time and continue until the inventory is depleted.

The source release modeling should take into account the depletion of waste contaminants over time. Inventories of all radionuclides will decline over time due to radioactive decay. Inventories of chemicals that undergo degradation will experience similar decreases. If the half-lives of these constituents are short relative to container lifetimes, the entire inventory may be essentially

depleted before leaching has a chance to begin. The amount of a given contaminant that is available for leaching may also be depleted if a portion of the constituent inventory volatilizes or is released as a gas.

A variety of contaminants may be released from the MDA of concern as gases. A handful of radionuclides may be released as vapor or gases including H-3, C-14, krypton, I-129, and radon; many organic chemicals undergo volatilization under natural conditions and enter the atmosphere. The rates at which gases are released from the site will depend upon several factors, including rates of gas generation, the thickness of the material through which gases must diffuse, contaminant diffusion coefficients in the waste and cover material, waste container lifetimes, in-situ moisture contents in the waste and cover, and the presence of preferential paths for the movement of gases (e.g., fractures). These factors should be considered in the development of the Source Release Conceptual Model.

Waste may be exposed at the surface or along the sides of the MDAs by biointrusion, erosion of the cover overlying the waste, and cliff retreat. All MDAs will be susceptible to biointrusion, wherein plants and animals penetrate into the disposed waste. Contamination taken up by the roots of the plants may be deposited on the surface when the plants die and decay to form litter. Animals burrowing into the waste may mix contamination in the soils overlying the waste and bring a portion of it to the ground surface. The rates at which contaminants reach the surface will depend upon the design of the cover placed over the waste, the root and burrow distributions of the plants and animals, plant uptake factors for the contaminants of concern, the rate at which organic matter decays at the ground surface, the form(s) of the waste being disturbed, and the long-term performance of the waste containers. Successional changes at the site may have significant effects on the quantities of contamination brought to the surface over extended periods of time.

Surface erosion may lead to eventual removal of a cover placed over an MDA, and subsequent exposure of the waste. Sheet erosion will remove the cover uniformly over time. Depending upon the thickness of the cover and it's design features, complete removal of the cover may require thousands to tens of thousands of years. More localized gully erosion may penetrate the cover over a small area at much earlier times, thereby exposing a portion of the buried contamination. Evaluations of the MDAs should take into consideration the modes of erosion that are expected to occur.

A form of erosion unique to the mesa-top MDAs is cliff retreat, wherein the sides of the mesa gradually recede. Cliff retreat occurs as a series of discrete events over very long periods of time.

Consequently, rates of cliff retreat and, therefore, the potential for exposing waste as a result of cliff retreat, are difficult to estimate. Nevertheless, some information specific to LANL has been collected and should be considered during the development of the Source Release Conceptual Model. This is especially true in cases where the sides of the disposal units at an MDA are close to the mesa sides.

3.3 ENVIRONMENTAL TRANSPORT MODELING

Contaminants released from the waste disposal units may be transported through the environment via a number of transport pathways. Potentially important transport pathways that affect the MDAs include, but are not necessarily limited to, the groundwater, surface water, atmospheric, and plant and animal uptake pathways. The first three of these are capable of moving contaminants great distances away from the site of release. The plant and animal uptake pathways account for the movement of contaminants into and up the food chain, and tend to operate on a local scale.

The groundwater pathway generally starts at the disposal units where contaminants undergo leaching. Leached constituents may be transported vertically through the vadose zone, discharging to the regional aquifer some distance below the disposal units. Alternatively, the contaminants may be transported laterally to the sides of the mesa and discharge to the adjacent canyons. A portion of the canyon contamination may be transported vertically to the regional aquifer via an alluvial aquifer. Contaminants within the regional aquifer may move laterally until they reach a point accessible to human or ecological receptors. The point of exposure for humans may be a well drilled to supply water, while exposures to biota may occur, for instance, after discharge to a stream or pond.

The development of the conceptual model for the groundwater pathway must account for the dominant stratigraphic, meteorologic, and hydrogeologic conditions at the MDA of concern. Contaminant transport in the unsaturated zone may be dominated by flow through porous media, or may be affected by the presence of fractures below the disposal units. The rate at which water flows through these media will depend, in part, upon the amount of water percolating through the MDA and the pattern of precipitation over the year. The hydraulic properties of the strata underlying the site will also have a direct effect on rates of groundwater movement. Special features may have important effects on contaminant transport via the groundwater pathway. Zones of interflow may disrupt normal flow patterns, causing water to flow laterally in the vicinity of the disposal units. Alternatively, fractures and the vapor phase notch may effectively slow

groundwater movement due to drying. These aspects, and others that may apply to the MDA of concern, need to be considered when the groundwater pathway is conceptualized.

