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Sandia National Laboratories

Justification for Class 3 Permit Modification Corrective Action Complete with Controls Solid Waste Management Unit 76 Mixed Waste Landfill

October 2014

Volume I of VIII
Class 3 Permit Modification for Corrective Measures, Final Order, and Corrective Measures Implementation Plan

Environmental Restoration Operations

U.S. DEPARTMENT OF ENERGY

United States Department of Energy
Sandia Field Office

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From: State of NM/ Curry
To: DOE/Sandia

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STATE OF NEW MEXICO
BEFORE THE SECRETARY OF ENVIRONMENT

MAY 2005
DOCKETED BY THE HEARING CLERK BEFORE THE SECRETARY OF ENVIRONMENT

IN THE MATTER OF REQUEST FOR A CLASS 3 PERMIT MODIFICATION FOR CORRECTIVE MEASURES FOR THE MIXED WASTE LANDFILL SANDIA NATIONAL LABORATORIES BERNALILLO COUNTY, NEW MEXICO EPA ID NO. NM5890110518

No. HWB 04-11(M)

FINAL ORDER

This matter comes before the Secretary of Environment following a hearing before the Hearing Officer on December 2-3 and 8-9, 2004 in Albuquerque, New Mexico. Sandia Corporation and the Department of Energy ("Sandia") seek a RCRA permit modification for Sandia National Laboratories ("SNL") pursuant to the New Mexico Hazardous Waste Act, NMSA 1978 Section 74-4-1 et seq., and the New Mexico Hazardous Waste Management Regulations (20.4.1 NMAC). The proposed modification would incorporate into the RCRA permit requirements for corrective action for SNL's Mixed Waste Landfill (MWL or landfill). The New Mexico Environment Department Hazardous Waste Bureau ("NMED") supports the approval of the proposed modification with the selection of a different remedy than that chosen by Sandia.

Having considered the administrative record in its entirety, including the Hearing Officer's Report; and being otherwise fully advised regarding this matter;

THE SECRETARY HEREBY ADOPTS THE HEARING OFFICER'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW (as corrected by interlineated substitute pages) WITH CHANGES ONLY TO THE FOLLOWING:

2. The Public Notice announced the availability of the Draft Permit for public review; a 90-day period for public comment on the draft; the setting of a public

hearing on the Draft Permit beginning December 2, 2004 in Albuquerque, New Mexico; the procedures for public participation, participation as a party and providing technical testimony. NMED Exhibit 1.

15. The landfill is SWMU 76 at SNL, and regulated under 40 CFR Section 264.101 (incorporated by 20.1.4.500 NMAC) TR 968-69; AR 04-077.

20. Most of 40 CFR Part 264 does not apply to the landfill as it is not included in any Part B permit, and 40 CFR Part 265 does not apply to the landfill as it is not an interim status facility in SNL's Part A permit application. TR 969.

23. NMED proposes to modify Module IV of the permit to: a) incorporate by reference the CMS Report dated May 2003 prepared by Sandia; b) select a vegetative soil cover with bio-intrusion barrier as the remedy for the landfill; c) require a Corrective Measures Implementation ("CMI") Plan for the landfill that incorporates the final remedy and provides implementation schedules, that Sandia must submit to NMED within 180 days of final remedy selection; d) require Sandia to submit progress reports during implementation of the remedy; e) require Sandia to submit a CMI Report for the landfill to NMED for approval within 180 days after implementation of the remedy is complete; and f) require that Sandia submit a long-term monitoring and maintenance plan to NMED for approval. NMED Exhibit 3.

60. The highest tritium flux (flow of tritiated water vapor off surface soils into the atmosphere) occurred at the east boundary of the classified area. TR 55-56, 953. Sandia estimated total tritium activity released from the landfill during 1993 to be 0.294 curies (which decreased to 0.09 curies per year in 2003). TR 954.

86. Sandia subsequently closed the ISS and moved the drums off-site. As part of the closure process, Sandia analyzed risk presented by the ISS, which predicted radiological risk significantly below background levels in Albuquerque. TR 82-83.

120. For the future excavation scenario (Alternative V.e, 39 years in the future), the total dose equivalent was exceeded for a worker excavating the landfill. In NMED's opinion, although the risk assessment could have used more realistic assumptions, it is clear that excavation of the landfill in the near-term could pose substantial risk to excavation workers. TR 1041-43.

169. A bio-intrusion barrier will discourage small animals (such as mice, prairie dogs, burrowing owls) from burrowing through the cover and coming into contact with waste and contaminated soil, and from transporting wastes and contaminated soil in the landfill to the surface. A bio-barrier will not stop insects (such as ants) from burrowing into the ground, and will not prevent deep-rooted plants from penetrating the cover. Any animals or plants living on the landfill will be exposed to low levels of tritium and radon, which will penetrate a bio-barrier. TR 1070.

U. Sandia should develop a comprehensive fate and transport model for the landfill, to be used in evaluating future options, triggers, monitoring and contingencies.

IT IS THEREFORE ORDERED:

Sandia's application for RCRA permit modification is hereby granted as proposed (NMED Exhibit 2), subject to the following changes and conditions:

1. The remedy shall be a vegetative cover with bio-intrusion barrier (Alternative III.c in Sandia's Corrective Measures Study, dated May 2003);

2. As part of the Corrective Measures Implementation Plan that incorporates the final remedy (described in the draft permit modification in Paragraph V.3), Sandia shall additionally include the following:

a. a comprehensive fate and transport model that studies and predicts future movement of contaminants in the landfill and whether they will eventually move further down the vadose zone and/or to groundwater;

b. triggers for future action, that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy.

3. NMED and Sandia shall provide a convenient method for the public to review Sandia's Corrective Measures Implementation Plan, Corrective Measures Implementation Report, progress reports, long-term monitoring and maintenance plan, and any other major documents developed by NMED or Sandia for the MWL ("the documents"), including but not limited to, posting the documents on a publicly-accessible website.

4. NMED and Sandia shall provide a method and schedule that allows interested members of the public to review and comment on the documents, and NMED shall review, consider and respond to these public comments prior to approving any of these documents (with the exception of any documents, such as progress reports, that NMED does not approve in the normal course of permit review and oversight).

5. Sandia shall prepare a report every 5 years, re-evaluating the feasibility of excavation and analyzing the continued effectiveness of the selected remedy. The report shall include a review of the documents, monitoring reports and any other pertinent data, and anything additional required by NMED. In each 5-year report, Sandia shall update the fate and transport model for the site with current data, and re-evaluate any likelihood of contaminants reaching groundwater. Additionally, the report shall detail all efforts to ensure any future releases or movement of contaminants are detected and addressed well before any effect on groundwater or increased risk to public health or the environment. Sandia shall make the report and supporting information readily available to the public, before it is approved by NMED. NMED shall provide a process whereby members of the public may comment on the report and its conclusions, and shall respond to those comments in its final approval of the report.

6. The Hearing Officer is granted until April 20, 2005 to submit her Report and Proposed Findings of Fact, Conclusions of Law and Proposed Order.

RON CURRY
Secretary, Environment Department

Volume I

TAB 2

Remedy Decision and Class 3 Permit Modification

Request to Incorporate into RCRA Permit Corrective Measures for

Mixed Waste Landfill (SWMU 76)

From: NMED/Kieling
To: SNL/Wagner

Back of Tab 2

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505-6303
Telephone (505) 428-2500
Fax (505) 428-2567
www.nmenv.state.nm.us

BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

DERRITH WATCHMAN-MOORE
DEPUTY SECRETARY

cc: MJ Davis, Ann Blumberg, [illegible]

August 2, 2005

Patty Wagner
Manager
Sandia Site Office/NNSA
U.S. Department of Energy
P.O. Box 5400, MS 0184
Albuquerque, NM 87185-5400

Peter B. Davies
Director, Geoscience and Environment
Center (6100)
Sandia National Laboratories
P.O. Box 5800, MS 0701
Albuquerque, NM 87185

RE: REMEDY DECISION AND CLASS 3 PERMIT MODIFICATION REQUEST TO INCORPORATE INTO RCRA PERMIT CORRECTIVE MEASURES FOR MIXED WASTE LANDFILL (SWMU 76)
SANDIA NATIONAL LABORATORIES EPA ID# NM5890110518
HWB-SNL-04-021

Dear Ms. Wagner and Mr. Davies:

As you are aware, on May 26, 2005, the Secretary of the New Mexico Environment Department (NMED) approved a remedy and a Class 3 permit modification request for corrective measures for the Mixed Waste Landfill (MWL) at Sandia National Laboratories (SNL).

A public hearing was conducted on the matter on December 2-3 and 8-9, 2005; a public comment period was held from August 11, 2004 to December 2, 2004, and extended until December 9, 2004. Based on the administrative record and the Hearing Officer's Report, the NMED Secretary selected a vegetative soil cover with bio-intrusion barrier (Corrective Measures Study Alternative III.c) as the remedy for the MWL. The draft permit modification issued by NMED was revised in accordance with the Secretary's final decision. A copy of the final permit modification is enclosed. Additionally, in accordance with Section 20.4.1.901.A(9) NMAC, attached are NMED's responses to public comment, including explanations for changes made to the draft permit in preparing the final permit. These documents are also located on the NMED web page at www.nmenv.state.nm.us/hwb/snlperm.html under Mixed Waste Landfill.

Please contact Mr. William Moats of my staff at (505) 284-5086 if you have questions or comments.

Sincerely,

John E. Kieling
Manager
Permits Management Program

JEK:wpm

cc: J. Bearzi, NMED HWB
W. Moats, NMED HWB
F. Nimick, SNL, MS 1089
D. Fate, SNL, MS 1089
J. Estrada, DOE/SSO/NNSA
J. Gould, DOE/SSO/NNSA
L. King, EPA-Region 6PD-N
File: SNL HSWA OU 1289, 2004

Enclosures

AUG 0 4 2005

V. CORRECTIVE MEASURES FOR THE MIXED WASTE LANDFILL (SWMU 76)

1. The report, *Mixed Waste Landfill Corrective Measure Study Final Report, Sandia National Laboratories, New Mexico*, dated May 2003, is incorporated herein by reference.

2. The remedy to be implemented by Permittees for the Mixed Waste Landfill shall be as defined as Alternative III.c--Vegetative Soil Cover with Bio-Intrusion Barrier, as set forth in the report referenced in V.1 of this section.

3. A Corrective Measures Implementation (CMI) Plan that incorporates the final remedy described in Section V.2 of this section shall be submitted by the Permittees for the Mixed Waste Landfill for the Administrative Authority's approval no later than 180 days following the selection of the remedy by the Administrative Authority. The CMI Plan shall provide details on the design, construction, operation, maintenance, and performance monitoring for the selected remedy, and a schedule for implementation. The CMI Plan shall, at a minimum, include:

   a. A description of the selected remedy;

   b. A description of the remediation system objectives;

   c. An identification and description of the qualifications of key persons, consultants, and contractors that will be implementing the remedy;

   d. Detailed engineering design drawings and systems specifications for all elements of the remedy;

   e. A construction and construction quality assurance work plan;

   f. An operation and maintenance plan;

   g. The results of any remedy pilot tests, such as landfill cover test plots;

   h. A schedule for submission to the Administrative Authority of periodic progress reports;

   i. A schedule for implementation of the remedy; and

   j. A health and safety plan.

4. A CMI Report for the Mixed Waste Landfill shall be submitted by the Permittees to the Administrative Authority for approval within 180 days after implementation of the remedy is complete. The CMI Report shall, at a minimum, include:

    a. A summary of the work completed;

    b. A statement signed by a registered professional engineer, that the remedy has been completed in full satisfaction of the specifications in the CMI Plan;

    c. As-built drawings and specifications signed and stamped by a registered professional engineer;

    d. Copies of the results of all monitoring, including sampling and analysis, and other data generated during the remedy implementation, if not already submitted in a progress report; and

    e. A certification, signed by a responsible Permittee official stating: "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations".

5. The Permittees shall submit to the Administrative Authority progress reports during implementation of the remedy in accordance with a schedule approved in the CMI Plan for the Mixed Waste Landfill. Each of the progress reports shall, at a minimum, include the following information.

    a. A description of the work completed during the reporting period;

    b. A summary of all problems, potential problems, or delays encountered during the reporting period;

    c. A description of all actions taken to eliminate or mitigate problems, potential problems, or delays;

    d. A discussion of the work projected for the next reporting period, including all sampling events; and

e. Copies of the results of all monitoring, including sampling and analysis, and other data generated during the reporting period.

6. A long-term monitoring and maintenance plan, which includes all necessary physical and institutional controls to be implemented in the future shall be submitted by the Permittees to the Administrative Authority for approval within 180 days after the Administrative Authority's approval of the CMI Report. The Administrative Authority may require monitoring, maintenance, and physical and institutional controls different than those specified in the Corrective Measures Study report referenced in Section V.1 of this section. The plan shall also include contingency procedures that must be implemented by the Permittees if the remedy set forth in Section V.2 above fails to be protective of human health and the environment.

NMED Responses to Public Comments on the Sandia National Laboratories' Mixed Waste Landfill Permit Modification for Corrective Measures August 2, 2005

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
A	For Citizen Action, Sue Dayton	Sodium	1.1	The unknown amounts of metallic sodium reportedly buried in the Mixed Waste Landfill (MWL or Landfill) (see FOIA document #20, par. 4) have been omitted from discussion in the Corrective Measures Study (CMS). Metallic sodium, used in the oxide reactor fuel experiments at Sandia National Laboratories (SNL), has not been identified as a hazardous substance in the inventory of the MWL nor has it been included in the CMS risk assessment. The commenter wants to know why it was not included.	R1	Sodium reacts with water and other oxidizers. Unknown, but likely small amounts of sodium metal may be present in canisters buried in the MWL that once held oxide reactor fuel samples. Provided that the canisters remain buried and are not exposed to water beyond normal soil moisture, chemical reaction of the sodium will not proceed at a rate that will threaten human health or the environment. See also Responses R5 and R49. The presence of sodium in the Landfill does not preclude the option of capping the MWL as a final remedy.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.26	An interview with George Tucker, former SNL employee, 1995 (FOIA 3) indicates that explosives were not allowed in the MWL, however FOIA document #21 states that metallic sodium "may be present". The commenter asked the New Mexico Environment Department (NMED) to address this apparent discrepancy.	R2	Metallic sodium is not classified as an explosive by the U. S. Bureau of Alcohol, Tobacco, Firearms, and Explosives.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
A	For Citizen Action, Sue Dayton	Beryllium	1.2	The commenter indicated that the MWL contains significant amounts of beryllium (218 cubic yards total) and PCBs (251 cu. yd). The commenter indicated that there is no discussion in the CMS about the beryllium and no response from the NMED regarding clean up of this material.	R3	While the Landfill contains wastes contaminated with beryllium and PCBs, there is no evidence that such wastes are migrating from the Landfill. Therefore, there is no risk to receptors regardless of the concentrations of these contaminants in the Landfill. See also Response R6. Continued monitoring during post-closure care will be conducted to ensure that hazardous waste or hazardous waste constituents are not migrating from the Landfill. The MWL is not subject to TSCA, but instead, is regulated under the New Mexico Hazardous Waste Act (NMSA 1978 §§ 74-4-1 et seq. (Repl. Pamp. 2000)) and the New Mexico Hazardous Waste Management Regulations (20.4.1 NMAC). Accordingly, the CMS did not need to address TSCA requirements.	No
A	For Citizen Action, Sue Dayton		1.3	The commenter indicated that according to the CMS the MWL contains 251 cubic yards of PCBs. Considering this amount the commenter asked why TSCA wasn't identified and discussed in the CMS	R3	See Response 3.	No
A	For Citizen Action, Sue Dayton	Risk Assessment Inhalation Factors	1.4	The commenter indicated that on pages I-84 and I-85 of the CMS (Tables 2 and 3, "Default Non-Radiological/Radiological Exposure Parameter Values for Various Land Use Scenarios"), the inhalation factors are different for	R4	It appears that the commenter is referring to Tables 2 and 3 on pages I-88 and I-89. The difference in inhalation factors is because for the chemical risks, the Environmental Protection Agency (EPA) exposure assumptions were applied; whereas, for	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				radiological and non-radiological under industrial, recreational and residential scenarios. The commenter wants to know the reason for these differences.		the radiological risk, Department of Energy/ Nuclear Regulatory Commission (DOE/NRC) exposure assumptions were applied. The most notable difference is the inhalation factors used for the recreational scenario. Both assessments use a base inhalation rate for the recreational scenario of 30 cubic meters per day; however the EPA-based rate as shown in Table 2 has been modified to allow for the limited exposure time and duration for the recreational receptor. RESRAD requires input of the base rate, and the other modifying factors (exposure time and duration) are separate input parameters and are applied to the base inhalation rate during the model calculations. So while the inhalation rates appear different in these tables, the final inhalations rates for both assessments for the recreational scenario are the same.	
A	For Citizen Action, Sue Dayton, 2nd submittal	Waste Inventory	1.7	Accurate records of the MWL waste inventory before 1965 no longer exist and records from 1965 to 1976 are incomplete with regard to waste disposal. (SNL ER Program, 1993, Phase 2 RFI Work Plan (FOIA 101)). The commenter had several questions regarding this issue. First, the commenter indicates that SNL states that the lost records have been found but indicated that the files contain conflicting data, the researcher	R5	NMED understands that some MWL records have been located at the Idaho National Environmental and Engineering Laboratory (INEEL). Records are incomplete and there are some discrepancies between the known inventory and historical accounts based on interviewed witnesses. However, the NMED believes that while the inventory for the MWL is not complete, it is adequate to select a final remedy for the MWL. See also Hearing	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				applied a straight-line average to waste disposal from 1959-1969; and the estimated values for individual waste categories. The commenter asked if NMED believes that these statements are representative of a Cold War waste site with an "excellent" inventory.		Officer's Findings of Fact and Conclusions of Law (HO FOF/COL), ¶¶ 43-45.	
A	For Citizen Action, Sue Dayton, 2nd submittal		1.10	"Most waste from this facility should be considered mixed waste since the exact composition of the waste is uncertain and radioactive chemicals as well as classified toxic materials could be expected". The commenter asked if this was indicative of a landfill with an excellent inventory.	R5	See NMED Response R5; see also HO FOF/COL, ¶¶ 43-45.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.28	The commenter indicates that between 1965 and 1970, before complete records were kept, there was a lot "unknown" about the final disposal of "Fission Product/Induced Activity. The commenter questions if these "unknown" statements are indicative of a landfill with an excellent inventory.	R5	See NMED Response R5; see also HO FOF/COL, ¶¶ 46-50.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's		1.52	The commenter stated that the purpose of RFI Phase 2 investigation was to "identify all potential or suspected sources of contamination" and "to determine thoroughly the contaminant	R5	See NMED Response R5; see also HO FOF/COL, ¶¶43-50.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
	comments			source". The commenter states that this has not been done. (pp. 6, 7)			
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments		1.54	The commenter indicated that SNL has not fully characterized the inventory of the MWL (p. 13).	R5	See NMED Response R5; see also HO FOF/COL, ¶¶ 43-50.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.64	Regarding the "WERC Independent Technical Peer Review of the Working Draft CMS for MWL", Executive Summary, the first comment in Section (ii. 1): the WERC states that the site operational history (section 1.0 of the draft CMS) fails to include information that the early inventory data (once believes to be lost) can now be found in microfiche at INEEL. This information was omitted from the CMS as well as the fact that the MWL was used for disposal of chemicals prior to the opening of the CWL. This information was obtained in a document found by Citizen Action under a FOIA request. The comment requests that the information be included in the CMS, that the records be released to the public, and that as complete MWL inventory as possible be prepared.	R6	The purpose of the CMS is for the facility to evaluate potential remedial options and recommend a remedy to the administrative authority (NMED). It is not necessary to include in the CMS Report detailed information concerning the operation of the Landfill, including the waste inventory, because this information is provided to the extent known in the RCRA Facility Investigation (RFI) Report(s). In the case of the MWL, most of this information is found in the Phase 1 and 2 RCRA RFI Reports, although some is located in other documents. The known waste inventory and other information have been made publicly available by both the NMED and the SNL to the extent that security classification requirements permit such a release of information. See also HO FOF/COL, ¶¶ 43-50.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
A	For Citizen Action, Sue Dayton, 2nd submittal	Changes to Waste Volume Estimates	1.5	The commenter provided selected statements taken from documents obtained by Citizen Action under a FOIA. Several following comments address this issue. The first comment indicated that an estimated 720,000 cubic feet of waste has been buried on site during the 28-year operation. (SNL ER Program Information Sheet, 1987 (FOIA 90)). The commenter asked why these estimated volumes continue to change.	R7	Estimates may change because the data from which SNL is working are old, incomplete, and in some cases may be inaccurate. This is a common occurrence for landfills that are as old as the MWL. The older estimates were made using the best available data at the time, and as new information became available, the volumes were modified accordingly. See also HO FOF/COL, ¶¶ 43-50. The records provided by SNL are more detailed than those of many such landfills used for disposal of hazardous and radioactive wastes during historical times. There are no waste disposal records for many old landfills. See also HO FOF/COL, ¶¶ 43-50.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.6	Approximately 50,000 cubic feet of radioactive waste has been buried at the site (SNL Working Draft, Sampling Plan 1992 (FOIA 92)). The commenter asked why these estimated volumes continue to change.	R7	See Response R7. See also HO FOF/COL, ¶¶ 43-50.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Knowledge of Exact Waste Quantities and Locations	1.8	The commenter asked what information NMED has on the "lost records" which have been found. The files indicate that all records prior to 1964 were destroyed as part of a record purge (letter from Delacroix Davis, Jr. to James G.	R8	NMED has relied chiefly on the waste inventory submitted with the Phase 2 RFI Report and does not possess additional records that have not been made available to the public. Although the inventory lists as much detail as possible about wastes disposed of in the individual	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				Steger, 1977, p. 11 (FOIA 50))		trenches and pits, the NMED does not have records for and does not generally know the exact volumes or mass, the exact levels of radioactivity, or the exact locations of most radioactive (including TRU), mixed, or hazardous wastes in the Landfill. The NMED does not possess records from INEEL; information from these records was summarized by SNL in the inventory provided in the Phase 2 RFI Report. The NMED does not know the quantities, types, or exact locations of fuel canisters, wastes from the Nevada Test Site (NTS), wastes contaminated with multiple fission products or metals, TRU wastes, or wastes disposed of in the radioactive chemical pit beyond the information provided in the inventory. See also HO FOF/COL, ¶¶ 43-50.	
A	For Citizen Action, Sue Dayton, 2nd submittal		1.11	"…the most common metal disposed of at MWL is lead. Also, barium, beryllium and chromium were probably disposed of. No records are available on the quantities of metals disposed of…" (SNL ER Program Information Sheet, FOIA, 1987 (FOIA 90)). The commenter asked if NMED has accurate records of quantities of metals (such as lead) disposed of at MWL.	R8	See Response R8. See also HO FOF/COL, ¶¶ 43-50.	No
A	For Citizen Action, Sue Dayton, 2nd		1.14	"… MWL received a variety of radioactive and potentially radioactive/hazardous mixed	R8	See Response R8. See also HO FOF/COL, ¶¶ 43-50.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
	submittal			waste…" Primary radionuclides are uranium and tritium; also there is some plutonium and plutonium-contaminated material, cobalt-60, cesium-137, radioactive tracers, radionuclear waste from operating and decommissioned Sandia Pulsed Reactors and experiments at the Nevada Test Site (NTS). Radioactively contaminated oils and naphthalene scintillation vials…" The commenter asked if there was a complete inventory of each of these specific waste products, i.e., quantity, type, curies, and method used for containment.			
A	For Citizen Action, Sue Dayton, 2nd submittal		1.15	"Chemical waste including acids, solvents, TCE, carbon tetrachloride, and scintillation cocktails. Other wastes disposed of in the classified area include uranium, thorium, plutonium, enriched lithium, various facilities, and plutonium-contaminated nuclear weapons test debris". The commenter states that SNL maintains that no liquid waste was disposed of in the MWL, the term "leaky" does not typically refer to solid waste. In addition, based on SNL's reports, less than a gram of plutonium was buried in the MWL. The commenter asked if that amount took into consideration the total volume of plutonium-contaminated wastes and the	R9	The less than 1 gram of plutonium includes small amounts of plutonium that contaminate some debris in the Landfill. The NMED does not possess the INEEL records. The information in the INEEL records has been summarized in the inventory, which is adequate in the case of the MWL for the purpose of remedy selection. See also Response R8 and HO FOF/COL, ¶¶ 43-50.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				plutonium reportedly contained in the 19 drums as reported in the MWL known inventory? The commenter also request that these records, apparently on microfiche and stored at INEEL, be made available to the public in order to fully characterize the content of the MWL.			
A	For Citizen Action, Sue Dayton, 2nd submittal		1.17	In an interview with former SNL employee H. Abbott (interview date unknown), he states "Possible mixed fission products went to dump. Lots of fuel in mountains stored. Only neutron activated material went to the dump. Lots, large amounts of DU (depleted uranium)." The commenter would like a list of the fission products, volumes, and curies disposed of at the MWL. The commenter asked if NMED has records of where these mixed fission products originated. The commenter also asked what "lots of fuel stored in mountains" refers to.	R10	NMED does not know where fission-product contaminated wastes were generated, although it is possible that some of the waste was generated locally at SNL. Some of the waste is from the NTS and possibly other DOE facilities in the U.S. NMED has no knowledge of any nuclear fuels stored "in mountains". Nuclear fuels are not hazardous waste, and thus are not subject to RCRA. See also Response R8.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.22	"Records of disposal in pits from Nevada Test Site and South Pacific were examined and then disposed of at the MWL." (Interview with former SNL employee Bob Schwing, 1995(FOIA 7).) The commenter asked if there are such records, and in which section at	R8	See Response R8.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				MWL these materials were disposed of.			
A	For Citizen Action, Sue Dayton, 2nd submittal		1.23	"…other records suggest that transuranic wastes may have been buried at the MWL; waste records did not define contents of the TRU waste before 1972, thus actual presence and quantities of these wastes cannot be accurately determined…". (SNL ER Program, 1993 Phases 2 RFI Work Plan (FOIA 101).) The commenter asked if NMED has further documentation about TRU wastes disposed of at MWL, and does NMED believe the information represents an accurate inventory of waste disposed of at the MWL.	R11	See Responses R5 and R8.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.24	"On the order of 1000s of REM/hr [disposed of in the MWL] on contact. Truckloads were disposed of during decommissioning. Some elements of reactor exceeded 5000 rem/yr. Disposal of much material in pits-100 rem/hr" (Interview with former SNL employee Max Moms regarding disposal of nuclear reactor material in dump, 1998 (FOIA 12).) The commenter asked what "elements of reactor waste exceeded 5000 rem/hr"	R12	NMED does not know how many reactor vessel plates exist in the MWL and which of these plates specifically had radioactivity levels of greater than 5000 rem/hr.	No
A	For Citizen Action, Sue		1.25	Interview with Frank Statzula a former SNL employee (FOIA 58)	R8	See Response R8.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
	Dayton, 2nd submittal			mentions a radioactive acid pit and indicates that chemicals, radioactive materials were disposed of in the pit until 1969. The commenter indicated that this pit was not disclosed to members of the SNL/Citizens Advisory Board. The commenter asked if NMED has a complete inventory of waste disposed of in the radioactive acid pit.			
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments		1.51	The commenter stated that pit contents (see examples, pits 35-36) do not match the gamma levels at surface taken by SNL (pp. 7, 8).	R13	That certain pit contents have gamma radiation sources in them that are not included in the inventory simply means that the inventory is incomplete. Again, NMED is aware that the inventory is incomplete; but it is adequate for remedy selection.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.65	WERC describes the MWL inventory as: Anecdotal testimony in the records regarding disposal of non-stabilized free liquids. The location of many dangerous materials appears to be unknown such as nuclear fuel canisters and radioactive sealed sources. The amount of hazardous waste is not well understood, i.e.; inventory does not match characterization of Pit 35 and Trench B and C. Volumes of waste vary widely in different sections of the report. Meanings of words “debris” and “all waste” in the CMS are	R14	The meaning of the terms “all waste” and “debris” as used in the CMS should be taken as their ordinary meanings. See also Responses R5, R8, and R13.	No

Commenter ID	Commenter/ Affiliation	Topic Area	Comment Number	Comment Summary	NMED Response Number	NMED Response	Revised Final Permit? Yes or No
				uncertain. The commenter requests that NMED responds to these issues.			
M	Citizen, Steve Dapra		13.4	The commenter indicated that although SNL does not know the identity of every item in the MWL, there is a thorough inventory of the Landfill's contents. No previously unknown items have been detected, either from the soil, water, or air sampling; or by radiation detection instruments. There is no reason to believe that any of the possibly unknown items are harmful. (See also Summary of the MWL, p.2, par. 4.)	R15	NMED agrees that samples of air, ground water, surface soil, and subsurface soil were analyzed for a wide variety of chemical and radiological parameters. Hazardous or radioactive contaminants released from the MWL are few and include low levels of tritium, radon, and cadmium. However, that other hazardous or radioactive contaminants were not detected as releases does not mean that other wastes/contaminants within the Landfill are of no harm to the human health and the environment should they ever migrate from the Landfill. This is one reason why it is prudent to continue monitor the MWL. See also Response R8.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Truck Trailer	1.29	"Trailer was buried in Trench F, deeper than the picture shows. The trailer was not a flatbed, but a box-type with doors, which was backed down the trench, unhooked and the truck drove out". The commenter asked if NMED knows of any box-type trailers that were disposed of at MWL. SNL responded by stating that no box-type trailers were buried in the Landfill. The commenter believes that this raises	R16	NMED has a copy of a photograph of the truck trailer. The truck trailer is of the flat-bed variety.	No

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				questions regarding the complete inventory at the Landfill.			
A	For Citizen Action, Sue Dayton, 2nd submittal	Off site tritium monitoring and source	1.9	"They have a feel for what is in there but the numbers are questionable…use vegetation as indicator, succulent plants work best. Elevated concentrations [found] up to 5 km away. (Interview the Donna Hartzel to G.L, 1989 (FOIA).) The commenter asked if NMED has reviewed this document and if NMED has conducted any off-site radiological monitoring to detect tritium in vegetation. Does the statement in the document mean that biological transport of tritium has been occurring for years? What are the elevated concentrations of tritium referred to in this report and is this still occurring. What does the term "have a feel for" mean in terms of describing the MWL inventory?	R17	NMED has been aware for many years that vegetation growing on and near the MWL contains small amounts of tritium, as tritium moves with water and has been released from the Landfill. NMED has not reviewed this particular report and has not collected and analyzed samples of vegetation at the MWL. However, the levels of tritium flux from the Landfill do not demonstrate that an unacceptable risk to the environment occurs at the Landfill.	No
A	For Citizen Action, Sue Dayton, 2nd Submittal	Reactor vessel plates	1.12	The commenter indicated that "SP-4 contains what is purported to be reactor vessel plates. Very little is known about these plates, their origin, number, size or configuration." (Memo from Jerry Pease/SNL to Mark Jackson, John Gould/DOE/KAO, 1997 (FOIA 22).) The commenter asked if there is still little known about the reactor vessel plates.	R18	NMED is only aware of what was reported in the inventory. As indicated in the inventory, sample pieces of reactor vessel plates, with radioactivity dose levels of 2 rem/hour on contact, are buried in pit SP-4. The plates originated from a reactor that was decommissioned in 1978, which once existed at a location in the San Fernando Valley. Sample sections are reported to be 6-ft long. Reactor vessel plates not retained as	No

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						samples were disposed of at Beatty, Nevada. SP-4 is concrete lined, the only lined pit at the MWL.	
A	For Citizen Action, Sue Dayton, 2nd submittal	Liquids and Liquid Waste	1.13	"Radioactivity contaminated waste water was discharged into one of the trenches during the month of 1967; the water could potentially have increased the migration rate of contamination through the soil column towards the aquifer." (SNL ER Program Information Sheet FOIA, 1987 (FOIA 90).) The commenter indicated that SNL maintains that no liquids were disposed of in the MWL, and those that were disposed of were containerized. Does NMED agree that this statement from the FOIA document 90 refers to liquid wastewater that is not containerized?	R19	In 1967, approximately 204,000 gallons of coolant wastewater from the SNL Engineering Reactor Facility was discharged into Trench D. This wastewater, a liquid, was not containerized prior to its disposal into the MWL. There is no evidence that the disposal of this wastewater increased the migration rates of any hazardous or radioactive constituents, except possibly that for tritium, which moves readily with water. Sampling and analysis of soil beneath Trench D during the installation of ground-water monitoring well MWL-MW4 show that only small levels of tritium have been released from this trench. No other contaminants besides tritium were found below the trench. It is clear to NMED that the MWL received some liquid wastes.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.16	"Characteristics of contamination: disposal in unlined pits and trenches; contaminated oils, liquids and solvents; solid and liquid wastes." The commenter indicated that SNL maintains that no liquid wastes were disposed of at the MWL, this statement refutes that claim. The commenter asked that NMED respond to the comment.	R19	See Response R19.	No

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A	For Citizen Action, Sue Dayton, 2nd submittal		1.27	"After 1975, SNL required liquid wastes to be solidified prior to disposal. Before this time unsolidified radioactive liquids, whether containerized or not were disposed of in the MWL. (ER Program/Site Health and safety Plan, 1992 (FOIA 115,116).) The commenter points out that this conflicts with SNL statement that no liquids were disposed of at MWL. The commenter wants NMED to comment on this.	R19	See Response R19.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.18	In a 1989 interview with SNL employee Donna Hartzel, she states "Two summers ago workers found 5 feet of water in nearby completed trench. Workers pumped water into the trench to the west." The commenter asked if the above quote supports the DOE/SNL assertion that workers were not allowed to dispose of liquids into MWL.	R19	See Response R19.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.20	"Organic wastes were disposed of at the MWL beginning in 1959 and continued until 1962 when the Chemical Waste Landfill (CWL) was opened." (ER Program/Site Health and Safety Plan, 1992 (FOIA 116).) Uncontainerized liquids were disposed of at the CWL ; it makes sense that liquids were disposed of at MWL prior to being sent to CWL. Why would	R20	There is abundant evidence that liquid wastes were commonly disposed of in the CWL. SNL has admitted to this practice. Although the waste disposal practices between the two landfills appear to be inconsistent, NMED does not know the reason why this was the case. Each landfill must be assessed on a site-by-site basis.	No

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				SNL indicate that liquids were solidified at MWL, and not at CWL.			
M	Citizen , Steve Dapra		13.1	The commenter indicated that there are no free liquids in the MWL. According to the Summary of MWL, Oct. 3, 2002, p. 2, par. 2: Disposal of free liquids was not allowed at the MWL. Liquids such as acids, bases, and solvents were solidified with commercially available agents such as Aquaset, Safe-T-Set, Petroset, vermiculite, marble chips, or yellow powder before containerization and disposal.	R21	The commenter is referring to information provided by the SNL, where they make a general statement that liquids were solidified prior to their disposal in the MWL. As mentioned above, it is clear to the NMED that the MWL received some liquid wastes.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Soil Gas Sampling	1.19	'Incompatible and un-neutralized ignitable and reactive gases may have been placed in pits and trenches. Subsequent reactions generate hazardous vapors which could penetrate soil caps and be released. Potential for release to air from pits 24-30 is high". (SNL ER Program Information Sheet, FOIA, 1992 (FOIA 90).) The commenter asked if it was true that no active soil gas surveys have been conducted in classified pits 24-30.	R22	Passive soil-gas surveys were done in the area of the pits. Active soil-gas surveys were conducted near the pits on all sides. The pits in the classified area of the MWL were also investigated by the sampling and analysis of soil beneath them via angled boreholes. NMED is satisfied that the SNL efforts to detect releases of contaminants from the pits in the classified area of the MWL are adequate. The only contaminants released from this area of the Landfill are low levels of tritium and radon.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Fuel Canisters	1.21	"Based on interviews with TA5 personnel there may be hazardous constituents in the canisters. As little process knowledge, there have	R23	The canisters that formerly contained samples of oxide reactor fuel may have contained hazardous components such as sodium and heavy metals. NMED has	No

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				been no controls since it was generated….” The commenter asked what those statements mean.		investigated this matter and has determined that the fuel rod samples were removed from the canisters prior to the disposal of the canisters in the MWL.	
M	Citizen, Steve Dapra		13.7	The commenter indicated that certain parties claimed that fuel rods are buried in the MWL. This claim is answered in a letter from Ron Curry, Secretary of New Mexico Environment Department to Dr. Maurice Weisberg, M.D, (August 22, 2003). The claim is both false and unreasonable. Fuel rods are extremely expensive and they would not be buried.	R23	See Response R23.	No
N	Citizen, Maurice Weisburg, M.D.		14.1	The commenter indicated that his principal concerns involve the possible presence of high-level wastes buried with metal containers that have undergone irradiation in onsite research reactors in TA-5. Related to that concern is an SNL document dated October 15,1993 “Site Team Report on Spent Fuels”, which is an assessment of the vulnerability of storage of irradiated nuclear fuels, both fresh as well as previously irradiated. In only a few instances are these materials referred as spend fuels or high-level wastes. Instead the term used is “RINM” (reactor irradiated nuclear material). The statement on page 3 of the executive summary states	R24	NMED believes that many of the steel containers within the Landfill have or will rust. Any liquids contained within the steel containers could migrate from the Landfill if conditions are appropriate; however, this does not necessarily mean that any release would pose unacceptable risk to human health and the environment. Thus, NMED agrees that continued monitoring of the vadose zone and the ground water is necessary to ensure protection of human health and the environment. With respect to comments on reactor irradiated nuclear material and the Sandia Pulse Reactor, this issue is not directly related to the MWL and will not be discussed further in these responses.	No

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				that " there is no spent reactor fuel onsite [disposed in MWL] from the SNL reactors." This would seem misleading since both fresh and pre-irradiated samples were used and exposed in the core for different time periods. Storage of RINM form experiments in one instance was into 32-foot deep holes with steel sides and an open gravel filled bottom. For storage after use, Sandia Pulse Reactor had 19 such storage areas. The commenter expressed concern that 11 years later we are still talking about long-term storage, with no approved method of disposal. The commenter is concerned about leaking from the unit into the vadose zone and ground water, and is concerned about the Albuquerque sole aquifer. The commenter is also concerned about the corrosion of the metal containers. He asked about the follow-up on the Tiger Team, and what findings were presented.		See also Response R23.	
A	For Citizen Action, Sue Dayton, 2nd submittal	1984 Landfill Excavation Estimate	1.30	The commenter indicated that in 1984 George Tucker of SNL made an estimate for the clean up of the MWL. The cost estimate included protective equipment, with the waste being shipped to the Nevada Test site. The cost estimate assumed "a lot of manual labor". The total in 1984 was	R25	The risk assessment demonstrated that it is not protective of workers to excavate the Landfill at this time because of the high level of risk associated with exposure to radioactive wastes. Costs have escalated since 1984, but it would be possible to excavate the MWL in the future should it become warranted. SNL is required by the final order issued by the	No

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				$181,570,000. The commenter asked why MWL couldn't be cleaned up today based on the above excavation scenario and the cost estimates performed in 1984.		NMED Secretary to reevaluate the performance of the Landfill cover/bio-intrusion barrier and the feasibility of excavation every five years.	
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Animal/plant transport of contaminants	1.31	The commenter stated that buried waste can be mobilized to the ground surface through plant roots and animals and insect burrowing can dramatically increase infiltration of water into the Landfill with covers as thick as those proposed.	R26	NMED agrees that bio-intrusion via burrowing animals and roots can cause contaminants to migrate to the ground surface, and can create open spaces that will locally increase cover permeability. Once on the surface, contaminants can continue to migrate by the activities of other animals, and by wind erosion and surface water erosion/solution. The degree of contamination that could be brought to the surface by plant roots or burrowing animals is case specific, depending much on the size and chemical/physical characteristics of the waste, and the size and burrowing habits of the animals. Water erosion is probably the most significant threat to cover integrity in terms of creating exposure to waste over a short time frame. All of these factors form the basis for NMED to require maintenance of the cover and continued monitoring of surface soil. In the case of the MWL, bio-intrusion is not expected to play a major role in the migration of contaminants because the wastes are relatively insoluble and the debris items mostly large in size. The required bio-barrier should limit the ability of small burrowing animals to	No

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						bring contaminants/debris to the surface, and should help limit root penetration.	
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D		1.32	The commenter indicated that vertical transport of contaminants to the ground surface by biota may be small on a short time scale, but over many decades these processes may become dominant in mobilizing buried wastes.	R26	See Response R26	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph. D.		1.33	The commenter indicated that Dr. Hakonson cites a study by the Pacific Northwest Laboratory that suggests radiological doses that result from bio-intrusion into low level waste landfills located in arid areas can ultimately over time become as high as doses calculated from human intrusion.	R26	See Response R26.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.		1.36	The commenter indicated that under the right conditions the roots of all types of vegetation have the ability to extend several meters into the soil and transport contaminants to the surface.	R26	See Response R26.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments		1.39	The commenter indicated that once contaminants are transported to ground surface a complex distribution process occurs that can result in widespread transport of	R26	See Response R26.	No

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	by Tom Hakonson, Ph.D.			contaminants across the Landfill surface to off-site areas.			
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.		1.38	The commenter states that SNL's conclusion that the waste has not been mobilized to the ground surface by animals is poorly supported as it is 1) based on soil sampling taken (in Part) from areas of the Landfill recently backfilled; 2) sampling was coarse in resolution; 3) samples were non-random in space; and 4) samples purposely did not include disturbed areas created by burrowing animals.	R27	Although the commenter criticizes surface soil sampling at the MWL because in his opinion it was not random, he also recommends the collection of samples from biased sampling locations (animal burrows and older parts of the Landfill). There have been several surface soil sampling events conducted at the MWL and these efforts have been adequate. For future monitoring, NMED believes that the collection and analysis of soil samples from burrows and ant mounds should be done as suggested by this commenter.	No
F	Citizen, Carl White, Dept. of Biology, UNM		6.1	The commenter stated that rodents are present on the site, and that they can burrow allowing water infiltration. The rodents can also bring up materials out of the Landfill, and then they would be consumed by other animals and predators, which would distribute any contaminates. The commenter believes it is foolish to discard the bio-intrusion barrier.	R28	NMED agrees that a bio-intrusion barrier is necessary at the MWL to minimize the impact of burrowing animals and reduce the penetration of plant roots. In addition, NMED intends for the SNL to maintain the cover system and monitor animal burrows for any future migration of contaminants.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments	Evapotranspiration Cap	1.35	The commenter indicated that both cap designs (Dwyer et, al. SNL Environmental Restoration Group) do a credible job of analyzing the evapotranspiration (ET) cover, and	R29	NMED agrees that an ET, with the addition of a bio-barrier, should provide adequate protection of ground water. NMED also agrees that it remains necessary to continue monitoring the	No

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	by Tom Hakonson, Ph.D.			in the reviewer's opinion both cap designs will provide adequate protection of ground water from contaminants assuming the site is diligently monitored and maintained throughout the post-closure monitoring period while assuming the surface pathway proves to be unimportant in contributing doses to humans.		ground water as well as the vadose zone and surface soil to ensure that any future migration of contaminants will not occur at levels that pose unacceptable risk. Monitoring of surface soil will ensure that the surface will not become an unrecognized pathway for contaminants that would threaten human health or the environment.	
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Vapor transport through evapotranspiration Cap	1.37	The commenter indicated that while an ET cap can minimize soil moisture it could contribute to vapor phase transport of volatiles.	R30	Vapor transport can occur through any ET cover. However, in the case of the MWL, active soil-gas surveys demonstrate that vapors of total volatile organic compounds within and beneath the Landfill are low, and do not threaten human health or the environment, including ground water. Tritium and radon are also present at the MWL in the form of gases. However, the levels of tritium and radon measured at the surface are also sufficiently low such that they do not threaten the environment or human health.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Human Intrusion	1.40	The commenter stated that human intrusion scenarios should take a conservative approach such as the loss of institutional controls under a subsistence farmer scenario.	R31	It appears that the commenter is referring to the NRC regulation in 40 Code of Federal Regulations (CFR) Section 61.59(b), which is not applicable to RCRA. Under EPA regulations, there is no requirement that a facility must assume a loss of institutional controls and evaluate a subsistence farming scenario at some time in the future (for example 100	No

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						years in the future). Nonetheless, NMED intends to enforce institutional controls through SNL's RCRA permit as long as such controls are needed.	
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments		1.53	The commenter suggests that SNL follow recommendation from EPA and DOE that SNL conduct a risk assessment that includes "no administrative controls in place after 100 years (pp. 12, 13).	R31	See Response R31	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Climate Change	1.41	The commenter stated that changes in climate could radically affect the integrity of the cap.	R32	SNL is required by order of the NMED Secretary to reevaluate the performance of the evapotranspiration cover every five years. If significant climatic changes were to occur during this period that would adversely affect the performance of the cover system, NMED can impose additional requirements or a new remedy for the MWL to ensure protection of human health and the environment.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Moisture Measurements	1.42	The commenter indicated that SNL's proposed plan to use a neutron moisture gauge (NMG) are vague on how the monitoring data will be used to conclude that percolation is or is not occurring. NMG is labor intensive (data must be downloaded and managed) and the NMG must be calibrated to soil (difficult when layered soils are involved), and reliable measurements are limited to	R33	NMGs have been shown to be an effective tool to monitor soil moisture. NMED agrees that specific calibrations must be conducted and that correction factors may need to be applied to account for changes in soil bulk density. The final order issued by the NMED Secretary requires that SNL submit for MNED approval a long-term monitoring plan, and a list of "triggers" which will set in motion additional testing or the implementation of an additional or	No

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				volumetric water content above 5% the NMG integrates moisture content over a relatively large area making it difficult to pinpoint the specific zone depth being interrogated. NMG provides instantaneous estimates of soil moisture so that measuring after precipitation is critical. NMG should not be used as an early warning system.		different remedy. Finally, NMED intends to require environmental monitoring beyond that of soil moisture. Thus, NMG and soil moisture will not be used as the sole early warning system.	
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.	Closure/post-closure	1.34	The commenter stated that one of the more important deficiencies in Sandia National Lab's closure plan proposed for the MWL is the assumption that vertical and horizontal transport of contaminants resulting from biological processes is not an important contributor to exposure pathways.	R34	The document reviewed by Dr. Hakonson was not a closure plan, which was the reason that details concerning long-term monitoring and maintenance were not provided in the document. Instead, the document was intended to describe chiefly the design and construction quality assurance of the proposed ET cover. See also Response R36.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.		1.43	The commenter stated that little or no planning has been done on the post-closure phase of the Mixed Waste Landfill closure and there is no contingency plan should the ET cap not perform as predicted.	R35	NMED has always intended that post-closure care, including monitoring, and maintenance, be addressed following selection of a remedy for the MWL. This is based on the fact that the details for such monitoring/maintenance are dependent on the chosen remedy. The final order issued by the NMED Secretary requires a long-term monitoring and maintenance plan (including the proposal for contingency options) to be submitted for approval by the NMED within 180	No

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						days of completion of the remedy (ET cover with bio-barrier).	
A	For Citizen Action, Sue Dayton, 2nd submittal, comments by Tom Hakonson, Ph.D.		1.44	Dr. Tom Hakonson has the following recommendations: 1) Any post-closure plan should provide measurements on all possible migration pathways that include vadose zone transport, soil sampling for surface contaminants and biological transport; 2) Soil surveys should be required in undisturbed areas closed early in the Landfill operation with comprehensive long-term sampling program after MWL is closed consisting of sampling of surface soils and biota; 3) A comprehensive sampling plan should be required that reflects the inventory of the contaminants in the Landfill, not just tritium; 4) The use of bio-intrusion barriers to keep animals from burrowing into the Landfill has had mixed reviews in terms of effectiveness, a wire mesh type barrier proposed by Dwyer is the best choice for the MWL in terms of effectiveness. The commenter would like NMED to address these recommendations.	R36	NMED agrees that a surface soil, subsurface soil, soil vapor, and ground water monitoring program must be established to ensure early detection of any future migration of contaminants. The scope of the exact program is to be detailed in the long-term monitoring and maintenance plan required by the RCRA permit as a result of the Secretary's final order. The NMED also agrees that the sampling plan should require a wide range of contaminants to be analyzed for, and not limit the analytes solely to tritium. Sampling, in part, should include the sampling of animal burrows and ant mounds. However, surface soil sampling should be conducted in every area of the MWL, and not be limited to older portions of the Landfill. The NMED prefers a rock bio-intrusion barrier to that of a wire mesh because the NMED believes that a rock barrier is likely to last longer and will not corrode and release heavy metals into the environment. Finally, NMED agrees that a bio-intrusion barrier is necessary.	No
A	For Citizen Ac For Citizen	Baseline Risk Assessment	1.45	The commenter indicated that a new baseline risk assessment for the MWL has not been conducted	R37	NMED accepts the baseline risk assessments as presented in the Phase 2 RFI and the CMS Reports. NMED	No

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	Action, Sue Dayton, 2nd submittal			by SNL due to the uncertainties of the inventory and source terms. This was verified by Tommy Tharp/SNL at a public meeting of the "WERC Independent Technical Peer Review of the Working Draft CMS for MWL", in December, 2002. This was also mentioned in the WERC Peer Review Report. The commenter would like NMED to comment on this.		acknowledges that there are some uncertainties associated with the contents of the Landfill. However, the goal of a baseline risk assessment is to assess risk to human health and the environment under current conditions, meaning contamination that has been released from the MWL. Therefore, uncertainties concerning contaminants that have not been released from the MWL do not affect the risk assessment. For additional information and the purpose of the baseline risk assessment, see EPA's Office of Solid and Hazardous Waste (OSWER) Directive No. 9355.0-30. See HO FOF/COL, ¶¶ 109-27.	
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Suspect Data	1.46	Resnikoff "Risk Screening Review of SNL Risk Assessment for MWL, SWMU 76" revealed numerous problems with SNL's methodology in its risk assessment for the MWL which are addressed in several comments. First, the commenter indicated that SNL had results for measurements of plutonium at 3 different labs, and that samples with plutonium detections were discarded and those without detections were kept because they were more favorable data (p. 9).	R38	Questionable laboratory results for plutonium-238 and plutonium-239/240 were obtained from several core samples recovered during the drilling of the borehole for well MWL- MW4. In response, NMED required SNL to repeat the analysis and in addition, NMED obtained split samples for an independent analysis. Results from the split sampling effort indicated that there had not been a release of plutonium into the subsurface in the vicinity of MWL-MW4. NMED carefully scrutinized the environmental and quality control data for the MWL and considers the data to be overall of acceptable quality, as did WERC.	No

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A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments		1.47	The commenter indicated that SNL discarded samples showing high concentration of constituents of concern and kept samples concentrations with false positives (p. 9)	R38	See Response R38.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, combining chemical and radiological risk	1.48	The commenter stated that radionuclide and cancer risk should be combined, not subtracted as SNL has done in its risk assessment (pp. 11, 12).	R39	NMED does not concur that the cancer and radiological risks were subtracted from each other, but rather the risks were evaluated independently as was the practice at the time the risk assessment was done. Currently, the EPA treats radiological contaminants as carcinogens, and calculates the risk differently as compared to the past. However, in the case of the MWL, the risk will not be sufficiently different if calculated using the newer method to require a different remedy for the Landfill. See also HO Report, ¶¶ 109-27.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Children vs adults	1.49	The commenter indicated that SNL's calculations apply only to an adult male and has used outdated conversion factors instead of newer dose conversion factors (DCF) that evaluate dose to children as well as adults (pp. 11, 12).	R40	NMED believes that DCFs were appropriately applied, as the site will be restricted to industrial use. The evaluation of an adult only is reasonable in this case. See also HO FOF/COL, ¶¶ 109-27.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr.	Filtered Water Samples	1.50	The commenter indicated there are questions which remain regarding the filtering of water samples by SNL (p. 8).	R41	NMED agrees that use of filtered water samples could result in an underestimation of the total levels of metals and radionuclides present in the ground water. However, most samples	No

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	Resnikoff's comments					were unfiltered in both the field and laboratory, and NMED has obtained and analyzed unfiltered water samples. In addition, no data from filtered water samples for either metals or radionuclides were used in the risk assessments.	
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Phase 2 RFI Report	1.55	The commenter states that the RFI Phase 2 conducted by SNL concluded that MWL contaminants "present little risk to ground water or as air emissions to potential receptors". This conclusion was disputed in a memo sent to Will Moats by Barbara Toth (August 11, 1999); in that memo she noted numerous deficiencies in the SNL risk assessment. The letter states "Surface/subsurface soil erosion due to surface/subsurface water movement and windblown contaminant transport acts as the primary means for contaminant migration out of the MWL to the surrounding environment… this subsequently threatens human health and the environment". The commenter asked if NMED agrees with this assessment of the MWL by Ms. Toth.	R42	The memorandum in question was written early in Ms. Toth's evaluation of the MWL risk assessment. Ms. Toth is a former employee of the NMED. Mr. Moats was informed by Ms. Toth prior to her departure from the NMED that given the lack of appreciable contaminant releases, any changes she would recommend for the risk assessment would not change the overall outcome of the risk assessment. She concluded that the MWL did not pose unacceptable risk to human health and the environment. After Ms. Toth's departure, two other experts have reviewed the risk assessment on behalf of the NMED and have independently determined that the risk assessment is adequate. Additionally, a risk assessor working with the WERC concluded that the risk assessment was technically adequate; however, it was also overly conservative because it took into account a number of contaminants which had not been actually released into the environment. See also HO FOF/COL, pp 109-27.	No

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A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Cr-VI versus Cr-III	1.56	The commenter asked why the RFI Phase 2 states all chromium contamination at MWL is chromium III, the most conservative type. The commenter asked if NMED knows the type of all chromium contaminants at MWL.	R43	NMED has previously provided comments to SNL concerning hexavalent (Cr-VI) versus trivalent (Cr-III) chromium. NMED concurs that the assumption that all chromium is trivalent chrome is not a conservative assumption, but rather is the least conservative approach. The inventory for the MWL does not specifically list any Cr-VI-contaminated wastes, suggesting that little, if any, Cr-VI wastes were disposed of in the Landfill. Sampling and analysis of soil beneath the trenches and pits did not find evidence of a chromium release. Finally, there is no evidence of a release of Cr-VI in filtered samples of ground water.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Inhalation of metals	1.57	The commenter stated that SNL claims the inhalation pathway doesn't apply to metals due to their "lack of volatility". This was found to be incorrect as metals can attach to soil particles and be inhaled. The commenter asked if SNL's risk assessment included inhalation pathway of heavy metals.	R44	NMED agrees that inhalation of metals in soil does occur and should be evaluated using a particulate emission factor (PEF). SNL did consider the inhalation of both vapor phase and particulate airborne compounds (see Appendix I, Table 1 and the soil inhalation equation presented on page I-85).	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, sources of toxicological parameters	1.58	The commenter states that NMED recommends SNL use EPA's IRIS and HEAST or EPA's NCEA to determine toxicological parameters. The commenter asked if information from these sources	R45	Toxicity data from these databases were applied in the risk assessments (refer to Table 13, Appendix I).	No

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				been integrated into the risk assessment.			
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Use of NMED risk parameters	1.59	The memo recommends SNL use exposure parameter values recommended by HRMB/NMED; the commenter asked if these have been integrated into the SNL risk assessment.	R46	The recommended exposure parameters were applied in the risk assessments. Refer to Tables 2 and 3 in Appendix I of the CMS.	No
A	For Citizen Action, Sue Dayton, 2nd submittal, Dr. Resnikoff's comments	Risk Assessment, Exposure parameters	1.60	The memo recommends exposure parameter values be used to evaluate exposure and risk from dermal contact with contaminants in soil under industrial, residential and recreational land use scenarios. The commenter asked if these had been done.	R47	SNL identified the dermal contact pathway as a potential nonradiological organic constituent pathway in all the land use scenarios. However, the exposure via this pathway was considered insignificant and excluded from the final risk analyses. However, potential risks associated with the dermal pathway were addressed in the uncertainty analysis.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Risk Assessment Risks for CMS alternatives	1.61	The commenter indicates that at a January 31, 2003 "WERC Independent Technical Peer Review of the "Working Draft CMS" for MWL it was pointed out by SNL staff that these risk assessments were only relative to the different remedies being investigated and did not relate directly to the predicted risk. This issue needs to be clarified as it only adds uncertainty to the overall remedy if the risk assessment is not modeled relative to a conservative model of the site	R48	Although several staff members were present, NMED has no recollection of the discussion mentioned in the comment. However, NMED can offer that the CMS provides a baseline risk assessment and a risk assessment for each proposed alternative. The latter assessments are done to determine the long-term and short-term risks of each of the remedial alternatives under evaluation. This is a standard procedure for conducting a CMS.	No

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				situation. The commenter asked for NMED to comment on this.			
A	For Citizen Action, Sue Dayton, 2nd submittal	Risk Assessment, waste vs releases	1.62	At the same meeting it was stated that "the risk assessment is based on known releases from the site…several questions remained unanswered during the meeting about the amount and type of waste in the MWL". The commenter would like NMED to respond to this.	R49	Pursuant to EPA Directive OSWER 9355.0-30, a risk assessment does not have to be conducted on contents of landfill but rather only on the contaminants released. See also HO FOF/COL, ¶¶ 109-27.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Risk Assessment, Sensitivity analysis	1.63	At the same meeting it was stated, "It would seem that a sensitivity analysis of the risk assessment would give some indication of the significance of this concern especially in light of the relative nature of the assessment noted above. (WERC executive summary, p.v.)	R50	A sensitively analysis of the contents of the MWL is not necessary, as direct exposure to these contents would result in unacceptable risk.	No
A	For Citizen Action, Sue Dayton, 2nd submittal		1.69	WERC addresses SNL's risk analysis and recommends that SNL conduct a sensitivity analysis. A problem is SNL's consistent "bending" of information to favor its preferred alternative. To correct this situation it would behoove the NMED to require DOE to conduct an independent sensitivity analysis. The commenter asked that the uncertainties related to the inventory of the Landfill be addressed in a risk assessment that	R50	See Response R50; see also HO FOF/COL, ¶¶ 109-27.	No

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				includes all waste products rather than the two contaminants that have been found to migrate from the Landfill.			
A	For Citizen Action, Sue Dayton, 2nd submittal	Temporary cover with future excavation	1.66	WERC strongly recommends that because the "uncertainly of the contents in the MWL could eventually lead to the requirement of excavation" SNL include an alternative that involves a temporary cap with future excavation.	R51	Although the CMS did not address this suggested remedial alternative directly, one can combine the capping and excavation alternatives presented in the CMS and obtain this information.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Onsite disposal	1.67	WERC recommends that SNL include an onsite disposal facility as an alternative for waste. SNL has buildings that could be utilized for this. WERC also recommends including an option for RCRA approved landfill and an onsite retrievable storage unit. The commenter requests that NMED require SNL to include these options as well as a scenario for the construction of a corrective action management unit (CAMU).	R52	The CMS Report addressed a RCRA cap option and onsite storage with off-site disposal. Although several buildings are located in the vicinity of the MWL, NMED does not know whether these buildings would become available to store waste in the future. Even if they were available, it seems doubtful that the existing buildings would have adequate capacity to store the volume of waste that would be generated by excavation of the MWL. Additionally, the existing buildings would have to be reconfigured for waste storage, which possibly could cost as much or more than erecting new structures to store waste. One potential problem with onsite storage of mixed waste is that RCRA prohibits the storage of such wastes beyond 1 year (with a possible extension of 1 additional year), unless the waste meets or can be	No

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						treated to meet the standards at 20.4.1.800 NMAC incorporating 40 CFR 268.40. Although a CAMU was not evaluated in the CMS, given the similar size of the CWL and the MWL, the costs and construction logistics for a CAMU would likely be on the order of that of the existing CAMU located next to the CWL.	
A	For Citizen Action, Sue Dayton, 2nd submittal	Soil Vapor Monitoring /Extraction	1.68	WERC recommends that SNL include a soil vapor extraction alternative as part of a long-term monitoring strategy.	R53	NMED agrees that a soil vapor monitoring system could be designed with the option to be convert it into a soil vapor extraction system should it become necessary in the future.	No
A	For Citizen Action, Sue Dayton, 2nd submittal	Fate and transport model	1.70	WERC recommends that SNL conduct a numerical fate and transport model for simulation of the MWL. The data from this could then be integrated into a risk assessment that considers the sensitivities of various options for the MWL. The commenter asked if NMED will require SNL to develop such a model.	R54	The final order issued by the NMED Secretary requires the SNL to submit to the NMED for approval a fate and transport model.	Yes
A	For Citizen Action, Sue Dayton, 2nd submittal	General Comments	1.71	The commenter indicated that in 2001 Citizen Action asked the Secretary of NMED to issue an order to SNL to complete a CMS for the MWL. Citizen Action believes that the plan to cover the Landfill with 3 feet of dirt was not	R55	The CMS evaluated several potential remedies, including the SNL preferred remedy of covering the Landfill and excavation. The remedy of a cover, with a bio-barrier, was shown to be protective of human health and the environment, to be cost-effective, and to offered	No

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				sufficient.		acceptable short-term and long-term risk; this remedial alternative meets the requirements of RCRA. Under RCRA, so long as the remedy is protective of human health and the environment; there is no requirement that the most protective or most expensive remedy be selected. In the case of the MWL, the fact that contaminants currently released into the environment pose no unacceptable risk, combined with the low potential for future significant releases, substantiated the cover remedy selected. See also HO FOF/COL and Report.	
A	For Citizen Action, Sue Dayton, 2nd submittal	General Comments	1.72	From the beginning SNL has downplayed the risk of the MWL. Numerous independent experts, including those who participated in WERC, have suggested that information on MWL is incomplete, biased, and disingenuous. They believe the term “Accelerated Clean Up” is misleading because it is not really a clean up.	R56	WERC as a group has agreed with NMED that data quality is acceptable and that data are sufficiently complete to make a decision on a remedy for the MWL. Split sampling results and the review of a sample of waste disposal records do not support a conclusion that the SNL has been disingenuous with data, or has held back critical data needed to make an informed decision. NMED is unaware of WERC’s opinion of the term “Accelerated Clean Up”. It is NMED’s responsibility to ensure that the clean up is undertaken in accordance with RCRA requirements; SNL’s terminology has no impact on RCRA’s requirements.	No
A	For Citizen Action, Sue Dayton, 2nd	General Comments	1.73	The commenter believes that the CMS failed to present a full range of options for the waste; did not	R57	Although SNL is not required to include in the CMS recommendations of third parties, SNL did include a number of	No

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	submittal			present the true costs of an excavation scenario; failed to produce a baseline risk assessment; failed to include historical data that relates directly to risk; failed to consider the full inventory of the Landfill and numerous uncertainties associated with the Landfill; and failed to consider recommendations of independent reviews that attempt to find an appropriate solution for this waste site.		important recommendations from WERC. The CMS Report presented an adequate number of alternatives, including excavation, the preferred alternative of Citizen Action. The cost data provided in the CMS are adequate for the intended purpose; the cost data represent estimates only, and are not intended to represent detailed cost estimates in support of procuring contracts. Whether the cost estimates are precisely accurate or not, the excavation alternatives will undoubtedly be much more expensive than the capping alternatives. NMED finds that the cost estimates for the alternatives, including the excavation alternatives, are within the proper order of magnitude. See also HO FOF/COL and Report. The CMS and the Phase 2 RFI Reports include a baseline risk assessment. Uncertainties with respect to the investigation of any solid waste management unit will always exist because sampling by definition means that only a sample of soil is analyzed for contaminants not all of the soil that exists at the site. Technical expertise and professional judgment must necessarily be used to make a decision on the adequacy of site investigations. See also Responses R5, R6, R7, R8, R48, and R49.	

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A	For Citizen Action, Sue Dayton, 2nd submittal	General Comments	1.74	The commenter believes that considering the volume of scientific knowledge available at SNL, the CMS is an embarrassing and biased document, which puts the public at risk.	R58	NMED does not agree with this comment. The remedy selected by NMED was one of the alternatives evaluated as part of the CMS. The CMS Report contained considerable detail on a fair number of potential remedial alternatives, and was found by the NMED to be adequate for the purpose of selecting a remedy that is protective of human health and the environment.	No
B	Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Janet Greenwald	Above Ground Retrievable Storage	2.1	The commenter believes that the wastes in the MWL should be placed in above ground retrievable storage, located close to where the wastes are now buried.	R59	The CMS Report addressed this potential remedial alternative. Above ground retrievable storage was not selected because of the high cost, the risk to workers, and the potential that hazardous wastes would be excavated that currently have no treatment/disposal options.	No
B	Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Janet Greenwald	Long half life of plutonium	2.2	The commenter is concerned about the disposal of plutonium that has a long half-life at the Landfill, and the length of time that governments are around. The commenter is concerned that the buried plutonium will outlast the government.	R60	It is correct that plutonium isotopes have long half-lives. However, it is likely that RCRA or some successor statute will ensure protection of human health and the environment as long as the MWL exists.	No

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B	Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Janet Greenwald	Future funding for excavation	2.3	The commenter urges NMED to clean up the MWL now; she is concerned about shrinking government budgets, and that addressing the clean up later may be too late. The commenter is concerned about the contamination of the land and water and nearby communities.	R61	Current releases of contaminants and expected future releases of contaminants do not pose and are not expected to pose unacceptable risk to the land, ground water, or the community. The evidence does not presently support excavation of the Landfill in the near term due to the unacceptable risk to onsite workers and because the cover with biobarrier is protective.	No
C	Anonymous Citizen	Capping and Monitoring the MWL	3.1	The commenter believes that capping and long-term monitoring is the correct choice. The commenter is concerned about the cost, the risk to workers and the waste management issues, which the commenter believes are substantial if the Landfill is excavated at this time.	R62	NMED generally agrees with this comment. However, NMED will not allow any remedy to be implemented that is not protective of human health and the environment, regardless of costs.	No
D	Citizen, Lois Chemistruct	No Further Action (NFA)	4.1	The commenter would like to see NFA at this time and a vegetative soil cover	R63	NMED believes that granting NFA status without implementing the selected remedy does not provide adequate protection of human health and the environment. For modest additional cost and effort, the facility can provide a more protective landfill cover with a higher degree of predictable performance. Also, compared to what is proposed in the Phase 2 RFI Report, NMED believes that more robust monitoring and post-closure care of the Landfill are needed to ensure protection of human health and the environment.	No

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						The selected remedy, an evapotranspiration cap with bio-barrier, is a type of vegetative soil cover.	
E	Citizen, JoAnne Rampone	Opposed to Excavation of MWL	5.1	The commenter expressed concern about any excavation taking place. The commenter was concerned about worker exposure, and is concerned about the unknown chemicals and the worker digging them up. The commenter asked that she be kept informed.	R64	NMED agrees that excavating the MWL in the near-term poses unacceptable risk to site workers. In the final order issued by the NMED Secretary, the public will be notified and given an opportunity to comment on all important documents related to corrective action at the MWL.	Yes. The final permit requires a public participa-tion process.
H	Citizen, Thomas P. Swiler, former member of the Sandia National Laboratories, Citizen Advisory Board		8.2	The commenter agrees with NMED that removal of the contents of MWL at this time or in the foreseeable future would be a greater risk to the environment than leaving in place. Therefore he indicated that he supports this.	R64	See Response R64.	
G	Citizen, Bob Long	O & M Direct Cost (Operations and Maintenance)	7.1	The commenter had a concern regarding alternative III.b (vegetative cover) versus III.c (vegetative cover with bio-barrier). The commenter asked why the operation and maintenance (O&M) direct cost for III.c was $540,000, more than for III.b. The commenter believes they should have the same	R65	The higher elevation and somewhat larger footprint of the cover with bio-barrier increases soil erosion potential. Soil erosion of the cover and any subsidence of the Landfill will be more costly to repair because of the addition of the rock bio-barrier layer. Nonetheless, the cost difference in SNL's estimates appears to be higher than expected, even over a 30	No

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				O& M cost.		year period upon which the estimate is based. NMED does not expect a lot of maintenance of the cover to be needed over any 30 year period.	
H	Citizen, Thomas P. Swiler, former member of the Sandia National Laboratories Citizen Advisory Board	Ground Water Monitoring	8.1	The commenter does not believe there is any evidence that the Landfill is leaking contaminates that would endanger ground water or cause a plume that would increase the cost of remediation. The commenter found the indication that showed contaminates could leak from the MWL, which was provided by Dr. Mark Baskaran to be flawed.	R66	Although a few contaminants have migrated from the Landfill and occur in surface soil and subsurface soil, data show that ground water has not been impacted, nor likely is it to be impacted in the future. Thus, NMED does not agree with the assertions made by Dr. Baskaran that ground water at the MWL is contaminated. However, NMED believes that continued ground water monitoring is prudent and necessary to ensure long-term protection of human health and the environment.	No
H	Citizen, Thomas P. Swiler, former member of the Sandia National Laboratories, Citizen Advisory Board	Questioning the need to cap the MWL	8.3	The commenter does not support the capping of the MWL. He believes that the MWL already has maintenance free vegetative cover formed by nature and the passing of time and is not convinced that adding an additional layer of soil and establishing a new vegetative cover over the MWL will make it safer. He is concerned that such action will give many a false sense of closure and about the additional cost of the cover. He would like to know how the additional cover would make MWL safer in terms of reducing the percolation of water through MWL, reducing moisture	R67	The scientific evidence shows that a properly designed and constructed ET cap and bio-intrusion barrier will provide additional protection over that of the current operational cover, with only modest additional cost. Furthermore, there is almost no scientific data on the physical characteristics of the operational cover, such as the cover thickness, the material(s) from which it was constructed, or construction quality assurance. This is a concern because the future performance of the current operational cover can not be modeled with confidence. Also, the NMED is aware of one instance where a piece of radioactive debris was not buried	No

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				content in the MWL, and reducing the possibility of inadvertent human or animal intrusion into the MWL.		sufficiently deep and was exposed on the surface (this has since been corrected by the SNL). NMED agrees with the commenter that monitoring of the site should continue. NMED intends to require at least 30 years of post-closure care and monitoring, and has the authority to extend this time period as necessary to protect human health and the environment. Given the long-half lives of some of the radionuclides buried in the Landfill, monitoring and maintenance may be required as long as the Landfill exists.	
M	Citizen, Steve Dapra		13.8	The commenter does not believe that a cap or cover at MWL is necessary. He recommends that a sufficient amount of soil be spread over the area to smooth out the lumps, that the soil be given a crown to prevent low spots from forming when the dirt settles, and that native grasses be planted on the MWL, so it will have the same appearance as the surrounding terrain. The commenter believes the current regimen of air and water sampling should continue for 20 years. If the Landfill has not leaked by that time, it probably isn't going to.	R67	See Response R67.	No
M	Citizen, Steve Dapra		13.10	The commenter does not support the placement of an engineered cover or cap, however he has no	R67	See Response R67	No

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				objection if that proposal is implemented. Also, he has no objection if the monitoring time is greater than 20 years.			
I	Citizen, Craig D. Richards	Re-evaluation of Data/assumptions	9.1	The commenter is satisfied with the vegetative cover for the near further, but asked where the funding will come from and when a re-evaluation of all the data and assumptions over time will be done. The commenter indicated that the radioactivity, transport modes, technology will change rapidly over the next 30-50 years and that technical breakthroughs may offer a full-scale disposal option rather than just monitoring and storage. MWL inventory charts indicate that Co-60 and H-3 “go away” by 2039/2049; what year has been selected for future excavation? The commenter believes the cost estimates for the NFA/vegetative cover and vegetative cover/barrier seem too low (i.e. less than $2 million for monitoring the MWL for the next 70 years). He expressed concern regarding the cost estimates.	R68	Under RCRA, SNL must provide the funds to implement the remedy. The final order issued by the NMED Secretary requires SNL to reevaluate the feasibility of excavation every five years. Therefore, new technologies will be taken into account during the re-evaluations. The future excavation alternatives did not include a specific date or time period after which excavation would begin. The cost estimates for future excavation assumed the Landfill would be excavated 50 years after closure. After the initial costs of installing the monitoring devices are incurred (some actually are already in place), annual monitoring costs will not exceed a few tens of thousands of dollars. The estimated costs for the cover alternatives are in the right order of magnitude.	Yes
J	Citizen, Robert Anderson	Avoiding excavation	10.1	The commenter believes that dangerous, unknown constituents at the site should not be left in place because there are too many risks associated with them for the	R69	The remedy selected by the NMED is protective of human health and the environment. Post-closure care and monitoring will be conducted to ensure the safety of the public and the	No

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				communities and the water supply.		environment. The MWL will be tracked in SNL's RCRA permit, along with many other solid waste management units/areas of concern identified at SNL.	
K	Citizen, Diana de la Rosa, Sandia Site	Capping	11.1	The commenter encourages capping the facility. The commenter states that digging it up would create emergency issues, ALARA (**a**s low as reasonably achievable) issues and potential lawsuits.	R70	NMED agrees that capping the Landfill is appropriate, provided that the Landfill is properly monitored for future releases. NMED also agrees that excavation of the Landfill would be difficult from both a safety and regulatory perspective, and that meeting the intent of ALARA would not be easy for excavation workers. The NMED does not support current excavation of the MWL due to unacceptable risks to site workers.	No
L	Citizen, J.D. Jojola	Ground Water	12.1	The commenter stated that he was submitting a copy of the WERC academy recommendations concerning vadose zone monitoring and the ground water protection plan.	R71	NMED agrees that the site must be continually monitored, including the vadose zone and the ground water. The final permit requires SNL to submit a long-term monitoring and maintenance plan to NMED for approval.	No
M	Citizen, Steve Dapra	Ground Water Contamination	13.2	The commenter stated that the MWL has not caused contamination of ground water. See the "Department of Energy and Sandia National Laboratories" response to Dr. Baskaran's Final Report, Mixed Waste Landfill Review, and pp. 20, 22-28.	R72	NMED agrees that currently there is no ground water contamination at the MWL. However, NMED believes it is prudent to continue monitoring the ground water.	No
M	Citizen, Steve Dapra	Air Monitoring	13.3	The MWL has not caused air contamination. See "Department of Energy and Sandia Nation	R73	Air quality data provided in the Phase 2 RFI Report and a separate report of radon emissions indicate that there is no air	No

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				Laboratories', Response to Dr. Baskaran's Final Report, "Mixed Waste Landfill Review," pp. 33-35.		contamination above risk-based standards. Air quality sampling conducted by the NMED DOE Oversight Bureau at the MWL and three background stations did not detect any air contamination above risk-based standards.	
M	Citizen, Steve Dapra	Tritium	13.5	The commenter indicated that tritium contamination below or near the MWL has been studied and discussed in some detail. See the "Department of Energy and Sandia National Laboratories' Response to Dr. Baskaran's Final Report, " Mixed Waste Landfill Review," pp.19, 24, 28-29, 33-35.	R74	NMED agrees that tritium contamination in surface soil and the vadose zone has been adequately characterized by SNL. The activity levels of the tritium contamination are sufficiently low that the tritium contamination does not pose unacceptable risk to human health or the environment under an industrial land use scenario.	No
M	Citizen, Steve Dapra	Hiding Behind Classified Status	13.6	The commenter stated that certain parties have claimed that SNL or DOE has been concealing Landfill contents using classified status, but the commenter believes that these claims are unsupported. (See Memorandum from Rich Kilbury, DOE Oversight Bureau SNL/ITRI, to Roger Kennett, DOE Oversight Bureau, Program Manager, SNL/ITRI, July 21, 2000).	R75	Other than security requirements associated with classified information, NMED has no evidence or reason to suspect that SNL has intentionally withheld information on the Landfill's contents. The inventory for the Landfill was in part prepared from classified records, with the classified information removed, in order to produce an inventory that the public could review. NMED reviewed a sample of these records and was able to correlate the information with the Landfill inventory. See HO FOF/COL, ¶¶ 43-50.	No
N	Citizen, Maurice	Monitoring	14.2	The commenter believes that air monitoring and monitoring of the	R76	NMED agrees with this comment.	No

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	Weisburg, M.D			vadose zone and the ground water is a prudent requirement.			
N	Citizen, Maurice Weisburg, M.D	Pro-Excavation	14.3	The commenter is concerned about waste material being located so close to the border of a major city; he believes it would be prudent to move the wastes to a more secure location.	R77	See Responses R55, 61, and 67.	No

LIST OF ACRONYMS

ALARA – As Low As Reasonably Achievable
CAMU – Corrective Action Management Unit
CMS – Corrective Measure Study
COL – Conclusions of Law
CWL – Chemical Waste Landfill
DCF – Dose Conversion Factor
DOE – U. S. Department of Energy
DU – Depleted Uranium
EPA – U. S. Environmental Protection Agency
ER – Environmental Restoration
FOF – Findings of Fact
FOIA -- Freedom of Information Act
HEAST – Health Effects Assessment Summary Table
HO – Hearing Officer
INEEL – Idaho National Environmental and Engineering Laboratory
IRIS – Integrated Risk Information System
MWL – Mixed Waste Landfill
NCEA – National Center for Environmental Assessment
NFA – No Further Action or Corrective Action Complete
NMED – New Mexico Environment Department
NMG – Neutron Moisture Gauge
NRC – Nuclear Regulatory Commission
O&M – Operation and Maintenance
OSWER – Office of Solid Waste and Emergency Response
PCB – Polychlorinated Biphenyl
PEF – Particulate Emission Factor
RCRA – Resource Conservation and Recovery Act
RFI – RCRA Facility Investigation
SNL – Sandia National Laboratories
TSCA – Toxic Substances Control Act
TRU - Transuranic

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TAB 3

Time Extension Request Approval Regarding Mixed Waste Landfill

Corrective Measures Implementation Plan and Report

August 4, 2005

From: NMED/Bearzi
To: SNL/Wagner

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CERTIFIED MAIL
RETURN RECEIPT REQUESTED

September 7, 2005

Patty Wagner
Manager
Sandia Site Office/NNSA
U.S. Department of Energy
P.O. Box 5400, MS 0184
Albuquerque, NM 87185-5400

Peter B. Davies
Director, Geoscience and Environment
Center (6100)
Sandia National Laboratories
P.O. Box 5800, MS 0701
Albuquerque, NM 87185-0701

RE: TIME EXTENSION REQUEST REGARDING MWL CMI PLAN AND CMI REPORT, AUGUST 4, 2005
SANDIA NATIONAL LABORATORIES
EPA ID# NM5890110518

Dear Ms. Wagner and Mr. Davies:

In Ms. Wagner's letter of August 4, 2005, the U. S. Department of Energy (DOE) requests that the due dates for the Sandia National Laboratories' Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan and CMI Report be extended to November 10, 2005 and October 29, 2007, respectively. The request is being made in accordance with the Compliance Order on Consent, Section III.J.2, and is related to the need for additional time to fulfill the requirements of the final order issued by the Secretary of the NMED on May 26, 2005.

Be advised that the original due dates in the subject letter are listed incorrectly; they should be September 12, 2005 and October 28, 2006 for the CMI Plan and CMI Report, respectively.

Pursuant to Section III.J.2 of the Compliance Order on Consent, DOE and Sandia Corporation are granted the subject request. The new due dates for the CMI Plan and the CMI Report for the MWL are November 10, 2005 and October 29, 2007, respectively.

SEP 12 2005

Please contact Mr. William Moats of my staff at (505) 284-5086 if you have any questions regarding this matter.

Sincerely,

James P. Bearzi
Chief
Hazardous Waste Bureau

JPB:wpm

cc: W. Moats, NMED HWB
J. Kieling, NMED HWB
F. Nimick, SNL, MS 1089
J. Gould, SNL MS 0184
L. King, EPA-6

File: SNL HSWA OU 1289, 05

Volume I

TAB 4

Mixed Waste Landfill Corrective Measures Implementation Plan

November 2005

From: SNL/Wagner
To: NMED/Bearzi

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Notes for Volume I, Tab 4:

The “Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005,” included herein has been updated to include two revisions:

1. Appendix E “Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories” has been replaced by the January 2007 SAND2007-017 document, “Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories (2nd Edition),” that includes revisions to address the NMED Notice of Disapproval (NOD) dated November 2006.

2. Three replacement pages;
    a. Mixed Waste Landfill (MWL) Corrective Measures Implementation Plan (CMIP) Appendix A, page 02930-4,
    b. MWL CMIP Appendix A, page 02200-6, and
    c. MWL CMIP Appendix B, page B-25,

   associated with the NMED “Conditional Approval Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005”, dated December 22, 2008 (Justification Binder Volume I, Tab 16). The replacement pages were transmitted to NMED in a DOE/SNL letter dated February 12, 2009 that can be found in Justification Binder Volume I, Tab 17.

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

NOV 0 3 2005

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Rd. East, Building 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the Department of Energy (DOE) and Sandia Corporation (Sandia), DOE is submitting the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan, November 2005, for planned activities at Sandia National Laboratories, New Mexico, EPA ID No. NM589011518. On May 26, 2005, the Secretary of the New Mexico Environment Department selected a vegetative soil cover with bio-intrusion barrier as the final remedy for the MWL, and approved the associated Class 3 permit modification request.

The enclosed MWL CMI Plan incorporates the final remedy described in Section V.2 of the Class 3 permit modification for the MWL. The CMI Plan documents the plans for construction of the cover for the landfill, and includes the results of a comprehensive fate and transport model that was used to assess the performance of the MWL. The CMI Plan also includes triggers for future action that identify and detail specific monitoring results that would initiate a defined evaluation process, which includes supplemental sampling, if necessary.

If you have any questions, please contact me at (505) 845-6036, or John Gould at (505) 845-6089.

Sincerely,

Patty Wagner

Patty Wagner
Manager

Enclosure

NOV 3 2005

cc w/enclosure:
W. Moats, NMED (Via Certified Mail)
L. King, EPA, Region 6 (Via Certified Mail)
M. Martin, NNSA/NA-56
J. Volkerding, NMED-OB (2 copies)

cc w/o enclosure:
J. Estrada, NNSA/SSO, MS 0184
A. Blumberg, SNL, MS 0141
F. Nimick, SNL, MS 1089
P. Freshour, SNL, MS 1089
R. E. Fate, SNL, MS 1089
J. Peace, SNL, MS 0750
T. Goering, SNL,MS 1089
C. Ho, SNL, MS 0735
M. Miller, SNL, MS 1042
M. J. Davis, SNL, MS 1089

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005**

Document authors: **Tim Goering, Dept. 6147 and Jerry Peace, Dept. 6116 Cliff Ho, Dept. 6115, and Mark Miller, Dept. 10331**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: [signature] 11/3/05

Peter B. Davies
Director
Geoscience & Environment Center
Division 6100
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico 87185
Operator

Date

and

Signature: Patty Wagner 11-3-05

Patty Wagner
Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Date

Sandia National Laboratories/New Mexico
Environmental Restoration Project

MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

November 2005

United States Department of Energy
Sandia Site Office

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories/New Mexico
Environmental Restoration Project

MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

November 2005

United States Department of Energy
Sandia Site Office

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

EXECUTIVE SUMMARY

Sandia National Laboratories/New Mexico (SNL) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico. KAFB occupies 52,233 acres. SNL is managed by the U.S. Department of Energy (DOE) and is operated by Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation. SNL performs research and development in support of various energy and weapons programs and national security. It also performs work for the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission, and other government agencies.

The Mixed Waste Landfill (MWL) is located 4 miles south of SNL's central facilities and 5 miles southeast of Albuquerque International Sunport. The landfill is a fenced, 2.6-acre compound in the north-central portion of Technical Area (TA)-3. The MWL was established in 1959 as a disposal area for low-level radioactive and mixed waste generated by SNL research facilities. The landfill accepted low-level radioactive and minor amounts of mixed waste from March 1959 through December 1988. Approximately 100,000 cubic feet of low-level radioactive and mixed waste containing approximately 6,300 curies of activity were disposed of in the landfill.

The MWL consists of two distinct disposal areas. The classified area occupies 0.6 acres and the unclassified area occupies 2.0 acres. Low-level radioactive and mixed waste was disposed of in each of these areas. Classified wastes were buried in unlined, cylindrical pits in the classified area. Unclassified wastes were buried in shallow, unlined trenches in the unclassified area.

A Phase 1 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL. The Phase 1 RFI indicated that tritium had been released to the environment. A Phase 2 RFI was conducted from 1992 to 1995 to determine the contaminant source, define the nature and extent of contamination, identify potential contaminant transport pathways, evaluate potential risks posed by the levels of contamination identified, and provide remedial action alternatives for the landfill.

The Phase 2 RFI confirmed that tritium is the contaminant of primary concern. Tritium has been a consistent finding at the MWL since environmental studies were initiated at SNL in 1969. Tritium occurs in surface and near-surface soil in and around the classified area of the landfill at levels ranging from 1,100 picocuries (pCi)/gram (g) in surface soil to 206 pCi/g in subsurface soil. The highest tritium levels are found within 30 feet of the surface in soil adjacent to and directly below classified area disposal pits. Below 30 feet from the ground surface, tritium levels fall off rapidly to a few pCi/g of soil. Tritium also occurs as a diffuse air emission from the landfill, releasing 0.09 curies/year to the atmosphere.

The State of New Mexico is authorized by the U.S. Environmental Protection Agency (EPA) to implement the hazardous waste management provisions of RCRA for treatment, storage, and disposal facilities within the state. On August 26, 1993, EPA Region 6 issued the Part B Hazardous and Solid Waste Amendment (HSWA) Permit Module to the DOE and Sandia. The purpose of the permit was to establish specific guidelines for assessment, characterization, and remediation of Solid Waste Management Units (SWMUs) at SNL. Under Module IV of the RCRA Part B Permit (HWSA Module), the MWL is identified as Activity Data Sheet 1289, Environmental Restoration Site No. 76, and RCRA Facility Assessment Site No. 24, 25, 26, 27,

28, 29, 30, 11, 5, and 116. The MWL is a SWMU regulated by the New Mexico Environment Department (NMED) under the corrective action provisions of the HSWA. In addition, DOE Orders provide requirements for landfill closure cover design and establish performance requirements for the closed facility.

HSWA corrective action regulations establish corrective action authority but, due to the delay in finalizing more definitive implementing provisions, do not provide prescriptive requirements. Because the HSWA regulations do not address technical specifications, such as those required for a SWMU cover, the more detailed RCRA operating unit regulations are often used as guidance. For the MWL cover design, Sandia has elected to use RCRA landfill (referred to here as "Subtitle C facilities") regulations as guidance.

The goal of the EPA-recommended design of final covers for RCRA Subtitle C facilities is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize erosion and further maintenance, to promote surface runoff and drainage, and to protect human health and the environment taking into consideration the future use of the site. The EPA accepts alternative cover designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. A fundamental concern of the EPA with cover designs is that all cover components be stable, and that the cover performs as intended without posing a significant risk to human health and the environment.

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the Mixed Waste Landfill.

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8-9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer's report. The Secretary requested that a Corrective Measures Implementation Plan incorporating the final remedy be developed within 180 days following the selection of the remedy.

This Corrective Measures Implementation Plan incorporates the final remedy selected by the NMED. The document contains a description of the selected remedy, the objectives for the remedy, detailed engineering design drawings and construction specifications, and a construction quality assurance plan and health and safety plan.

The remedy, a vegetative soil cover, will consist of a thick layer of native soil. The design would rely upon soil thickness and evapotranspiration to provide long-term performance and stability, and would be inexpensive to build and maintain because of the availability of suitable soil in TA-3.

This design is hereby formally submitted to the NMED for final closure of the MWL. The cover is a 3-foot-thick, vegetated soil cover. The cover will be underlain by a 1-foot-thick biointrusion barrier and a subgrade layer up to 40 inches in thickness. The proposed cover meets the intent of RCRA Subtitle C regulations, which include the following:

- Water migration through the cover is minimized.
- Maintenance is minimized by using a monolithic soil layer.
- Cover erosion is minimized by using erosion control measures.
- Subsidence is accommodated by using a “soft” design.
- Permeability of the cover is less than or equal to that of natural subsurface soil present.