The point at which contaminated groundwater is assumed to be accessible to receptors will depend upon the nature of the receptor, assumptions made about future land use, and groundwater flow patterns at the site. In terms of human receptors, access will typically occur when water is drawn from a well that intersects a zone of contamination emanating from the MDA. The location of the well may be immediately down-gradient of the site or a considerable distance away, depending upon the access restrictions placed on the site. The location of the well may change over time as these restrictions change. Groundwater flow patterns will be an important factor in defining groundwater accessibility as well. For example, if groundwater flow has a strong lateral component to a nearby canyon, contamination may be accessible at earlier times than if vertical flow to a regional aquifer is dominant. The presence of perched water or alluvial aquifers in nearby canyons will also affect how and when groundwater contaminants may be accessed by humans.

Exposure of naturally-occurring plants and animals to groundwater contaminants will typically occur after the water has discharged to the surface. Discharge could occur close to the MDA if lateral flow to a nearby canyon occurs. If vertical movement to the regional aquifer was dominant, discharge to the Rio Grande River or its tributaries may represent the first opportunity for exposures to occur. Food crops and domestic animals raised by humans may come in contact with contaminated water after it has been drawn from a well.

Surface water transport is typically used to refer to the movement of contaminants with runoff from the surface of the MDA into the adjacent canyons. Contaminants reaching the canyon floor may enter canyon streams and be transported downstream, may be transported vertically with alluvial waters, or may be deposited in the canyon soils. The importance of surface water transport will depend on the amount of runoff observed at the site, itself a function of meteorological conditions and the design of the cover placed over the disposal units, and the characteristics of the neighboring streams and canyons.

Contaminated soils at the surface of the MDAs and gases entering the atmosphere may be transported to downwind locations with the prevailing winds. The rates and patterns of atmospheric transport will be influenced most by the wind conditions at the site and the dominant land features. The conceptual model for the pathway should account for diurnal changes in wind speeds and directions, as well the effects of the complex terrain found across the Laboratory. Transport modeling should be carried out to locations accessible to receptors. Those locations

will be specific to the MDA of concern and will be influenced by the assumptions made about present-day and future land use.

Contaminants moved to the surface of the MDA and those transported off-site may be incorporated into the food chain by plant and animal uptake. Plants may become contaminated due to depositional processes (e.g., airborne deposition, contamination from irrigation water, and rainsplash) and as a result of root uptake of contamination in surface soils. Animals may inhale airborne contaminants and ingest contaminated soils, vegetation, and water. Direct contact with contamination may be significant for animals that routinely contact contaminated soils (e.g., burrowing animals). The development of the conceptual model for food chain transport should account for these various processes and mechanisms to the extent that they are appropriate for the MDA in question.

3.4 EXPOSURE ASSESSMENT

The exposure assessment uses results from the transport modeling to estimate intakes and consequent risks to human and ecological receptors. In order to conduct the exposure assessment, the manner in which the receptors may be exposed, and the extent of these exposures, must be defined. Considerations that go into defining these exposures are provided below.

The means through which organisms may be exposed to contaminants are called exposure pathways. Each pathway includes a source or release from a source, a transport or exposure medium, a location at which the exposure occurs, and an exposure route. The actual pathways that may lead to exposures will depend upon the activity patterns of the organisms relative to the disposal site and assumptions made about future land use.

In terms of humans, a collection of exposure pathways is generally used to define activity patterns that are consistent with expectations about future land use in the vicinity of the disposal site. This collection of pathways is referred to as an exposure scenario. Exposure scenarios that are commonly considered for human receptors at LANL include, but are not limited to, the following:

- Establishment of a residence down-gradient or down-wind of the disposal site.
- Establishment of a residence over the closed facility
- Recreational use of the closed site
- Light industrial use of the closed site
- Return of the closed site to Native American ownership and use

The suitability of these scenarios for a given MDA will depend upon the restrictions placed on the site. For example, if an MDA was closed and released for recreational use, exposure scenarios that call for establishment of a residence on the site or light industrial use would not pertain. Release under these conditions would not, however, rule out the possibility that a person may take up residence down-gradient or down-wind of the MDA.

The exposure routes through which humans may be exposed to contaminants will depend upon the exposure pathways and contaminant characteristics. Exposure routes commonly considered in exposure modeling include the ingestion of contaminated drinking water, crops, meat, milk, and soils; inhalation of airborne particulates and gases; direct radiation from airborne dust and contaminated soils; and dermal contact with soils and water. The level of exposure for each route is defined using food and water utilization rates and times of exposure. These parameters should be consistent with the conceptualized exposure scenarios.

Ecological receptor exposures are generally considered for all environmental media contaminated by MDA releases. As discussed earlier, surface soils may be contaminated at the MDA and in the adjacent canyons, as well as at downwind locations that have been contaminated by the deposition of airborne contaminants. Streams, rivers, and lakes may become contaminated due to the discharge of contaminated groundwater and surface runoff. Exposures are characterized in terms of their effects on key species or community attributes such as species richness and abundance. Ecological exposure assessments will be specific to the MDA of concern and may need to consider successional changes over long periods of time.

Many aspects of the exposure assessment are influenced by regulatory aspects. Regulations and regulatory guidance play a major role in defining future land use scenarios, receptor locations, and times of compliance. For example, recent U.S. Department of Energy (DOE) guidance (DOE, 1996) requires that protection of inadvertent intruders and persons living down-gradient of low-level waste (LLW) disposal sites be demonstrated for a period of 1,000 years. Other regulations and guidance go so far as to define periods of exposure, suggest exposure pathways and routes deserving consideration, and discuss the need to consider age-specific exposures. An example of this is the guidance published by the EPA on the conduct of risk assessments for Superfund sites (EPA, 1989). Constraints introduced by these sources need to be taken into consideration during the development of the conceptual model.

4. MDA G PA AND CA MODELING APPROACH

The ability to apply the MDA G PA and CA to another MDA will generally require that the two MDAs are conceptually similar and that the mathematical models used to conduct the MDA G analyses are also valid for the MDA under consideration. Previous discussions have addressed the development of conceptual models for the MDAs of concern. General background information on MDA G and descriptions of the conceptual models and methods used to conduct the PA and CA are provided in the following paragraphs.

4.1 GENERAL DESCRIPTION OF MDA G

MDA G was established in the late 1950s for the disposal of radioactive waste generated at the LANL. The 65-acre site is situated on Mesita del Buey near the eastern edge of the Laboratory. It is bounded by Pajarito Canyon to the south and Canada del Buey to the north. The site was chosen for its favorable hydrogeologic properties which include a depth to groundwater on the order of 250 m and relatively impermeable strata in which to dispose waste. The site is the Laboratory's only active disposal site for LLW and is expected to remain so for the foreseeable future.

The majority of the waste disposed of at MDA G is placed in large rectangular pits excavated using backhoes. While the sizes of the pits vary, the typical pit measures 20 m wide, 150 m long, and 20 m deep. Historically, unpackaged waste was placed in lifts in the pits and compacted by running heavy equipment over the material. Successive lifts were separated by a layer of uncontaminated crushed tuff. More recently, waste has been placed in metals drums, boxes, and transportainers, and stacked in the pits. These practices may result in greater waste emplacement efficiencies, but may also increase the likelihood of disposal unit subsidence. Cylindrical disposal shafts are used for the disposal of specific types of waste including high-activity tritium waste, PCB-contaminated waste, and asbestos waste. The shafts are typically cylindrical, 20 m deep, and range in diameter from 0.5 to 1 m.

Pits and shafts are filled with waste to within 1 to 3 m of the ground surface, then backfilled and covered with consolidated crushed tuff. A layer of topsoil is placed over the crushed tuff and seeded with native grasses to minimize surface erosion and water infiltration. Crushed tuff is mounded over the disposal shafts and allowed to settle for up to five years. Concrete caps are placed over closed shafts after this period.

4.2 MDA G MODELS

A series of conceptual and mathematical models was used to conduct the MDA G PA and CA, these addressed the waste inventory, source releases, environmental transport, and human exposures. These models, and the manner in which they were implemented for the MDA G analyses, are described below.

4.2.1 Inventory

The MDA G PA and CA were conducted to address DOE LLW management requirements. These requirements address the management and potential impacts of radioactive waste, without regard to hazardous chemical constituents that may also occur in the waste. Therefore, the analyses completed to date evaluated the potential impacts of radioactive constituents only. The MDA G analyses will be extended to include chemical constituents as the first step in implementing the Core Document.

Radioactive waste has been disposed at MDA G since 1957, disposal of routine waste began in 1959. Although the waste currently disposed of at the facility is restricted to LLW, TRU waste was routinely disposed of at MDA G prior to 1971. Since that time, most TRU waste has been segregated from the LLW and retrievably stored. Prior to 1986, most of LANL's mixed LLW was disposed of at MDA G. This waste has been stored on-site or shipped off-site for treatment and disposal since July 1986.

The inventory information required for the MDA G PA and CA includes the volume of waste contaminated with each radionuclide, the radionuclide-specific activities in the waste, and the distribution of the disposed waste across specific waste streams. Routine LANL operations, environmental restoration (ER) of contaminated sites, and decontamination and decommissioning (D&D) activities generate a variety of waste streams, including trash, plastic, scrap metal, glass, oil, soils, sludges, equipment, debris, asbestos and PCB-contaminated waste, and irradiation sources. The required inventory information was developed for each of these waste streams, separate inventories were developed for the disposal pits and shafts.