Performance of the cover will be integrated with the natural site conditions at TA-3, producing a “system performance” that will ensure that the cover protects both human health and the environment. The natural site conditions at the site include:

- Extremely low precipitation and high potential evapotranspiration
- Negligible recharge to groundwater
- An extensive vadose zone
- Groundwater approximately 500 feet below the surface
- A versatile, native flora that will persist indefinitely as a climax ecological community with little or no maintenance

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LIST OF PLATES

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ACRONYMS AND ABBREVIATIONS

Am	americium
amsl	above mean sea level
bgs	below ground surface
Be	beryllium
CFR	Code of Federal Regulations
Ci	curie(s)
cm	centimeter(s)
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CPN	California Pacific Nuclear
°F	degrees Fahrenheit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FOP	field operating procedure
g	gram
HELP-3	Hydrologic Evaluation of Landfill Performance Model, Version 3
hr	hour
HSWA	Hazardous and Solid Waste Amendment
HWB	Hazardous Waste Bureau
IP	instantaneous profile
KAFB	Kirtland Air Force Base
m	meter(s)
m^2	square meter(s)
mph	mile(s) per hour
mrem	millirem
MUSLE	modified universal soil loss equation
MWL	Mixed Waste Landfill
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NOD	Notice of Deficiency
pCi	picocurie(s)
PET	potential evapotranspiration
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RSI	request for supplemental information
s	second(s)
Sandia	Sandia Corporation
SNL	Sandia National Laboratories/New Mexico
SWMU	Solid Waste Management Unit
TA	Technical Area
TEDE	total effective dose equivalent
UNSAT-H	Unsaturated Soil Water and Heat Flow Model
USGS	U.S. Geological Survey
USLE	universal soil loss equation

ACRONYMS AND ABBREVIATIONS (Concluded)

VS2DT	Variably-Saturated 2-D Flow and Solute Transport Model
WEQ	wind erosion equation
yd^3	cubic yard(s)
yr	year

1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico (Figure 1-1). KAFB occupies 52,233 acres. SNL research and administration facilities are divided into five technical areas (TAs), designated 1 through 5, and several additional test areas, occupying 2,842 acres. TA-1, TA-2, and TA-4 are separate research facilities in the northwestern portion of KAFB. TA-3 and TA-5 are contiguous research facilities forming a 4.5-square-mile, rectangular area in the southwestern portion of KAFB (Figure 1-2). TA-3 alone occupies 2,000 acres. The Mixed Waste Landfill (MWL) is a 2.6-acre, fenced compound located in north-central TA-3 at SNL (Figure 1-3).

The goal of the U.S. Environmental Protection Agency (EPA)-recommended design of final covers for Resource Conservation and Recovery Act (RCRA) Subtitle C facilities is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize erosion and further maintenance, and to protect human health and the environment by taking into consideration the future use of the site. In general, the EPA provides the performance-based requirements for Subtitle C landfill cover design. These requirements are specified in Title 40 of the Code of Federal Regulations (CFR), Section 264.310. However, the EPA accepts alternative cover designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. A fundamental concern of the EPA with cover design is that all cover components be stable, and that the cover performs as intended without imposing a significant risk to human health and the environment.

In this Corrective Measures Implementation (CMI) Plan, the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) have demonstrated that the MWL alternative cover meets EPA performance-based criteria in 1) minimizing infiltration of water through the cover; 2) minimizing erosion and further maintenance; 3) promoting surface runoff and drainage; 4) accommodating subsidence; and 5) having a permeability equal to or less than the MWL subsurface soil.

Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation, has a Management and Operations Contract with DOE/NNSA for SNL. SNL, which is owned by the DOE, is co-operated by both the DOE and Sandia for purposes of hazardous waste management and corrective action, per Sandia's RCRA Permit. SNL performs research and development in support of various energy and weapons programs. It also performs work for the U.S. Department of Defense, the U.S Nuclear Regulatory Commission, and other government agencies.

The MWL is designated as a Soil Contamination Area and a Hazardous and Solid Waste Amendments (HSWA) Solid Waste Management Unit (SWMU) subject to corrective action under state and federal regulations. The New Mexico Environment Department (NMED), the lead regulatory agency, will oversee the corrective action process for the MWL.

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using

guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the Mixed Waste Landfill.

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8-9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer's report. The Secretary requested that a Corrective Measures Implementation Plan incorporating the final remedy be developed within 180 days following the selection of the remedy.

This Corrective Measures Implementation Plan incorporates the final remedy selected by the NMED. The document outlines the deployment of an alternative cover at the MWL (Chapter 2), the regulatory basis (Chapter 3), MWL characteristics (Chapter 4), the technical basis for the cover (Chapter 5), the MWL alternative cover design (Chapter 6), and cover performance monitoring (Chapter 7).

This document outlines the deployment of an alternative cover at the MWL (Chapter 2), the regulatory basis (Chapter 3), MWL characteristics (Chapter 4), the technical basis for the cover (Chapter 5), the MWL alternative cover design (Chapter 6), and cover performance monitoring (Chapter 7).

Appendices include construction specifications (Appendix A), a construction quality assurance plan (Appendix B), the identification and qualifications of key persons implementing the remedy (Appendix C), a health and safety plan (Appendix D), and a comprehensive fate and transport model with triggers for monitoring (Appendix E).

1.1 Acknowledgements

The alternative cover design presented in this document is based upon fruitful collaborations with engineering firms, industry, and state and federal regulatory agencies. The authors benefited greatly from visits and discussions with the following individuals and organizations: William Moats, Rich Kilbury, and Bill McDonald of the NMED; Howard Stone, Gordon Walhood, and Sarah Ganley of Bohannan-Huston; and Paul Knight of Marron and Associates, Inc. The authors also acknowledge valuable discussions with Mike Fayer of Pacific Northwest National Laboratory. Charles Reith, Jack Caldwell, Jack Nyhan, Tom Hakonson, and Glendon Gee deserve special recognition for their pioneering work on alternative landfill covers.

2.0 ALTERNATIVE COVER FOR THE MWL

Due to the lack of specific HSWA technical requirements, Sandia has elected to use RCRA landfill regulations as guidance. The design of a final cover for RCRA Subtitle C facilities recommended by the EPA is, at a minimum, made up of three layers: (1) a vegetated or armored top layer comprised of 24 inches of soil graded at a slope of 3 to 5 percent; (2) a drainage layer, 12 inches thick, composed of a high-conductivity sand layer; and (3) a 24-inch-thick, low-conductivity compacted soil layer with a geomembrane (EPA 1991). The design of the cover elements must take into consideration failure caused by desiccation cracking, settling, and subsidence. The goal of the EPA-recommended design is to limit the formation of leachate by minimizing the contact of waste with water, minimize further maintenance, and protect human health and the environment under future land-use conditions.

The fundamental concern of the EPA with cover designs is ensuring that all cover components are stable and the cover performs as intended, without posing a risk to human health and the environment (EPA 1991). The EPA accepts alternative designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. The EPA acknowledges that in arid regions where vegetation cannot be maintained, other materials for the surface cover layer should be selected to prevent erosion and allow for surface drainage, and the middle drainage layer can be eliminated from the design.

The alternative cover for the MWL is a 3-foot-thick, vegetated soil cover underlain by a 1-foot-thick biointrusion barrier that will be built by placing subgrade fill and lifts of native soil over the existing landfill surface. The topsoil layer will be seeded with native vegetation to mitigate surface erosion and promote transpiration. During the long-term care plan period, native soil can be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers and rills that result from surface erosion. If necessary, additional native soil can be added to compensate for future subsidence and erosion. Because the cover will be constructed without rigid layers, it can accommodate differential subsidence without undue impairment of its performance. This “soft” cover design provides additional assurance for adequate long-term performance of the cover.

The alternative cover meets the RCRA requirements of 40 CFR 264.310, as follows:

- Water migration is minimized through the cover. The 3-foot-thick, vegetated soil cover will minimize water migration into waste disposal cells.

- Maintenance will be minimized by using a monolithic soil layer. Individual layers, such as those used in traditional RCRA covers, are rigid and would require extensive maintenance and repair due to eventual degradation as well as tensile and shear failure.

- Cover erosion will be minimized by using erosion control measures. The cover will be centrally crowned and sloped at 2 percent. The topsoil layer will be vegetated and admixed with 25 percent 3/8-inch crushed gravel.

- Subsidence will be accommodated by using a “soft” cover. During the long-term care period, soil can be added to the cover to repair erosion and subsidence as it

occurs. At the end of this time, additional soil can be added to mitigate future erosion and subsidence.

- Permeability of the cover soil will be less than or equal to the permeability of MWL subsurface soil. The "bathtub" effect is unlikely to occur.

Performance of the cover cannot be isolated from the performance of the site itself. Natural site conditions, integrated with the cover, produce a "system performance" that will ensure that the alternative design adequately meets the regulatory requirements. The natural site conditions of TA-3 that will be relied upon as part of the system include:

- Extremely low precipitation and high potential evapotranspiration (PET).

- Negligible recharge to groundwater. Chloride data collected from boreholes at the MWL (Peace et al. 2002) indicate significant rainfall has not percolated beyond the upper 20 feet of soil for tens of thousands of years.

- An extensive vadose zone. Groundwater lies approximately 500 feet below ground surface (bgs).

- The site has low potential for volcanic and seismic activity, with low hazard potential. The Albuquerque volcanoes were active for only a short period about 190,000 years (yrs) ago (Clary et al. 1984).

- The vegetated soil cover will adapt to climatic change, will recover from severe damage (fire and drought), and will persist indefinitely with little or no maintenance.

Performance of the cover will not be impacted by natural environmental events such as flooding or earthquakes. The MWL is not located within the 100-yr or 500-yr floodplains (Figure 2-1) and the expected low recurrence interval and low expected ground motion of seismic events in the Albuquerque basin renders earthquakes of little significance (Figure 2-2).

2.1 Proposed Schedule for Implementation and Periodic Progress Reports

The DOE and Sandia anticipate initiating construction activities for the MWL alternative cover in July 2006. Completion of the alternative cover is expected within 4 months provided the project enjoys favorable weather conditions. Adverse weather conditions may extend the project 4 to 6 weeks.

The DOE and Sandia will submit quarterly progress reports to the NMED during construction of the MWL alternative cover. These reports will include a description of the work completed during the reporting period.

A CMI Report for the MWL will be submitted to the NMED within 180 days after implementation of the remedy is complete. The CMI Report will include a summary of the work completed, as-built drawings and specifications signed and stamped by a registered professional engineer, copies of the results of monitoring and sampling data generated during remedy implementation, and a legal certification that the information is true, accurate, and complete.

2.2 Waste Management

The DOE and Sandia do not anticipate generating any waste during construction of the MWL alternative cover. All construction activities will be nonintrusive and above the existing landfill surface.

2.3 Maintenance and Performance Monitoring

A long-term maintenance and monitoring plan, which contains all necessary physical and institutional controls and long-term monitoring to be implemented at the site in the future, will be submitted by the DOE and Sandia to the NMED for review and approval. The plan will be submitted after the alternative cover has been deployed, and within 180 days of the NMED's approval of the CMI Report. Planned maintenance and monitoring activities and the frequency at which these will be performed will be determined in consultation and collaboration with the NMED and described in detail in the long-term care document.

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3.0 REGULATORY BASIS

The MWL is subject to regulations governing both radioactive and hazardous waste. The DOE meets its responsibility for conducting and overseeing radioactive material operations at its contractor-operated facilities, under the Atomic Energy Act authority, through DOE Orders, which set requirements and standards for closures. DOE Orders and federal and state regulations that contain pertinent requirements for corrective action at the MWL are as follows:

- DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (DOE 1993)
- DOE Order 435.1, "Radioactive Waste Management" (DOE 1999)
- DOE Order 6430.1A, "General Design Criteria" (DOE 1989)
- 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (used as guidance)
- 10 CFR 835 "Occupational Radiation Protection"
- New Mexico Administrative Code (NMAC), 20 NMAC 4.1, Subpart V, 40 CFR 264.101, "Corrective Action for Solid Waste Management Units"

Requirements under federal and state regulations and DOE Orders are summarized in the following sections.

3.1 Corrective Action Requirements under HSWA

The MWL was identified as a SWMU in the August 1993 issuance of the HSWA Module, the corrective action portion of the SNL RCRA operating permit. Under the corrective action program, SNL is required to investigate and remediate, if necessary, the SWMUs identified in the HSWA Module of the permit. For the MWL, SNL has completed the assessment and characterization phase and has proposed to design and deploy an alternative cover as the final remedy. The NMED selected a final remedy (a vegetative soil cover with biointrusion barrier) on May 26, 2005.

Due to both the lack of prescriptive corrective action guidance and the practical similarities of landfill corrective action and landfill closure under RCRA, SNL has elected to use the RCRA landfill closure requirements as guidance for the MWL final remedy. The purpose of closure is to contain and prevent migration of hazardous waste and hazardous constituents from MWL disposal cells. Closure includes construction of engineered controls (i.e., closure cover); the post-closure phase will include implementation of a post closure environmental monitoring and surveillance plan.

Hazardous waste landfill closure requirements are codified under 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart G (Facility Closure Standards) and Subpart N (Landfills). These standards are performance-based regulations that specify performance criteria without specifying design,

construction materials, or operating parameters. The EPA has provided numerous guidance documents to aid in interpreting the level of performance required to design, construct, and operate a compliant closure system. The closure performance standard is defined in 40 CFR 264.111 as follows:

> "The owner or operator must 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 runoff, 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 . . . ."

The following performance-based requirements for landfill covers are established in 40 CFR 264.310:

> "At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:
>
> (1) Provide long-term minimization of migration of water through the closed landfill;
>
> (2) Function with minimum maintenance;
>
> (3) Promote drainage and minimize erosion or abrasion of the cover;
>
> (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and
>
> (5) Have permeability less than or equal to the permeability of any bottom liner system or natural subsoil present."

The NMED, the lead regulatory agency, has adopted the federal regulations as written, which are incorporated into 20.4.1.500 New Mexico Administrative Code (NMAC), incorporating the landfill closure requirements of 40 CFR 264.111 and 264.310 as well as 40 CFR 264.101, "Corrective Action for Solid Waste Management Units."

3.2 Closure Requirements under DOE Orders

Low-level radioactive and mixed waste disposal operations at the MWL followed the requirements set by DOE Order 5820.2, "Radioactive Waste Management" (DOE 1984) and those requirements subsequently set by DOE Order 5820.2A, "Radioactive Waste Management" (DOE 1988). On July 9, 1999, DOE Order 5820.2A was cancelled and replaced by DOE Order 435.1 "Radioactive Waste Management" (DOE 1999). The objective of these

Orders is to ensure that all DOE radioactive waste is managed in a manner that protects the health and safety of both workers and the public, and the environment.

DOE Order 435.1 does not set specific closure system design criteria, but establishes performance objectives for the closed facility. The objectives and limits are as follows:

a) Doses to representative members of the public shall not exceed 25 millirem (mrem) in a year total effective dose equivalent (TEDE) from all exposure pathways, excluding the dose from radon and its progeny in air.

b) Dose to representative members of the public via the air pathway shall not exceed 10 mrem in a year TEDE, excluding the dose from radon and its progeny in air.

c) Release of radon shall be less than an average flux of 20 picocuries (pCi)/square meters (m^2)/second (s) at the surface of the disposal facility.

3.3 Regulatory Review and Response Actions

In order to meet the challenge that came with approval and fielding of an innovative technology at the MWL, SNL Environmental Restoration (ER) Project engineering design staff met with the NMED Hazardous Waste Bureau (HWB) on a regular basis throughout the alternative cover research and design process. The design of alternative covers has to date been an isolated activity at various sites in the United States. Meetings were held with the HWB to determine both specific risks at the MWL and construction and performance requirements. The HWB reviewed 30-percent, 60-percent, and 90-percent design specifications and grading plans for appropriateness. The final design report was submitted to the NMED on September 23, 1999.

The MWL alternative cover design was reviewed internally by the NMED, and externally by TechLaw Inc., a Lakewood, Colorado, civil engineering firm under contract to the NMED. The NMED issued a formal request for supplemental information (RSI) to Sandia on June 5, 2000, to address technical comments and questions raised by TechLaw Inc. and NMED technical and regulatory staff. Sandia submitted its response to the RSI to the NMED on September 8, 2000. The NMED issued a second RSI on February 16, 2001, to clarify certain subject areas of the September 8, 2000, Sandia response. The RSI process was closed in 2001 with no further technical comments or questions.

A design similar to the MWL alternative cover design has received regulatory approval for implementation at the Chemical Waste Landfill, a landfill at SNL that closed under RCRA interim status. At the CWL, the alternative cover was reviewed by the EPA Region 6 in 2001 and 2002 and determined to be adequate for Toxic Substances Control Act substances remaining in the closed CWL. EPA approval was obtained on June 26, 2002. Deployment of the CWL alternative cover design was approved by the NMED in April 2004 as an interim measure at the CWL under the RCRA interim status closure regulations. These regulatory approvals indicate that the alternative cover design is appropriate for implementation in the semi-arid environment at SNL and that the underlying premises of the MWL design are sound.

3.4 Corrective Measures Study

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. A CMS Workplan (SNL December 2001) was written by the SNL Environmental Restoration Project in accordance with requirements set forth in Module IV (Hazardous and Solid Waste Amendments) of the DOE and SNL RCRA Permit. The CMS Workplan was submitted to the NMED on December 19, 2001, and approved with conditions by the NMED on October 10, 2002.

The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the MWL.

The NMED issued a Notice of Deficiency (NOD) to the DOE and Sandia on November 5, 2003. The DOE and Sandia responded to the NOD on December 19, 2003. On January 5, 2004, the NMED determined that the MWL CMS Report was complete.

3.5 Remedy Selection

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8–9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier (Corrective Measures Study Alternative III.c) as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer’s report. The Secretary requested that a CMI Plan incorporating the final remedy be developed within 180 days following the selection of the remedy. The draft permit modification issued by the NMED in the matter prior to the hearing was revised by the NMED in accordance with the Secretary’s final decision.

4.0 MWL CHARACTERISTICS

The weather for Albuquerque and vicinity, including SNL, is typical of high-altitude, dry continental climates. The normal daily temperature ranges from 23 to 52 degrees Fahrenheit (°F) during winter months and from 57 to 91°F during summer months. The average annual relative humidity is 46 percent; however, the relative humidity can range from as low as 5 percent to as high as 70 percent (Bonzon et al. 1974).

Under normal conditions, wind speeds seldom exceed 32 miles per hour (mph) and are generally less than 8 mph (Bonzon et al. 1974). Strong winds, often accompanied by blowing dust, occur mostly in late winter and early spring. During these months, the prevailing surface winds are from the southwest. Rapid night-time ground-cooling produces strong temperature inversions and strong winds through mountain canyons.

The average annual precipitation for the Albuquerque area is 8.5 inches (21.6 centimeters [cm]). Monthly precipitation can range from a minimum of less than 0.5 inch during winter months to 1.5 inches during summer months. Average annual snowfall in the Albuquerque area is 11 inches. Summer precipitation, particularly in July through August, is usually in the form of heavy thundershowers that typically last less than 1 hour (hr) at any given location (Williams 1986). Average annual Class A pan evaporation at Albuquerque International Sunport Station 224 is 89 inches, approximately 10 times the average annual precipitation.

TA-3 is situated within coalescing alluvial fans emanating from the Manzanita Mountains to the east that form an expansive, relatively featureless, arid mesa. TA-3 is underlain by an extensive vadose zone comprised of unconsolidated, braided channel, interchannel, flood plain, and aeolian deposits. The water table beneath TA-3 occurs within the Santa Fe Group approximately 500 feet bgs. The MWL lies in the north-central portion of TA-3. Elevations at the MWL range from 5,385 feet above mean sea level (amsl) on the east to 5,375 feet amsl on the west. Mean elevation is 5,381 feet amsl.

There are no permanent structures at the MWL. All disposal pits and trenches were excavated below grade. The only visible surface features are the earthen berms above unclassified area trenches, and security fences that surround the compound. There are no perennial streams in the immediate area of the MWL. Surface runoff is regionally controlled and generally to the west. There are no man-made surface runoff controls. Surface runoff flows from the landfill surface to dirt roads that surround the fenced compound.

The MWL accepted containerized and uncontainerized low-level radioactive and mixed waste from SNL research facilities and off-site generators from 1959 to 1988. Approximately 100,000 cubic feet of low-level radioactive and mixed waste (excluding waste containers, packaging, construction and demolition debris, and contaminated soil) containing 6,300 curies of activity (at the time of disposal) were disposed of at the MWL, which contains minor quantities of RCRA hazardous metals and solvents. Disposal cells at the landfill are unlined and have been compacted to grade with native soil.

There are two distinct disposal areas at the MWL that include the classified area (occupying 0.6 acres) and the unclassified area (occupying 2.0 acres) (Figure 1-3). Wastes in the classified area were disposed of in a series of vertical, cylindrical pits. Historical records indicate that early pits were 3 to 5 feet in diameter and 15 feet deep. Later pits were 10 feet in diameter and

25 feet deep. Once pits were filled with waste, they were backfilled with soil and capped with concrete. Wastes in the unclassified area were disposed of in a series of parallel, north-south, excavated trenches. Records indicate that the trenches were 15 to 25 feet wide, 150 to 180 feet long, and 15 to 20 feet deep. Trenches were reportedly backfilled with soil on a quarterly basis and, once filled with waste, capped with the original soil that had been excavated and locally stockpiled.

Containment and disposal of waste commonly occurred in tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, 55-gallon steel and polyethylene drums. Larger items, such as glove boxes and spent fuel shipping casks, were disposed of in bulk without containment. Disposal of free liquids was not allowed at the MWL. Liquids such as acids, bases, and solvents were solidified with commercially available agents including Aquaset, Safe-T-Set, Petroset, vermiculite, marble chips, or yellow powder before containerization and disposal.

Most pits and trenches contain routine operational and miscellaneous decontamination waste including gloves, paper, mop heads, brushes, rags, tape, wire, metal and polyvinyl chloride piping, cables, towels, quartz cloth, swipes, disposable lab coats, shoes covers, coveralls, high-efficiency particulate air filters, prefilters, tygon tubing, watch glasses, polyethylene bottles, beakers, balances, pH meters, screws, bolts, saw blades, Kleenex, petri dishes, scouring pads, metal scrap and shavings, foam, plastic, glass, rubber scrap, electrical connectors, ground cloth, wooden shipping crates and pallets, wooden and lucite dosimetry holders, and expended or obsolete experimental equipment.

A detailed MWL waste inventory, by pit and trench, is provided in the Environmental Restoration Project "Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996" (SNL 1998).

5.0 TECHNICAL BASIS

The MWL alternative cover design is based upon federal regulations and guidance, DOE Orders and guidance, NMED regulations and guidance, an extensive review of published studies conducted over the past 20 yrs, and the geological, hydrological, and ecological conditions specific to TA-3 and the MWL. Performance of the overall “system” relies on both the cover design and natural site characteristics. The objective was to capture and condense these design “elements,” as appropriate, to design a cover that meets the intent of the regulations and that improves, rather than degrades, over time as inevitable natural processes act on the system. Engineered covers must be viewed as evolving components of larger, dynamic ecosystems (Waugh 1997).

The DOE has been actively pursuing alternative cover design and construction for more than 20 yrs. Most of the research to date has been conducted in arid and semiarid regions. Much of this research was evaluated and incorporated, as appropriate, in the design proposed for the MWL. Research and published information to date is limited to short-term demonstrations and monitoring, predictive models, and natural analogs. There is little information published on the long-term performance of alternative cover systems.

5.1 Potential Evapotranspiration

PET estimates have been made for TA-3 in support of predictive modeling. The Hydrologic Evaluation of Landfill Performance Model, Version 3 (HELP-3) (Schroeder et al. 1994) was used to estimate PET data with its built-in functions and localized database for Albuquerque, New Mexico. The resulting PET data are shown along with pan evaporation data from four New Mexico National Weather Service Stations in Figure 5-1. The average annual PET modeled by HELP-3 for the 65-yr period (1932 to 1996) is 75.4 inches, approximately nine times the average annual precipitation recorded at Albuquerque International Sunport.

5.2 MWL Vadose Zone Characteristics

Extensive field investigations and analytical studies have been undertaken in TA-3 and at the MWL to address regulatory-driven assessment and characterization requirements. A comprehensive RCRA Facility Investigation (RFI) Report (Peace et al. 2002) and two NMED Notice of Deficiency submittals, including an extensive inventory of wastes disposed of at the MWL, are available for review (SNL 1998, SNL 1999). Data collected from boreholes, groundwater monitoring wells, and instantaneous profile (IP) tests were used to measure saturated and unsaturated zone characteristics, augment characterization and assessment, and support final closure of the site. These data included volumetric water content, saturated and unsaturated hydraulic conductivity, bulk density, and isotopic chloride content. The data are summarized in Goering et al. (1995), Wolford (1998), and Peace and Goering (2005).

5.2.1 Water Movement in the Unsaturated Zone under Natural Conditions

MWL Phase 2 RFI characterization data show no evidence of significant water migration past the root zone of plants or the upper 2 feet of soil. Infiltrating surface water returns to the

atmosphere via evapotranspiration. Recharge to the water table at the MWL is insignificant under current climatic and vegetative conditions.

The following characteristics summarize the vadose zone in TA-3 and at the MWL.

- The underlying alluvium, which makes up the vadose zone, is well-graded, very fine sand with occasional layers of gravel, coarse sand, silt, and clay. The relative percentages of silt and clay increase with depth, and predominate at depths greater than 250 feet bgs.

- Water content of the alluvium is very low near the surface and may decrease with depth. Soil-water contents average approximately 3 percent by weight and peak at about 13 percent by weight.

- Very little infiltration of water occurs beyond the upper 2 feet of the surface. Unsaturated hydraulic conductivities are extremely low due to low soil-water contents. The operational unsaturated hydraulic conductivities of these soils are on the order of 10^{-9} to 10^{-10} cm/s.

- Soil profiles show an enrichment of stable chloride near the surface (Figure 5-2). Chloride in the top 20 feet of soil represents the accumulation of atmospheric chloride over tens of thousands of years. The implication of this chloride accumulation is that very little water has infiltrated beyond 20 feet bgs during that period of time. Water that exists deeper in the vadose zone probably entered the system much earlier and under much wetter climatic conditions.

5.2.2 The Bathtub Effect

RCRA Subtitle C regulations, specifically 40 CFR 264.310 (a) (5), state that at final closure of a landfill, the operator must cover the landfill with a final cover designed and constructed to: “have permeability less than or equal to the permeability of any bottom liner system or natural subsoil present.” This prescriptive requirement was established to prevent what is commonly referred to as the bathtub effect, which occurs when a more permeable cover is constructed over a less permeable bottom liner or natural subsurface soil. If the more permeable cover were to remain saturated during its design life, water would eventually accumulate in disposal cells, filling pits and trenches as if they were basins. Such an event could accelerate deterioration of waste containers, initiate subsidence of the cover, and mobilize hazardous constituents.

The cover has been carefully designed using native soil selected from appropriate borrow areas to prevent the bathtub effect. This section presents the permeability (hydraulic conductivity) data for MWL subsurface soil and for the soil that will be used to construct the cover. These data demonstrate that the MWL alternative cover meets the permeability requirements of 40 CFR 264.310, and that the bathtub effect is unlikely to occur.

5.2.2.1 MWL Subsurface Soil Hydraulic Conductivities

During the MWL Phase 2 RFI and in subsequent hydrologic studies, the permeability of MWL subsurface soil was determined by directly measuring the saturated hydraulic conductivity in the field, and by measuring the hydraulic conductivity of core samples in the laboratory.

5.2.2.1.1 Field measurements of Subsurface Soil Hydraulic Conductivity

The most representative measurement of saturated hydraulic conductivity is obtained in situ in the field, because the sampled areas are undisturbed and the area tested is considerably larger than the cross-sectional area of a core sample analyzed in the laboratory. In addition, field conductivity values reflect the presence of naturally occurring macropores (or channels of preferential flow), which may significantly affect the saturated hydraulic conductivity. Two in situ tests were conducted on surface soil west of the MWL to obtain measurements of the saturated hydraulic conductivity. The results from these tests are summarized in Table 5-1.

The first test was an IP test conducted on a 16- by-16-foot area that was flooded with more than 5,000 gallons of water. Water infiltration through the upper 6 feet of soil was monitored and measured over 890 days. The saturated hydraulic conductivity determined from steady-state flow is 4.0×10^{-4} cm/s.

The second in situ test was conducted on an adjacent 10- by-10-foot area. This site was flooded to emulate a rainfall event, and the saturated hydraulic conductivity was determined to be 5.3×10^{-4} cm/s. The average (geometric mean) hydraulic conductivity from these two in situ tests is 4.6×10^{-4} cm/s.

5.2.2.1.2 Laboratory Measurements of Subsurface Soil Hydraulic Conductivity

During the MWL Phase 2 RFI, laboratory measurements of saturated hydraulic conductivity were obtained from 18 core samples collected from subsurface soil directly below the MWL at depths ranging from 10 to 104 feet bgs. Core samples were collected ahead of the drill bit using a California split-spoon sampler and brass rings. Laboratory measurements of hydraulic conductivity were also obtained from six core samples collected from the IP test site at depths ranging from 1 to 6 feet bgs. The IP test core samples were collected with a sliding hammer core sampler and brass rings. Hydraulic conductivities for core samples obtained from Phase 2 RFI drilling and from the IP test site were measured using the relatively undisturbed soil samples, without remolding. Two additional hydraulic conductivity measurements were obtained by remolding soil from the IP test site. The results from these tests are summarized in Table 5-1.

The average (geometric mean) of the 26 laboratory measurements of hydraulic conductivity is 1.1×10^{-4} cm/s. These results are very similar to the results obtained from the in situ hydraulic conductivity test at the IP test site west of the MWL, which yielded an average hydraulic conductivity of 4.6×10^{-4} cm/s.

5.2.2.2 MWL Alternative Cover Hydraulic Conductivity

Nine composite soil samples were collected from borrow areas west of the MWL and from existing Corrective Action Management Unit (TA-3 borrow pits) soil stockpiles in TA-3. The cover will be constructed of soil from each of these borrow areas. Borrow soil was analyzed for a full suite of geotechnical parameters, including saturated hydraulic conductivity, moisture-density relationships, Atterberg Limits, grain-size analysis, and shear strength.

Saturated hydraulic conductivities were obtained at 90 percent of the maximum dry bulk density to satisfy earthwork specifications for percent (relative) compaction. Hydraulic conductivity data for the cover soil are presented in Table 5-2. The saturated hydraulic conductivity for borrow soil from areas west of the MWL averaged 3.6 x 10^{-5} cm/s, while the saturated hydraulic conductivity for the soil in the TA-3 borrow pits averaged 1.6 x 10^{-5} cm/s. Fill for the subgrade layer, the native soil layer, and the topsoil layer will come from the TA-3 borrow pits. The average (geometric mean) hydraulic conductivity of all soil samples from both borrow areas is 2.1 x 10^{-5} cm/s, which is a realistic estimate of the saturated hydraulic conductivity of the final cover.

These data demonstrate that the saturated hydraulic conductivity of the cover will be lower than the saturated hydraulic conductivity of the underlying natural subsurface soil. The estimated saturated hydraulic conductivity of the natural subsurface soil is 4.6 x 10^{-4} cm/s. The estimated saturated hydraulic conductivity of the final cover is 2.1 x 10^{-5} cm/s. Thus, the bathtub effect is unlikely to occur.

5.2.2.3 Natural Analog of the MWL Cover

The most convincing evidence that the bathtub effect will not occur at the MWL lies in the analog of natural moisture conditions in soil in the vicinity of the MWL. Existing moisture contents in this soil provide an excellent natural analog for predicting moisture contents in the cover. Soil moisture content at the MWL averages 3 percent by weight. Although the upper few inches of soil may become saturated briefly following rainfall events, evapotranspiration causes the soil to dry rapidly. Even during winter months, when plants are dormant and transpiration is low, saturated conditions rarely occur.

The vegetated soil cover for the MWL is designed to simulate natural conditions, utilizing evapotranspiration to remove excess moisture. When excess moisture is removed, water is no longer available to percolate downward into waste disposal cells. Because the alternative cover was designed to simulate natural site conditions, the cover is predicted to be unsaturated during most of its design life, which is consistent with the cover performance modeling results presented in Section 5.3.

Under these unsaturated conditions, the "operational hydraulic conductivity" of the cover will be orders of magnitude lower than the saturated hydraulic conductivity of both the cover and the natural subsurface soil. The operational hydraulic conductivity of the MWL cover is equal to the average flux through the cover, assuming a unit gradient. Performance modeling at the MWL using the Unsaturated Soil Water and Heat Flow Model (UNSAT-H) (Fayer and Jones 1990) predicted an average flux through the 3-foot cover to be 4.1 x 10^{-9} cm/s (see Section 5.3.3). HELP-3 and Variably-Saturated 2-D Flow and Solute Transport Model (VS2DT) (Healy 1990) predicted this value to be 7.1 x 10^{-11} cm/s and 2.1 x 10^{-10} cm/s, respectively. Thus, the operational hydraulic conductivity of the final cover is conservatively estimated to be 4.1 x 10^{-9} cm/s, five orders of magnitude lower than the estimated saturated hydraulic conductivity of the MWL subsurface soil (4.6 x 10^{-4} cm/s), and four orders of magnitude lower than the predicted saturated hydraulic conductivity of the cover (2.1 x 10^{-5} cm/s).

5.3 Cover Performance

Alteration of the MWL natural site conditions by grading the land surface and removing the established native vegetative cover, deploying an engineered cover, and building drainage swales will alter the site's hydrologic response. The long-range plan is to establish soil and vegetative conditions similar to existing natural conditions. Both the long-term as well as the short-term responses of the cover must be considered in its design. Engineering designs are analyzed under hypothetical scenarios that have a reasonable chance of future occurrence to demonstrate that the potential for infiltration and contaminant migration from waste disposal cells to the vadose zone and groundwater is unlikely, and to ensure that the intent of federal and state regulations and DOE orders is met.

The regulatory requirements for closure and post-closure of landfills are provided in several EPA guidance documents (EPA 1989, EPA 1991, EPA 1994). The primary closure requirement is that the owner must design and construct a low-permeability cover over the landfill to minimize infiltration of water into waste disposal cells and provide long-term care and maintenance in order to prevent releases of hazardous constituents to the environment.

5.3.1 Cover Performance Modeling

In order to demonstrate that the MWL alternative cover design complies with the regulatory guidance, it is necessary to model the hydrologic performance of the cover. The EPA (EPA 1994) suggests that the water-balance model, HELP, be used for these demonstrations. Performance of the cover was evaluated using HELP-3 (Schroeder et al. 1994) and two additional unsaturated flow models, UNSAT-H (Fayer and Jones 1990) and VS2DT (Healy 1990). Although HELP-3 is commonly used to predict infiltration through landfill covers and is widely accepted by the regulatory community, UNSAT-H and VS2DT are more rigorous and were used for comparison with the HELP-3 modeling results.

Performance modeling results were used to predict infiltration through the cover and to determine optimal cover thickness. Because construction costs are directly proportional to the thickness of a cover, the optimal cover design is one that meets the performance criteria with the least amount of thickness. Inherent in the determination of optimal cover thickness is the ability of the cover design to limit infiltration of water into waste disposal cells. In order to model the hydrologic performance of the cover, historical rainfall records from Albuquerque International Sunport, dating from 1919 to 1996, were used. This historical record provides data for assessing both the short- and long-term responses of the cover design as well as determining the performance criteria for the post-closure care and maintenance period.

HELP-3 (Schroeder et al. 1994) was specifically developed for designing landfill covers, but lacks rigorous mathematical flow calculations. This water-balance model uses simplified schemes to model both the infiltration of water through soil layers and the removal of water by evapotranspiration and overland flow. HELP-3 contains databases describing soil parameters, meteorological conditions, and vegetation; however, site-specific data for the MWL were used wherever possible to more accurately model the performance of the cover.

UNSAT-H (Fayer and Jones 1990) was designed to predict performance of waste burial sites at Hanford, Washington, an area with low rainfall and relatively dry soil, conditions similar to Albuquerque, New Mexico. UNSAT-H uses a finite-difference implementation of a modified form of Richards' equation to predict unsaturated liquid and vapor flow in soil layers as well as

water removal through plant roots (transpiration). UNSAT-H employs many of the best procedures for simulating the hydrology of soil covers (EPA 2002, Albright et al. 2002) and was used in this analysis to complement HELP-3 results.

VS2DT (Healy 1990) is a U.S. Geological Survey (USGS) code used to model flow and solute transport in variably-saturated, single-phase flow in porous media. VS2DT uses a finite-difference approximation to solve Richards' equation for flow, and the advection-dispersion equation for transport. While it offers rigorous unsaturated flow mathematics, VS2DT is designed more specifically for transport estimation than for landfill cover design, and does not include flows past a particular depth among its output files. VS2DT is the least user-friendly of the three codes, but was used in this analysis primarily because it is a well-validated USGS code commonly used to predict flow and transport of water in the vadose zone.

5.3.2 Model Input Parameters

Input parameters for the models included precipitation and climate data, evapotranspiration data, soil hydrologic properties, thickness, and miscellaneous model-dependent input parameters such as evaporative zone depth and leaf area index. Table 5-3 summarizes the input parameters specific to HELP-3, UNSAT-H, and VS2DT. HELP-3 is the most popular code in use for evaluating landfill covers. UNSAT-H generally provides the most accurate predictions of infiltration (Albright et al. 2002). Input parameters vary between models depending on whether the code is a water-balance model (HELP-3) or a Richards' equation-based model (UNSAT-H).

Numerous preliminary modeling studies of the MWL alternative cover were conducted prior to the formulation of the final results presented in this report. These studies focused on the sensitivity of the selected models to various input parameters. The results of these sensitivity analyses are presented in "Preliminary Unsaturated Flow Modeling and Related Work Performed in Support of the Design of a Closure Cover for the MWL" (Wolford 1998). The modeling results presented in this design report vary slightly from preliminary modeling results, reflecting more consistent use of input parameters between models. During the early modeling efforts for the proposed MWL alternative cover, slight variations existed between the models in parameters including rooting depth, atmospheric tension, and nodal spacing. The modeling results presented in this report used more consistent input parameters between each model to ensure compatibility between models and to facilitate comparison of the results. Modeling results were corroborated in 2004 using UNSAT-H Version 3.0 (Fayer 2000) and conservative site-specific input parameters. These modeling data are provided in Peace and Goering 2005.

5.3.2.1 Precipitation Data

All three models were run using two discrete sets of precipitation data. The first set, the "Historical Precipitation Data," included 65 yrs of daily rainfall recorded from 1932 to 1996 at Albuquerque International Sunport. The second set, the "Maximum Precipitation Data," included the eight heaviest years' rainfall between 1919 and 1996, repeated eight times for a total of 64 yrs. The heaviest rainfall years were 1919, 1929, 1940, 1941, 1982, 1986, 1988, and 1992. These rainfall data are representative of a significant climate change, and would have the greatest influence on the long-term performance of any cover system. Precipitation during these years ranged from 12 inches to more than 15 inches (30.5 to 38.1 cm/yr). These annual

totals contrast markedly with the current average annual precipitation for the Albuquerque area of 8.5 inches/yr (21.6 cm/yr).

Ecological studies performed by Waugh (1997), using proxy paleoclimate data (tree rings, packrat middens, lake sediment pollen, and archeological records) indicate bounding conditions for future climate states of twice the current precipitation at Monticello, Utah. This 64-yr (artificial) rainfall data set adequately approximates and addresses a similar climate change in New Mexico for the cover.

5.3.2.2 Soil Parameters

The soil parameters for the models were selected based upon the results from field and laboratory tests conducted in soil near the MWL. Several large-scale infiltration tests were conducted in soil west of the MWL to measure water movement through the soil and the effects of evapotranspiration and unsaturated flow. Data collected during these tests were used to select the most applicable soil parameters and to calibrate the HELP-3, UNSAT-H, and VS2DT models.

5.3.2.3 Evapotranspiration Data

Each model used synthetic PET data generated separately by the HELP-3 code for both the 65-yr historical rainfall and the 64-yr maximum rainfall runs.

5.3.2.4 Lower Boundary Conditions

HELP-3 does not require lower boundary conditions, so it was not necessary to include soil beneath the cover with the HELP-3 model. The UNSAT-H and VS2DT models, however, include soil beneath the cover. This was done to limit the potential for lower boundary conditions to influence predicted infiltration through upper soil layers. The lower boundary condition for the UNSAT-H model was a unit gradient, simulating drainage by gravity. The VS2DT model does not have a unit gradient option for a lower boundary condition. Instead, a coarse sand layer with an initial water content of 0.036 cubic centimeters was used for its lower boundary condition. This water content remained constant during the model runs.

5.3.2.5 Leaf Area Index.

A maximum leaf area index of 1.0 was used in the HELP-3 model and a maximum leaf area index of 0.8 was used in the UNSAT-H model. VS2DT does not use the leaf-area index parameter.

5.3.2.6 Model Calibration and Sensitivity Analysis

Model input parameters were tested by modeling three field infiltration experiments conducted in soil west of the MWL. The data from these infiltration experiments were used to calibrate the three models.

5.3.3 Model Results

HELP-3, UNSAT-H, and VS2DT predicted minimal infiltration through vegetated soil covers of 1, 2, 3, 4, and 5 feet in thickness, with infiltration varying as a function of cover thickness, the precipitation data set, and the model used. In each case, the models predicted an average infiltration rate of less than 4 percent of the total precipitation, regardless of cover thickness or the model used. The modeling results are discussed in detail below.

5.3.3.1 Modeling Results Using Historical Precipitation Data

During the 65-yr historical record (1932 to 1996), a total of 561.2 inches (1,425.6 cm) of precipitation was measured at Albuquerque International Sunport. The average annual precipitation during this period was 8.5 inches/yr (21.6 cm/yr). Daily precipitation values measured during the 65-yr period were input into the three models (HELP-3, UNSAT-H, and VS2DT) and the total infiltration through soil covers varying in thickness from 1 to 5 feet was predicted. These results are summarized in Table 5-4, which presents the cumulative infiltration in cm predicted through each cover during the 65-yr period, as well as the average flux in cm/s and the average infiltration rate in cm/yr. The maximum volumetric moisture content (θ) predicted for the 65-yr period is also presented in Table 5-5.

5.3.3.2 Average Annual Infiltration

The HELP-3 modeling using historical precipitation data predicted average annual infiltration ranging from 0.43 cm/yr for a 1-foot cover to 0 cm/yr for 4- and 5-foot covers (Figure 5-3). The HELP-3 modeling results indicate that average annual predicted infiltration is less than 2 percent of the total precipitation, regardless of cover thickness.

The modeling results for UNSAT-H and VS2DT (Figures 5-4 and 5-5) were similar to the results for HELP-3. In each case, the predicted average annual infiltration through the various covers modeled was only a small percentage of the total precipitation. All three models show a significant decrease in the average annual infiltration as the cover thickness is increased from 1 to 3 feet (Figures 5-3 through 5-5).

5.3.3.3 Cumulative Infiltration

Figures 5-6 and 5-7 present the cumulative infiltration predicted by UNSAT-H and VS2DT using historical precipitation data. The cumulative infiltration through a 1-foot cover over the 65-yr period of record varied from 41.5 cm (UNSAT-H) to 37.5 cm (VS2DT). HELP-3 predicted a cumulative infiltration of 28.0 cm through a 1-foot cover (see Table 5-3). A plot of cumulative infiltration versus time could not be generated for HELP-3 due to the limitations of the code.

For comparison, the total precipitation measured at Albuquerque International Sunport during 1932 to 1996 was 561.2 inches (1,425.6 cm). The cumulative infiltration through a 1-foot cover predicted by HELP-3, VS2DT or UNSAT-H during this 65-yr period was less than 3 percent of

the total precipitation, regardless of the model used, and was even less for covers of greater thickness.

5.3.3.4 Predicted Annual Infiltration through the Covers

The performance of the cover was also evaluated on a year-to-year basis to compare infiltration rates between wetter and drier years. During the years of higher precipitation, the moisture content of the cover increases, and as a result, the hydraulic conductivity of the cover, which is a function of percent saturation, increases. Consequently, infiltration is greater during the wetter years. Similarly, during drier years, the lower moisture content of the cover results in a lower hydraulic conductivity and, therefore, lower infiltration.

Annual infiltration predicted by UNSAT-H through each cover using historical precipitation data is shown in Figures 5-8 through 5-12, which demonstrate cover performance under current climatic conditions, with higher infiltration during the wetter years, and lower infiltration during the drier years. Maximum infiltration during wetter years falls significantly as cover thickness is increased from 1 to 3 feet, but less significantly as cover thickness is increased to 4 and 5 feet. Negative infiltration values shown during several years for the 1- and 2-foot covers (Figures 5-8 and 5-9) indicate net upward flux during dry years, as evapotranspiration removes moisture from the soil below the cover.

Figures 5-13 through 5-17 show the corresponding annual flux through each cover in cm/s. The maximum annual flux through a 1-foot cover is predicted to be 8.1×10^{-8} cm/s. The maximum annual flux through a 3-foot cover is significantly lower, at 1.9×10^{-8} cm/s. As cover thickness is increased to 4 and 5 feet, maximum annual flux decreases only slightly, to 1.5×10^{-8} cm/s and 0.8×10^{-8} cm/s, respectively. Thus, the most significant performance is achieved by increasing cover thickness from 1 to 3 feet, with rapidly diminishing performance improvement achieved by increasing cover thickness to 4 and 5 feet.

5.3.3.5 Predicted Moisture Contents at Various Depths within the Cover

Figures 5-18 through 5-22 show predicted moisture contents at various depths in a 5-foot cover. These moisture contents were predicted by UNSAT-H using the historical precipitation data. Moisture contents in the upper few feet of the cover fluctuate dramatically (Figures 5-18 and 5-19), with increases due to precipitation, and decreases due to evapotranspiration. These fluctuations diminish with increasing depth, indicating that precipitation is stored primarily in the upper few feet of the cover, and is rapidly removed by evapotranspiration. Lower water contents at depth and the limited fluctuations of these water contents result in a unit gradient and a very low unsaturated hydraulic conductivity, which limits infiltration to very minute levels.

5.3.3.6 Modeling Results Using Maximum Precipitation Data

To be conservative and to approximate reasonable bounding conditions for future climate states, a second set of precipitation data was modeled. These data included daily rainfall from Albuquerque International Sunport for the eight highest years on record. Precipitation during these years ranged from 12 inches to more than 15 inches (30.5 to 38.1 cm/yr). Maximum precipitation data was constructed by placing these 8 yrs of unusually high rainfall back-to-back,

and repeating this procedure eight times for a total of 64 yrs of (artificial) record. The total precipitation applied to the models in the maximum precipitation data was 855.9 inches (2,174.1 cm), approximately 50 percent greater than the precipitation applied in historical precipitation data. The results are summarized in Table 5-5 and discussed below.

5.3.3.7 Average Annual Infiltration.

The HELP-3 model using the maximum precipitation data predicted average annual infiltration ranging from 0.55 cm/yr for a 1-foot cover to less than 0.02 cm/yr for covers ranging from 2 to 5 feet in thickness (Figure 5-23). Thus, even with the maximum precipitation data, average annual infiltration through the soil cover is still less than 2 percent of the total precipitation.

The modeling results for UNSAT-H and VS2DT (Figures 5-24 and 5-25) were similar using the maximum precipitation data. In each case, the average annual infiltration through the various covers was only a small percentage of the total precipitation. All three models showed a significant decrease in average annual infiltration as the cover thickness was increased from 1 to 3 feet (Figures 5-23 through 5-25).

5.3.3.8 Cumulative Infiltration

Figures 5-26 and 5-27 present the cumulative infiltration predicted by UNSAT-H and VS2DT using the maximum precipitation data. All soil covers ranging in thickness from 1 to 5 feet proved to be effective in minimizing infiltration, with cumulative infiltration predicted to be no more than 77.7 cm during the 64-yr period. This corresponds to less than 3.6 percent of the 855.9 inches (2,174.1 cm) of precipitation applied using the maximum precipitation data. These results indicate that even if the climate changes dramatically and precipitation increases by 50 percent, a vegetated soil cover would significantly reduce infiltration.

5.3.3.9 Predicted Annual Infiltration through the Covers

The performance of the cover using maximum precipitation data was also evaluated on a year-to-year basis using the results from UNSAT-H. Figures 5-28 through 5-32 present the predicted annual infiltration through covers of varying thicknesses under significantly wetter climatic conditions. Using maximum precipitation data, infiltration exceeds 2.5 cm/yr through a 1-foot cover. Peak annual infiltration rates decrease to 1 cm/yr for a 3-foot cover and approximately 0.75 cm/yr for a 5-foot cover.

Figures 5-33 through 5-37 show the corresponding annual flux through each cover in cm/s under the maximum precipitation scenario. The maximum annual flux through a 1-foot cover is predicted to be 8.8×10^{-8} cm/s. The maximum annual flux through a 3-foot cover is predicted to be 3.1×10^{-8} cm/s, while the maximum annual flux through a 5-foot cover is 2.3×10^{-8} cm/s. Again, the most significant performance improvements are achieved by increasing cover thickness from 1 to 3 feet, with performance improvements rapidly diminishing when increasing cover thickness to 4 and 5 feet.

5.3.3.10 Performance Modeling Summary

As recommended by the EPA, performance modeling was conducted in order to demonstrate that the cover minimizes infiltration and complies with the minimum 30-yr performance criteria. The water-balance model, HELP-3, along with two additional models, UNSAT-H and VS2DT, were used to predict the performance of soil covers ranging in thickness from 1 to 5 feet. All three models demonstrate that deployment of a vegetated soil cover for final closure of the MWL will reduce infiltration into the landfill to a small percentage of the total precipitation. The models also demonstrate that a 3-foot-thick vegetated soil cover is the optimum design thickness based on predicted performance. It is evident that additional cover thickness does not lead to significantly better performance.

Although the modeling suggests that a 1- or 2-foot-thick cover will significantly limit the average rate of infiltration, "spikes" or peaks may occur during years with higher precipitation. These infiltration spikes are fewer and lower in magnitude as the cover thickness is increased to 3 feet, and as the storage capacity of the cover increases. The storage capacity of a 3-foot cover is 50 percent greater than the storage capacity of a 2-foot cover, and would provide an additional degree of conservatism should there be extreme precipitation events or significant, long-term climatic changes.

Increasing cover thickness to 4 or 5 feet results in limited improvement in cover performance yet increases construction costs. Cover construction costs are directly proportional to the thickness of the cover, and the optimal cover design is one that meets the performance criteria with the least cover thickness (Ankeny et al. 1997). A reduced finished elevation above grade would provide additional environmental benefits, reducing the cover's exposure to wind and water erosion.

Under current climatic conditions, annual infiltration through a 3-foot cover is typically less than 0.3 cm and rarely exceeds 0.5 cm (Figure 5-10). The cover's performance will actually approximate that of a 4- or 5-foot cover due to the placement of subgrade fill. Up to 40 inches of compacted fill will be placed over the existing landfill surface prior to construction of the actual cover to provide a stable, uniform subgrade for the cover (see Plate 5—Final Cover Cross Sections).

5.4 Biointrusion

Burrowing by small and large mammals is a potential pathway for transfer of hazardous constituents to the accessible environment (Kennedy et al. 1985, Hakonson et al. 1992, Gee and Ward 1997). Burrowing animals may physically transfer subsurface contaminated soil and waste to the surface and increase water infiltration by decreasing the bulk density of the soil or creating pathways of preferential flow. Burrows of small mammals have been observed at the MWL and are a potential pathway for transfer of hazardous constituents from waste disposal cells to the accessible environment.

The presence of small and large animal burrows and their effect on cover performance has been a concern for scientists and engineers at the Hanford site in Washington for many years (Gee and Ward 1997). Gee summarizes observations at Hanford as follows:

> From the results of lysimeter tests performed at the Animal Intrusion Lysimeter Facility, the presence of small mammal burrows does not appear to have a

> significant influence on the deep percolation of water. During the summer months, more water is lost from plots with animal burrows than from plots with no animal burrows. During winter months, plots with animal burrows and plots without animal burrows gain water. In addition, water does not infiltrate below 36 in., even though burrow depth exceeds 48 in. The lack of significant infiltration at depth and the overall loss of water in the lysimeters occurs even though 1) no vegetative cover exists, 2) no runoff is allowed, 3) burrow densities in the lysimeter are greater than burrow densities found in natural settings, 4) extreme rainfall events are applied frequently, and 5) animal burrows are deeper in the lysimeter than in natural settings. The overall water loss from soils with small mammal burrows appears to be enhanced by a combination of soil turnover and subsequent drying, ventilation effects, and high ambient temperature.

Similar water loss results have been observed at the Arid Land Ecology Reserve at the Hanford site for large mammal burrows excavated by coyotes and badgers in search of prey. Large mammals do appear to cause increased deep infiltration but much of this water is removed by co-located, dense vegetation. The density of vegetation near large mammal burrows was significantly greater than in adjacent, undisturbed areas away from the burrows (Gee and Ward 1997).

A biointrusion barrier consisting of crushed rock could be placed at depth within a cover to mitigate burrowing mammals. Plant root growth also may be restricted to soil above the biointrusion barrier. If roots are restricted to the soil above the biointrusion barrier, the net transpiration and effective water storage capacity of the cover system could be significantly reduced. In this case, depth of emplacement of a biological intrusion barrier within the soil profile is paramount.

In 1993, researchers at Idaho State University and the Environmental Research Foundation initiated a large-scale experiment to compare the performance of two soil-plant cover designs that included biological intrusion barriers at depths of 0.5 and 1.0 meters (m) (Anderson 1997). The objectives of the study were to examine the effects that placing a rock intrusion layer in a soil cap would have on water infiltration, water storage capacity, and plant rooting depths. Anderson (1997) summarizes their observations as follows:

> Biobarriers are clearly an impediment to root growth. We have only seen extraction below the biobarriers when volumetric water content below the barrier was initially at least 25 percent. There may be a threshold of water content below which plants are unable to detect the presence of extractable water below a biobarrier. Plants can, however, penetrate biobarriers and extract water from the soil if water content is sufficiently high.

Another study performed by Anderson (Anderson and Forman 2002) determined that if a biointrusion barrier is used, a 0.5-m gravel/cobble barrier should be placed at the bottom of a 1.2-m homogeneous soil reservoir.

The final phase of nearly two decades of research on biointrusion by Idaho State University at Idaho National Engineering and Environmental Laboratory (INEEL) was published in 2002 (Anderson and Forman 2002). Two cap configurations were recommended including a soil-only cap consisting of a 2-m depth of homogenous soil or a cap of a 1.2-m depth of homogenous soil overlying a 0.5-m thick gravel/cobble intrusion barrier. Caps constructed according to either of

these configurations should preclude virtually any precipitation from reaching interred waste. A major advantage of the soil-only cap is simplicity of construction. Anderson and Forman (2002) recommend that if a biobarrier is used, it should be placed at the bottom of the soil reservoir.

Field studies at the MWL have shown that maximum root density of dominant species occurs in the upper 12 inches (30 cm) of the soil profile (Peace et al. 2004). Lesser root density has been observed to depths of 31 inches (80 cm), and root growth rarely exceeds 39 inches (1 m).

Emplacement of a woven steel mesh at a shallow depth (e.g., below the topsoil layer) would discourage small and large mammals from burrowing deep into the cover and would have little effect on root density and depth or the effective water storage capacity of the cover system. The cost of a woven steel mesh could be significant, however, and the durability of metal biointrusion barriers has not been established. A crushed rock biointrusion barrier placed at the bottom of the soil reservoir would be a more cost-effective approach. Rock is less expensive, readily available from off-site suppliers, and more durable. The size of the crushed rock and the requirements for placement (e.g., thickness) are usually determined in collaboration with the regulatory authority.

5.5 Subsidence

Waste in disposal cells at the MWL may contain voids resulting from incomplete filling of waste containers, limited internal compaction of contents, and voids between containers. These voids may induce subsidence as waste containers deteriorate and/or collapse over time. Rates of decay will vary for different containers. Although subsidence has the potential to damage a landfill cover, predicting subsidence effects is very difficult because of the heterogeneous nature of the waste forms, backfill materials, and local climatic conditions.

Cover designs that include compacted clay soil, flexible membrane liners, and geosynthetic clay liners would not function as intended when subject to tensile and shear stresses during subsidence. These common liners, geomembranes, and geosynthetic materials require rigorous quality control during manufacture and are easily damaged during installation on an operational scale. The MWL alternative cover design, consisting of a thick layer of native soil, is constructed without liners, and thus will accommodate differential subsidence without undue impairment of its performance. During the long-term care period, soil readily available in TA-3 will be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers. Topsoil will be replaced according to original construction specifications. This provides additional assurance for adequate long-term performance of the cover system.

5.6 Runoff and Run-On Control

The amount of water available for infiltration is a function of the amount of precipitation that falls on the cover surface less the amount of water that runs off and away from the cover surface. The surface of the cover has been designed with a central crown and a 2-percent slope to promote runoff of surface water while minimizing erosion of the topsoil layer.

A design requirement of RCRA is that the cover withstands a 25-yr, 24-hr storm event. Storm water run-on will be prevented from impacting the cover by constructing an earthen swale along the eastern perimeter of the site. Run-on will be diverted at the perimeter and directed to the south and the north toward the surrounding landscape. Cover surface erosion from storm water

runoff will be mitigated by native vegetation and admixed gravel in the topsoil layer. Cover surface runoff will be directed toward the surrounding landscape.

For the Albuquerque area, the rainfall amount for a 25-yr, 24-hr storm is 2.5 inches (City of Albuquerque 1993).

5.7 Erosion Control

Erosion of the cover by wind and water is a significant design consideration. The design should minimize the effects of wind and water erosion of the surface, side slopes, and toe of the cover. The cover has been designed to have native vegetation growing over the surface, side-slopes, and toe throughout the design life. The presence of vegetation on the cover surface combined with the presence of gravel admixed with the topsoil layer will significantly reduce the amount of fine soil lost from wind and water erosion.

Wind erosion studies by Ligotke and Klopfer (1990) and Ligotke (1993, 1994) at the Pacific Northwest National Laboratory Aerosol Wind Tunnel Research Facility have demonstrated that soil and gravel admixtures with particle sizes of 3 to 7 millimeters provide superior surface protection. The best gravel admixtures reduced surface deflation rates by greater than 96 percent compared to unprotected surfaces. Water erosion studies by Walters et al. (1990) and Gilmore and Walters (1993) determined that the most dominant factor in reducing runoff and sediment yield was the presence of a vegetated cover.

Erosion studies by Finley et al. (1985) and soil water balance studies by Waugh et al. (1994) and Sackschewsky et al. (1995) demonstrate that moderate amounts of gravel mixed into cover topsoil will control both water and wind erosion with little effect on plant growth or soil-water balance. As wind and water pass over the surface, some winnowing of fines from the admixture occurs, leaving a vegetated erosion-resistant pavement (Waugh 1997). The amount of gravel used in the admixture is a major design consideration. If too much gravel is used, plant transpiration and surface evaporation could be significantly reduced which would increase the potential for water infiltration. Overall, the presence of a 15 to 30 percent gravel admixture is effective in reducing the deflation of fine soil from a cover surface by wind and water erosion (Ligotke 1994).

5.7.1 The Universal Soil Loss Equation

The empirical equation known as the universal soil loss equation (USLE) was devised by Wischmeier and Smith in 1965. The EPA recommends use of the equation to estimate average annual soil loss from a cover. The equation is as follows:

$$A = R\ K\ LS\ C\ P$$

where

A = Estimated average annual soil loss in tons/acre/yr;
R = Rainfall erosivity factor;
K = Soil erodibility factor;

LS = Topographic factor;
C = Surface-cover factor; and
P = Management factor.

A modified version of the USLE (EPA 1980) was employed to estimate the soil erosion potential from the surface and side slopes of the cover by overland runoff. The modified universal soil loss equation (MUSLE) is

$$A = R\ K\ (LS)\ (VM)$$

where

A = Estimated average annual soil loss in tons/acre/yr;
R = Rainfall factor;
K = Soil erodibility factor;
LS = Topographic factor; and
VM = Erosion control factor.

Soil loss was calculated using the MUSLE for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. The estimated average annual soil loss from the cover surface and side slopes is 0.77 tons/acre/yr and 0.08 tons/acre/yr, respectively. These losses are well below the design requirement recommended by the EPA (EPA 1989) of less than 2 tons/acre/yr.

The MUSLE contains inherent limitations. In general, erosion is not a steady, orderly, easily predictable process. Much of it takes place episodically. A single torrential rainfall striking a barren soil may cause more soil loss in a few hours than a whole season's "normal" rainfall over a fully vegetated cover. Inherent limitations include:

- The MUSLE is not intended for estimating erosion in a particular year, but rather estimating long-term averages.
- The condition of the cover is not static over time, so the erosion will vary from year to year. For example, the cover will initially have little vegetation and will be more susceptible to erosion. After initial erosion, remaining soil may be less susceptible than the initial surface, because the more susceptible fractions are lost first.
- The slope factor, LS, assumes that the central, gently sloping portion of the cover surface does not increase the amount of runoff that occurs down the side slopes, i.e., all rain falling on the cover surface infiltrates rather than running off the surface. This assumption may not be valid for the most intense storms.
- Wind may cause erosion from the cover that is not accounted for by the MUSLE.

5.7.2 The Wind Erosion Equation

The wind erosion equation (WEQ) was used to estimate the soil erosion potential from the surface and side slopes of the cover by wind. The WEQ was introduced in 1963 because it was recognized that wind could be a major geological phenomenon for erosion. In 1997, the WEQ

was modified by the U.S. Department of Agriculture (USDA 1997) in the National Agronomy Manual.

The WEQ is

$$E = f\,[(IKC)\,LV]$$

where

E = Estimated average annual soil loss in tons/acre/yr;
I = Soil erodibility index;
K = Ridge roughness factor;
C = Climatic factor;
L = Unsheltered distance; and
V = Vegetative factor.

Soil loss was calculated using the WEQ for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. In both cases, the estimated average annual soil loss from the cover surface and side slopes is 0 tons/acre/yr.

A number of inherent limitations are also present in the WEQ. These limitations include:

- When the unsheltered distance, L, is sufficiently long, the transport capacity of the wind for saltation and creep is reached. If the wind is transporting all of the soil it can carry across a given surface, the inflow into the downwind is equal to the outflow for saltation and creep. The net soil loss is then only the suspension component. This does not imply a reduced soil erosion problem because theoretically there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the surface.

- Surface armoring by nonerodible gravel, snow cover, and inherent seasonal change is not addressed in the soil erodibility factor, I.

- The WEQ does not estimate soil erosion from single storm events.

5.8 Slope Stability

A common problem leading to cover failure is slope failure at barrier interfaces caused by excessive soil moisture, especially on steep side slopes. Documented slope failures have been attributed to slip planes created at synthetic layer interfaces (Daniel and Gross 1995). Covers usually contain multiple layers of earthen and synthetic materials. Performance usually depends upon maintaining discrete boundaries between earthen layers and synthetic materials during construction and throughout the design life of the cover system. Interfaces between layers are susceptible to lateral flow of infiltrating water that leads to reduced friction and subsequent failure. Layer interfaces are also susceptible to root and animal intrusion and soil illuviation.

The cover has been designed to mitigate all such potential failure mechanisms. The cover is centrally crowned and sloped at 2 percent to the side slopes that, in turn, are tied to the surrounding landscape at 6:1. The monolithic cover will not be susceptible to failures common to conventional, multi-layer, multi-component designs.

5.9 Vegetated Cover

The influence of vegetation on the hydrologic relationships of the cover cannot be overemphasized. Vegetation will play a key role in stabilizing the newly constructed surface by mitigating wind and water erosion. Vegetation will also play a key role in maintaining the cover's water balance, significantly reducing the amount of water available for contact with disposal cell waste and subsequent contaminant transport. Vegetated covers are also extremely versatile, adapting to climatic change through natural selection and severe disturbance (fire and drought). Once native flora is established, it will persist indefinitely with little or no maintenance.

The flora in the TA-3 area is predominantly Mesa and Desert Grassland and, to a lesser degree, Sandsage and Chihuahuan Desert Shrubland. Flora exhibit influences from the Great Basin Desert, Rocky Mountains, Chihuahuan Desert, and the Great Plains. Typical plant species occurring in the area include grasses (black grama, dropseed, galleta, burrograss, bush and ring muhly), wildflowers (globemallow, aster, spectacle pod), and shrubs (sandsage, winterfat, mormon tea, yuccas, prickly pear, snakeweed) (Sullivan and Knight 1992; Peace et al. 2004).

The vast majority of TA-3 is dominated by grassland vegetation. Specifically, it represents the Mesa and Desert Grassland habitat types. The extreme western portion of the TA-3 area falls into the Sandsage Shrubland vegetation habitat. Most of the vegetation at the MWL is composed of elements of the Black Grama Grass Series. This series includes black grama, dropseed, threeawn, galleta, Indian ricegrass, and burrograss.

The desired plant community for the MWL vegetated cover is desert grassland. Grasses root at shallower depths than shrubs and, when they do root deeply, the roots are fibrous, thinner, and less damaging to the cover than the woody roots of shrubs and trees. Grass roots form a dense and interwoven fibrous network that binds the soil. Grasses concentrate their biomass close to the surface, forming a protective mat that provides protection against wind and water erosion.

5.10 Radon Gas Emission

Emission of radon gas from the MWL was investigated in 1997 by SNL Environmental Management. No significant difference between the MWL and the background measurements in terms of median, mean, and standard deviation was observed. The radon flux measurement technique employed for this study was capable of detecting radon flux in the range of 1 to 2 percent of the 20 pCi/m^2/s limit listed in 10 CFR 834.

5.11 Tritium Flux Measurements

Sandia conducted studies in 1992/1993 and in 2003 to measure the tritium flux emitted from the MWL to the atmosphere. During each study, emission isolation flux chambers were deployed at various locations across the landfill to measure the tritium flux to the atmosphere. The data collected show that the overall tritium emissions from the MWL were significantly lower in 2003

than in 1992/1993. The estimated tritium emitted from the MWL to the atmosphere in 2003 was 0.090 curies (Ci)/yr, whereas the estimated tritium emitted from the MWL in 1993 was 0.486 Ci/yr. This 82 percent reduction reflects the natural radioactive decay of tritium, and its relatively short half-life of 12.3 yrs.

6.0 MWL ALTERNATIVE COVER DESIGN

The MWL alternative cover design drawings are provided on Plates 1 through 6. The construction specifications and the construction quality assurance plan are included in Appendices A and B, respectively. The qualifications of persons implementing the CMI plan and the health and safety plan are included in Appendices C and D, respectively. The design drawings include plates showing the MWL existing site plan, subgrade grading plan, final cover grading plan, final cover cross-sections, and miscellaneous details. The cover will be placed over the original 2.6-acre landfill surface and tied to the surrounding landscape. A vegetated topsoil layer admixed with 25 percent 3/8-inch crushed gravel will be applied to maintain water balance and mitigate water and wind erosion. The components of the cover are shown in Figure 6-1 and are discussed in the following sections.

6.1 Existing Landfill Surface

The existing landfill surface will be prepared for cover construction by clearing and grubbing. Perimeter fences will be removed and the landfill surface cleared of vegetation and rock. Grubbing will not exceed 6 inches in depth to minimize disturbance to surface soil and conform to radioactive area soil contamination requirements. Grubbed material will be disposed of according to SNL waste management policy and procedures. The landfill surface will be compacted to achieve the appropriate density in preparation for subgrade fill.

6.2 Subgrade Layer

Subgrade fill will be obtained from the TA-3 borrow pits located approximately 1.5 miles south of the MWL. Soil from the TA-3 borrow pits has been tested to verify engineering properties specified in the design. Subgrade fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. Approximately 6,500 cubic yards (yd^3) of subgrade fill will be placed and graded to establish a central crown and uniform 2-percent slope in preparation for the biointrusion barrier.

6.3 Biointrusion Barrier

A crushed rock biointrusion barrier will be placed on the subgrade layer. This bio-barrier will be composed of approximately 4,900 yd^3 of rock fragments 1 to 6 inches in dimension. The rock will be highly siliceous in nature and have 100 percent fracture face. The crushed rock will be placed in a single lift of uniform thickness and compacted until the crushed rock fragments are firmly locked in place.

6.4 Native Soil Layer

Native soil layer fill will be obtained from the TA-3 borrow pits. Approximately 13,200 yd^3 will be placed and graded to construct the native soil layer, which will act as a water storage reservoir, retaining and storing water that infiltrates through the topsoil layer until it can be removed by

evapotranspiration. Native soil layer fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. The native soil layer will be graded to maintain the central crown and the uniform 2-percent slope. Any grade stakes used on the project will be removed and backfilled with cover material to meet design specifications.

6.5 Topsoil Layer

Topsoil layer fill will be obtained from the TA-3 borrow pits. Approximately 3,900 yd^3 of surface soil will be obtained from TA-3 borrow pits. The topsoil layer will serve as the vegetative cover and erosion protection layer. A 25-percent (by volume) 3/8-inch crushed gravel will be admixed into the topsoil layer to control erosion without adversely affecting desirable vegetation and soil-water balance. The topsoil layer will be minimally compacted to facilitate plant growth and root development.

6.6 Vegetation

Following installation of the topsoil layer, reclamation seeding activities will take place. The designated native vegetative seed mix will be applied to the cover, lay-down areas, and any other areas disturbed by construction operations. The surface will be fertilized, drill-seeded, mulched and crimped. The native seed mixture is based upon on biological assessments of TA-3 (Sullivan and Knight 1992, Peace et al. 2004). The mixture will consist of black grama, spike dropseed, galleta grass, and ring muhly. The initial plant community is designed to approximate the dominant and subdominant species and will gradually develop into a climax community indistinguishable from the natural analog.

7.0 VADOSE ZONE MOISTURE MONITORING

The MWL alternative cover will incorporate a shallow vadose zone monitoring system deployed directly beneath the landfill. The shallow vadose zone monitoring system will consist of three neutron probe access holes drilled at a 30 degree angle directly below waste disposal cells. The shallow vadose zone monitoring system will function as an “early warning system.” Early detection of a potential threat to groundwater will allow corrective action to be initiated before significant contaminant migration occurs. This monitoring approach was designed to protect groundwater resources and is proposed for the MWL because of its simplicity, low cost, and long-term viability.

The shallow vadose zone monitoring system will provide water infiltration and performance information, early detection of potential contaminant migration from the landfill, as well as establishing background and trend analysis information. The shallow vadose zone monitoring system is a simple system designed to meet the intent of long-term RCRA and DOE performance requirements. The shallow vadose zone monitoring system will be monitored regularly once the alternative cover has been deployed. The frequency and duration of long-term monitoring will be established in consultation with the NMED and formally documented in the MWL Long-Term Monitoring and Maintenance Plan.

7.1 Shallow Vadose Zone Moisture Monitoring

Three angled, 4.5-inch-outside-diameter, 3.75-inch-inside-diameter access holes will be installed in the shallow vadose zone directly beneath the MWL: two to the west and one to the east of the cover (Figure 7-1). The vadose zone access holes will be spaced at equal increments, with the east access hole bisecting the two west access holes. The holes will be installed using the Resonant Sonic drilling technique. Resonant Sonic is the preferred drilling technique because it literally fluidizes and displaces the surrounding soil as the drill-string advances, creating a very tight fit between the drill-string and the formation.

Each access hole will be collared approximately 10 feet outside the projected toe of the cover side slopes. Each access hole will be drilled 200 linear feet at 30 degrees to a true vertical depth of 173 feet (Figure 7-2). As each access hole is completed, the 4.5-inch sonic drill-string will be left in place and uncoupled at the surface leaving about 2 feet of drill pipe above grade. Each pipe will remain open to the vadose zone for future vadose zone soil gas sampling. A 3- by-3-foot concrete pad will be placed around each protective cover to prevent preferential flow down the annulus. Protective stanchions, 4 inches in diameter, will be placed at the outer corners of the concrete pad. The stanchions will be set 2 feet below grade and 3 feet above grade.

7.1.1 Neutron Moisture Monitoring

Neutron moisture probes take advantage of the neutron moderation process in which high-energy neutrons emitted from a radioactive source are moderated, or slowed, by collisions with surrounding atoms. Slowed neutrons, also called thermalized neutrons, emit a pulse of detectable energy, which is counted in a neutron detector contained in the neutron probe.

The neutron moderation process is dominated by neutron-hydrogen collisions that result in appreciable neutron moderation. Thus, relatively high hydrogen density (near the source) results in rapid neutron moderation. Hydrogen in geologic materials occurs as water, mineralogically bound H^+, organic soil components, and organic liquids (solvents, petroleum fuels). Water is nearly always the greatest source of hydrogen in soil. Therefore, as dry soil becomes wet, the thermalized neutron density near a neutron source and detector increases. The radius of influence for neutron moisture probes depends upon source strength, hydrogen density, soil density, and chemistry. Practical limits are from 6 to 24 inches from the point between probe source and detector. The cloud of thermalized neutrons is compact in wet and/or dense soil, and expanded in dry and/or loose soil (Jury et al. 1991).

A neutron probe consists of a compact americium (Am)-beryllium (Be) source and a thermal neutron detector that can be lowered into an access hole for readings at discrete footage intervals. The Am-Be source emits high-energy neutrons that collide with hydrogen nuclei (moisture) in the surrounding soil. Hydrogen nuclei substantially slow the neutrons, and thus the neutron counts by the detector are linearly increased with the amount of hydrogen in the soil. A California Pacific Nuclear (CPN) Model 503DR Hydroprobe containing a 50-millicuries Am-241:Be neutron source has been used to date for monitoring the shallow vadose zone.

The neutron moisture probe is increasingly being applied to address characterization and infiltration issues at environmental sites undergoing long-term care. Neutron moisture measurement was established in agriculture in the 1960s before environmental monitoring needs were identified (Kramer et al. 1992). Neutron moisture monitoring has become the industry standard for soil moisture measurement and its operation and data interpretation is well established. The technique's principal advantage is repeatability, precision, and long-term viability. The access-hole casings are not permanently installed, which allows for periodic calibration of the neutron probe.

The number and location of neutron probe access holes is guided by practical considerations and knowledge of vadose zone hydrologic processes. The number and location of shallow vadose zone neutron probe access holes was determined in consultation with the NMED HWB and the Oversight Bureau staff. Neutron moisture monitoring and data collection will follow field operating procedures (FOP) as outlined in SNL ER FOP 95-21, "Use of the CPN Model 503 Hydroprobe for Subsurface Moisture Measurement."

8.0 CONCLUSIONS

The EPA has established performance-based criteria for RCRA Subtitle C covers for hazardous and radioactive waste landfills, but allows for alternative designs based upon a demonstration that the alternative design, together with natural site conditions, prevents the future migration of hazardous constituents into the groundwater or surface water. The NMED, the lead regulatory agency, has adopted EPA's 40 CFR 264 regulations and likewise accepts alternative cover designs as long as the design meets the intent of the regulations.

In this report, Sandia has demonstrated that the MWL alternative cover meets the performance-based criteria in 1) minimizing infiltration of water through the cover; 2) minimizing maintenance and erosion; 3) promoting surface drainage; 4) accommodating subsidence; and 5) having a permeability equal to or less than the MWL subsurface soil.

Performance modeling indicates that a 3-foot-thick, vegetated soil cover is the most propitious design for the MWL. The vegetated soil cover is a simple, elegant, and effective design that takes advantage of TA-3 native soil and natural hydrological processes. The cover adequately protects groundwater resources under historical and projected future climatic conditions.

The 3-foot-thick, vegetated soil cover with a 1-foot-thick biointrusion barrier, integrated with natural site conditions, produces a "system" performance that will ensure that federal and state regulatory requirements and DOE Orders are met. Specifically, the vegetated soil cover will:

- Minimize water infiltration through the closure cover. The combined cover/subgrade with native vegetation will minimize water infiltration into waste disposal cells. Modeling data indicates that water does not migrate significantly past a 3-foot-thick layer of native soil.

- Function with minimum maintenance. Maintenance will be minimized by using a monolithic soil layer. Multi-layer, multi-component covers, such as those used in conventional designs, would require continuous maintenance and are more susceptible to failure.

- Promote drainage and minimize erosion of the cover surface. The cover will be centrally crowned and sloped at 2 percent to the edge of the side slopes which, in turn, tie into the surrounding landscape at a slope of 6:1. Native vegetation will minimize wind and water erosion while promoting water removal from the cover through evapotranspiration.

- Accommodate settling and subsidence so that the integrity of the cover is maintained. Subsidence will be accommodated using a "soft" design. During the cover's design life, soil can be added to the cover to correct subsidence and erosion as it occurs.

- Have a permeability less than or equal to the permeability of the MWL subsurface soil. The cover will be constructed with soil native to TA-3. Evaluation of the bathtub effect demonstrates that the permeability of the cover soil is equal to or less than that of the natural subsurface soil present.