The primary sources of information for estimating MDA G inventories were the LANL LLW and TRU waste databases (see Appendix 2e in the MDA G PA and CA report). These databases include disposal records dating back to 1971. The records were used directly to estimate the quantities of LLW disposed of between 1971 and 1995, retrievably stored TRU waste placed in MDA G during this period was assumed to be removed prior to facility closure. Characteristics of the waste disposed at MDA G prior to 1971 were extrapolated from LLW and TRU waste disposal

data for the 1970s. All TRU waste disposed of prior to 1971 was assumed to remain in place. Operational LLW requiring disposal in the future (i.e., between 1996 and 2044) was assumed to resemble waste disposed of between 1990 and 1995. Volumes of ER and D&D waste requiring disposal in the future were estimated using projections developed by ER Program personnel; quantities of Chemistry and Metallurgy Research (CMR) facility upgrade waste were projected using information collected from facility personnel. The radiological characteristics of ER, D&D, and CMR LLW were assumed to be the same as those for mixed ER LLW, the characteristics of this latter waste had been developed in anticipation of a dedicated ER mixed LLW disposal facility.

Several types of waste underwent special consideration in the process of developing inventories for the PA and CA. The volume and activity of high-activity tritium waste requiring disposal in the future were conservatively estimated by assuming all of it would be disposed of at MDA G. While options for recovering tritium from this waste were being evaluated at the time the PA and CA were prepared, it was not clear that processes for recovery would, in fact, be implemented.

Waste included in the LLW and TRU waste databases as Mixed Fission Products was allocated to specific radionuclides on the basis of fission product yields for thermal and fast neutrons (see Appendix 2f in the MDA G PA and CA report). Allocations assumed the average age of the waste was two years, and took into account all radionuclides with half-lives of 0.5 years or more. Mixed Activation Product waste was allocated to specific radionuclides based on data for trash generated at LANSCE. Activities of some of the waste included in the databases were indicated in terms of material types, each one of which refer to specific isotopic ratios. Those ratios were used to allocate the total activities listed to the appropriate radionuclides.

Several radionuclides included in the MDA G PA and CA inventories are short-lived. The characteristics of the site and the assumptions made about future land use (see discussions below) are such that significant exposures to humans are unlikely for 100 years or more. Consequently, most radionuclides with half-lives of 5 years or less were removed from the projected MDA G inventories and were not included in the formal modeling. Exceptions to this included radionuclides that either gave rise to daughter radionuclides that had half-lives in excess of 5 years or were daughters of long-lived parent radionuclides.

4.2.2 Source Release Modeling

The predominant modes of contaminant release from MDA G disposal units were assumed to be leaching, gaseous diffusion through the cover, and biointrusion into the disposed waste (see Appendices 3a, 3b, 3c, and 3e in the MDA G PA and CA report). These mechanisms of release

are illustrated in Figure 4-1. Releases following complete erosion of the cover and cliff retreat were considered but excluded from formal modeling for the reasons given below.