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FIGURES

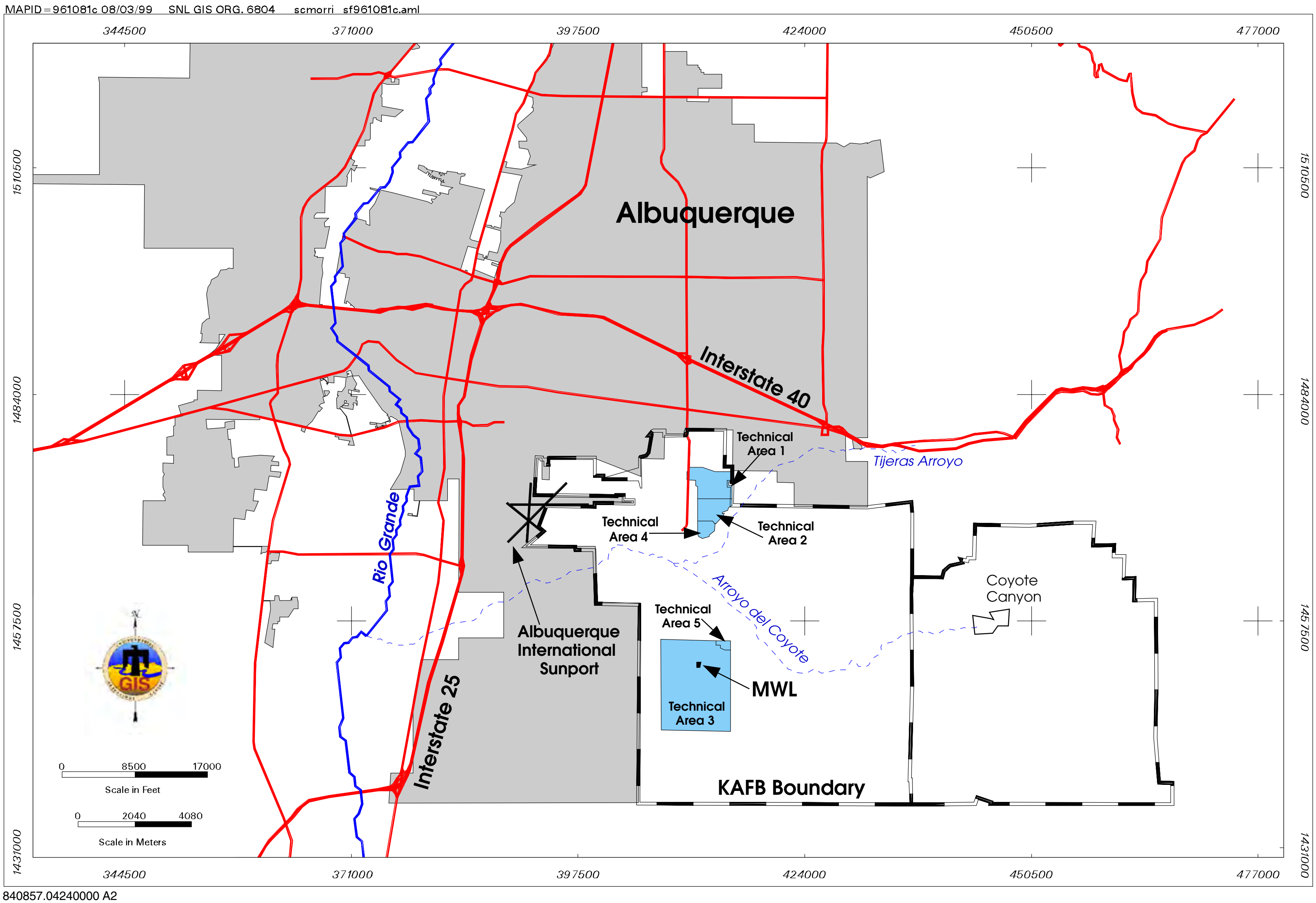

Figure 1-1 Location of Kirtland Air Force Base and Sandia National Laboratories, New Mexico

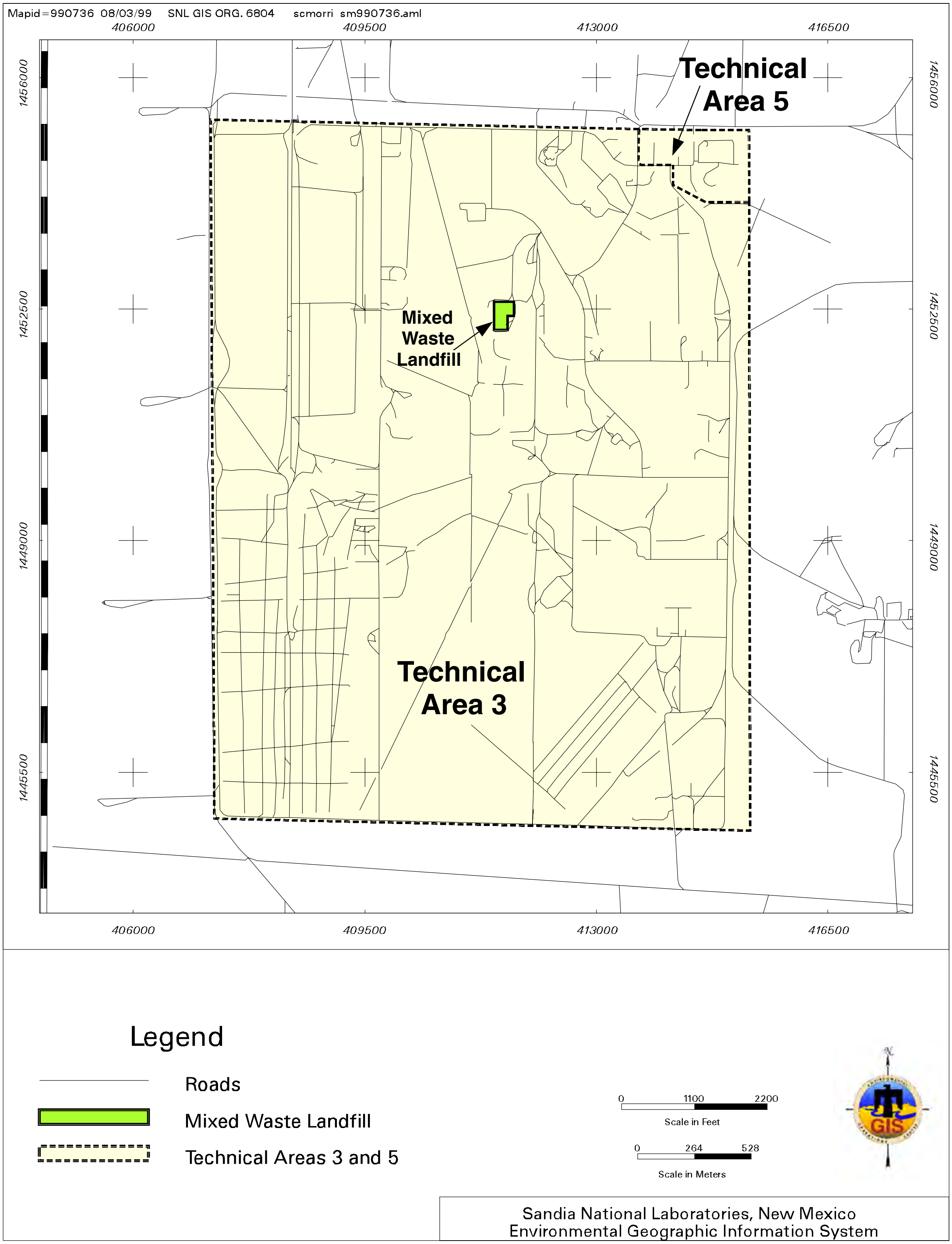

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Figure 1-2 Location of Technical Areas 3 and 5 and the Mixed Waste Landfill

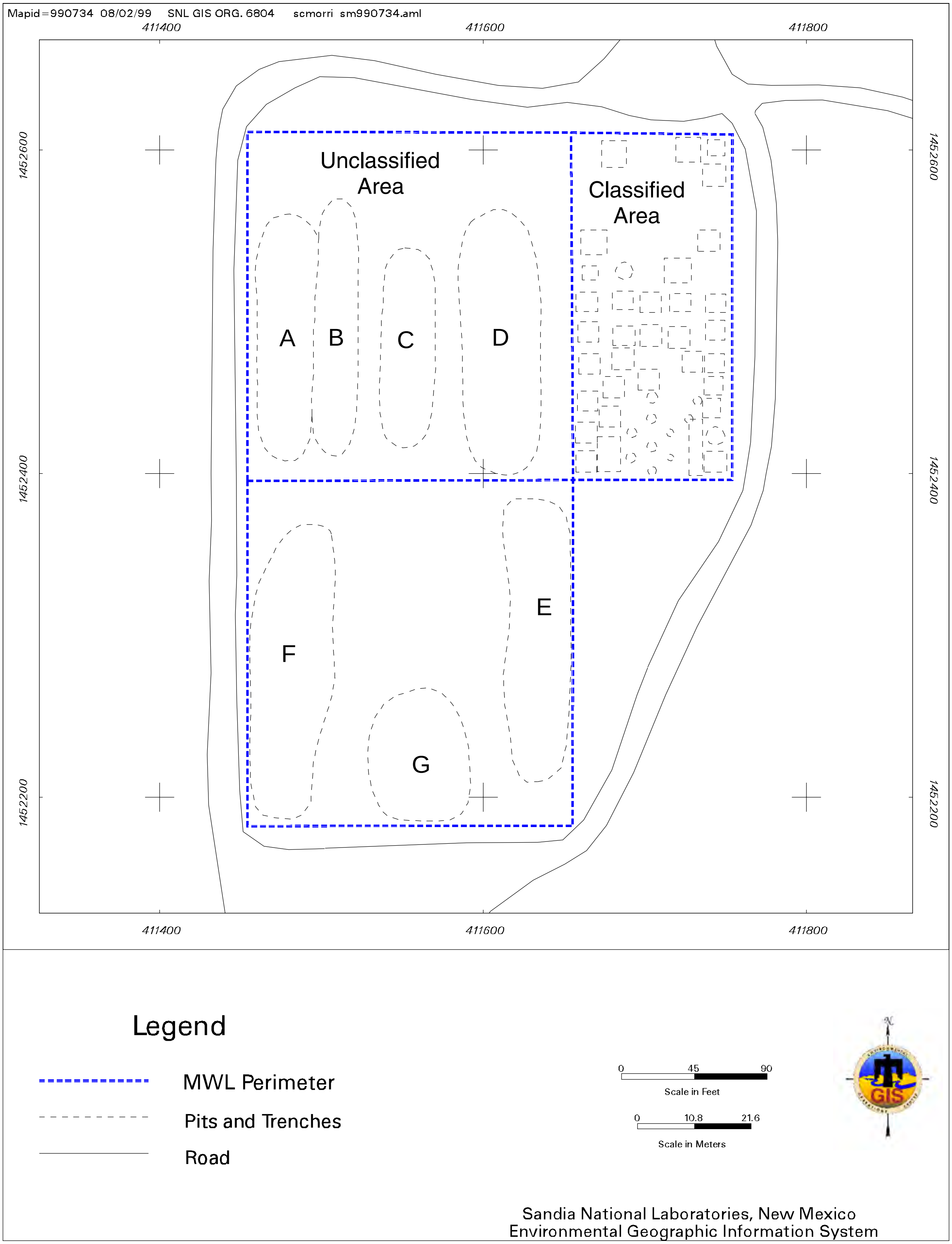

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Figure 1-3 Map of the Mixed Waste Landfill

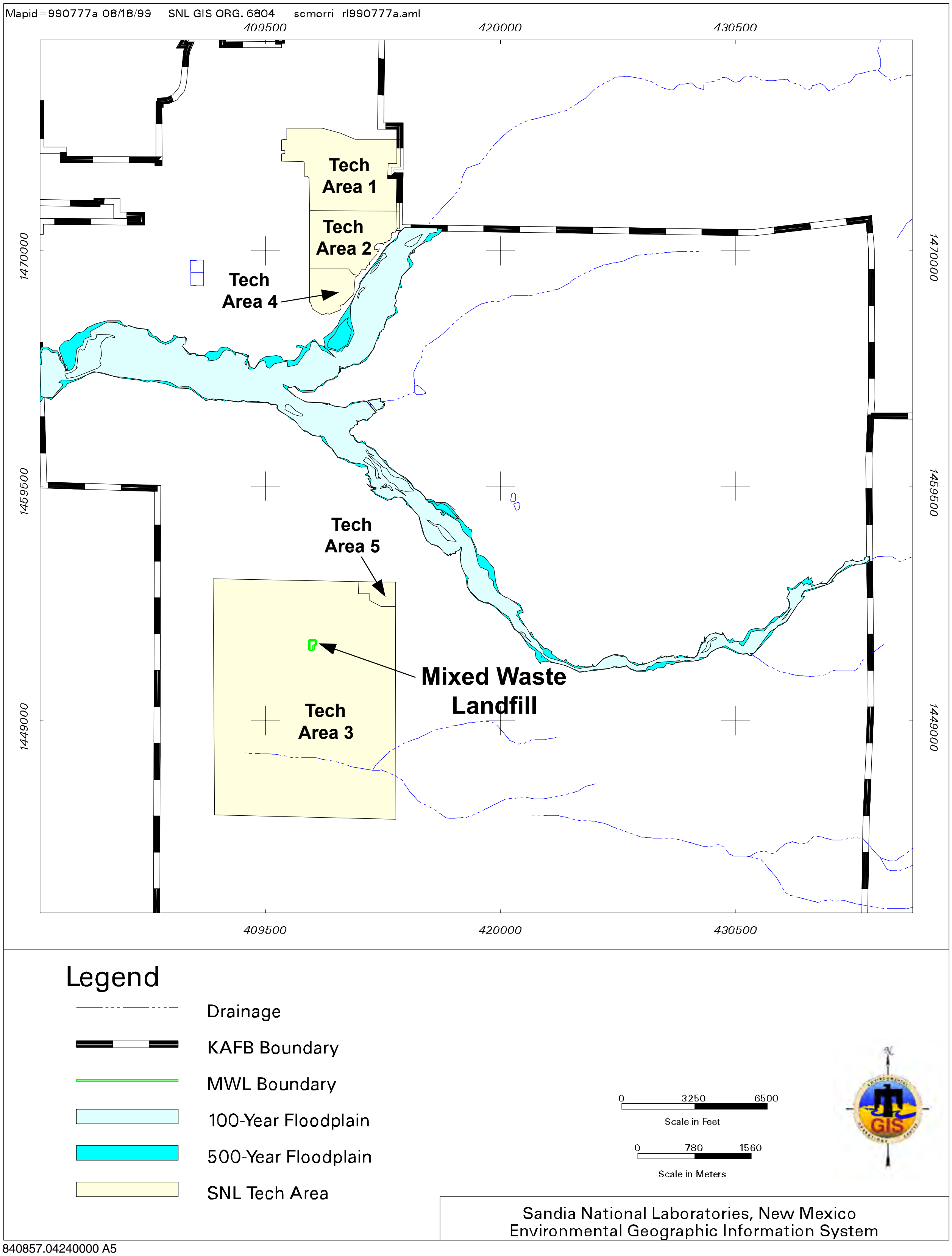

Figure 2-1 Location of the 100–Year and 500–Year Floodplains at Kirtland Air Force Base

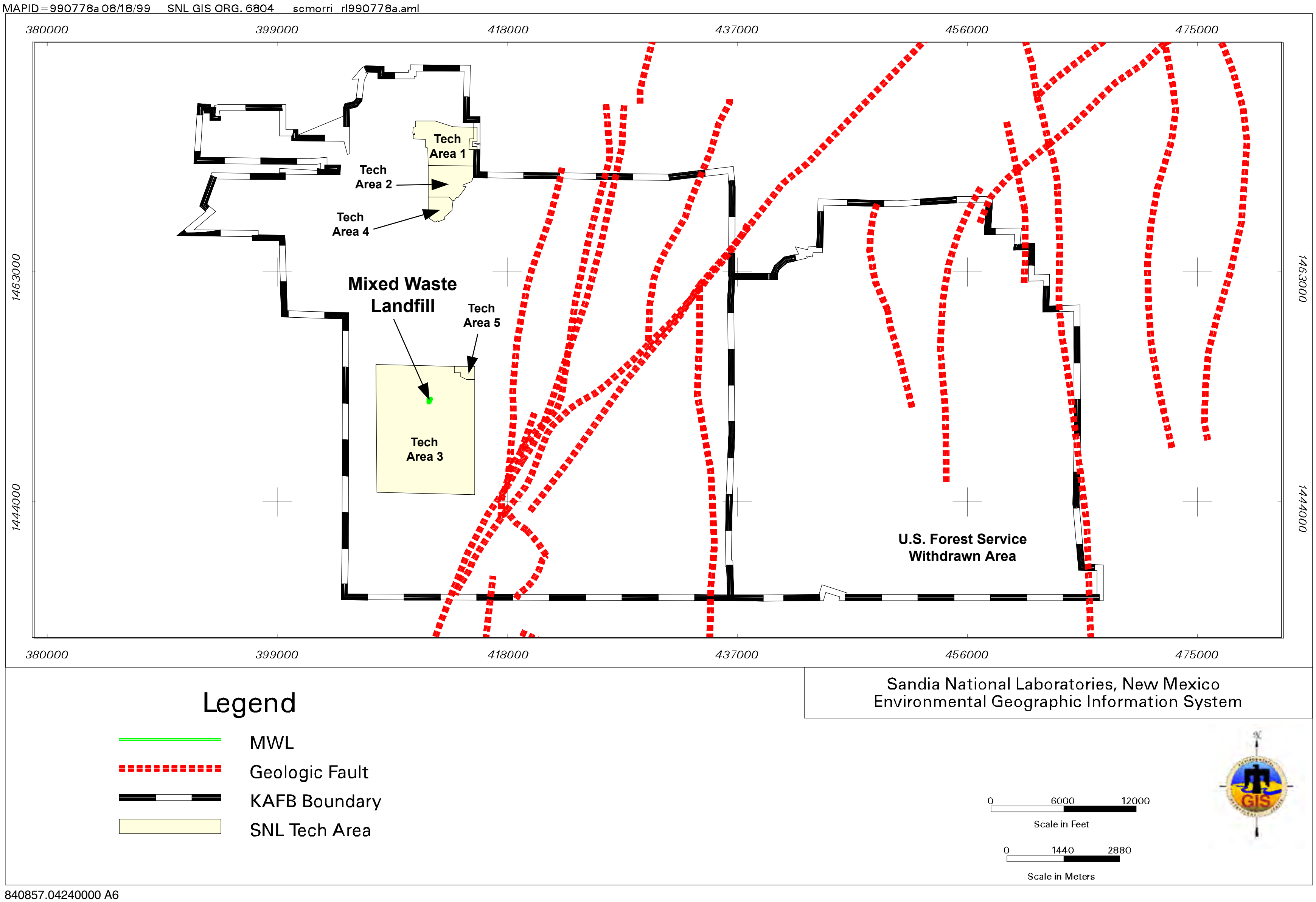

Figure 2-2 Location of Geologic Faults at Kirtland Air Force Base

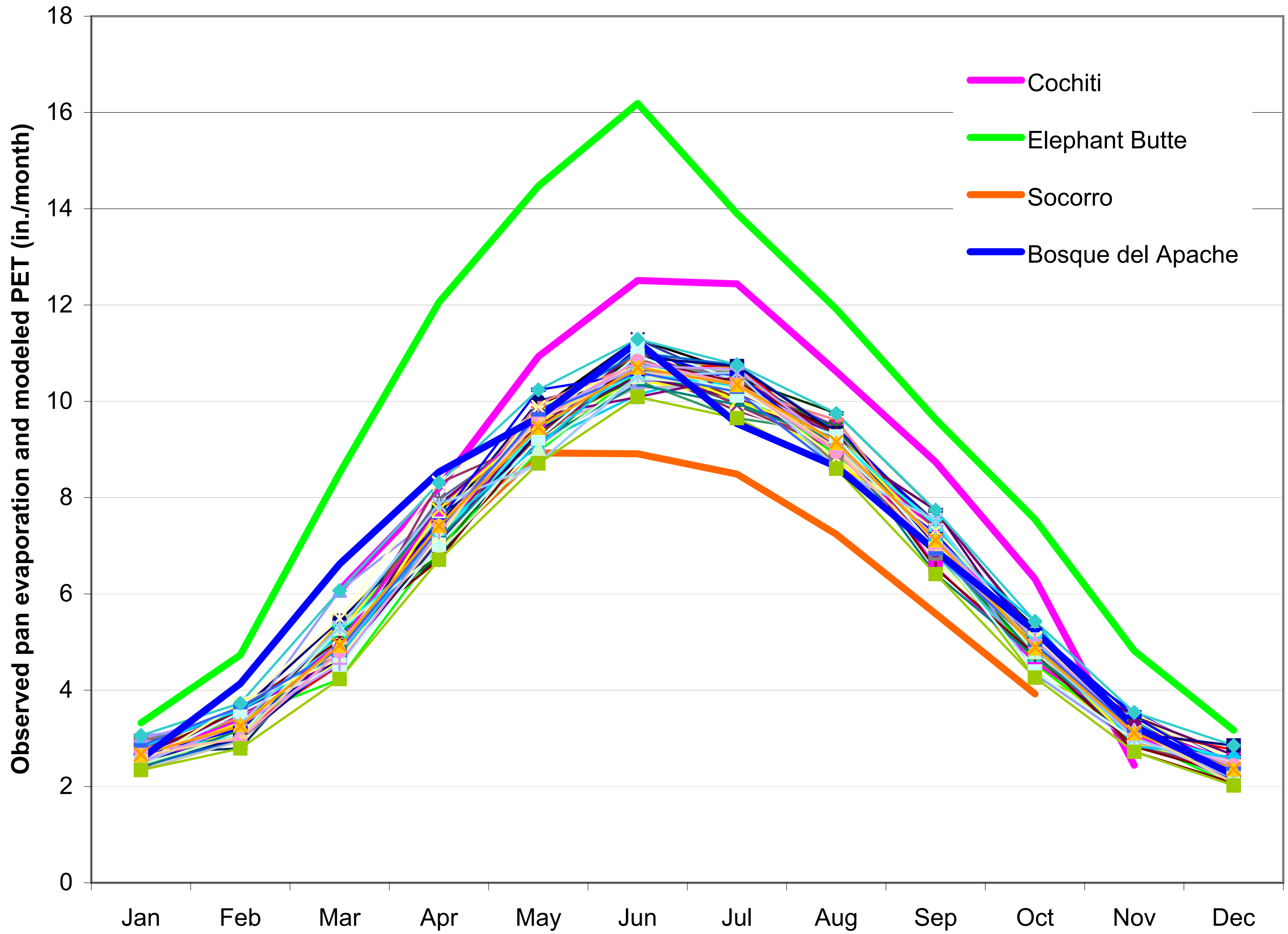

Figure 5-1 65 Years of Monthly PET Predicted by HELP-3 Shown with Average Monthly Pan Evaporation from Four National Weather Service Stations in New Mexico

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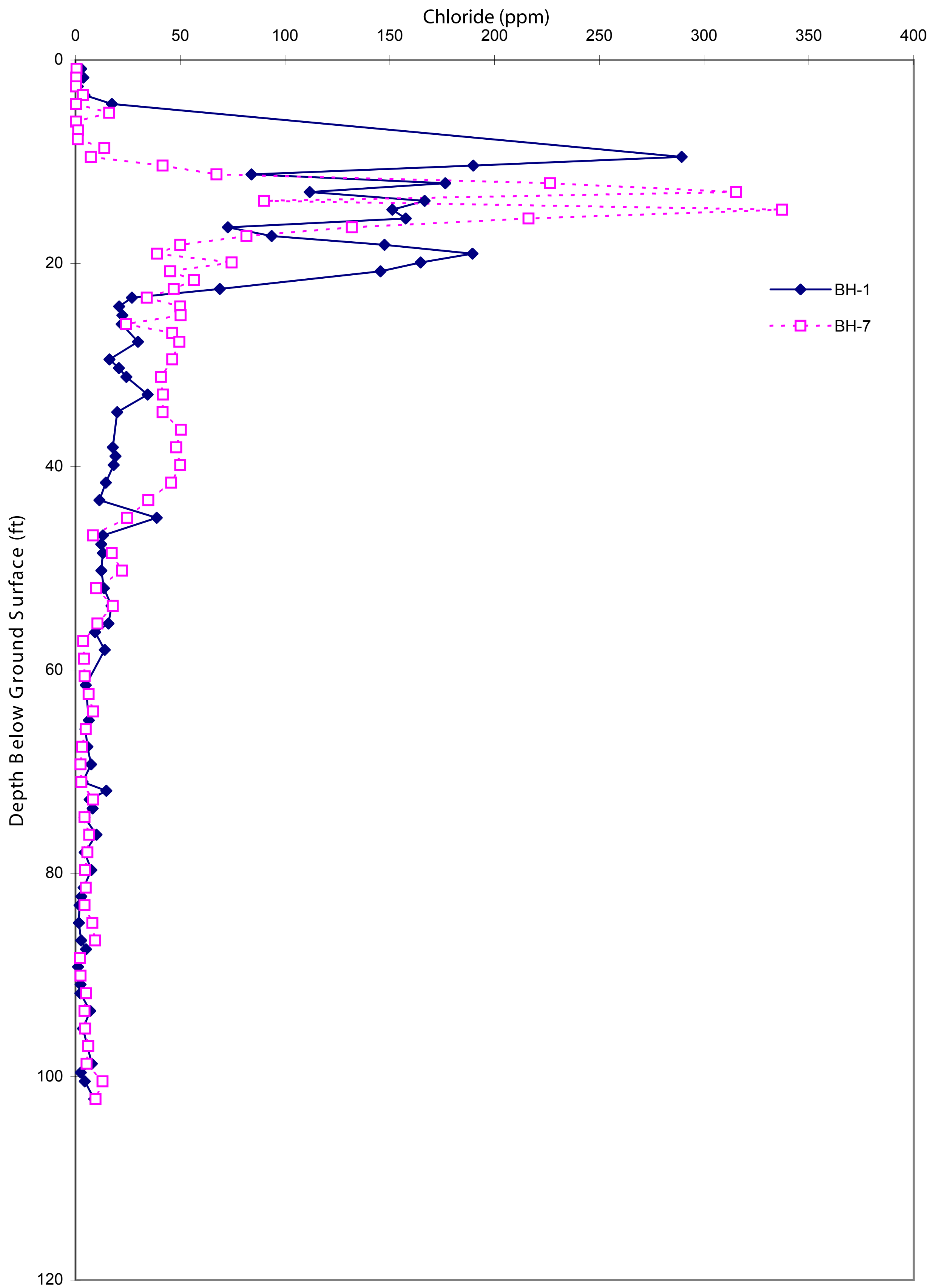

Figure 5-2 Chloride Concentration Profiles in Subsurface Soil at the Mixed Waste Landfill

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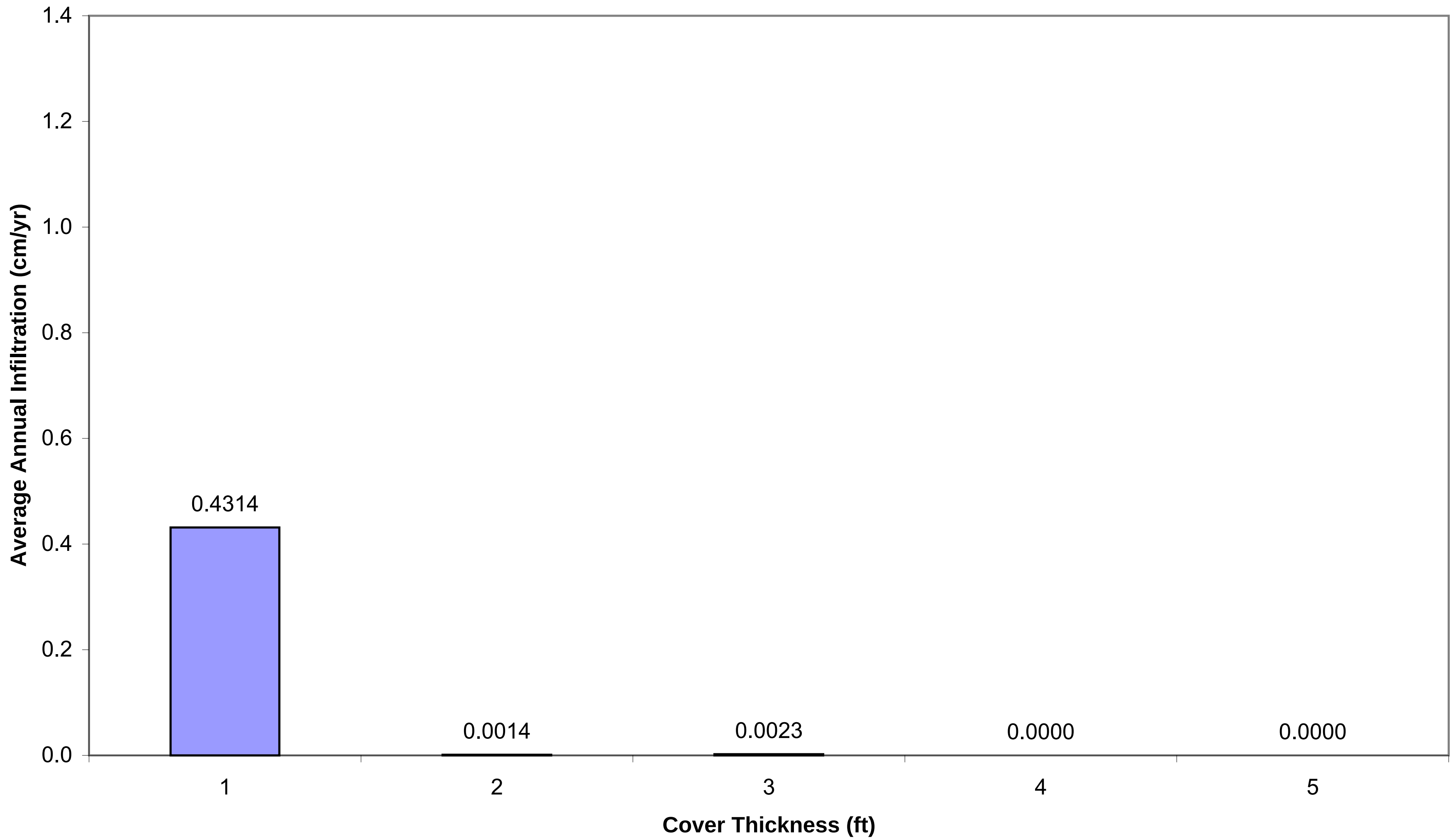

Figure 5-3 Average Annual Infiltration Predicted by HELP-3 Using Historical Precipitation Data

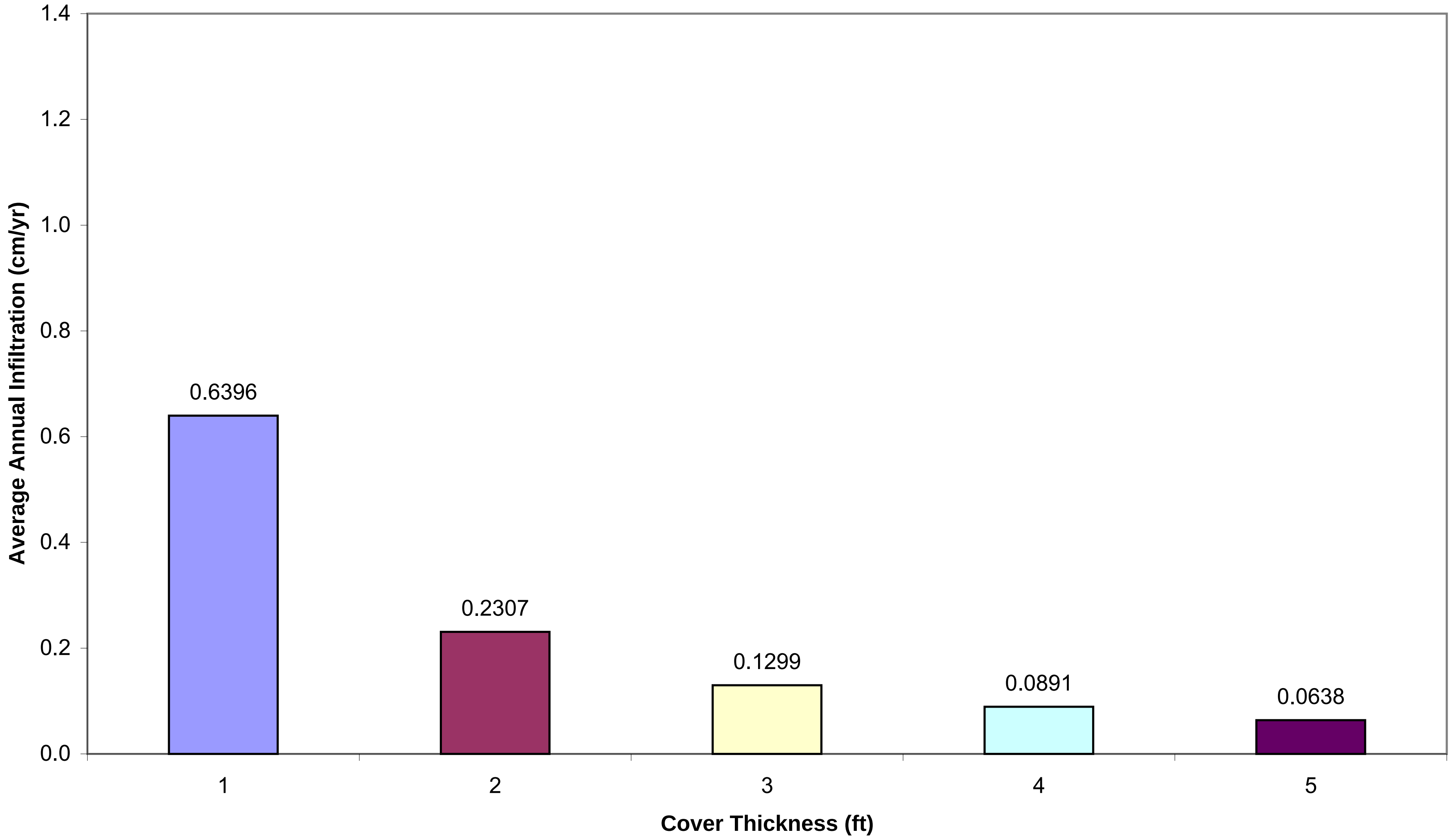

Figure 5-4 Average Annual Infiltration Predicted by UNSAT-H Using Historical Preciptiation Data

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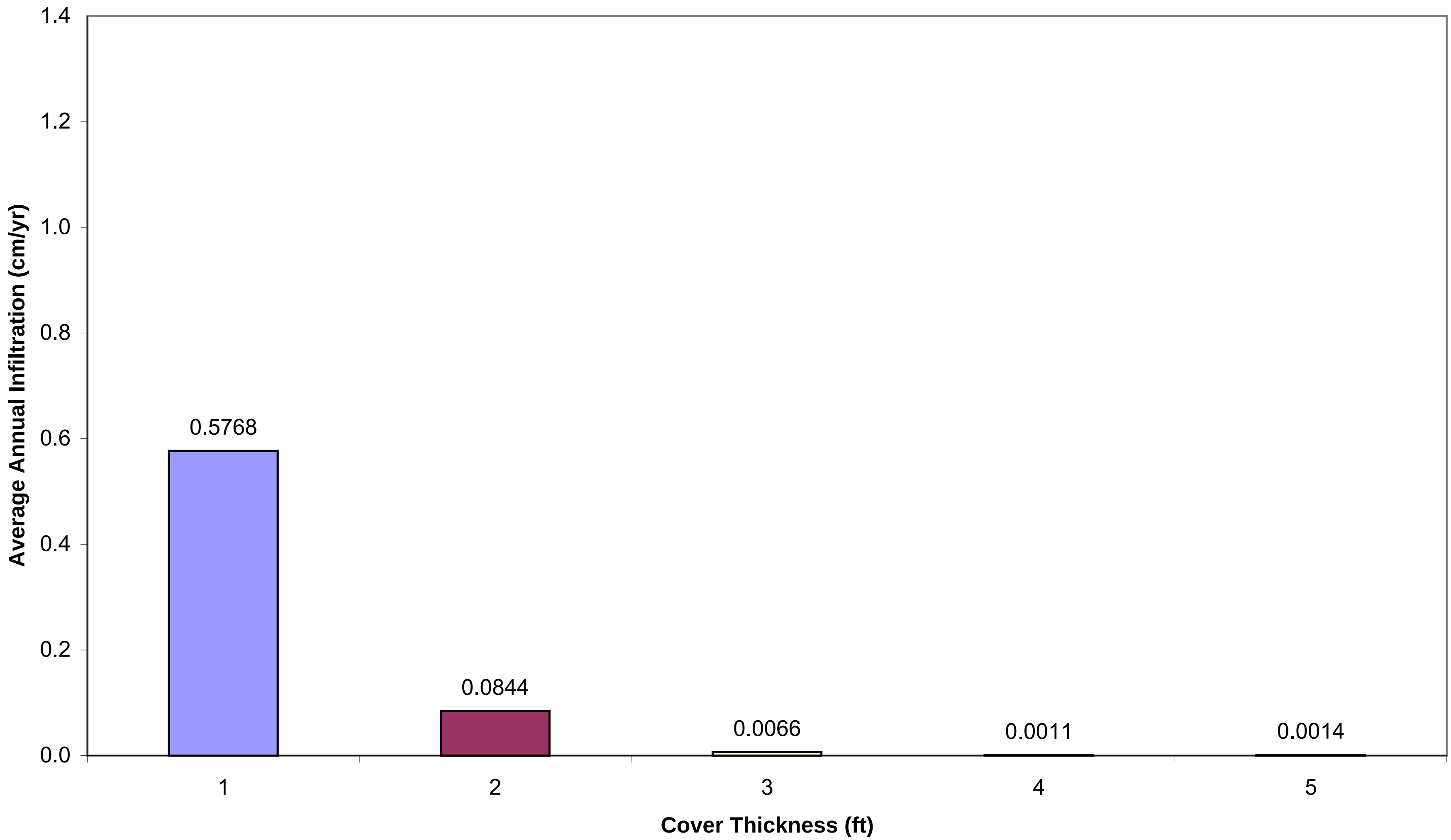

Figure 5-5 Average Annual Infiltration Predicted by VS2DT Using Historical Precipitation Data

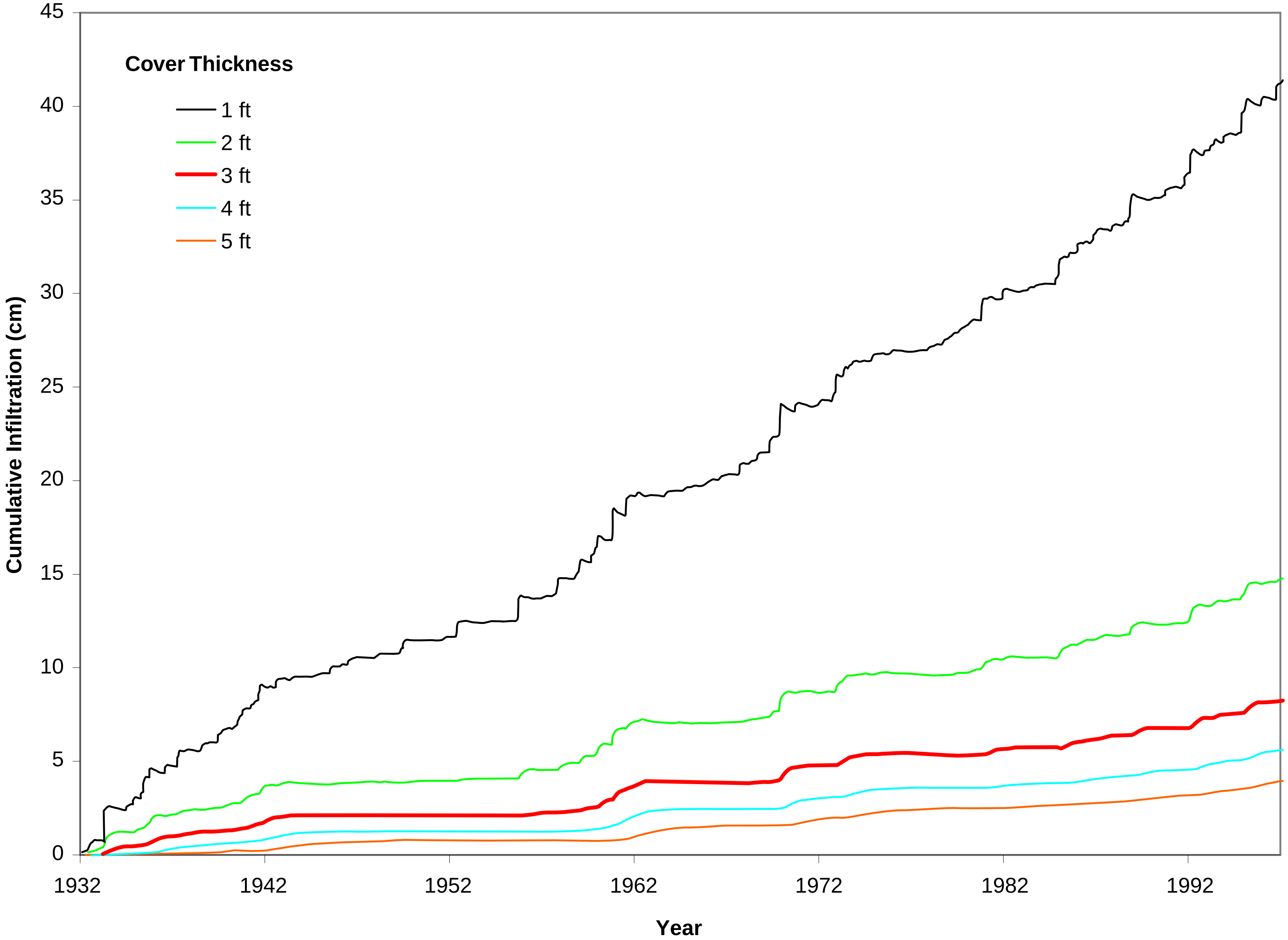

Figure 5-6 Cumulative Infiltration Predicted by UNSAT-H Using Historical Precipitation Data

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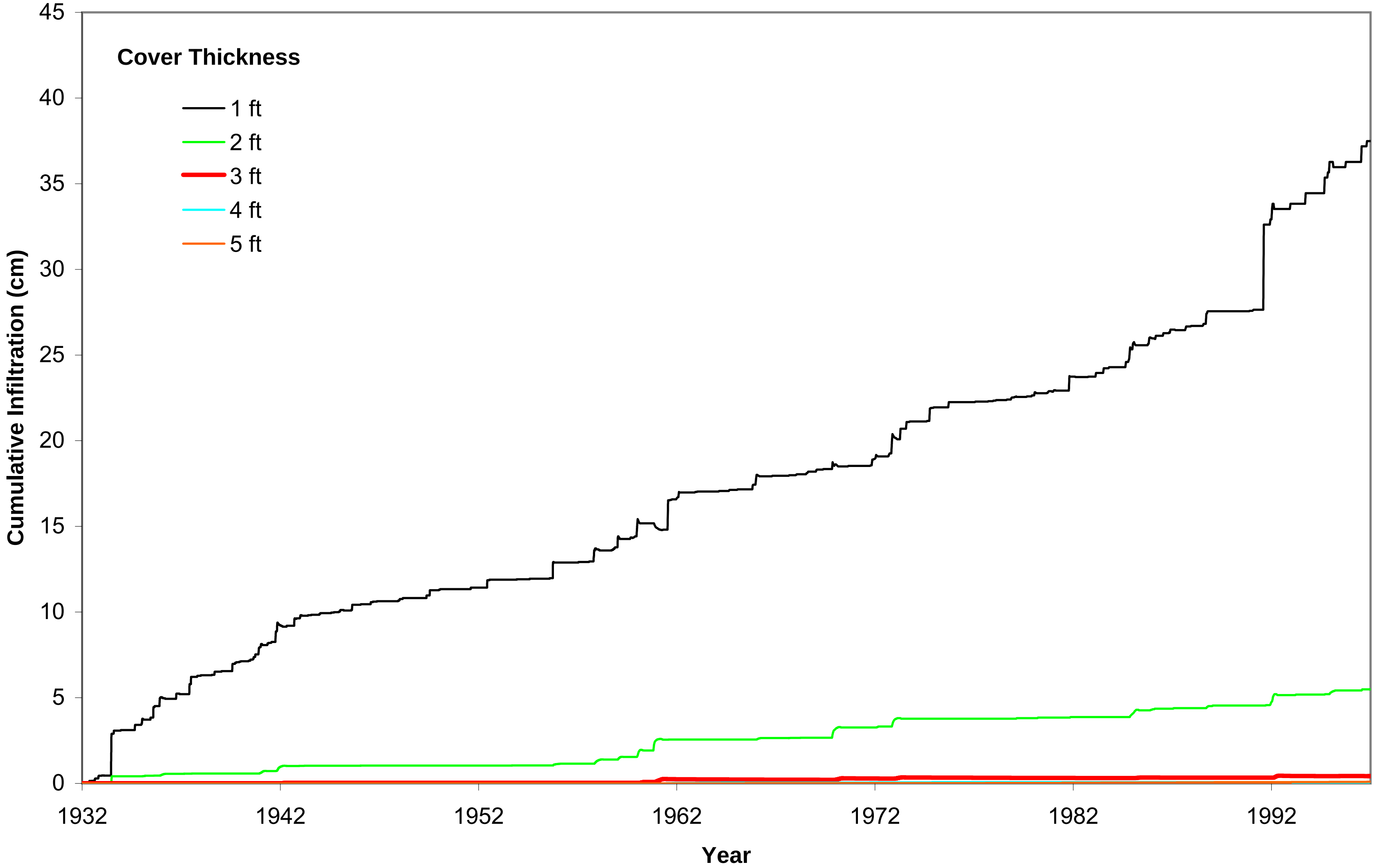

Figure 5-7 Cumulative Infiltration Predicted by VS2DT Using Historical Precipitation Data

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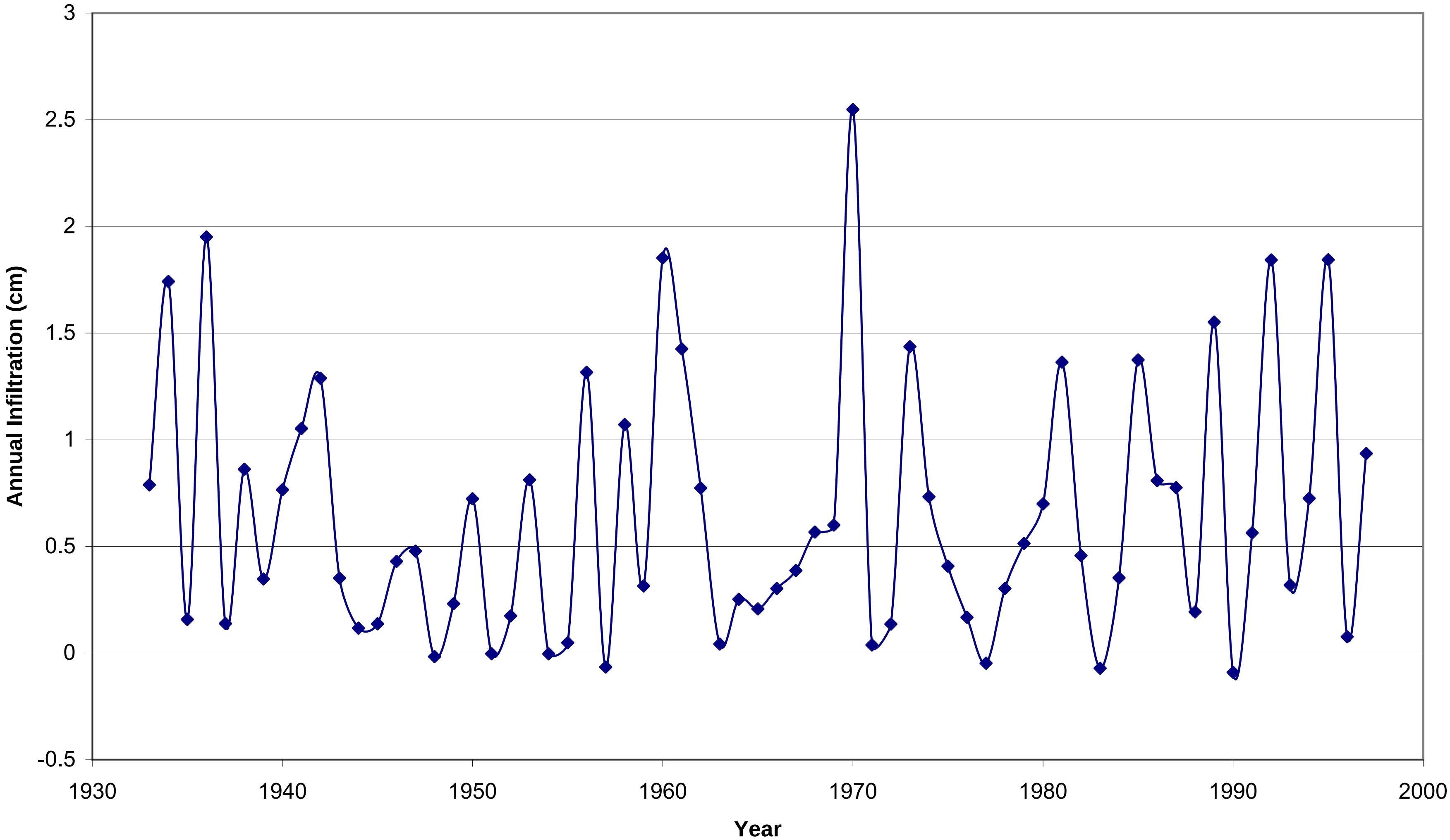

Figure 5-8 Annual Infiltration Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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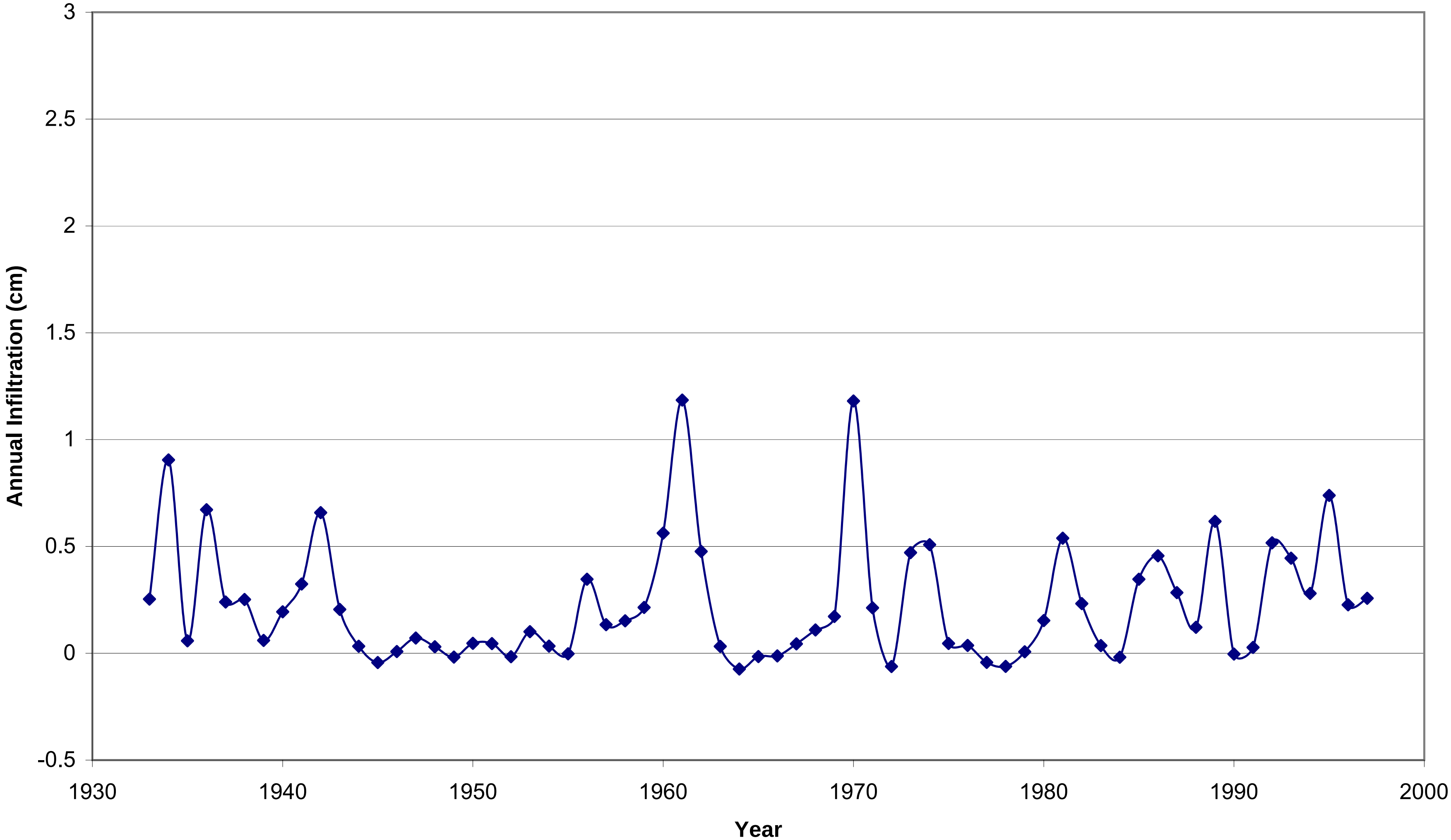

Figure 5-9 Annual Infiltration Through a 2-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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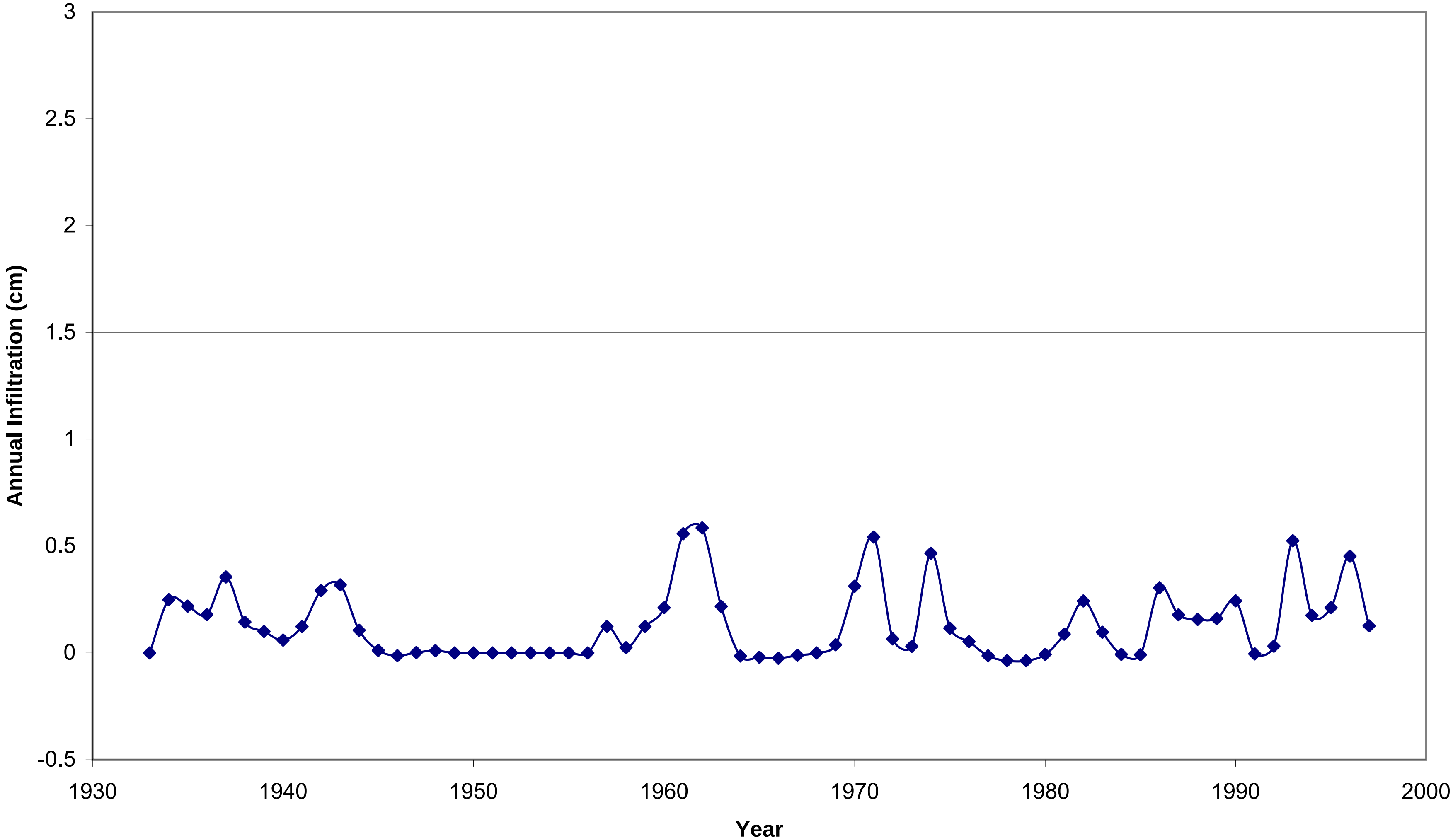

Figure 5-10 Annual Infiltration Through a 3-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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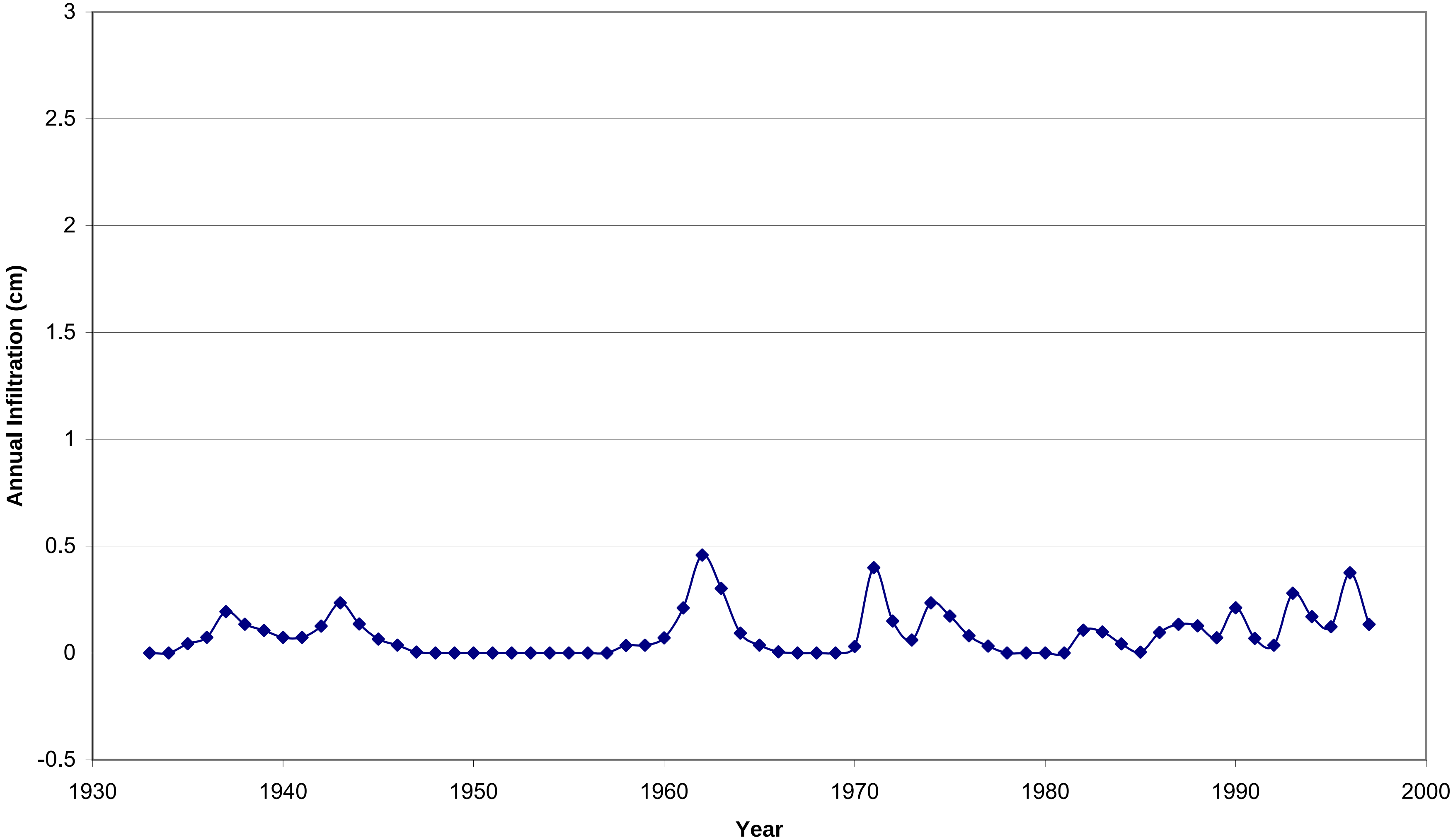

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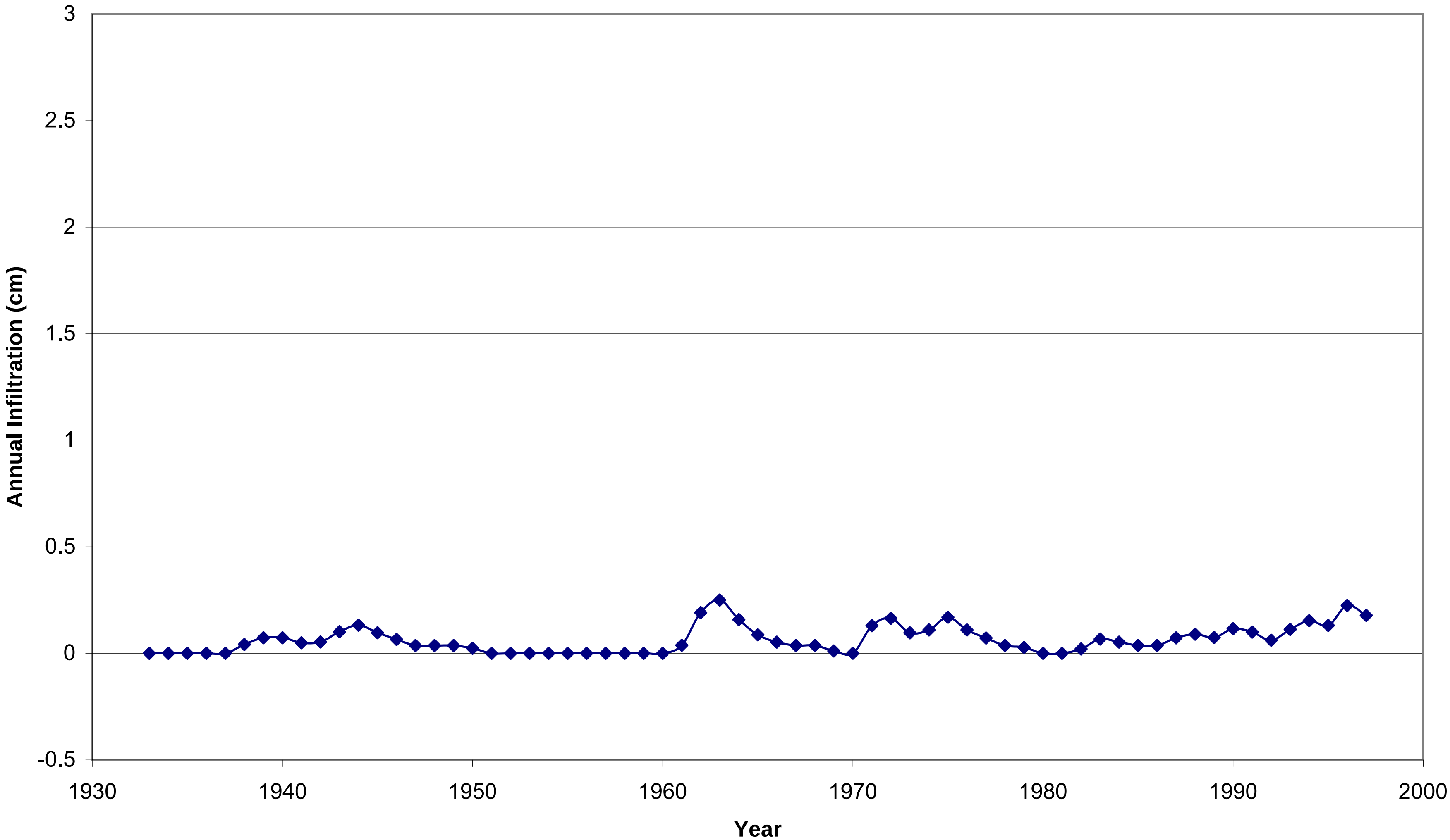

Figure 5-12 Annual Infiltration Through a 5-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

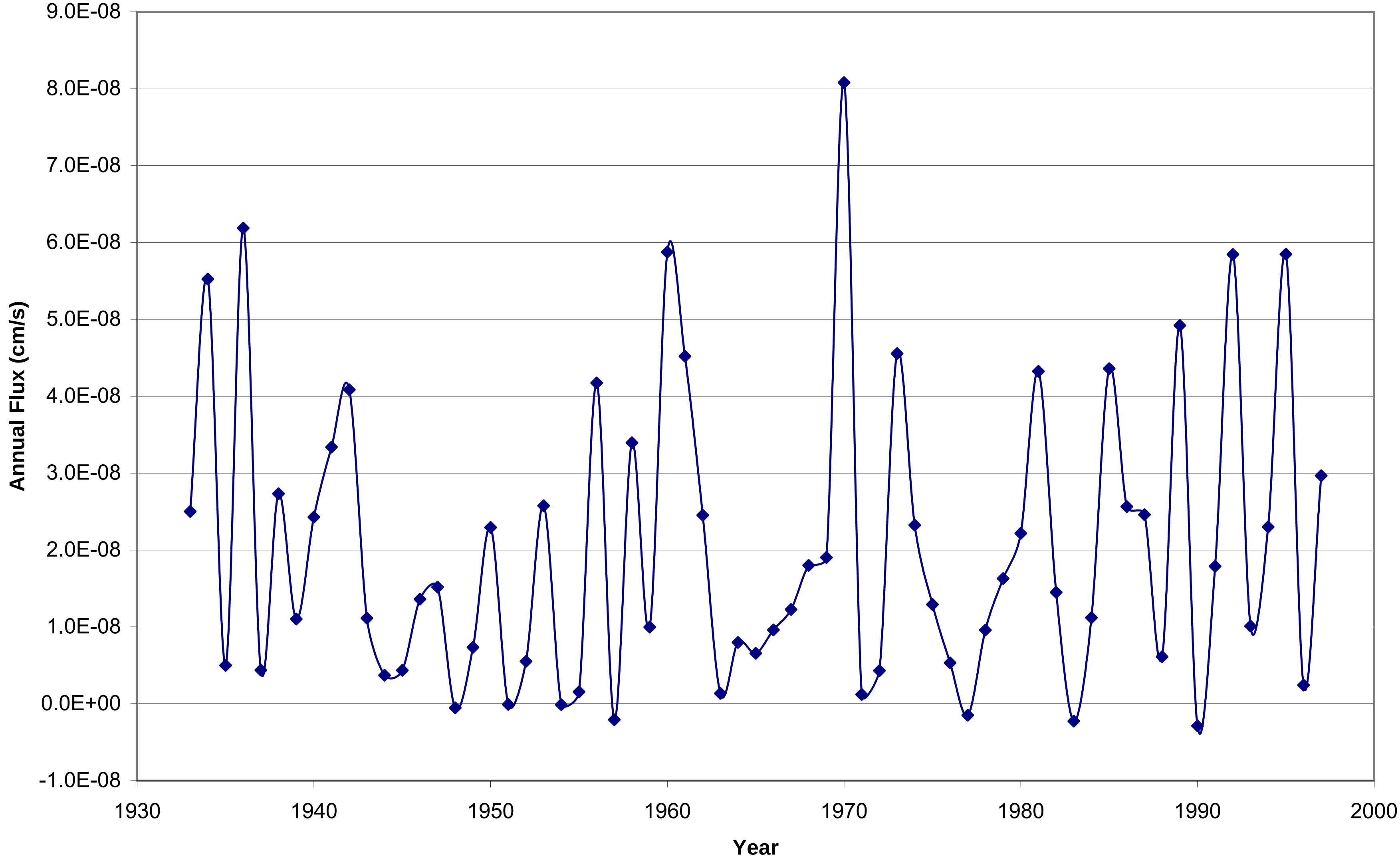

Figure 5-13 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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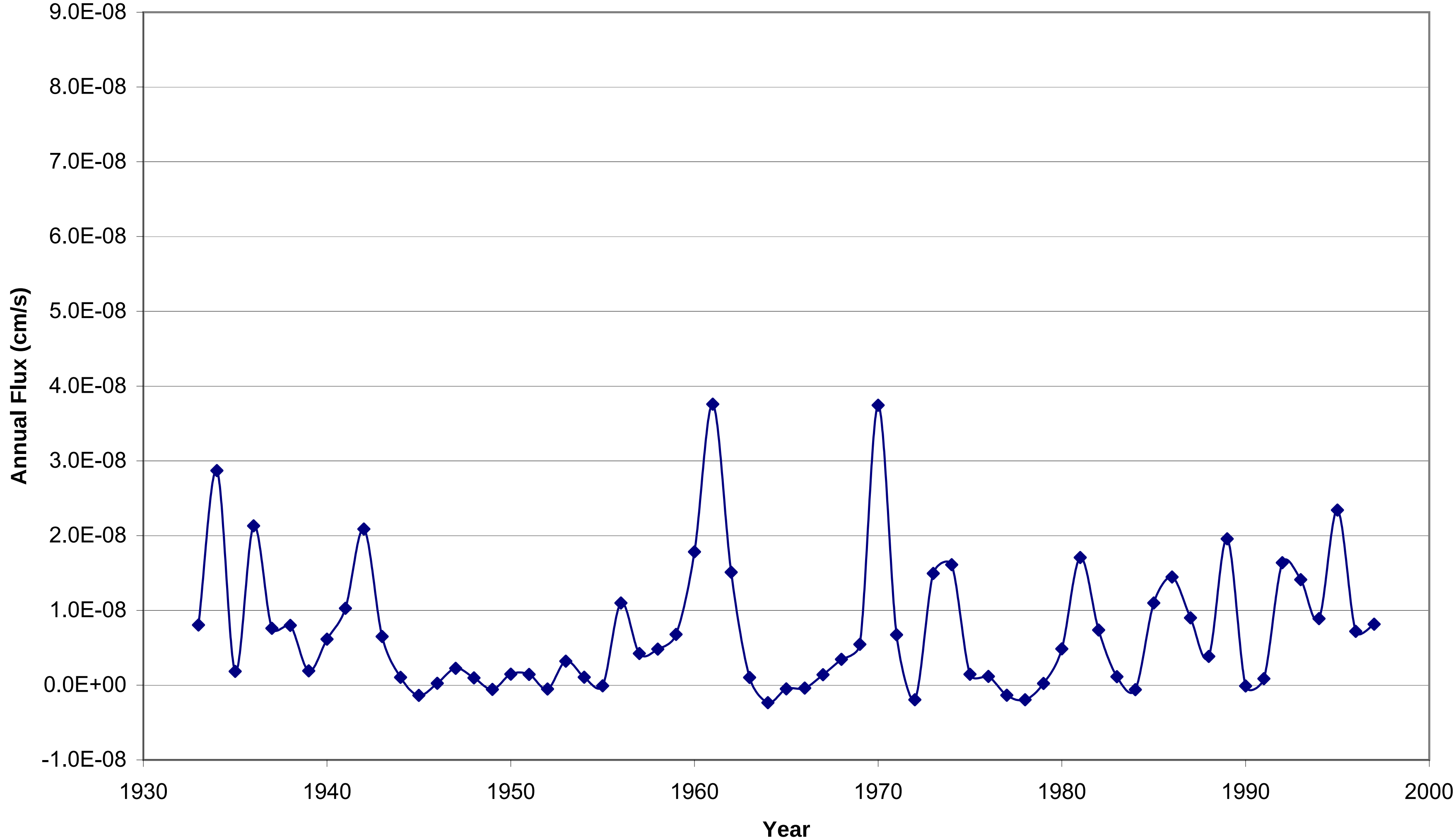

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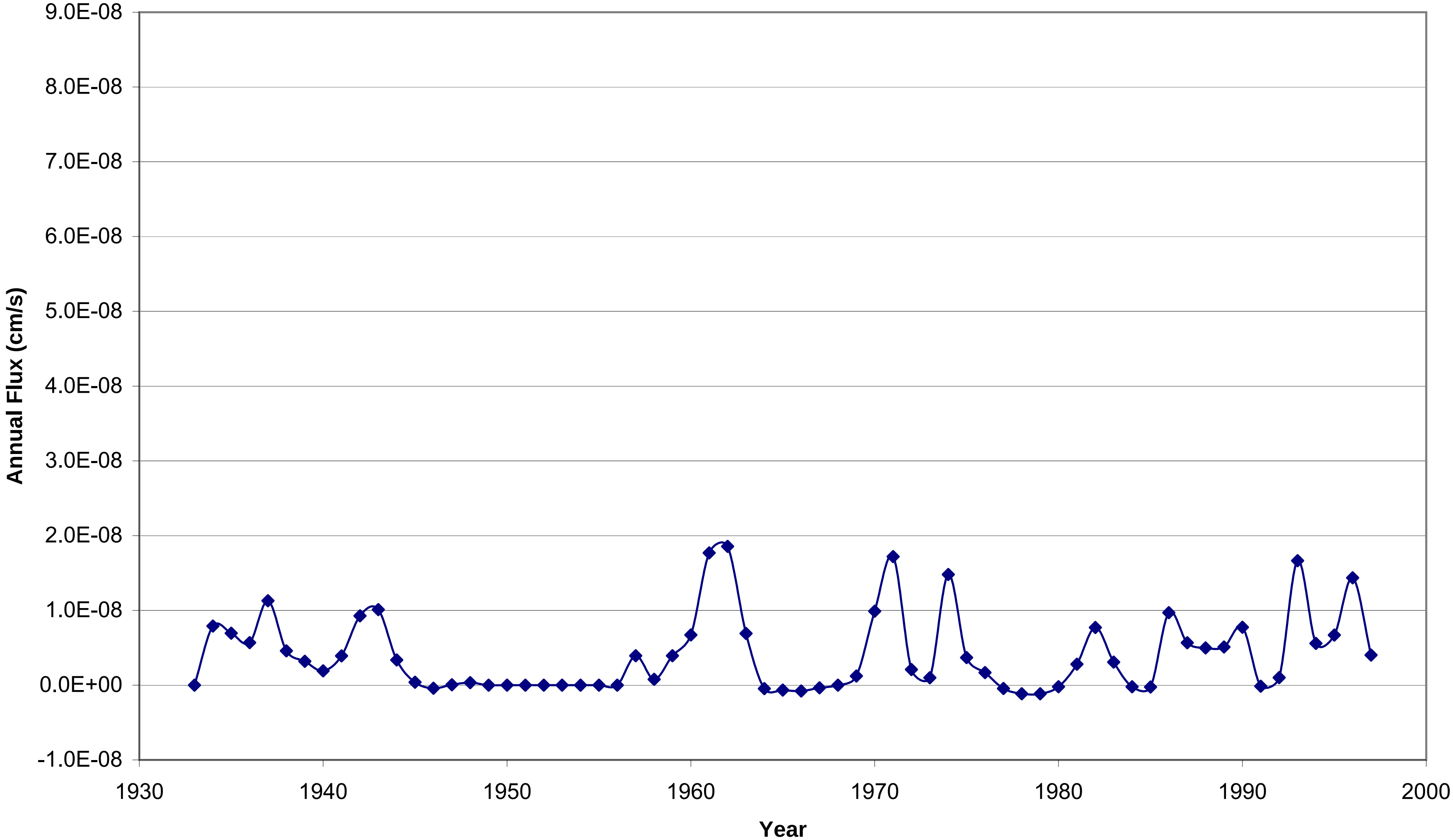

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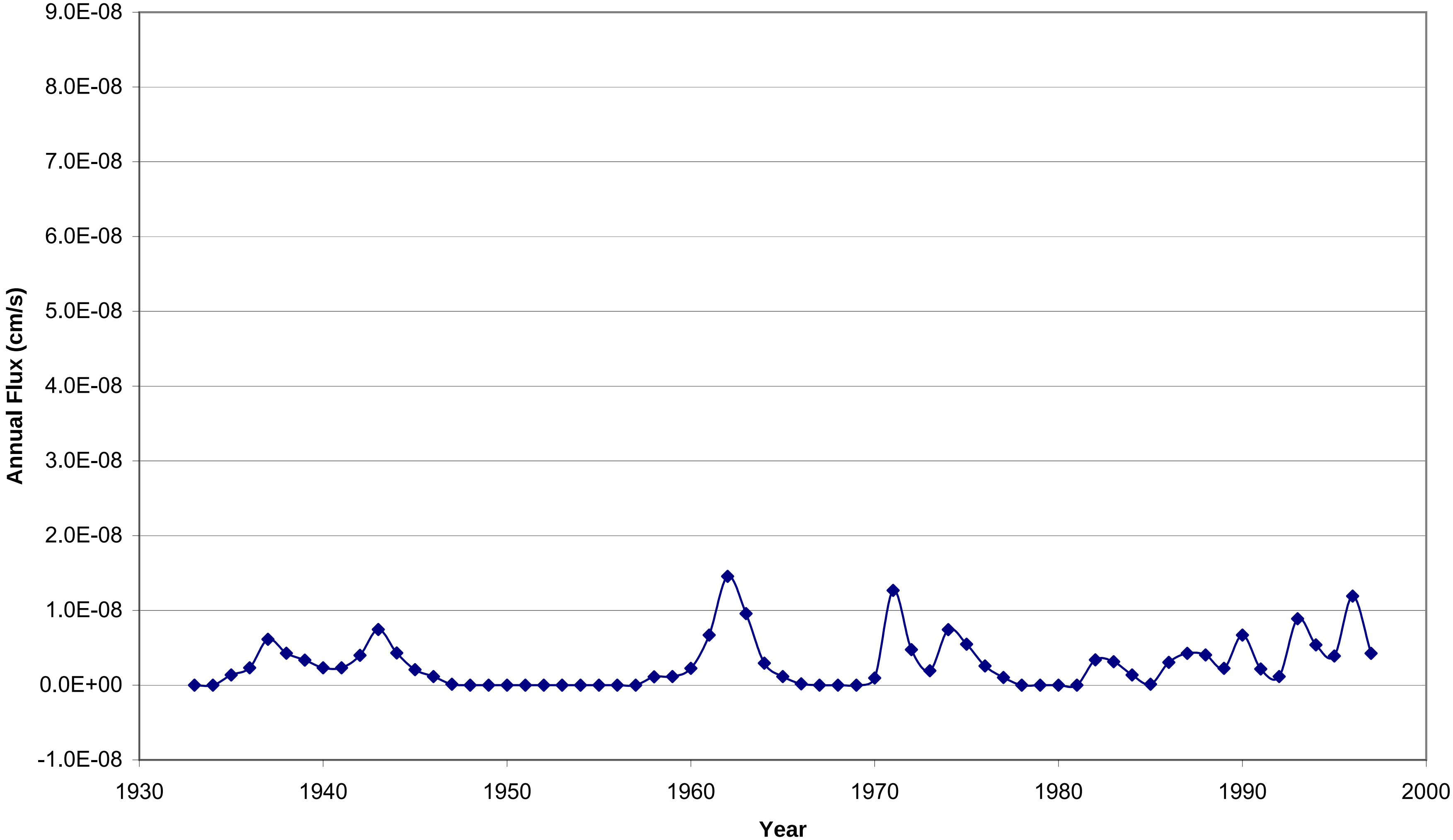

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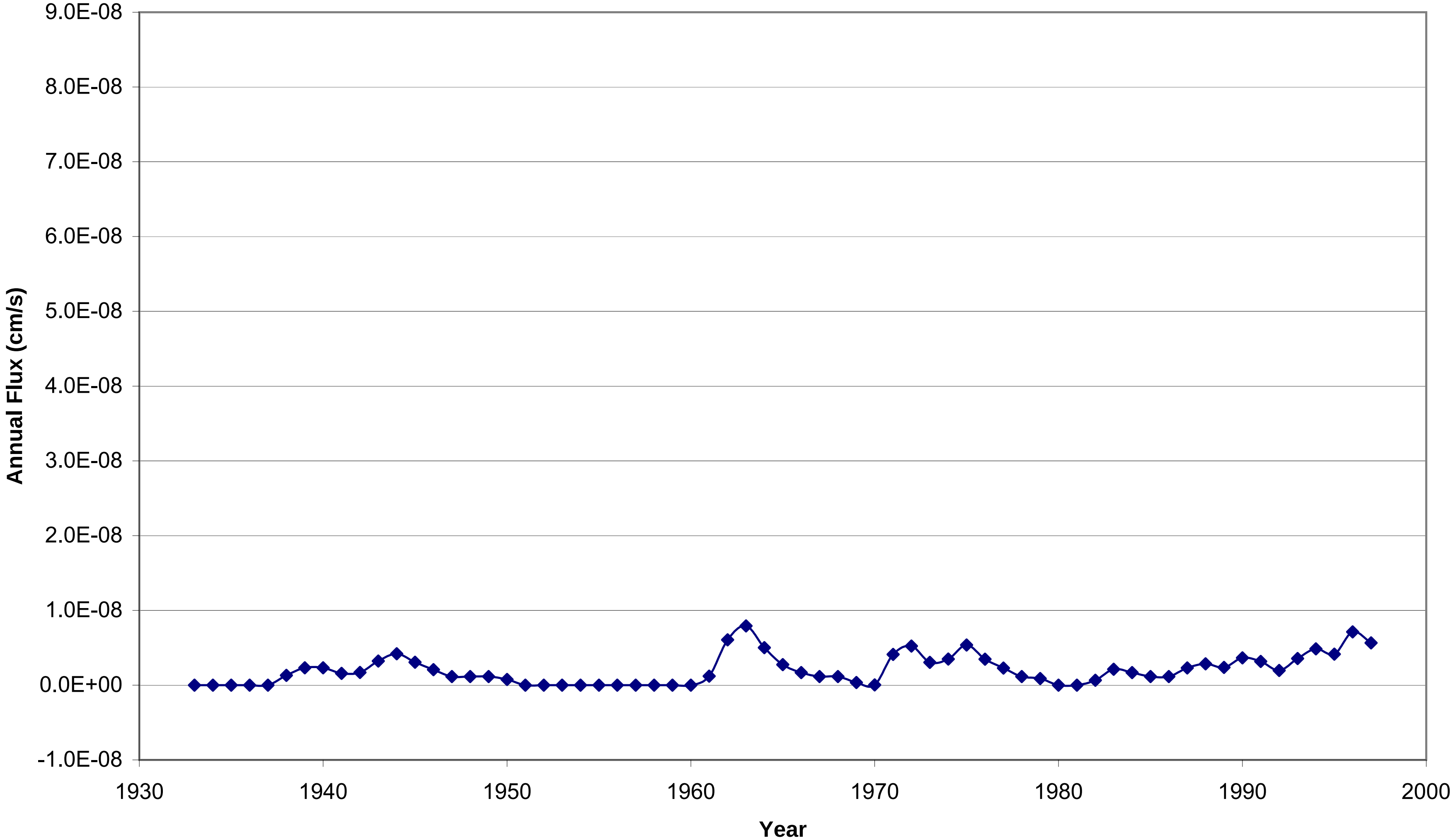

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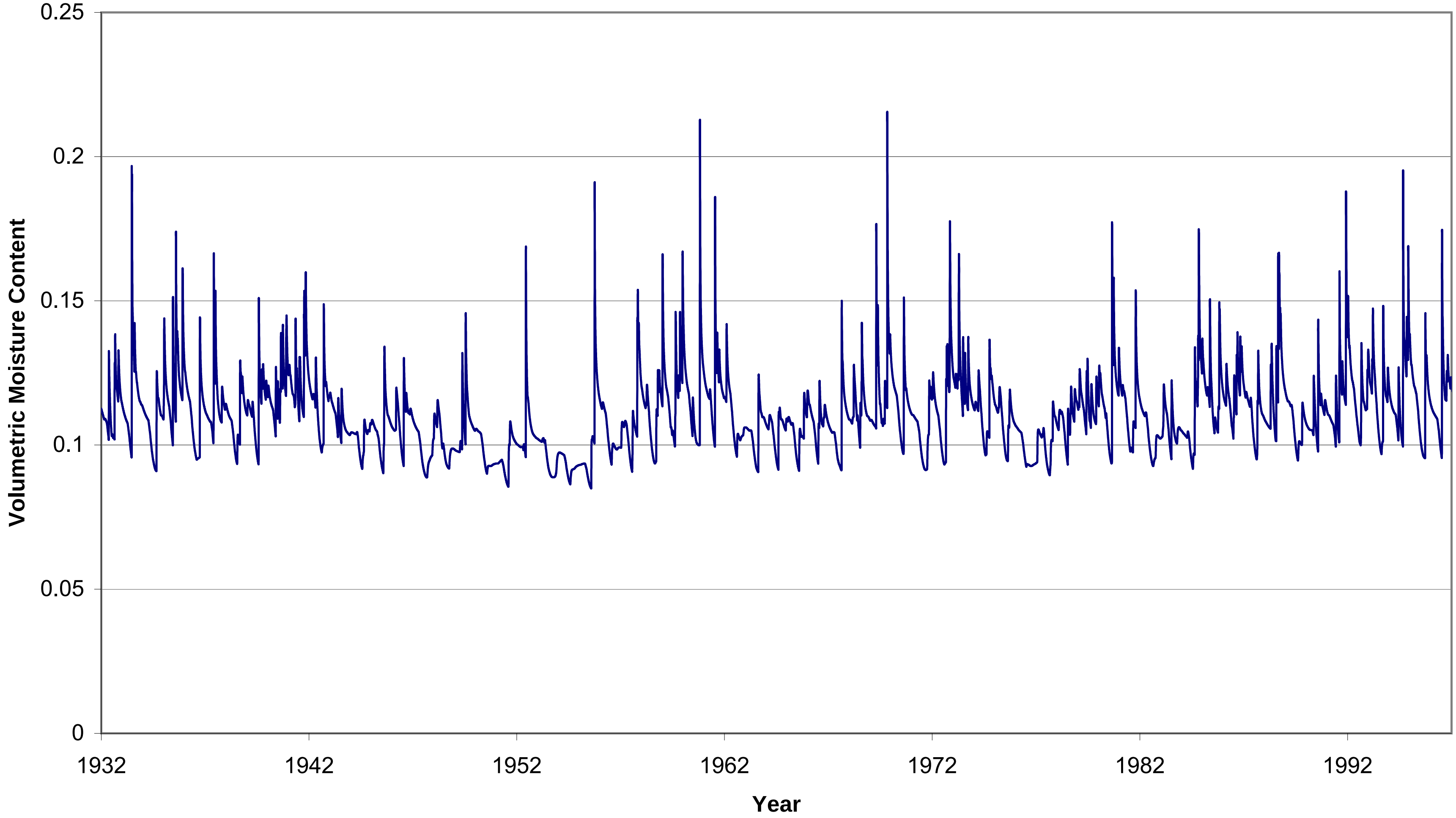

Figure 5-18 Moisture Content at 1-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

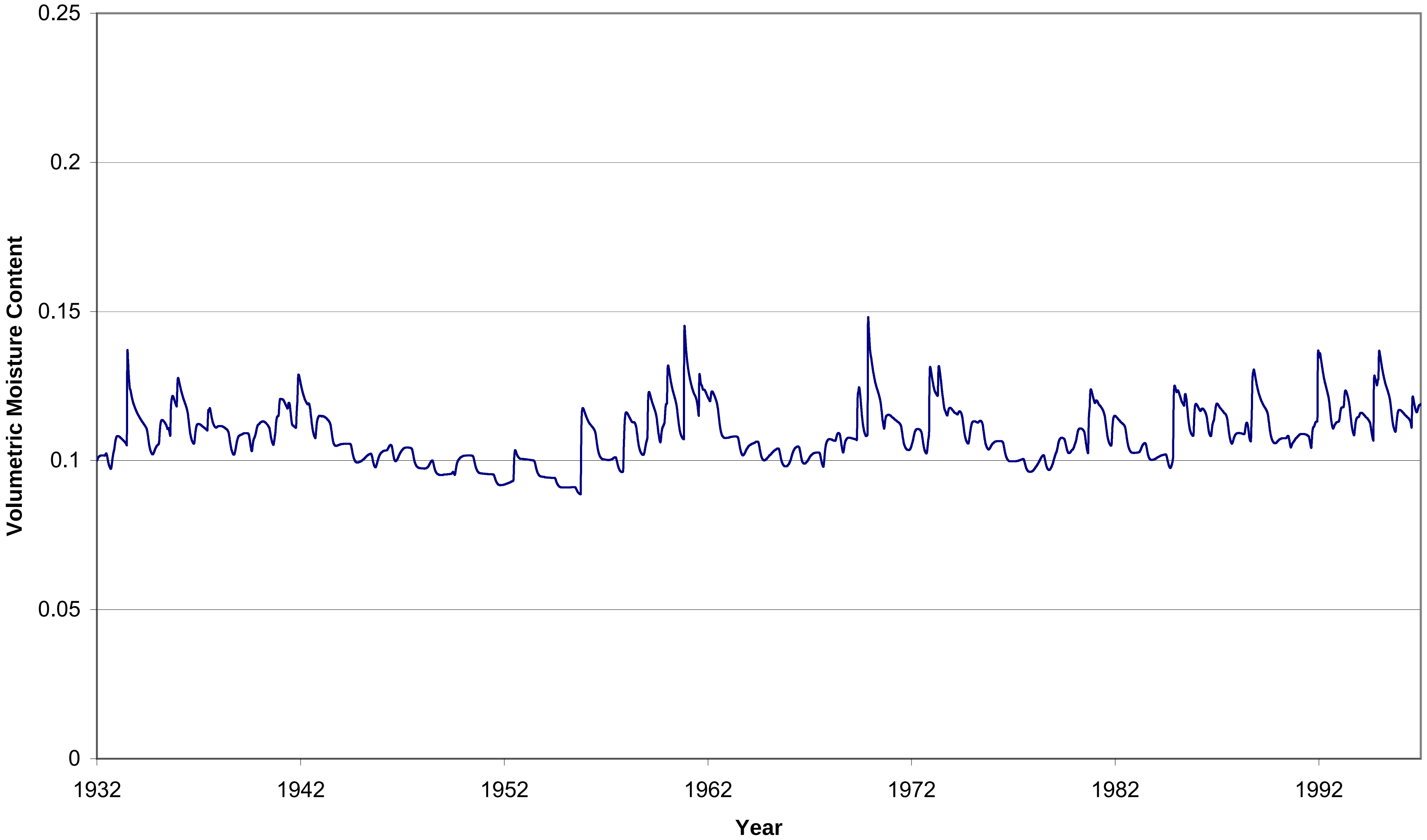

Figure 5-19 Moisture Content at 2-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

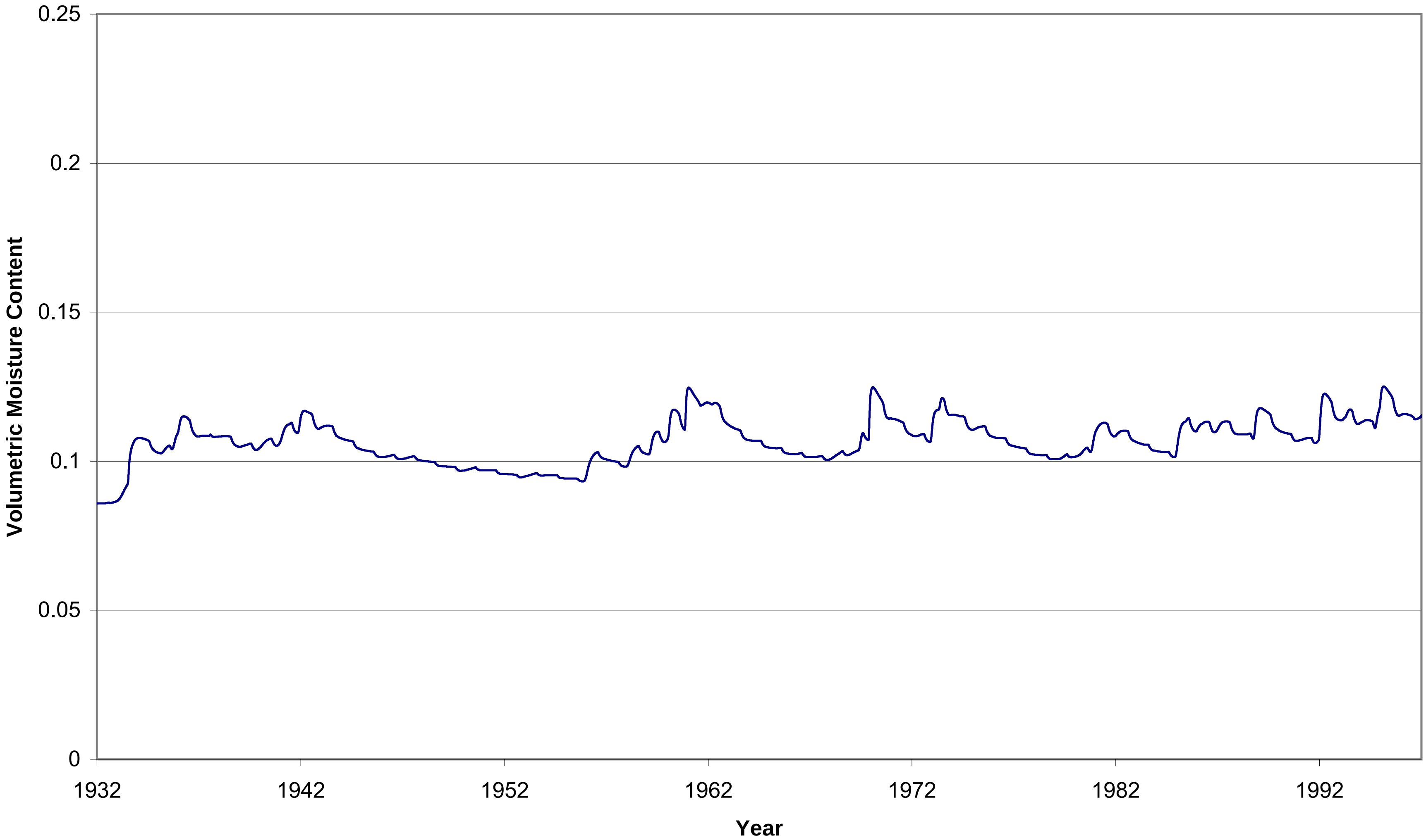

Figure 5-20 Moisture Content at 3-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

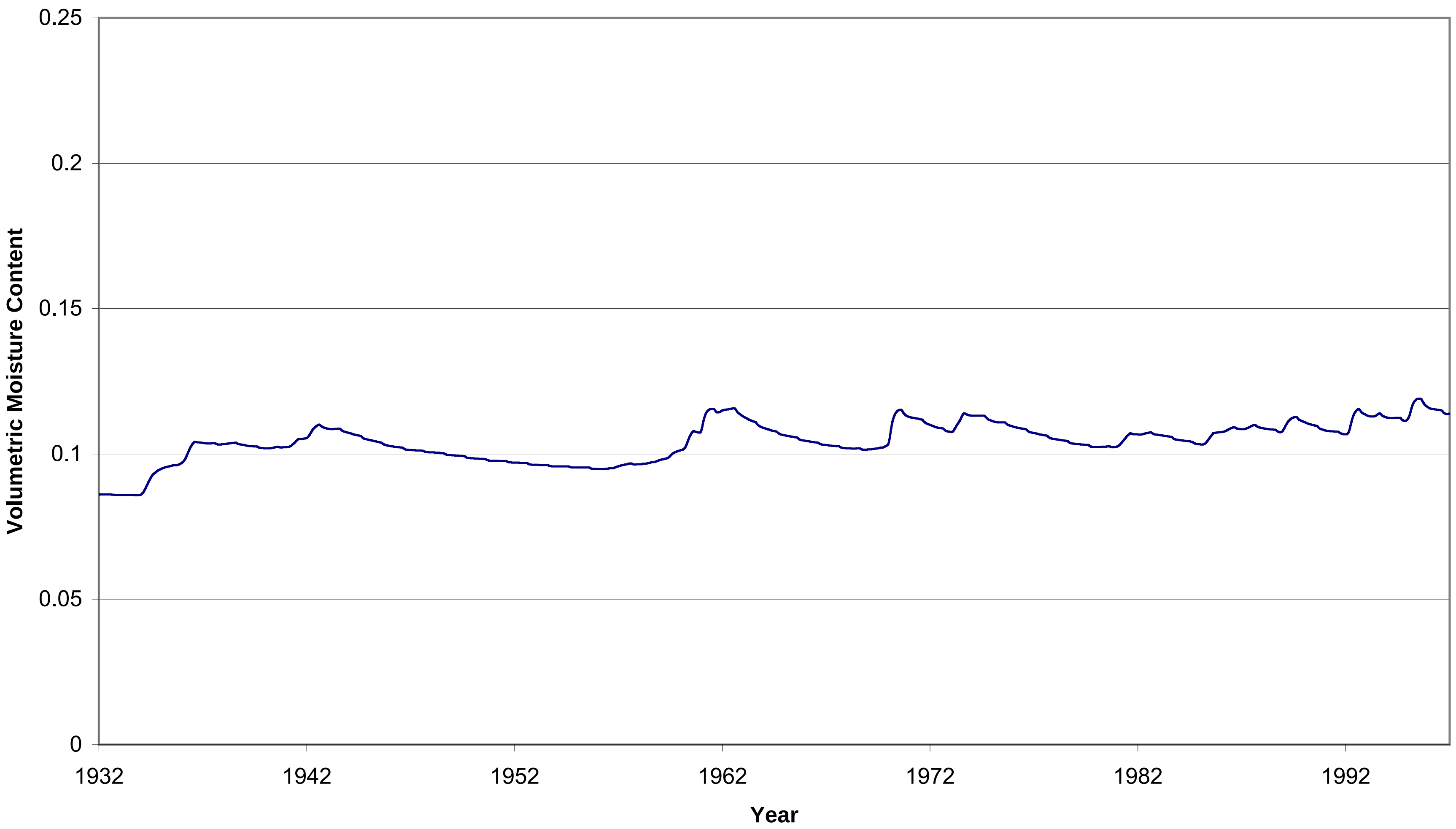

Figure 5-21 Moisture Content at 4-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

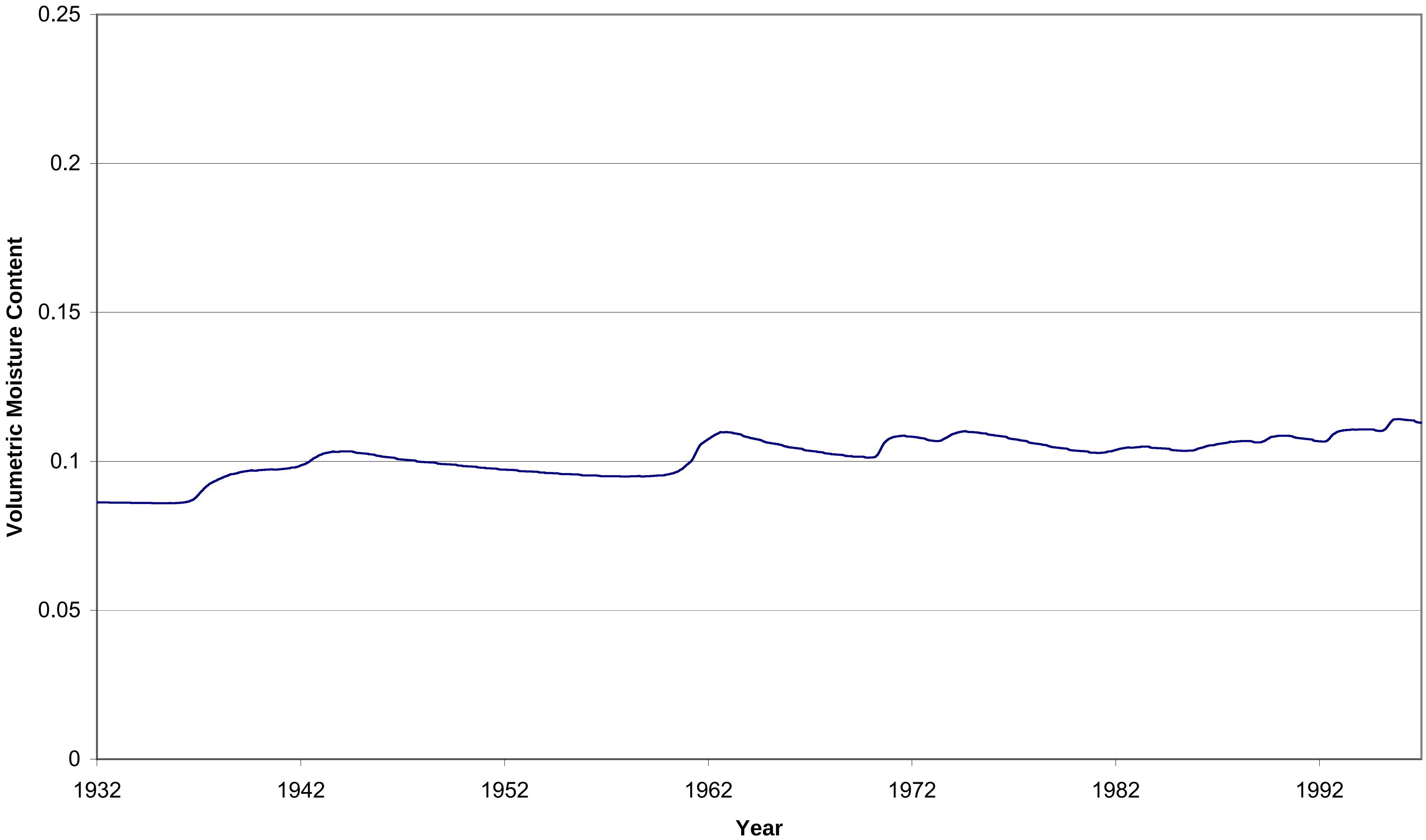

Figure 5-22 Moisture Content at 5-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