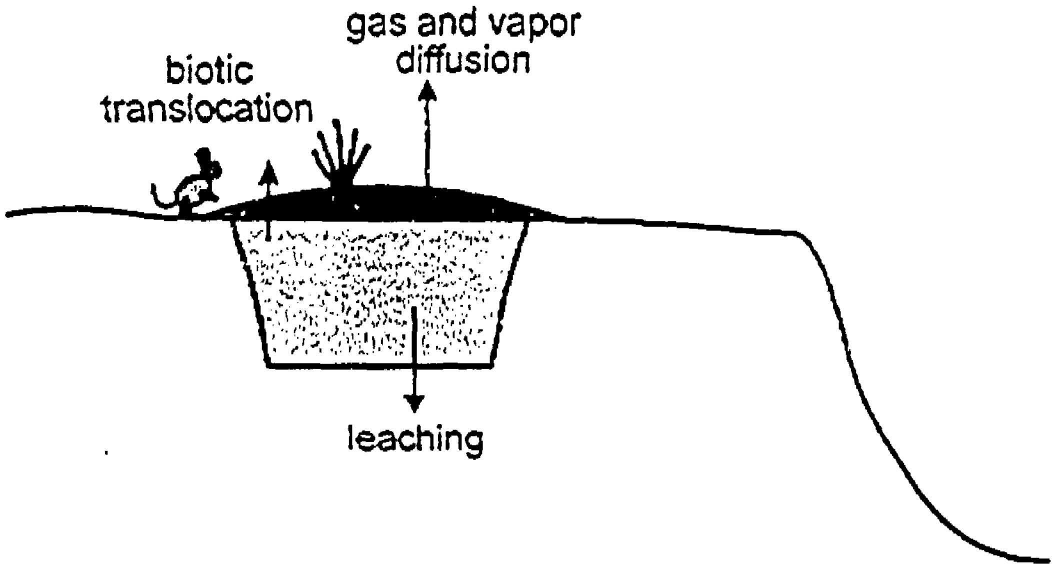

figure 4-1. conceptual model of source release

Radionuclides in the waste will be subject to leaching as water percolates through the disposal units. Rates of release will depend, in part, on the form of the waste exposed to the water. In order to address the diversity of wastes placed in MDA G while maintaining modeling complexity at a tractable level, the different waste streams were organized in terms of four waste categories. These included surface-contaminated waste, soils, concrete and sludges, and bulk-contaminated waste. Specific waste streams included in the PA and CA inventories were assigned to each category prior to conducting the source release modeling. Uncharacterized waste streams were assigned to surface-contaminated waste, which had the greatest projected rates of release, unless specific knowledge about the waste allowed it to be assigned to another waste category.

Source releases were modeled differently for each of the four waste categories. Radionuclides in surface-contaminated were assumed to enter into solution as water passing through the disposal units rinsed the contamination from the waste. Releases from soils, and concrete and sludges were controlled by the contaminants' distribution coefficients in the different media. Rates of release from bulk-contaminated waste were controlled by rates of corrosion or deterioration of the waste form. All estimated releases were subject to solubility limits.

The vast majority of each radionuclide's inventory at MDA G was assigned to the surface-contaminated category. Given this, and the fact that the rates of release were greatest for surface-contaminated waste, releases from the other waste categories were not included in the MDA G PA

and CA. Advective leach modeling was modeled for the surface-contaminated waste based on the assumption that radionuclide activities were uniformly distributed throughout the disposal pits and shafts. The moisture content of the disposal units and the amount of water percolating through the disposed waste were assumed to remain constant over the 10,000-year simulation period used for the groundwater pathways.

Volatile constituents in the MDA G inventory may diffuse upward from the waste and enter the atmosphere. The rates at which gases are released to the atmosphere will depend upon the rates at which they are formed and how quickly they diffuse through the overlying cover material. Gaseous releases were considered for six radionuclides disposed of at MDA G, including H-3, C-14, Kr-81, Kr-85, Rn-220, and Rn-222. With the exception of radon gas, the rates at which gases were formed were not considered. Rather, it was assumed that the entire inventories were available for diffusion at the end of disposal operations. Radon gas was assumed to be generated over time as U-238 and Ra-226 underwent radioactive decay.

The rates at which radioactive gases diffuse from the waste and enter the atmosphere depend upon the diffusion coefficients of the isotopes and the distance that must be traveled. Diffusion coefficients from the pits were assumed to be limited by the porosity and tortuosity of the crushed tuff used as backfill, these coefficients were a fraction of the free air diffusion coefficient. The diffusion coefficients used to model the disposal shafts were selected to account for the presence of fractures and the effect of barometric pumping. The entire inventories of all gases were assumed to be located at the top of the waste horizon, thereby minimizing the distance the constituents had to diffuse to be released from the site.

Plants and animals penetrating the disposed waste may move contamination to the ground surface, where it is available for atmospheric and surface water transport. Radionuclides taken up by plant roots may be deposited on the ground surface when the plant dies and decays. Animals burrowing into the waste may mix contamination in the overlying cover and bring radionuclides to the ground surface. The rate at which releases due to biointrusion occur will depend upon the density of the plants and animals, the root distributions of the plant species, and the burrowing characteristics of the animals.

Radionuclide releases at MDA G due to plant and animal intrusion were estimated using a representative species of each class of organism. The plant species used for modeling had a maximum rooting depth of 2 m. While other species of plants may have greater rooting depths, the establishment of those species was assumed to be prevented by DOE maintenance of the site. Plant matter contaminated by the uptake of radionuclides was assumed to decay within one

year and become incorporated into site soils. The burrowing characteristics of the deer mouse and pocket mouse were combined and used to estimate rates of radionuclide release due to the burrowing activities of animals. The rate and extent of animal intrusion into the waste were assumed to remain constant over the simulation period. Contamination brought to the surface of the site by plants and animals was assumed to be spread uniformly over the area of the disposal units.