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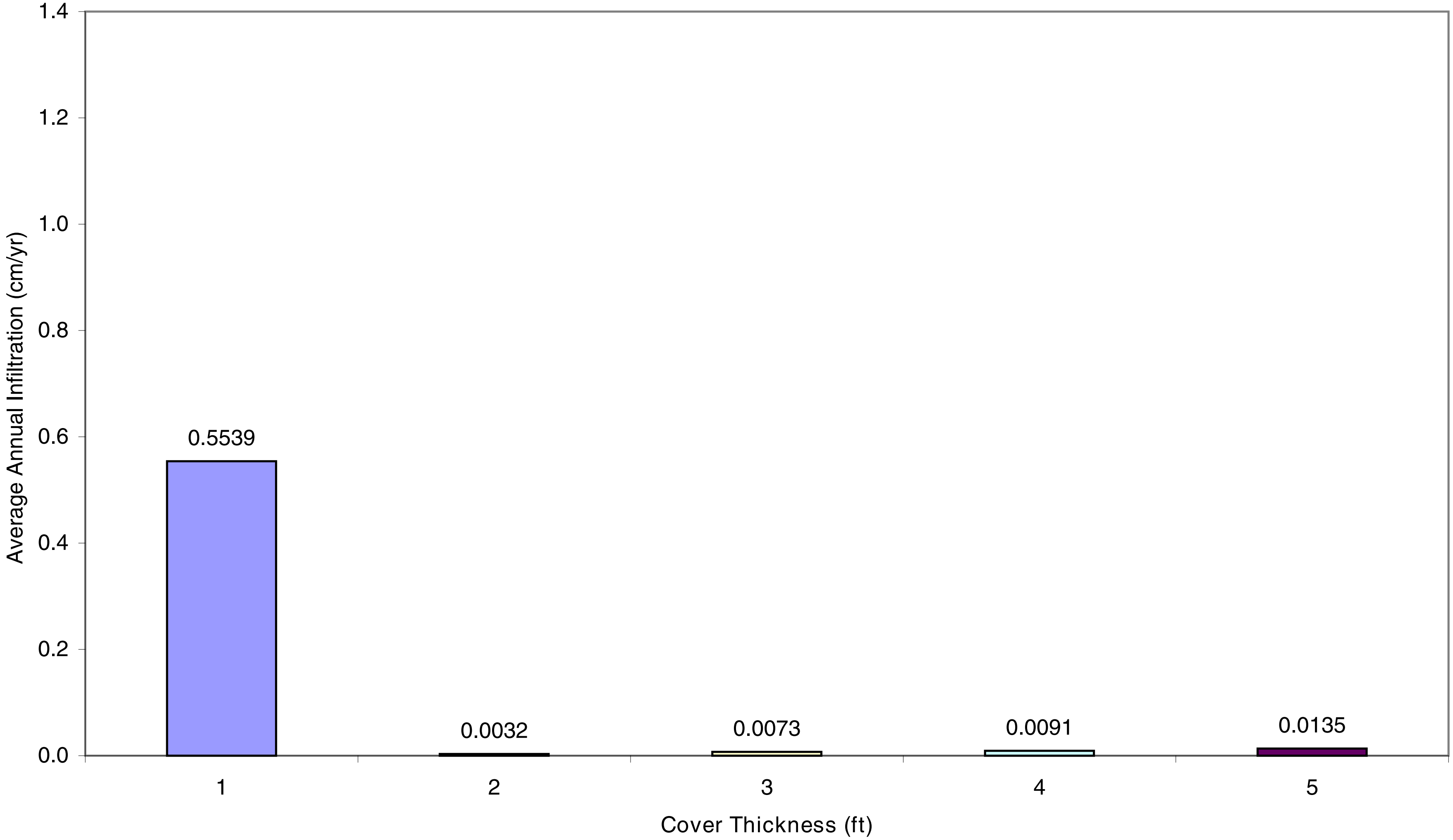

Figure 5-23 Average Annual Infiltration Rates Predicted by HELP-3 Using Maximum Precipitation Data

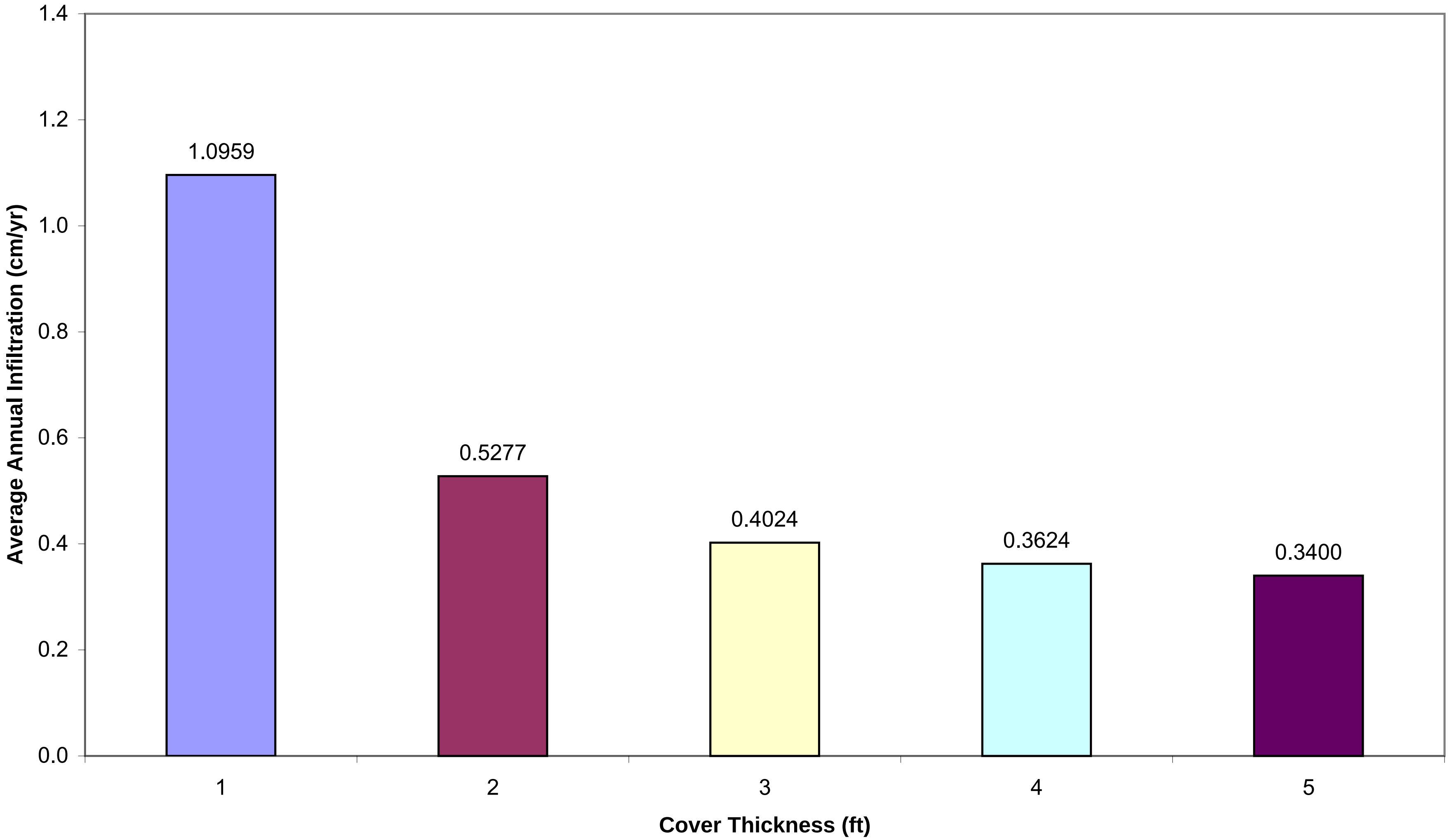

Figure 5-24 Average Annual Infiltration Predicted by UNSAT-H Using Maximum Precipitation Data

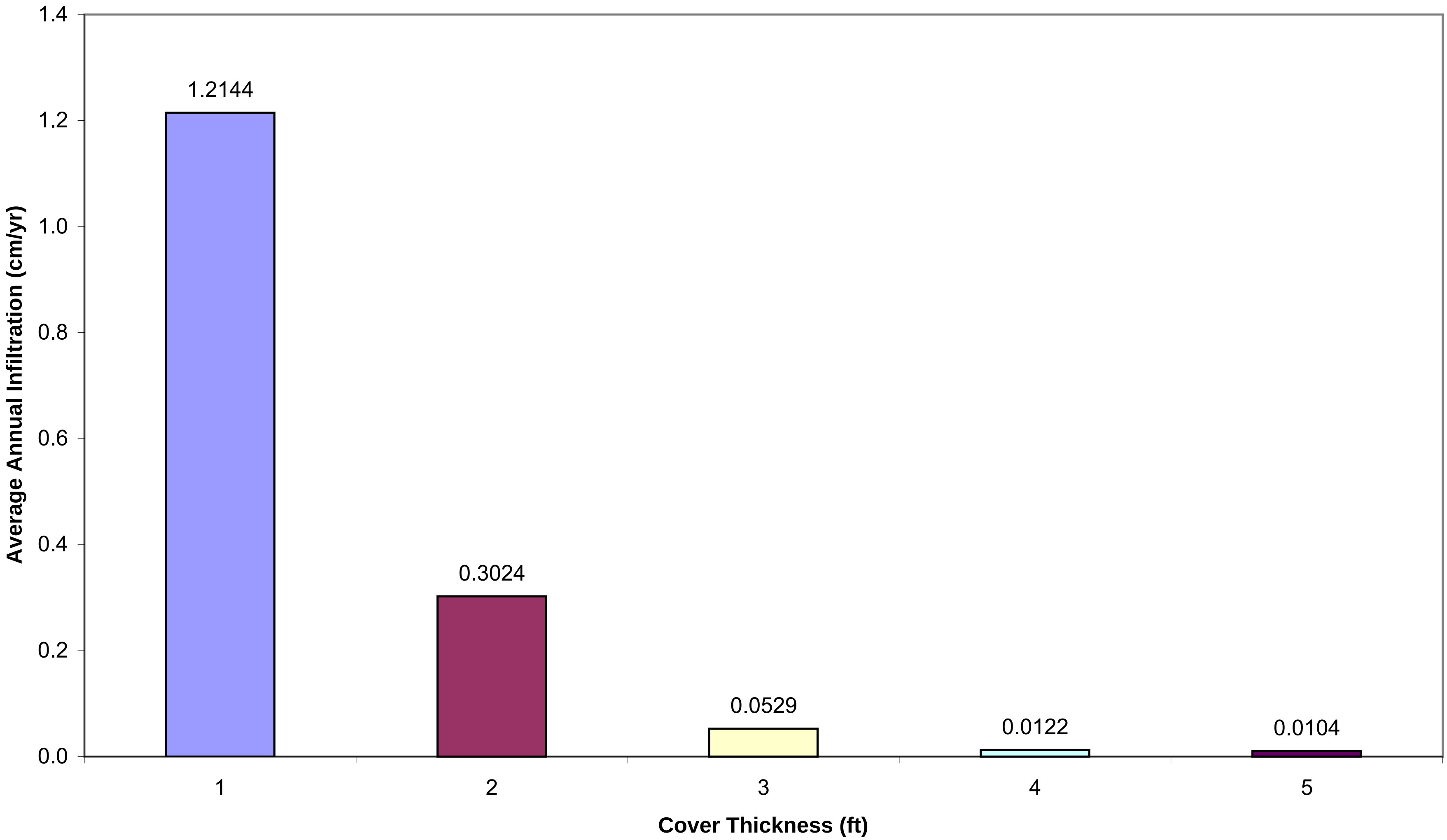

Figure 5-25 Average Annual Infiltration Rates Predicted by VS2DT Using Maximum Precipitation Data

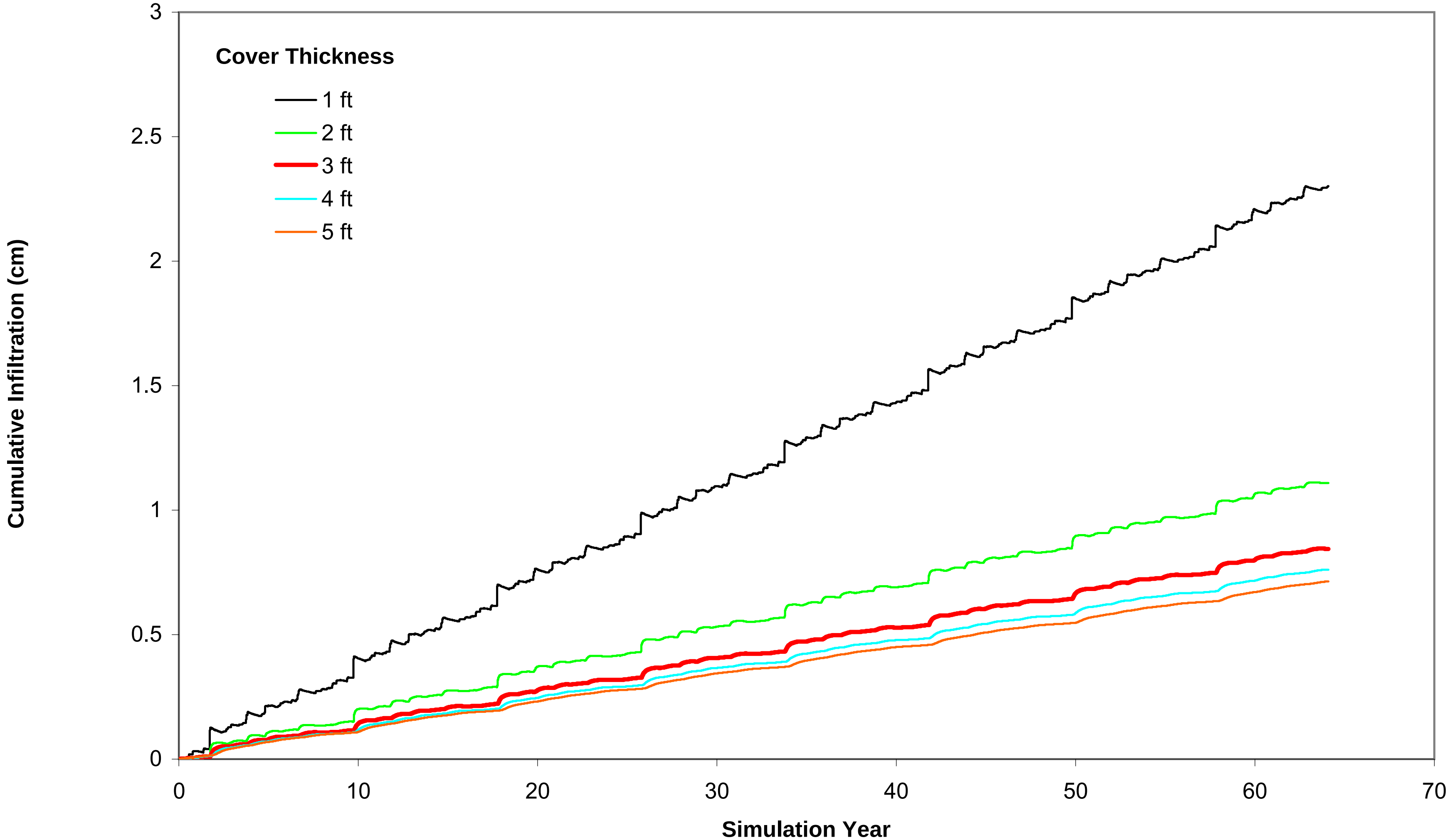

Figure 5-26 Cumulative Infiltration Predicted by UNSAT-H Using Maximum Precipitation Data

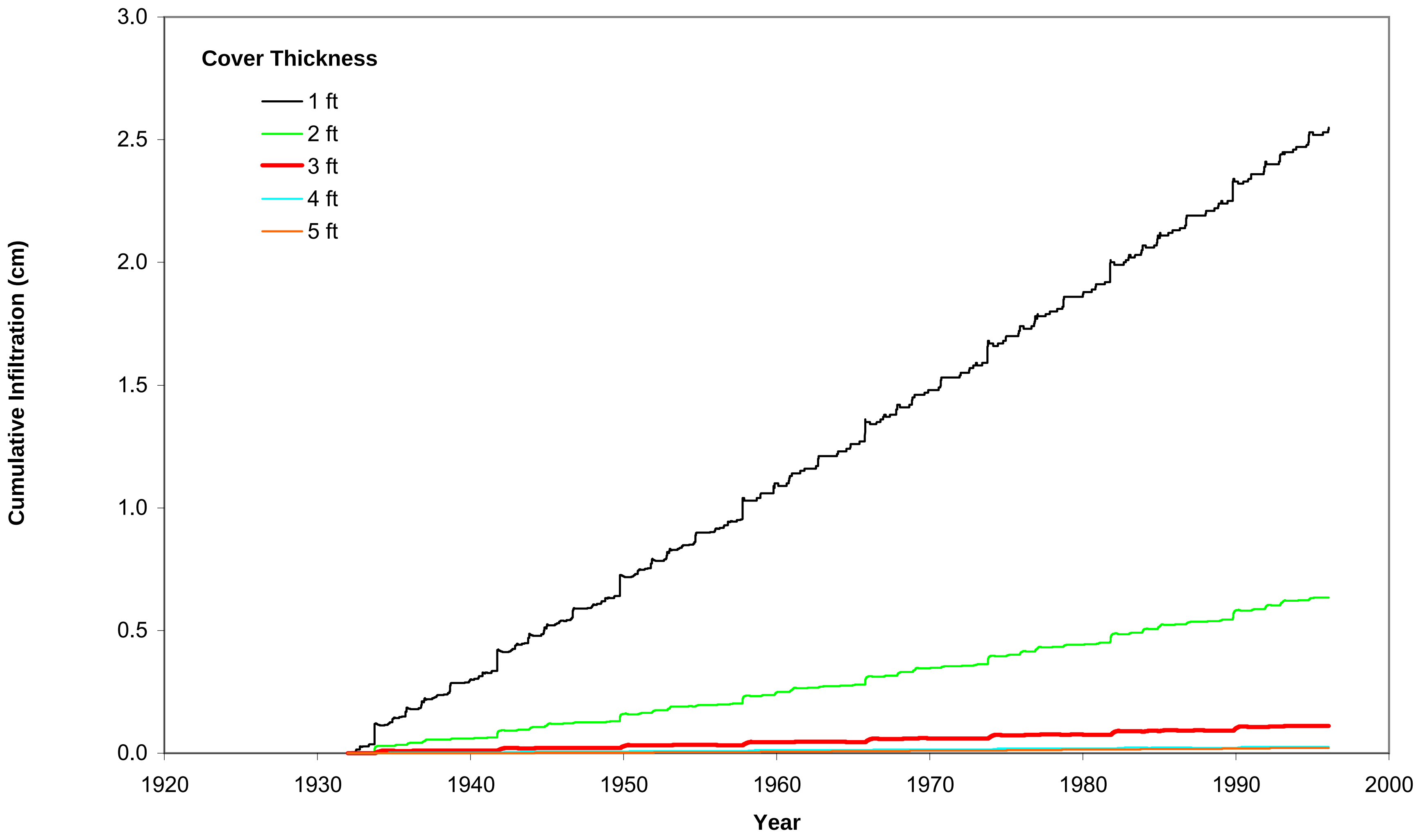

Figure 5-27 Cumulative Infiltration Predicted by VS2DT Using Maximum Precipitation Data

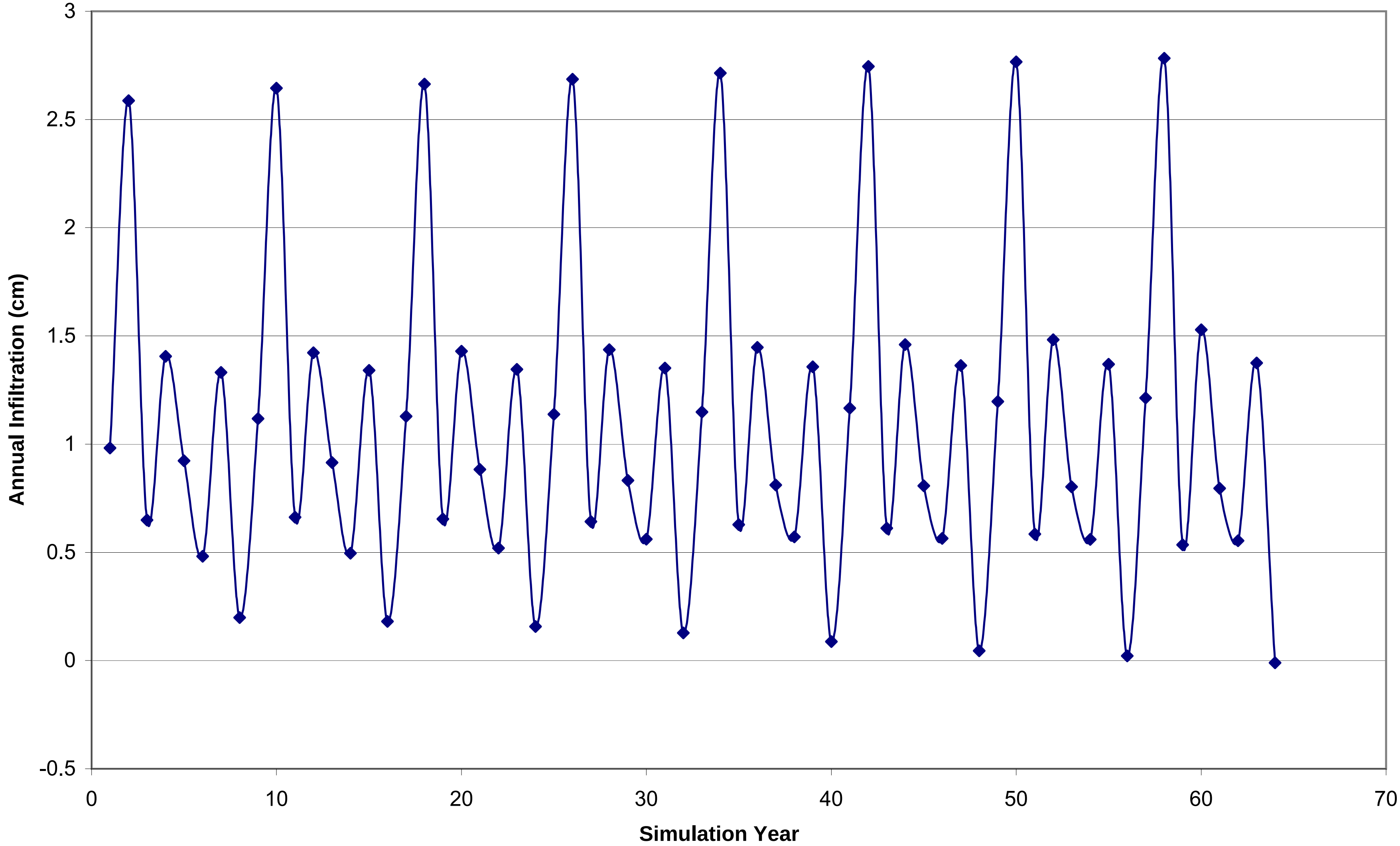

Figure 5-28 Annual Infiltration Through a 1-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

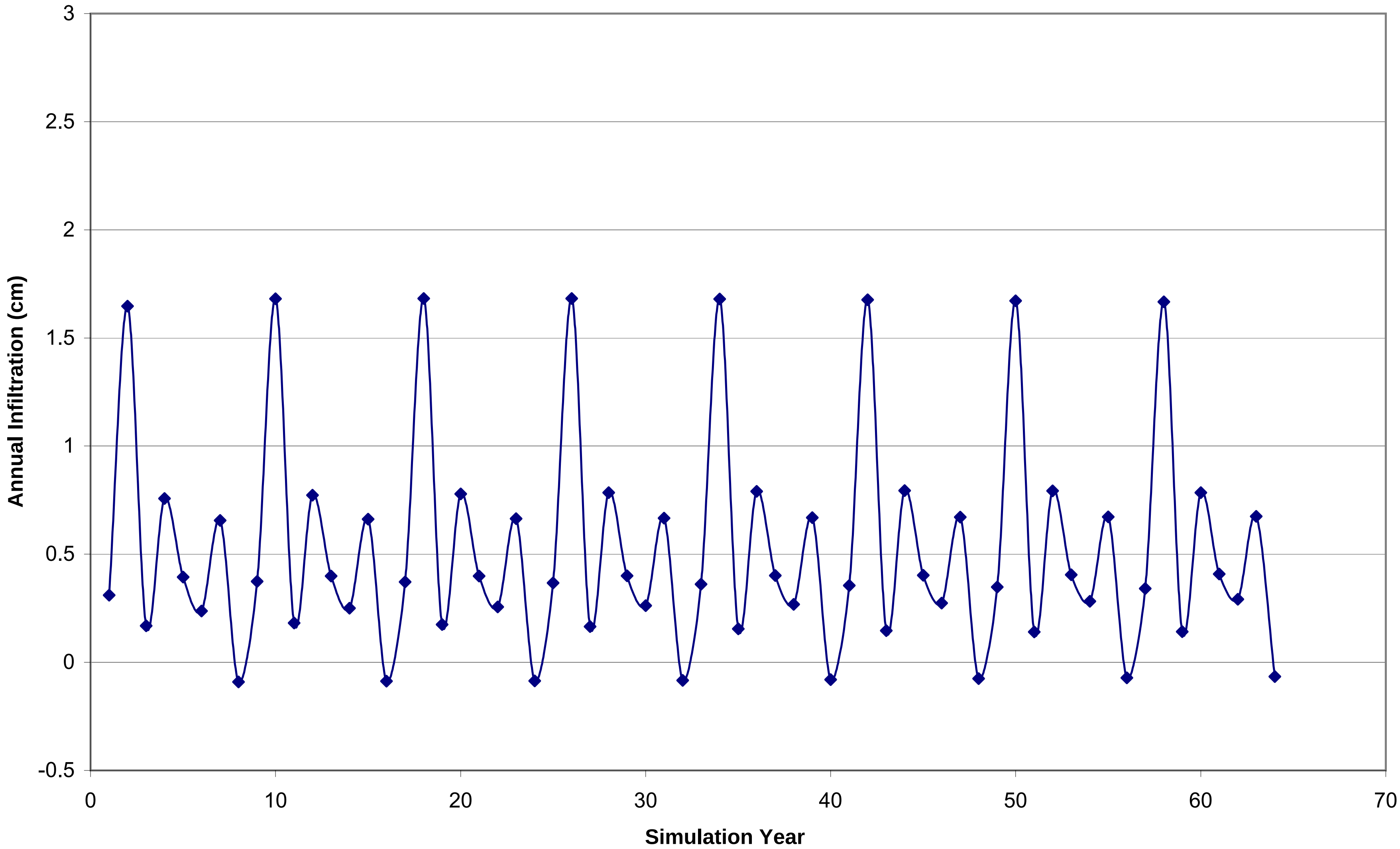

Figure 5-29 Annual Infiltration Through a 2-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

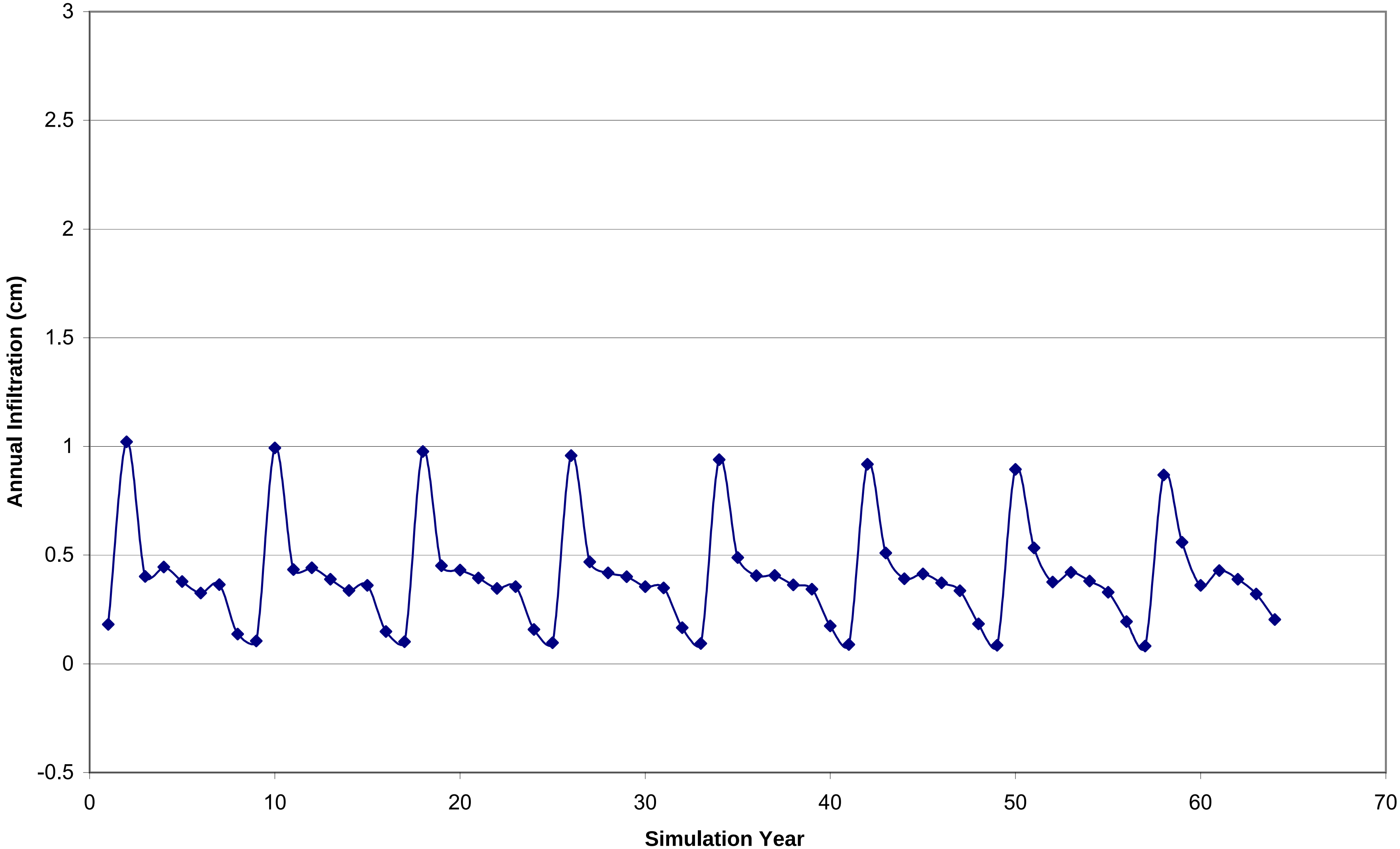

Figure 5-30 Annual Infiltration Through a 3-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

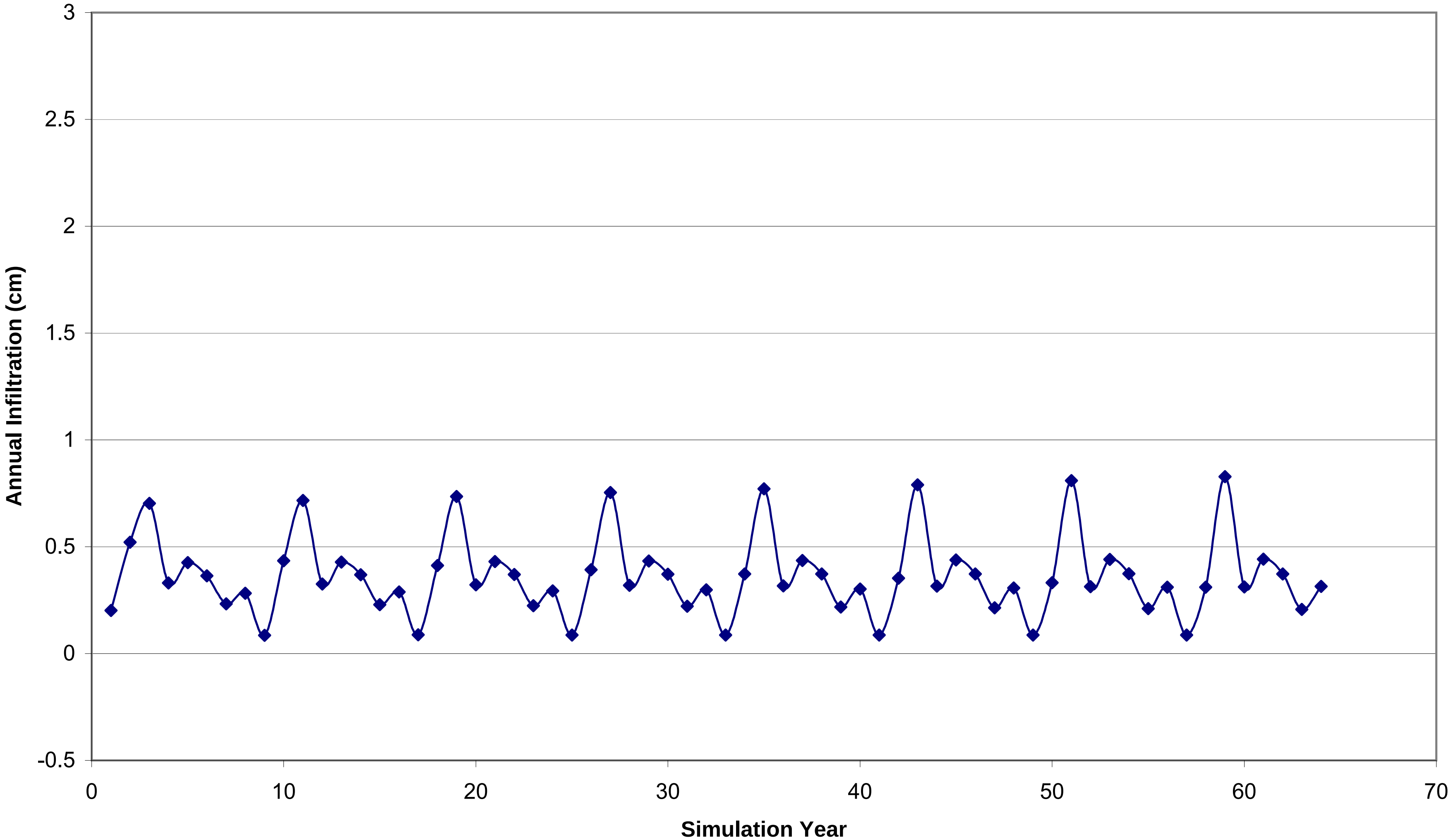

Figure 5-31 Annual Infiltration Through a 4-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

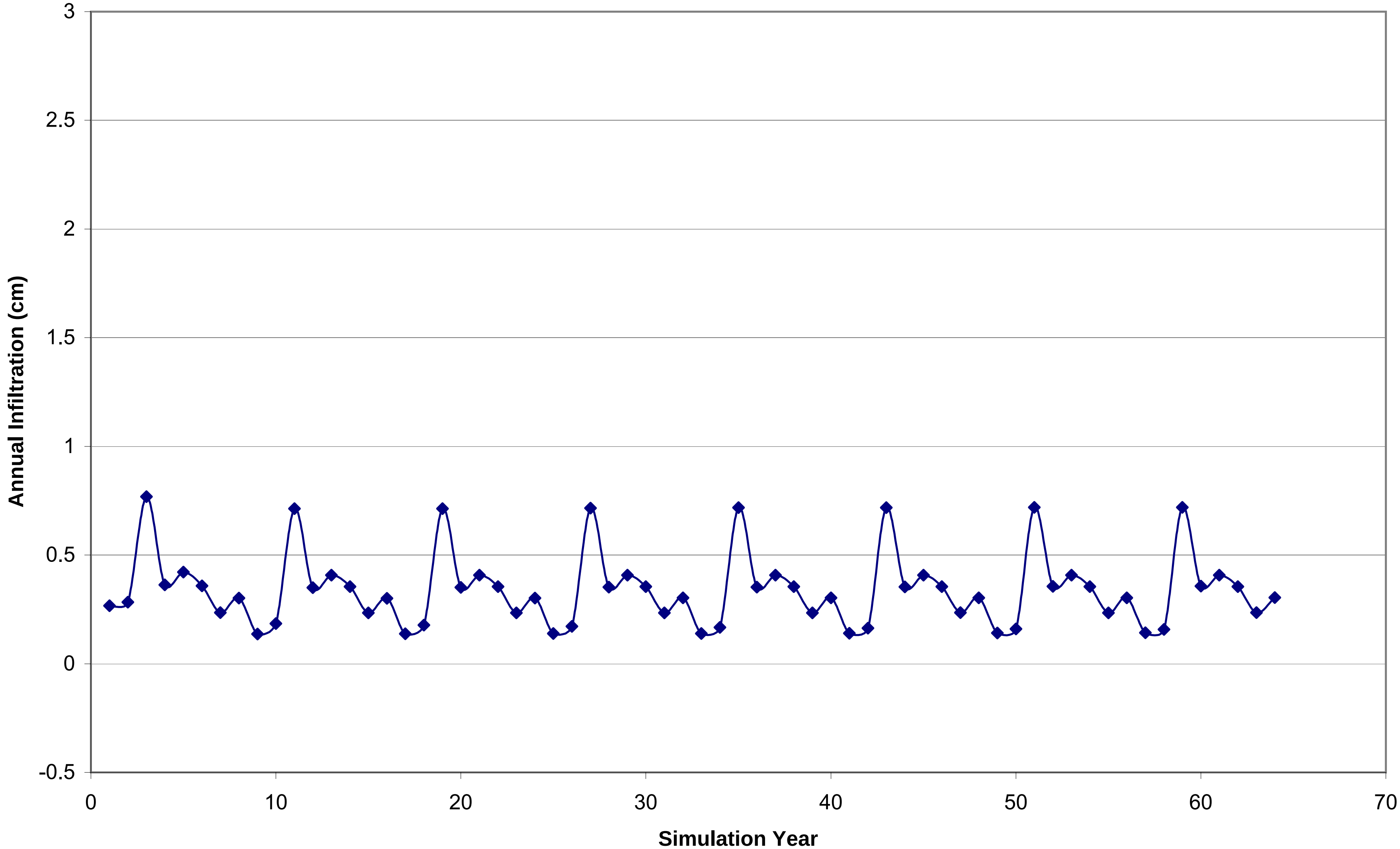

Figure 5-32 Annual Infiltration Through a 5-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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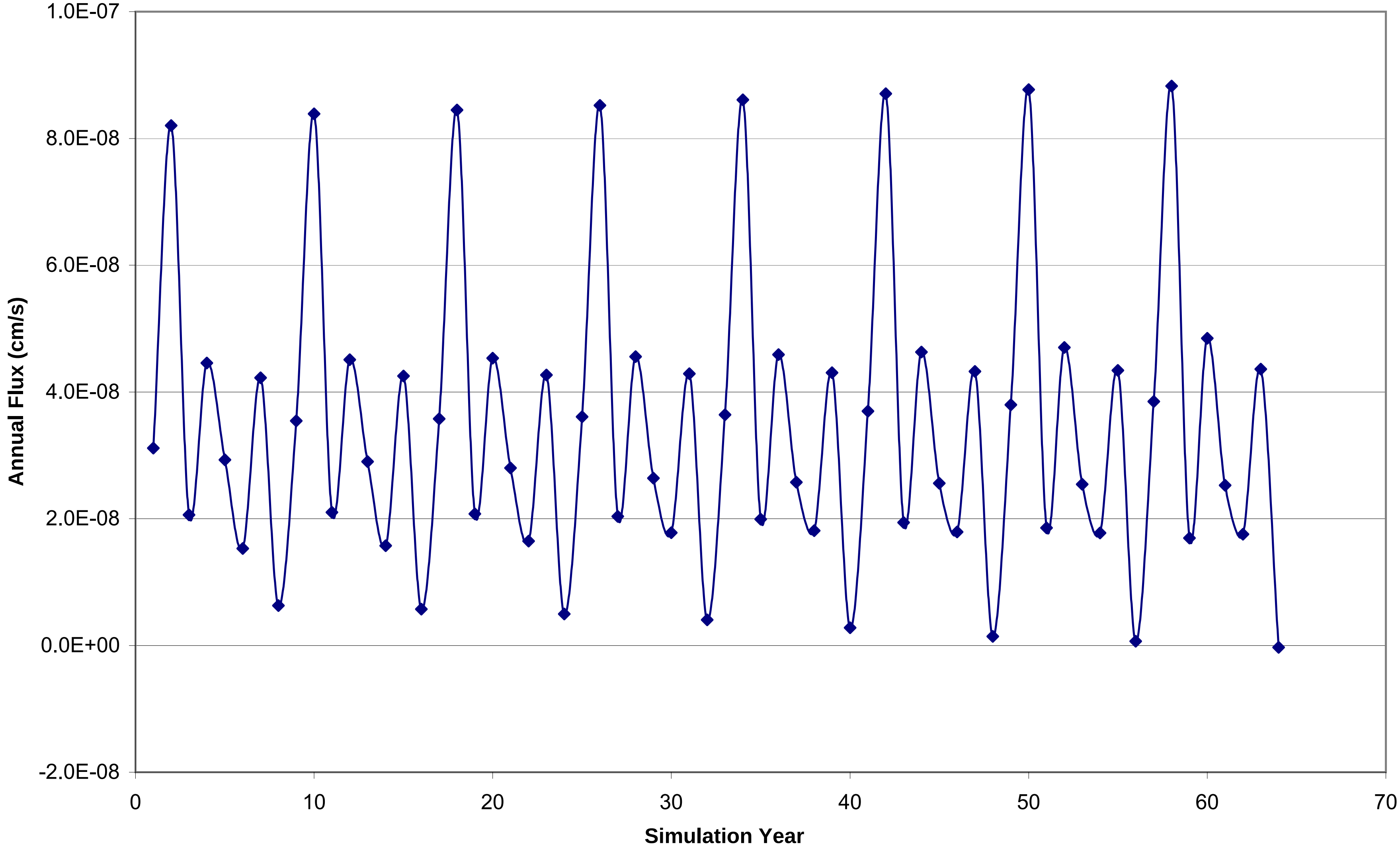

Figure 5-33 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

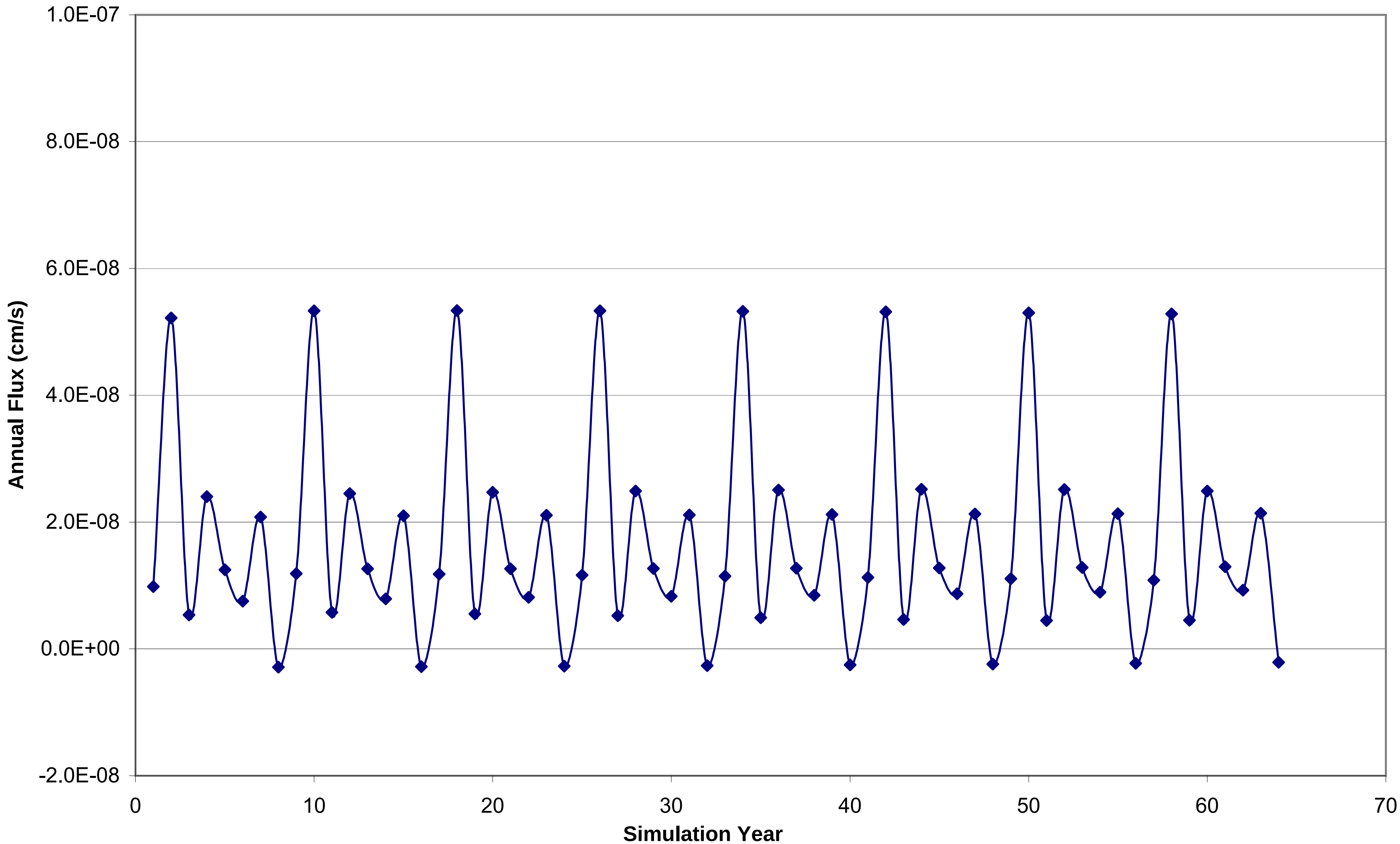

Figure 5-34 Annual Flux Through a 2-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

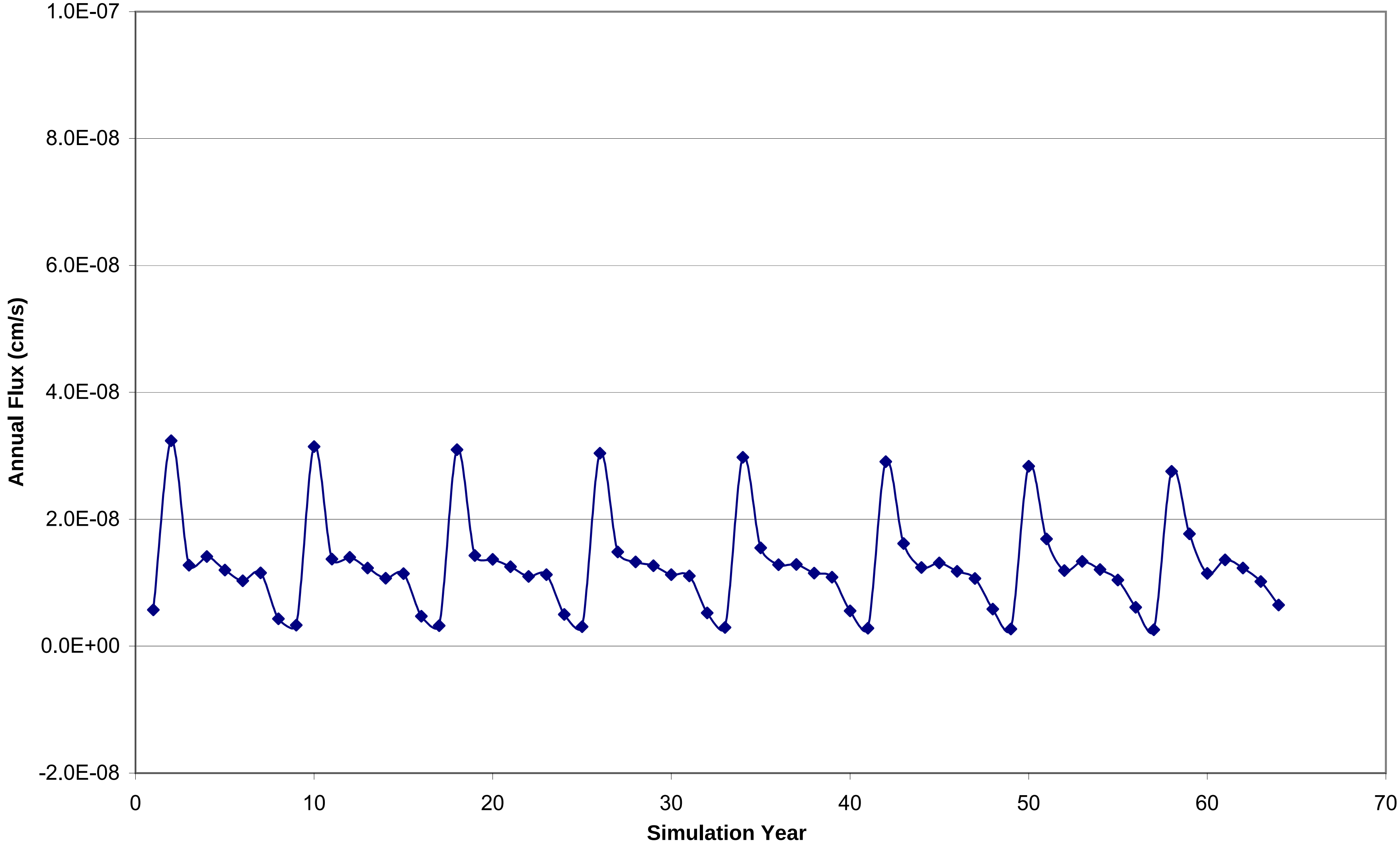

Figure 5-35 Annual Flux Through a 3-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

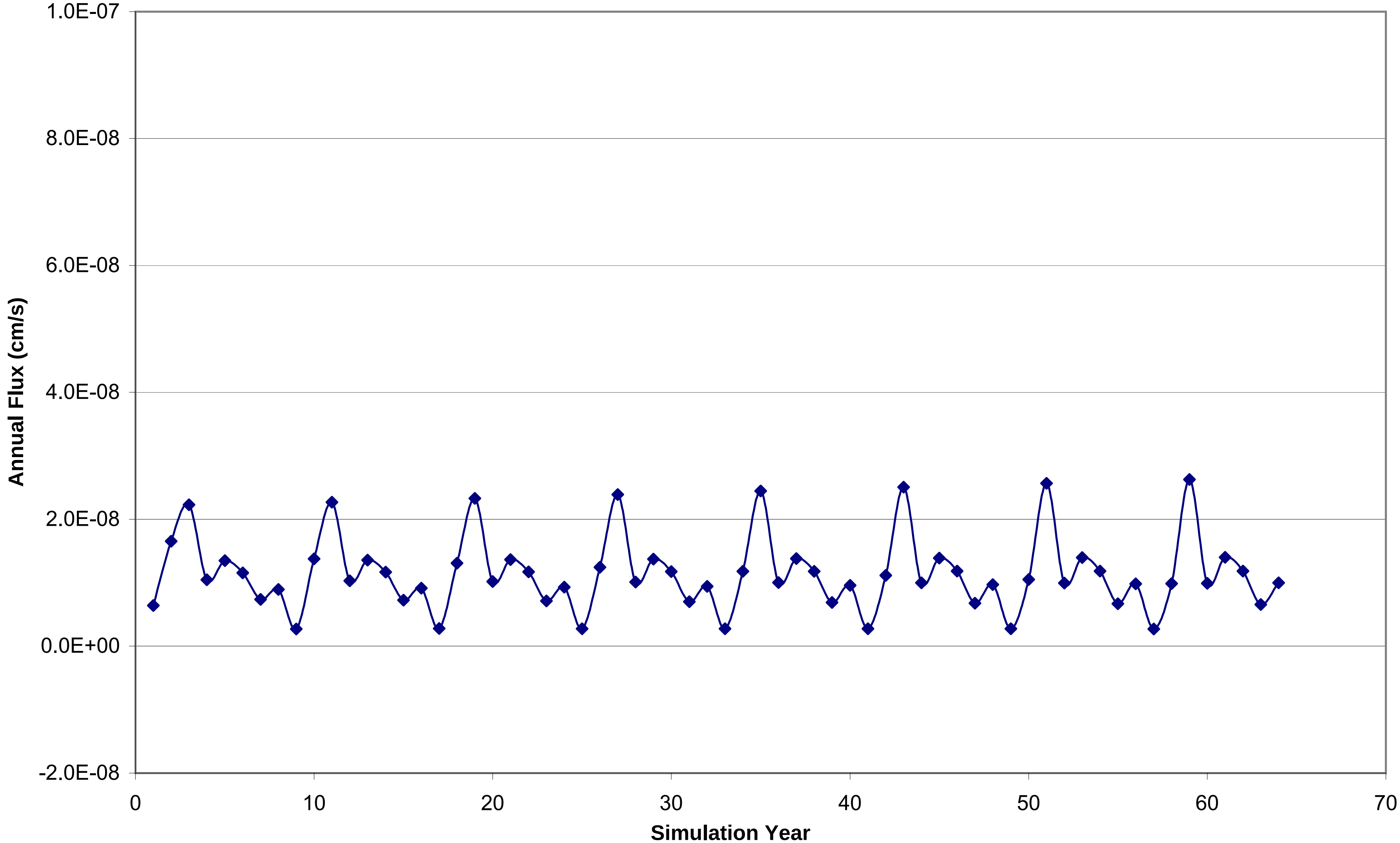

Figure 5-36 Annual Flux Through a 4-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

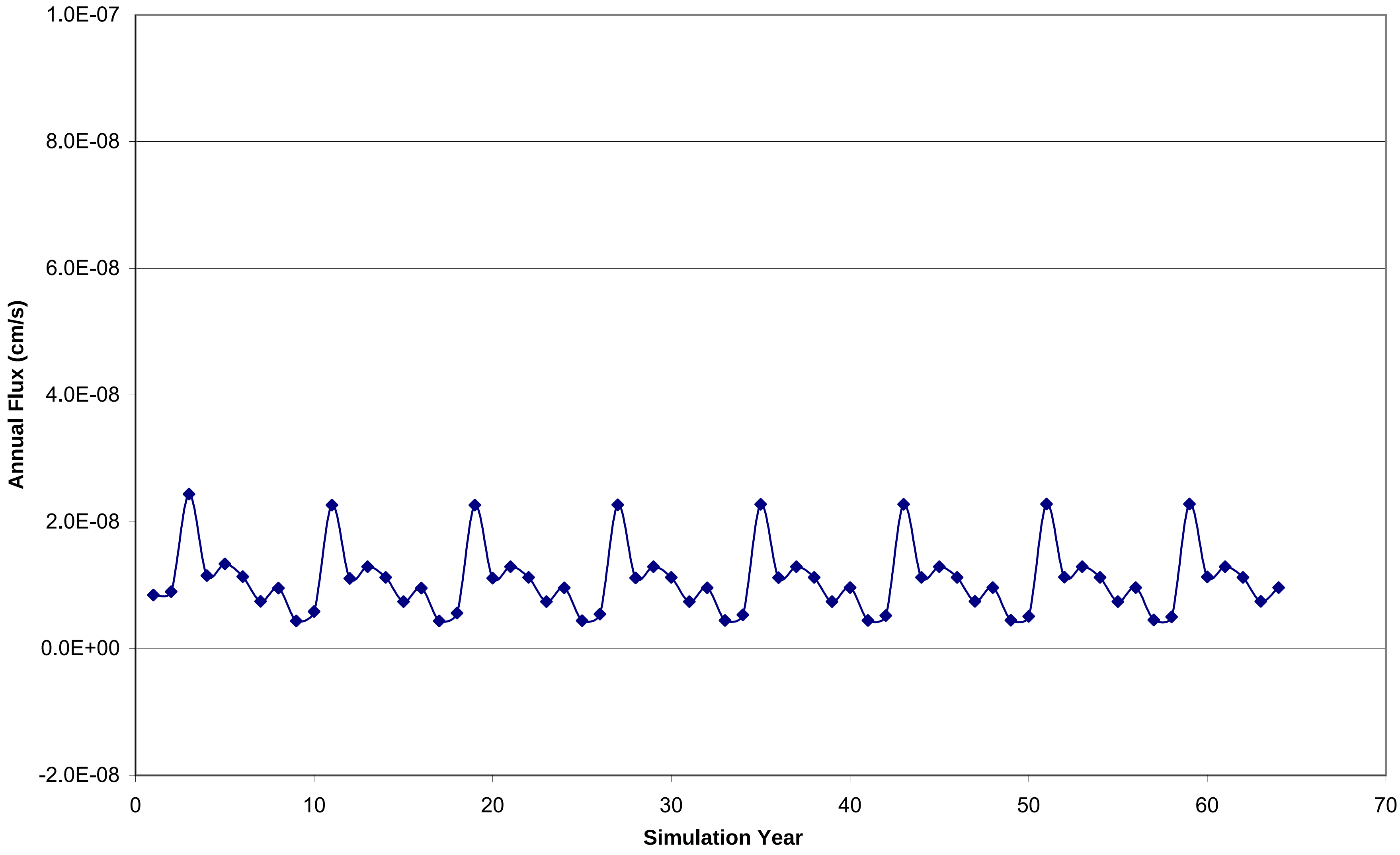

Figure 5-37 Annual Flux Through a 5-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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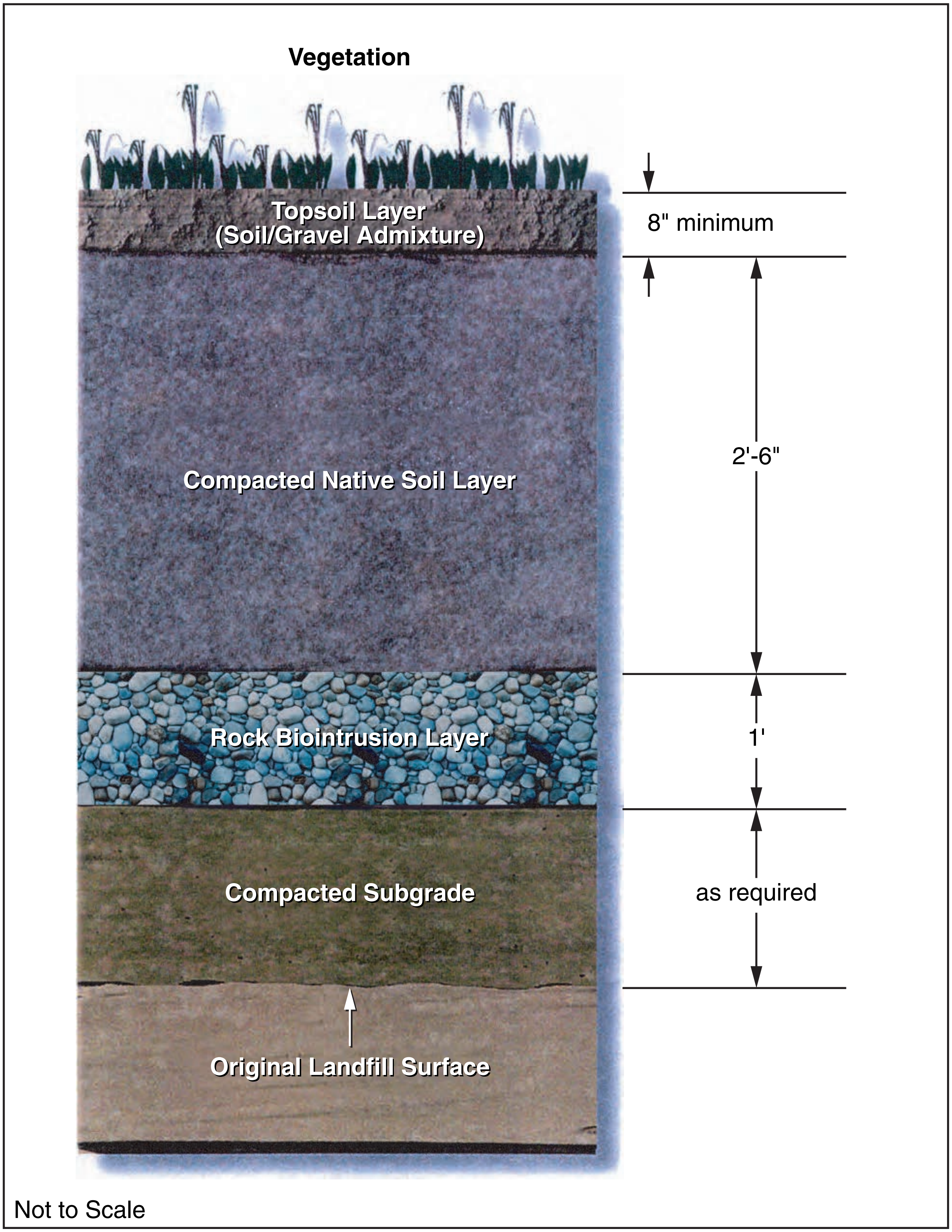

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Figure 6-1 Schematic of Mixed Waste Landfill Alternative Cover

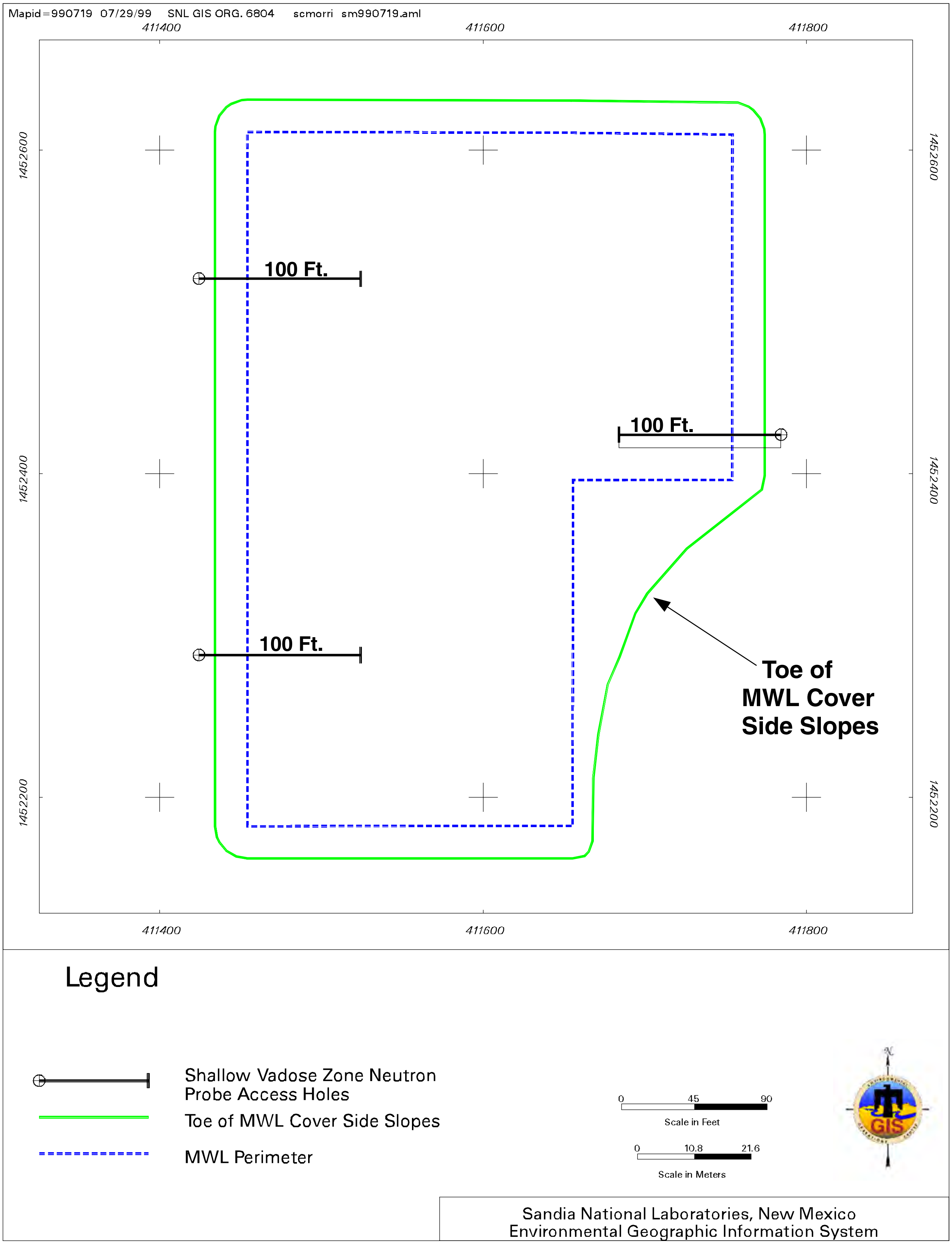

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Figure 7-1 Location of Shallow Vadose Zone Neutron Probe Access Holes

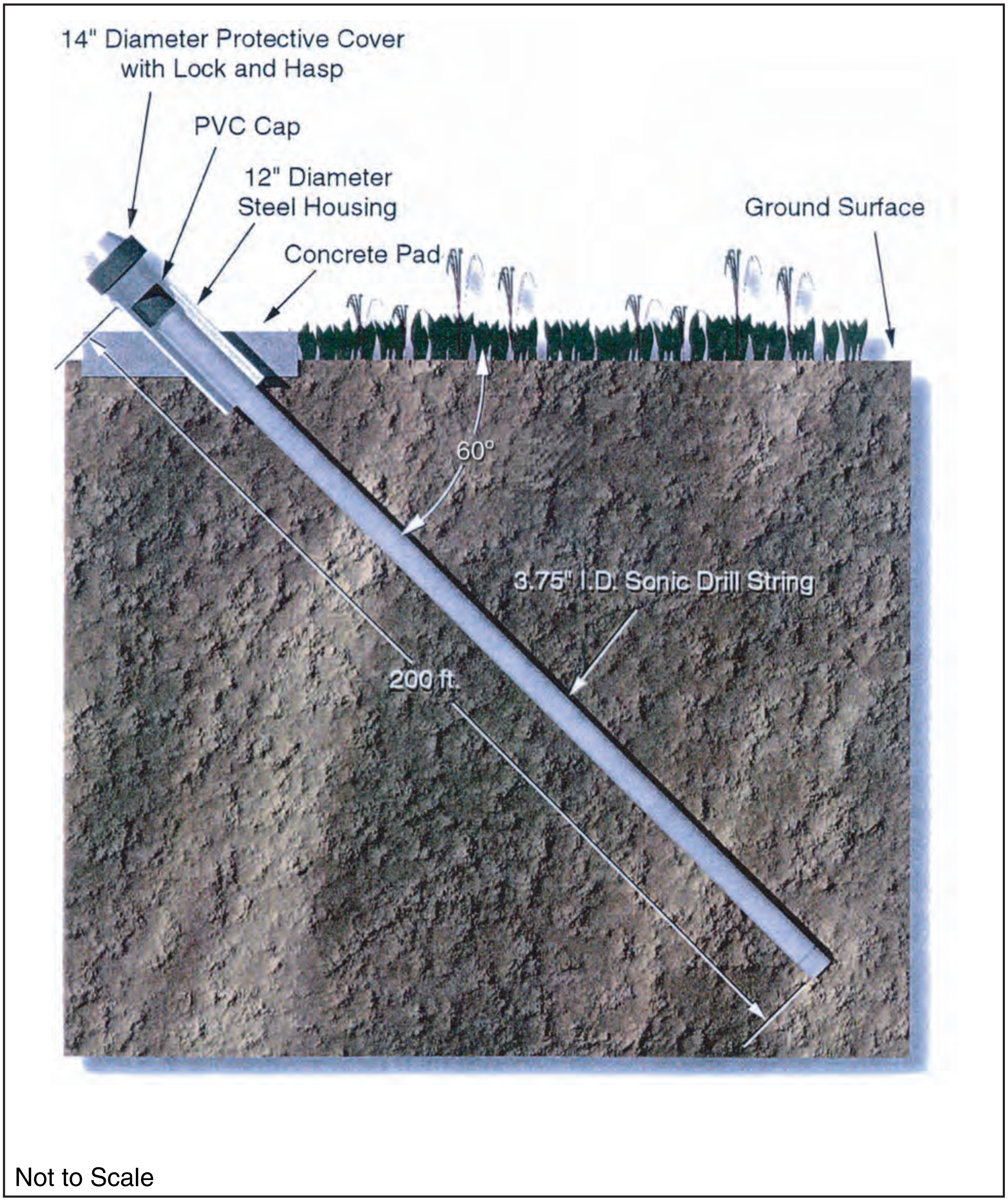

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Figure 7-2 Schematic of Vadose Zone Neutron Probe Access Holes and Casings

TABLES

Table 5-1
Hydraulic Conductivity Data for Subsurface Soil at the Mixed Waste Landfill

Sample Location	Sample/Borehole	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Laboratory
Field Measurements				
60 feet north of IP Test Site	Artificial Rainfall Test	2	5.3E-04	In Situ Field Measurement
MWL IP Test Site	IP Test	3	4.0E-04	In Situ Field Measurement
Geometric Mean of Field Measurements			**4.6E-04**	**NA**
Laboratory Measurements				
MWL Perimeter	MWL-BH-01	10	3.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	26	1.1E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	52	9.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	78	3.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	26	8.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	52	5.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	78	4.4E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-04	98	2.6E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	26	1.1E-03	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	52	1.7E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	78	7.5E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	104	9.2E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	30	2.1E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	52	8.4E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	26	6.8E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	56	1.0E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	15	4.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	36	1.6E-04	SNL Hydrology Laboratory
MWL IP Test Site	015-045	1	2.3E-05	SNL Hydrology Laboratory
MWL IP Test Site	045-075	2	2.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	075-105	3	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	105-135	4	2.0E-03	SNL Hydrology Laboratory
MWL IP Test Site	135-165	5	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	165-195	6	9.0E-04	SNL Hydrology Laboratory
MWL Test Pit Area 2	Knight Piesold 1a	0.33	3.1E-04	Knight Piesold Laboratory
MWL Test Pit Area 2	Knight Piesold 1b	1.50	2.1E-04	Knight Piesold Laboratory
Geometric Mean of Laboratory Measurements:			**1.1E-04**	**NA**

BH = Borehole.
cm/s = Centimeter(s) per second.
ft = Foot (feet).
IP = Instantaneous profile.
MWL = Mixed Waste Landfill.
NA = Not applicable.
SNL = Sandia National Laboratories.

Table 5-2
Hydraulic Conductivity Data for Mixed Waste Landfill Cover Soil at 90 Percent Compaction

Sample Location	Sample	Depth Range (ft)	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Percent Compaction	Laboratory
MWL Test Pit Area 2	Composite 2A	0–2	1	1.0E-05	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1A	0–2	1	1.1E-04	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1B	> 2	3	4.3E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas:				**3.6E-05**	**NA**	**NA**
CAMU Soil Piles	Native Soil 1 of 3	Upper 2	1	1.5E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 2 of 3	Upper 2	1	1.7E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 3 of 3	Upper 2	1	3.2E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 1 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 2 of 3	Surface to 5	3	2.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 3 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from CAMU Stockpiles:				**1.6E-05**	**NA**	**NA**
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas & CAMU Stockpiles:				**2.1E-05**	**NA**	**NA**

CAMU = Corrective Action Management Unit.
cm/s = Centimeter(s) per second.
ft = Foot (feet).
MWL = Mixed Waste Landfill.
NA = Not applicable.

Table 5-3
Summary of Input Parameters Used for HELP-3, UNSAT-H, and VS2DT Predictive Modeling

Parameter	HELP-3[a]	UNSAT-H	VS2DT
Porosity, cm^3/cm^3	0.453	0.4	0.4
Field Capacity cm^3/cm^3	0.19	NA	NA
Residual Water Content cm^3/cm^3	NA	0.08	0.08
Wilting Point cm^3/cm^3	0.085	NA	NA
Head at Wilting or Pressure Head in Roots	NA	345 ft (10508 cm)	330 ft (10,058 cm)
Air Entry Parameter Alpha	NA	0.641 ft^{-1} (0.021 cm^{-1})	0.641 ft^{-1} (α' = -1.56 ft)
Van Genuchten “n”	NA	2.00	2.00
Initial Water Content	0.085	0.0862	0.0862
Initial Head, ft	NA	80 ft (2438 cm)	80 ft (2438 cm)
Saturated Hydraulic Conductivity	2.04 ft/day	0.85 ft/day (1.08 cm/hr)	0.85 ft/day
Slope	0.02 ft/ft	0 (1-dimensional)	0 (1-dimensional)
Drainage Length	200 ft	NA	NA
Maximum Root Depth	NA	3.25 ft	3.28 ft
Evaporative Zone Depth	42 inches	NA	NA
Atmospheric Pressure Potential	NA	750 ft (22860 cm)	500 ft to 1,000 ft
Head where Transpiration Starts to Decrease	NA	165 ft (5029 cm)	NA
Temperature	Air temp varies	293°K	NA
Membrane Defects	No membrane	NA	NA

[a]HELP-3 runs used HELP-3’s default Type 6 soil because the model was very sensitive and inconsistent in its response to soil parameters.

cm = Centimeter(s).
cm^3 = Cubic centimeter(s).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
°K = Degree(s) Kelvin.
ft = Foot (feet).
hr = Hour.
NA = Not applicable.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.

Table 5-4
Summary of Mixed Waste Landfill Cover Modeling Results Using Historical Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	28.0	0.09	0.15	0.00	0.00
UNSAT-H	Cumulative Infiltration (cm)	41.5	15.00	8.44	5.79	4.15
VS2DT	Cumulative Infiltration (cm)	37.5	5.49	0.43	0.07	0.09
HELP-3	Average Flux (cm/s)	1.4E-08	4.3E-11	7.1E-11	0.0E+00	0.0E+00
UNSAT-H	Average Flux (cm/s)	2.0E-08	7.3E-09	4.1E-09	2.8E-09	2.0E-09
VS2DT	Average Flux (cm/s)	1.8E-08	2.7E-09	2.1E-10	3.6E-11	4.5E-11
HELP-3	Average Infiltration Rate (cm/yr)	0.4314	0.0014	0.0023	0.0000	0.0000
UNSAT-H	Average Infiltration Rate (cm/yr)	0.6396	0.2307	0.1299	0.0891	0.0638
VS2DT	Average Infiltration Rate (cm/yr)	0.5768	0.0844	0.0066	0.0011	0.0014
HELP-3	Maximum Volumetric Moisture Content	0.28	0.18	0.17	0.16	0.16
UNSAT-H	Maximum Volumetric Moisture Content	0.21	0.15	0.13	0.12	0.11
VS2DT	Maximum Volumetric Moisture Content	0.20	0.13	0.10	0.09	0.09

cm = Centimeter(s).
ft = Foot (feet).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
s = Second.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.
yr = Year.

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Table 5-5
Summary of Mixed Waste Landfill Cover Modeling Results Using Maximum Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	35.4	0.20	0.47	0.58	0.86
UNSAT-H	Cumulative Infiltration (cm)	70.1	33.8	25.8	23.2	21.8
VS2DT	Cumulative Infiltration (cm)	77.7	19.4	3.38	0.78	0.66
HELP-3	Average Flux (cm/s)	1.8E-08	1.0E-10	2.3E-10	2.9E-10	4.3E-10
UNSAT-H	Average Flux (cm/s)	3.5E-08	1.7E-08	1.3E-08	1.1E-08	1.1E-08
VS2DT	Average Flux (cm/s)	3.8E-08	9.6E-09	1.7E-09	3.9E-10	3.3E-10
HELP-3	Average Infiltration Rate (cm/yr)	0.5539	0.0032	0.0073	0.0091	0.0135
UNSAT-H	Average Infiltration Rate (cm/yr)	1.0959	0.5277	0.4024	0.3624	0.3400
VS2DT	Average Infiltration Rate (cm/yr)	1.2144	0.3024	0.0529	0.0122	0.0104
HELP-3	Maximum Volumetric Moisture Content	0.30	0.20	0.18	0.17	0.17
UNSAT-H	Maximum Volumetric Moisture Content	0.24	0.17	0.14	0.14	0.13
VS2DT	Maximum Volumetric Moisture Content	0.22	0.15	0.12	0.10	0.10

cm = Centimeter(s).
ft = Foot (feet).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
s = Second.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.
yr = Year.

APPENDIX A
Construction Specifications

MIXED WASTE LANDFILL ALTERNATIVE COVER
CONSTRUCTION SPECIFICATIONS
REVISION 2
July 29, 2005

SPECIFICATION NUMBER	TITLE
01001	Definitions
01563	Temporary Diversion and Control of Water during Construction
02110	Clearing and Grubbing
02115	Biointrusion Barrier
02200	Earthwork
02210	Grades, Lines, and Levels
02221	Trenching, Backfilling, and Compaction
02445	Administrative Control Fences and Gates
02670	Monitoring Well MW-4 Extension
02930	Reclamation Seeding and Mulching

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SECTION 01001

DEFINITIONS

General Conditions	General terms and conditions for construction projects at Sandia National Laboratories, New Mexico.
Operator	Sandia National Laboratories, New Mexico
Construction Team or Contractor	Hereinafter referred to as the "Contractor." Operates separately from the Operator and the Construction Quality Assurance (CQA) Engineer. Responsible for constructing the Mixed Waste Landfill (MWL) alternative cover in strict accordance with the design criteria, specifications, design drawings, and CQA Plan using the necessary construction procedures and techniques.
Construction Quality Assurance Engineer	Hereinafter referred to as the CQA Engineer. Operates separately from the Operator and the Contractor. Responsible for activities specified in the CQA Plan (e.g., inspection, verification testing, and documentation).

END OF SECTION

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SECTION 01563

TEMPORARY DIVERSION AND CONTROL OF WATER DURING CONSTRUCTION

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment for controlling surface water and dewatering work areas prior to and throughout construction operations. Control measures implemented may include berms, swales, ditches, temporary pipes/hoses, portable pumps, silt fences, sediment traps, or any other measure approved by the Operator in accordance with this specification.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

2. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

3) Earthwork shall be in accordance with Section 02200 of these specifications.

4) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve data submittals as required by this specification.

2) Inspect work for compliance with requirements of these specifications, in addition to inspection by the Contractor and with the design drawings.

3) Review pre-placement conditions, placement of controls, and other job conditions during performance of the work.

4) Perform final inspection and acceptance of water diversion and control work.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 Equipment

1) All equipment and tools shall conform to the safety requirements of the MWL Health and Safety Plan.

2) All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and maintained in satisfactory working condition at all times.

3) The Contractor's equipment shall be adequate and capable of controlling water prior to and throughout construction as required by this specification.

2.1.2 Materials

1) All materials shall be furnished by the Contractor and shall be subject to approval by the Operator.

2) Maintenance, repairs, and replacement of materials damaged by the Contractor or his subcontractors shall be the responsibility of the Contractor.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Standing water outside the construction boundary may be allowed to infiltrate.

3.1.2 The Contractor shall manage storm water such that all construction areas shall be free of standing water. Suitable water control measures shall be constructed at all locations where construction work may be affected by surface water at the time of the work.

3.1.3 The Contractor shall divert surface water around the periphery of the construction area by constructing temporary ditches, berms, or other means of control.

3.1.4 The Contractor shall be solely responsible for the protection of work against damage, delay, or environmental impacts from water flow.

3.1.5 The Contractor shall direct and control surface water in a manner that protects adjacent structures and facilities.

3.2 WORK IN EXTREME WEATHER

3.2.1 In the event of extreme storm activity, the Contractor shall provide protective measures to prevent damage to the construction area and maintain control of runoff and run-on. During such extreme storm events, the Contractor shall protect slopes by methods approved by the Operator. The Contractor shall inspect erosion protection structures within 24 hours after extreme storm events to verify that erosion protection structures are in place and functional. To maintain the integrity of erosion prevention structures, the Contractor shall clean out, as necessary, all temporary control structures of debris and sediment buildup, and repair or replace any damaged areas either in the temporary control structures or in permanent work areas as identified by the Operator.

3.3 INSPECTIONS AND REPAIRS

3.3.1 The Contractor shall inspect temporary water control structures and materials on a regular basis and shall record inspection findings in the Daily Field Report. The inspection records shall be submitted weekly to the Operator.

3.3.2 The Contractor shall remove debris and sediment build-up from the temporary control structures as required to maintain the intended flow path.

3.3.3 Should an overflow or breach condition be encountered or any other damage observed at the temporary water control structures, repair and/or replacement of the damaged area shall be completed by the Contractor.

3.3.4 Acceptance criteria for repaired and/or replaced temporary water control structures shall be in accordance with the requirements of this section.

3.4 REMOVAL OF TEMPORARY CONTROL MEASURES

Temporary storm water control measures shall be removed once the work has been completed and as approved by the Operator. The materials removed shall be properly disposed of by the Contractor, at locations designated by the Operator. All areas where temporary control structures are removed shall be regraded and revegetated in accordance with Sections 02200 and 02930 of these specifications.

3.5 ACCEPTANCE

The Contractor shall submit a description of any repair or replacement work required to the Operator prior to implementation. Acceptance criteria for repaired or replaced water control measures shall be in accordance with the requirements of this specification.

END OF SECTION

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SECTION 02110

CLEARING AND GRUBBING

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment, and shall perform clearing and grubbing during construction activities in accordance with this specification and as shown on the design drawings.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

3) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve submittals as required for this specification.

2) Designate items that require salvage, storage, reuse, and/or relocation.

3) Perform final inspection and confirm acceptance of clearing and grubbing.

4) In addition to inspection by the Contractor, the Operator and/or the CQA Engineer may inspect work for compliance with the requirements of this specification.

1.2 SUBMITTALS

1.2.1 Procedures, Certifications, and Records

The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can

review work for compliance with the requirements of this specification and make CQA decisions in real-time.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition by the Contractor at all times.

2.1.2 The Contractor's equipment shall have the capability to perform the indicated clearing and grubbing specified herein.

2.1.3 The Contractor shall ensure that all equipment used for clearing and grubbing work is fitted with appropriate safety devices that comply with all applicable Federal laws and the MWL Health and Safety Plan, and that will adequately protect equipment operators and minimize exposure of site workers and others.

2.2 ITEMS SALVAGED FOR REUSE, STORAGE, OR RELOCATION

The Operator will designate items that require reuse, storage, or relocation.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Site Inspection

The Contractor shall inspect the site to determine the nature, location, size, and extent of vegetative material, debris, and obstructions to be removed or preserved, as specified herein.

3.1.2 Traffic

The Contractor shall conduct clearing and grubbing operations to ensure minimum interference with roads, walks, and adjacent facilities. The Contractor shall not close or obstruct roads, walks, or adjacent operational facilities without written permission from the Operator.

3.1.3 Protection of Existing Structures and Facilities

The Contractor shall provide protection necessary to prevent damage to the existing structures and facilities which are to remain in place. The Contractor shall restore or replace damaged property to original condition, or to the satisfaction of the Operator.

Items damaged in removal shall be repaired and refinished, or replaced by the Contractor with new matching items as required by the Operator.

3.1.4 Salvageable Items

Items damaged in removal shall be repaired, refinished, or replaced by the Contractor with new matching items as required by the Operator. The Contractor shall save and protect from construction damage all vegetative materials (shrubs, grass, and other vegetation) beyond the limits of the required clearing and grubbing. The Contractor shall restore or replace damaged vegetative materials to the conditions as required by the Operator, in accordance with Section 02930 of these specifications.

3.1.5 Protection of Monuments and Other Permanent Surface Features

The Contractor shall locate and mark existing monuments, monitoring wells, stanchions, and markers before construction operations commence and shall protect such items during construction. The Contractor shall restore or replace damaged items to original condition as required by the Operator.

3.2 CLEARING AND GRUBBING

3.2.1 Clearing and Grubbing

The Contractor shall clear the site of shrubs, vegetation, rocks and debris as required within the limits of the landfill cover, laydown and stockpile areas south of the MWL. Roots exceeding 1 inch in dimension, as well as rocks and other debris exceeding 2 inches in dimension in the top 6 inches of the existing site grade shall be removed by hand or mechanical means. Removal methods shall minimize the disturbance of soils below 6 inches in depth. Clearing and grubbing shall conform to the Radiological Work Permit (RWP).

3.2.2 Reclamation Seeding and Mulching

The Contractor shall seed and mulch disturbed areas in accordance with Section 02930 of these specifications.

3.3 DISPOSAL OF WASTE AND DEBRIS MATERIALS

3.3.1 Organic Material

Organic materials, including grass, shrubs, stumps, roots, and other organic debris removed due to clearing activities, shall be transported by the Contractor to a stockpile/disposal site designated by the Operator. The stockpile/disposal site shall be located within ¼ mile of the project area. Organic material shall be stockpiled or disposed of as directed by the Operator.

3.3.2 Disposal

The Contractor shall remove all materials not designated for relocation, reuse, or salvage. These materials shall be disposed of or stockpiled as directed by the Operator.

3.4 DAMAGED AREAS

The Contractor shall confine clearing and grubbing operations to within those areas required for cover construction or as directed by the Operator. Any areas outside the designated areas that are damaged or disturbed by the Contractor's operations shall be reclaimed by the Contractor. Reclamation shall be in accordance with Section 02930 of these specifications.

3.5 ACCEPTANCE

Clearing and grubbing not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor at the Contractor's expense. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for approval before use. Acceptance criteria for repaired and/or replaced clearing and grubbing shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02115

BIOINTRUSION BARRIER

PART 1 GENERAL

1.1 TOPOGRAPHIC SURVEY

A topographic survey shall be performed immediately prior to and after placement of the biointrusion barrier in order to document as-built conditions and elevations. Ground elevations shall be determined to the nearest 0.1 ft using conventional ground surveying techniques.

1.2 DESCRIPTION OF WORK

This section describes the requirements for placement of crushed rock directly on the subgrade layer for use as a biointrusion barrier to discourage small and large burrowing mammals from penetrating the cover. Crushed rock for use as a biointrusion barrier will be provided by the Operator in stockpiles located south of the MWL.

PART 2 BIOINTRUSION BARRIER MATERIAL

The biointrusion barrier material shall consist of crushed rock of stone size so that 50 percent of the fragments, by weight, shall be larger than the D_{50} = 4-inch size. The graded material shall be a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the larger rock fragments. The diameter of the largest rock fragment in such a mixture shall be 6 inches (1.5 times the D_{50} = 4-inch size).

PART 3 EXECUTION

3.1 PLACEMENT

The biointrusion barrier shall be placed in a single lift directly on the subgrade layer. The completed biointrusion barrier layer shall be a minimum of 1 ft in thickness and not exceed 1.25 ft in thickness.

3.2 COMPACTION

The biointrusion barrier material shall be compacted using heavy equipment approved by the Operator prior to use. Compaction shall consist of repeated passes over all areas where biointrusion barrier material has been placed until the crushed rock fragments are firmly locked in place. The compaction equipment shall be operated at a speed that prevents displacement of the biointrusion barrier material.

END OF SECTION

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SECTION 02200

EARTHWORK

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment for all types of earthwork to be performed during the construction activities in accordance with this specification and as shown in the design drawings. Earthwork includes grading and placement of all earthen cover materials, disposal of unsuitable materials, and reclamation of areas designated by the Operator.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

5) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

6) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve submittals as required by this specification,

2) Review and approve results of quality assurance tests and surveying performed for compliance with this specification,

3) Document and monitor corrective actions,

4) Identify the acceptable borrow areas and soil stockpiles,

5) Have the option to approve all compaction equipment prior to use,

6) Have the option to inspect and approve surface conditions prior to placement of fill and crushed rock,

7) Have the option to inspect and approve all fill and crushed rock prior to placement, and

8) Have the option to perform final inspection and confirm acceptance of earthwork.

1.2 SUBMITTALS

1.2.1 Procedures, Certifications, and Records

The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can review work for compliance with the requirements of this specification and make CQA decisions in real-time.

1.3 QUALITY ASSURANCE

The Contractor shall prepare, maintain, and use a written QA/QC Manual for the work performed. The QA/QC Manual shall include requirements to ensure the application of the latest design documents and the incorporation of approved changes. As a minimum, the Contractor shall record and maintain appropriate data that verify the quality of materials, the application of approved procedures, and performance of tests and inspections. The Contractor shall maintain appropriate written approval signatures for acceptance of work performed.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIALS

2.1.1 Equipment

1) All equipment and tools shall comply with the safety requirements of the MWL Health and Safety Plan.

2) All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition at all times. All compaction

equipment shall be inspected for acceptance by the Operator prior to the start of construction.

3) The Contractor's equipment shall be adequate for and have the capability to produce the requirements specified herein. Compaction equipment shall be appropriate to compact the fill as specified by the manufacturer.

2.1.2 Fill

Fill shall be from an Operator-designated soil stockpile or borrow area and shall be free of plants, rubble, litter, insect infestation, and other deleterious matter and be free of rocks larger than 2-inches in dimension.

1) Subgrade fill shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Subgrade fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 - 100
#40	70 - 100
#200	20 - 40

2) Crushed rock for the biointrusion barrier shall be obtained from the stockpile south of the MWL. The material shall have a minimum dimension of 1 inch and be free of all fine material. The crushed rock will be free of organic material, soft and friable fragments, and other objectionable materials as determined by the Operator. The maximum fragment size of the biointrusion barrier shall be 6 inches with D_{50} = 6 inches, and each fragment shall have 100 percent fracture face.

3) Native Soil Layer fill shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Native Soil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 – 100
#40	70 – 100
#200	20 – 40

4) Topsoil Layer soil shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Topsoil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	90 - 100
#40	85 - 100
#200	20 - 45

The Topsoil Layer fill shall be admixed with 3/8-inch, crushed gravel 25 percent by volume, before placing and grading. The gravel is to be clean with no more than 5 percent passing the #4 sieve.

5) Pre-acceptance QC testing of fill soils shall be in accordance with Section 3.4 of this specification. Acceptance of materials with variations from this classification will be evaluated by the CQA Engineer and the Operator.

PART 3 EXECUTION

3.1 PROTECTION AND SAFETY

The Contractor shall keep all operational areas adjacent to or part of this project usable at all times. The Contractor shall provide all necessary measures for the protection of the workers and the public, as per the standards established by the Operator or the Occupational Safety and Health Administration (OSHA).

3.1.1 The Contractor shall provide protection necessary to prevent damage to existing structures indicated in the design drawings or indicated by the Operator to remain in place. The Contractor shall restore damaged property to original condition, and obtain written approval of repairs from the Operator.

3.1.2 The Contractor shall clearly mark all laydown areas.

3.1.3 The Contractor shall mark or otherwise indicate the location of existing monuments and markers, and protect these structures before construction operations commence. The Contractor shall be responsible for the marking and/or protection of all necessary objects.

3.1.4 During earthwork operations, a representative of the Contractor shall be present at all times to observe work and notify the CQA Engineer and Operator immediately upon the discovery of any deviations from this specification.

3.2 EXISTING UTILITIES

3.2.1 There may be existing utilities within the limits of the construction or borrow areas. Known utilities shall be identified by the Operator and the utilities protected by the Contractor. The Operator shall be immediately notified of utilities not shown on the design drawings.

3.3 INSTALLATION OF COVER MATERIALS

3.3.1 General Requirements

1) The Contractor shall ensure that the stockpiling and handling of fill and crushed rock is confined within the limits of the designated work area. Stockpiling of clean imported material shall be confined to the Contractor's laydown and storage area as approved by the Operator. Stockpiled materials shall have stable slopes and be evenly graded and self-draining. Materials shall be stockpiled in such a way that any storm water can be controlled to prevent escape of excessive fill from the stockpile area.

2) The Contractor shall place all materials to the lines, grades, and elevations as shown in the design drawings and as specified in Section 02210 of these specifications.

3) The Contractor shall not begin placement of fill or crushed rock until after acceptance by the CQA Engineer and the Operator of the existing landfill surface or layer and placement conditions for all underlying layers.

4) The Contractor shall not place fill or crushed rock on frozen surfaces, in standing water, or when fill contains snow or ice.

5) The Contractor shall operate compaction equipment so that structures or underlying instrumentation are not damaged or overstressed during placement operations. The Contractor shall use hand-operated mechanical tampers for compaction of fill and crushed rock adjacent to wells or instrumentation wherever rolling compaction equipment is impractical for use.

6) The Contractor shall use placement methods which ensure the integrity of the underlying fill and crushed rock.

7) The Contractor shall slope temporary grades to direct water away from the construction area to reduce the potential for ponding of water. The Contractor shall provide erosion protection as specified in Section 01563 of these specifications.

8) Previously approved compacted subgrade, lifts, or layers disturbed by subsequent construction operations by the Contractor or adverse weather shall

be reworked to the required placement conditions specified herein or to the satisfaction of the CQA Engineer and Operator.

9) Application of water for dust suppression activities shall comply with Section 01563 of these specifications. Standing water will be minimized during dust suppression operations.

10) The Contractor shall ensure that unsuitable materials shall not enter the construction area.

3.3.2 Fill

1) The Contractor shall perform field-testing of the compacted materials in accordance with Section 3.4 of this specification. The Contractor shall submit results of the testing to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

2) The Contractor shall take care to avoid disturbance of the underlying lifts, layers, and instrumentation.

3) The Contractor shall reclaim borrow areas in accordance with Section 02930 of these specifications. Borrow areas shall be regraded to minimize erosion and sustain vegetation.

3.3.3 Existing Landfill Surface

1) The existing grade shall be prepared as required in Sections 02110 of these specifications.

2) The existing grade shall be scarified to a depth not to exceed 6 inches.

3) The contractor shall remove all rock and debris greater than 2 inches in dimension in preparation for compaction.

4) The Contractor shall moisten the soil to approximate optimum moisture (-2 to +2 percentage points) and compact/proof-roll the surface utilizing 10 passes of a roller. Depressions that are formed with the proof-rolling shall be filled with moistened, clean fill, and the filled area recompacted with 10 passes of the roller. The roller shall have a minimum total ballasted weight of 25 tons and a minimum pneumatic tire pressure of 90 psi. No proof rolling shall be allowed within a ~~2-ft~~ 3-ft radius of any groundwater monitoring well, measuring device, or other placed surface as designated by the Operator and/or CQA Engineer.

3.3.4 Subgrade

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain fill.

2) Subgrade fill may be stockpiled at an Operator-approved location at the MWL.

3) The Contractor shall remove all rock and debris greater than 2 inches in dimension from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

7) The Contractor shall take care to minimize disturbance to underlying lifts.

8) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.5 Biointrusion Barrier

1) The biointrusion barrier stockpile, located south of the MWL, shall be used to obtain crushed rock for the biointrusion barrier.

2) The biointrusion barrier shall be constructed using a graded, crushed rock. Crushed rock shall be of stone size so that 50 percent of the fragments, by weight, shall be larger than the D_{50} = 4-inch size. The graded material shall be a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the larger rock fragments. The diameter of the largest rock fragment in such a mixture shall be 6 inches (1.5 times the D_{50} = 4-inch size).

3) The Contractor shall place the crushed rock at a minimum of 1 ft in thickness and not exceed 1.25 ft in thickness.

4) The Contractor shall compact the crushed rock layer until the crushed rock fragments are firmly locked in place. Compaction equipment shall be operated at a speed that prevents displacement of the biointrusion barrier material.

3.3.6 Native Soil Layer

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain Native Soil Layer fill.

2) Native Soil Layer fill may be stockpiled at an Operator-approved location at the MWL.

3) The contractor shall remove all rock and debris greater than 2 inches in dimension from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform hydraulic conductivity testing on samples obtained from each lift as it is constructed. Samples shall be obtained by means of a thin-walled sample tube or equivalent sampling device in a manner that minimizes disturbance to the lift and in the direction perpendicular to the plane of compaction. Samples shall be sealed and carefully stored to prevent drying during storage and transport. Hydraulic conductivity testing shall be performed in the laboratory according to ASTM specifications for rigid wall testing.

7) The hydraulic conductivity of the samples from each lift shall have a target maximum value of 4.6×10^{-4} cm/s, the estimated hydraulic conductivity of the underlying natural soils. It is expected that approximately 5 percent of the hydraulic conductivity tests will fail to meet the target value of 4.6×10^{-4} cm/s. The failing samples shall have a hydraulic conductivity no greater than one-half order of magnitude above the target value.

8) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to initiation of placement of subsequent lifts.

9) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full

depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.7 Topsoil Layer

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain topsoil.

2) Topsoil may be stockpiled at an Operator-approved location at the MWL.

3) The topsoil shall be admixed with 25 percent, by volume, 3/8-inch crushed gravel.

4) The Contractor shall place topsoil in a minimum 8-inch loose lift.

5) Topsoil shall be minimally compacted to facilitate root development.

6) The Contractor shall take care to minimize disturbance to the underlying layer.

3.4 TESTING

3.4.1 General

The Contractor shall be responsible for the performance of all pre-acceptance and quality control testing. The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can review work for compliance with the requirements of this specification and make CQA decisions in real-time. Test results shall be provided from an approved independent soils testing laboratory.

3.4.2 Fill and Borrow Area Testing

The Contractor shall submit results for the following tests conducted during construction:

1) Subgrade Layer: Standard Proctor (ASTM D698), Gradation (ASTM C136), Classification (ASTM D2487 and D4318)

2) Native Soil Layer: Standard Proctor (ASTM D698), Gradation (ASTM C136), Classification (ASTM D2487 and D4318), Saturated Hydraulic Conductivity (ASTM rigid wall testing)

3) Topsoil Layer: Gradation (ASTM C136), Classification (ASTM D2487 and D4318)

The CQA Engineer and Operator shall review and accept submittals pertaining to testing prior to the transportation and placement of fill.

3.4.3 Field Placement Testing

The Contractor shall be responsible for the performance of all field testing and for confirmation of placement conditions. The Contractor shall submit all field test data for review and approval by the CQA Engineer and Operator. Table 3.1 outlines the material type, test methods, and test frequency for field placement activities.

3.5 INSPECTION

3.5.1 The Contractor shall be responsible for pre-operation, operation, and post-operation inspection during the performance of all work.

3.5.2 The Operator reserves the right to inspect all work for compliance with this specification.

3.6 ACCEPTANCE

The Contractor shall be responsible for documenting all test results and the number of compaction passes completed per lift. Placed materials not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced materials shall be in accordance with the requirements of this specification.

Areas that do not conform to the compaction specifications will be first investigated by the Contractor for the extent of the non-conformance. Areas that are of a different material type or that have failed the specifications after efforts to recompact the fill shall undergo additional testing regardless of the testing frequency guidelines. The Operator will determine when additional testing is required. Additional testing may include Standard Proctor and Gradation tests. Results of additional testing shall be submitted to the Operator for review. Following review of the testing results, the Operator shall determine whether a new moisture-density relationship curve shall be developed or if the Contractor shall continue to rework the non-conforming areas to meet specifications. If a new moisture-density relationship curve is produced for a change in soil type, all tests outlined in Table 3.1 shall be conducted for the new material type.

Final acceptance shall be explicitly detailed by survey location, layer description, material type, and lift number. A final report shall be submitted by the Contractor within 30 calendar days after final acceptance of the cover, detailing all field survey and quality control information performed during construction operations.

TABLE 3.1
Testing Methods and Frequencies for Borrow and Fill Areas

Item	Test Method	Frequency
Existing landfill surface	No Field Testing	Not applicable
Borrow Area Testing:		
Subgrade	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487)	1/500 cubic yards
	Standard Proctor (ASTM D698)	1/500 cubic yards
Fill Area Testing:		
Subgrade	Field Density and Moisture Testing (ASTM D2922 and ASTM D3017)	5/acre/lift
Borrow Area Testing:		
Native Soil Layer	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487 and D4318)	1/500 cubic yards
	Standard Proctor (ASTM D698)	1/500 cubic yards
Fill Area Testing:		
Native Soil Layer	K_{sat} (saturated hydraulic conductivity)	1/acre/lift
	Field Density and Moisture Testing (ASTM D2922 and ASTM D3017)	5/acre/lift
Borrow Area Testing:		
Topsoil Layer	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487 and D4318)	1/500 cubic yards
Fill Area Testing:		
Topsoil Layer	No Field Testing	

END OF SECTION

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SECTION 02210

GRADES, LINES, AND LEVELS

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment to perform surveying. The Contractor shall perform surveying to ensure that the proper grades, lines, and levels are established as set forth in these specifications and as shown in the design drawings. The Operator may procure an independent survey, provided by an independent firm registered in the State of New Mexico, to verify construction surveys. Construction surveys may be completed by the Contractor or an independent firm provided the work is completed under the supervision of a Registered Land Surveyor in the State of New Mexico.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be performed in accordance with Section 02110 of these specifications.

2) Earthwork shall be performed in accordance with Section 02200 of these specifications.

3) The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

5) Monitoring Well MW-4 Extension shall be performed in accordance with Section 02670 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required for this specification,

2) Provide Contractor with SNL/NM survey grid information,

3) Provide two benchmarks near the landfill, as shown in the design drawings,

4) Inspect work for compliance with the requirements of this specification in addition to inspection by the Contractor,

5) Verification of "as constructed" survey of the final cover closure surface,

6) Perform final inspection and confirm acceptance of surveying work.

1.2 REFERENCE DOCUMENTS

SNL/NM topographic grid and MWL design drawings.

1.3 SUBMITTALS

1.3.1 <u>Procedures</u>

1) The Contractor shall submit a plan for the work, including descriptions of survey equipment, procedures used to establish temporary or permanent benchmarks or measurements, field notes, calculations, reductions, closures, and documentation for any benchmarks or monuments to the Operator for approval.

2) Data shall be reduced and plotted by the Contractor in a form acceptable to the Operator. Legible notes, drawings, and reproducible documentation shall be submitted to the Operator for approval. The Contractor shall supply the following survey data to the Operator for approval:

    A) Topography map of final grade of each of the intermediate layers of the cover (Subgrade, Biointrusion Barrier, Native Soil Layer) with a contour interval of 0.5 feet and the location, as appropriate, of groundwater monitoring wells and instrumentation.

    B) Topography map of the final grade of the cover with a contour interval of 0.5 feet and the location, as appropriate, of groundwater monitoring wells and instrumentation.

3) All topography plats and all project benchmarks shall be based upon the SNL/NM grid. In addition to the above noted submittals, all plats shall also be submitted in electronic microstation or autocad format.

4) The Contractor shall not proceed with placement of an overlying layer or with subsequent work phases until the surveyor has completed the survey of the existing layer measurements and the data have been reviewed and accepted by the Operator.

1.3.2 Certifications

The Contractor shall submit a letter to the Operator after completion of the work specified herein, verifying conformance to the requirements identified in this specification. The letter shall be prepared and executed by a Professional Land Surveyor registered in the State of New Mexico.

1.3.3 Records

The Contractor shall submit to the Operator for information, all field notes from surveying and layout activities.

1.4 QUALITY ASSURANCE

The Contractor shall be responsible for protecting and maintaining all horizontal and vertical control points during construction.

1.4.1 Accuracy

Optical survey, tape measurement, and electronic measurement shall have a minimum accuracy of ± 0.1 feet in horizontal locations and ± 0.01 feet in elevations, or as superseded by criteria set forth in other sections of these specifications.

1.4.2 Tolerances

The Contractor shall survey all finished layers within the tolerances specified below:

Description	**Tolerances**
Subgrade:	-0.00 to +0.25 feet
Biointrusion Barrier	-0.00 to +0.25 feet
Native Soil Layer	-0.00 to +0.25 feet
Topsoil Layer	-0.00 to +0.25 feet

The Contractor shall ensure that no low points capable of retaining water are present in the final cover surface. If any low points are identified, the Contractor shall repair such locations.

PART 2 PRODUCTS

None.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 All surveying shall be recorded in the New Mexico State plane central zone NAD 27.

3.1.2 The Contractor shall check and verify that as-built thickness and elevations match those shown in the design drawings based on site benchmarks, and prepare as-built drawings of the cover.

3.1.3 The Contractor shall be responsible for controlling lift thickness and individual layer thickness such that overall cover thickness conforms to the specified tolerances. The Contractor shall be responsible for establishing, recording, protecting, and maintaining all permanent and temporary horizontal and vertical control benchmarks.

3.2 SURVEY MEASUREMENTS

3.2.1 Prior to commencement of construction work, the Contractor shall establish survey control at the construction area.

3.2.2 Survey control points shall be established so that any point within the construction area can be accurately re-established and elevations can be obtained to the required tolerances at any time during the course of construction. The Contractor shall verify all baselines, and horizontal and vertical control benchmarks stipulated in the information provided by the Operator.

3.3 ACCEPTANCE

3.3.1 Surveying work not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the corrective action methods to the Operator for approval before use. Acceptance criteria for corrected actions shall be in accordance with the requirements of this specification.

3.3.2 In the event of a survey discrepancy, the area in question shall be re-surveyed and verified at no cost to the Operator.

END OF SECTION

SECTION 02221

TRENCHING, BACKFILLING, AND COMPACTING

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The Contractor shall furnish all materials, labor, tools, and equipment to complete trenching, backfilling, and compacting necessary during construction activities for installing drainage swales.

1.1.2 <u>Related Work Specified Elsewhere</u>

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Earthwork shall be in accordance with Section 02200 of these specifications.

5) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

6) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 <u>Work to be performed by the Operator and/or CQA Engineer:</u>

1) Review and approve data submittals required by this specification,

2) Have the option to perform final inspection and acceptance of trenching, backfilling, and compacting.

PART 2 <u>GENERAL REQUIREMENTS</u>

2.1 The Contractor shall be responsible for trenching, backfilling, and compacting.

2.2 The Contractor shall contain trenching, backfilling, and compacting operations within the designated areas, layers, and lifts as indicated in the design drawings. If conditions encountered warrant modification to the designated limits, the Operator shall be notified prior to proceeding.

2.3 The Contractor shall perform trenching, backfilling, and compacting operations in a manner that maintains drainage and control of water at all times, in accordance with Section 01563, Temporary Diversion and Control of Water during Construction.

PART 3 DRAINAGE SWALE EXCAVATION

3.1 The Contractor shall excavate the drainage swale to the required cross-section and grade shown in the design drawings.

3.2 The Contractor shall take care to avoid excavating the drainage swale below the grade indicated except where unsuitable materials are encountered as defined by the Operator. Areas where existing grade is less than that required in the design drawings shall be backfilled to grade.

3.3 The Contractor shall ensure positive drainage of the drainage swale.

3.4 The drainage swale shall be revegetated in accordance with Section 02930.

3.5 The drainage swale shall be maintained by the Contractor until final acceptance of the work.

PART 4 INSPECTION

4.1 The Contractor shall be responsible for in-process inspection during performance of all work.

4.2 In addition to inspection by the Contractor, the CQA Engineer and/or Operator shall inspect all work for compliance with the requirements of this specification.

PART 5 ACCEPTANCE

Trenching, backfilling, and compacting not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced trenching, backfilling, and compacting shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02445

ADMINISTRATIVE CONTROL FENCES AND GATES

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment to construct administrative control fences and gates in accordance with this specification and as shown in the design drawings. Fence material shall be produced and installed by methods recognized as good commercial practices.

1.1.2 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve data submittals required by this specification;

2) Have the option to inspect work for compliance with the requirements of this specification, in addition to inspection by the Contractor;

3) Have the option to review pre-installation conditions, installation, and other job conditions during performance of the work, and;

4) Have the option to perform final inspection and confirm acceptance of administrative control fences and gates.

1.2 REFERENCE DOCUMENTS

None.

1.3 SUBMITTALS

1.3.1 Data

The Contractor shall submit the proposed administrative control fence, gate, and sign materials to the Operator for written approval prior to procurement.

1.3.2 Test Reports

None.

1.3.3 Procedures

The Contractor shall submit a description of methods for repair and/or replacement of administrative control fences and gates that are not in accordance with the requirements of this specification to the Operator for written approval before use.

1.3.4 Certifications

The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification and as shown in the design drawings.

1.3.5 Records

1) The Contractor shall submit records of inspection to the Operator after completion of the inspection. Inspection records shall include on-site inspection records of the administrative control fences and gates.

2) The Contractor shall submit to the Operator for information all field notes from surveying and layout activities after completion of these activities.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 General

1) Administrative control fences shall be strand barbed wire with tee posts driven into the ground and steel corner posts set in concrete.

2) All fence materials shall be galvanized in accordance with ASTM A123, A384, and A385.

3) All fence items shall be the product of an established fence manufacturer.

2.2.2 Barbed Wire

1) Barbed wire shall conform to ASTM A121 with a Class 1 coating.

2) Fence shall consist of 3 horizontal runs of barbed wire spaced as shown in the design drawings.

3) Barbed wire shall be No. 12-1/2 gauge, 2-strand, copper-bearing, hot-galvanized steel wire with large, four-point-pattern, hard-tempered, round barbs spaced 5 inches apart.

4) Tie wires for fastening barbed wire to steel posts shall be No. 12 gauge copper-bearing steel wire. Tie wires shall be heavily galvanized by the hot-dip process.

5) Stays shall be No. 9 gauge copper-bearing steel wire conforming to the requirements of ASTM A116. Stays shall be 42 inches long.

2.2.3 Posts

1) End and corner posts shall be nominal 2-1/2-inch diameter standard galvanized pipe per ASTM A53, Type S, Grade B, or Operator approved equivalent.

2) Tee posts shall be fabricated from rail, billet, or commercial grade steel which conforms to the requirements of ASTM A702.

2.2.4 Gates

1) All gates, hardware, and accessories for installation of the gates shall be furnished and installed by the Contractor.

2) Hinges shall be pivot-type, galvanized and industry standard size to suit gate size as shown in the design drawings. Hinges shall be non-lift-off type and offset to permit 180-degree gate opening. Each gate leaf shall be provided with 2 hinges.

3) Gates shall be galvanized high carbon-welded, 2-inch diameter, tubular steel 40 inches high, or Operator approved equal, with internal bracing. Gate fabric shall be No. 14 gauge copper-bearing open-hearth steel wire, woven in a 2-inch by 4-inch mesh, and heavily galvanized by the hot-dip process after weaving.

4) Gate posts shall be nominal 2-1/2-inch diameter standard galvanized steel pipe.

2.2.5 Bracing

All end and corner posts shall be braced by means of diagonal trusses. Trusses shall be hot-galvanized 3/8-inch steel rod complete with turnbuckles.

PART 3 EXECUTION

3.1 FOOTINGS

3.1.1 General

1) All corner and end posts shall be set and centered in a concrete encasement to the diameters and depths shown in the design drawings.

2) Concrete footings shall be neatly domed off at the finish grade line to shed water from the posts.

3) Concrete shall have a minimum 28-day strength of 3000 psi.

3.2 ERECTION OF FENCING

3.2.1 General

1) The Contractor shall assemble and erect fences and gates as specified herein and in the design drawings, and in accordance with detailed instructions furnished by the fence manufacturer.

2) Where necessary, the Contractor shall adjust the grade of the fence to fit the contour of the ground. The Operator shall be notified prior to any grading of surface soils.

3.3 ACCEPTANCE

Installation of fences and gates not in accordance with the materials and method requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired fences and gates shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02670

MONITORING WELL MW-4 EXTENSION

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all labor, tools, and equipment necessary to extend groundwater monitoring well MW-4 in accordance with this specification and as shown in the design drawings. The Operator shall provide the Contractor with the materials necessary for extension of monitoring well MW-4.

1.1.2 Related Work Specified Elsewhere

Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required by this specification,

2) Inspect and approve existing conditions prior to extension of monitoring well MW-4.

3) Perform final inspection and confirm acceptance of monitoring well MW-4 extension.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 General

The components, materials, and configuration required for monitoring well extension are shown in the design drawings.

PART 3 EXECUTION

3.1 Monitoring Well MW-4 Extension

1) The Contractor shall remove the existing MW-4 concrete pad, stanchions, protective casing, and locking top cap prior to initiation of construction activities.

2) The Contractor shall complete the well extension utilizing acceptable PVC construction techniques before or during cover construction, whichever is most convenient and practical.

3) Existing MW-4 Schedule 80 PVC well casing shall be extended such that the top of the PVC well casing is located a minimum of 2' - 6" above the final grade of the constructed cover.

4) Only hand-operated compaction equipment shall be used to compact soils around the extended well casing as each lift is placed during cover construction.

5) The concrete pad, protective casing, and locking top cap shall be refitted to its original configuration, consisting of steel cover, locking top cap, and concrete pad.

6) The final location and elevation of the top of the new PVC well casing and four corners of the concrete pad shall be surveyed. The results of the survey shall be retained for future use to prepare as-built drawings.

3.2 INSPECTION

3.2.1 The CQA Engineer and Operator shall be responsible for in-process inspection during performance of all work.

3.2.2 Monitoring well extension not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced monitoring well extension shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02930

RECLAMATION SEEDING AND MULCHING

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The Contractor shall furnish all labor, materials, tools and equipment, and shall place seed and mulch in accordance with this specification and as indicated in the design drawings. This section describes the Contractor's requirements to provide a final vegetated surface in those areas designated herein. These designated areas shall be seeded and mulched as set forth in this section.

1.1.2 <u>Work to be performed by the Operator and/or CQA Engineer:</u>

1) Review and approve submittals as required by this specification,

2) Have the option to inspect equipment, work, and materials for compliance with the requirements of this specification, in addition to inspection by the Contractor,

3) Have the option to review pre-seeding conditions and other related job conditions during performance of the work, and,

4) Have the option to perform inspection and acceptance of the final vegetated surfaces.

1.2 REFERENCE DOCUMENTS

City of Albuquerque, Specification 1012, Native Grass Seeding

Biological Assessment for the Sandia National Laboratories Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico, July 1992

Vegetation Study in Support of the Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico, SAND2004-6144.

1.3 SUBMITTALS

1.3.1 Procedures

The Contractor shall submit a Seeding and Mulching Plan to the Operator for written approval after notice to proceed. The plan shall describe the methods of placement and the equipment to be used during operations.

1.3.2 Certification

1) The Contractor shall submit the seed vendor's certified statement for the seed mixture required, stating scientific and common names, percentages by weight, and percentages by purity and germination.

2) The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification after completion of the work specified herein.

1.3.3 Records

The Contractor shall submit records of inspection to the Operator after completion of the inspection.

PART 2 PRODUCTS

2.1 GENERAL

Seed, fertilizer, mulch, and equipment shall be inspected upon arrival at the job site by the Operator and/or CQA Engineer for the conformity to type and quality in accordance with these requirements. Unacceptable materials shall be removed from the job site by the Contractor.

2.2 EQUIPMENT AND MATERIAL REQUIREMENTS

2.2.1 Seed Mix for Cover and Reclaimed Areas

Seed shall be labeled in accordance with USDA rules and regulations under the Federal Seed Act. Seed shall be furnished in sealed bags or containers clearly labeled to show the name and address of the supplier, the seed name, the lot number, net weight, origin, the percentage of weed seed content, the guaranteed percentage of purity and germination, pounds of live seed of each seed species, the total pounds of pure live seed in the container, and the date of the last germination test which shall be within a period of 6 months prior to commencement of planting operations. Seed shall be from a current or previous year's crop.

The following seed mixture shall be used:

Species	**(lb/acre pure live seed)**
Galleta grass	8.0
Black grama	6.0
Spike dropseed	3.0
Ring muhly	3.0
Total rate:	20 lb/acre

2.2.2 Fertilizer

A starter fertilizer containing nitrogen, phosphorous, potassium, and sulfur shall be used. A 20-20-0-22 shall be acceptable.

2.2.3 Mulch

The Contractor shall furnish all labor, materials, tools and equipment to place a grain straw (wheat, oats, or barley) mulch on the reclaimed areas. The straw mulch shall be applied at the rate of 2 tons/acre. The straw mulch shall be clean, free of seed, and free of noxious weeds.

2.2.4 Equipment

The Contractor shall provide appropriate types of equipment for the performance of drill seeding and mulch spreading. Seeding of the grass species shall be performed with a rangeland grass drill equipped with multiple seed bins, depth bands, and press wheels. Drills shall have agitators to prevent the seed from segregating and lodging in the seed box. The depth bands should be suitable for placing the seed at a depth that does not exceed 1/2 inch.

Mulch crimping equipment shall properly crimp the straw without cutting the straw. Discing equipment shall not be used.

2.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

2.3.1 Delivery

The Contractor shall deliver seed to the site in the original, unopened containers bearing the container labels or tags stating the producer's guaranteed statement of analysis.

2.3.2 Storage

Materials shall be stored in areas designated by the Operator. Seed shall be stored in cool, dry locations away from contaminants and in accordance with manufacturer's recommendations. Storage times shall not exceed manufacturer's recommendations.

2.3.3 Handling

Except for bulk deliveries, the Contractor shall not drop or dump materials from vehicles.

PART 3 EXECUTION

3.1 APPLICATION PROCEDURES

3.1.1 Topsoil Preparation

Prior to seeding, the Contractor shall till the top 3 inches of the surface into an even and loose seed bed, free of clods in excess of 4 inches in dimension, and bring the tilled surface to the desired line and grade. The area to be seeded shall be free of erosion rills and gullies.

3.1.2 Seeding

1) ~~The Contractor shall seed the constructed cover, laydown and stockpile areas, drainage swale, and other locations impacted by construction activities. The TA-3 borrow pits shall not be seeded.~~ Once the MWL cover has been constructed and the TA-3 borrow pits are no longer required for environmental restoration activities, they may be transferred over to Sandia Facilities for continued use at Sandia. However, if the TA-3 borrow pits are not needed by Facilities, they will be seeded and reclaimed.

2) The Contractor shall apply the seed mix uniformly to the prepared surface by means of drill seeding at not less than the minimum rate specified in Part 2.2.1 of this specification.

3) Seed shall be uniformly drilled to a maximum depth of 1/2 inch using equipment specified in Part 2.2.4 of this specification.

4) The Contractor shall seed in a pattern perpendicular to the slope, working from the top of the slope down and using row markers to indicate seeded areas.

5) The Contractor shall seed the grass mixture in either the spring or fall. Spring seeding shall be performed after the chances of freezing temperatures have passed. Fall seeding shall be performed before the ground is frozen and covered with snow and after the time temperatures would cause germination.

6) The stand of grass resulting from the seeding shall not be considered satisfactory until accepted by the Operator. The Contractor shall provide a one-year warranty to assure the stand of grass from the seeding. If areas are

determined to be unacceptable, the unacceptable areas shall be reseeded in accordance with these specifications.

3.1.3 Fertilizer

Fertilizer shall be placed at a spreading volume of 10 lb/acre unless otherwise specified by the Operator.

3.1.4 Mulch

Mulch shall be straw spread uniformly at a rate of 2 tons/acre immediately following seeding. Mulch shall be anchored into the soil to a depth of at least 2 inches with no more than one pass of the crimping equipment. The crimping operation shall proceed perpendicular to the slope so as not to encourage the formation of rivulets down slope. Mulching shall not be performed when wind interferes with placement.

3.2 MAINTENANCE

3.2.1 General

1) Maintenance of the constructed cover, laydown and borrow areas, drainage swale, and other locations impacted by construction activities during seeding shall be provided by the Contractor.

2) Areas damaged by the Contractor during seeding shall be repaired and reseeded by the Contractor at the Contractor's expense.

3.3 ACCEPTANCE

Seeding and mulching not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced seeding or mulching shall be in accordance with the requirements of this specification.

END OF SECTION

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APPENDIX B
Construction Quality Assurance Plan

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
CQA	construction quality assurance
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
MWL	Mixed Waste Landfill
NMED	New Mexico Environment Department
QC	quality control
Sandia	Sandia Corporation
SCA	Soils Contamination Area
SCR	Sandia Construction Representative
SNL	Sandia National Laboratories/New Mexico

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1.0 INTRODUCTION

A construction quality assurance (CQA) Plan is essential for determining, with a reasonable degree of certainty, whether a completed final cover meets or exceeds all design criteria, plans, and specifications. This document presents the various controls established by the CQA Plan for construction of the Mixed Waste Landfill (MWL) alternative cover at Sandia National Laboratories/New Mexico (SNL). It should be recognized that the management of construction quality involves using scientific and engineering principles and practices to verify that the alternative cover to be constructed meets or exceeds design criteria, plans, and specifications. This management activity begins prior to construction, continues throughout construction, and ends when the alternative cover is accepted by the New Mexico Environment Department (NMED).

1.1 Concept and Objectives of the CQA Plan

The governing purpose for the CQA Plan is to verify that the MWL alternative cover is constructed as specified in the design. To verify proper construction, the following objectives must be met:

- Guidelines and requirements in design drawings and construction specifications are followed
- Inspection and verification testing throughout construction to verify that design features are implemented as intended
- Evaluation of variances to the design and their effects upon system performance
- Complete documentation demonstrating that the design has been implemented and that performance requirements have been met.

In meeting these objectives, the following are defined as part of the CQA Plan:

- Quality-related qualifications, responsibilities, and authorities of personnel
- Controls for the procurement of services and materials
- Direction for necessary inspections and verification testing during construction so that execution of the design documents can be confirmed. Acceptance criteria for the inspections and testing are also included
- Provision for team communication throughout construction so that the work progresses as an organized, planned sequence of events which allows revision and change
- Direction for the preparation and maintenance of records so that it can be demonstrated that the construction was performed in accordance with design requirements.

An audit system will be established to provide evaluation of the implementation of the design drawings and construction specifications, the CQA program, and work areas and activities including materials and workmanship.

1.2 Basis of the CQA Plan

The following sources have been used as guidance in the preparation of the CQA Plan:

- U.S. Environmental Protection Agency (EPA), Technical Guidance Document, "Quality Assurance and Quality Control for Waste Containment Facilities," Report No. EPA/600/R-93/182, September 1993

- EPA, Design and Construction of RCRA/CERCLA Final Covers, EPA/625/4-91/025, May 1991

- New Mexico Administrative Code Title 20, Chapter 4, Part 1, Subpart V

- SNL, Mixed Waste Landfill Voluntary Corrective Measures Plan, July 2005

1.3 Presentation of the CQA Plan

The CQA Plan contains general direction for the control of construction activities, such as the definition of organizational responsibilities and authorities, CQA personnel qualifications, and specific technical information, such as execution guidance and verification tests to be performed throughout construction.

Inspection checklists have been developed for use by CQA personnel to document the inspection and verification requirements in the CQA Plan. These checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of these checklists are included in Attachment B1 of this Plan.

Whenever possible, nationally recognized test methods such as those published by the American Society for Testing and Materials (ASTM) will be utilized. In general, recognized standards will be cited only by reference and not included verbatim. If a test method is not a nationally recognized standard, the test method will be defined, including criteria for acceptability.

2.0 RESPONSIBILITY AND AUTHORITY

The principal organizations involved in construction of the SNL MWL alternative cover include:

- NMED (Lead Regulatory Agency)
- U.S. Department of Energy (DOE) (Owner/Operator)
- Sandia Corporation (Sandia) (Designer and Operator)

- CQA Contractor
- Construction Team or Contractor
- Testing Laboratory

The areas of responsibility and lines of authority are delineated in the following sections such that the lines of communication are established to effectively implement the CQA Plan. An organizational chart for the project during cover construction is shown in Figure B-1.

2.1 Review/Permitting Agency

The NMED, the lead regulatory agency, has the authority to review the MWL alternative cover design and approve construction of the cover. It is the responsibility of the NMED to review the Operator's site-specific CQA Plan for compliance with the agency's regulatory requirements, and to review all CQA documentation during and/or after construction of the cover to confirm that the CQA Plan was followed and that the cover was constructed as specified.

2.2 DOE (Owner/Operator)

The DOE and Sandia have responsibility for compliance with the regulatory requirements of the NMED in order to obtain approval of the MWL alternative cover design and assure the NMED, by the submission of CQA documentation, that the cover was constructed as specified in the approved design. The DOE also has the authority to accept or reject design drawings and construction specifications, the CQA Plan, reports and recommendations of the CQA Engineer, and the materials and workmanship of the Construction Contractor (see Table 3.1 of Construction Specification 02200).

2.3 Sandia (Designer and Operator)

Sandia's primary responsibility is to design and specify an alternative cover that fulfills the closure needs of the Owner and the regulatory requirements of the NMED. Design activities may not end until the cover is completed. Revisions to the design may be required if unexpected site conditions are encountered or changes in construction methodology occur that could adversely affect cover performance. The CQA program provides assurance that these unexpected changes or conditions will be detected, documented, and addressed during construction.

Sandia has the authority to select and dismiss the organizations responsible for the CQA and construction activities. Responsibilities and authority of Sandia include formulating and implementing the CQA Plan, periodic review of CQA documentation, modifying construction site activity, and specifying corrective measures in cases where deviation from the approved design or failure to meet design criteria, plans, and specifications is identified by CQA personnel. Sandia will have a Construction Representative (Sandia Construction Representative [SCR]) on site to coordinate and oversee all construction-related activities.

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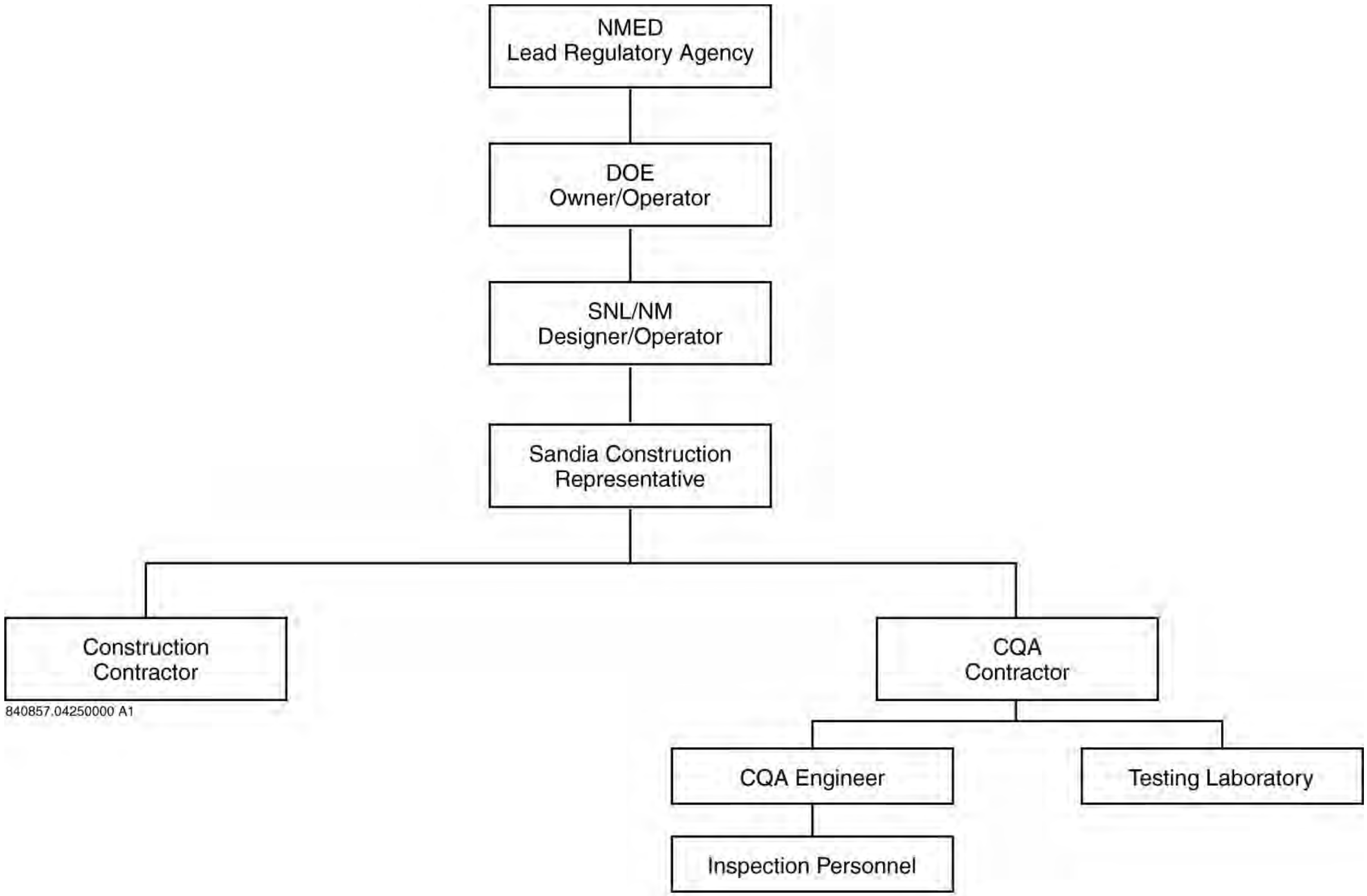

Figure B-1 Organizational Chart, SNL Mixed Waste Landfill Alternative Cover Construction

Note: The original document did not include page B-6 due to a pagination error.

2.4 Sandia Construction Representative (Owner’s Representative)

The Sandia Construction Representative (SCR) will report directly to Sandia and has the following responsibilities:

- Overall coordination of construction activities
- Oversee implementation of the CQA Plan
- Notify the CQA Contractor, and the Construction Contractor of any nonconformances observed
- Approve changes and notify other personnel, as appropriate, of the changes
- Ensure that inspections and verification tests performed by the CQA Contractor are conducted at required intervals and in accordance with the CQA Plan
- Review as-built drawings, results of inspections, and field and laboratory data from verification testing
- Stop work if conditions adverse to quality are persistent, and ensure that conditions are corrected before proceeding
- Maintain construction documents and records after transfer from the CQA Contractor.

2.5 Construction Team or Contractor

It is the responsibility of the Construction Team or Contractor, hereinafter referred to as the "Contractor," to construct the MWL alternative cover in strict accordance with the design criteria and drawings, construction specifications, and CQA Plan using the necessary construction procedures and techniques.

2.6 CQA Contractor

The overall responsibility of the CQA Contractor is to perform those activities specified in the CQA Plan (e.g., inspection, sampling, and documentation). At a minimum, the CQA Contractor will include a CQA Engineer and the necessary supporting CQA inspection personnel. Specific responsibilities and authority of the CQA Contractor's personnel are defined clearly below and in the associated contractual agreements with the Owner.

2.6.1 CQA Engineer

Specific responsibilities of the CQA Engineer include, but are not limited to, the following:

- Review of design criteria and drawings, and construction specifications for clarity and completeness so that the CQA Plan can be implemented

- Educate CQA inspection personnel on CQA requirements and procedures

- Schedule and coordinate CQA inspection activities

- Direct and support the CQA Inspectors in performing observations and tests by:

— Confirming that regular calibration of testing equipment is properly conducted and recorded

— Confirming that the testing equipment (e.g., nuclear density gauge), personnel, and procedures do not change over time or making sure that changes do not adversely impact the inspection process

— Confirming that the test data are accurately recorded and maintained (this may involve selecting reported results and backtracking them to the original observation and test data sheets)

— Verifying that the raw data are properly recorded, validated, reduced, summarized, and interpreted

— Ensuring that construction CQA testing is conducted at the proper frequency.

- Maintain CQA-related documents, including but not limited to the CQA Plan, field notes, meeting notes, test results, and miscellaneous reports

- Provide the SCR with recommendations and reports on the inspection results including:

— Review and interpretation of data sheets, as-built drawings, and reports

— Identification of work that will be accepted, rejected, or uncovered for observation, or that may require special testing, inspection, or approval

— Verification that corrective measures are implemented.

- Report nonconformances to the SCR

- Report to the SCR activities that are adverse to overall quality

- Document nonconformances

- Work with the SCR and the Construction Contractor to resolve problems prior to and during cover construction phases.

2.6.2 CQA Inspection Personnel

The CQA Inspectors will provide day-to-day inspections and field verification tests. Their role is critical to successful demonstration of construction procedures and required documentation. Their major responsibilities include:

- Performing independent on-site inspection of the work in progress to assess compliance with cover design criteria and drawings, and construction specifications

- Inspect delivery tickets and manufacturers quality control (QC) reports to verify that materials meet construction specifications

- Verifying that the equipment used in testing meets the test requirements and that the tests are conducted in accordance with standardized procedures defined by the CQA Plan

- Collecting samples in the field for subsequent verification testing by off-site laboratories. CQA testing will be conducted at a frequency of at least 5% of that done by the Construction Contractor

- Reporting to the CQA Engineer results of all inspections including work that is not of acceptable quality or that fails to meet the specified design criteria

- Reporting of nonconformances, as appropriate, to the construction foremen, superintendents, or manager if correction can be made during the normal course of work

- Reporting of nonconformances to the CQA Engineer if correction cannot be readily achieved to the satisfaction of the CQA Inspector, so that resolution can be accomplished by the CQA Engineer

- Reporting to the CQA Engineer any activities which are adverse to overall quality and any nonconformances which are recurring

- Documenting nonconformances

- Reporting to the CQA Engineer any changes in the design drawings and/or construction specifications

- Documenting inspection and verification testing activities through the completion of specified forms and daily logs.

2.6.3 CQA Certifying Engineer

The CQA Certifying Engineer is responsible for certifying to the Owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications, and certifying the CQA document has been approved by the NMED. The certification statement is normally accompanied by a final CQA report that contains all the appropriate documentation, including daily observation reports, sampling locations, test results,

drawings of record or sketches, and other relevant data. The CQA Certifying Engineer may be the CQA Engineer or someone else in the CQA Engineer's organization that is a registered professional engineer with experience and competency in certifying like installations.

2.7 Testing Laboratory

The testing laboratory will have its own internal QC plan to verify that the laboratory procedures conform to the appropriate ASTM standards or other applicable testing standards. The testing laboratory is responsible for ensuring that tests are performed in accordance with applicable methods and standards, internal QC procedures are followed, sample chain-of-custody records are maintained, and data are effectively and accurately reported. The testing laboratory must be willing to allow the Operator, CQA Engineer, or the NMED to observe the sample preparation, testing procedures, or record-keeping procedures, if they so desire. The Operator, CQA Engineer, or the NMED may request that they be allowed to observe some or all tests on a particular job at any time, either announced or unannounced. The testing laboratory personnel must be willing to accommodate such a request, but the observer will not interfere with the testing or slow the testing process.

3.0 PERSONNEL QUALIFICATIONS

The key individuals involved in CQA and their minimum recommended qualifications are listed in Table B-1.

Table B-1
Recommended Personnel Qualifications

Individual	Minimum Recommended Qualifications
Sandia Construction Representative	The specific individual designated by the Owner with knowledge of the project, its plans, specifications, and Quality Assurance/Quality Control documents.
CQA Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer.
CQA Inspectors	Employed by an organization that operates separately from the Construction Contractor and the Owner/Operator; experienced in performing the appropriate field tests and making observations during construction activities.
CQA Certifying Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer in the State of New Mexico.

4.0 PROJECT COMMUNICATIONS

Communication between CQA program participants is crucial. Required reporting to program participants is necessary so that activities can be reviewed and work can proceed. Communications in the form of construction documents, inspection reports, audit reports, verification test results, and daily logs must be timely so that reviews and evaluations can take place.

Throughout this Plan, required report preparation and the individuals responsible for distribution, review, and approval are cited.

4.1 Meetings

Meetings will be held throughout the course of construction. Following are discussions of three specific meeting formats.

4.1.1 Preconstruction Meeting

Prior to the start of construction of the MWL alternative cover, a Preconstruction Meeting will be held to review and acquaint personnel with the requirements of the CQA Program, design drawings, and construction specifications. The Preconstruction Meeting will include a tour of the MWL, borrow areas, and access routes. The meeting will be led by the SCR and the CQA Engineer. Attendance at the meeting is required of all key personnel involved in the project. Meeting notes will be prepared by the CQA personnel and will be maintained in the on-site records system. If any subcontractors arrive on site after construction begins and the preconstruction meeting has been held, the SCR and CQA Engineer will meet with those subcontractors to review appropriate activities of their work. These meetings will be documented as well.

The preconstruction meeting should present the following:

- Organization
- Schedule
- Review requirements of the design drawings and construction specifications
- MWL Health & Safety Plan
- Review requirements of the CQA Program including:
    - Responsibilities and authority of specific personnel such as the CQA Inspectors and the SCR
    - Inspection and verification testing methods, frequencies, and acceptance criteria

- A review of required documentation and operation of the on-site records system

- A discussion of potential nonconformances, the resolution of any such nonconformances, and the responsibility of all personnel to bring nonconformances to the CQA Engineer

- A discussion of the procedure for changes to design drawings and construction specifications and the means for review and approval.

4.1.2 Progress Meetings

Progress meetings will be held at the request of the SCR and should include, as appropriate, members of the Construction Contractor personnel, and the CQA personnel. Progress meetings will be documented in the form of meeting notes prepared by the CQA personnel. These notes will be maintained in the on-site construction and/or CQA records system.

The purpose of the progress meeting is to:

- Review activities and accomplishments
- Review the work location and activities
- Identify the Construction Contractor's personnel and equipment assignments
- Discuss any potential construction problems.

4.1.3 Quality Resolution Meetings

Special meetings may be called by Owner, the Operator, the SCR, or the CQA Engineer to discuss activities adverse to construction quality and to define resolution. It is intended that these meetings be called to discuss quality problems that cannot be readily resolved, or those that continue to be ongoing or recurring.

The purpose of this meeting is to:

- Define and discuss the quality-related problems
- Review appropriate solutions
- Implement a plan to resolve any quality-related problems that have been defined.

Resolution of quality-related problems will be approved by the Operator and/or the SCR, as appropriate. A member of the CQA personnel will prepare meeting notes.

5.0 ALTERNATIVE COVER—OBSERVATIONS, INSPECTION ACTIVITIES, AND TESTS

The alternative cover design for the MWL includes up to 40 inches of compacted subgrade; a 1.0-foot biointrusion barrier; 2.5 feet of compacted native soil fill; and a maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel. The final cover will be seeded with native grasses, mulched and crimped. The layers of the cover in descending order are as follows:

- A maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel
- 2.5 feet of compacted native soil
- A 1.0-foot, compacted biointrusion barrier containing 1.0-in. to 6.0-in. crushed rock
- Up to 40 inches of compacted subgrade.

5.1 Earthwork

This section specifies the observations, inspections and tests necessary to control, verify, and document that the earthwork for the MWL alternative cover conforms to the design drawings and construction specifications.

Earthwork activities include:

- Clearing, grubbing, and compaction of existing MWL surface and perimeter
- Placement and compaction of subgrade fill
- Placement and compaction of biointrusion barrier
- Placement and compaction of native soil layer fill
- Placement and minimal compaction of topsoil layer.

In order to verify proper CQA, inspection checklists have been developed for use by CQA personnel. The checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer to ensure that construction of the cover was according to design drawings and construction specifications. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of the inspection checklists for each phase of cover construction are included in Attachment B1 of this Plan. Attachment B1 inspection sheets may be modified as needed to enhance CQA.

5.1.1 Existing Landfill Surface

The alternative cover will extend beyond the MWL fenced perimeter as shown in the design drawing plates. Appropriately, the existing surface and perimeter of the MWL will be cleared, grubbed, and compacted to provide a stable surface for the final cover and side slopes.

5.1.1.1 Observations and Inspections

CQA personnel will perform the following observations and inspections during the preparation of the MWL surface and perimeter:

- Ensure that the MWL surface and perimeter has been cleared of all vegetation, organic matter, rubble, trash, and deleterious material. Rocks larger than 2 inches in dimension will be removed

- Ensure that any loose or soft zones have been appropriately compacted.

- Observe coverage and number of passes by compaction equipment.

5.1.1.2 Laboratory Tests

The Operator will provide archived laboratory data for use in preparation of the existing MWL surface and perimeter. The MWL is designated as a Soils Contamination Area (SCA). Soil samples from the existing landfill surface shall not be taken off-site.

5.1.1.3 Field Tests

In addition to performing the required observations and inspections, CQA personnel will perform the following field tests as required by the earthwork specifications:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor (see Table 3.1 of Construction Specification 02200). Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.2 Subgrade Fill

Subgrade fill will be obtained from the TA-3 borrow pits. Subgrade fill will bring the entire landfill surface to a central crown and a uniform 2% grade. Subgrade fill will be placed in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing). The subgrade will tie to the existing landscape to achieve a stable and functional slope.

5.1.2.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction of the subgrade:

- Inspect the fill to be used for construction of the subgrade. Fill will be obtained from the TA-3 borrow pits. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in dimension will be removed from subgrade fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect individual and final lift thickness

- Verify lines and grades of the completed subgrade.

5.1.2.2 Laboratory Tests

Laboratory tests of subgrade fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D698 for each 500 cubic yards of fill, or more often if there is a change of material

- Gradation as determined by ASTM C136 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

5.1.2.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the subgrade fill will be performed. Fill placed at densities and/or moisture contents not conforming to the construction specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.3 Biointrusion Barrier

A biointrusion barrier composed of 1.0-in. to 6.0-in. and D_{50} = 4 in. crushed rock will be placed between the subgrade fill and the native soil layer. The crushed rock will be placed in a 1-ft minimum, 1.25-ft maximum thickness layer. The crushed rock shall be compacted using heavy equipment. Compaction shall consist of repeated passes over all areas where crushed rock has been placed until the crushed rock fragments are firmly locked in place.

5.1.3.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the crushed rock to be used for construction of the biointrusion barrier. Crushed rock will be obtained from the stockpile south of the MWL. Visual inspections of crushed rock will be made by CQA personnel to verify that the material conforms to the construction specification and to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction.

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect final lift thickness

- Verify lines and grades of the completed biointrusion barrier.

5.1.3.2 Laboratory Tests

No laboratory tests of the biointrusion barrier will be performed.

5.1.3.3 Field Tests

No field tests of the biointrusion barrier will be performed.

5.1.4 Native Soil Layer

A 30-inch layer of native fill will be placed and compacted between the biointrusion barrier and the topsoil layer. Native fill will be placed in successive 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of the maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

5.1.4.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the fill to be used for construction of the native soil layer. Fill will be obtained from TA-3 borrow pits. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in dimension shall be removed from native soil layer fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect individual and final lift thickness

- Verify lines and grades of the completed native soil layer.

5.1.4.2 Laboratory Tests

Laboratory tests of the compacted native soil fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D698 for each 500 cubic yards of fill, or more often if there is a change of material

- Gradation as determined by ASTM C136 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

- Hydraulic conductivity testing on each sample as determined by ASTM rigid wall methods (one per acre per lift), or when CQA personnel notice a change in material.

5.1.4.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the compacted native soil fill will be performed. Fill placed at densities and/or moisture contents not conforming to the constructions specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.5 Topsoil Layer

A minimum 8-inch topsoil layer containing 25% by volume 3/8-inch crushed gravel will be placed on top of the native soil layer. Topsoil will be minimally compacted to provide a uniform, prepared surface for seeding and to facilitate root development.

5.1.5.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the topsoil to be used for construction of the topsoil layer. Topsoil will be obtained from the TA-3 borrow pits. Visual inspections of topsoil will be made by CQA personnel to detect the presence of rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. Organic matter is desirable in the topsoil and, therefore, only gross organic matter, such as Russian thistle will be removed.

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Verify topsoil is free of rocks greater than 2 inches in dimension

- Inspect final thickness

- Verify lines and grades of the completed topsoil layer.

- Verify gravel size and volume admixture with topsoil

5.1.5.2 Laboratory Tests

Laboratory tests of the topsoil layer will be performed to document the engineering properties and to verify the acceptability of the topsoil for use in construction.

The laboratory tests will include the following:

- Gradation as determined by ASTM C136 (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 (one per 500 cubic yards), or when CQA personnel notice a change in material.

5.1.5.3 Field Tests

No field tests of the topsoil layer will be performed.

5.1.6 Reclamation Seeding and Mulching

The topsoil layer will be seeded with native grasses in accordance with the construction specifications.

5.1.6.1 Acceptance of Seed

Following the delivery of the seed mix, the CQA Engineer will inspect the delivery ticket to verify that the quantity and type of seed supplied by the manufacturer is consistent with construction specifications.

5.1.6.2 Storage and Handling

CQA personnel will verify that the seed will be stored in a cool area, free of moisture and standing water.

5.1.6.3 Observations and Inspections

CQA personnel will perform the following observations and inspections during seeding of the topsoil layer:

- Inspect the seed to ensure that it has been stored appropriately and has not rotted

- Verify that seeding takes place during favorable weather conditions (i.e., low winds)

- Verify that the appropriate application method is used
- Observe and verify that the application rate of soil additives and seed are in accordance with the construction specifications
- Survey lines and grades of the final cover
- Verify mulching and crimping.

6.0 MONITORING WELL MW-4 EXTENSION

Groundwater monitoring well MW-4 will be extended such that the top of the PVC casing is located a minimum of 30 inches above the final grade of the completed cover. MW-4 will be refitted to its original configuration, consisting of steel protective cover, locking top cap, and concrete pad. Protective stanchions will not be required.

6.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Ensure that the existing concrete pad, protective steel stanchions, protective steel well casing cover and locking top cap are removed prior to cover construction
- Observe extension of the existing MW-4 PVC well casing. The well casing will be extended before or during cover construction
- Ensure that only hand-operated compaction equipment is used to recompact fill around the extended well casing as each lift is placed during cover construction
- Observe completion of the new concrete pad, protective steel well casing cover and locking top cap to ensure that construction is performed in accordance with construction specifications
- Observe that the final location and elevation of the top of the new PVC well casing and four corners of the concrete pad are surveyed. The results of the survey will be retained for future use to prepare as-built drawings.

6.2 Laboratory Tests

No laboratory tests will be performed during the extension and reconstruction of monitoring well MW-4.

6.3 Field Tests

No field tests will be performed during the extension and reconstruction of monitoring well MW-4.

7.0 NONCONFORMANCE

7.1 Laboratory and Field Nonconformances

Nonconforming items and activities are those that do not meet the design drawings, construction specifications, procurement document criteria, approved work procedures, or the CQA program.

Nonconformances may be detected and identified by any site workers including:

- CQA personnel—during construction operations by observation, field inspections, and/or verification testing
- Laboratory personnel—during the preparation for and performance of laboratory testing and/or during calibration of equipment
- SCR—during the performance of audits, surveillances, and/or other CQA-related activities
- Construction Contractor—during construction operations by field inspections.

Each nonconformance affecting quality will be documented by the personnel identifying or originating nonconformance. For this purpose, the results of calibration and laboratory analysis quality control tests, audit reports, inspection reports, or an internal memorandum or letter can be used as appropriate. This documentation will be compiled by the CQA Engineer and documented in a Nonconformance and Corrective Action Report and submitted to the SCR.

This report will, when necessary, include:

- Description of nonconformance
- Identification of individual(s) identifying or originating the nonconformance
- Method(s) for completing corrective action and corrective action taken
- Schedule for completing corrective action and corrective action taken
- Responsible individuals for correcting the nonconformance and verifying satisfactory resolution.

Documentation will be available to the Owner, SCR, Construction Contractor, CQA Contractor, and/or subcontractor(s), as necessary. It is the responsibility of everyone working at the project

site to inform CQA personnel of potential nonconformances. The CQA personnel will discuss the potential nonconformance and, if necessary, stop work to address the potential nonconformance. In addition, the SCR will be notified by the CQA Engineer as soon as possible of all nonconformances that could impact the results of the work. Corrective action, if warranted, will be determined and implemented.

CQA personnel, as part of future activities, should verify completion of corrective actions for nonconformances.

Any recurring nonconformance should be evaluated by the SCR, CQA Contractor, and/or testing laboratory to determine its cause and the appropriate changes instituted to prevent future recurrence. When such an evaluation is performed, the results will be documented.

8.0 DOCUMENTATION

Compliance with the requirements of the construction specifications for the MWL alternative cover will be documented throughout all phases of construction. Documentation will consist of records prepared by CQA personnel, the independent testing laboratory, the Construction Contractor, and any subcontractors.

8.1 Daily Summary Report

Whenever there is any construction activity, a Daily Summary Report will be prepared. Other records required will depend on the specific work being performed that day.

The Daily Summary Report will be prepared by the CQA Inspector and reviewed by the CQA Engineer. It will contain the following:

- The date
- A summary of the weather conditions
- A summary of locations where construction is occurring
- A list of personnel on the project
- A summary of any meetings held and attendees
- A description of all materials used and references or results of testing and documentation
- The certificates for calibration and recalibration of test equipment
- The inspection checklists.

8.2 Inspection Checklists

Inspection checklists (Attachment B1) will be reviewed by the CQA Engineer, and submitted to the SCR. The purpose of the checklists is to document all inspections performed by CQA personnel during construction activities.

At a minimum, each inspection checklist will contain the following information:

- The date and time of inspection
- The location
- Weather conditions
- The type of inspection
- The procedure used (e.g., ASTM method)
- Test data
- The results of the activity
- Personnel involved in the inspection and sampling activities
- The signature of the inspector.

8.3 Nonconformance and Corrective Action Reports

Whenever any material or workmanship does not meet the requirements of the construction specifications or has an obvious defect, the appropriate personnel will be notified and a Nonconformance and Corrective Action Report will be completed by the CQA Engineer. Additional information on nonconformance, corrective action, and the documentation thereof is presented in Section 8.0 of this Plan.

8.4 Field and Laboratory Test Reporting

Reports of all field and laboratory tests will be submitted to the CQA Engineer and SCR.

8.4.1 Field Test Data

The soil testing technicians will submit reports of all field tests and retests to the CQA Engineer and SCR as soon as possible upon completion of the required tests.

The reports may include, but are not limited to, the following:

- Date of the test and date submitted

- Location of test
- Weather
- Test method (ASTM or approved)
- Wet weight, moisture content, and dry weight of field sample (if required)
- Description of soil
- Ratio of field dry density to maximum lab dry density expressed as a percent (if required)
- Comments concerning the field density passing or failing the specified compaction
- Comments about results.

CQA Inspectors will record field test data on the appropriate inspection checklists or approved forms.

8.4.2 Laboratory Test Data

The independent testing laboratory will submit data reports of all laboratory tests to the CQA Engineer as soon as possible upon completion of the tests. The reports will include, but not be limited to, the following:

- Date of the test and date submitted
- Identification and description of sample tested
- Test method (ASTM or approved)
- Results of test.

8.5 Photographic Reporting

Any photographs used to document the progress and acceptability of cover construction may be incorporated into the daily summary report and the acceptance report.

Each photo will be identified individually as well as in a photograph log that contains the following information:

- The date, time, location, and direction of the photograph
- The name of the photographer
- Brief description of the activity photographed.

8.6 As-Built Drawings

Final as-built drawings will be prepared by the CQA Contractor and will be retained by the Owner as a permanent record of the final configuration and dimensions of the cover features (e.g., subgrade, biointrusion barrier, and final cover). As-built drawings must be reviewed and approved by the CQA Engineer and the SCR.

8.7 Final Documentation

When construction of the MWL alternative cover has been completed and the final inspection/punch list shows that all items have been resolved, a final report will be prepared for submittal to the Operator.

The Construction Quality Assurance Report will include all quality control data generated by the construction contractor as well as quality assurance data generated by the CQA contractor. The Construction Quality Assurance Report will be submitted to the NMED as part of the CMI Report.

The final report will be certified as correct by the CQA Engineer and will contain the following:

- Daily summary reports
- Inspection checklists
- Nonconformance and corrective action reports
- Field test results
- Laboratory test results
- Photographs and photograph logbook
- As-built drawings
- Internal CQA memoranda or reports with data interpretation or analyses
- Design changes.

8.8 Document Control and Storage of Records

During construction of the MWL alternative cover, the CQA Engineer will be responsible for storage of all CQA documents. All records prepared by the CQA Contractor will remain on-site during the project to provide documentation of the cover construction. The CQA documents will include:

- Design drawings
- Construction specifications
- CQA Plan
- Inspection checklists
- Field test data reports
- Laboratory test data reports
- Nonconformance and corrective action reports

- Meeting notes
- Daily summary reports.

Duplicate copies will be kept at another location as a safeguard in case the originals are damaged or lost. Once construction is complete, the originals will be transferred to the SCR.

ATTACHMENT B1
Inspection Checklists

The inspection checklists contained in this attachment are provided for use by CQA personnel during construction of the MWL alternative cover. The format of the inspection checklists may be modified by the CQA Engineer; however, the revised inspection checklist must include all checks and information contained in the original form and meet the approval of the Operator. The inspection checklists will be completed and signed by CQA Inspectors and reviewed by the CQA Engineer. These checklists will become part of the final cover construction report documenting the CQA process throughout construction.

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LIST OF FORMS

Title **Form No.**

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RI-01
RECEIVING INSPECTION FORM
SEED/FERTILIZER/MULCH

Project Name ________________________________

Material Name ________________________________
Transporter/Supplier ____________________________
Number of Bags/Bales ___________________________

Date ______________ Time___________
Received by ______________________
Inspected by ______________________
Delivery Shipment No. ______________
Storage Location __________________

	SPECIFICATION	MATERIAL RECEIVED	NOTE NO.
Supplier	________	________	________
Supplier designation	________	________	________
Material	________	________	________

(Provide explanatory notes if the answers to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Checks before unloading:		
Have delivery tickets and QC certificates been provided for seed/fertilizer/mulch received?	_______	_________
Does the material description match the construction specifications?	_______	_________
Is the material free of damage?	_______	_________
Is the material acceptable for use?	_______	_________
Checks after unloading:		
Is the material free of damage?	_______	_________
Is the material properly stored?	_______	_________
Is the storage area free of water and/or moisture?	_______	_________

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TI-01
TESTING INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER FIELD TEST FORM

Project Name ________________________________ Date ______________ Time______________

Inspected by ________________________________ Weather ______________________________

Compaction Equipment ____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is “no.” Include any remedial steps required.)

	YES/NO	NOTE NO.
Has soil been moistened to approximate optimum moisture content?	_______	________
Has surface been compacted/proof-rolled utilizing 10 passes of a roller?	_______	________
Have depressions been filled with moistened, clean fill, and recompacted with 10 passes of a roller?	_______	________
Did roller have a minimum ballasted weight of 25 tons?	_______	________
Did roller have a minimum pneumatic tire pressure of 90 psi?	_______	________
Was any proof rolling conducted within a 2-ft radius of any groundwater monitoring well?	_______	________

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TI-02
TESTING INSPECTION FORM
SUBGRADE FILL FIELD TEST FORM

Project Name ________________________________ Date ________________ Time____________

Lift Number __________________________________ Inspected by ___________________________

Borrow Area _________________________________ Weather _______________________________

Compaction Equipment ____

Soil Description ____
____
____

Volume and location of soil placed during shift ____
____
____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed at the frequency required?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the in situ density and moisture content tests been performed in accordance with ASTM D2922 and ASTM D3017, and recorded on Form TI-07 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________

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TI-03
TESTING INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD TEST FORM

Project Name ________________________________ Date _______________ Time______________

Lift Number ________________________________ Inspected by ___________________________

Borrow Area ________________________________ Weather _______________________________

Compaction Equipment ____

Soil Description ____
____
____

Volume and location of soil placed during shift _______________________________________
____
____

Surface area and location covered during shift _______________________________________
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed at the frequency required?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the in situ density and moisture content tests been performed in accordance with ASTM D2922 and ASTM D3017, and recorded on Form TI-07 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________
Have the laboratory hydraulic conductivity tests been performed at the specified frequency and the locations plotted?	_______	_________

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TI-04
TESTING INSPECTION FORM
SUBGRADE FILL LABORATORY TEST VERIFICATION FORM

Project Name __________________________________ Date _______________ Time______________

Inspected by ____________________________

Weather ________________________________

(Provide explanatory notes if the answer to any of the following questions is “no.” Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

NOTES:

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TI-05
TESTING INSPECTION FORM
NATIVE SOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ________________________________ Date _______________ Time____________

Inspected by __________________________

Weather ______________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Has hydraulic conductivity testing been performed in accordance with ASTM rigid wall testing procedures?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

NOTES:

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TI-06
TESTING INSPECTION FORM
TOPSOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ______________________________ Date ______________ Time____________

Inspected by ________________________

Weather ____________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

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TI-07
TESTING INSPECTION FORM
MOISTURE/DENSITY FIELD TEST RESULTS FORM

LOCATION SKETCH

Project Name:
Stockpile Area:
Borrow Area:
Type of Construction:
(landfill surface and perimeter, subgrade, native soil layer, topsoil layer)
Maximum Dry Density (pcf):
Optimum Moisture:
Date:
Time:
Weather:

Test Number	Approximate Location			In Situ Dry Density (pcf)	Percent Compaction	In Situ Water Content (WC %)	Percent Water Content Variation	Soil Description
	North	East	Elevation					

NOTES:

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CI-01
CONSTRUCTION INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER CLEAR AND GRUB FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date ______________ Time___________

Weather ____ Inspected by ______________________

Compaction Equipment ____

Surface area and location covered during shift ____

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have all shrubs, grass, roots, and other vegetation been completely cleared and grubbed from the landfill surface and perimeter?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that all loose or soft zones have been properly compacted?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-02
CONSTRUCTION INSPECTION FORM
SUBGRADE FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ________________________________ Date ____________ Time__________

Inspected by ____________________

Borrow Area ________________________________ Max Dry Density (pcf) ______________

Weather ________________________________ Optimum Moisture (%) ____________

Compaction Equipment ____

Fill Description

____

____

____

Volume and location of soil placed during shift ______________________________

____

____

Surface area and location covered during shift ______________________________

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has all organic matter, rubble, trash, and deleterious material been removed from subgrade fill prior to use?	_______	_________
Has the prepared subgrade been surveyed for final grades to verify that it conforms to the construction drawings?	_______	_________
Have TA-3 borrow soils been determined to be suitable for subgrade fill?	_______	_________
Has approved fill been used during subgrade construction?	_______	_________
Has the subgrade been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-03
CONSTRUCTION INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date ______________ Time___________
Lift Number ____ Inspected by ______________________
Borrow Area ____ Max Dry Density (pcf) _______________
Weather ____ Optimum Moisture (%) ______________

Compaction Equipment ____

Fill Description
____
____
____

Volume and location of soil placed during shift ____
____
____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is “no.” Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grades to verify that it conforms to the construction specifications?	_______	_________
Have TA-3 borrow soils been determined to be suitable for native soil lifts?	_______	_________
Has approved fill been used during lift construction?	_______	_________
Has the lift been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-04
CONSTRUCTION INSPECTION FORM
TOPSOIL LAYER FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date _____________ Time__________

Inspected by ______________________

Borrow Area ____

Weather ____

Topsoil Description

____

____

____

Volume and location of topsoil placed during shift ____

____

____

Surface area and location covered during shift ____

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grade to verify that it conforms to the construction specifications?	_______	_________
Has the topsoil been admixed with 25% by volume 3/8-inch crushed gravel?	_______	_________
Has approved topsoil been used for topsoil layer?	_______	_________
Has the topsoil layer been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________

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CI-05
CONSTRUCTION INSPECTION FORM
RECLAMATION SEEDING AND MULCHING FIELD FORM
(Complete One Form Per Shift When This Work Is Being Done)

Project Name ____ Date _____________ Time__________

Weather ____ Inspected by ______________________

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the cover surface been surveyed for final grade prior to placement of seed?	_______	_________
Has approved seed been used for seeding?	_______	_________
Has the cover surface been mulched and crimped after seeding?	_______	_________
Did seeding take place during favorable weather conditions?	_______	_________
Did application rate of seed mix meet the construction specifications?	_______	_________

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APPENDIX C
Qualifications of Persons Implementing the CMI Plan

Mary Creech

Qualifications

Ms. Creech has seven years experience, six of which have been in the environmental field. She is the assistant task leader for Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration Chemical Waste Landfill (CWL), Solid Waste Management Unit (SWMU) 91 (Lead Firing Site), and SWMU 68 (Old Burn Site) projects. She provides regulatory reporting, strategic planning, and waste management coordination services.

At the CWL, Ms. Creech is responsible for managing and documenting the effort to close the associated site operational boundary. She is also responsible for regulatory compliance and documenting removal of waste from the CWL, including writing the final waste management report and detailing the removed waste its final disposition. She heads efforts to prepare the final Toxic Substance Control Act report required by the U.S. Environmental Protection Agency. She has also provided project management for waste management, site closure activities, and personnel as well as client interface for scheduling site closure, budgetary issues, project reporting, and support for contract closure. She has completed disposal packages for project-generated, chemical and bulk wastes generated from the remediation of the CWL and managed the disposition of over 200 waste parcels, including the quality control and assurance for all data.

Ms. Creech has provided strategic planning for the lead-contaminated soil removal and radiological investigation at SWMU 68. She leads in negotiating the waste management and radiological protection aspects of the project with both SNL/NM waste management facilities. She is the primary author for the radiological sampling, analysis, and waste management plan for SWMU 68 (required to comply with both the Nevada Test Site and Envirocare of Utah's waste acceptance criteria) as well as the final report and request for closure.

Ms. Creech is one of the ATLs working on the closure of SWMU 91. She is currently providing waste management coordination and peer review services for the project, which has involved the removal of 18.6 tons elemental lead from an inactive firing range. She provided waste management planning and oversight services as well as strategic planning support for the field implementation aspect of the project.

Training/Education

B.S., Biology, New Mexico Institute of Mining & Technology

Joseph E. Fritts, P.G.

Qualifications

Mr. Fritts is a senior geologist with 19 years of technical and management experience in the environmental field. His experience in hydrogeology and waste management includes investigations of soil and groundwater contamination, site characterization, site remediation, waste management, groundwater protection, and Resource Conservation and Recovery Act (RCRA) Remedial Investigation/Feasibility Studies. Mr. Fritts has Environmental Restoration (ER) experience at Sandia National Laboratories/New Mexico (SNL/NM), Los Alamos National Laboratory, and the U.S. Department of Energy (DOE) Mound Plant. Has worked on hydrogeological investigations at the Naval Air Weapons Station in China Lake, California, and at Project Shoal near Fallon, Nevada.

He has participated in all aspects of a classified landfill remediation project including managing all waste characterization, waste disposal, and waste minimization activities. He has worked to remediate environmental sites including the excavation of contaminated soil and materials, and has worked on earthen covers installed over closed landfill sites. Mr. Fritts has performed extensive fieldwork involving hydrogeologic site investigations at twenty-two mine tailings sites located throughout the western United States.

Mr. Fritts has extensive regulatory compliance experience including RCRA, National Environmental Policy Act, and Uranium Mill Tailings Remedial Action regulations. He has worked with regulators in the New Mexico Environment Department, the DOE, and the U.S. Environmental Protection Agency in order to resolve environmental issues. He has extensive experience supervising drilling programs supervising rotosonic, air rotary, mud rotary, air rotary casing hammer, ODEX, Stratex, and auger drilling methods. He also has experience drilling and installing soil vapor monitoring systems.

He currently provides technical support for various sites that are part of the ER Project at SNL/NM. He is working on a project to install an earthen cover over recently excavated and remediated chemical waste landfill. He oversaw writing and implementation of the quality assurance plan, scheduling, and daily oversees cover installation operations.

Training/Education

B.S., Geology, University of New Mexico

A.A., Humanities, Orange County Community College

Timothy J. Goering

Qualifications

Mr. Goering has more than 22 years of technical experience in the environmental field, including 18 years experience as a groundwater hydrologist working on various U.S. Department of Energy (DOE) projects, including Remedial Action and Environmental Restoration Programs. His expertise includes groundwater hydrology, vadose zone characterization, aquifer characterization, corrective measures studies, Resource Conservation and Recovery Act (RCRA) facility investigations (RFI), and Superfund investigations as well as waste management and compliance with state and federal regulations including RCRA, Comprehensive Environmental Response, Compensation, and Liability Act, National Environmental Policy Act, Uranium Mill Tailing Remedial Action, Toxic Substances Control Act, and DOE orders pertaining to radioactive, mixed, and hazardous wastes. He works with regulators in the New Mexico Environment Department (NMED), the Nuclear Regulatory Commission (NRC), and the U.S. Environmental Protection Agency to resolve issues on environmental problems and provides expert testimony for public hearings and private litigation.

Mr. Goering supports Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration Project on a variety of groundwater-related issues. His responsibilities at the Mixed Waste Landfill (MWL) include overseeing groundwater characterization and monitoring activities, including vadose zone characterization activities, and preparation of RCRA documents such the recently completed MWL Corrective Measures Study (CMS) and the Corrective Measures Implementation Plan. The CMS included evaluating technologies and potential remedial alternatives for the MWL, and developing their cost estimates. In addition, he provided expert testimony on the CMS in support of the DOE and SNL/NM in a public hearing held by the NMED in December 2004.

For the MWL, Mr. Goering assisted with development of an alternative cover, a thick layer of soil and native vegetation that uses evapotranspiration to minimize infiltration. He helped to develop and conduct the Phase 2 RFI Work Plan for the MWL, which included performing surface geophysics to delineate waste trench boundaries at the site, sampling volatile organic compounds in soil vapor and tritium in soils, designing and installing groundwater monitoring wells, conducting aquifer pump-and-recovery tests, overseeing groundwater sampling activities, and drilling angled boreholes beneath pits and trenches to assess subsurface contamination.

Training/Education

M.S., Hydrology and Water Resources, University of Arizona

B.A., Environmental Science, University of Virginia

J. Ben Martinez

Qualifications

Mr. Martinez serves as environmental scientist, engineer, and project manager specializing in construction/remediation, removal/installation of above- and underground storage tanks (ASTs and USTs) and field service activities. He has ten years of experience in project supervision/management on numerous Sandia National Laboratories/New Mexico (SNL/NM) and U.S. Department of Defense environmental construction projects. He prepares budgets and implements workplans, technical reports, final assessment reports, environmental impact statements, environmental assessments, quality assurance project plans, and health and safety plans. He is also an experienced heavy equipment operator.

Mr. Martinez has participated in numerous field operations at SNL/NM since 1997. His duties include project/site management, health and safety oversight, operation of heavy machinery, and soil, water, and radiological sampling and screening. He is currently the project/site manager of four Environmental Restoration Project sites, the TA-II Classified/Radiological Landfill Backfill Projects, the TA-III Chemical Waste Landfill Backfill Project, Solid Waste Management Unit (SWMU) 91 (Lead Firing Site), and SWMU 68 (Old Burn Site).

Mr. Martinez was contractor-oversight manager for the U.S. Postal Service (USPS) UST Removal, Replacement, and Upgrade Project, in New Mexico and Colorado. He was involved in the decommissioning and retrofitting and modifications (upgrading) of the UST systems to comply with 1998 USPS U.S. Environmental Protection Agency regulations.

Mr. Martinez investigated several SWMUs at Kirtland Air Force Base (KAFB) to characterize the nature and extent of hazardous and radioactive material releases from each unit. All sites were part of a Resource Conservation and Recovery Act facility investigation and involved sampling with direct push technology for the collection of subsurface soil samples.

As assistant project manager/field operations manager for the U.S. Army Corps of Engineers (USACE) Program at KAFB, Mr. Martinez was responsible for implementation of the work plan by subcontracted personnel performing UST removal/replacement construction activities in adherence with USACE military specifications. The scope of work required removal of 102 USTs, some of which were compromised and leaking. He sampled for contaminants in excavations, logged, and coordinated with laboratories in compliance with applicable regulatory protocols. Other technical tasks included coordination with basewide network personnel including water, sewer, gas, communication, and other associated utilities. He ensured that all Occupational Safety and Health Administration and Brown & Root safety procedures were followed. To replace some tanks that were removed, 20 ASTs and 10 vaulted below storage tanks were constructed.

Training/Education

B.S., Environmental Science, New Mexico Highlands University

Anthony R. Martinez

Qualifications

Mr. Martinez has worked in the environmental field for more than five years as a site safety officer, field technician, heavy equipment operator, and waste management specialist. He has been part of the Chemical Waste Landfill (CWL) and Corrective Action Management Unit project teams at Sandia National Laboratories/New Mexico (SNL/NM) since 2000. His experience includes the operation of heavy equipment, environmental sampling/ characterization, hazardous/mixed/solid waste management, and the development, writing, and field implementation of Health and Safety (H&S) plans and task-specific hazard analyses. He was the site safety officer for three major SNL/NM Environmental Restoration remediation/construction projects.

Mr. Martinez's responsibilities include conducting and documenting daily safety meetings, coordinating with adjacent facility safety personnel, interacting with other SNL/NM safety professionals, and tracking H&S training records. He has also been a key member of the management team for CWL Solid Waste Management Unit (SWMU) 91 (Lead Firing Site) and SWMU 68 (Old Burn Site) and is actively involved with problem solving and process improvement. He is currently the site safety officer for the CWL cover installation field project and is responsible for implementing the Integrated Safety Management System approach, which involves ensuring that all related project hazards are identified and addressed on a continual basis. The combination of his field and H&S experience has resulted in an excellent project safety record while maintaining operational efficiency.

Mr. Martinez has provided site H&S oversight on three major projects since 2004, including the CWL backfilling and final cover installation and SWMU 68 and SWMU 91 Voluntary Corrective Actions (VCAs). He was the site safety officer responsible for these VCAs, which included significant excavation of lead-contaminated soil and various debris. Because simultaneous activities were needed, careful advance planning, communication, organization, coordination, and oversight were necessary. The SWMU 91 VCA involved the excavation of approximately 18,000 cubic yards of soil and debris, from which approximately 18 tons of lead were removed for recycling using a three-stage mechanical screen plant as part of a waste/debris segregation process. Approximately 500 cubic yards of soil and solid waste were disposed of off site. SWMU 68 also involved the excavation and disposal of over 500 cubic yards of soil and solid waste, as well as the disassembly of a burn pan test structure and surrounding earthen berm. He led the effort to remove the pan structure and berm, which included scanning the soil for radiological contamination. Using an approach to minimize waste, under his direction the team safely decommissioned the burn pan and earthen berm, generating less than a cubic yard of depleted uranium and thorium soil waste.

Training/Education

Occupational Safety and Health Administration Hazardous Waste Operations and Emergency Response Supervisor Certification

Site Safety Officer Training, IT Corporation

Michael M. Mitchell

Qualifications

Mr. Mitchell has more than 16 years of technical and management experience in environmental consulting, covering all phases of project work driven by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA). His experience includes preparing major reports under RCRA, including Final Voluntary Corrective Measure, Corrective Measures Study (CMS), Final Closure, and Post-Closure Care Plans and Reports as well as a Permit Application for an interim status landfill closing under both 40CFR264 and 40CFR265 requirements.

Mr. Mitchell prepares hydrogeological investigations for RCRA and CERCLA sites, including definition of vadose zone and aquifer characteristics, groundwater flow patterns, geologic and exposure pathways, and the nature and extent of contamination in soil and groundwater. He develops health and safety plans, work plans, waste management plans, and environmental sampling procedures. He designs and implements remediation plans at U.S. Department of Defense and U.S. Department of Energy sites contaminated with hazardous and radioactive materials and manages remediation projects involving heavy equipment and excavation, waste screening and segregation, and waste management. He coordinates and supervises drilling, sampling, analytical laboratory services, heavy equipment operation, and waste management and disposal.

Mr. Mitchell is assistant task leader for the Chemical Waste Landfill (CWL) and Solid Waste Management Unit 91 (Lead Firing Site) for Sandia National Laboratories/New Mexico Environmental Restoration Project. He negotiates final resolution of CMS Report and Post-Closure Care Permitting issues with the New Mexico Environmental Department, coordinates and documents technical aspects of the CWL vegetative soil cover construction project, and oversees final closure reporting to meet RCRA and Toxic Substance Control Act requirements. He is the primary author of regulatory deliverables that set the foundation for final CWL closure.

Mr. Mitchell ensures compliance with state and federal RCRA, National Environmental Policy Act, and Occupational Safety and Health Administration requirements associated with characterization and remediation projects as well as providing public and regulatory presentations support.

Training/Education

M.S., Geology, University of Tennessee

B.A., Geology, Trinity University

Jerry L. Peace

Qualifications

Mr. Peace is a geologist, geophysicist, and civil engineer for Sandia National Laboratories/New Mexico (SNL/NM). His diverse background includes environmental, geoscience, civil engineering, applied geophysics, drilling engineering, soil physics and mechanics, geology, vadose zone hydrology, predictive modeling, groundwater monitoring, remote sensing, environmental sensors, public relations, and environmental regulations experience. He heads all activities at the Mixed Waste Landfill.

Mr. Peace is the project manager and technical leader of a multidisciplinary team of experienced, hands-on professionals who investigate the geologic, hydrologic, and engineering properties of SNL/NM cold-war-legacy waste sites. His team develops documentation, implements noninvasive and invasive technologies, reduces and interprets data, reports findings, and implements the best available remedial measures.

He is also the project manager and technical leader of environmental restoration project geophysics at SNL/NM, which includes airborne and ground magnetic and electromagnetic surveys to delineate subsurface legacy waste burials and the Rio Grande basement structure to determine regional geology, structure, and groundwater transport mechanisms.

He is also the project manager and technical leader of environmental restoration project drilling engineering at SNL/NM, which includes air/rotary casing hammer, resonant sonic, Stratex, reverse circulation drilling technologies to delineate subsurface structure, lithology, geohydrology to determine vadose zone and groundwater transport mechanisms.

Training/Education

Ph.D., Geophysical Engineering, New Mexico State University

M.S., Civil Engineering, New Mexico State University

M.S., Geophysics, University of Alaska

B.S., Geology, New Mexico State University

Donald P. Schofield

Qualifications

Mr. Schofield has worked at Sandia National Laboratories/New Mexico (SNL/NM) for more than 20 years, the last 11 of which have been with the Environmental Restoration (ER) Project. He has overseen the successful deployment of both large and small cleanup operations. He has served as field technician, assistant task leader, and task leader. He managed the ER Field Office that provided personnel and equipment to support Solid Waste Management Unit (SWMU) characterization and remediation. He has extensive experience in contract placement and oversight, as well as project management (schedule, scope, and cost). He has played key roles in the selection, procurement, and implementation of remediation technologies in the field.

From 1998 through 2002, Mr. Schofield was the Assistant Task Leader for the Chemical Waste Landfill, Landfill Excavation Voluntary Corrective Measure, which involved the complete excavation and removal of the original landfill contents. His focus on this four-year, multimillion dollar remediation project (the largest ER Project at SNL/NM) was on contract management and field problem solving. The contents of the former CWL, approximately 52,000 cubic yards of contaminated soil and waste, were removed, segregated, and characterized for final disposal. He established a multidisciplinary team of environmental professionals that backfilled the CWL in two distinct phases from 2002 to 2004. The CWL excavation met all risk-based cleanup goals. The final report was approved by the New Mexico Environment Department in December 2004.

Mr. Schofield is the Task Leader for the CWL cover installation project completed in July 2005. He also serves as the Task Leader of the SWMU 68 (Old Burn Site) and SWMU 91 (Lead Firing Site) Voluntary Corrective Action (VCA) projects that were completed in 2004 and 2005 (final reporting pending). He is responsible for project management, including field construction activities. The SWMU 91 VCA included the excavation of soil and debris, from which lead and metal were removed for recycling. Confirmatory sampling and geophysical surveys were used to demonstrate that corrective action objectives had been met. SWMU 68 was also remediated to maximize operational efficiencies using the same field personnel. The remediation at SWMU 68 included the removal of soil and solid waste for disposal, man-made structures, and radiological soil contamination. Confirmatory sampling demonstrated project goals had been met, as well as site grading, re-vegetation, and related reporting tasks. Projects were safely completed on time and within budget

He was also the assistant task leader for the treatment and disposal of soil at SNL/NM's Corrective Action Management Unit from 2002 to 2003, providing technical input and oversight for the construction of the aboveground, mounded cover. During 2003 he managed the backfilling operations for two excavated landfills at TA-II.

Training/Education

B.S., University of Minnesota, College of Forest Engineering

APPENDIX D
Health and Safety Plan

Site or Activity Name: Mixed Waste Landfill Vegetative Cover Installation

Job Site Location: Technical Area 3

Technical Task Leader: Jerry Peace, SNL/NM, 6116

Alternate: Don Schofield, SNL/NM, 6134

Site Safety Officer: To Be Determined

Alternate: Various personnel

Amendment No.: NA

( ) Amendment to Existing Approved HASP

( ) Date Existing Approved HASP

HASP prepared by:

Tim Goering, SNL/NM 6147
Assistant Task Leader

Date 7/7/05

HASP approved by:

Jerry Peace, SNL/NM 6116
Task Leader - MWL

Date 7/7/05

Michael Oborny, SNL/NM 6328
Industrial Hygienist

Date 5 Jul 2005

Dick Fate, SNL/NM 6147
Department Manager

Date 7/29/05

1.0 INTRODUCTION

1.1 Objective

This Health and Safety Plan (HASP) for the Mixed Waste Landfill addresses installation of the vegetative cover and bio-intrusion barrier at Sandia National Laboratories' Mixed Waste Landfill (MWL). The vegetative cover design and additional details for cover installation are presented in the MWL Voluntary Corrective Measures Work Plan. A detailed history of the MWL and additional background information are presented in the Mixed Waste Landfill Phase 2 RFI Report (Peace et al. September 2002).

The Mixed Waste Landfill (MWL) is located approximately 5 miles southeast of Albuquerque International Sunport and 4 miles south of Sandia National Laboratories/New Mexico (SNL/NM) Technical Area (TA)-1. The landfill occupies 2.6 acres in the north-central portion of TA-3. The MWL accepted containerized and uncontainerized low-level radioactive waste and minor amounts of mixed waste from SNL/NM research facilities and off-site generators from March 1959 to December 1988. Approximately 100,000 cubic feet of low-level radioactive waste (excluding packaging, containers, demolition and construction debris, and contaminated soil) containing 6300 curies (Ci) of activity (at the time of disposal) were disposed of at the MWL.