Erosion of the cover placed over the disposal units at MDA G or cliff retreat along the sides of the mesa may expose the disposed waste, and make waste radionuclides available for atmospheric and surface water transport. These processes were not of concern in the MDA G PA and CA. Estimated erosion rates were small and did not remove significant portions of the cover during the 1,000-year compliance period used in the analyses. Similarly, the rate of cliff retreat estimated for MDA G and the distance from the edge of the mesa to the disposal units are such that waste is not expected to be exposed during the compliance period.

4.2.3 Environmental Transport Modeling

Radionuclides released from the waste disposed at MDA G may be transported off-site by a variety of pathways. These pathways include unsaturated and saturated zone groundwater transport to down-gradient locations, surface water transport to the adjacent canyons, and atmospheric transport to downwind locations. Each of these pathways was explicitly modeled in the MDA G PA and CA.

The transport of radionuclides to the regional aquifer takes long periods of time, a reflection of the low precipitation rates at the site and the great distances to the aquifer (see Appendices 3g and 3h in the MDA G PA and CA report). In general, flow is expected to be controlled by matrix flow rather than fracture flow because of the low moisture contents within the mesa. Flow in fractures may occur after large influxes of water (e.g., following snowmelt or intense summer storms), but is expected to dissipate within a short distance of the ground surface. Significant evaporation may occur within the unsaturated zone due to the presence of fractures, surge beds, and the vapor phase notch.

Unsaturated zone ground water modeling conducted for the MDA G PA and CA was based on the assumption that flow was steady-state. Contaminant migration through the upper units of the vadose zone was controlled by matrix flow, rather than fracture flow. Incomplete characterization data for the basalt layer led to the assumption that contaminant migration through this unit required only five years. Homogeneous properties were assumed to apply to all units of the

vadose zone, linear adsorption isotherms were assumed to apply to all radionuclides. Groundwater flow and transport in the regional aquifer was simulated using a steady-state model, the aquifer itself was assumed to be a single homogeneous unit.

Surface contamination resulting from plant and animal intrusion into the disposed waste may be transported into the adjacent canyons by surface runoff following snowmelt and rain storms. Radionuclides transported into the canyons may contaminate surface soils or enter the alluvial aquifer in the bottom of the canyons and be transported downward to the regional aquifer. Rates of ground water transport under these conditions may be greater than those through the mesa because of the greater water infiltration rates beneath the alluvial aquifers.

The MDA G PA and CA were conducted in a manner that minimized the need to consider how contamination was distributed in the canyons following runoff. Surface contamination from the top of the mesa was assumed to be transported instantaneously to the floor of Pajarito Canyon. Mobile contaminants were transported vertically using water infiltration rates expected to capture annual average percolation rates through the alluvial aquifer in the canyon (see Appendix 3g in the MDA G PA and CA report). Contamination remaining in surface soils was assumed to be spread over an area equivalent to that from which it was removed on the mesa-top (see Appendix 3e in the MDA G PA and CA report).

Atmospheric transport conditions in the vicinity of MDA G are complex, largely due to the mesa-canyon topography. Winds are strongly channeled by the canyons, flowing up canyon during the daytime and draining from the canyons at night. Mesa top winds also change between night and day, and may be channeled by the adjacent canyons. This channeling behavior may result in higher concentrations of airborne contaminants than would occur in the absence of the canyons.

The effects of channeling were included in the MDA G atmospheric transport modeling (see Appendix 3f in the MDA G PA and CA report). Winds from several windrose sectors were assumed to enter into Canada del Buey during the day, a different set of sectors was assumed to converge on the town of White Rock during the nighttime hours.

4.2.4 Exposure Assessment

The MDA G PA and CA are interested in the potential long-term impacts of LLW disposal on human health and safety. Consistent with this objective, the analyses projected potential exposures to humans for a period of 1,000 to 10,000 years. The former period was used for estimating exposures for atmospheric transport and on-site intruder pathways, while impacts from

groundwater pathways were evaluated for 10,000 years. Climatic and ecological characteristics of the site were assumed to remain constant over these periods.

Contaminant releases from MDA G may result in exposures to humans through a variety of pathways. Contaminated water drawn from the regional aquifer may be used for direct consumption, irrigating forage and food crops, and watering animals grown for meat or milk; airborne radioactivity may be inhaled, or assimilated by forage and food crops following its deposition on plant surfaces and soils. Radionuclides deposited on the ground or remaining aloft may result in exposures to direct radiation as well. On-site, human intrusion into the waste after facility closure may bring contamination to the ground surface and result in ingestion, inhalation, and direct radiation exposures.

The potential for human exposures depends upon the rates of radionuclide release and transport, as well as the accessibility of the contamination to humans. The MDA G PA and CA estimated exposures for a variety of on-site and off-site receptors that were identified based on expected patterns of future land use (see Appendix 3e in the MDA G PA and CA report). The land use scenario adopted assumes the disposal facility stops receiving waste in the year 2044. Final closure activities at the site require two years to complete. After that period, DOE is assumed to maintain active institutional control over the facility for the next 100 years, through the year 3045. Thereafter, DOE maintains control of MDA G to the facility's present-day fenceline. The site is assumed to be used for light industrial purposes, long-term recreational or residential uses are not permitted.