1.2 Project Organization

The MWL project is managed by SNL/NM Environmental Restoration (ER) Project Task Leaders (TLs). Jerry Peace is the TL responsible for the MWL Project. Don Schofield will be the primary Sandia interface with other SNL/NM Departments, such as Compliance and Generator Interface, Hazardous Waste Management, Radioactive and Mixed Waste Management, Security, and Radiation Protection Operations. Daily coordination of activities involving other SNL/NM Departments will be routinely performed by Assistant Task Leaders (ATLs) and/or task-specific SSOs, as appropriate. Mike Mitchell will be Project Manager, and Tim Goering and Joseph Fritts will be responsible for QA/QC and hydrologic testing of the cover.

1.3 Health and Safety Goals and Objectives

The goal of the Health and Safety program is to deploy the MWL vegetative cover with zero occupational injuries or illnesses for site workers. This HASP integrates the information and experience gained from 15 years of characterization, sampling activities, and waste management conducted at the MWL to anticipate and recognize potential hazards associated with the remaining MWL activities, evaluate those hazards in a systematic fashion, and describe the engineering and administrative methods that will be used to control the hazards. This approach, along with the commitment of MWL ER staff and management to continuous process improvement, is consistent with the principles of the Integrated Safety Management System (ISMS). If new information about site hazards is obtained, this HASP will be amended and the changes communicated to all affected parties as appropriate based upon the identified hazards.

2.0 Project Health and Safety Roles and Responsibilities

Section 1.3 presents the general project-level organization. The following sections provide additional information relative to the task-specific implementation of this HASP and related task work. According to SNL/NM policy, any site worker has the authority to stop work if unsafe conditions exist at the site.

2.1 ER Task Leaders (TLs)

The ER TLs have the primary responsibility for project completion and are the focal point of communication and direction between SNL/NM support organizations and contractor personnel. The TLs are responsible for all task work at the MWL, including administering contracted project activities and contractor personnel technical work. The TLs report directly to the SNL/NM ER Department 6147 Manager and work with the SNL/NM Contract Representative to administer contracts. The TLs will coordinate all interactions and activities with SNL/NM, DOE, the public, and other organizations, except those interactions or responsibilities they specifically delegate.

2.2 Assistant Task Leaders (ATLs)

The ER ATLs will assist the TLs and will interact with other contractor personnel and SNL/NM support organizations to ensure safe task completion. ATLs will typically coordinate day-to-day work the task-specific contractors are performing, under the direction of the TL(s). ATLs will be responsible for maintaining appropriate training and serve as the focal point of communication between support organizations and task-specific contractor personnel. ATLs will also coordinate with the Hazardous Waste Management Office (HWM), the Radioactive and Mixed Waste Management Facility (RMMF), and the Radiation Protection Office (RPO).

2.3 Task-Specific Contractor Personnel

The TLs will staff specific task work with appropriate, qualified contractor personnel. Task-specific contractors will be responsible for maintaining appropriate training and performing site work safely, as specified in their contracts.

2.4 Site Safety Officer (SSO)

The SSO may vary based upon the task work being performed. For each task, at least one SSO will be designated by the TL. The SSO role may be filled by a TL, ATL, or task-specific contractor. The SSO will be responsible for the following specific activities:

- Conduct and document daily tailgate safety briefings for all task-specific personnel and identify who will be responsible for carrying the two-way radio or cell phone and/or pager;
- Verify appropriate training documentation is maintained on site for each task-specific site worker;
- Review Task Hazard Analysis (THA) information with site workers, including PPE requirements;
- Coordinate health and safety issues and emergency response actions with site personnel and others, as appropriate.

- Monitor weather conditions;
- Maintain site safety field logs that include the following information: weather conditions, employees on-site, safety issues and any corrective actions implemented;
- Coordinate with SNL/NM industrial hygiene, safety, and radiation protection personnel as necessary and appropriate; and
- Enforce compliance with all requirements of this HASP and stop work if an unsafe condition is identified.

2.5 Site Visitors

All visitors most obtain permission prior to visiting the site from the SNL/ER Department Manager or the ER TL on site. Site visitors will be required to receive a task-specific site safety briefing and comply with health and safety requirements as specified by the SSO if they are present in an area of the site where work is being performed. The TL or ATL on site can then appropriately respond to the visitor and notify available on-site personnel of the visitor's purpose and request appropriate support.

3.0 Identified Work Tasks and Task Hazard Analyses

Identified work tasks and the Task Hazard Analysis (THA) process are described in this section. The THA process is the tool that will be used to evaluate and control hazards associated with identified work tasks. If new tasks are added to the MWL work scope, THAs will be prepared and reviewed with all involved site workers prior to starting the new task.

Identified work tasks at the MWL are summarized below.

Task Scope	Comments
<u>Cover Installation</u> ▪ Remove perimeter fences, and install temporary area boundary using T-posts and rope. ▪ Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. ▪ Compact landfill surface to prepare for subgrade fill. ▪ Place and compact subgrade fill (from TA-3 soil stockpiles). ▪ Place rock bio-intrusion barrier. ▪ Place and compact native soil layer fill (from TA-3 soil stockpiles). ▪ Place and minimally-compact topsoil layer.	Grubbed material will be stockpiled and used as mulch or rip-rap as needed in the design specifications. The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA, and will follow the RWP during cover construction activities. However, once the subgrade fill has been applied, the only applicable radiological control to be applied will be no intrusive work.

▪ Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix, as needed. Additional tasks to be conducted include: ▪ Soil screening ▪ Surveying ▪ Equipment decontamination, if needed (see Section 7.0). ▪ Clearing, grubbing, shallow excavation (at the TA-3 borrow area), minor cut and fill, contouring, scarifying, and harrow work. ▪ Road maintenance and dust control ▪ QA/QC sampling ▪ Nuclear gauge moisture and density verification measurements	Mechanical screening, grading, shallow excavation for surface water drainage features, and other closure activities are covered under this THA. Shallow excavation to generate additional clean fill from a borrow pit area is also covered under this THA. Soil screening will be conducted on clean soils near the TA-3 borrow area west of the CAMU. During screening, personnel at the nearby RWMMF will be notified regarding heavy equipment traffic. A dust permit and digging permit will be required.
Task Scope	**Comments**
Waste Management Activities ▪ Miscellaneous waste management tasks, including waste characterization, packaging, labeling, inspections, and movement.	No wastes are anticipated other than PPE, miscellaneous operational wastes, and decon water. The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA. However, once the subgrade has been applied, the only applicable radiological control to be applied will be no intrusive work.
Mobilization, Demobilization and Site Closure ▪ Fence removal and installation ▪ Addition or removal of temporary structures including site trailers ▪ Miscellaneous site clean-up activities ▪ Loading, unloading, and moving equipment and supplies. ▪ Geophysical surveys and other surveys	Much of this work will be performed between other task work as the schedule and personnel availability permit.

3.1 Task Hazard Analyses

The Task Hazard Analysis (THA) tool is the approach used to identify hazards and establish hazard controls prior to the execution of work. This approach is an integral part of implementing SNL/NM's Integrated Safety Management System initiative at the MWL.

Preliminary THA summaries have been prepared for each identified task and are provided in Attachment D1. Each task is described, the required equipment listed, and the anticipated level of PPE specified. Hazards are sorted into four categories: chemical, physical, radiological, and biological, and then rated based upon the probability of occurrence and the severity of the consequences. Anticipated control measures are then described. The hierarchy of controls is elimination, substitution, engineering, administration, and PPE. Potential offsite impacts are considered and control measures described, although for most of the remaining task work there is very low probability of any off-site impacts. These THAs will be modified and/or new ones generated as new information becomes available and/or new tasks are added to the work scope. THAs for non-routine tasks will be performed and reviewed with site workers prior to conducting the specific task. The results of these THAs will be incorporated in the daily, task-specific tailgate safety briefings. The TL will maintain the most current version of THAs, distribute them to personnel as appropriate, and attach them to the site HASP.

3.2 Underground Utilities

All soil disturbance, regardless of depth, will require a dig permit so the location of buried utilities can be identified prior to the start of field work. A comprehensive excavation permit has been submitted to cover all activities described in this HASP, and to comply with the SNL/NM Excavation and Penetration Activities Procedure AP-004 Revision 8. In the past, if the activity did not penetrate below 1 foot, an excavation permit was not required and the hazard of encountering underground utilities was not, as a rule, considered. Now all surface-disturbing activities will follow the procedures below. Surface disturbing activities include:

Digging	Sampling
Scraping	Fence construction
Grading	Posting & signage installation

- Before any excavation is performed, submit a request for an Excavation Permit to Facilities.
- Have any underground utilities identified, spotted and marked by Facilities before start of the activity.
- When submitting a request for an excavation permit describe the work area and note the exact location on a drawing of the site.
- Designate a sufficient size work area to allow the opportunity to locate work away from marked utilities.
- Pre-inspect the area after spotting has been completed to see if there are buried utility issues that need to be resolved.
- Do not mechanically dig closer than 5 feet to any marked or mapped buried utilities.
- If hand digging within the 5-foot exclusion area is not possible, call the Excavation Permit organization in Facilities Management for other options.

- No intrusive digging activities are planned at the Mixed Waste Landfill. However, clean soils will be excavated to a depth of up to 3 ft from the TA-3 borrow area, located approximately ¾ mile south of the MWL.
- Alert authorities if any underground utilities are encountered. Call 311, the non-emergency hotline (24/7) for guidance. For emergencies call 911. Notify your line management.
- Report even known utilities that are uncovered so that Facilities can determine their exact location with GPS equipment and correct their drawings, if needed.
- Report any site-installed utilities to Facilities so they may add them to the drawings of the area.

3.4 Hot Work

Various activities at the MWL may require welding, cutting metal with a cutting torch, or other forms of hot work. The SNL/NM Hot Work Administrative Procedure AP-032 Revision 1 will be followed for all applicable hot work at the MWL, including obtaining a hot work permit prior to conducting the related work. The permit process identifies hazards associated with hot work and identifies appropriate controls for those hazards. The hot work permit will be maintained on site. Any hot work being conducted by outside contractors will be performed under the MWL hot work permit, and Sandia will provide oversight and fire watch support during the hot work. The SSO will also ensure that any person performing hot work will be provided with and will wear proper protection specific to the particular task.

3.5 Weather

Weather-related hazards include heat stress, sunburn, cold stress, rain, wind, hail, snow, and lightning. The task-specific SSO is responsible for briefing workers on weather-related hazards, warning signs, and appropriate hazard control measures. All site personnel are responsible for monitoring weather conditions while performing activities outside, and stopping work if weather conditions create an unsafe work environment. If lightning occurs within 1 mile of the work area (5 to 7 second count between the lightning flash and the sound of thunder), work will be stopped until the lightning moves further away or the storm dissipates.

3.6 Borrow Area Excavation

The TA-3 borrow area is located west of the CAMU in the southern part of TA-3. The excavation at the borrow area will extend no deeper than 3 ft bgs, and therefore, does not constitute a significant hazard.

4.0 Personal Protective Equipment

Due to the nature of the hazards at the MWL, this work will be performed in Level D PPE, as described below.

Level D Protection

- Cotton coveralls
- Climate appropriate underclothes
- Hard Hat*
- Safety shoes/boots
- Safety glasses w/sideshields or goggles
- Work Gloves (leather or cotton)*

*Task-specific PPE requirements will be determined by the SSO and communicated to workers at the tailgate safety briefing.

The SSO is responsible for evaluating the PPE requirements and can make appropriate changes based upon actual site conditions and/or information obtained during task work. The SSO for each task will determine if hard hats are necessary based upon whether or not an overhead hazard exists. Equipment operators working in closed cabs for all tasks do not need to wear safety glasses or hardhats. No buried MWL wastes are likely to be encountered during cover construction activities, as wastes are buried several feet or more below ground surface. For this reason, Tyvek or other disposable coveralls are not required, and Level D PPE will be adequate for all activities on site.

Tritium is present in surface soils at the MWL. Most of the tritium occurs in soils primarily in the northern half of the MWL, with the greatest concentration occurring in the Classified Area. Figure D-1 shows the distribution of tritium in surface soil at the MWL, based on sampling activities conducted in the early 1990's. Tritium activities in surface soil are relatively low and do not pose a threat to human health or the environment (Peace et al, 2002).

Plutonium-238 has been detected at concentrations of up to 0.103 pCi/g in localized surface soils in the unclassified area of the MWL (Figure D-2). Risk assessment shows the plutonium (at the concentrations detected) does not pose a threat to human health or the environment (SNL/NM 2002).

Standard dust suppression techniques will be used to minimize the generation of windblown dust. These techniques include the limited spraying of soils with water or the use of soil fixatives to minimize dust generation. Fixatives used for dust control shall be reviewed prior to application for potential effects on landfill leachate and landfill surface runoff. Over-application of water resulting in free liquids will not be allowed because of waste minimization controls.

If required and specified, fixatives may be used to mitigate dust. Dust control will be in accordance with the New Mexico Environment Department's Ambient Air Quality Standards (NMAC Title 20 Chapter 2 Part 3) and all applicable DOE and SNL standards. Work will be restricted or suspended if unacceptable amounts of dust are being generated as determined by the SSO and/or radiological control technician. Work areas that have the potential for generating dust will require dust suppression techniques.

PPE requirements by task are summarized below and in the task-specific THAs provided in Attachment D1.

Task Activities	PPE Requirements and Comments
Cover Installation ▪ Remove perimeter fences, and install temporary area boundary using T-posts and rope. ▪ Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. ▪ Compact landfill surface to prepare for subgrade fill. ▪ Place and compact subgrade fill (from TA-3 soil stockpiles). ▪ Place gravel/cobble bio-intrusion barrier. ▪ Place and compact native soil layer fill (from TA-3 soil stockpiles). ▪ Place and minimally-compact topsoil layer. ▪ Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix, as needed. Additional tasks to be conducted include: ▪ Soil screening ▪ Surveying ▪ Equipment decontamination, if needed ▪ Clearing, grubbing, shallow excavation (at the TA-3 soil borrow area), minor cut and fill, contouring, scarifying, and harrow work ▪ Road maintenance and dust control ▪ QA/QC sampling ▪ Nuclear gauge moisture and density verification measurements	All activities can be performed in Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO, or by the Rad Technician in accordance with the RWP # 2562 .

Waste Management Activities ▪ Miscellaneous waste management tasks, including waste characterization, packaging, labeling, inspections, and movement.	All waste management tasks are adequately covered by Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO.
Mobilization, Demobilization and Site Closure ▪ Fence removal and installation ▪ Addition or removal of temporary structures including site trailers ▪ Miscellaneous site clean-up activities ▪ Loading, unloading, and moving equipment and supplies ▪ Geophysical surveys and other surveys	All activities can be performed in Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO.

5.0 Personnel Training and Medical Monitoring Requirements

All on-site workers must sign the HASP compliance agreement in Section 10.0 and attend the daily, task-specific tailgate safety meetings. All site visitors entering active work areas, regardless of employer, must receive a site-specific safety briefing delivered by the SSO or designee for that work area.

The task-specific SSOs are responsible for verifying training compliance for site workers involved in the specific tasks they are assigned to. The TLs, with support from the task-specific SSOs, ATLs and administrative staff are responsible for tracking and notifying personnel when training updates are needed. Copies of training records will be maintained at the MWL site. Unless otherwise noted, all training must be documented by a certificate of completion, by signing a training log, or an SNL/NM TEDS printout. Site workers are responsible for providing the SSO or designee with training documentation prior to starting work, and attending scheduled training. All site workers must comply with medical surveillance requirements outlined in 29 CFR 1910.120(f).

Site Safety Officers will be required to have RAD Worker II training. Because construction activities will be noninvasive, heavy equipment operators in closed cabs are required to have Rad Worker 1 training. For any work requiring use of a respirator, site workers must have medical approval, respiratory protection training, and a respiratory fit test. At least one person on site must have CPR, First Aid, and Fire Extinguisher training. Site workers that operate a forklift must have the appropriate SNL/NM training (FKL153G) or equivalent training from another source.

Training requirements for site personnel are summarized in the Table below.

Responsibility	Required Training*
Task-Specific Site Safety Officers (SSOs)	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 8 Hr. HAZWOPER Supervisor Training, 24-Hr. Supervised OJT, ESH100, Rad Worker II
Task Leaders and Assistant Task Leaders	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 8 Hr. HAZWOPER Supervisor Training, 24-Hr. Supervised OJT, ESH100, Rad Worker II
Site Workers (including Task Specific Contractors)	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 24-Hr. Supervised OJT, ESH100, Rad Worker 1
Heavy Equipment Operators	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 24-Hr. Supervised OJT, ESH100, Rad Worker 1, Drivers License [CDL not required, as operators will not be on public roads]

*SNL/NM security training requirements applicable to the level of clearance for each worker will be completed and documented.

6.0 Monitoring

Dust monitoring may be required during the initial phase of the construction project. If it is requested by a task-specific SSO, dust monitoring will be coordinated with the MWL TL(s).

Because the MWL is an SCA, work in radiologically-controlled areas is addressed under RWP # 2562 and subsequent revisions. Screening and sampling for radiological contamination will be conducted as per the RWP and project waste characterization criteria. Radiation monitoring may be required by the RWP. The radiation monitoring instruments will be calibrated and maintained by SNL/NM Radiation Protection. The criteria for stopping work and notifying the SNL/NM Radiological Control Technician are specified in the RWP.

7.0 Work Zones and Decontamination

Chemical decontamination for personnel and equipment will not be required, as no wastes will be excavated from the site. Radiological decontamination of equipment may be required during the subgrade preparation phase of the project, when heavy equipment may encounter contaminated soils. Radiological decontamination is addressed in RWP # 2562 and subsequent revisions. Once clean subgrade have been placed over the contaminated soils, radiological decontamination will no longer be necessary

7.1 Work Zones

An exclusion zone (EZ) will be established to protect personnel during heavy equipment operations on the cover. A contamination reduction zone (CRZ) will not be necessary, as no excavation into contaminated materials is anticipated, and personnel decontamination should not be required. The SSO will be responsible for setting up appropriate task-specific EZs within the MWL site operational boundary. The necessity for a radiological buffer and decontamination area will addressed in RWP # 2562 and subsequent revisions.

7.2 Personnel Decontamination

Personnel decontamination should not be necessary during the MWL cover construction project, as contamination levels in MWL soils are relatively low. Once soils are covered by the subgrade layer, there will be no potential for contamination of personnel during the remaining cover construction activities. RWP # 2562 and associated revisions discuss radiological requirements for decontamination when exiting a radiologically-controlled area.

7.3 Equipment Decontamination

Equipment that comes into contact with contaminated MWL soil during the initial phase of the project may require decontamination, in accordance with the MWL RWP # 2562. The approved MWL decontamination procedure involves either a dry decon or washing equipment with a high-pressure spray or a low-pressure wash/brush, using a surfactant such as Alconox mixed with water.

If necessary (and if required by the RWP), a decontamination pad may be set up alongside the landfill and used for heavy equipment decontamination. Smaller equipment may also be decontaminated in this location or in leak-proof containers. All decontamination fluids will be collected and sampled for disposal following established waste management procedures.

After the subgrade material has been placed, heavy equipment will no longer require decontamination for the remainder of site work, and radiological control procedures will be eliminated because there will be no further potential for contamination. The only radiological control remaining in place will be the requirement for no intrusive activities at the site.

8.0 Emergency Response Plan

This section provides information regarding the action(s) to be taken by site personnel in the event of an emergency situation. Based on the current activities at the MWL, the potential for a project emergency, such as encountering buried unexploded ordnance, is extremely unlikely. The potential for other TA 3 operations to affect work at the MWL is possible, but also limited. This section provides important emergency information, including lines of communication, to ensure site personnel are prepared to deal with an on-site emergency or off-site evacuation.

8.1 Communication and Muster Points

Direct voice communication and/or two-way radios will be the primary means for communication on-site. Because more than one crew may be working on site at the same time, each crew will carry a site radio or cell phone if crews are not working in the same general area. A designated member of the work crew (typically the SSO, site supervisor, or designee) will carry and monitor the radio or cell phone. More than one work crew may be covered by one radio or cell phone if they are all working in the same general area and have coordinated ahead of time to notify each other in case of an emergency situation. This will be documented through the tailgate safety briefing in the morning before the field work begins.

Site emergencies will be communicated either directly (person to person) or through the site radios or cell phones. An off-site emergency within TA 3/5 that requires the notification and/or evacuation of MWL site personnel will be communicated via two-way radios from the SNL/NM Incident Command (two-way IC radios) and/or Sandia alpha-numeric pagers. Because MWL personnel may not be in the site trailers at all times during the day, the two-way IC radio or cell phone/Sandia pager will provide a back-up means to ensure MWL personnel are notified of a TA 3/5 emergency situation (off-site emergency). At least one, on-site, MWL representative will carry and monitor the two-way IC radio or wear the Sandia pager and carry a cell phone. The person(s) carrying the two-way IC radio or cell phone/Sandia pager will be identified in the daily tailgate safety briefings and be responsible for notifying the other MWL site personnel in the event of an off-site emergency.

In the event of an off-site or on-site emergency situation, the MWL TL(s) will be notified immediately. The MWL TLs, if available, or designee, will be responsible for communicating with other SNL/NM organizations/personnel. In the event of an emergency that requires the evacuation of the immediate area, personnel will muster at the MWL muster points (Figure D-3).

If an evacuation of TA 3 is required, all MWL site personnel will proceed directly to the Kirtland Air Force Base Golf Course parking lot and wait there until further information is available, or as directed by the SSO, TL(s), or designee.

Specific roles and responsibilities to be carried out by site personnel will depend on the nature of the incident. Site workers will carry out the various initial response actions, including notifying everyone in the immediate vicinity of the emergency situation and associated hazards.

Communications during site emergencies will occur in the following sequence:

1. On-site personnel will be notified first via direct voice communication, supplemented if necessary by two-way radio or cell phone communication, to ensure all on-site MWL personnel are aware of the situation. If more practical given the circumstances, two blasts on a vehicle or hand-held horn will be repeated to sound the initial warning. If someone is injured, site workers will check scene for hazards and notify the closest, properly-trained First Aid/CPR responder. If imminent danger exists, proceed directly to step 4 and then proceed with the following steps.

2. If possible based upon the situation, notify the MWL TL(s) immediately, who in turn will notify the 6147 Department Manager. The TL(s) and/or SSO(s) will determine appropriate initial responses, including selecting a muster point if appropriate (Figure D-3). As per Section 3.2, if a buried utility is encountered, notify the non-emergency hotline immediately and stop intrusive work in the area.
3. Activate the SNL/NM Incident Command by phone, two-way IC radio, or cellular phone.
4. Use tailgate safety briefing forms or site entry logs and the buddy system at the muster point to account for all site workers.

MEDICAL EMERGENCY

In case of a medical emergency/injury, the SSO (or nearest site worker) will survey the scene and ensure that it is safe to enter and render assistance. If emergency medical attention is needed the SSO will immediately activate or have someone else activate the SNL/NM Emergency Response by calling 911 on a land line or 844-0911 by cell phone, or by using the two-way IC radio. The SSO or the nearest trained site worker will then provide CPR and/or emergency first aid as necessary. If the situation is not a medical emergency, the injured individual(s) should be transported to the Sandia Medical Clinic or Lovelace Medical Center for non-business hours, as appropriate. Lovelace Medical Center will typically be used by contractors for minor injuries and non-emergency medical conditions. The evacuation routes to Sandia Medical Clinic and the Lovelace Medical Center are shown in Figure D-4.

Medical Clinic Information	
SNL Medical Clinic Address: Building 831, corner of F & 7th Streets, KAFB, NM Route to SNL Medical Clinic: Exit east from TA-3 to Pennsylvania (Lovelace Rd.), then left (northwest) to Wyoming, then right (north) to F Street, east on F Street to 7th Street *[Used during normal business hours of 0700-1700]*	**SNL Medical Clinic: 845-8692 (reception)** **845-8159 (Dr. McCarthy)**
Lovelace Hospital Address: 5400 Gibson Blvd. SE. Route to Lovelace Hospital: Exit east from TA 3 to Pennsylvania Ave, go left (northwest) to Wyoming, go right (north) to Gibson, go left (west) to Emergency Entrance, 5400 Gibson Blvd. See Figure D-4 for map to Lovelace. *[Used only during non-regular business hours]*	**Lovelace Phone:** **262-7000 (main switchboard)** **262-7222 Emergency Room**

8.2 Emergency Contact Information

Emergency contact information provided below for the MWL Project.

EMERGENCY CONTACTS	NAME/ORGANIZATION NUMBER	PHONE
24-Hour Emergency Line	Incident Command System/3137	911 (base) / 844-0911 (cell)
Non-Emergency Hotline	Incident Command System/3137	311 (base) / 844-6515 (cell or base)
Sandia Medical Clinic	Staff	911 (base) / 844-0911 or 844-0081 (cell or base)
Lovelace Medical (Gibson)	Staff	Emergency Room: 262-7222 (cell) or 7-262-7222 (base)
Department Manager	Dick Fate / 6147	284-2568 (office)
Project Task Leaders	Jerry Peace / 6116 Don Schofield / 6141	284-2472 (office) 844-4088 (office) / 259-7098 (cell)
Assistant Task Leaders	Mike Mitchell / 6141 Tim Goering / 6147 Joe Fritts / 6146	284-6757 (office) 250-7224 (cell) 284-2563 (office) 845-8703 (office) / 681-8016 (cell)
Fire Department	KAFB	911 (base) / 844-0911 (cell)
KAFB EOD	Staff	846-2229
Radiation Protection Operations	To Be Determined	To Be Determined
Industrial Hygiene	Michael Oborny / 6328	845-8040
Safety Engineering	Michael Oborny / 6328	845-8040
6100 ES&H Coordinator	Johnny Ethridge / 6140	845-9295

9.0 References for Key MWL Project Documents

The following project documents contain information that is relevant to the task work described and covered by this HASP.

Peace, J.L. and T.J. Goering, January 2005. "Calculation Set for Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2005-0480.

Peace, J.L. and T.J. Goering, March 2004. "Mixed Waste Landfill Corrective Measures Study Final Report, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2004-0627.

Peace, J.L, T.J. Goering, M.D. McVey, and D.J. Borns, May 2003. "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico," SAND Report SAND2003-0836.

Peace, J.L., Goering, T.J. and M.D. McVey, September 2002. "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2002-2997.

Sandia National Laboratories/New Mexico (SNL/NM), July 2005. "Mixed Waste Landfill Voluntary Corrective Measures Work Plan, Sandia National Laboratories/New Mexico", prepared at Sandia National Laboratories by J. Peace and T. Goering for the US Department of Energy, Albuquerque, New Mexico.

10.0 Compliance Agreement

All site workers will be required to review and comply with the information contained in this HASP. This will be documented by the site workers signing the compliance agreement form on the following pages. The signed agreement will be maintained on site.

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT:
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT (continued):
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT (continued):
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

Attachment D1

Task Hazard Analyses

For:

Vegetative Cover Installation Activities

Waste Management Activities

Mobilization, Demobilization and Site Closure Activities

TASK HAZARD ANALYSIS
Task — MWL Vegetative Cover Installation

Description —
A vegetative cover with a rock bio-intrusion barrier will be installed on the Mixed Waste Landfill (MWL). The cover will be placed over the original 2.6-acre landfill surface and will consist of three feet of compacted native soil, overlying a rock bio-intrusion layer. A vegetated topsoil layer admixed with 25 percent 3/8-in. crushed gravel will be applied to maintain water balance and mitigate water and wind erosion.

Tasks associated with MWL Vegetative Cover Installation activities include:

- Remove perimeter fences and install temporary operational boundary using T-posts and rope.
- Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. Grubbed materials will be stockpiled onsite and used as mulch or rip-rap where needed.
- Compact landfill surface to prepare for subgrade fill.
- Place and compact subgrade fill (from TA-3 soil stockpiles).
- Place rock bio-intrusion barrier.
- Place and compact native soil layer fill (from TA-3 soil stockpiles).
- Place and minimally-compact topsoil layer.
- Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix. The surface will be drill-seeded, mulched and crimped.

Additional tasks to be conducted include:

- Mechanical screening of fill material
- Surveying
- Equipment decontamination (if required by the RWP) and cleaning
- Clearing, grubbing, minor cut and fill, contouring, scarifying, and harrow work. Shallow excavation (≤3 feet) will be conducted at the TA-3 borrow area west of the CAMU.
- Road maintenance and dust control

- QA/QC sampling
- Moisture and density verification measurements using a CPN MC-3 Portaprobe

Equipment Required:

- Heavy Equipment- excavator, four yard loader, dozer (D-6 or equivalent), dozer (JD 650 or equivalent) grader, soil compactor, 60-ft boom lift, high reach fork lift
- Mechanical screen (ScreenAll)
- Vehicles-14-yard dump truck, water truck (2000 and 4000 gallon), water wagon, pick-ups
- Hand Tools-shovels, picks, etc.
- GPS and survey equipment
- CPN MC-3 Portaprobe
- Safety Equipment

Level of Protection: Level D PPE will be appropriate for all cover installation activities (see Section 4.0 for discussion of PPE). The task-specific SSO is responsible for evaluating the PPE requirements and can make appropriate changes based upon actual site conditions and/or information obtained during task work. The SSO for the cover installation tasks will determine if hard hats are necessary based upon whether or not an overhead hazard exists. Equipment operators working in closed cabs do not need to wear safety glasses or hardhats.

MWL Vegetative Cover Installation - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical • Direct contact with chemically-contaminated soil and debris	Not Applicable	Chemical contamination of MWL surface soils is not significant, and will not be an issue. Only clean soil and rock will be used for MWL cover construction.
Physical • Cover construction • Heavy Equipment • Excavation Activities-Utilities • Mechanical screening • Tools • Worker fatigue • Heat and Cold stress • Slip, Trip and Fall • Heavy Lifting	Medium	The construction area will be controlled, and these controls will be maintained until cover installation are completed. Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. Heavy equipment will be inspected daily when used. The number of workers in the work area will be minimized when heavy equipment is operating. Any excavation activities will follow OSHA requirements for sloping, as appropriate. An SNL/NM excavation permit will be required for the TA-3 borrow area. The permit requirements and reporting protocol will be reviewed with workers. The mechanical screen will be located downwind of personnel and water will be used for dust control. If dust control measures are not adequate, screening will be stopped. All tools will be inspected prior to use. A work/rest plan will be implemented as appropriate by the SSO. Workers will dress appropriately for the weather conditions and heat/cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible) slip, trip and fall hazards. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible.

Potential Hazard	Hazard Rating	Control
Radiological • Ingestion or inhalation of radiologically-contaminated soil and dust	Low	The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA. Dust suppression techniques will be used to minimize the generation of dust during construction. These include limited spraying of soils with water or the use of soil fixatives. Work areas that have the potential for generating dust will require dust suppression.
Explosive	Not Applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, Insects	Low	Work areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

TASK HAZARD ANALYSIS
Task — MWL Vegetative Cover Installation (Concluded)

Potential Off-Site Impacts:

1. Increased traffic – Considerable vehicle and heavy equipment traffic related to cover construction will occur within the site operational boundary. However, subgrade and native soil layer fill from the TA-3 soil stockpiles will be trucked to the MWL from the soil stockpiles and borrow area, located approximately 1 mile south of the MWL. Increased localized traffic in TA-3 is anticipated during the four month construction period for the cover. Suggested truck routes from the soil stockpiles to the MWL are shown in Figure D-5. Additional traffic will also be generated during the trucking of rock from an offsite source to the MWL for the bio-intrusion layer. Traffic impacts on KAFB as a whole are expected to be minimal, however. If necessary, local traffic near the MWL will be re-directed.
2. Increased noise – no significant off-site impact anticipated.
3. Utility outages - no off-site impact anticipated.
4. Dust - suppress dust with limited water as necessary, or with soil fixatives, if appropriate. Use magnesium chloride/water mixture as appropriate to maintain soil stockpiles and local road surfaces. The decision to apply magnesium chloride will be made by the site

manager or the SSO. Mechanical screening will be terminated at the request of the SSO if dust suppression techniques are not adequate to prevent offsite dust releases due to wind that adversely impacts on-site or off-site personnel.

5. Fire - Task Leader, SSO, or designee will communicate with local facility Points of Contact and initiate emergency response plan if necessary.

TASK HAZARD ANALYSIS
Task — Waste Management

Description —
Minimal waste will be generated by the MWL cover construction project. Waste generated will likely be limited to small quantities of miscellaneous operational wastes. Although the MWL is an SCA, the generation of radiological waste should be minimal. Organic debris removed during clearing and grubbing the landfill surface will be utilized onsite as mulch during the seeding operation. Similarly, rocks removed during clearing and grubbing and concrete waste generated during fence removal will be utilized onsite in the rock bio-intrusion barrier, or as rip rap for the cover.

Waste management tasks include

- Waste characterization sampling
- Waste packaging, labeling, inspections, and other miscellaneous waste management tasks

Heavy equipment and light vehicles may be used when necessary to move waste containers and waste materials. Radiological release surveys may be required for items, equipment, containers, etc. before leaving the SCA. RWP # 2562 and subsequent revisions will be followed for all work in the SCA. The task-specific SSO for any waste management activities conducted in the SCA will be responsible for reviewing the RWP with site workers and coordinating with Radiation Protection, as appropriate, to ensure compliance with the RWP and this HASP.

Equipment Required:
- Heavy Equipment-backhoe, forklift, front loader
- Vehicles- pick-ups.

- Hand Tools-shovels, picks, hammers, screwdrivers, etc…
- Power Tools-drill, saws, air-tools, etc…
- Rigging-slings, chokers, barrel lifters, chains, shackles, hooks
- Safety Equipment- radiation monitors as per RWP
- Polyethylene sheeting

Level of Protection: Level D is required for waste management tasks. See Section 4.0 for discussion of PPE.

Waste Management - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical • No hazards anticipated	Not Applicable	No contact with chemical contamination is anticipated during MWL cover construction.

Potential Hazard	Hazard Rating	Control
Physical • Heavy Equipment • Motor vehicle use for transport • Tools • Worker fatigue • Heavy lifting • Heat and Cold Stress • Slip, Trip and Fall	Medium	Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. Heavy equipment will be inspected daily when used. The number of workers in the work area will be minimized when heavy equipment is operating. Site workers using motor vehicles will have a current driver's licenses and obey all traffic laws. All tools will be inspected prior to use. A work/rest plan will be implemented as appropriate by the task-specific SSO. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible for heavy lifting. Workers will dress appropriately for the weather conditions and heat and cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible) slip, trip and fall hazards.
Radiological • Handling potentially contaminated soil/debris	Low	The MWL is a soil contamination area (SCA). MWL soils are contaminated with tritium and plutonium. SCA controls will be maintained within the MWL perimeter until the subgrade layer has been placed. Waste management tasks have a low potential radiological hazard rating, and will be conducted in accordance with the RWP.
Explosive	Not applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, Insects	Low	Areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

Potential Off-Site Impacts:
No offsite impacts anticipated.

TASK HAZARD ANALYSIS
Task — Mobilization, Demobilization, and Site Closure Activities

Description — This task covers numerous activities that are related to mobilization, demobilization, and site closure activities. Site closure activities include permanently closing down site restoration operations at the MWL and the associated temporary infrastructure. The following list summarizes the main types of activities covered under this task.

- Fence removal and installation
- Removal of temporary structures, including site trailers
- Removal of temporary utilities (if applicable)
- Redistribution of SNL/NM owned equipment and material
- Miscellaneous site clean up activities
- Loading and unloading, movement of equipment, supplies, and waste materials
- Preparing equipment and supplies for transport off-site
- Surveys

These activities will be conducted in a phased manner, as personnel and resources allow. Also covered under this task will be any welding or hot work required as part of remaining MWL task work (see Section 3.4). A final survey is planned after completion of cover installation. After completion of the site closure activities the site will be in its end-state condition.

Equipment Required:
- Heavy Equipment – forklift, front-end loader, track-hoe, backhoe, small front-end loader
- Hand Tools – hammers, shovels, sledge hammer, etc.
- Power Tools – electric drill, circular saw, etc.
- Rigging-slings, chokers, barrel lifters, chains, shackles, hooks
- Welding/hot work equipment (Section 3.4)
- Vehicles – pick-up trucks, dump truck, semi-trucks
- Safety Equipment

Level of Protection: Level D PPE should cover all demobilization activities (see Section 4.0 for discussion of PPE). The task-specific SSO and the assigned rad technician are responsible for evaluating the PPE requirements and can make appropriate changes based on the specific demobilization task work being performed. Hot work may require additional PPE, which will be determined by the task-specific SSO and consistent with the SNL/NM Hot Work Permit (Section 3.4).

Mobilization, Demobilization, and Site Closure Activities - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical	Not Applicable	No intrusive work in contaminated areas.
Physical • Heavy equipment • Motor vehicle use for transport • Electrical • Tools • Hot work • Heat and cold stress • Slips, trips, and falls • Heavy lifting	Medium	Heavy equipment will be inspected daily when used. Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. The number of workers in the work area will be minimized when heavy equipment is operating. If a crane is needed it will be obtained, along with a SNL/NM qualified operator, through SNL/NM Facilities. Site workers using motor vehicles will have a current drivers license and obey all traffic laws. Qualified electricians perform electrical work. Lock out tag out procedures will be followed where applicable. An SNL/NM excavation permit covering the entire MWL area has been obtained. The permit requirements and reporting protocol will be reviewed with workers who are involved with any type of intrusive activities. All tools will be inspected prior to use. A hot work permit will be obtained from SNL/NM Facilities prior to conducting hot work. Proper precautions, including fire prevention, will be followed as per the permit. Workers will dress appropriately for the weather conditions and heat/cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible)

Potential Hazard	Hazard Rating	Control
		slip, trip and fall hazards, as part of a "good house-keeping" approach. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible for heavy lifting.
Radiological	Low	The MWL is an SCA. Soils are contaminated with tritium and localized plutonium. SCA controls will be maintained within the MWL perimeter until the subgrade layer has been placed. Mobilization, demobilization, and site closure tasks have a low potential radiological hazard rating, and will be conducted in accordance with the RWP.
Explosive	Not Applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, and Insects	Low	Areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

Potential Off-Site Impacts:
No off-site impacts anticipated.

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Figures

Figure D-1
1993 Tritium Surface Soil Sampling Results

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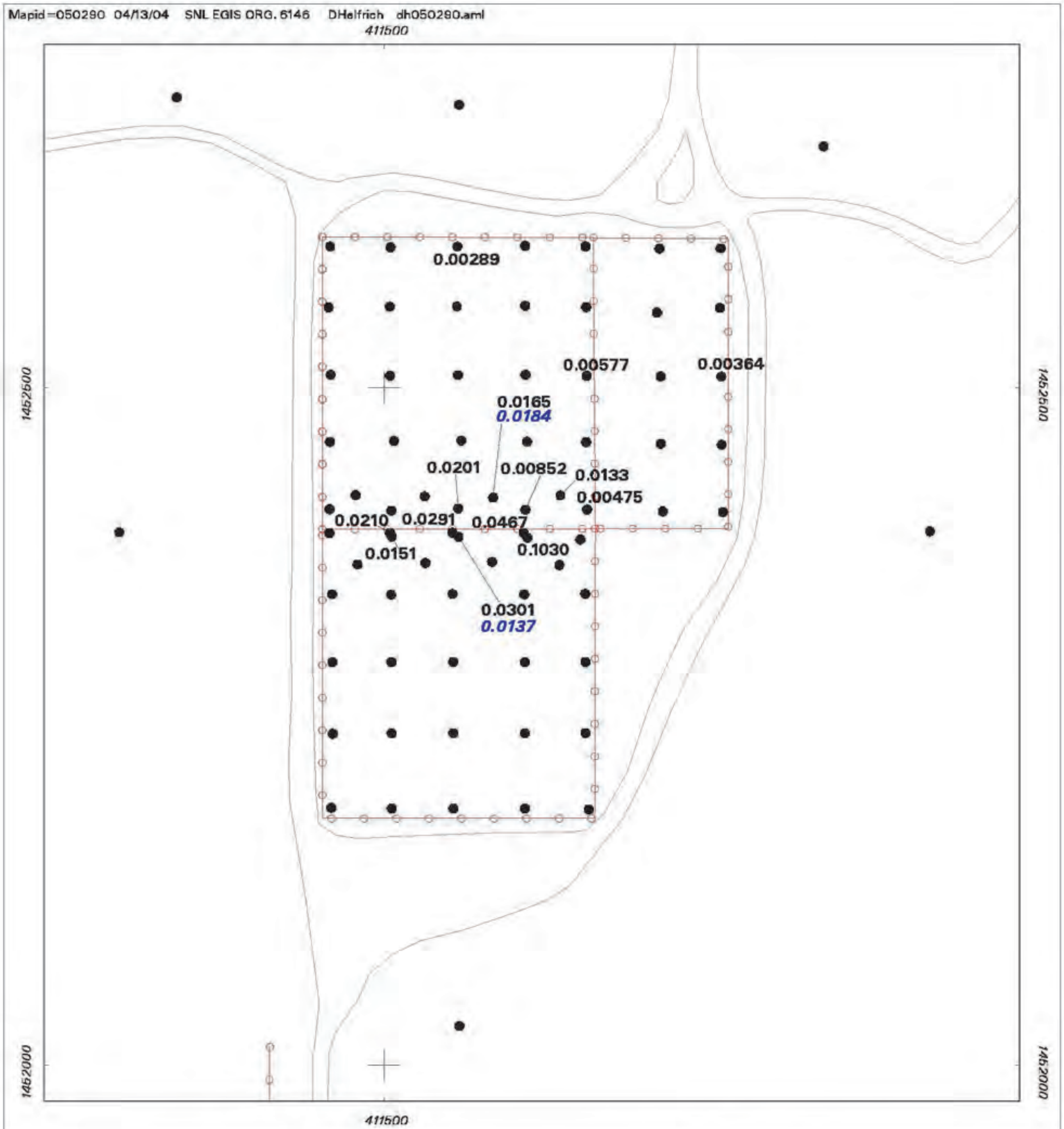

Legend

- PU-238 Surface Soil Sample units measured in pCi/g (no value = 0.0 pCi/g) (*0.0137* = duplicate sample)
- Unpaved Road
- Fence / MWL Boundary

Figure D-2
Plutonium-238 Concentrations Detected in Surface Soil at the Mixed Waste Landfill

0 60 120
Scale in Feet

0 14.4 28.8
Scale in Meters

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

Figure D-3
Mixed Waste Landfill
Muster Points

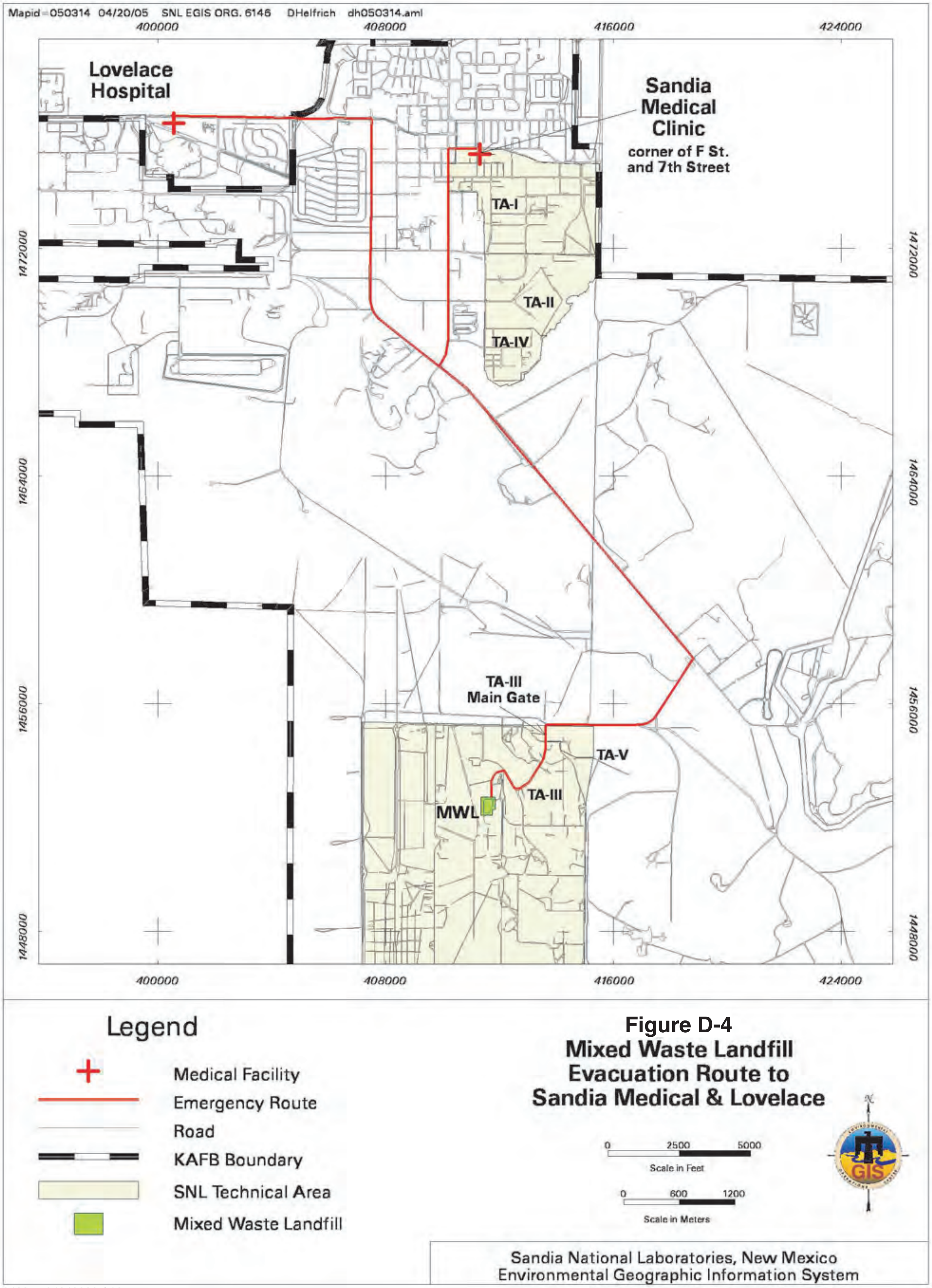

Figure D-4
Mixed Waste Landfill Evacuation Route to Sandia Medical & Lovelace

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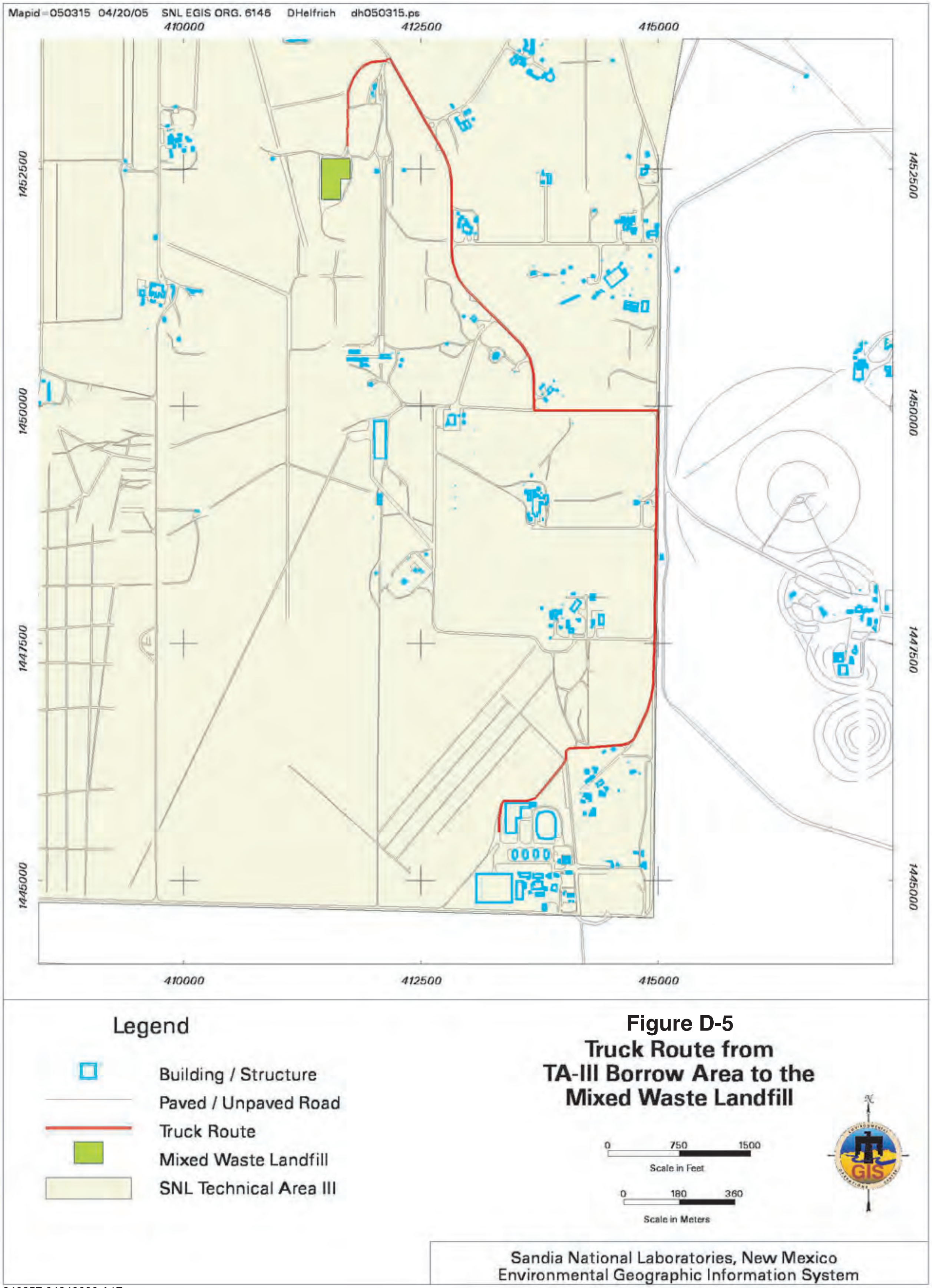

Figure D-5
Truck Route from TA-III Borrow Area to the Mixed Waste Landfill

APPENDIX E
Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories

SANDIA REPORT

SAND2007-0170
Unclassified-Unlimited Release
Printed January 2007

Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories (2nd Edition)

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Prepared by
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Sandia is a multiprogram laboratory operated by Sandia Corporation,
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National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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SAND2007-0170
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Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories

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Abstract

A probabilistic performance assessment has been conducted to evaluate the fate and transport of radionuclides (amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, radon-222, strontium-90, thorium-232, tritium, uranium-238), heavy metals (lead and cadmium), and volatile organic compounds (VOCs) at the Mixed Waste Landfill (MWL). Probabilistic analyses were performed to quantify uncertainties inherent in the system and models for a 1,000-year period, and sensitivity analyses were performed to identify parameters and processes that were most important to the simulated performance metrics. Comparisons between simulated results and measured values at the MWL were made to gain confidence in the models and perform calibrations when data were available. In addition, long-term monitoring requirements and triggers were recommended based on the results of the quantified uncertainty and sensitivity analyses.

At least one-hundred realizations were simulated for each scenario defined in the performance assessment. Conservative values and assumptions were used to define values and distributions of uncertain input parameters when site data were not available. Results showed that exposure to tritium via the air pathway exceeded the regulatory metric of 10 mrem/year in about 2% of the

simulated realizations when the receptor was located at the MWL (continuously exposed to the air directly above the MWL). Simulations showed that peak radon gas fluxes exceeded the design standard of 20 pCi/m^2/s in about 3% of the realizations if up to 1% of the containers of sealed radium-226 sources were assumed to completely degrade in the future. If up to 100% of the containers of radium-226 sources were assumed to completely degrade, 30% of the realizations yielded radon surface fluxes that exceeded the design standard. For the groundwater pathway, simulations showed that none of the radionuclides or heavy metals (lead and cadmium) reached the groundwater during the 1,000-year evaluation period. Tetrachloroethylene (PCE) was used as a proxy for other VOCs because of its mobility and potential to exceed maximum contaminant levels in the groundwater relative to other VOCs. Simulations showed that PCE reached the groundwater, but only 1% of the realizations yielded aquifer concentrations that exceeded the regulatory metric of 5 μg/L.

Based on these results, monitoring triggers have been proposed for the air, surface soil, vadose zone, and groundwater at the MWL. Specific triggers include numerical thresholds for radon concentrations in the air, radionuclide and heavy-metal concentrations in surface soil, soil-gas concentrations of VOCs in the vadose zone, moisture content in the vadose zone, and uranium and VOC concentrations in groundwater. The proposed triggers are based on U.S. Environmental Protection Agency and Department of Energy regulatory standards. If a trigger is exceeded, then a trigger evaluation process will be initiated which will allow sufficient data to be collected to assess trends and recommend corrective actions, if necessary.

Acknowledgments

The authors would like to thank Dick Fate, Mike Nagy, Fran Nimick, Ray Finley, MJ Davis, Amy Blumberg, John Gould, and Joe Estrada for their reviews of this report. We also thank Randal Taira and Mitch Pelton at Pacific Northwest National Laboratory for their assistance with FRAMES/MEPAS. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Preface to the 2nd Edition

This 2nd Edition includes revisions to address comments made by the New Mexico Environment Department (NMED, November 2006).

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1. Introduction

1.1 Background and Objectives

The Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill (MWL) at Sandia National Laboratories, Albuquerque, NM, is being submitted to the New Mexico Environment Department (NMED). As part of the final order selecting a remedy for the MWL (NMED May 2005), NMED required that the CMI Plan include a comprehensive fate and transport model to determine if contaminants will move from the MWL down through the vadose zone to groundwater. In addition, the NMED required that the CMI Plan include triggers for future action that identify and detail specific monitoring results that will require additional testing or implementation of an additional or different remedy.

This report presents the probabilistic fate and transport models that were used to assess the performance of the MWL. Relevant contaminants of concern at the site were included, and site-specific models and parameters were used in a probabilistic analysis. Results of the analysis were compared to regulatory performance metrics, and sensitivity analyses were performed to determine the most important parameters and processes that impacted the variability of the simulated performance metrics. Based on these simulations and results, appropriate triggers were identified and defined to address long-term monitoring requirements at the site.

A period of 1,000 years was selected for the probabilistic analysis to be consistent with DOE Order 435.1. DOE Order 435.1 requires that performance assessments be conducted for low-level radioactive waste disposed after September 26, 1988, and that performance objectives be evaluated for a 1,000-year period to determine potential risk impacts to the public and environment. Although most of the MWL wastes were disposed of prior to September 26, 1988, a 1,000 year period was nonetheless determined to be appropriate for assessment of regulatory performance metrics.

1.2 Overview of the Mixed Waste Landfill

The Mixed Waste Landfill (MWL) is located approximately five miles southeast of Albuquerque International Sunport and four miles south of Sandia National Laboratories' (SNL) central facilities (Figure 1). The landfill is a fenced, 2.6-acre area in the north-central portion of Technical Area 3 (TA-3). The mean elevation at the MWL is 5381 feet.

The MWL was established in 1959 as a disposal area for low-level radioactive and mixed waste that was generated at SNL research facilities. Originally, the landfill was opened as the "Area 3 Low-level Radioactive Dump," when the low-level radioactive disposal area in Technical Area 2 was closed in March 1959. The MWL accepted low-level radioactive waste and minor amounts of mixed waste from March 1959 through December 1988. Approximately 100,000 cubic ft of low-level radioactive waste containing approximately 6,300 curies of activity was disposed of at the landfill.

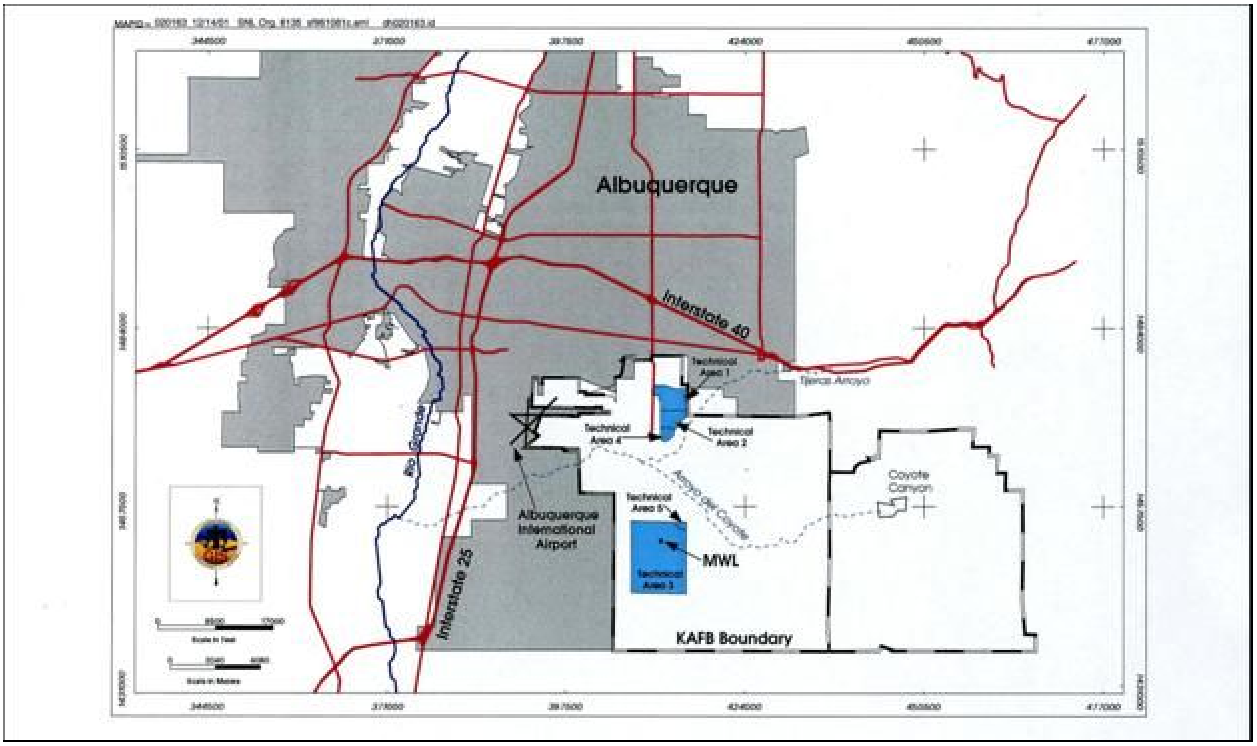

Figure 1. Location of the Mixed Waste Landfill relative to Albuquerque, NM, and Kirtland Air Force Base.

1.2.1 Site Description

The MWL consists of two distinct disposal areas: the classified area, occupying 0.6 acres, and the unclassified area, occupying 2.0 acres (Figure 2). Low-level radioactive and mixed waste has been disposed of in each area. Wastes in the classified area were buried in unlined, vertical pits. Wastes in the unclassified area were buried in unlined, shallow trenches.

A Phase 1 RCRA facility investigation was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL and to begin characterizing the nature and extent of any such release. The Phase 1 facility investigation indicated that tritium was the primary contaminant of concern. No organic contaminants were identified. A Phase 2 RCRA facility investigation was initiated in 1992 to determine contaminant source, define the nature and extent of contamination, identify potential contaminant transport pathways, evaluate potential risks posed by the levels of contamination identified, and recommend remedial action, if warranted, for the landfill.

The Phase 2 RCRA facility investigation incorporated the streamlining approach, combining data quality objectives and the observational approach. Nonintrusive field activities were conducted first to facilitate the efficiency and cost-effectiveness of intrusive field activities. Data collected during the Phase 2 RCRA facility investigation were evaluated using U.S. Environmental Protection Agency-approved methods. Initially, a constituent population was statistically compared to natural background. Any constituent failing the statistical comparison was further

analyzed for spatial distribution. Constituents that failed the statistical comparison to background and showed a strong spatial correlation were identified as potential contaminants of concern.

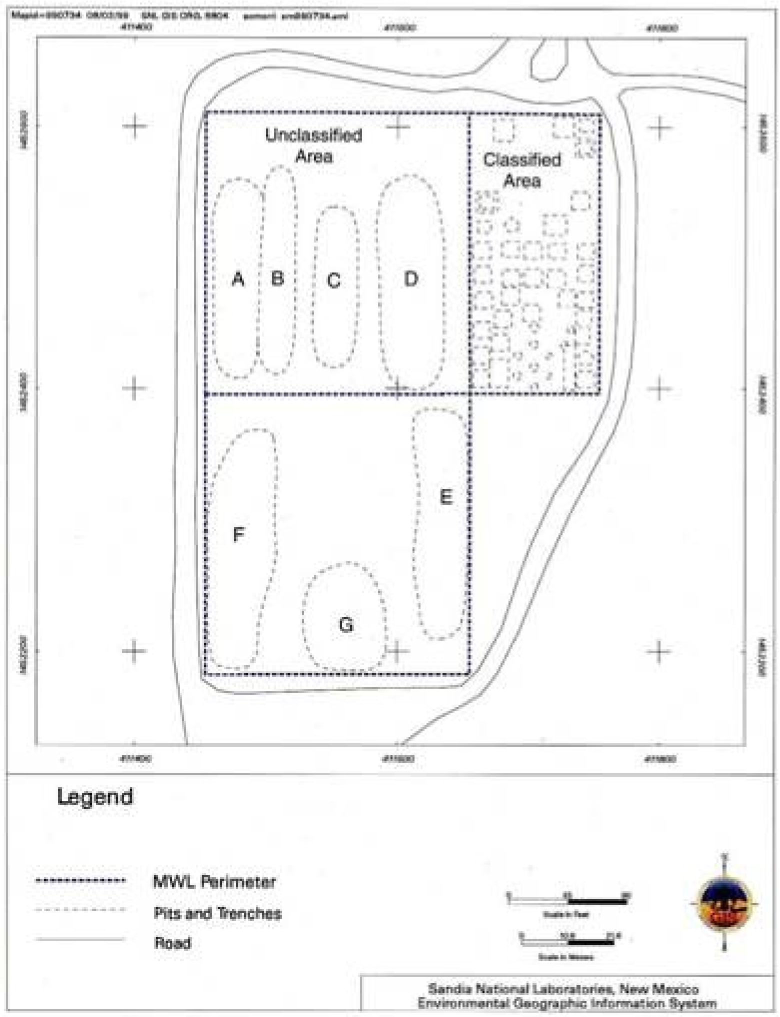

Figure 2. Map of the Mixed Waste Landfill.

The Phase 2 RCRA facility investigation was completed in 1995. This investigation included surface radiological surveys; ambient air sampling; soil sampling for background metals and radionuclides; soil sampling for volatile organic compounds (VOCs), semivolatile organic compounds, target analyte list metals, and radionuclides; nonintrusive geophysical surveys; passive and active soil gas sampling; borehole drilling; installation of groundwater monitoring wells; groundwater sampling; vadose zone tests; aquifer tests; and risk assessment. The Phase 2 RCRA facility investigation confirmed the findings of the Phase 1 RCRA facility investigation.

1.2.2 Contaminants of Concern

Based on the results of the Phase 1 and Phase 2 RCRA Facility Investigations, tritium was found to be the primary contaminant of concern that has been released from the MWL. An estimated 2400 curies of tritium were disposed of in the MWL. Tritium is extremely mobile when incorporated in water in liquid and vapor form, moving easily through the vadose zone and into the atmosphere.

Tritium levels range from 1100 picocuries/gram in surface soils to 206 picocuries/gram in subsurface soils in the classified area of the landfill. The highest tritium levels are found within 30 feet of the surface in soils adjacent to and directly below classified area disposal pits. At depths greater than 30 feet below ground surface, tritium levels fall off rapidly to a few picocuries/gram of soil.

Tritium also occurs as a diffuse air emission from the landfill. Tritium emissions from the MWL are diminishing with time due to its half-life of 12.3 years. Total tritium emissions to the atmosphere were measured at 0.294 curies/year in 1993 and at 0.090 curies/year in 2003 (Peace et al., 2002; Anderson, 2004).

An estimated 27,900 kg (9.3 curies) of uranium-238 (depleted uranium) are present in the MWL inventory. Based on the results from the Phase 1 and Phase 2 RFIs, there is no indication that uranium has been released from the MWL. However, because of the large quantity of depleted uranium disposed of in the MWL, the fate and transport of uranium was modeled in this study.

Other radionuclides present in the MWL inventory include cobalt-60, strontium-90, cesium-137, plutonium-238 and -239, americium-241, radium-226, and thorium-232. The fate and transport of these radionuclides was modeled, although there is no evidence that these radionuclides have been released from the MWL.

There is an estimated 128,000 kg of lead disposed of within various pits and trenches in the landfill. Most of the lead is in the form of shielding (i.e. lead bricks, casks, pigs, and shipping canisters). Smaller lead items include containers commonly used to dispose of radioactive sources. The lead containers were typically placed in concrete-filled A/N cans or 55-gallon drums. Larger lead items include five massive stainless steel and lead casks disposed of in Trench F, each weighing up to 40 tons. The fate and transport of lead was modeled, although there is no evidence that lead has been released from the MWL.

Cadmium is not specifically listed in the MWL inventory. However, slightly-elevated cadmium has been detected in five boreholes along the west side of the MWL to depths of up to at least 104 ft bgs. The cadmium concentrations in MWL soils range from non-detect to 1.97 mg/kg, approximately two times the NMED maximum background value of 0.9 mg/kg. The source of cadmium in MWL soils is unknown.

Cadmium has occasionally been detected in MWL groundwater at concentrations above the EPA MCL, although these detections are sporadic and unpredictable. Because the cadmium detections above the MCL are inconsistent, it is believed that these detections do not indicate contamination from the MWL. Nevertheless, cadmium is considered a contaminant of concern, and the fate and transport of cadmium was modeled.

During the Phase 2 RCRA Facility Investigations, low levels of VOCs were detected in soil gas samples obtained from the landfill. The primary VOCs detected in soil gas at the MWL include tetrachloroethene (PCE), trichloroethene (TCE), dichloro-difluoromethane, 1,1,1-trichloroethane (1,1,1-TCA), trichlorofluoromethane, and 1,1,2-trichloro,1,2,2-trifluoroethane. Of these VOCs, PCE was determined to have the highest potential to reach groundwater at concentrations near its maximum contaminant level (Klavetter, 1995a). Other VOCs were either not as mobile or did not have sufficiently high initial soil gas concentrations. For this reason, PCE is a contaminant of concern, and the fate and transport of PCE was modeled. However, because the remaining VOCs still have some potential to contaminate groundwater, PCE was modeled in this study as a proxy for all of the VOCs.

Radon gas generation from the landfill is based on the estimated 6 curies of radium-226 in the MWL inventory. Most of the radium-226 in the MWL is in the form of sealed sources. Emission of radon gas from the MWL was investigated in 1997. No significant difference between the MWL and the background measurements in terms of median, mean, and standard deviation was observed (Haaker, 1998). However, at the request of the NMED, radon was included in the MWL fate and transport model.

In summary, the following list of actual and potential contaminants was included in the MWL fate and transport model: tritium, americium-241, cesium-137, cobalt-60, plutonium-238 plutonium-239, radium-226, radon-222, strontium-90, thorium-232, uranium-238, lead, cadmium, and PCE.

2. Modeling Approach

2.1 Previous Modeling Studies

This section summarizes previous modeling studies conducted for the MWL. These studies include fate and transport modeling studies conducted by Argonne National Laboratory, Sandia, and WERC (Consortium for Environmental Education & Technology Development). Cover performance modeling studies were conducted by Sandia in support of the MWL cover design, and are summarized in this section as well.

2.1.1 Fate and Transport Modeling Studies

Previous fate and transport modeling studies conducted for the MWL include a study by Argonne National Laboratory in 1995 as part of a preliminary human health risk assessment for the MWL; a subsequent study conducted by Sandia in 1995 regarding the potential migration of radionuclides and organic compounds from the MWL; a 1997 study to model the infiltration of reactor coolant water discharged into an MWL trench in 1967; and a study conducted in 2001 by WERC of tritium migration through the vadose zone beneath the MWL.

Argonne National Laboratory Modeling Study

One of the earlier modeling studies on the MWL was conducted by Johnson et al. (1995) at Argonne National Laboratory (ANL). The ANL study used a "worst case" scenario approach in which they took conservative values of parameters at different levels of model complexity to ascertain the probable fate and transport of, as well as risk from, the contaminants. The study used a tiered approach for modeling the fate and transport of contaminants, with increasing model complexity and more justifiable simplifying assumptions.

The first-tier screen was a geometric approach in which tritium from the MWL was distributed evenly throughout the vadose zone. This first-tier screening suggested that tritiated water from the MWL could potentially reach groundwater, although the likelihood was considered small.

The second-tier analysis utilized a one-dimensional analytical solution for flow and transport in the vadose zone, but did not include lateral dispersion, which would reduce concentrations of tritium and the distance traveled by tritium from the landfill. This analysis showed that tritium concentrations could exceed the EPA drinking water guideline of 20,000 pCi/L after 57 years if the underlying soils were fully saturated. However, because of the uncertainty of the input parameters (particularly velocity, which was considered too high), the analysis over-predicted tritium concentrations in subsurface soils.

The final tier utilized a three-dimensional numerical code, TRACR3D, which still is extensively used for flow and transport calculations. This code is relatively complex, utilizing finite-element solutions for both the saturated and unsaturated zones. Tritium was the primary contaminant modeled because of its assumed higher mobility compared to other radionuclides and organic contaminants. Conservative assumptions were used in the model, boundary conditions, and hydrologic parameters to bound the probable extent and concentration of tritium. The model predicted that 27 years after disposal, the maximum tritium contamination reaches 184 ft below ground surface (bgs) with a maximum concentration of 2.8×10^6 pCi/L, significantly higher than measured field values. After an additional 100 years, the tritium was predicted to have traveled to a depth of 230 ft bgs, with a maximum tritium concentration of 5,400 pCi/L. The ANL study concluded that no detectable tritium concentrations would be likely to reach groundwater at the MWL.

The study also included screening calculations for aqueous-phase transport of PCE and TCE, and predicted that these VOCs could reach the water table approximately 250 years from time of disposal. No calculations were conducted for vapor-phase transport, which has proven to be the most significant transport mechanism for organic compounds in the vadose zone at nearby ER sites, including the Chemical Waste Landfill.

Sandia Modeling of Radionuclide and Organic Compound Transport

A subsequent study was conducted by Sandia in August 1995 to simulate potential contaminant flow and transport from the MWL. The study was conducted using the code Borehole Optimization Support System (BOSS), originally developed to determine the optimum number and location of boreholes and monitoring wells necessary to define the nature and extent of contamination. Monte Carlo uncertainty analysis of flow and transport was used to simulate the

migration of radionuclides and organic compounds from the MWL. (Klavetter, 1995a; Klavetter, 1995b).

BOSS was first used to simulate the migration of radionuclides, including tritium, cesium-137, and strontium-90 from the MWL, using more representative hydrologic property values than were applied in the ANL study. The modeling study predicted that no detectable tritium would reach groundwater at the MWL, and that detectable tritium would not migrate below a depth of 40 m (131 ft). These results are consistent with the actual tritium distribution data for subsurface soils collected during the Phase 2 RFI. The model also predicted that no detectable activity of cesium-137 and strontium-90 would migrate even 10 m below the MWL pits and trenches.

The code BOSS was also used to simulate the vapor-phase and aqueous-phase transport of the six VOCs detected in MWL soil gas (Section 1.2.2). The modeling results demonstrated that aqueous-phase transport of organic contaminants from the MWL was not a significant transport mechanism. The modeling results also demonstrated that vapor-phase transport of five of the six organic compounds was not significant, due to the low concentrations of these contaminants detected in the soil gas.

Concentrations of PCE detected in soil gas near the MWL surface were calculated to be high enough to result in concentrations of sub-ppb to a few ppb in groundwater within 50 years. The model predicted that the lateral extent of PCE in the groundwater would be limited, with PCE at concentrations greater than 1 ppb extending less than 130 m (426 feet) downgradient of the MWL. The study recommended that further evaluation of the fate and transport of PCE be considered, including a review of PCE concentrations in borehole soil samples collected during the Phase 2 RFI. PCE was detected at low concentrations in soil samples from 2 of the 16 boreholes drilled during the Phase 2 RFI. PCE was detected in BH-3 at a maximum concentration of 2.45 *J* µg/kg, and in MW-4 at a maximum concentration of 5.4 µg/kg (Peace et. al., 2002).

Modeling Study of Reactor Coolant Water Infiltration

In 1997, a modeling study was conducted to simulate the infiltration of 271,500 gallons of reactor coolant water from a trench at the MWL (Wolford1997). The objective of the study was to evaluate the potential migration of coolant water discharged into Trench D of the MWL in May and June, 1967. The water originated from the Sandia Engineering Reactor Facility in Technical Area 5, and contained approximately 1 Ci of total radioactivity, primarily short-lived fission products. Trench D was an active disposal trench at the time, and was believed to be the most likely source for contaminant release and migration from the MWL.

The modeling study used the code VS2DT (Healy, 1990), a finite difference unsaturated flow and transport model developed by the U.S. Geological Survey. The modeling results indicated that the reactor coolant water, and any tritium mobilized by the water, would not have migrated beyond a depth of approximately 120 ft, based on a 30-year simulation. The modeling results were consistent with Phase 2 RFI field measurements of tritium activities in subsurface soils, which showed tritium detected to a maximum depth of 120 ft bgs.

The study also simulated the fate and transport of the coolant water and tritium for a period of 90 years into the future. The study predicted that the coolant water and any tritium in the water would not migrate more than 5 to 10 ft below its current predicted depth of 120 ft. Due to radioactive decay, tritium concentrations in the water were predicted to decrease at a faster rate than the downward movement of the wetting front.

WERC Modeling of Tritium Migration through the Vadose Zone

In January 2001, WERC was requested by the U.S. Congress to perform an independent peer review of the performance of the MWL. The results of the study are presented in WERC (2001).

As part of this study, members of the WERC review team developed a fate and transport model of tritium migration in the vadose zone beneath the MWL. The code GoldSim, a generalized object-oriented probabilistic spreadsheet, was used to model tritium contaminant concentrations and fluxes at various depths beneath the MWL over time. The model incorporated mass transport from a source (inventory), various release mechanisms, transport processes, migration pathways, and radionuclide decay.

The WERC team concluded that based on their model results, the spatial and temporal distribution of tritium activities measured in the vadose zone appear to be consistent with those expected, given the inventory, regional meteorology, subsurface soil conditions, and hydrologic parameters. Their modeling results showed good agreement with the Phase 2 RFI data regarding tritium distributions in subsurface soils beneath the MWL. The WERC team also concluded that future concentrations of tritium in subsurface soils at the MWL should decrease over the next 10 years, based on diffusion and natural decay of tritium.

2.1.2 Cover Performance Modeling

In addition to the fate and transport models discussed above, Sandia has conducted extensive cover performance modeling to predict infiltration through various thicknesses of alternative covers. The results from these studies were used to develop the MWL alternative cover design.

Early Cover Performance Modeling

Sandia's early cover performance modeling studies utilized multiple codes to assess infiltration through various thicknesses of alternative covers. The codes used included the water balance model, HELP-3 (Schroeder et al. 1994), and two unsaturated flow models, UNSAT-H (Fayer and Jones 1990) and VS2DT (Healy 1990).

The earlier modeling studies are documented in Wolford (1998); SNL (April 1999); and culminate with the modeling results presented in the original MWL design document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL September 1999). This report was submitted to the NMED in September 1999 for technical review and comment, and was later published as a SAND report by Peace et al. in 2003. The cover performance modeling results from the report are also presented in Section 5.3 of the main text of the MWL Corrective Measures Implementation Plan.

In order to demonstrate that the MWL alternative cover design complies with regulatory guidance, the hydrologic performance of the cover was modeled using HELP-3, UNSAT-H and VS2DT. These codes were used to predict infiltration through soil covers ranging in thickness from 1 to 5 ft. All three models demonstrated that deployment of a vegetated soil cover for final closure of the MWL would reduce infiltration into the landfill to a small percentage of the total precipitation. The models also demonstrated that a 3-ft-thick vegetated soil cover meets the intent of RCRA Subtitle C regulations. Additional cover thicknesses did not lead to significantly better performance. Additional details on the cover performance modeling using HELP-3, UNSAT-H and VS2DT are presented in Section 5.3 of the MWL CMI Plan.

Recent Cover Performance Modeling

The most recent cover performance modeling was conducted in 2003 and 2004 using site-specific climate, hydrologic, and vegetation input parameters. The modeling simulated infiltration of water through the MWL soil cover using the one-dimensional, numerical code UNSAT-H. UNSAT-H is a Richards' equation-based model that simulates infiltration, unsaturated flow, redistribution, evaporation, plant transpiration, and deep infiltration of water. The modeling results corroborated the results from earlier modeling studies. The recent modeling results are published in the SAND report entitled, "Calculation Set for Design and Optimization of Vegetative Soil Covers" (Peace and Goering, 2005). The modeling results were used to determine infiltration input parameters for the MWL probabilistic performance-assessment model.

One of the objectives of the modeling was to assess whether a 3-ft soil cover would meet the EPA-prescribed technical equivalency criteria. The EPA performance-based, technical equivalency criteria used are 31.5 millimeter (mm)/year (yr), or less, for net annual infiltration and 1×10^{-7} centimeter (cm)/second (s) average infiltration rate, based on a hydraulic conductivity of 1×10^{-7} cm/s and the assumption of unit-gradient conditions. The modeling results verified that the 3-ft MWL cover will meet the EPA-prescribed technical equivalency criteria for RCRA landfills under both present and future conditions.

Present conditions were simulated by modeling infiltration through various thicknesses of an engineered cover, while future conditions were simulated by modeling infiltration through various thicknesses of soil under natural conditions (i.e. the "natural analog"). The recent cover modeling results are discussed further in Section 3.4 below. Complete modeling input parameters, boundary conditions, and results are presented in Peace and Goering (2005).

2.2 Probabilistic Performance-Assessment Modeling Approach

This section summarizes the approach used in this study to provide a comprehensive performance assessment of the MWL. Previous studies have looked at individual components of the landfill performance, and nearly all of the studies relied on deterministic evaluations. This study describes a probabilistic performance-assessment approach that captures the inherent uncertainties in the system while honoring site-specific features, processes, and parameters. Sensitivity analyses are also introduced that utilize the probabilistic results to identify the parameters and processes that are most important to the simulated performance metrics.

A performance assessment is defined in DOE M 435.1-1 as “an analysis of a radioactive waste disposal facility conducted to demonstrate there is a reasonable expectation that performance objectives established for the long-term protection of the public and the environment will not be exceeded following closure of the facility.” In addition, DOE M 435.1-1 states that the method used for the performance assessment must include uncertainty analyses. A method that addresses these requirements has been used for the Waste Isolation Pilot Plant (DOE, 1996), the Yucca Mountain Project (DOE, 1998), and the intermediate-depth Greater Confinement Disposal Boreholes (Cochran et al., 2001) to assess the long-term performance of nuclear waste repositories. Probabilistic performance assessments have also been used for sites with uranium mill tailings (Ho et al., 2004). A similar systematic approach has been used here to conduct a performance assessment of the MWL. The approach is outlined as follows:

1. Develop and screen scenarios based on regulatory requirements (performance objectives) and relevant features, events, and processes

2. Develop models of relevant features, events, and processes

3. Develop values and/or uncertainty distributions for input parameters

4. Perform calculations and sensitivity/uncertainty analyses

5. Compare results to performance objectives, identify important parameters and processes, and provide feedback to improve calculations, as needed

In Step 1, a scenario is identified as a well-defined sequence of features, events and processes that describes possible future conditions at the disposal site. An example of a scenario is the release of radionuclides from a landfill via the vadose zone to the aquifer, where water is pumped from a well and ingested by an individual. The decision to evaluate various scenarios depends, in part, on relevant performance objectives set forth by regulatory requirements. In addition, scenarios should be chosen that represent features, events, and processes that are relevant to the specific site being evaluated.

Step 2 develops the models that are necessary to simulate the chosen scenarios in the performance assessment. The models that are used vary in complexity, and a hierarchy of models can exist. A conceptual model of each scenario is developed to guide the development of more detailed mechanistic models of individual features, events, and processes that comprise the scenario. These detailed models are then integrated into a total-system model of the entire scenario. The integration of the more detailed models may include the models themselves or a simplified abstraction of the model results.

In Step 3, values are assigned to the parameters to populate the models. If the parameter is well-characterized, a single deterministic value may be assigned. However, uncertainty and/or variability in the parameter may require the use of distributions (e.g., log-normal, uniform) to define the values. Experimental data, literature sources, and professional judgment are often used to determine these distributions. The development of uncertainty distributions for parameters used in this study is described in Section 3.3.

In Step 4, calculations are performed using the integrated models. Because stochastic parameters are used, a Monte Carlo approach is taken to create an ensemble of simulations that use different combinations of the input parameters. For each run (realization), a value for each input parameter is sampled from the uncertainty distribution, and the simulation is performed. The results of each realization are equally probable, and the collection of simulation results yields an uncertainty distribution that can be compared to performance objectives to assess the risk of exceeding those performance objectives or metrics. Sensitivity analyses can also be performed to determine which parameters the performance metrics are most sensitive to (see Section 2.2.1).

The last step (Step 5) is to analyze and compare the results with relevant performance objectives. The findings are typically documented as cumulative distribution functions that present the probability of exceeding a performance objective. Important parameters and processes are also identified through sensitivity analyses. Together, these results may be used to assess the overall performance, prioritize site characterization, evaluate alternative designs, or identify triggers for future actions to address long-term monitoring requirements for regulatory compliance. In this study, the primary purpose of the performance assessment is to determine which contaminants and performance objectives are at risk based on the simulated performance of the MWL. This information will then provide a basis for the triggers that are identified and recommended for the site.

2.2.1 Sensitivity Analyses

A probabilistic performance assessment provides not only a quantification of uncertainties in the simulated performance metrics, it also allows for a quantified sensitivity analysis to be performed. A sensitivity analysis of the probabilistic assessment results can provide valuable information regarding the processes and parameters that are most important to the simulated performance metric(s). This information provides understanding about the relationship between uncertainty in individual input parameters and the uncertainty in the performance of the system. In addition, knowledge of the parameters having the greatest influence on future performance can be used to help prioritize site characterization activities, to help optimize landfill cover design, and to assist in the design of monitoring systems and triggers. Using a sensitivity analysis provides the quantitative information necessary to ensure that resources are directed to those aspects of the cover system that “drive” performance and not on those aspects of cover design that have little significance.

The sensitivity of the performance-assessment model can be determined from the Monte Carlo probabilistic realizations using regression analysis. Multiple regression analysis involves construction of a linear regression model of the simulated output (the dependent variable) and the stochastic input variables (independent variables) using a least-squares procedure. Stepwise linear regression is a modified version of multiple regression that selectively adds input parameters to the regression model in successive steps (Helton and Davis, 2000). In this method, a sequence of regression models is constructed that successively adds the most important input parameters to the regression to improve the overall correlation. In the end, the sensitivity analysis identifies those parameters that are significantly correlated to the performance metric, and omits those parameters that are not. This study uses a stepwise linear rank regression to perform sensitivity analyses on simulated performance metrics that are at risk of being exceeded.

3. Performance-Assessment Modeling of the Mixed Waste Landfill

3.1 Scenarios and Performance Objectives

In this study, relevant contaminants of concern were grouped into the following categories: (1) radionuclides, (2) heavy metals, and (3) VOCs. Table 1 summarizes the specific contaminants, scenarios, and performance objectives that were considered in this study. In general, the two pathways of concern include transport of volatile or gas-phase contaminants from the MWL to the atmosphere, and migration of aqueous-phase or vapor-phase contaminants through the vadose zone to the groundwater. For each of these primary pathways, relevant performance objectives and metrics were identified for each of the contaminants of concern. The chosen scenarios represent the most likely releases of contaminants from the MWL based on estimated inventories, contaminant properties, and previous studies.

Table 1. Summary of scenarios and performance objectives used in the performance assessment of the MWL.

Scenario	Description	Performance Objectives[a]
1	Water percolates through the cover to the waste	• Infiltration through the cover shall be less than 10^{-7} cm/s (a unit-gradient flow is assumed to equate infiltration to hydraulic conductivity) (U.S. EPA 40 CFR 264.301)
2	Tritium diffuses to the atmosphere and migrates via gas and aqueous phases through the vadose zone to the groundwater	• Dose to the public via the air pathway shall be less than 10 mrem/yr (excludes radon) (U.S. EPA 40 CFR 61.92) • Dose from beta particles and photon emitters shall be less than 4 mrem/yr (U.S. EPA 40 CFR 141.66; U.S. EPA, 2003) • Tritium concentrations in groundwater shall not exceed 20,000 pCi/L (40 CFR 141.66 Table A; tied to 4 mrem/yr)
3	Radon steadily diffuses to the atmosphere and migrates via gas and aqueous phases through the vadose zone to the groundwater	• The average flux of radon-222 gas shall be less than 20 pCi/m^2/s at the surface of the landfill (U.S. EPA 40 CFR 192) • Radon concentrations in groundwater shall not exceed 300 pCi/L (proposed EPA rules, Federal Register: November 2, 1999 (Volume 64, Number 211) Pages 59345-59378)
4	One or more radionuclides migrate via the aqueous phase through the vadose zone to the groundwater	• Maximum concentrations in groundwater of gross alpha particle activity (including radium-226 but excluding radon and uranium) is 15 pCi/L (U.S. EPA 40 CFR 141.66; U.S. EPA, 2003) • Uranium concentrations in groundwater shall not exceed EPA MCL of 30 μg/L (U.S. EPA 40 CFR 141.66; U.S. EPA, 2003) • Dose from beta particles and photon emitters shall be less than 4 mrem/yr (U.S. EPA 40 CFR 141.66, U.S. EPA, 2003)
5	Lead and cadmium migrate via the aqueous phase through the vadose zone to the groundwater	• Lead concentrations in groundwater shall not exceed the EPA action level of 15 μg/L (U.S. EPA, 2003) • Cadmium concentrations in groundwater shall not exceed the EPA MCL of 5 μg/L (U.S. EPA, 2003)
6	PCE migrates through the vadose zone to the groundwater	• PCE concentrations in groundwater shall not exceed the EPA MCL of 5 μg/L (U.S. EPA 40 CFR 141.61; U.S. EPA, 2003

MCL = Maximum Contaminant Level

[a]The point of compliance is taken at the boundary of the waste site. The period of performance was specified as 1,000 years in the regulations for some of the performance metrics, but for many of the performance metrics, the period of performance was not specified. In this study, a 1,000 -year period was simulated.

3.2 Performance-Assessment Models

The following sections describe the models that were developed and used to simulate the fate and transport of the different contaminants in the various scenarios summarized in Table 1.

3.2.1 FRAMES/MEPAS

The aqueous transport of heavy metals (lead and cadmium) and the radionuclides were simulated using the probabilistic simulation tools FRAMES[1] (Framework for Risk Analysis in Multimedia Environmental Systems; Whelan et al., 1997) and MEPAS[2] (Multimedia Environmental Pollutant Assessment System; Whelan et al., 1992), developed by Pacific Northwest National Laboratory. The FRAMES system, which integrates the fate and transport models comprising MEPAS, allows for a holistic approach to modeling in which models of different type (i.e., source, fate and transport, exposure, health impact), resolution (i.e., analytical, semi-analytical, and numerical), and operating platforms can be combined as part of the overall assessment of contaminant fate and transport in the environment. The FRAMES system employs a graphical user interface for integrating computer models, an extensive contaminant database, a probabilistic sensitivity/uncertainty module, and textual and graphical viewers for presenting modeling outputs.

Existing models in FRAMES include those derived from MEPAS (Whelan et al., 1992). MEPAS is a physics-based environmental analysis code that integrates source-term, transport, and exposure models for endpoints such as concentration, dose, or risk. MEPAS is capable of computing contaminant fluxes for multiple routes, which include leaching to groundwater, overland runoff, volatilization, suspension, radioactive decay, constituent degradation, and source/sink terms. In this study, only the source-term and vadose-zone models were implemented. The source-term model conservatively simulates leaching from the waste zone (assuming no containment) based on either the solubility or the inventory-limited concentration (Streile et al., 1996). Decay of constituents can also occur within the source-term model. The transport of the contaminant through the vadose-zone is then simulated assuming liquid-phase advection, dispersion, adsorption, and decay of the contaminant (Whelan et al., 1996). It should be noted that gas-phase transport is not assessed in FRAMES/MEPAS. Separate models were used to evaluate the gas-phase transport of tritium, radon, and VOCs.

In this study, the aquifer concentration and subsequent dose, if applicable, were conservatively estimated based on the simulated concentration of the constituent in the groundwater at the interface of the vadose-zone and the water table (e.g., dilution caused by transport in the saturated zone was ignored). Section 3.3 presents the input parameters that were used in the radionuclide-transport models.

Uncertainty analyses are performed in FRAMES using the sensitivity module. The sensitivity module can be attached to any model that has been integrated into FRAMES and allows the user to stochastically vary any input parameter that is identified in the process models. Input parameters can be stochastically varied by a distribution, correlation coefficient, an equation, or

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[1] http://mepas.pnl.gov/FRAMESV1 (FRAMES v. 1.5)
[2] http://mepas.pnl.gov/earth/mepasmain.html (MEPAS v. 4.1.1)

any combination of these three options. Four distributions are currently available: (1) uniform, (2) log uniform, (3) normal, and (4) log normal. The sensitivity module utilizes the Latin Hypercube Sampling (Wyss and Jorgensen, 1998) technique to minimize the number of modeling runs that must be performed to accurately represent distributions selected by the user. In this study, 100 realizations were simulated for each scenario (a sensitivity analysis was performed using 100 vs. 200 realizations in Section 3.5.2.2, and results showed that 100 realizations were sufficient to adequately represent the distribution of the simulated output).

3.2.2 Transient Gas- and Liquid-Phase Transport

A separate model was used to model the transient transport of tritium in both the gas and liquid phases at the MWL. As stated in the previous section, FRAMES/MEPAS was used to simulate the transport of radionuclides such as tritium, but only in the liquid phase. Tritium, in the form of tritiated water, is volatile and can be transported via both the gas and liquid phases. Regulatory metrics exist for dose caused by exposure to tritium (a beta particle emitter) in both the air and groundwater pathways (see Table 1). Also, because the half-life of tritium is relatively short (12.3 years), a transient analysis was required. Therefore, the transport of tritium was modeled using a transient model that accounts for advective liquid-phase transport, diffusive gas-phase transport, decay, and adsorption (if applicable) in the vadose zone (Jury et al., 1983; Jury et al., 1990). This same model was also used to model the transport of PCE. In this model, a contaminated zone is assumed to initially exist with a defined thickness and concentration. Over time, the contaminant migrates and decays (if applicable) assuming a flux boundary condition at the surface, defined by an atmospheric boundary layer thickness (see Jury et al., 1983) and a zero concentration boundary beneath the waste zone at a location infinitely far away from the source. Superposition is used to account for a clean overburden (cover) above the waste zone (Jury et al., 1990). The analytical solution to this model was implemented in Mathcad,® and a Monte Carlo analysis was implemented with the uncertain variables using 100 realizations. Section 3.3 presents the input parameters and distributions that were used in the tritium- and PCE-transport models.

3.2.3 Steady-State Gas- and Liquid-Phase Transport

Radon-222 is generated from the decay of radium-226, which is a decay product of uranium-238. Because these parent constituents have long half lives, the source of radon-222 production is assumed to last indefinitely. Therefore, the transient model described in the previous section that accounts for a finite source of contaminant is not appropriate. Instead, a steady-state model of radon transport was developed to account for steady generation of radon-222, advective liquid-phase transport, diffusive gas-phase transport, and decay (see Appendix A in Section 7). Mathcad® was used to provide a Monte Carlo analysis of the analytical solution using 100 realizations. Section 3.3 presents the input parameters and distributions that were used in the radon-transport model.

3.3 Input Parameters and Distributions

The constituents that were included in the performance assessment of the MWL are summarized in Table 2. The parameter values and distributions that were used are also summarized in the table. The adsorption coefficient (K_d) was assumed to be an uncertain parameter, so a range of values was obtained from the literature for the constituent and soil type (sandy loam) at the MWL. A log-uniform distribution was used to emphasize the lower values in the distribution. The inventory of each constituent was also assumed to be an uncertain variable. The estimated inventory from previous reports and studies was used as the lower bound in a uniform distribution for each constituent. The lower bound was multiplied by two to obtain the upper bound for the assumed uniform distribution. The maximum solubility obtained from the literature for each constituent was used. All other parameters were obtained from site-specific reports, scientific literature, or EPA recommendations.

Table 3 summarizes the parameters and distributions used to define the contaminated waste zone (source term) in the models. The waste-zone length, width, and thickness is based on the size of the pits, trenches, and dimensions of the MWL. The maximum thickness of the cover is based on the design specifications given in Peace et al. (2005). The minimum thickness of the cover is set equal to zero as a bounding value to account for the possibility that complete erosion of the cover may occur in the future. This is a conservative bounding assumption since the intent is to maintain the integrity of the cover at the MWL.

Table 4 summarizes the parameters and distributions used to describe the vadose-zone in the models. Uncertainty was included for a number of variables including thickness of the vadose zone, infiltration rate, hydraulic conductivity, and site-specific transport parameters. The distributions used for the various vadose-zone parameters were derived from site-specific data or literature pertaining to the constituents and scenarios evaluated in this study. The liquid- and gas-phase tortuosity coefficients are used to calculate effective diffusion coefficients in porous media. The tortuosity coefficient accounts for the increased tortuosity and reduced area available for diffusion in porous media. The minimum value is based on formulation by Millington (1959), and the maximum value is assumed to be equal to one (the upper bound), which yields the maximum diffusion. Studies of enhanced vapor diffusion have shown that large values of the tortuosity coefficient (yielding diffusion rates equivalent to those in free space) are possible in unsaturated porous media because of evaporation and condensation mechanisms across liquid islands in pores (Ho and Webb, 1998).

Finally, Table 5 summarizes the parameters and distributions used to estimate dose due to exposure via the atmospheric (e.g., inhalation) or groundwater pathway. Dose via inhalation and dermal adsorption of gas-phase tritium was calculated based on the surface flux (pCi/m^2/s) of tritium determined in the models.[3] The length and width of the waste zone was used to determine the flux rate of tritium at the surface (pCi/s), and the average wind speed and vertical mixing height was used to determine the average concentration above the landfill. The inhalation rate was then used to estimate the human intake of gas-phase tritium, and the dose-

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[3] Inhalation and dermal adsorption of gas-phase radon and PCE were not used as performance metrics in this analysis because the enforceable regulatory metrics pertaining to radon and PCE do not use dose (surface flux of radon and groundwater concentration of PCE was used). Table 1 summarizes the performance metrics that were used for these constituents.

conversion factor (Table 2) was used to determine the dose. For groundwater exposure, a conservative estimate for water ingestion (10 L/day) was used together with the simulated groundwater concentrations to determine intake. The assumed water ingestion rate of 10 L/day is five times greater than the EPA drinking-water standard of 2 L/day and is intended to account for indirect sources of water ingestion and absorption such as consumption of vegetables and fruits irrigated by contaminated water. The dose-conversion factor was then used to estimate dose via the groundwater pathway.

Table 2. Summary of input parameters and distributions for constituents used in the models.

Constituent and Molecular Weight	Inventory[a]	Half-Life[b]	Specific Activity (Ci/g)[c]	Adsorption Coefficient, K_d (mL/g)[d]	Max Solubility (mg/L)[e]	Liquid-Phase Diffusion Coefficient (m^2/s)[f]	Gas-Phase Diffusion Coefficient (m^2/s)[f]	Henry's Constant (C_g/C_l)[g]	Dose Conversion Factor (rem/pCi)[h]
Americium-241[α]	Uniform: 0.04 - 0.08 Ci	433 yrs	3.43	Log-Uniform: 1900 – 9600	$2.4x10^{4}$	$6x10^{-10}$	N/A	N/A	$3.64x10^{-6}$
Cesium-137[β]	Uniform: 410 – 820 Ci	30.2 yrs	86.4	Log-Uniform: 30 – 4600	137,000	$6x10^{-10}$	N/A	N/A	$5.0x10^{-8}$
Cobalt-60[β]	Uniform: 3500 – 7000 Ci	5.27 yrs	1130	Log-Uniform: 60 – 1300	600	$6x10^{-10}$	N/A	N/A	$2.69x10^{-8}$
Plutonium-238[α]	Uniform: 0.0012 - 0.0024 Ci	87.7 yrs	17.1	Log-Uniform: 80 – 520	0.24	$6x10^{-10}$	N/A	N/A	$3.2x10^{-6}$
Plutonium-239[α]	Uniform: 0.0012 - 0.0024 Ci	$2.41x10^{4}$ yrs	0.0621	Log-Uniform: 80 – 470	0.24	$6x10^{-10}$	N/A	N/A	$3.54x10^{-6}$
Radium-226[α]	Uniform: 6-12 Ci	1,600 yrs	0.989	Log-Uniform: 500 – 36,000	0.45	$6x10^{-10}$	N/A	N/A	$1.32x10^{-6}$
Radon-222[α]	Constant generation from Radium-226	3.82 days	$1.54x10^{5}$	0	N/A	$0.07\exp[-4(S - S\phi^2 + S^5)]$ where S=liquid saturation, ϕ=porosity		0.26^{-1}	$1.44x10^{-8}$ (inhalation)
Strontium-90[β]	Uniform: 410 -820 Ci	29.1 yrs	137	Log-Uniform: 15 – 20	90,000	$6x10^{-10}$	N/A	N/A	$1.42x10^{-7}$
Thorium-232[α]	Uniform: 1 – 2 Ci	$1.4x10^{10}$ yrs	$1.10x10^{-7}$	Log-Uniform: 20 – 2000	23	$6x10^{-10}$	N/A	N/A	$2.73x10^{-6}$
Tritium[β] H-3	Uniform: 2400 – 4800 Ci	12.3 yrs	9690	0	N/A	$2.3x10^{-9}$	$2.6x10^{-5}$	$1.7x10^{-5}$	$6.4x10^{-11}$ (inhalation; x1.5 to include dermal absorption)

Constituent and Molecular Weight	Inventory[a]	Half-Life[b]	Specific Activity (Ci/g)[c]	Adsorption Coefficient, K_d (mL/g)[d]	Max Solubility (mg/L)[e]	Liquid-Phase Diffusion Coefficient (m^2/s)[f]	Gas-Phase Diffusion Coefficient (m^2/s)[f]	Henry's Constant (C_g/C_l)[g]	Dose Conversion Factor (rem/pCi)[h]
Uranium-238[α]	Uniform: 9.3 – 18.6 Ci	4.47×10^9 yrs	3.35×10^{-7}	Log-Uniform: 0.4 – 15	24	6×10^{-10}	N/A	N/A	2.55×10^{-7}
Cadmium 112.41	Uniform: 1350 – 2700 kg	stable	N/A	Log-Uniform: 8 – 80	1.4×10^6	6×10^{-10}	N/A	N/A	N/A
Lead 207.2	Uniform: 128,000 – 256,000 kg	stable	N/A	Log-Uniform: 270 – 4360	4.43×10^5	6×10^{-10}	N/A	N/A	N/A
PCE 165.83	Uniform: 5 – 70 kg	Log-Uniform: 9 mos – 10^{10} yrs	N/A	Log-Uniform: 0.038 - 2	N/A	9.2×10^{-10}	9.5×10^{-6}	0.42	N/A

N/A–Not Applicable or not used in the model; for solubility, this indicates that the value is not limiting

[α]Alpha particle; [β]Beta particle

[a]Minimum inventory of all constituents except cadmium and PCE was estimated from values in SNL (1993); maximum value was assumed to be twice the minimum value. Cadmium inventory was estimated from measured soil concentrations (Peace et al., 2002) and maximum simulated penetration depth (120 feet) of coolant water potentially carrying the cadmium (Wolford, 1997). PCE inventory is estimated from measured soil-gas concentrations (Peace et al., 2002); the maximum measured gas concentration (5,900 ppb) was used as a minimum value in a uniform distribution increasing to ten times this value (calibrated to available data). The maximum areal extent of the MWL was used (430 feet x 300 feet) along with an uncertain thickness ranging from 10-27 feet (see Table 3 for waste-zone description).

[b]Lide (2005); half-life of PCE is assumed to range from 9 months (EPA fact sheet: www.epa.gov/OGWDW/dwh/t-voc/tetrachl.html) to 10^{10} yrs (no degradation)

[c]Specific activity is calculated as 3.575×10^5/(half-life (yrs) x molecular weight)

[d]U.S. EPA (1999), Sheppard and Thibault (1990), Looney et al. (1997), EPA fact sheet: www.epa.gov/OGWDW/dwh/t-voc/tetrachl.html

[e]Looney et al. (1997), Chen et al. (2002), Ohe et al. (2002), Elless and Lee (1998), BSC (2005), and EPA Online Fact Sheets (www.epa.gov/safewater/dwh/t-ioc/cadmium.html; www.epa.gov/safewater/dwh/t-ioc/lead.html). Based on the maximum inventory and minimum waste volume possible, the solubility may potentially limit the maximum aqueous source concentration for radium-226, thorium-232, uranium-238, and lead; all other constituents are not limited by the solubility.

[f]Whelan et al. (1996), Smiles et al. (1995), Rogers et al. (1994), U.S. NRC (1989), Reid et al. (1987)

[g]Rogers et al. (1984), U.S. NRC (1989), Smiles et al. (1995), steam tables, and EPA's online Henry's Constant calculator (www.epa.gov/athens/learn2model/part-two/onsite/esthenry.htm)

[h]U.S. EPA (1988)

Table 3. Summary of input parameters and distributions for the waste zone.

Input Parameter	Value or Distribution	Basis and Comments
Waste-Zone Length [m]	Uniform 3.05 – 131	Minimum value determined by size of individual pit (10'). Maximum value determined by extent of Mixed Waste Landfill.
Waste-Zone Width [m]	Uniform 3.05 – 91.4	Minimum value determined by size of individual pit (10'). Maximum value determined by extent of Mixed Waste Landfill.
Waste-Zone Thickness [m]	Uniform 3.05 – 8.23	The thickness of the waste zone for all constituents except for cadmium is based on the depth of the trenches and pits, which range from 3 – 8 m (10 – 27 feet). The thickness of the cadmium contamination zone is assumed to be equal to 36.6 m (120 feet), which is the maximum simulated penetration depth of the coolant water that may have carried the cadmium (Wolford, 1997).
Thickness of Cover and Clean Overburden [m]	Uniform 0 – 4.88	Minimum value is assumed to be zero due to erosion.[a] Maximum value is based on maximum thickness of the cover at various locations (Peace et al., 2005).

[a]The intent is to maintain the integrity of the cover at the MWL. Complete erosion of the cover is a conservative bounding assumption for modeling purposes.

Table 4. Summary of input parameters and distributions for the vadose zone.

Input Parameter	Value or Distribution	Basis and Comments
Thickness of Vadose Zone[a] [m]	Uniform 133 - 148	Thickness of the vadose zone for all constituents except for cadmium is based on measured depths to the water table. The depth to the water table from the surface ranges from 141 – 151 m (461 - 495 feet) (Goering et al., 2002). The range of vadose-zone thicknesses accounts for the waste-zone thickness. For cadmium, the thickness is assumed to be 104 m (461 – 120 = 341 feet).
Infiltration Rate [m/s]	Uniform 1.18×10^{-11} – 6.12×10^{-11}	Minimum value based on infiltration through 2 ft of engineered cover under current climate (Peace and Goering, 2005); maximum value based on two times the current maximum precipitation in a natural analog vegetative cover to account for future climates (Waugh, 1997; Menking et al., 2004).
Saturated Hydraulic Conductivity [cm/day]	Log-Normal Mean log: 1.039 S.D. log: 0.705 Upper bound: 173 Lower bound: 0.38	Peace et al. (2003)
Porosity [-]	Uniform 0.302 – 0.445	Peace and Goering (2005)
Volumetric Moisture Content [-]	Uniform 0.053 – 0.225	Peace and Goering (2005)
Longitudinal dispersivity [m]	0.1 times the travel distance (vadose-zone thickness)	Based on field data reported in Gelhar et al. (1992). This is used in the FRAMES/MEPAS models for liquid transport to the groundwater.
Liquid-Phase Tortuosity Factor [-]	Uniform 0.001 – 1	Lower bound based on formulation of Millington (1959); upper bound is physical limit. This is used in the tritium and PCE models.
Gas-Phase Tortuosity Factor [-]	Uniform 0.1 – 1	Lower bound based on formulation of Millington (1959); upper bound is physical limit. This is used in the tritium and PCE models.

[a]Used only in FRAMES/MEPAS. For all other models, the depth to the water table (141-151 m) is used.

Table 5. Summary of input parameters and distributions for the biosphere.

Input Parameter	Value or Distribution	Basis and Comments
Atmospheric Boundary Layer Thickness [m]	Uniform 0.001 – 1	Minimum is based on values reported by Jury et al. (1983). Maximum is a conservative upper value.
Vertical Atmospheric Mixing Length [m]	2	Conservative value to encompass volume occupied by a human (Yu et al., 1993).
Average Wind Speed [m/s]	3.63	Average value based on seven years of site data (SNL Site Environmental Monitoring Reports 1990-1996).
Inhalation Rate [m^3/day]	20	U.S. EPA (1991)
Water Intake [L/day]	10	Conservative estimate to account for drinking water and indirect ingestion or absorption via plants, animals, showering, etc. Recommended value for drinking water is 2 L/day (U.S. EPA, 2000).
Distance to Receptor [m]	0	The point of compliance for groundwater concentrations is assumed to be at the boundary of the landfill. Receptor is assumed to be located adjacent to landfill for inhalation, and water used for drinking, irrigation, etc. is assumed to be drawn from the aquifer directly beneath the MWL.

Key Assumptions:

The key assumptions regarding the models and input parameters used in the performance assessment of the MWL are summarized below:

- Receptor located adjacent to MWL
    - Tritium dose caused by continuous inhalation and exposure of tritium flux directly above MWL.
    - Groundwater dose calculated based on concentrations in aquifer directly beneath MWL. Water intake assumed to be 10 L/day (five times EPA standard of 2 L/day for drinking water).
- Maximum waste inventory set equal to twice estimated values based on historical records.
- Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor for radon-222 allowed to increase).
- Cover allowed to completely erode in 1,000 years.
- 1-D model: yields maximum transport to surface and groundwater.
- Bounding tortuosity coefficients: yields maximum diffusion rates.

3.4 Water Infiltration through the Cover

Infiltration of water through a proposed soil cover for the MWL was modeled using the one-dimensional, numerical code UNSAT-H (Peace and Goering 2005). UNSAT-H is a Richards' equation-based model that simulates infiltration, unsaturated flow, redistribution, evaporation, plant transpiration, and deep infiltration of water. The modeling was conducted in 2003 and 2004 using site-specific climate, hydrologic, and vegetation input parameters. The modeling results corroborated the results from earlier modeling studies presented in Section 5.3 of the MWL Corrective Measures Implementation Plan. Complete modeling input parameters, boundary conditions, and results are discussed in Peace and Goering (2005).

One of the objectives of the modeling was to assess whether the proposed 3-ft cover will meet the EPA-prescribed technical equivalency criteria. The EPA performance-based, technical equivalency criteria used in this study are 31.5 millimeter (mm)/year (yr), or less, for net annual infiltration and 1×10^{-7} centimeter (cm)/second (s) average infiltration rate, based on a hydraulic conductivity of 1×10^{-7} cm/s and the assumption of constant unit gradient conditions. The modeling results demonstrate that the proposed 3-ft MWL cover will meet the EPA-prescribed technical equivalency criteria for RCRA landfills under both present and future conditions.

3.4.1 Model Description

The modeling study was formulated in one dimension, vertically, and was discretized by placing computational nodes at predetermined vertical spacing in a conceptual soil profile to evaluate the performance of a cover 3 ft in thickness. Figure 3 shows a cross-section of the conceptual soil profile and its numerical discretization. A total of 30 nodes were used to discretize a conceptual soil profile 6 ft in thickness. A thickness of 6 ft is used so that the overlying nodes of interest are not adversely impacted by the lowermost boundary conditions.

The conceptual soil profile was simulated as a lithologic monolayer. A soil profile with uniform soil and hydrologic properties translates into a significant conservative estimate of liquid water flow. If multiple layers are simulated, the water potential in the underlying layer must equal the water potential in the overlying layer before flow into the lower layer occurs. Multiple layering in performance modeling as well as multiple layers in nature attenuate the downward flow of liquid water (e.g., multiple capillary barriers). UNSAT-H input parameters for the cover are summarized in Table 6-1 in Peace and Goering (2005). All parameters are site-specific and were carefully measured to obtain the most accurate estimate of infiltration possible.

Climatic data represent the site-specific conditions to the maximum extent possible. The historical rainfall record from Albuquerque International Sunport, dating from 1919 to 1996, was used to input precipitation and simulate infiltration through the cover. Two discrete sets of precipitation data were compiled from the historical record. The first data set, the "historical precipitation data," included 65 years of daily rainfall recorded from 1932 to 1996. The second data set, the "maximum precipitation data," included the 8 heaviest years' rainfall recorded between 1919 and 1996, repeated 8 times for a total of 64 years. The heaviest rainfall years were 1919, 1929, 1940, 1941, 1982, 1986, 1988, and 1992. These maximum precipitation data represent a climate change of 50% more precipitation overall (1.5 times the current level).

Precipitation during these years ranged from 12 in. to over 15 in. The current average annual precipitation for the Albuquerque area is 8.65 in./yr.

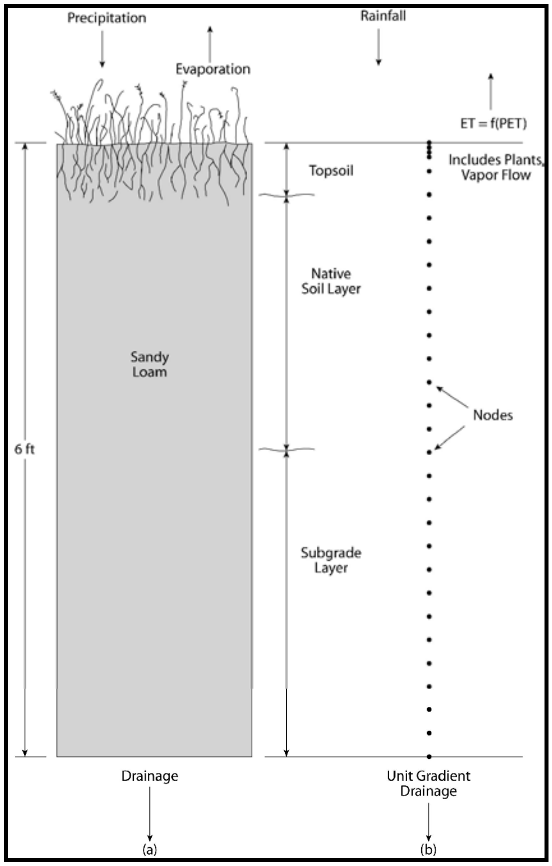

Figure 3. (a) Conceptual model for infiltration model. (b) Nodal discretization in UNSAT-H.

Literature evidence suggests that wetter conditions probably occurred during the last glacial episodes in the Southwest. Studies of paleoclimate during the Last Glacial Maximum suggest that precipitation in the Estancia basin, located west of the Manzano Mountains, nearly doubled relative to modern levels during brief, decade- to century-long episodes of colder and wetter climate (Menking et al. 2004). Farther west, studies of floral assemblages in late Pleistocene packrat middens near Yucca Mountain, Nevada, indicate that precipitation was an estimated 2.4 times modern levels during the Last Glacial Maximum (Menking et al. 2004).

Because precipitation in the southwest may have been significantly higher in the past, a precipitation multiplier of 2X was used to estimate maximum infiltration levels in the future through the MWL cover. A polynomial extrapolation of infiltration was developed using the results from modeling the “historical precipitation data” and the “maximum precipitation data”, and assuming that hydrologic properties of the cover are at equilibrium with the natural system.

Plant transpiration is the primary mechanism in removing water from a cover. Without plants, covers would only depend on evaporation to remove water from the soil profile. Vegetative input for the UNSAT-H code included root depth, root length density, leaf area index, growing season, and percent bare area. Root depth, root length density, leaf area index, growing season, and percent bare area for a climax community were measured in the field (Peace and Goering, 2005).

3.4.2 Model Results

The UNSAT-H code simulated infiltration through a soil cover with a climax community of native vegetation. The range of average infiltration rates for the MWL was predicted under current and future climate conditions. For both the current and future scenarios, the estimated infiltration rates through a 2-ft cover rather than a 3-ft cover were used to be conservative, as the model predicted infiltration through a 3 ft cover to be slightly negative, i.e. a net upward flux (Peace and Goering 2005).

Under present climate conditions, the model predicted the average infiltration rate through the proposed MWL cover to be 1.18 X 10^{-9} cm/s for the historical precipitation scenario and 5.34 X 10^{-9} cm/s for the maximum precipitation scenario.

Under future climate conditions, the properties of the MWL cover soils will gradually revert towards those of the natural soils around the landfill, as the bulk density and porosity of the soil equilibrate with natural conditions. Under these conditions, the model predicted the average infiltration rates to be 2.44 X 10^{-10} cm/s for the historical precipitation scenario and 1.04 X 10^{-9} cm/s for the maximum precipitation scenario.

Since the maximum precipitation scenario represents a 50% increase in precipitation over the historical precipitation scenario, a polynomial regression for infiltration as a function of precipitation can be determined (assuming that zero infiltration occurs with zero precipitation). We assign a normalized precipitation value of one to the historical precipitation scenario and a value of 1.5 to the maximum precipitation scenario. The quadratic regression then allows extrapolation to future climates where the precipitation is expected to be twice as high as present values. If the future precipitation is twice as high as current precipitation, the precipitation multipliers will increase to 2X for the historical scenario and 3X for the maximum scenario. Applying these multipliers to the quadratic regression yields estimated future infiltration rates of 2.29 X 10^{-9} cm/s for the historical precipitation scenario and 6.12 X 10^{-9} cm/s for the maximum precipitation scenario (Figure 4). We use 6.12×10^{-9} cm/s as an upper bound for the infiltration distribution to represent maximum precipitation conditions in the future, and we use 1.18×10^{-9} cm/s as a lower bound for the infiltration distribution to represent current precipitation conditions with the engineered cover design.

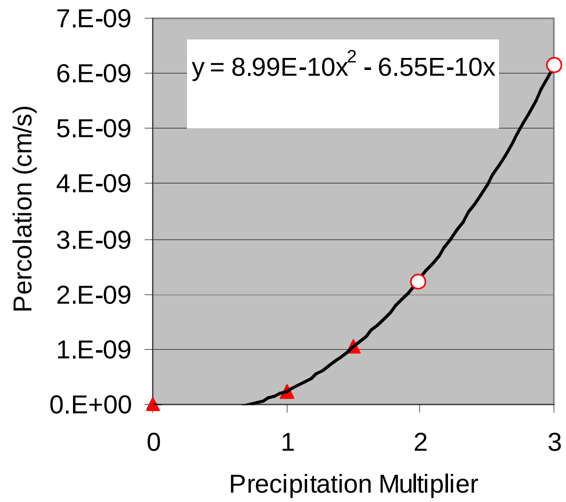

Figure 4. Polynomial regression used to estimate future infiltration values as a function of precipitation multipliers. Triangles denote simulated values; circles denote extrapolated values.

In summary, the modeling results demonstrate that the proposed 3-ft soil cover will meet the EPA-prescribed technical equivalency criteria for both present and future climate conditions, even if precipitation is significantly higher. The EPA performance-based, technical equivalency criteria are 31.5 mm/yr or less for net annual infiltration and 1 x 10^{-7} cm/s average infiltration rate, based on a hydraulic conductivity of 1 x 10^{-7} cm/s and the assumption of constant unit gradient conditions. Predicted average infiltration rates through the MWL cover are expected to range from 1.18 X 10^{-9} cm/s for present conditions to 6.12 X 10^{-9} cm/s for future conditions, under the assumption of significantly higher precipitation. These infiltration rates are considerably lower than the EPA performance-based, technical equivalency criterion of 1 x 10^{-7} cm/s.

3.4.3 Summary of Key Results and Assumptions

- Simulations of infiltration through the engineered cover at the MWL show that the net annual infiltration will be less than the regulatory metric of 10^{-7} cm/s.
- Predicted average infiltration rates through the MWL cover are expected to range from 1.18 X 10^{-9} cm/s for present conditions to 6.12 X 10^{-9} cm/s for future conditions.
- Key Assumption:
    - Predicted range of infiltration rates was based on simulated infiltration averaged over 64 years of data (as opposed to selected annual or daily averages).

3.5 Fate and Transport of Tritium

3.5.1 Model Description

As described in Section 3.2.2, the fate and transport of tritium was simulated using a model that accounts for transient liquid advection, gas diffusion, and decay (Jury et al., 1983; Jury et al., 1990). The upper boundary condition at the surface allowed for gas-phase transport of tritium to the atmosphere across a prescribed (uncertain) boundary-layer thickness. The concentration at the bottom of the model was specified as zero infinitely far away from the source.

The initial inventory of tritium was estimated from past records (SNL, 1993), and the extent of the contaminated waste zone was allowed to vary from the size of an individual pit to the entire size of the MWL. The inventory was allowed to vary between the estimated value (as a lower bound) and an upper bound equal to twice the estimated value. The simulations were run until tritium concentrations decreased to negligible values in the system. One hundred realizations were used in the simulations.

3.5.2 Model Results

3.5.2.1 Comparison to Field Data

In 1990 and 1993, measurements of tritium at the surface and at locations in the subsurface were measured at the MWL (Johnson et al., 1995). These measurements were used as a reference to check the simulated results of the model. Figure 5 shows the simulated tritium surface flux as a function of time for 100 realizations. The minimum and maximum measured tritium surface flux values taken in 1993 are also shown in the figure. The measured values are shown spanning 5 to 33 years because the actual time elapsed since the tritium was emplaced is uncertain. Emplacement of waste at the MWL began in 1960 and ended in 1988; therefore, the measured values sampled in 1993 could have occurred between 5 and 33 years after emplacement. Results show that the simulated results during this span of time are either within or above the measured bounding values. Figure 6, Figure 7, and Figure 8 show similar plots and results for different locations in the subsurface. In most cases, the simulated fluxes and concentrations are higher than the measured values. These results and comparisons provide evidence that the models can provide realistic values for the simulated outputs. In addition, the comparisons confirm that the model is producing conservatively high results for surface fluxes and subsurface concentration because of the conservative values and distributions used for the model parameters.

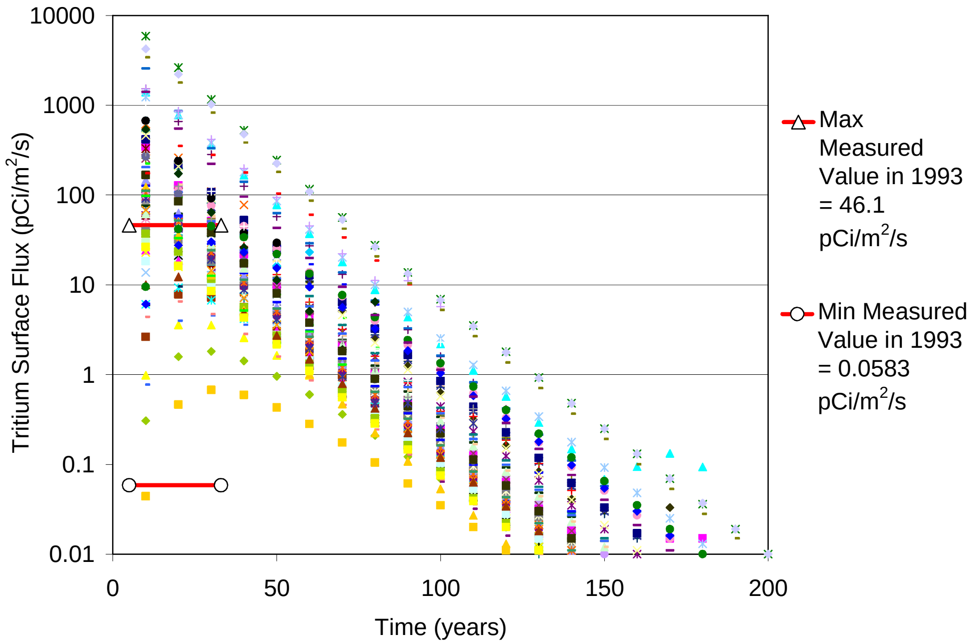

Figure 5. Comparison of simulated tritium surface flux as a function of time for 100 realizations with range of measured values in 1993.

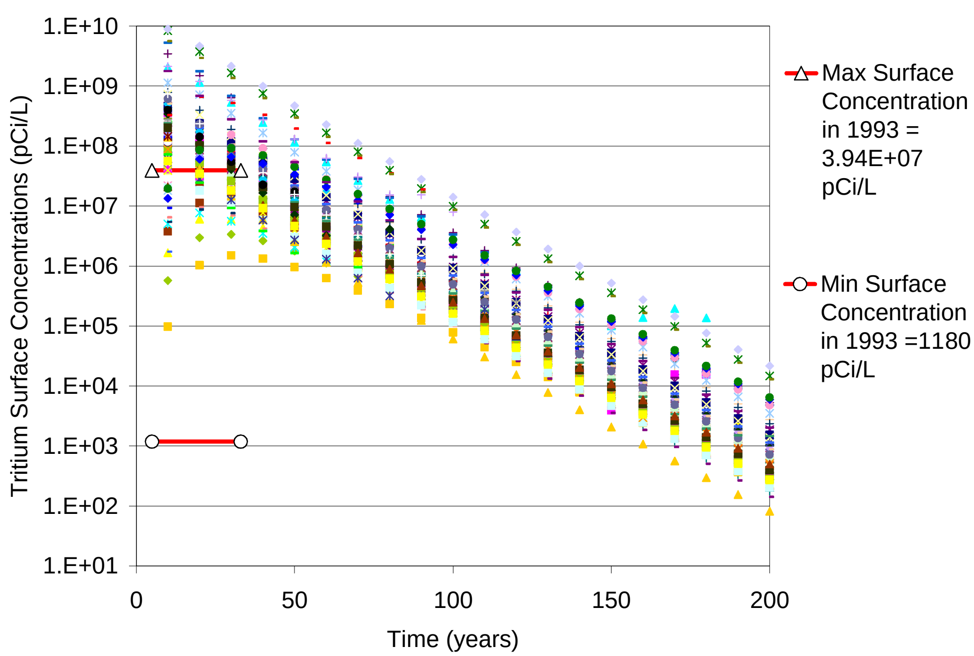

Figure 6. Comparison of simulated tritium surface concentration as a function of time for 100 realizations with range of measured values in 1993.

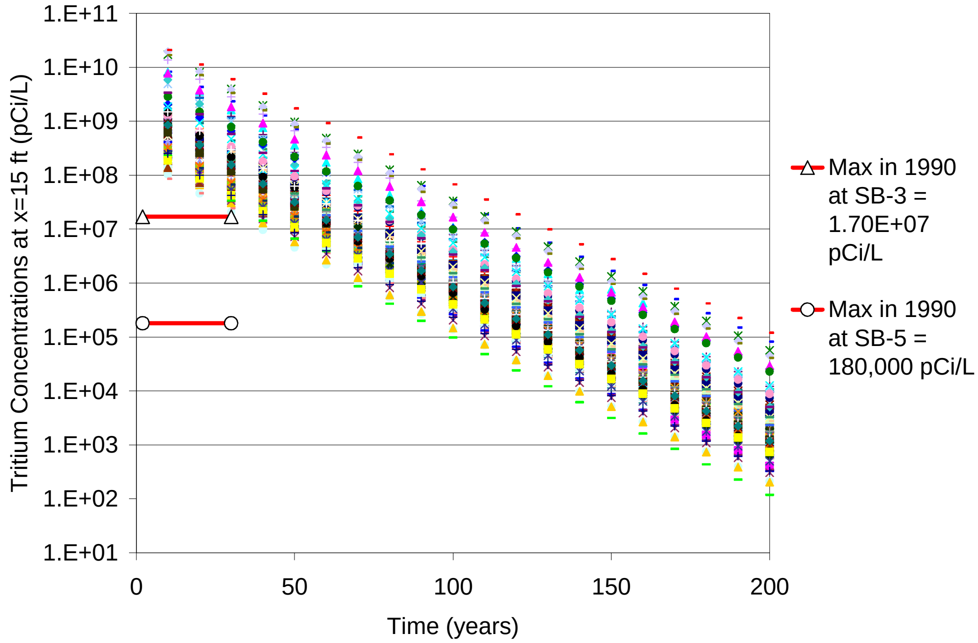

Figure 7. Comparison of simulated tritium concentration at a depth of 15 feet as a function of time for 100 realizations with measured maximum values in 1990.

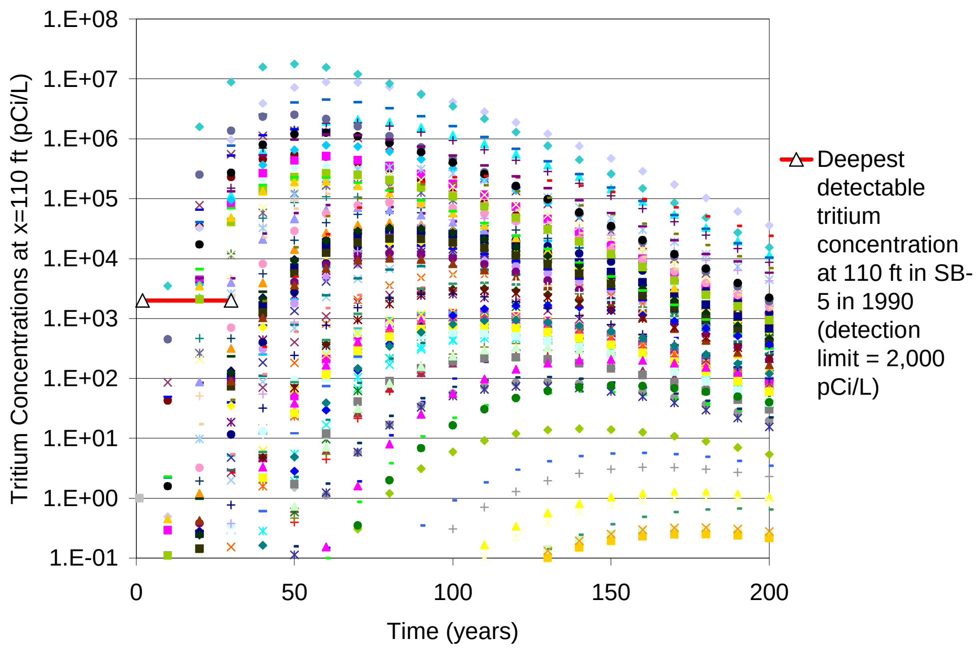

Figure 8. Comparison of simulated tritium concentration at a depth of 110 feet as a function of time for 100 realizations with measured value in 1990.

3.5.2.2 Comparison to Performance Objectives

The simulated tritium concentrations reaching the groundwater are shown in Figure 9 for all 100 realizations as a function of time. The peak tritium groundwater concentrations are all small, and Figure 10 shows the cumulative probability of the peak concentrations for 100 realizations and 200 realizations. The results show that the simulated tritium groundwater concentrations are all well below 20,000 pCi/L. In addition, the distribution resulting from 100 realizations is nearly the same as the distribution resulting from 200 realizations (therefore, all subsequent analyses only use 100 realizations).

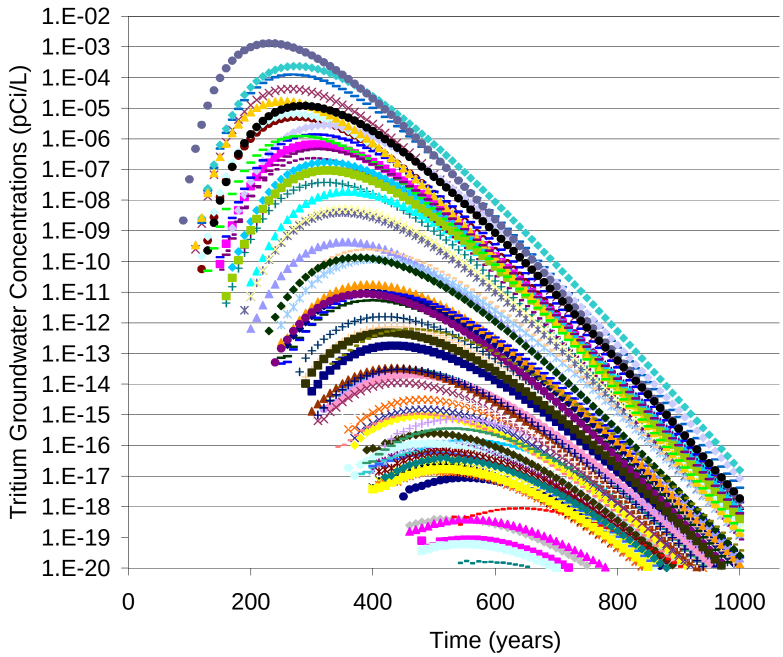

Figure 9. Simulated tritium concentrations in the aquifer as a function of time for 100 realizations.

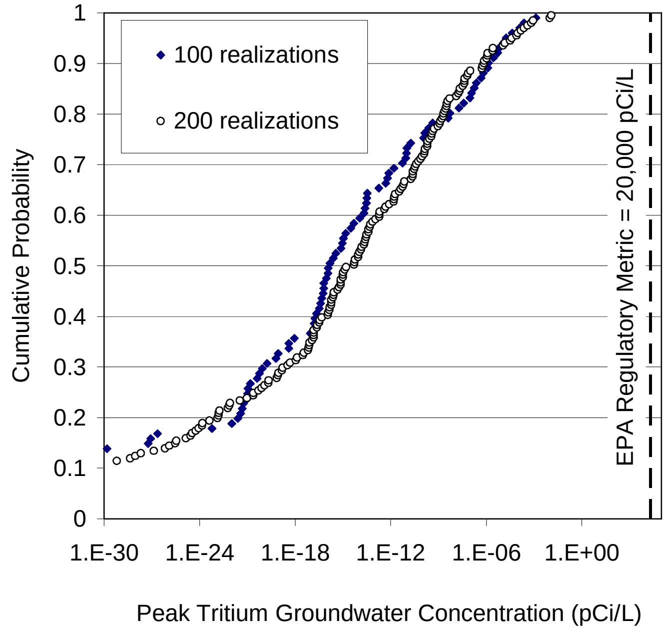

Figure 10. Cumulative probability for simulated peak tritium groundwater concentrations using 100 and 200 realizations.

Figure 11 shows the cumulative probability for the simulated peak tritium dose via groundwater, which is calculated based on the simulated aquifer concentrations and a conservative water intake of 10 L/day (accounts for drinking water, indirect ingestion via plants and animals, absorption and inhalation via showering, etc.). The results shows that all realizations are well below the EPA metric of 4 mrem/year.

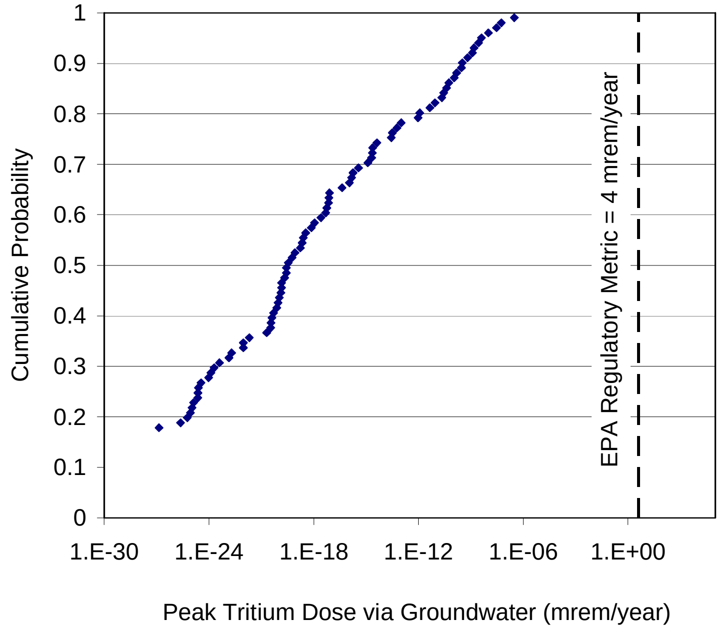

Figure 11. Cumulative probability for simulated peak tritium dose via the groundwater pathway using 100 realizations.

Figure 12 shows the cumulative probability for the simulated peak tritium dose via the air pathway for 100 realizations. The simulated dose due to inhalation (and skin absorption) is based on the concentration of gas-phase tritium immediately above the MWL. The average wind velocity, vertical mixing length, and surface flux of tritium are used to calculate the air concentration above the MWL, and the inhalation rate is used to calculate the intake (Table 5). The dose conversion factor (Table 1) is then used to calculate the dose rate. Because the simulated surface flux of tritium for several realizations was quite high (Figure 5), a small percentage (~2%) of the realizations yield a dose via the air pathway that exceeds the EPA metric of 10 mrem/year.

It should be noted, however, that Figure 5 shows the peak tritium surface fluxes occurring before 50 years due to the natural decay of tritium. The simulated maximum surface concentrations of tritium that yielded the peak fluxes are on the order of 10^{10} pCi/L. If measured values of tritium vapor concentrations at the surface over the next few decades are not shown to increase from previously measured values, which are several orders of magnitude less than maximum simulated values, the dose due to tritium via the air pathway is not likely to be exceeded.

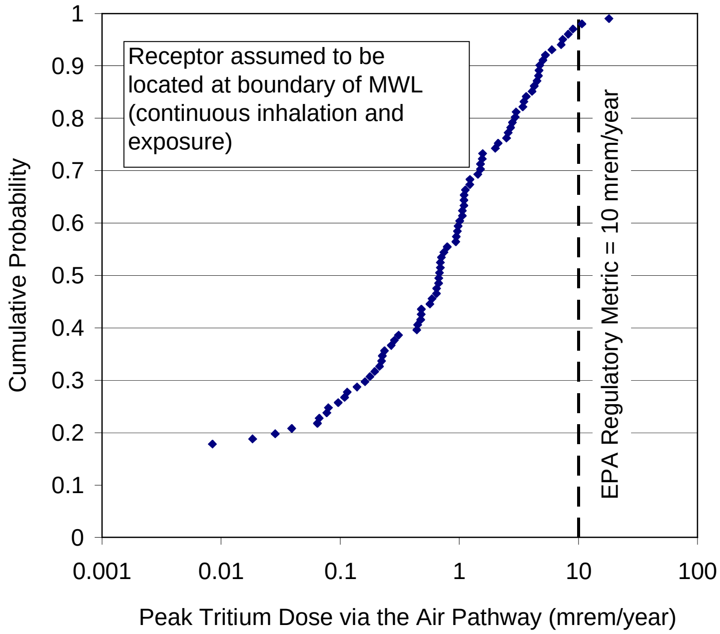

Figure 12. Cumulative probability for simulated peak tritium dose via the air pathway for 100 realizations.

3.5.2.3 Sensitivity Analysis

A sensitivity analysis (as described in Section 2.2.1) was performed to determine the parameters that were most important to the simulated performance metrics of aquifer concentration and inhalation dose. Figure 13 presents a chart that summarizes the results of the stepwise linear rank regression analysis. All of the uncertain input variables summarized in Table 2 through Table 5 relevant to tritium transport were evaluated, but only the most important input variables are shown in Figure 13. The ΔR^2 values in Figure 13 provide a measure of the incremental contributions from each input variable to the variability in the simulated performance metric. For example, the uncertainty in the liquid-phase tortuosity accounts for about 60% of the variability in the simulated tritium aquifer concentration

The sensitivity of the inhalation dose to liquid-phase tortuosity and moisture content indicates that the transport of tritium is dependent on upward diffusion through the liquid phase as well as the gas phase. A conservative upper bound for the liquid- and gas-phase tortuosity coefficients was implemented in this study (Table 4) to account for the possible effects of enhanced vapor diffusion (Ho and Webb, 1998). The dependence on cover thickness and atmospheric boundary-layer thickness indicates that the inhalation dose is also dependent on the upper boundary conditions of the landfill. Therefore, the thickness and integrity of the cover should be monitored and maintained to mitigate tritium migration to the surface. Finally, although not included as an uncertain parameter, the location and disposition of the receptor played an

important role in the simulated inhalation dose. In this study, the receptor was assumed to be located adjacent to the MWL, continuously inhaling air directly above the MWL (24 hours a day, 365 days a year). If the receptor were located further away from the site, or if the exposure were not continuous, the simulated dose via the air pathway would be considerably less.

The variability of the tritium aquifer concentration is shown to be dependent on the liquid-phase mobility parameters, indicating that diffusion of liquid-phase tritium is important. A separate ("one-off") sensitivity analysis of infiltration revealed that the infiltration would have to be increased by several orders of magnitude (close to the saturated hydraulic conductivity of the vadose zone) in order for the tritium to reach substantial concentrations in the groundwater.

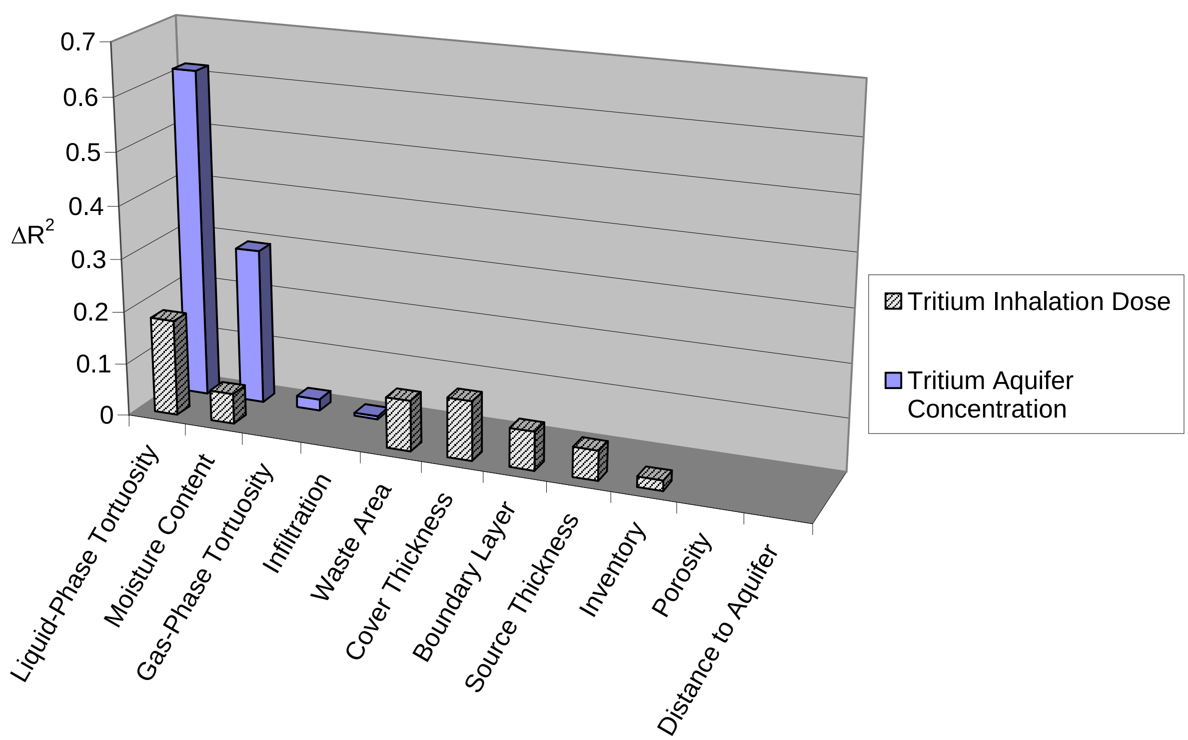

Figure 13. Analysis of sensitivity of simulated tritium inhalation dose and aquifer concentration to uncertain input parameters.

3.5.3 Summary of Key Results and Assumptions

- All simulated realizations of tritium aquifer concentration and dose via the groundwater pathway were well below the regulatory metrics of 20,000 pCi/L and 4 mrem/year, respectively.

- A small percentage (2%) of the simulated dose due to tritium via the air pathway exceeded the regulatory metric of 10 mrem/year.

- Parameters impacting tritium diffusion through both the liquid and gas phases (e.g., tortuosity coefficient, moisture content, cover thickness, atmospheric boundary-layer thickness) were found to be important to the simulated inhalation dose.

- Key Assumptions:

    - Receptor located at MWL; continuous inhalation and exposure of tritium flux from subsurface
    - Cover allowed to erode completely
    - 1-D model: maximum transport to surface
    - Bounding tortuosity coefficients: maximum diffusion rate
    - Maximum waste inventory set equal to twice estimated value of 2,400 Ci

3.6 Fate and Transport of Radon

3.6.1 Model Description

Section 3.2.3 and Appendix A describe the steady-state radon transport model that was developed for this study. Diffusion, advection, and decay of radon is included in the model. A constant generation of radon is assumed to occur in the prescribed waste zone, which can vary in size. A significant difference between the current model and previous models of radon transport in geological media (see, for example, Rogers et al., 1984) is the nature of the radium-226 source. In previous studies, the radium-226 originated from ore deposits containing uranium. At the MWL, pure radium-226 was disposed of in sealed containers. Therefore, the overall concentration of radium-226 can be much higher in the current analysis, but the emanation factor, *E*, which governs how much radon-222 gas can be released from the radium-226, can be significantly lower because of the containment. Generally speaking, the integrity of radioactive sealed sources is very robust. The radium-226 sealed sources disposed of in the MWL were most likely fabricated according to design standards that required tests to evaluate the integrity of the sources subject to extreme temperature, impact, pressure, and vibration (see, for example, 10 CFR 39.41). Radon-222 originating from uranium-238 was not considered in the radon-transport model because the activity of radium-226 (parent of radon-222) resulting from the decay of uranium-238 is negligible (15 microCuries after the first 1,000 years) relative to the radium-226 activity assumed in the model (6-12 Curies). However, radon-222 was included as a decay product of uranium-238 in the FRAMES/MEPAS liquid-phase transport simulations of the radionuclides (see Section 3.7.2.2).

3.6.2 Model Results

3.6.2.1 Comparison to Field Data

Radon surface fluxes at the MWL were measured in 1997 (Haaker, 1998). A total of 89 four-inch-diameter activated charcoal radon canisters were used to evaluate the radon surface fluxes in the vicinity of the MWL, as well as background values. Results showed that the measured radon fluxes above the MWL were not significantly different than the background values. The median flux in the vicinity of the MWL was 0.33 pCi/m^2/s while the median background flux was 0.35 pCi/m^2/s. The maximum measured fluxes for the MWL and background were 1.02 and 0.664 pCi/m^2/s, respectively. This difference in maximum values was used to calibrate the emanation factor in the radon transport model. The emanation factor governs how much radon is released to the immediate surroundings from the radium-226 source. A factor of zero represents no emission (complete containment), and a factor of one represents total emission (no containment).

The potential sources of radon-222 (radium-226) were sealed and contained, and the sealed sources were likely tested for integrity before disposal in the MWL. Therefore, the containment is assumed to be generally intact at present, but defects or breaks may still be present. The minimum emanation factor, which accounts for present-day emissions, was adjusted to yield a radon flux between 0.1 and 1 pCi/m^2/s (equivalent to the difference in maximum measured and background fluxes). The resulting minimum emanation factor used in the probabilistic simulations was 10^{-6}. The maximum emanation factor was estimated based on the possibility that the sealed containers may degrade in the future. The integrity of the containers is expected to last well beyond 1,000 years, but an upper value of the emanation factor was set equal to 0.01 to represent the possibility that 1% of the containers will completely degrade within 1,000 years. An evaluation was also performed assuming that the maximum emanation factor was equal to one, which is equivalent to complete degradation of the containment of all the radon sources within 1,000 years. A log-uniform distribution between 10^{-6} and the maximum value was used for the emanation factor.

3.6.2.2 Comparison to Performance Objectives

Figure 14 shows the cumulative probability for the simulated peak radon-222 surface flux for 100 realizations. For the scenario with a maximum emanation factor of 0.01 (1% of the radon-source containers degrades completely), the results show that 97% of the simulated radon surface fluxes are below the design standard of 20 pCi/m^2/s (3% of the realizations yield radon surface fluxes that exceed the design standard). In the bounding scenario, where we allow all of the containment of the sealed sources to completely degrade, nearly 30% of the realizations exceed the design standard of 20 pCi/m^2/s. As shown in the sensitivity analysis in the next section, the large uncertainty in the emanation factor allowed significant variations in the simulated radon surface flux. It is unlikely that the sealed sources and containers for radium-226 will degrade significantly over the next few hundred years, but because the half-life of radium-226 and uranium-238 is extremely long, radon-222 will continue to be generated from these parent products indefinitely. Therefore, degradation of the containers may eventually cause the emanation factor for radon-222 to increase at some point in the future. For a 1,000-year

evaluation period, however, the probability of exceeding the radon surface-flux design standard is very small if the sealed sources and containers do not degrade significantly and the emanation factor remains below 0.01.

Simulated radon concentrations in groundwater were negligible ($<10^{-20}$ pCi/L). The short half-life of radon (3.8 days) and the large thickness of the vadose zone prohibit radon from migrating significant distances to the water table when the source originates from the landfill. However, in Section 3.7, small amounts of radon are shown to reach the groundwater after 10,000 years when radon is included as progeny of uranium-238, which is fairly mobile (relative to the other non-volatile radionuclides). This effectively mobilizes the source of radon toward the groundwater. However, the decay chain for uranium-238 to radium-226 to radon-222 is an extremely long process (billions of years). Therefore, the amount of radon-222 produced from uranium-238 in 1,000 years is extremely small; no radon-222 is simulated to reach the groundwater in 1,000 years, even when it is included as progeny of uranium-238.

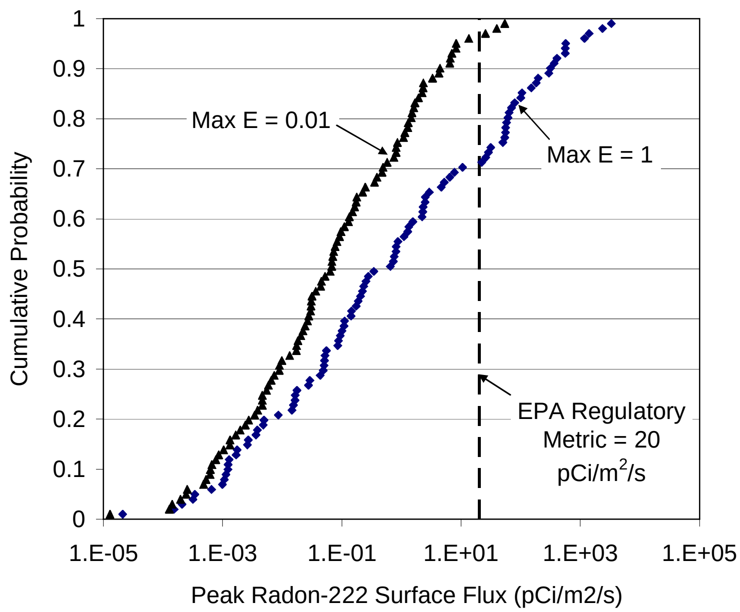

Figure 14. Cumulative probability for simulated peak radon-222 surface flux for 100 realizations using two different maximum values for the emanation factor, E.

3.6.2.3 Sensitivity Analysis

A sensitivity analysis (as described in Section 2.2.1) was performed to determine the stochastic input parameters that were most important to the simulated radon surface flux. Figure 15 presents a chart that summarizes the results of the stepwise linear rank regression analysis. The emanation factor was by far the most significant variable that influenced the variability in the simulated radon surface flux. The waste volume, cover thickness, and effective diffusion coefficient were also shown to be statistically correlated to the simulated radon surface flux, but to a much lower degree.

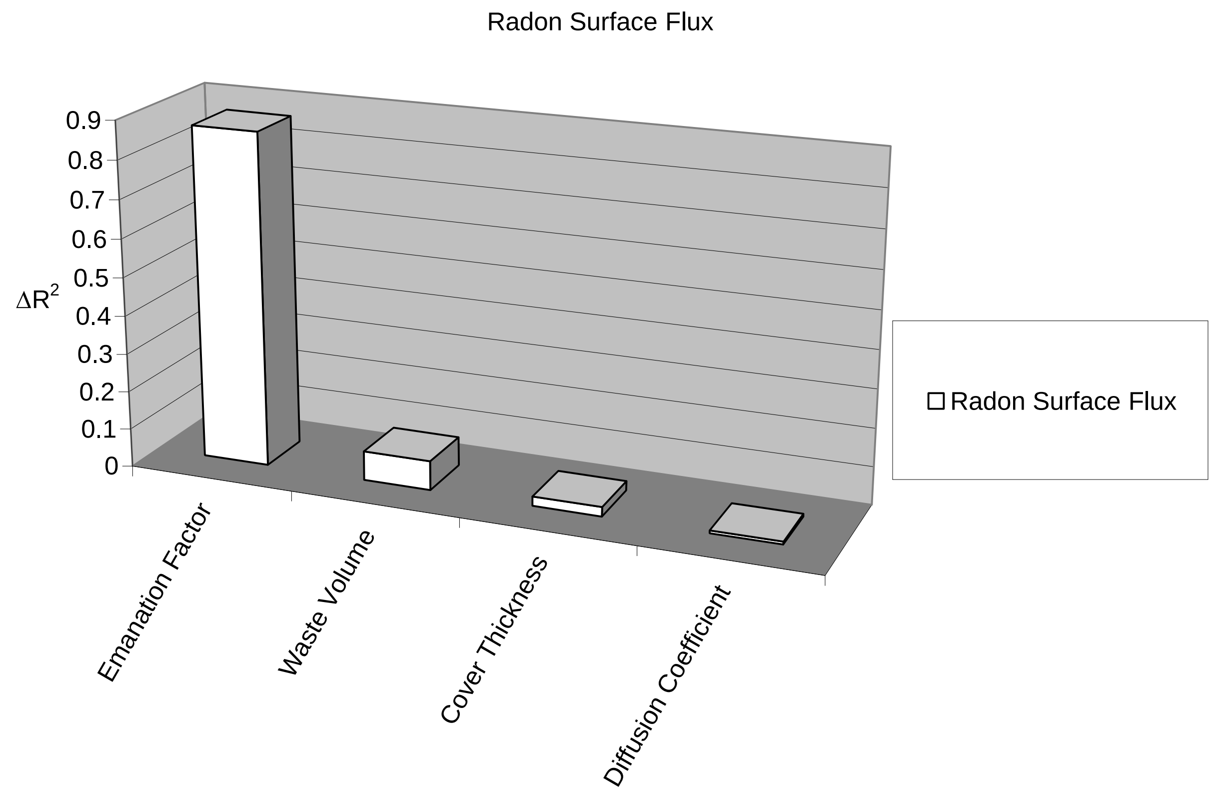

Figure 15. Analysis of sensitivity of simulated radon surface flux to uncertain input parameters.

3.6.3 Summary of Key Results and Assumptions

- Sensitivity studies show that the emanation factor, which depends on the integrity of the radium-226 containment, is important to the performance of the landfill with regard to surface radon fluxes.

- For a maximum radon emanation factor of 0.01 (1% of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard of 20 pCi/m^2/s in about 3% of the realizations. For a maximum radon emanation factor of 1 (100% of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard in about 30% of the realizations.

- Simulated radon concentrations in the groundwater were negligible.

- Key Assumptions:

  - Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor allowed to increase)
  - Cover allowed to erode completely
  - 1-D model: maximum transport to surface

3.7 Fate and Transport of Other Radionuclides

3.7.1 Model Description

The FRAMES/MEPAS source-term and vadose-zone models (see Section 3.2.1) were used to evaluate the aqueous-phase transport of the following radionuclides to the groundwater: amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, strontium-90, thorium-232, tritium, and uranium-238. Although tritium was simulated separately using the model of Jury et al. (1983, 1990), it was also included in the FRAMES/MEPAS model. Decay products of plutonium-238 (e.g., uranium-234), radium-226 (e.g., radon-222), and uranium-238 (e.g., uranium-234, radium-226) are also simulated in the FRAMES/MEPAS model (see Whelan et al., 1996).

3.7.2 Model Results

3.7.2.1 Comparison to Field Data

Other than the detection of tritium and radon in the atmosphere and subsurface as discussed in previous sections, no other radionuclides have been detected at the surface or in the subsurface beyond the extent of the landfill. The inventory for each of the radionuclides shown in Table 2 was estimated based on past records regarding the content of the MWL (SNL, 1993). The upper value for the inventory distribution of each radionuclide was conservatively assumed to be equal to twice the estimated value from past records.

3.7.2.2 Comparison to Performance Objectives

In all realizations, none of the radionuclides were simulated to reach the groundwater in 1,000 years.[4] All of the radionuclides were retarded sufficiently by adsorption to prevent significant migration in 1,000 years, even with the realistically conservative distributions used for model inputs (Table 2). In order to assess potential failure mechanisms, additional scenarios were performed.

Alternative Scenario: Increased Infiltration

First, the infiltration was increased while holding all other input parameters at fixed, conservative values. After 1,000 years, uranium (uranium-238, uranium-234) reached the groundwater when the Darcy infiltration through the vadose-zone was increased by an order of magnitude over its maximum stochastic value ($6.12x10^{-11}$ m/s) to $6.12x10^{-10}$ m/s, but the groundwater concentrations were still less than the regulatory metric of 30 μg/L. Groundwater concentrations of uranium exceeded the regulatory metric when the simulated Darcy infiltration increased by two orders of magnitude over the maximum stochastic value to $6.12x10^{-9}$ m/s.

[4] Tritium was simulated to reach the groundwater when vapor-phase transport was included in Section 3.5, but simulated tritium groundwater concentrations and dose were well below the regulatory metrics.

Alternative Scenario: Increased Simulation Period

FRAMES/MEPAS was allowed to run past 1,000 years to assess the potential travel times of the different radionuclides to the groundwater using the original distributions and parameter values (Table 2). Only uranium-238 and its decay products (uranium-234, radon-222) were simulated to reach the groundwater after ~10,000 years. The other radionuclides were retarded by their relatively large adsorption coefficients. The radon-222 that reached the groundwater was a decay product of uranium-238. As shown in previous simulations of radon originating from the waste zone (Section 3.6), radon originating from the MWL was not simulated to reach the water table because of its short half-life (3.8 days). However, since uranium-238 has a small distribution coefficient (K_d) and long half-life, a number of realizations showed that uranium-238 and some of its daughter products (uranium-234 and radon-222) could reach the water table after ~10,000 years. Although the decay of uranium-238 to radon-222 is extremely slow, some small but finite amount of radon-222 is generated from uranium-238 as it moves toward the water table. In MEPAS, the Bateman equation (Bateman, 1910) is used to estimate the relative concentrations of the daughter products as a function of the concentration of the parent, the half lives of the parent and daughter products, and the time elapsed.

Figure 16 shows the cumulative probability for simulated peak radon-222 (progeny from uranium-238) aquifer concentrations for 100 realizations after a simulated period greater than 10,000 years. Although the radon-222 reached the water table as a result of the transport of its parent product, uranium-238, the concentration of radon-222 in the groundwater is still well below the proposed limit of 300 pCi/L.

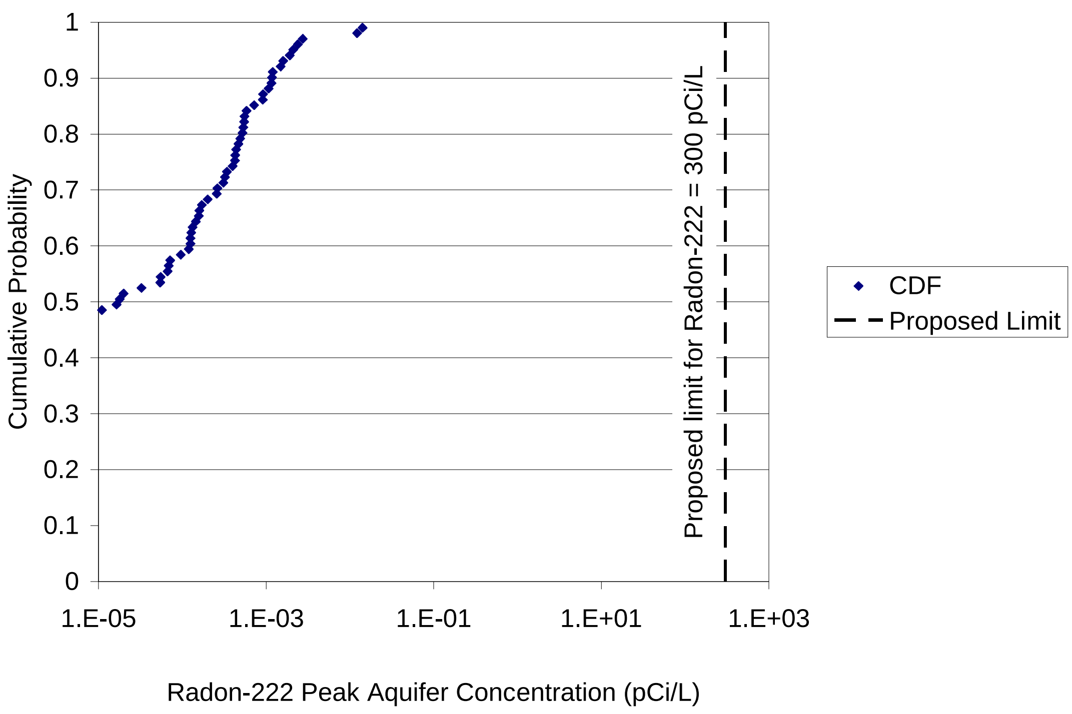

Figure 16. Cumulative probability for simulated peak radon-222 (progeny from U-238) aquifer concentrations for 100 realizations for a time period extending beyond 10,000 years.

Figure 17 shows the cumulative probability for the simulated peak uranium concentration in the groundwater for 100 realizations after a simulated time period greater than 10,000 years. The total uranium concentration is comprised of both uranium-234 (decay product of plutonium-238 and uranium-238) and uranium-238. All realizations yielded peak uranium aquifer concentrations that were less than the EPA regulatory metric of 30 μg/L.

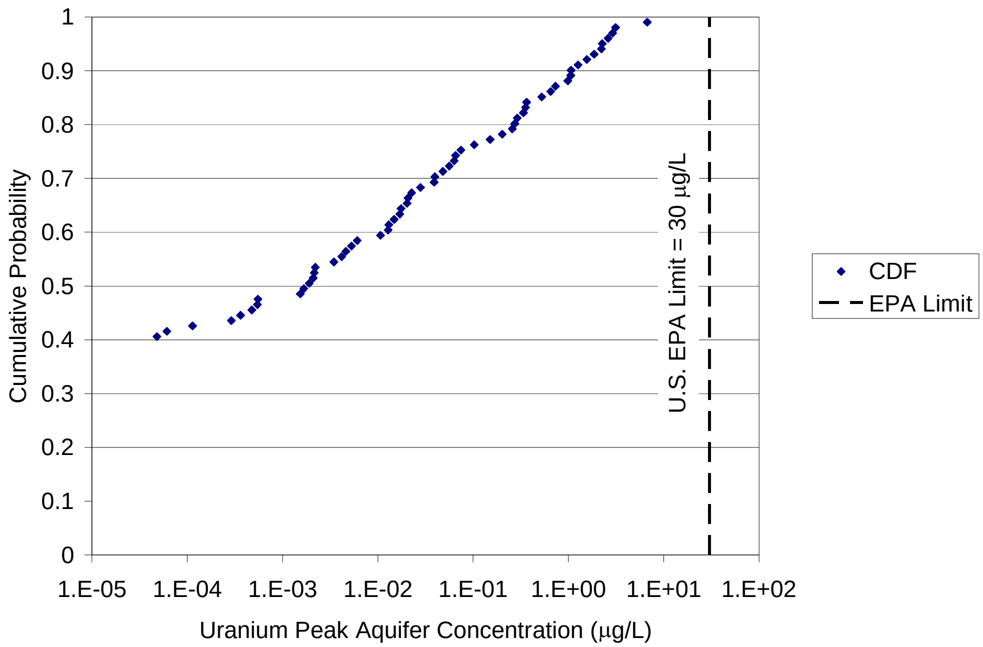

Figure 17. Cumulative probability for simulated peak uranium aquifer concentrations for 100 realizations for a time period extending beyond 10,000 years.

The total groundwater dose for extended periods of time (past 10,000 years) is calculated from the peak aquifer concentrations of uranium (uranium-234 and uranium-238) and radon. The groundwater consumption is assumed to be a conservative 10 L/day to account for drinking water, indirect ingestion through irrigation of vegetables and intake by food-producing animals, and absorption via showering. Figure 18 shows the cumulative probability for the simulated total peak groundwater dose for 100 realizations after a simulated period greater than 10,000 years. The EPA regulatory metric of 4 mrem/year (for beta particles) is shown for reference, but it does not actually apply to the primary constituents contributing to the dose, uranium-234 and uranium-238, which are alpha particles.

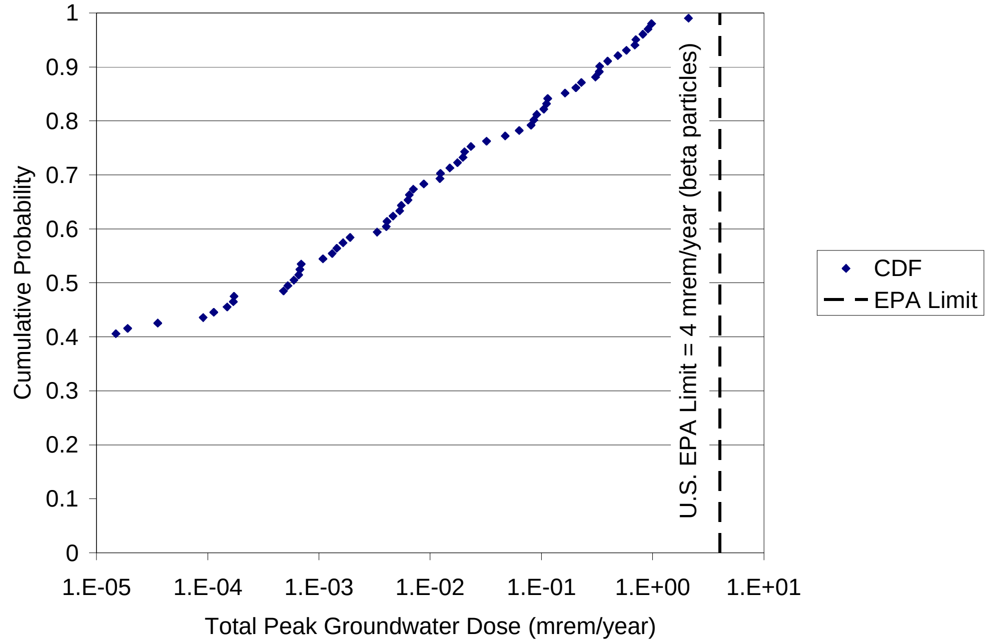

Figure 18. Cumulative probability for simulated peak groundwater dose for all radionuclides for 100 realizations for time periods extending beyond 10,000 years.

3.7.2.3 Sensitivity Analysis

Although no radionuclides were simulated to reach the groundwater within 1,000 years, sensitivity analyses were performed on the extended simulations (>10,000 years) to identify important parameters and processes (Figure 19). Sensitivity analyses show that the infiltration is the primary parameter impacting the variability in the simulated aquifer concentrations for uranium-238, its decay products (uranium-234, radon-222), and the simulated dose via groundwater. A "one-off" sensitivity analysis showed that the infiltration would have to be increased by two orders of magnitude to increase the uranium concentrations above the regulatory metric of 30 μg/L within 1,000 years. Other parameters that were found to be statistically correlated to the variability in the simulated performance metrics were waste length and width, uranium-238 K_d, and the bulk density (which, together with the K_d value, impacts the retardation).

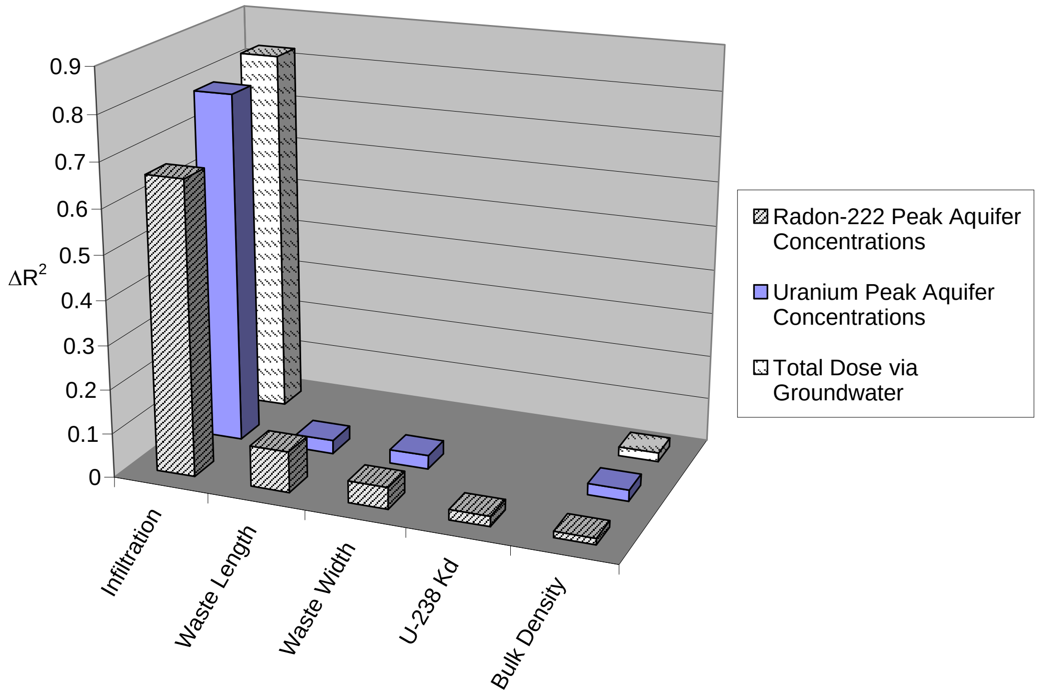

Figure 19. Analysis of sensitivity of simulated peak radon aquifer concentrations, peak uranium aquifer concentrations, and total dose via groundwater to uncertain input parameters for a time period extending beyond 10,000 years.

3.7.3 Summary of Key Results and Assumptions

- None of the radionuclides were simulated to reach the groundwater within 1,000 years for all realizations.
- Only uranium-238 (and some of its decay products) were simulated to reach the water table for extended periods (>10,000 years). All peak aquifer concentrations were still less than the EPA regulatory metric of 30 µg/L.
- Infiltration rate was found to be the most significant parameter impacting the variability in the simulated groundwater concentrations and dose via groundwater. Uranium groundwater concentrations were simulated to exceed the regulatory metric of 30 µg/L if the infiltration increased two orders of magnitude above the maximum stochastic value to 6.12×10^{-9} m/s.

- Key Assumptions:
    - 1-D model: maximum transport to groundwater
    - Receptor assumed to be located at MWL. Water intake assumed to be 10 L/d (5 times greater than EPA standards)

3.8 Fate and Transport of Heavy Metals

3.8.1 Model Description

The fate and transport of two heavy metals, lead and cadmium, were simulated using FRAMES/MEPAS (see Section 3.2.1). The inventory of lead was estimated from previous records (SNL, 1993), and uncertainty in the inventory was captured by using a uniform distribution with the estimated value as a lower bound (see Table 2). There were no records of cadmium being disposed of at the MWL, but soil samples revealed concentrations of cadmium in the subsurface (Peace et al., 2002). The maximum soil concentrations of cadmium were used with the bulk density of the soil and maximum simulated penetration of coolant water (Wolford, 1997) to estimate the mass of cadmium in the MWL. This value was then used as a lower bound in a uniform distribution (see Table 3).

3.8.2 Model Results

Neither lead nor cadmium were simulated to reach the groundwater in all 100 realizations for 1,000 years. Extended simulation periods (>10,000 years) also did not yield any breakthrough of lead or cadmium to the water table. Therefore, comparisons to the regulatory metrics of 15 μg/L and 5 μg/L for lead and cadmium, respectively, are not plotted. Both lead and cadmium have relatively large adsorption coefficients (see Table 2), which retard their transport through the thick vadose zone.

3.8.2.1 Sensitivity Analysis

A "one-off" sensitivity analysis was performed to determine the impact of infiltration on the transport of lead and cadmium while holding all other parameters at constant conservative values. Results showed that cadmium could reach the groundwater in 1,000 years and exceed its regulatory metric if the Darcy infiltration were increased by three orders of magnitude over the maximum expected infiltration, which is based on future climate scenarios (i.e., from $6x10^{-11}$ m/s to $6x10^{-8}$ m/s). Lead was simulated to reach the water table in 1,000 years if the infiltration were increased by four orders of magnitude over the maximum expected infiltration. Although this additional increase in infiltration is not expected to occur based on detailed infiltration simulations (see Section 3.4), the infiltration at the MWL should be monitored in the future. Significant increases (by several orders of magnitude or more) may lead to increased potential for migration of heavy metals and other contaminants to the groundwater.

3.8.3 Summary of Key Results and Assumptions

- Neither lead nor cadmium were simulated to reach the groundwater in 1,000 years (or extended periods past 10,000 years)

- Additional increases in infiltration would (3-4 orders of magnitude over expected maximum infiltration rates) allow cadmium and lead to reach the groundwater in 1,000 years.

- Key Assumptions:

    - 1-D model: maximum transport to groundwater

3.9 Fate and Transport of Volatile Organic Compounds

3.9.1 Model Description

Volatile organic compounds (VOCs) were used as cleaners and solvents for machining and other industrial processes at Sandia National Laboratories. Rags, residual containers, and other wastes contaminated with these contaminants were disposed of at the MWL. Although no quantitative estimates of the volumes of these contaminants disposed of in the MWL exists, soil samples provide an estimate of the extent and concentration of the region contaminated with VOCs at the MWL. Previous studies have shown that VOCs such as trichloroethylene (TCE) and tetrachloroethylene (PCE) can migrate long distances in the vapor phase. Klavetter (1995a) showed that among the VOCs of concern at the MWL, PCE was the only VOC that posed a threat to exceeding regulatory metrics in the groundwater (PCE has a greater Henry's constant and, hence, greater gas-phase transport rate than TCE for the same aqueous source concentration). However, because there is still a potential for other VOCs from the MWL to migrate to groundwater due to their mobility, PCE was modeled in this study as a proxy for other VOCs detected in soil gas and in soils beneath the MWL.

In this study, PCE is simulated using the transient model of Jury et al. (1983, 1990), which accounts for aqueous-phase advection, gas-phase diffusion, adsorption, and decay (see Section 3.2.2). Table 2 summarizes the uncertainty distributions that were used in the model. The inventory was calculated based on the maximum measured soil gas concentration (5,900 ppb) at 30 feet (Peace et al., 2002). We assumed that the PCE vapor was in equilibrium with its aqueous phase (using Henry's constant). The maximum measured gas concentration (5,900 ppb) was used as a minimum value in a uniform distribution increasing to ten times this value to develop a range of equilibrium aqueous concentrations. The maximum value was based on calibrations with measured data (see next section). The total mass of PCE was then calculated using the moisture content, maximum areal extent of the MWL (430 feet x 300 feet), and an uncertain thickness ranging from 10-27 feet. Other values in Table 2 were taken from conservative values and ranges found in the literature for PCE.

3.9.2 Model Results

3.9.2.1 Comparison to Field Data

Samples of PCE soil-gas concentrations were taken at the MWL in 1993 (Johnson et al., 1995). The ranges of measured values at two different depths (10 feet and 30 feet) were compared to simulated soil-gas concentrations using the transient PCE transport model described in the previous section. Figure 20 and Figure 21 show the comparisons for all 100 simulated realizations. As discussed in previous sections, the measured values in 1993 are shown spanning a time period between 5 and 33 years, which accounts for the uncertainty in the time of emplacement. Results show the majority of simulated soil-gas concentrations during this time period at the two depths are between the maximum and minimum values measured in 1993.

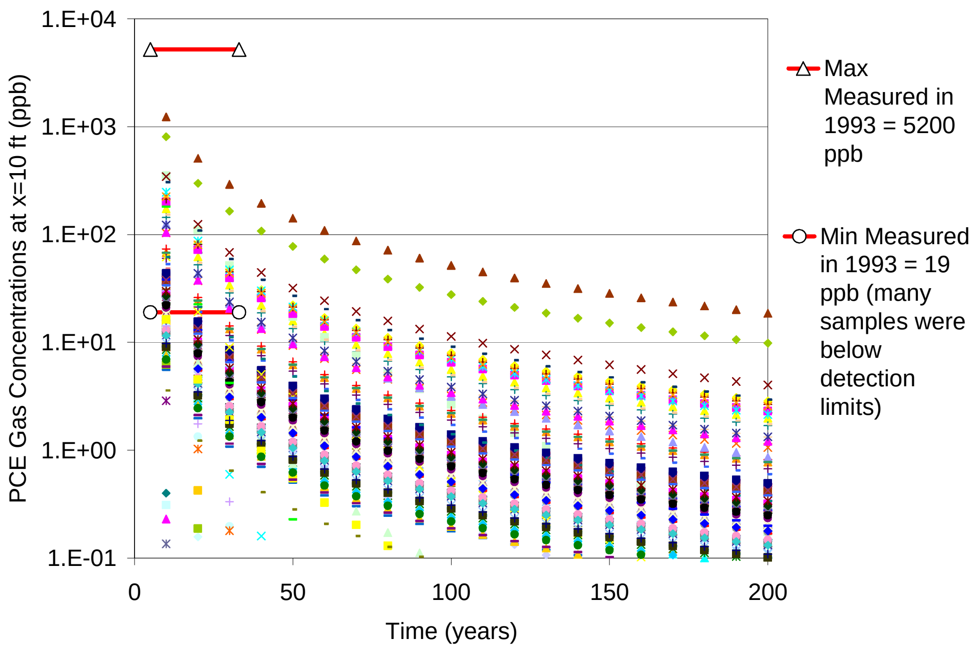

Figure 20. Simulated PCE gas concentration at a depth of 10 feet as a function of time for 100 realizations with a range of measured values in 1993.

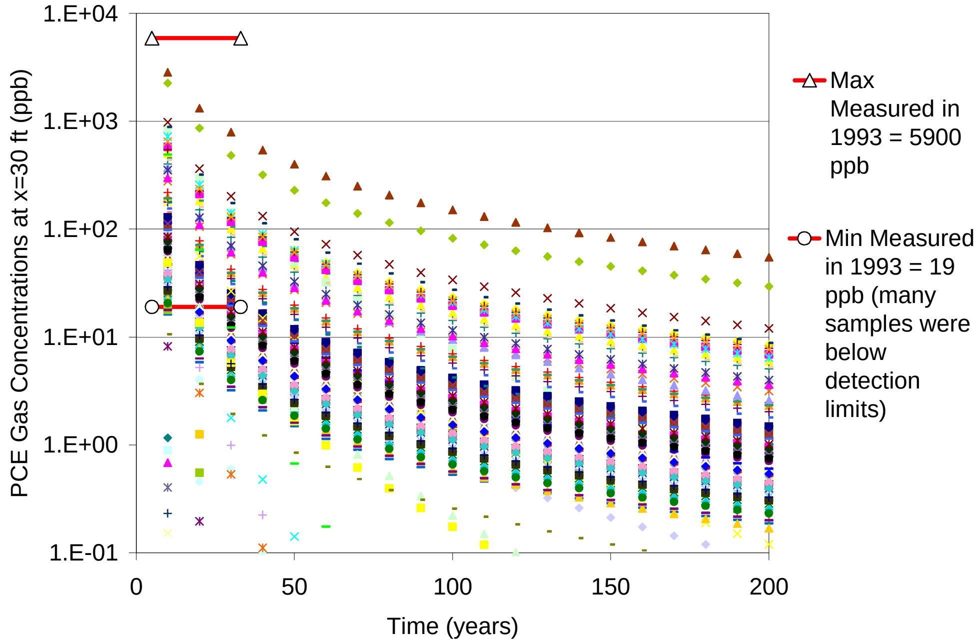

Figure 21. Simulated PCE gas concentration at a depth of 30 feet as a function of time for 100 realizations with a range of measured values in 1993.

3.9.2.2 Comparison to Performance Objectives

Figure 22 shows the simulated PCE concentrations in the groundwater as a function of time for all 100 realizations. The majority of the realizations show the aquifer concentrations peaking before 50 years. Depending on the time of disposal, this corresponds to peak concentrations occurring by 2010 – 2040. So far, no detectable amounts of PCE have been found in the groundwater at the MWL. This is still consistent with the simulations, which show a large amount of variability in the simulated concentrations resulting from uncertainty included in the input parameters (see next section).

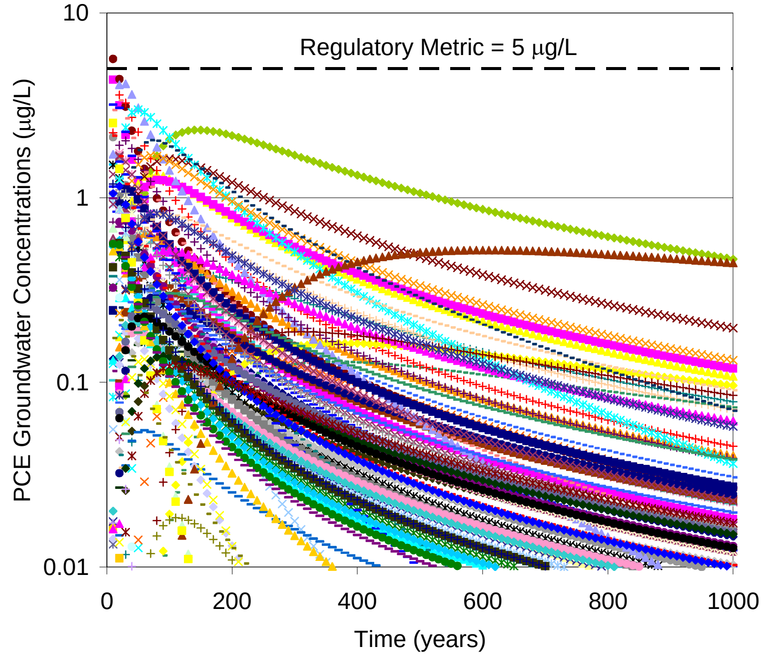

Figure 22. Simulated PCE groundwater concentrations for 100 realizations.