The land use assumptions described above limit access to MDA G by members of the public. During the 100-year active institutional control period, receptors were restricted to locations outside of the present-day LANL boundary. The locations assessed for the PA and CA are the town of White Rock and a point in Canada del Buey north of MDA G. Following this period, members of the public were assumed to reside in the vicinity of the disposal facility, but outside of the present-day MDA G fenceline. Receptors were located 100 m east of MDA G, directly below the site in Pajarito Canyon, and in Canada del Buey. Inadvertent intrusion into the disposed waste was assumed to occur for periods of time on the order of a few years due to complacency on the part of DOE's site maintenance program.

Members of the public were exposed to radionuclides via groundwater and atmospheric pathways. Groundwater pathway receptors were assumed to use contaminated water drawn from the regional aquifer as a source of drinking water, to irrigate food crops, and to water animals raised to supply milk and meat. Exposures occurred through the ingestion of contaminated foodstuffs,

water, and soil; inhalation of airborne radionuclides; and direct radiation from contaminated soils and airborne particulates. Receptor exposures were projected for the point of maximum exposure.

The atmospheric pathway exposure modeling considered doses received by persons in White Rock and Canada del Buey. Gaseous releases and plant and animal intrusion into the disposed waste were the mechanisms of release for this pathway. Airborne contamination deposited on crops grown by the receptors was subsequently ingested, airborne contamination was inhaled and gave rise to direct radiation exposures. Contamination deposited on the ground added to the direct exposures.

An agricultural intruder scenario was used to bound potential doses to a person who inadvertently intrudes into the disposed waste after the active institutional control period. This scenario estimates exposures to an individual who establishes a home at the site, and raises a portion of his or her food requirements. Waste excavated by the intruder is mixed uniformly in clean cover soil disturbed during excavation, the resulting mixture is spread uniformly over the person's lot. Exposures occur from the ingestion of contaminated crops and soil, inhalation of airborne radioactivity, and direct radiation from contaminated soils and airborne particulates. A separate native American scenario was not modeled, as the exposures projected for the agricultural intruder were expected to bound exposures to native Americans.

Intrusion into the waste disposed of in shafts was assumed to be prevented for a period of 300 years by the concrete caps placed over these units. Otherwise, no waste packages or waste forms were assumed to prevent intrusion following the active institutional control period. The spatial distribution of the disposal shafts was altered to simplify the intruder dose assessment. While these units are scattered about MDA G in small groups, uniform "shaft fields" were constructed and used for estimating exposures.

5. COMPARISON OF MDA MODELING NEEDS TO MDA G MODELING ANALYSES

The final step in determining MDA G PA and CA suitability is to compare the modeling conducted for MDA G with the modeling needs for the MDA in question. This comparison is conducted using a two-step process. In the first step, the MDAs are compared in terms of their conceptual models, while modeling details are considered in the second step. These steps are described in the following paragraphs.

The comparison of the conceptual models for MDA G and the MDA of interest is conducted to determine if the two sites function or operate similarly in a conceptual sense only. To illustrate, consider a groundwater pathway wherein contaminants are leached from the disposed waste, and transported through the unsaturated and saturated zones to a person's well down-gradient of the sites. As discussed earlier, groundwater transport through the unsaturated zone was modeled at MDA G assuming steady-state flow through a porous medium. If flow through the vadose zone at the MDA of concern is similar, the two sites may be judged to be similar in a conceptual sense. On the other hand, if the conceptual model for the MDA in question suggests that flow through fractures on an intermittent basis is the dominant flow mechanism, the two sites may be judged to be conceptually different. In this case, it may be concluded that the modeling performed for MDA G cannot be readily applied to the MDA of concern.

The comparison of conceptual models is conducted on a pathway-by-pathway basis, where pathway refers to the complete sequence of events that must occur to transfer contaminants to environmental media that are accessible to humans or ecological receptors. For each pathway, the contaminant inventory available for release, the mechanisms of release from the MDA, and the processes through which constituents are transported to the access locations are compared between the MDA in question and MDA G. As an example, the comparison for the groundwater pathway would look at the inventories available for leaching, the ways in which the contaminants are released to water infiltrating through the disposal units, and the transport of these releases through the unsaturated and saturated zones to locations down-gradient of the MDAs. Similarly, comparisons for the atmospheric pathway would examine the inventories available for release as gases or particulates, the actual release mechanisms, and the subsequent transport of releases to downwind receptor locations.

The comparison of MDA conceptual models is conducted on a pathway-specific basis to determine how much of the MDA G PA and CA may be applied to other MDAs. Whereas the MDA G analyses may be conceptually similar to another MDA with respect to groundwater flow and transport, it may differ significantly for atmospheric transport. If this were the case, the MDA G

analyses could be used for the groundwater pathway, but alternate models may be necessary to estimate impacts for the air pathway at the MDA of concern.

In the event that MDA G and the MDA of concern are comparable in terms of their conceptual models, further comparisons are made to determine the manner in which the MDA G PA and CA can be applied to the MDA in question. For this second step, the details of the modeling conducted for MDA G are evaluated in terms of their suitability for describing the same processes at the MDA. If the parameters and models used for MDA G directly apply to the MDA of concern, it may be possible to use the results from the MDA G PA and CA to estimate exposures at the MDA of concern, scaling for differences in a constituent inventories. In contrast, if the process details differ significantly between the sites, it may be necessary to implement the MDA G modeling methodology using input parameters specific to the MDA in question.

The difference between the two steps of the modeling comparison may be illustrated with an example. For this example, assume that only radionuclides were disposed at the MDA of concern and that source releases are dominated by leaching of surface-contaminated waste. Leached radionuclides are subject to steady-state, porous media flow in the vadose zone; the regional aquifer to which contaminants are discharged is a single homogeneous unit. As discussed earlier, this conceptual model of the groundwater pathway is the same as that used in the MDA G PA and CA. In this respect, then, the MDA of concern and MDA G are conceptually the same. This ends the first step of the comparison process for the example.

In the second step of the comparison, MDA G and the MDA of concern are compared in terms of the parameters and models used to implement the conceptual models. Focusing on input parameter values, assume the infiltration rates; moisture contents; stratigraphy; characteristic curves; vadose and saturated zone densities, dispersivities, and porosities; and flow velocities in the aquifer are the same or differ by very small amounts. Assume further that the waste constituents found in the MDA of concern are the same as those found at MDA G but in quantities tens times smaller. Given these hypothetical conditions, the two MDAs could be judged to be the same with respect to the groundwater pathway. The modeling results for the MDA G PA and CA could be scaled downward by a factor of ten to estimate the risks posed by the radionuclides contained in the MDA of concern.

Alternatively, assume for illustration purposes that the MDA of concern and MDA G are conceptually similar but differ in terms of several input parameters. The water infiltration rate at the MDA of concern is 1.5 times that at MDA G, leading to higher moisture contents in the disposal units. While steady-state porous flow predominates, the stratigraphic properties of the two sites

differ with respect to unit thickness; hydraulic properties of the different units also exhibit dissimilarities. Given these conditions, it may be decided that the uncertainties associated with scaling the performance of the MDA of concern using MDA G modeling results are great enough that the PA and CA results should not be used directly. Instead, it may be decided to implement the MDA G modeling methodology using infiltration rates, moisture contents, and hydraulic properties appropriate for the MDA of concern.

The detailed comparison of input parameters and models for MDA G and the MDA of concern is conducted on a pathway-specific basis. As discussed above with respect to the comparison of conceptual models, the MDA G analyses may be applicable to the MDA in question for one pathway, but not another. Consequently, conducting the comparison on a pathway-specific basis will maximize the utility of the MDA G PA and CA.

It is expected that the characteristics of many MDAs are similar enough to those of MDA G that the MDA G PA and CA will prove useful in conducting the MDA risk assessments. However, it is unlikely that all site characteristics and, hence, all modeling needs will be identical between the MDA in question and MDA G, even for a single pathway. The problem, then, becomes one of determining if differences between the two sites are sufficient to invalidate using the MDA G PA and CA in the MDA risk assessment process. If differences exist between the sites but those differences are insignificant, it may still be concluded that the modeling needs for the MDA in question can be effectively addressed using the MDA G analyses.

The significance of differences between the MDA of concern and MDA G ultimately depends upon the impact the differences have on the risks posed by the site to human health, safety, and the environment. These impacts, in turn, will depend upon the sensitivity of the models to changes in assumptions and input parameters, and the range over which those assumptions and parameters may reasonably vary. These aspects of the modeling are formally addressed through sensitivity and uncertainty analyses.

The precise nature of the comparison of modeling details will be specific to the MDA of concern. Successful completion of this step will require persons familiar with contaminant source release mechanisms, environmental transport, and risk assessment; how contaminant behavior is modeled for risk assessments; and the models and parameters used to conduct the MDA G PA and CA. It is anticipated that a cross-disciplinary team will be required to supply the needed expertise and professional judgement to complete this process.

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