The cumulative probability of the peak PCE groundwater concentration for all 100 realizations is shown in Figure 23. The results show that approximately 99% of the realizations yield groundwater concentrations less than the regulatory metric of 5 µg/L. Only 1% of the realizations yielded groundwater concentrations that exceeded the regulatory metric.

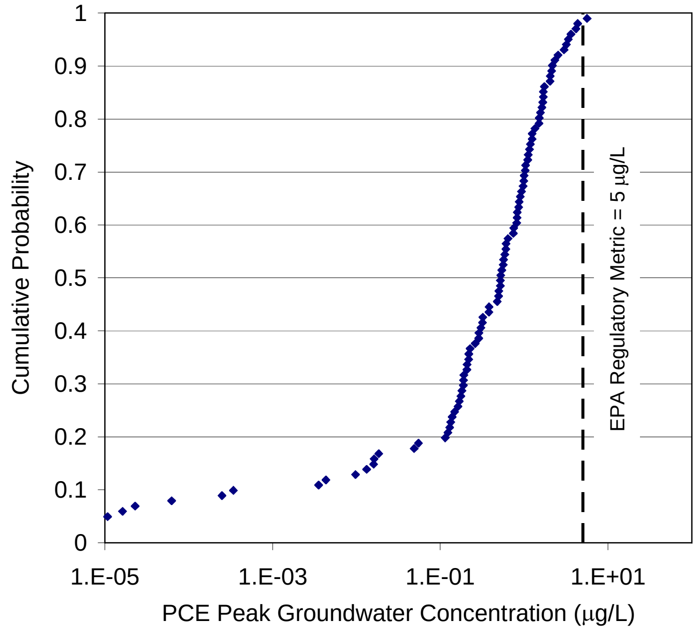

Figure 23. Cumulative probability for simulated PCE peak groundwater concentrations for 100 realizations.

3.9.2.3 Sensitivity Analysis

The uncertainty in the PCE K_d, half-life (degradation), inventory concentration, source thickness, and cover thickness values were found to be the most statistically significant parameters that impacted the variability in the simulated PCE aquifer concentrations. As stated in previous sections, the adsorption coefficient, K_d, plays an important role in the retardation and mobility of the constituent. The half-life and inventory both govern the persistence and availability of the PCE during migration to the groundwater. The source thickness also contributes to the overall inventory of PCE since the inventory concentration is applied to the entire source volume.

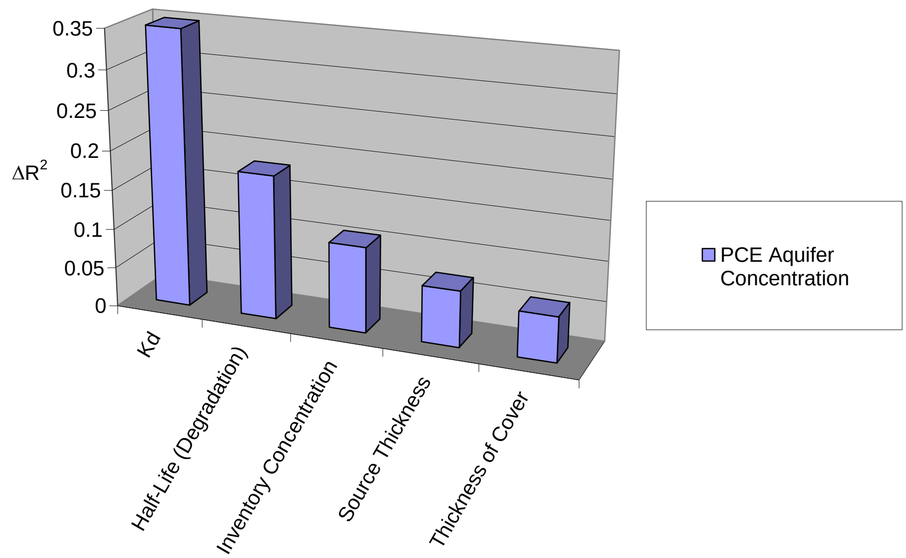

Figure 24. Analysis of sensitivity of simulated PCE peak aquifer concentrations to uncertain input parameters.

3.9.3 Summary of Key Results and Assumptions

- 99% of the realizations yielded peak PCE concentrations in the groundwater that were less than the regulatory metric of 5 μg/L. The majority of the realizations showed that the peak PCE groundwater concentration occurred within 100 years.

- Uncertainty in the PCE adsorption coefficient, half-life, inventory concentration, source thickness, and cover thickness were found to be significantly correlated to the simulated groundwater concentrations.

- Key Assumptions:

    - 1-D model: maximum transport to groundwater

4. Recommended Triggers for Long-Term Monitoring

The NMED's Class 3 permit modification (NMED, May 2005) requires that the MWL CMI Plan include triggers for future action that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy. Based on the results of the probabilistic performance-assessment modeling for the MWL, the following parameters were identified as important for meeting the performance metrics:

- Surface emissions of tritium and radon
- Infiltration through the MWL cover
- Concentrations of uranium in groundwater
- Concentrations of VOCs in the vadose zone and in groundwater

Monitoring triggers are proposed for these parameters to ensure that the MWL performance metrics and corrective action objectives are met. The proposed triggers are based on EPA and DOE regulatory standards, and are discussed in Section 4.2. To address concerns regarding potential mobilization of contaminants by biota, additional monitoring triggers are proposed for metals and radionuclides in surface soil near animal burrows and ant nests.

A trigger evaluation process is proposed in Section 4.1. This process will be initiated if a trigger is exceeded during long-term monitoring at the MWL. The logic and rationale behind specific triggers are presented in Section 4.2.

Additional details regarding long-term monitoring at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan. This plan will be submitted within 180 days after the NMED's approval of the MWL CMI Report. The plan will include all necessary physical and institutional controls to be implemented in the future, and will also include contingency procedures to be implemented if the MWL remedy fails to be protective of human health and the environment.

4.1 Trigger Evaluation Process

A trigger evaluation process is recommended for the MWL during long-term monitoring activities at the site. The process will be a phased approach designed to ensure the protection of human health and the environment, while allowing adequate data collection to evaluate whether corrective action is warranted. This process is based upon the "Conceptual Corrective Measure Evaluation Process' proposed in the Post-Closure Care Plan for the Chemical Waste Landfill (SNL, September 2005).

In the event that a trigger level is exceeded, the process shown in Figure 25 will be used to ensure that adequate data are collected to determine whether additional corrective action is warranted. The increased frequency of data collection proposed in the trigger evaluation process (see Step 3 in Figure 25 and the corresponding explanation on the reverse side of the figure) will ensure that adequate data are collected to eliminate field sampling error, laboratory error, or short-term exceedances that do not reflect long-term trends. Thus, any recommendations for corrective action because of trigger exceedances will be based upon data trends rather than upon single detection values above the trigger level. If data trends in the monitored parameters indicate an established trend above the proposed trigger value, the process requires that a technical letter report be submitted to the NMED recommending whether or not corrective action should be implemented.

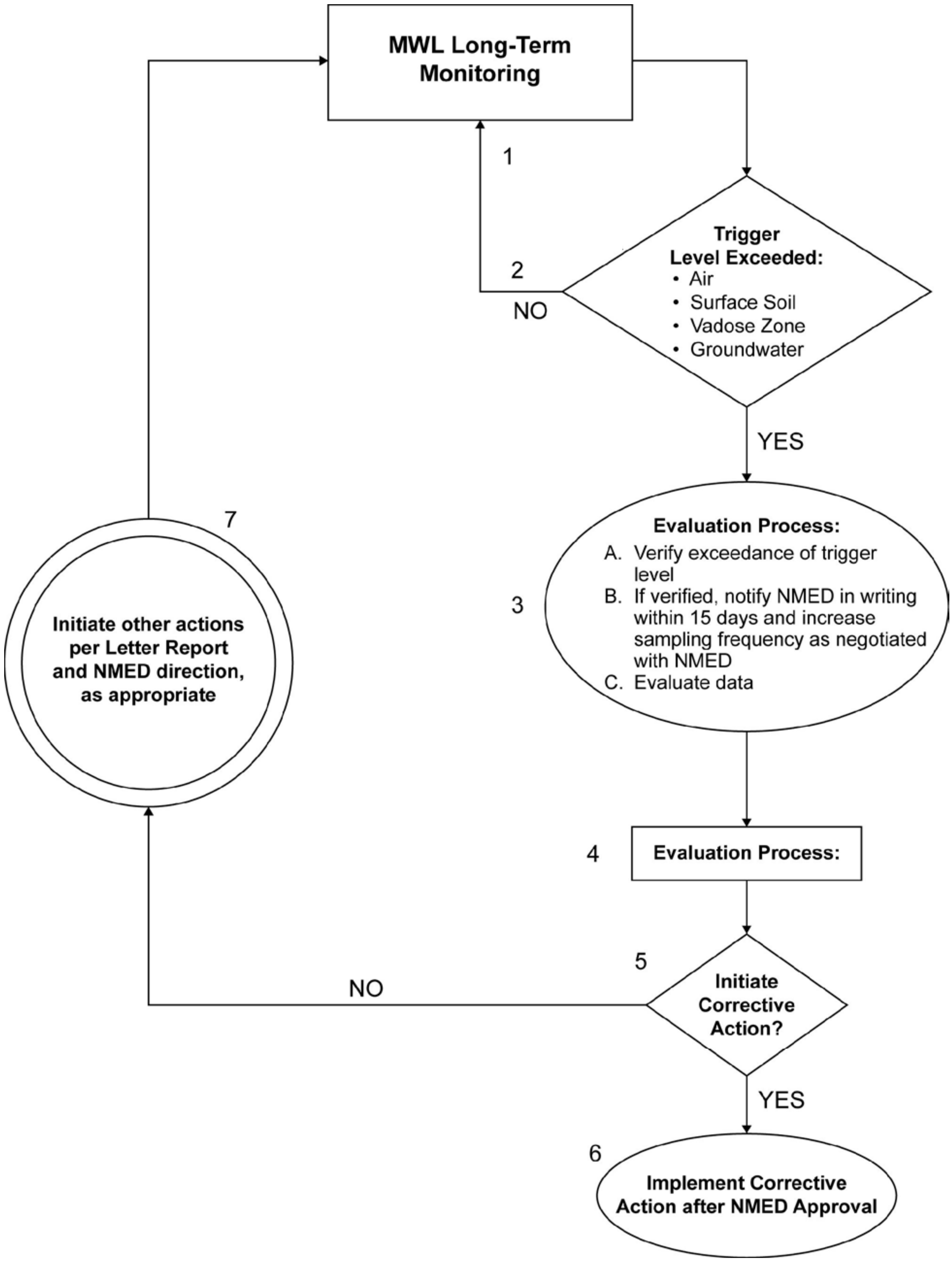

Figure 25. Trigger evaluation process for the Mixed Waste Landfill.

The steps outlined in Figure 25 are explained below:

1. Long-term monitoring of the air, surface soil, vadose zone, and groundwater at the MWL.

2. Exceedance of one or more trigger levels initiates the specific actions described below.

3. Step A of the evaluation process initiates resampling to verify the result(s) that exceeded the trigger level. Step B is based upon the conceptual model for the MWL. Because infiltration through the MWL cover is expected to be very low, and contaminant transport times in the vadose zone and groundwater are anticipated to be relatively slow, a longer period for data collection at an increased sampling frequency is recommended to determine trends. The length of this period and the increased sampling frequency will be negotiated with the NMED. Once the increased sampling data have been collected, the data and any resulting trends will be evaluated to determine the significance of the exceedance (Step C).

4. After the resulting trends have been evaluated, a brief technical letter report will be prepared and submitted to the NMED within three months of receiving the final data set that summarizes the trigger exceedance(s), presents the results of the increased monitoring, and provides recommendations regarding corrective action.

5. NMED Decision Point: after the technical letter report is submitted to the NMED, a meeting will be held to discuss the data evaluation and the recommendations regarding corrective action. If the NMED determines that further investigation of the trigger exceedance is needed, NMED may require corrective action based on a finding that releases of contaminants have occurred, are occurring, or are likely to occur.

6. If the data trend is increasing and higher than the proposed trigger value, corrective action may be necessary. The technical letter report will address appropriate options and form the basis for further discussion with NMED to determine the final corrective action.

7. If the data trend is not clear or is decreasing, corrective action may not be necessary, but other actions may be required as proposed in the technical letter report or requested by the NMED.

4.2 Proposed Triggers

Based on the results of the probabilistic performance-assessment modeling conducted for the MWL, and on subsequent input received from the NMED, monitoring triggers are proposed for the air, surface soil, vadose zone, and groundwater at the MWL These triggers are listed in Table 6, and are discussed below.

Table 6. Proposed Monitoring Triggers for the Mixed Waste Landfill.

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Air	Radon	Humans	4 pCi/L (measured by Track-Etch radon detectors)	MWL Perimeter	Average flux of radon-222 gas shall be less than 20 pCi/m^2/s at the landfill surface (design standard)	EPA Action Threshold for radon in air (U.S. EPA 2005)
Surface Soil	Tritium	Humans and ecological receptors	20,000 pCi/L tritium in soil moisture	MWL Perimeter	Dose to the public via the air pathway shall be less than 10 mrem/yr	DOE Order 5400.5, 10 CFR 61 Subpart H, 40 CFR 141.66
Surface Soil	Cs-137	Humans and ecological receptors	0.664 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	Ra-226	Humans and ecological receptors	2.30 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	Th-232	Humans and ecological receptors	1.01 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	U-235	Humans and ecological receptors	0.16 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)

Table 6 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Surface Soil	U-238	Humans and ecological receptors	1.4 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	Arsenic	Humans and ecological receptors	17.7 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Barium	Humans and ecological receptors	100,000 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Cadmium	Humans and ecological receptors	56.4 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Chromium	Humans and ecological receptors	3400 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Lead	Humans and ecological receptors	800 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Mercury	Humans and ecological receptors	100,000 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)

Table 6 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Surface Soil	Selenium	Humans and ecological receptors	5680 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Silver	Humans and ecological receptors	5680 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Subsurface Soil	Moisture Content	Humans via groundwater	23 percent by volume	Linear depths of 10 ft to 100 ft along neutron probe access holes beneath the MWL	Infiltration through the cover shall be less than the EPA-prescribed technical equivalence criterion of 31.5 mm/yr [10E-7 cm/s]	RCRA 40 CFR Part 264.301
Subsurface Soil Gas	PCE	Humans via groundwater	20 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Subsurface Soil Gas	TCE	Humans via groundwater	20 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Subsurface Soil Gas	Total Volatile Organic Compounds	Humans via groundwater	25 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Uranium	Humans via groundwater	15 µg/L	Downgradient monitoring well locations	Uranium concentrations in groundwater shall not exceed the EPA MCL of 30 µg/L	EPA Primary Drinking Water Standard
Groundwater	1,1,1-Trichloroethane (1,1,1-TCA)	Humans via groundwater	100 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,1,2-Trichloroethane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

Table 6 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Groundwater	1,1-Dichloroethene	Humans via groundwater	3.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,2-Dichloroethane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,2-Dichloropropane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Benzene	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Carbon tetrachloride	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Chlorobenzene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Ethyl benzene	Humans via groundwater	350 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Methylene chloride	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Styrene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Tetrachloroethene (PCE)	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Toluene	Humans via groundwater	500 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

Table 6 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Groundwater	Trichloroethene (TCE)	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Vinyl Chloride	Humans via groundwater	1.0 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Xylenes (Total)	Humans via groundwater	5,000 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	cis-1,2-Dichloroethene	Humans via groundwater	35 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Trans-1,2-Dichloroethene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Method 8260 VOCs with no MCLs	Humans via groundwater	EPA Region 6 Human Health Medium-Specific Screening Levels	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA Region 6 Human Health Medium-Specific Screening Levels	EPA Region 6 Human Health Medium-Specific Screening Levels

CFR = Code of Federal Regulations.
cm = Centimeter(s).
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
ft = Foot (feet).
L = Liter(s).
m = Meter(s).
m^2 = Square meter(s).
µg = Microgram(s).
MCL = Maximum contaminant level.
mm = Millimeter(s).
mrem = Millirem.
MWL = Mixed Waste Landfill.
pCi = Picocurie(s).
RCRA = Resource Conservation and Recovery Act.
s = Second(s).
TCA = Trichloroethane.
VOC = Volatile organic compound.
yr = Year(s).

4.2.1 Surface Soil and Air Monitoring Triggers

Proposed surface soil and air monitoring triggers include a trigger for tritium concentrations in soil collected at select locations along the MWL perimeter, and a trigger for radon emissions from the MWL. Triggers are also proposed for radionuclides and metals in surface soil near animal burrows and ant nests to address concerns regarding potential mobilization of contaminants by biota.

4.2.1.1 Tritium

Tritium is the most mobile radionuclide disposed of at the MWL, and the performance-assessment modeling indicates that there is a possibility that tritium emitted from the MWL may exceed the performance objective of 10 mrem/yr dose to the public via the air pathway. For this reason, a trigger is proposed for tritium emitted from the MWL. Figure 12 shows that the simulated peak tritium dose via air exceeded the performance objective in only 2% of the realizations. Figure 6 reveals that the maximum simulated surface concentration of tritium for the realizations that yielded the peak doses via air are on the order of 10^9-10^{10} pCi/L. Therefore, we propose a conservative trigger value of 20,000 pCi/L in surface soils at the MWL perimeter.

The proposed tritium trigger would apply to surface soil samples currently collected annually at select locations along the MWL perimeter by Sandia's Environmental Monitoring group. Soil samples have been collected from these locations and analyzed for tritium on an annual basis since 1985. Soil moisture is extracted from these samples, and tritium concentrations in the soil moisture are determined using liquid scintillation. Any increase in tritium emissions from the MWL would be indicated by elevated tritium concentrations in these soil samples.

Figure 26 shows a comparison between historical tritium concentrations measured in samples from the four perimeter locations, and the proposed trigger value of 20,000 pCi/L. All exceedances of the trigger value occurred prior to 1998, and exceedances are not anticipated in the future due to radioactive decay and the relatively short (12.3 year) half-life of tritium. If measured concentrations of tritium at the surface exceed 20,000 pCi/L, this would indicate a significant increase relative to present-day values, and the trigger evaluation process (Figure 25) would be followed. Because the proposed trigger value is 4-5 orders of magnitude less than simulated concentrations that yielded exceedances in the dose via air, the proposed trigger value serves as a conservative early-warning indicator for potential exceedances of tritium dose via air.

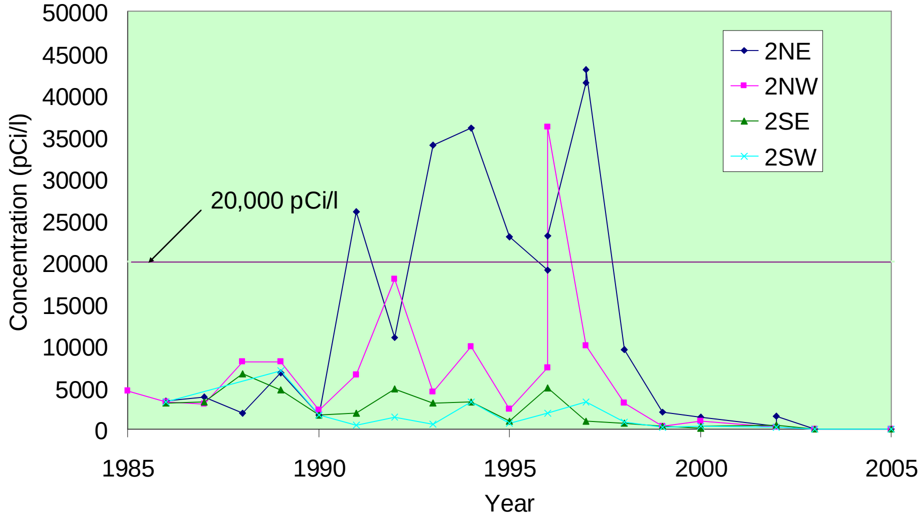

Figure 26. Comparison between historical tritium concentrations measured in samples from the four perimeter locations, and the proposed trigger value of 20,000 pCi/L.

4.2.1.2 Gamma-Emitting Radionuclides and Heavy Metals

NMED has requested that surface soil near animal burrows and ant nests be monitored for radionuclides and heavy metals (NMED, Nov 2006). Triggers proposed for gamma-emitting radionuclides are the NMED-HWB Approved Background Values (Dinwiddie 1997). Triggers proposed for RCRA metals concentrations in surface soil are the NMED Industrial/Occupational Soil Screening Levels (NMED June 2006).

Triggers for gamma-emitting radionuclides and RCRA metals are listed in Table 6. Specific details regarding monitoring frequency and locations will be included in the MWL Long Term Monitoring and Maintenance Plan, to be submitted following completion of the MWL cover.

4.2.1.3 Radon

A trigger for radon is also recommended based on the results of the probabilistic performance-assessment modeling. The modeling indicates that there is a possibility that the radon-222 flux from the MWL to the atmosphere will exceed the design standard of 20 pCi/m^2/s at the landfill surface. Commercially-available Track-Etch radon detectors are recommended to measure the radon concentration in air along the MWL perimeter. These detectors provide an integrated average concentration of radon in air over long exposure periods, on the order of 3 to 6 months. The alternative monitoring detectors, charcoal canisters, are useful only for short exposure periods, on the order of a few days.

The proposed trigger for radon in air is 4 pCi/L, and the proposed point of compliance is the MWL perimeter. The 4 pCi/L value is the EPA "action threshold" for radon in household air (U.S. EPA, 2005). This proposed value is much lower than the simulated radon-gas

concentrations (>10,000 pCi/L) at the surface of the MWL that yielded fluxes that exceeded the design standard of 20 pCi/m^2/s. Should the radon trigger of 4 pCi/L be exceeded in air at the MWL point of compliance, then the trigger evaluation process shown in Figure 25 will be implemented. Additional details regarding long-term monitoring of radon at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.2 Vadose Zone Monitoring Triggers

The vadose zone beneath the MWL extends nearly 500 ft from ground surface to groundwater. Because VOCs released from the MWL have the potential to migrate to groundwater, a robust monitoring system is planned for the vadose zone at the MWL to serve as an early warning system for protecting groundwater. This system will provide early evidence of potential threats to groundwater, and it will allow corrective action to be initiated long before groundwater contamination occurs.

Long-term-monitoring of the vadose zone is planned for VOCs and for moisture content to ensure that the MWL remedy remains protective of human health and the environment. Details of the proposed monitoring systems for VOCs, moisture content, and trigger values are discussed below. Additional details regarding the frequency and extent of long-term monitoring activities will be included in the MWL Long-Term Monitoring and Maintenance Plan.

4.2.2.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) are the most mobile of the hazardous constituents detected in soils beneath the MWL. Two passive and three active soil-gas surveys at the MWL have shown the presence of low concentrations of VOCs in soil gas (Peace et al., 2002). In addition, low concentrations of VOCs were detected in a 1993 study of VOC and tritium fluxes to the atmosphere from MWL soils (Radian Corp., 1993). Low concentrations of VOCs were also detected in subsurface soil samples collected from boreholes drilled during the MWL Phase 2 RFI.

VOC concentrations with depth will be monitored using three Flexible Liner Underground Technologies (FLUTe™) sampling wells. The FLUTes™ are proposed to be constructed in vertical boreholes located immediately outside the perimeter of the MWL cover with the locations selected near areas where the highest concentrations of VOCs were detected during earlier studies at the MWL. Actual locations of the FLUTe™ boreholes will be selected in conjunction with NMED. Soil gas sampling ports are proposed to be installed in each FLUTe™ at depths of 50 ft, 100 ft, 200 ft, 300 ft, and 400 ft below ground surface. Soil gas data collected from the FLUTes™ will be used to assess current VOC distributions with depth, and to monitor VOC concentrations over time, allowing early identification of any potential threats to groundwater.

Triggers are proposed for PCE, TCE, and total VOCs in soil gas at the MWL. The proposed triggers are 20 ppmv for PCE and TCE, and 25 ppmv for total VOCs. These triggers, although not based on risk or regulatory limits, are sufficiently low to protect groundwater quality of the

aquifer. All triggers would apply to samples collected from the deepest sampling port in each FLUTe™. Triggers would not apply to samples collected from shallower ports.

4.2.2.2 Moisture Content

Moisture content with depth will be monitored using a neutron moisture meter in three neutron probe access boreholes that were installed to a linear depth of 200 ft at a 30 degree angle directly below the waste disposal cells. The moisture content data will be used to evaluate infiltration through the MWL disposal cell cover. Infiltration is an important parameter for determining whether or not MWL performance objectives are met.

Infiltration through the cover will be indirectly monitored by monitoring the moisture content in the vadose zone beneath the MWL. A significant increase in moisture content beneath the landfill may indicate that the disposal cell cover may not be performing as originally designed, and that infiltration through the cover is greater than originally predicted.

Moisture contents will be measured using neutron logging, and data will be compared to baseline moisture content data collected prior to deployment of the MWL cover. A significant increase in moisture content within the vadose zone may indicate that corrective action is warranted in order to prevent the downward movement of liquid water through the disposal cell. Moisture content data will be evaluated to ensure that the performance objective of infiltration through the MWL cover is less than the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr), as detailed below.

Infiltration may be estimated indirectly using Darcy's Law. The method is based on soil-physics and the relationship between unsaturated hydraulic conductivity and volumetric moisture content of subsurface soils. The method is described in detail in the MWL Phase 2 RFI SAND Report (Peace et al., 2002). Assumptions required for this method include one-dimensional, steady-state flow, a vertical hydraulic gradient of unity, and the assumption that the downward flux of water beneath the root zone will eventually reach groundwater.

If one applies these assumptions, then the downward flux at a particular depth is equivalent to the unsaturated hydraulic conductivity as a function of the moisture content at that depth. Thus, by monitoring the moisture content of the vadose zone beneath the MWL, one can also indirectly monitor the downward flux through the vadose zone. If infiltration through the cover increases significantly, than the downward flux through the vadose zone would increase as well, resulting in higher moisture content in the vadose zone beneath the landfill. Hence, by monitoring moisture content in the vadose zone, one can indirectly monitor the performance of the MWL cover. A significant increase in moisture content beneath the MWL may indicate that the cover is not performing as designed.

Figure 27 shows the calculated unsaturated hydraulic conductivity curves for 18 subsurface soil samples collected from the IP Test site, located approximately 500 ft west of the MWL. Based on this figure, and assuming a unit gradient in the vadose zone, if infiltration through the MWL cover exceeds the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr), then volumetric moisture content in the underlying soils will exceed approximately 23 percent.

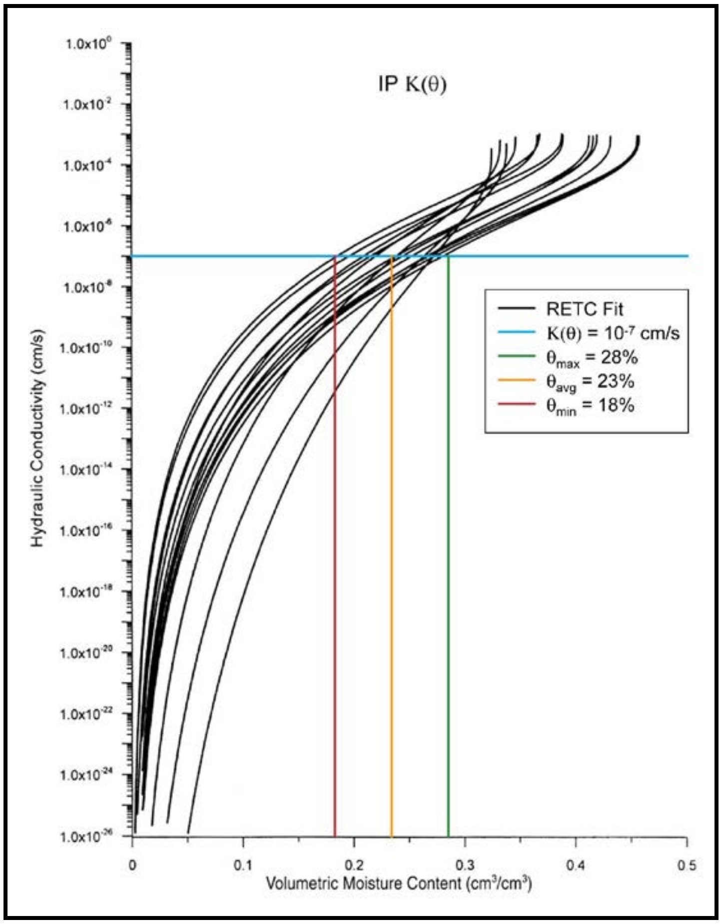

Figure 27. Hydraulic conductivity as a function of volumetric moisture content for different soil samples at the site

The recommended trigger level is the moisture content which corresponds to an unsaturated hydraulic conductivity equal to the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr). The moisture content at which this occurs is 23 percent by volume, and the proposed trigger level for moisture content in the vadose zone is, therefore, 23 percent by volume. This value is based arbitrarily on the EPA-prescribed technical equivalence criteria, and does not necessarily indicate that hazardous constituents or radionuclides are migrating from the landfill.

The 23-percent trigger is proposed for linear depths of 10 ft and 100 ft (vertical depths of 8.7 ft to 86.6 ft) along the neutron probe access holes in the vadose zone beneath the MWL. This interval is proposed as the "regulated interval" because it lies beneath the root zone, and yet is shallow enough that a response would be detected fairly rapidly if there is a significant increase in infiltration through the cover. Should this 23-percent trigger level be exceeded in the regulated interval, then the process shown in Figure 25 will be implemented. Additional details regarding vadose zone monitoring at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.3 Groundwater Monitoring Triggers

Based on the results of the probabilistic performance-assessment modeling, monitoring triggers are proposed for uranium and VOCs in groundwater at the MWL. These proposed triggers are discussed below.

4.2.3.1 Uranium

Uranium occurs naturally in MWL groundwater at concentrations ranging from 1.34 to 9.23 μg/L, and averaging 5.97 μg/L. Total uranium concentrations in groundwater beneath the MWL are well within the total uranium ranges established by the United States Geological Survey (USGS) for the Middle Rio Grande Basin (USGS, 2002). Isotopic analyses of uranium have demonstrated that it is of natural origin (Goering et al., 2002).

The probabilistic performance-assessment modeling for the MWL indicates that there is a possibility that uranium will reach the groundwater (although none of the simulations showed the uranium concentrations exceeding the regulatory metric of 30 μg/L). For this reason, a monitoring trigger of 15 μg/L (1/2 of the EPA MCL) is proposed for uranium in MWL groundwater at the point of compliance. The proposed point of compliance is at the downgradient monitoring wells. Should the uranium trigger value be exceeded in MWL groundwater at the point of compliance, then the trigger evaluation process shown in Figure 25 will be implemented. Additional details regarding long-term monitoring of uranium in groundwater will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.3.2 Volatile Organic Compound Triggers for Groundwater

Groundwater monitoring for VOCs at the MWL has been conducted for sixteen years, since September 1990, and there is no evidence that wastes from the MWL have contaminated groundwater. However, earlier studies as well as the current probabilistic performance-assessment modeling have shown that there is a potential for VOCs to contaminate groundwater at the MWL.

The potential downward vertical transport of six organic compounds to groundwater by both aqueous-phase transport and vapor-phase transport was evaluated in 1995 (Klavetter, 1995). The study showed that PCE could eventually migrate to groundwater through vapor-phase transport. Although the modeling predicted that the most likely PCE concentrations in groundwater would be considerably lower than the detection limit of 0.5 ppb, sensitivity analyses suggested that PCE concentrations could potentially reach 1 to 5 ppb within 50 years (Klavetter, 1995a).

The current probabilistic performance-assessment modeling also simulated the migration of PCE to groundwater and arrived at similar conclusions regarding the potential contamination of groundwater by PCE through vapor-phase transport. Because PCE was modeled in this study as a proxy for other VOCs detected in soil gas and in soils beneath the MWL, there is a potential for other VOCs from the MWL to also migrate to groundwater in the future. For this reason, continued groundwater monitoring for VOCs at the MWL is recommended.

Groundwater trigger levels are proposed for all Target Compound List VOCs for which there are primary EPA MCLs, or for which there are EPA Region 6 Human Health Medium-Specific Screening Levels. The proposed groundwater trigger levels for VOCs with MCLs are equal to ½ of the EPA MCLs; concentrations of VOCs with no corresponding MCLs will be compared to the EPA Region 6 Human Health Medium-Specific Screening Levels.

The proposed point of compliance is the downgradient monitoring wells. Should any VOC trigger values be exceeded in MWL groundwater at the point of compliance, then the trigger evaluation process shown in Figure 25 will be implemented. Additional details regarding long-term monitoring of VOCs in groundwater will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.3 Summary of Recommended Triggers

Based on the results of the probabilistic performance-assessment modeling conducted for the MWL, monitoring triggers have been proposed for the air, surface soil, vadose zone, and groundwater at the MWL. Specific triggers include numerical thresholds for (1) radon concentrations in the air, (2) tritium, gamma-emitting radionuclides, and heavy metal concentrations in surface soil, (3) VOC concentrations and moisture content in the vadose zone, and (4) uranium and VOC concentrations in groundwater. The proposed triggers are based on EPA, DOE and NMED regulatory standards, as well as on NMED maximum background concentrations for select radionuclides. If a trigger is exceeded, then SNL/DOE will initiate a trigger evaluation process which will allow sufficient data to be collected to assess trends and recommend corrective action, if necessary.

By utilizing these triggers during long-term monitoring at the MWL, SNL/DOE will ensure that the MWL remedy continues to protect human health and the environment, while meeting the performance objectives for the cover and the corrective action objectives established in the MWL Corrective Measures Study.

5. Summary and Conclusions

A probabilistic performance assessment has been conducted to evaluate the fate and transport of contaminants of concern at the Mixed Waste Landfill. The contaminants that were simulated include radionuclides (amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, radon-222, strontium-90, thorium-232, tritium, and uranium-238), heavy metals (lead and cadmium), and a volatile organic compound (PCE). The current analysis differs from previous analyses in several ways: (1) probabilistic analyses[5] were performed to quantify uncertainties inherent in the system and models; (2) a comprehensive analysis of the performance of the MWL was evaluated and compared against relevant regulatory metrics; (3) sensitivity analyses were performed to identify parameters and processes that were most important to the simulated performance metrics; and (4) long-term monitoring requirements and

[5] One hundred realizations were used in the probabilistic analyses. A preliminary comparison between the results of 100 vs. 200 realizations revealed that the output distribution was adequately represented by 100 realizations.

triggers were recommended based on the results of the quantified uncertainty and sensitivity analyses. The key results of this study are summarized below:

Infiltration through the Cover:

- Net infiltration through the engineered cover at the MWL was simulated to be less than the regulatory metric of 10^{-7} cm/s for all conditions and scenarios.

- Predicted average infiltration rates through the MWL cover are expected to range from 1.18 X 10^{-9} cm/s for present conditions to 6.12 X 10^{-9} cm/s for future conditions. These values were used in a uniform distribution for the performance-assessment simulations.

- To ensure that future infiltration rates will not exceed the regulatory metric of 10^{-7} cm/s, the moisture content of the vadose zone will be monitored. Based on the site-specific two-phase characteristic curves of the soil, a moisture content of 23 percent by volume will be used as a trigger to indicate if the infiltration metric is exceeded.

Release of Radionuclides to the Atmosphere:

- A small percentage (2%) of the simulated dose due to exposure to tritium via the air pathway exceeded the regulatory metric of 10 mrem/year.

- Parameters impacting tritium diffusion through both the liquid and gas phases (e.g., tortuosity coefficient, moisture content, cover thickness, atmospheric boundary-layer thickness) were found to be important to the simulated inhalation dose.

- Sensitivity studies show that the emanation factor, which depends on the integrity of the radium-226 containment, is important to the performance of the landfill with regard to surface radon fluxes.

- For a maximum radon emanation factor of 0.01 (1% of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard of 20 pCi/m^2/s in about 3% of the realizations. For a maximum radon emanation factor of 1 (100% of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard in about 30% of the realizations.

- Based on these results, both radon and tritium concentrations are recommended to be monitored at the surface of the MWL in the future. In addition, other radionuclides that may be brought to the surface by burrowing animals or insects are also proposed to be monitored. Specific triggers are identified in Table 6.

Release of Radionuclides to the Groundwater:

- None of the radionuclides were simulated to reach the groundwater within 1,000 years for all realizations.

- Only uranium-238 (and some of its decay products) were simulated to reach the water table for extended periods (>10,000 years). All peak aquifer concentrations were still less than the EPA regulatory metric of 30 µg/L.

- Infiltration rate was found to be the most significant parameter impacting the variability in the simulated groundwater concentrations and dose via groundwater. Uranium groundwater concentrations were simulated to exceed the regulatory metric of 30 µg/L if the infiltration increased two orders of magnitude above the maximum stochastic value to 6.12×10^{-9} m/s.

- Uranium in the groundwater will be monitored in the future and a trigger value of 15 µg/L, equal to ½ of the U.S. EPA maximum contaminant level in drinking water, is proposed.

Release of Heavy Metals to the Groundwater:

- Neither lead nor cadmium were simulated to reach the groundwater in 1,000 years (or extended periods past 10,000 years)

- Additional increases in infiltration (3-4 orders of magnitude over expected maximum infiltration rates) allowed cadmium and lead to reach the groundwater in 1,000 years.

- No triggers are recommended for lead or cadmium in groundwater at this time. However, heavy metals are proposed to be monitored in surface soils to account for transport by burrowing animals or instects (see Table 6).

Release of VOCs to the Groundwater:

- Only 1% of the realizations yielded peak PCE concentrations in the groundwater that exceeded the regulatory metric of 5 µg/L. The majority of the realizations showed that the peak PCE groundwater concentration occurred within 100 years.

- Uncertainty in the PCE adsorption coefficient, half-life (degradation), inventory concentration, source thickness, and cover thickness were found to be significantly correlated to the simulated groundwater concentrations.

- Based on these results, PCE and other volatile organic compounds are recommended to be monitored in the vadose zone and in groundwater at the MWL in the future (see Table 6). Trigger values for the soil gas in the vadose zone will be 20 ppmv for TCE and PCE, and 25 ppmv for total VOCs. Trigger values in groundwater will be based on values equal to ½ of the U.S. EPA maximum contaminant levels in drinking water. Concentrations of VOCs with no corresponding MCLs will be compared to the EPA Region 6 Human Health Medium-Specific Screening Levels.

Key Assumptions:

- Receptor located adjacent to MWL
    - Tritium dose caused by continuous inhalation and exposure of tritium flux directly above MWL.
    - Groundwater dose calculated based on concentrations in aquifer directly beneath MWL. Water intake assumed to be 10 L/day (five times EPA standard of 2 L/day for drinking water).
- Maximum waste inventory set equal to twice estimated values based on historical records.
- Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor for radon-222 allowed to increase).
- Cover allowed to completely erode in 1,000 years.
- 1-D model: yields maximum transport to surface and groundwater.
- Bounding tortuosity coefficients: yields maximum diffusion rates.

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7. Appendix A: Derivation of a Steady-State Gas and Liquid-Phase Radon Transport Model

A steady-state radon transport model is derived here to account for advection in the liquid phase, diffusion in both the liquid and gas phases, and decay of radon-222. Because radium-226, which is the source of radon-222, has a half-life of 1,600 years, we assume steady-state conditions (e.g., the source of radon-222 is constant and the resulting long-term radon-222 concentration profile does not change with time). Assuming steady-state conditions is conservative because the radon-222 concentration profile is assumed to develop instantaneously.

We define three regions in the model: (1) a clean overburden (or cover) free of radium-226 that extends to a depth, L_1, beneath the surface; (2) a contaminated source zone of radium-226 that extends to a depth, L_2, from the surface; and (3) a vadose zone free of radium-226 that extends a distance, L_3, to the water table (see Figure 28). The radon-222 generated by the radium-226 is free to diffuse and advect upward to the atmosphere and downward toward the water table. Downward liquid advection also carries aqueous-phase radon toward the water table. Partitioning of radon between the gas and liquid phases is assumed to occur instantaneously and can be described by a liquid/gas partitioning coefficient, k (this is the inverse of Henry's constant, K_H). The steady-state governing equations for the transport of radon-222 in these two regions is as follows:

$$D_{eff}^{(1)} \frac{d^2 C_g^{(1)}}{dx^2} - kq \frac{dC_g^{(1)}}{dx} - \lambda C_g^{(1)} \left(\theta_g^{(1)} + k\theta_w^{(1)} \right) = 0 \tag{1}$$

$$D_{eff}^{(2)} \frac{d^2 C_g^{(2)}}{dx^2} - kq \frac{dC_g^{(2)}}{dx} - \lambda C_g^{(2)} \left(\theta_g^{(2)} + k\theta_w^{(2)} \right) + \dot{Q} = 0 \tag{2}$$

$$D_{eff}^{(3)} \frac{d^2 C_g^{(3)}}{dx^2} - kq \frac{dC_g^{(3)}}{dx} - \lambda C_g^{(3)} \left(\theta_g^{(3)} + k\theta_w^{(3)} \right) = 0 \tag{3}$$

where

$$D_{eff} = \frac{0.07}{10^4} e^{\left[-4\left(S_l - S_l\phi^2 + S_l{}^5\right)\right]} \tag{4}$$

$$\dot{Q} = \frac{E\ Ci_{226}}{SA_{226} 1000} \frac{\lambda_{226}}{V} \tag{5}$$

where the superscripts (1), (2), and (3) denote the three regions shown in Figure 28, C_g is the radon gas-phase concentration [kg/m^3], x is the distance from the surface [m] (positive downward), D_{eff} is the effective diffusion coefficient [m^2/s] for combined gas and aqueous phases (Rogers et al., 1984), S_l is the liquid saturation [-], k is the water/gas partitioning coefficient (i.e., water concentration/gas concentration) [-], q is the Darcy infiltration rate [m/s], λ is the decay

coefficient for radon-222 and is calculated as ln(2)/half-life [1/s], θ_g and θ_w are the gas and moisture volumetric contents, respectively, $\dot{Q}$ is the volumetric generation rate of radon-222 [kg/m^3/s], E is the emanation factor for radon-222 that accounts for containment of the radium-226 (0 = complete containment; 1 = no containment), Ci_{226} is the concentration of radium-226 in curies, SA_{226} is the specific activity of radium-226 [Ci/g], λ_{226} is the decay coefficient for radium-226 [1/s], and V is the total volume of the contaminated waste zone (region 2). In this derivation, we assume local equilibrium between the gas and aqueous phases; therefore, the equation can be expressed entirely in terms of the gas concentration, C_g, and the partitioning coefficient, k, is used to convert between the gas concentration and aqueous concentration.

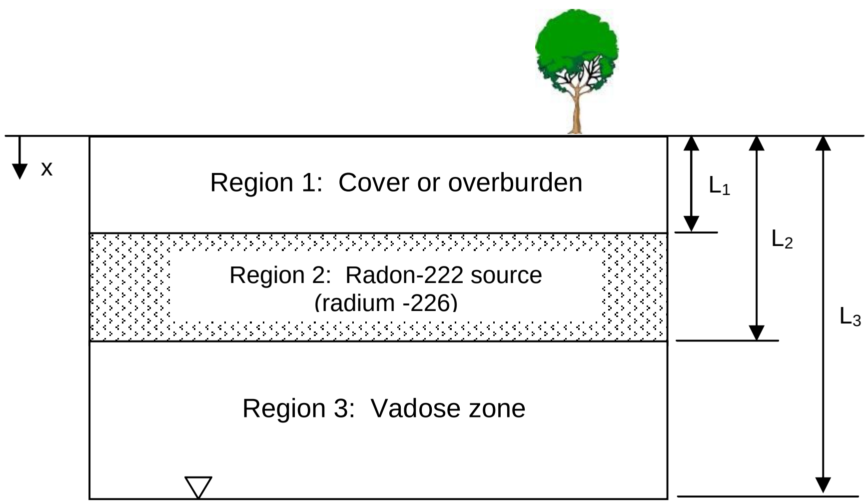

Figure 28. Conceptual model of three-region radon-transport model.

The boundary conditions for this system are as follows: (1) the radon concentration at the surface in region 1 is zero (this is conservative because it creates the largest gradient for radon flux to the atmosphere); (2) the radon concentration in region 1 is equal to the radon concentration in region 2 at the interface of regions 1 and 2; (3) the radon flux in region 1 reaching the interface between regions 1 and 2 must be equal to the radon flux entering region 2; (4) the radon concentration in region 2 is equal to the radon concentration in region 3 at the interface of regions 2 and 3; (5) the radon flux in region 2 reaching the interface between regions 2 and 3 must be equal to the radon flux entering region 3; and (6) the radon concentration infinitely far away from the source (as $x \rightarrow \infty$) goes to zero. These boundary conditions can be expressed as follows:

$$C_g^{(1)}(x=0)=0 \tag{6}$$

$$\begin{aligned} C_g^{(1)}(x=L_s) &= C_g^{(2)}(x=L_s) \\ C_w^{(1)}(x=L_s) &= C_w^{(2)}(x=L_s) \end{aligned} \tag{7}$$

$$D_{eff}^{(1)} \left. \frac{dC_g^{(1)}}{dx} \right|_{x=L_s} = D_{eff}^{(2)} \left. \frac{dC_g^{(2)}}{dx} \right|_{x=L_s} \tag{8}$$

$$\begin{aligned} C_g^{(2)}(x = L_s) = C_g^{(3)}(x = L_s) \\ C_w^{(2)}(x = L_s) = C_w^{(3)}(x = L_s) \end{aligned} \tag{9}$$

$$D_{eff}^{(2)} \left. \frac{dC_g^{(2)}}{dx} \right|_{x=L_s} = D_{eff}^{(3)} \left. \frac{dC_g^{(3)}}{dx} \right|_{x=L_s} \tag{10}$$

$$C_g^{(3)}(x \to \infty) = 0 \tag{11}$$

If we assume that the soil properties and hydrologic conditions are the same in all three regions, the solutions to the ordinary differential equations (1) - (3) for the three regions can be expressed as follows:

$$C_g^{(1)} = c_1 e^{r_1 x} + c_2 e^{r_2 x} \tag{12}$$

$$C_g^{(2)} = c_3 e^{r_1 x} + c_4 e^{r_2 x} + Q_{source} \tag{13}$$

$$C_g^{(3)} = c_5 e^{r_1 x} + c_6 e^{r_2 x} \tag{14}$$

where

$$c_1 = -c_2 \tag{15}$$

$$c_2 = \frac{c_3 e^{r_1 L_1} \left(r_1 - r_2 \right) - r_2 Q_{source}}{e^{r_1 L_1} \left(r_2 - r_1 \right)} \tag{16}$$

$$c_3 = \frac{r_2 Q_{source}}{e^{r_1 L_2} \left(r_1 - r_2 \right)} \tag{17}$$

$$c_4 = \frac{c_2 \left(e^{r_2 L_1} - e^{r_1 L_1} \right) - c_3 e^{r_1 L_1} - Q_{source}}{e^{r_2 L_1}} \tag{18}$$

$$c_5 = 0 \tag{19}$$

$$c_6 = \frac{c_3 e^{r_1 L_2} + c_4 e^{r_2 L_2} Q_{source}}{e^{r_2 L_2}} \tag{20}$$

$$r_1 = \frac{kq + \sqrt{(kq)^2 + 4D_{eff}\lambda_{eff}}}{2D_{eff}} \tag{21}$$

$$r_2 = \frac{kq - \sqrt{(kq)^2 + 4D_{eff}\lambda_{eff}}}{2D_{eff}} \tag{22}$$

$$\lambda_{eff} = \lambda\left(\theta_g + k\theta_w\right) \tag{23}$$

$$Q_{source} = \frac{\dot{Q}}{\lambda_{eff}} \tag{24}$$

Equations (12) - (24) yield the solutions for the gas concentrations in the three regions defined in Figure 28. The aqueous concentration can be obtained by multiplying the gas concentration at any location by the liquid/gas partition coefficient, *k*. The groundwater concentration at the interface of the vadose zone and the water table, $C_w^{(3)}(L_3)$, can be expressed as follows:

$$C_w^{(3)}(L_3) = k\,C_g^{(3)}(L_3) \tag{25}$$

The upward flux of radon-222 gas at the surface, q_s [kg/m^2/s] can be determined by evaluating the gas-phase concentration gradient at the surface (region 1) using Fick's Law:

$$q_s = -\left(-D_{eff}\left.\frac{dC_g^{(1)}}{dx}\right|_{x=0}\right) = D_{eff}\,c_2(r_2 - r_1) \tag{26}$$

The negative sign preceding the term in parentheses is to account for the positive downward direction of *x*. Equation (26) is used to estimate the radon gas flux at the surface in the performance assessment, and Equation (25) is used to determine the radon groundwater concentration. The concentration and flux of radon can be converted to pCi/L and pCi/m^2/s using the specific activity of radon (see Table 2) and appropriate unit conversions.

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Volume I

TAB 5

Notice of Public Comment Period for Mixed Waste Landfill
Corrective Measures Implementation Work Plan, November 2005
(Including Fate and Transport Model)

From: NMED/Kieling
To: Interested Citizen

Back of Tab 5

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505-6303
Telephone (505) 428-2500
Fax (505) 428-2567
www.nmenv.state.nm.us

BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

DERRITH WATCHMAN-MOORE
DEPUTY SECRETARY

December 9, 2005

SUBJECT: NOTICE OF PUBLIC COMMENT PERIOD FOR SANDIA NATIONAL LABORATORIES' MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN (INCLUDING FATE AND TRANSPORT MODEL)

Dear Interested Citizen:

Enclosed is a **Public Notice** regarding the U. S. Department of Energy (DOE)/Sandia Corporation's (Permittees) Corrective Measures Implementation (CMI) Work Plan for the Sandia National Laboratories (SNL) Mixed Waste Landfill (MWL). The CMI Work Plan includes the results of a fate and transport model that predicts the future movement of contaminants at the MWL.

The DOE is owner, and with Sandia Corporation, co-operator of SNL. The Permittees are located at the following addresses: SNL, 1515 Eubank SE, Albuquerque, NM, 87123; and NNSA/DOE, Sandia Site Office, KAFB-East, Pennsylvania & H Street, Albuquerque, NM 87116.

The enclosed Public Notice provides locations where the CMI Work Plan and the associated fate and transport model may be reviewed by any member of the public. Comments on the CMI will be received through **5:00 p.m.** on **February 7, 2006**.

Any person seeking additional information may contact:

Mr. William Moats
New Mexico Environment Department
C/O Sandia National Laboratories
P. O. Box 5800/MS 1089
Albuquerque, NM 87185
E-mail: wpmoats@sandia.gov
Telephone: (505) 284-5086
Fax: (505) 284-2616

Mr. John E. Kieling
Program Manager
New Mexico Environment Department
Hazardous Waste Bureau
2905 Rodeo Park Dr. East, Bldg 1
Santa Fe, NM 87505
E-mail: john.kieling@state.nm.us

Sincerely,

John E. Kieling
Manager
Permits Management Program

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

DERRITH WATCHMAN-MOORE
DEPUTY SECRETARY

PUBLIC NOTICE NO. 05-18

NEW MEXICO ENVIRONMENT DEPARTMENT
HAZARDOUS WASTE BUREAU
SANTA FE, NEW MEXICO
December 9, 2005

NOTICE OF PUBLIC COMMENT PERIOD
FOR SANDIA NATIONAL LABORATORIES MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN
(INCLUDING FATE AND TRANSPORT MODEL)

The federal Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901 to 6992(k), provides for the regulation of hazardous waste. Congress waived the immunity of the United States for actions brought under state hazardous and solid waste laws as well as under RCRA. Pursuant to Section 3006 of RCRA, 42 U.S.C § 6926, the U.S. Environmental Protection Agency (EPA) delegated to the New Mexico Environment Department (NMED), on April 16, 1985 by delegation numbers 8-31 and 8-32, the authority to enforce the Hazardous Waste Act (HWA) and its implementing regulations, the New Mexico Hazardous Waste Management Regulations (HWMR), 20.4.1 NMAC, in lieu of EPA enforcement through RCRA. NMED has maintained its delegation from EPA over hazardous waste management in New Mexico and from time to time has amended its state program to conform to statutory or regulatory changes in RCRA. The HWMR require corrective action at solid waste management units (SWMUs) where releases of hazardous waste or hazardous constituents have or may have occurred.

The U. S. Department of Energy, owner and operator, and Sandia Corporation, co-operator, (hereinafter referred to as the Permitees) have been issued a RCRA Permit for the Sandia National Laboratories (SNL) Facility, located in Bernalillo County, New Mexico, EPA ID# NM5890110518. The Permittees must comply with the HWA, the HWMR, and the SNL RCRA Permit and must conduct corrective action as necessary to protect human health and the environment.

On May 26, 2005, the NMED Secretary approved a final permit and ordered a final remedy for SNL's Mixed Waste Landfill. As part of these actions, the Permittees were required to submit to the NMED a Corrective Measures Implementation (CMI) Work Plan, which is to include a fate and transport model predicting the future movement of contaminants. The CMI Work Plan was submitted to the NMED on November 3, 2005 and includes a fate and transport model. Pursuant to the Secretary's order, the NMED is seeking public comment on the CMI Work Plan prior to making a final decision on whether to approve the plan.

LOCATION OF THE SNL FACILTY AND THE MWL

The Permittees are located at the following addresses: SNL, 1515 Eubank SE, Albuquerque, NM, 87123; and NNSA/DOE, Sandia Site Office, KAFB-East, Pennsylvania & H Street, Albuquerque, NM 87116. The Permittee's primary contact for this action is Mr. John Gould, NNSA/Sandia Site Office, DOE, at P.O. Box 5400, Albuquerque, NM 87185.

SNL is located within the boundaries of Kirtland Air Force Base (KAFB), south of Albuquerque in Bernalillo County, New Mexico. KAFB occupies 52,233 acres. SNL research and administration facilities occupy 2,842 acres and are divided into five Technical Areas (TAs), (designated 1 through 5) and several test areas. TA-1, TA-2, and TA-4 are separate research facilities in the north-central portion of KAFB. TA-3 and TA-5 are contiguous research facilities forming a 4.5-square-mile rectangular area in the southwestern portion of KAFB. TA-3 alone encompasses 2,000 acres.

The Mixed Waste Landfill (MWL) is located approximately 5 miles southeast of the Albuquerque International Sunport and 4 miles south of TA-1. The landfill occupies 2.6 acres in the north-central portion of TA-3.

FACILITY OPERATIONS

SNL, in operation since 1945, is engaged in research and development of conventional and nuclear weapons, alternative energy sources, and a wide variety of national security related research and development. As a result of these activities, SNL has generated hazardous, radioactive, mixed (those wastes containing both hazardous and radioactive components), and solid wastes. From 1945 to 1988 most of these wastes were disposed of at SNL at numerous locations, which have been classified by the NMED as Solid Waste Management Units (SWMUs) or Areas of Concern (AOCs). The SWMUs and AOCs include unpermitted landfills, septic-system drainfields and seepage pits, outfalls, waste piles, and test areas. Past waste management activities at SNL have caused the release of hazardous and radioactive contaminants into the environment. The Mixed Waste Landfill is classified as SWMU 76.

DESCRIPTION AND HISTORY OF THE MIXED WASTE LANDFILL

The MWL was opened as the "TA-3 low-level radioactive waste dump" in March 1959. The MWL accepted low-level radioactive waste and mixed waste from SNL research facilities and off-site generators from March 1959 to December 1988. Approximately 100,000 cubic feet of radioactive waste containing 6,300 curies (Ci) of activity (at the time of disposal) were disposed of at the MWL in unlined trenches and pits.

Investigations at the landfill indicate that tritium is the primary contaminant that has been released from the landfill. Results of a risk assessment prepared by the Permittees indicate that releases of contaminants from the MWL pose little risk to human health or the environment under an industrial land use scenario. Tritium activities at the MWL will decrease steadily with time due to its relatively short half-life of 12.3 years. Because of tritium's short half-life and in consideration of current activity levels, the NMED does not believe that tritium releases at the MWL pose a threat to groundwater, human health, or the environment.

REGULATORY BACKGROUND

NMED issued a RCRA Permit for storage of hazardous waste at SNL on August 6, 1992. On February 6, 2002, the Permittees applied to the NMED to renew their RCRA permit (the current Permit remains in effect until a final decision is made on the renewal request). On October 11, 2001, the NMED directed the Permittees to conduct a Corrective Measures Study (CMS) for the MWL because of concerns raised by the public. The CMS Work Plan was approved with conditions by the NMED on October 10, 2002.

After approval of the CMS Work Plan, the CMS was conducted by the Permittees to identify, develop, and evaluate corrective measures alternatives and to recommend a final remedy to be taken at the MWL. The results of the CMS were documented in a CMS Report following completion of the study; the report was transmitted to the NMED on May 21, 2003. The CMS Report was deemed complete by the NMED on January 5, 2004.

On January 23, 2004, the Permittees proposed a Class 3 modification of the SNL RCRA Permit, requesting that the NMED select a final remedy for the MWL. As part of a 60-day public notice and comment period initiated by the Permittees, a public meeting was held on February 26, 2004 in Albuquerque, New Mexico. Following completion of the Permittees public comment period, the NMED issued a public notice and began a public comment period starting August 11, 2004.

A public hearing on the selection of a final remedy for the MWL was held on December 2-3 and 8-9, 2005 in Albuquerque. The NMED public comment period was held from August 11, 2004 to December 2, 2004, and extended until December 9, 2004. Based on the administrative record and the Hearing Officer's Report, on May 26, 2005, the NMED Secretary approved a final permit and ordered a final remedy for SNL's Mixed Waste Landfill, selecting a vegetative soil cover with bio-intrusion barrier as the final remedy. In addition to selection of the final remedy, the final permit decision requires, among other deliverables, a CMI Work Plan. The CMI Work Plan must address the following:

a. A description of the selected remedy;
b. A description of the remediation system objectives;
c. An identification and description of the qualifications of key persons, consultants, and contractors that will be implementing the remedy;
d. Detailed engineering design drawings and systems specifications for all elements of the remedy;
e. A construction and construction quality assurance work plan;
f. An operation and maintenance plan;
g. The results of any remedy pilot tests, such as landfill cover test plots;
h. A schedule for submission to the Administrative Authority of periodic progress reports;
i. A schedule for implementation of the remedy;
j. A health and safety plan;
k. A comprehensive fate and transport model that studies and predicts future movement of contaminants in the landfill and whether they will eventually move further down the vadose zone and/or to groundwater; and
l. Triggers for future action that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy.

The Secretary's order requires that the NMED review, consider and respond to public comments prior to

approving certain documents related to the MWL, including the CMI Work Plan. The purpose of this public notice is for the NMED to solicit such public comment on the CMI Work Plan, including the fate and transport model.

PUBLIC REVIEW OF THE CORRECTIVE MEASURES WORK PLAN

The CMI Work Plan (including the fate and transport model) may be reviewed by any member of the public at the following locations during the public comment period:

NMED – Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505-6303
(505) 428-2500
Monday - Friday from 8:00 a.m. to 5:00 p.m.

NMED-District 1 Albuquerque Office
5500 San Antonio NE
Albuquerque, New Mexico 87109
(505) 222-9500
Monday - Friday from 8:00 a.m. to 5:00 p.m.

The CMI Work Plan, including the fate and transport model (as Appendix E), are also available electronically on the NMED website at: http://www.nmenv.state.nm.us/HWB/snlperm.html under Mixed Waste Landfill. A separate report, *SAND 2005-6888*, entitled *Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories*" is also included on the web page and contains much of the same information as that in Appendix E of the CMI Work Plan. Although the *SAND 2005-6888* report is included on the web page for convenience, the NMED is only seeking public comment on the CMI Work Plan, including Appendix E and all of the other appendices.

To obtain a copy of the CMI Work Plan or a portion thereof, in addition to further information, please contact Ms. Pam Allen at (505) 428-2500, or at the Santa Fe address given above. NMED will provide copies, or portions thereof, at a charge to the requester.

NMED issues this public notice on **December 9, 2005,** to announce the beginning of a 60-day comment period that will end at **5:00 p.m., February 7, 2006**. Any person who wishes to comment should submit written or electronic mail (e-mail) comment(s) with the commenter's name and address to the respective address below. Only comments received on or before **5:00 p.m., February 7, 2006** will be considered.

John E. Kieling, Program Manager
Hazardous Waste Bureau - New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303
Ref: Sandia National Laboratories – MWL CMI Work Plan
E-mail: john.kieling@state.nm.us

Written comments must be based on the MWL CMI Work Plan (including the fate and transport model).

The NMED must ensure that the approved CMI Work Plan will be consistent with the New Mexico Hazardous Waste Management Regulations. All written comments submitted will become part of the administrative record, will be considered in formulating a final decision, and may cause the CMI Work Plan to be modified. NMED will respond in writing to all significant public comment. The response will

specify which provisions, if any, of the CMI Work Plan have been changed in the final decision, and the reasons for the change. This response will also be posted on the NMED website in addition to NMED notifying all persons providing written comments.

After consideration of all written public comments received, NMED will approve, or approve with modifications the CMI Work Plan. If NMED modifies the CMI Work Plan, the Permittees shall be provided by mail a copy of the modified CMI Work Plan and a detailed written statement of reasons for the modifications. The NMED will make the final decision publicly available and shall notify the Permittees by certified mail. All persons on the mailing list, or that provided written comments, or who requested notification in writing, will be notified of the final decision by mail.

The final decision will become effective immediately upon service of the decision to the Permittees, unless a later date is specified.

ARRANGEMENTS FOR PERSONS WITH DISABILITIES

Any person with a disability requiring assistance or auxiliary aid to participate in this process should contact Judy Bentley by 10 days prior to the end of the public comment period at the following address: New Mexico Environment Department, Room N-4030, P.O. Box 26110, 1190 St. Francis Drive, Santa Fe, New Mexico 87502-6110, (505) 827-9872. TDD or TDY users please access Ms. Bentley’s number via the New Mexico Relay Network at 1-800-659-8331.

Volume I

TAB 6

Response to Public Comments Regarding The Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

From: SNL/Wagner
To: NMED/Bearzi

Back of Tab 6

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

APR 2 4 2006

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

RECEIVED
APR 2006
NMED Hazardous
Waste Bureau

Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Rd. East, Building 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the Department of Energy (DOE) and Sandia Corporation (Sandia), DOE is submitting responses to public comments received by the New Mexico Environment Department (NMED) regarding the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan. The public comments on the MWL CMI Plan were submitted to NMED during the 60-day public comment period, which ended on February 7, 2006. These responses to the public comments were informally requested by NMED on February 28, 2006.

Enclosed please find two documents containing our response. Enclosure 1, entitled "SNL Responses to Public Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan", briefly summarizes the various public comments, and provides Sandia's responses. Enclosure 2, entitled "SNL Responses to Citizen Action Comments", includes more detailed responses to the fairly extensive comments submitted by Citizen Action.

If you have any questions, please contact me at (505)845-6036 or John Gould, (505) 845-6089, of my staff.

Sincerely,

Kimberly A Davis for
Patty Wagner
Manager

Enclosures (2)

cc w/enclosures:
W. Moats, NMED (Via Certified Mail)
L. King, EPA, Region 6 (Via Certified Mail)
J. Volkerding, NMED-OB

cc w/o enclosures:
M. Martin, NNSA/NA-56
A. Blumberg, SNL/NM, Org. 11100, MS 0141
F. Nimick, SNL/NM, Org. 6140, MS 1089
P. Freshour, SNL/NM, Org. 6140, MS 1089
R. E. Fate, SNL/NM, Org. 6147, MS 1089
J. Peace, SNL/NM, Org. 1525, MS 0372
T. Goering, SNL/NM, Org. 6147, MS 1089
M. J. Davis, SNL/NM, Org. 6147, MS 1089
R. Finley, SNL/NM, Org. 6115, MS 0735
C. Ho, SNL/NM, Org. 6115, MS 0735
J. Estrada, NNSA/SSO, MS 0184

AOP 95-45, 06

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **SNL Responses to Public Comments and Citizen Action Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan, April 2006**

Document authors: **Cliff Ho, Dept. 6115 and Tim Goering, Dept. 6147**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: Peter B. Davies — 4/20/06

Peter B. Davies
Director
Geoscience & Environment Center
Division 6100
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico 87185
Operator

Date

and

Signature: Kimberly A. Davis for — 4/21/06

Patty Wagner
Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Date

SNL RESPONSE TO PUBLIC COMMENTS AND CITIZEN ACTION COMMENTS ON THE MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

April 20, 2006

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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SNL RESPONSE TO PUBLIC COMMENTS AND CITIZEN ACTION COMMENTS ON THE MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

April 20, 2006

INTRODUCTION

On May 26 2005, the Secretary of the New Mexico Environment Department (NMED) approved a remedy and a Class 3 permit modification request for corrective measures for the Mixed Waste Landfill at Sandia National Laboratories, New Mexico (NMED, 2005). As part of their decision, the NMED required that the Department of Energy (DOE) and Sandia Corporation (Sandia) prepare, for NMED review and public comment, a Corrective Measures Implementation (CMI) Plan, which included a Fate and Transport Model for the MWL. The CMI Plan was prepared in the Fall of 2005, and NMED established a public comment period which ended February 7, 2006. A number of parties submitted comments, including an extensive set of comments from Citizens Action (CA), dated February 7, 2006 (Robinson, 2006).

This document presents Sandia National Laboratories' response to the public comments received by the New Mexico Environment Department regarding the Mixed Waste Landfill Corrective Measures Implementation Plan. The first portion of this document, titled "SNL Responses to Public Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan," briefly summarizes the various public comments and provides Sandia's responses. The second portion of this document, titled "SNL Responses to Citizen Action Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan and Fate and Transport Model," includes more detailed responses to the fairly extensive comments submitted by Citizen Action. The original Citizen Action comments are presented in bold font, and DOE/Sandia responses are presented in italic font.

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Enclosure 1

SNL Response to Public Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan

(www.nmenv.state.nm.us/hwb/snlperm_comments.htm)

Clifford K. Ho and Timothy J. Goering
Sandia National Laboratories
April 20, 2006

Some comments are paraphrased for brevity

Comment from Donna Detweiler (received 1/27/2006):

General comment regarding the "possible contamination of groundwater resulting from spread of toxins now lodged in the SNL Mixed Waste Landfill". If indeed the Fate & Transport Model is correct and this could happen in as little as 50 years, then my investments could easily be trashed, and the whole neighborhood dependent on Burton Well is likely to be only the first of many to be abandoned."

SNL Response:

Of all the contaminants of concern simulated in the performance-assessment model, only tetrachloroethylene (PCE) was predicted to reach the groundwater in 1,000 years. In those simulations that showed PCE reaching the groundwater, 70% of the runs showed that the groundwater concentration immediately beneath the landfill (no dilution) would be less than 1 microgram per liter (detectable limit). Only 1% of the runs showed that the groundwater concentration would exceed the regulatory metric of 5 micrograms per liter. Thus, the models show that the probability of "contaminating" the aquifer with concentrations large enough to pose health risks is very small. Furthermore, long-term groundwater monitoring will be conducted at the MWL. If contamination is detected in the future, the NMED may impose additional measures.

Comments from Floy J. Barrett (received 1/31/2006):

These comments replicate the comments submitted by Citizen Action. Please see the responses to the Citizen Action comments.

Comments from David M. Brugge (received 1/31/2006):

1. **In addition to intrusion and disruption by plants, animals, and insects identified by Citizen Action, other species of insects, spiders, worms, and similar invertebrates must be identified. Subsurface fungi, molds, bacteria, and related**

species (especially those that can become airborne) need to be taken into consideration. The agent that causes valley fever may be subject to mutation in the radioactive environment of the landfill.

2. **Human intrusion is a serious matter, especially in light of the potential for domestic terrorism and the creation of a "dirty bomb" at the landfill.**
3. **Just the knowledge, threat, or perception that inadequate attention to the dangers of the landfill could cause serious impact to land values for the Mesa del Sol development, as well as potential liability for the University of New Mexico and the state.**

SNL Response:

1. *The current performance-assessment model scenarios included processes and pathways considered to be the most significant and probable.*

2. *See response to #1.*

3. *SNL is responsible for adhering to the requirements of the NMED for the MWL. All the requirements ensure the protection of public health and the environment.*

Comments from Maurice A. Weisberg (received 2/5/2006):

The comments from Maurice Weisberg include a number of general observations and opinions. Specific comments relevant to the results of the performance-assessment model are addressed here:

1. **Biotransport of radioactive contaminants, including vegetative, animal, and insect uptake, is likely to occur over time.**
2. **"At the rate tritium is moving laterally and deeply through the soil, we could expect contamination of the aquifer in less than ten years."**
3. **Contaminants can move much faster through the vadose zone than predictions show, possibly because of torrential rains (episodic events).**

SNL Response:

1. *The current performance-assessment model scenarios included processes and pathways considered to be the most significant and probable. Sandia has conducted a study of the root depths and density in the vicinity of the MWL (Peace et al, November 2004), and care will be taken during long-term monitoring to prevent deep-rooting plant species from establishing themselves on the MWL cover. In addition, the rock biointrusion barrier will be constructed with the intent to prevent intrusion by burrowing animals, and it should restrict root growth so long as the underlying materials are relatively dry (Anderson and Forman, 2002).*

2. *This assertion is not supported by our studies. Our studies show that no detectable levels of tritium will reach the groundwater. Some MWL wastes have been in place now for nearly 50 years, yet groundwater is not contaminated by tritium.*

Furthermore, recently collected data indicate tritium emissions from the landfill are decreasing with time as a result of radioactive decay and other natural processes (Anderson, 2004), further reducing the potential to contaminate groundwater over time.

3. *Our models included a broad range of percolation rates based on detailed modeling studies and precipitation data spanning over 60 years, including heavy rainfall periods. In addition, future climate states were considered where the precipitation was projected to increase to twice the current values. Field evidence shows that even after heavy rainfall events, water penetrates only the upper foot or two of the soil, and is subsequently removed from the soil profile by evapotranspiration.*

Comments from Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping (received 2/6/2006):

These comments support the comments submitted by Citizen Action. Please see the responses to the Citizen Action comments.

SNL Response:

The triggers proposed for soil, air, the vadose zone, and groundwater are at low concentrations and are based on EPA and DOE regulatory standards. Triggers were not proposed for concentrations in plants and animals because there are no applicable regulatory standards, and their populations may vary significantly from year to year. Nevertheless, biota will be monitored to ensure that they do not provide a significant mechanism for contaminant transport.

Comments from Penelope McMullen (received 2/6/2006):

These comments replicate the comments submitted by Citizen Action. Please see the responses to the Citizen Action comments.

SNL Response:

Regarding revision of the CMI Plan, the objective of the CMI Plan was to present a detailed design of the remedy selected by the NMED for the MWL. The proposed design meets the full intent of RCRA Subtitle C regulations, which include requirements for minimizing water migration through the cover, minimizing maintenance and erosion, accommodating subsidence, and having a permeability less than or equal to that of the natural subsurface soils. The Fate and Transport model results do not show any need to modify the proposed design in the CMI Plan.

Long-term monitoring and maintenance at the MWL will be discussed in more detail in the MWL's Long-Term Monitoring and Maintenance Plan, which will be developed after implementation of the remedy.

Comments from John Tauxe (received 2/7/2006):

1. **The uncertainty distribution for the inventory of radionuclides in the MWL is undefended. It is highly unlikely that all inventory constituents share the exact same uncertainty distribution. A more thorough analysis of these distributions should be performed.**
2. **The contaminant transport modeling of the MWL lacks any contributions by biotic activity, including plant uptake and animal redistribution (e.g., ants).**
3. **Current modeling of radon-222 release to the surface assumes the parent (radium-226) remains at depth. If constituents are biotically transported to the surface, the parent of radon-222 could also be transported to the surface. More sophisticated techniques are needed to model the subsequent radon-222 release to the atmosphere.**
4. **The decay products of radon-222 (e.g., lead-210) must be accounted for in assessing dose from exposure to radionuclides involved in surface processes. Diffusing radon-222 gas will decay to lead-210 near the surface and within the cap, which will provide additional exposure to potential future receptors.**
5. **Exposures from radionuclides in the ground surface and near surface (known as "shine") should be included along with inhalation of gases and particulates and incidental ingestion of soils by potential future receptors.**
6. **A reasonable potential future receptor scenario is that of a residence built directly atop the MWL. This would trigger additional exposure pathways, such as exposure to indoor air with concentrations of gaseous radionuclides and VOCs.**
7. **The period of performance of 1,000 years may not be sufficient to model peak doses.**
8. **The future releases and decay products of PCE should be considered.**
9. **The model touts itself as being conservative in its assumptions, but this philosophy was applied inconsistently. Large infiltration rates may be conservative for the groundwater pathway, but not for surface-based exposure.**
10. **Monitoring of tritium and radon as triggers should occur directly above the MWL as opposed to on the perimeter.**
11. **The sensitivity analyses are rather *ad hoc*. Selection of the parameters for the sensitivity analyses may not have included all parameters in the model.**

SNL Response:

1. *We assumed that the minimum inventory was equal to the values recorded in SNL (1993), and that the maximum inventory was equal to twice the recorded inventory values (except for PCE, which was increased to ten times measured concentrations for calibration). Lacking any additional information regarding the uncertainty of the recorded values, we chose a uniform distribution. Comparisons between simulated soil concentrations and measured soil concentrations for tritium showed that this assumed inventory range was adequate (and even conservative) in allowing simulated concentrations to match (and even exceed) measured tritium soil concentrations. In addition, results of sensitivity analyses showed that the inventory was not an important parameter for mobile constituents.*

2. *The current performance-assessment model did not consider scenarios associated with intrusion, uptake, transformation, or disruption by humans, animals, plants, insects, or other biota. The scenarios that were studied included processes and pathways considered to be the most significant and probable.*

   Sandia has conducted a study of the root depths and density in the vicinity of the MWL (Peace et al, November 2004), and care will be taken during long-term monitoring to prevent deep-rooting plant species from establishing themselves on the MWL cover. In addition, the rock biointrusion barrier will be constructed with the intent to prevent intrusion by burrowing animals, and it should restrict root growth so long as the underlying materials are relatively dry (Anderson and Forman, 2002).

3. *Our probabilistic analysis already accounts for the possibility that the radium-226 source term is at the surface (with no cover). The thickness of the cover is allowed to vary between 0 and the designed value. Therefore, the simulations already include the effect of the radon-222 source term being at the surface. Results of the sensitivity analysis shows that the impact of the cover thickness is small, relative to the uncertainty in the emanation factor, which is governed by the assumed containment integrity of the sealed radium-226 sources.*

   Additionally, most of the potential source term for Rn-222 is in hermetically sealed stainless steel source capsules. The potential release of Rn-222 from these capsules was "allowed" for modeling purposes with an assumption that up to 100% of these capsules will fail, allowing their contents to be released. Even in the event of this unlikely scenario, the area-weighted average MWL contents "vulnerable to biotic CT" would be a very small fraction of the area/volume of the MWL.

4. *Decay products of Rn-222 were not considered in the model of Rn-222 transport to the surface, but the steady decay of Rn-222 was included. Accumulation and accountability of Rn-222 decay products would require a transient model, but a steady-state model was chosen to accommodate the long-lived parent products of Rn-222 and to accommodate liquid-phase advection in the analytical solution. It should be noted that the simulations of radon-222 leaching to the groundwater (using FRAMES/MEPAS) did include evaluation of the decay products.*

5. *The current performance assessment did not include exposure due to "shine" or incidental ingestion of surface soils. However, indirect ingestion of radionuclides through consumption of vegetables and animals irrigated or fed by contaminated water was accounted for by assigning a large intake of water (10 L/day).*

6. *The atmospheric-transport scenario in the current performance assessment assumed a "worst-case" scenario, where a receptor was inhaling air above the MWL 24 hours a day, 7 days a week. This is even more conservative than assuming a home on top of the MWL, where the structure would provide additional resistance to exposure.*

7. *The 1,000-year performance period was used for those constituents that peaked well before 1,000 years (e.g., tritium, PCE). For radionuclides and heavy metals, simulations were run past 10,000 years, and these results are presented in the study. For radon, steady-state simulations were assumed, which conservatively assumes the instantaneous transport of radon to the surface.*

8. *Future releases of PCE are not considered because the entire inventory of PCE is assumed to be available for release at time zero. PCE was used as a proxy for all other VOCs because of its relatively large Henry's Constant and mobility. Several decay products of PCE, including TCE and 1,1- dichloroethene, have already been proposed for long-term monitoring in groundwater, and triggers have been established for these constituents. Vinyl chloride (VC) has never been detected in soils or groundwater at the MWL.*

9. *Parameters were not conservatively estimated if they could have a confounding effect on other processes. For example, a conservative assumption was made that the receptor drinks 10 L/day of water (as opposed to the EPA-recommended 2 L/day). This was to conservatively reflect indirect ingestion from irrigated vegetation or animals. In contrast, the range of infiltration was based on past historic data and was an accurate reflection of the range we believe will occur in the future, including climate change. Another conservative assumption was that groundwater concentration at the base of the vadose zone was compared against the regulatory metric, and did not account for dilution caused by mixing within the aquifer.*

10. *The proposed locations were selected to be consistent with the last 26 years of environmental monitoring at the MWL. However, the locations for tritium and radon monitoring could certainly be placed directly on top of the MWL cover, if considered appropriate by the NMED. Specific details on long-term monitoring at the MWL, including parameters and locations, will be determined in consultation with the NMED in the MWL Long-Term Monitoring and Maintenance Plan (LTMMP). The LTMMP is scheduled to be completed after implementation of the final remedy.*

11. *All stochastic parameters used in the model were included in the sensitivity analyses. The results of the sensitivity analyses (presented in charts) only included those parameters that were found to be statistically significant.*

Comments from Citizen Action (received 2/7/2006):

The following includes an abbreviated list of comments submitted by Citizen Action regarding the fate and transport (performance-assessment) model. A separate document, Enclosure 2, entitled "SNL Responses to Citizen Action Comments", contains additional responses to the detailed comments submitted by Citizen Action..

1. **The model fails to consider biological transport of contaminants.**

2. **The model fails to consider human intrusion.**
3. **The model fails to consider beryllium and metallic sodium as potential contaminants of concern, among others.**
4. **The model fails to consider new compounds formed as a result of radiolysis.**
5. **The model fails to consider animals, plants and humans as "triggers."**
6. **The model fails to consider "trigger levels" for the entire inventory of contaminants in the known inventory of the landfill.**
7. **The model fails to consider conducting a risk assessment for the F & T model.**
8. **The model fails to use current data for current levels of radionuclides, heavy metals and volatile organic releases.**
9. **The model fails to consider the deterioration of waste containers.**

SNL Response:

1. *The model did not specifically address biological uptake and transport of contaminants by plants and animals. The intent of the biointrusion barrier is to prevent this occurrence. Sandia has conducted a study of the root depths and density in the vicinity of the MWL (Peace et al, November 2004), and care will be taken during long-term monitoring to prevent deep-rooting plant species from establishing themselves on the MWL cover. In addition, the intent of the rock biointrusion barrier is to prevent intrusion by burrowing animals, and it should restrict root growth so long as the underlying materials are relatively dry (Anderson and Forman, 2002). .*
2. *Human intrusion was not considered in the model as the model was necessarily limited to conservative, reasonable scenarios. For modeling purposes, we assumed that the exposed individual was located at the landfill. Inhalation and dermal exposure was assumed to occur 24/7 above the landfill. In addition, drinking water was assumed to be taken directly beneath the landfill and consumed at a rate of 10 L/day (2 L/day recommended by EPA for risk assessments).*
3. *The constituents that were modeled were chosen because of their high relative mobility and/or their large inventory. Beryllium and metallic sodium were not evaluated in the current model. Beryllium is a relatively minor component of the MWL inventory, and metallic sodium is not listed in the inventory.*
4. *Radiolysis was not considered in the current model. Radiolysis is considered unlikely at the MWL, as it is not significant in low-level radioactive waste.*
5. *Our recommended triggers include surface-concentration measurements for radon gas and tritium in soil pore water. Long-term monitoring will include monitoring of biota to ensure that they do not provide a significant mechanism for contaminant transport.*
6. *Triggers were specified for the constituents that were found to potentially exceed performance metrics. For PCE, which was a proxy for all VOCs, triggers were specified for all VOCs measured at the site since PCE was found to potentially exceed the groundwater concentration metric.*
7. *Our study does provide a risk-based performance-assessment analysis using relevant regulatory performance standards as metrics (e.g., dose, groundwater concentrations). Probabilistic, uncertainty analyses are performed to develop distributions of scenario results that are compared against the metrics. Sensitivity*

analyses are also performed to identify the most important parameters and processes that impact the simulated performance metrics. Standard conversion factors (U.S. EPA slope factors) can be used to convert dose (which is reported in our analysis) to risk of cancer incidence or fatality.

8. *The latest data that were available to evaluate concentrations of tritium and PCE at various depths beneath the MWL were from 1993. These data provided the necessary calibration for the models. Additional data will be collected during long-term monitoring of the MWL, and these data can be used to update the MWL Fate and Transport model, if necessary. Groundwater concentrations are taken much more frequently (on an annual basis), and there is no evidence of groundwater contamination from the MWL.*
9. *All of the constituents (except for radium-226, which are contained in "sealed sources") were conservatively assumed to be uncontained and available for leaching.*

REFERENCES:

Anderson, February 2004, *"Results of Tritium Emission Flux Measurements for Sandia National Laboratories Mixed Waste Landfill,"* URS Corporation, Austin, Texas.

Anderson, J.E. and A.D Forman, March 2002. *"The Protective Cap/Biobarrier Experiment. A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory,"* prepared by Stoller for U.S. Department of Energy – Idaho Field Office Environmental Surveillance, Education and Research Program, Contract DE-AC07-00ID13658, Idaho Falls, Idaho.

Peace, J.L., P.J. Knight, T.S. Ashton, and T.J. Goering, November 2004, *"Vegetation Study in Support of the Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico,"* SAND2004-6144, Sandia National Laboratories, Albuquerque, NM.

Enclosure 2:

SNL Responses to Citizen Action Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan and Fate and Transport Model

(www.nmenv.state.nm.us/hwb/snlperm_comments.htm)

Clifford K. Ho and Timothy J. Goering
Sandia National Laboratories

April 20, 2006

Introduction

This document contains SNL responses to comments submitted by Citizen Action regarding the MWL Corrective Measures Implementation Plan and Fate and Transport model. The complete set of Citizen Action comments is presented below, along with Sandia responses in italics.

All public comments, including the Citizen Action comments, are also available on the NMED website, at www.nmenv.state.nm.us/hwb/snlperm_comments.htm

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Review of Sandia National Laboratories'
Mixed Waste Landfill Corrective Measure Implementation Plan
and
Fate and Transport Model:

Comments and Recommendations

February 7, 2006

Prepared on behalf of:
Citizen Action New Mexico
Sue Dayton, Director
P.O. Box 262
Albuquerque, NM 87047
Sue Dayton, Coordinator
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INTRODUCTION

These Comments and Recommendations address portions of the Sandia National Laboratories' (SNL) Mixed Waste Landfill (MWL) Corrective Measure Implementation Plan (CMIP) and Fate and Transport Models (FTM) posted on the New Mexico Environment Department (NMED) Website. NMED required SNL to provide these documents as part of the Permit Modification issues to SNL regarding the MWL in May, 2005.

The Corrective Measure Implementation Plan ("CMIP") is posted at http://www.nmenv.state.nm.us/hwb/SNL/MWL/SNL_Mixed_Waste_Landfill_CMI_Work_Plan_(11-2005).pdf. The Fate and Transport Model ("FTM"), titled "Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories" Document Number SAND 2005-6888 is posted at http://www.nmenv.state.nm.us/hwb/SNL/MWL/Fate_and_Transport_(Probabilistic_Performance-Assessment_Modeling_of_the_MWL;%2011-2005).pdf).

The Permit Modification issued by New Mexico Environment Department for the Mixed Waste Landfill (posted at http://www.nmenv.state.nm.us/hwb/SNL/MWL/Final_Decision/Permit_Language_for_the_Mixed_Waste_Landfill.pdf) requires that Sandia/DOE submit a CMIP that "shall, at a minimum, include:

a. A description of the selected remedy;
b. A description of the remediation system objectives;
c. An identification and description of the qualifications of key persons, consultants, and contractors that will be implementing the remedy;
d. Detailed engineering design drawings and systems specifications for all elements of the remedy;
e. A construction and construction quality assurance work plan;
f. An operation and maintenance plan;
g. The results of any remedy pilot tests, such as landfill cover test plots;
h. A schedule for submission to the Administrative Authority of periodic progress reports;
i. A schedule for implementation of the remedy;
j. A health and safety plan;
k. A comprehensive fate and transport model that studies and predicts future movement of contaminants in the landfill and whether they will eventually move further down the vadose zone and/or to groundwater;
l. Triggers for future actions that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy."

In response to comments identified during review of the FTM and CMIP, recommendations regarding specific revisions to the FTM and CMIP are identified. The recommendations include revising the CMIP to reflect modifications proposed for the FTM.
Due to the technical nature of the FTM, the reliance of NMED on a contractor to conduct a technical review of the FTM, and the numerous areas of deficiency in the FTM noted in these comments it is also strongly recommended that NMED convene a "technical discussion group"

to serve as a public meeting to provide for an exchange among interested stakeholders regarding the adequacy of the FTM and CMIP. It is recommended that such a technical discussion group include representatives of the permittee, the NMED and members of the public who have expressed an interest in the studies conducted by SNL and/or submitted comments to the NMED on the CMIP and/or FTM. It is recommended that this technical discussion group be convened prior to the determinate that the FTM and CMIP are either “comprehensive” or “complete” with respect to the technical requirements applicable to the wastes at the MWL.

I. Fate and Transport Model Comments and Recommendations

A. General Comments: The document submitted to comply with the FTM requirements in the Permit Modification is not comprehensive with respect to:

    1. The volume of each individual waste product and physical state of containers for the full range of contaminants at the Mixed Waste Landfill;
    2. Potential for releases including vadose zone and groundwater contamination due to transport not considered in the FTM including mechanisms such as biological transport of contaminants through the ground surface, human intrusion, and movement of contaminants by wind/air;
    3. Modeling for the complete suite of radionuclides and daughter products, metals, and volatile and semi-volatile organic compounds in the known inventory of the MWL.

RECOMMENDATION: The FTM should be revised to provide the “comprehensive” model required by the Permit Modification and the CMIP should be modified to reflect the findings of the revised FTM following its acceptance as technically complete and comprehensive by NMED.

<u>SNL Response</u>*: See response to each of the detailed items below.*

B. Areas not addressed in the FTM:

    1. The FTM fails to address biological transport of contaminants resulting from plant and animal uptake of contaminants and subsequent dispersion of soil, plant and animal material by wind, including vertebrate and invertebrate animals entering the landfill and plants transporting contaminants taken up through their root systems. Data presented at the December 2004 MWL Public Hearing by SNL demonstrate that deer mice and vegetation at the MWL show contamination with low levels of tritium and radon.

<u>SNL Response</u>*: The model did not specifically address biological uptake and transport of contaminants by plants and animals. However, the biointrusion barrier will be constructed with the intent to prevent this pathway for uptake and transport.*

    2. The FTM fails to address transport of contaminants resulting from human intrusion associated with accidental events and the eventual failure of the land use restriction portions of the institutional controls proposed by SNL for the MWL. Accidental or unforeseen events that could be included in FTM model assumptions should be understood to include discharges of large volumes of water at the site on the order of disposal of more than 270,000 gallons of reactor cooling water at the site or the

pooling of snow melt and rain water above trenches, circumstances that occurred at the MWL while it was an active disposal site.

<u>SNL Response</u>: Land-use restrictions are recorded on the facility property legal documentation for notification purposes in accordance with regulation. Further, the institutional controls are to be carried out under the Long-Term Monitoring and Maintenance Plan (LTMMP). Inhalation and dermal exposure was assumed to occur continuously (24/7) above the landfill. In addition, drinking water was assumed to be taken directly beneath the MWL, and dilution caused by mixing within the aquifer was neglected (groundwater concentrations were taken to be equal to the concentration at the base of the vadose zone). Finally, the reactor cooling water was placed within the MWL when placement could occur as an active disposal site and no such additional placement will occur in the now-closed unit.

3. The FTM fails to provide a comprehensive fate and transport analysis as it does not include calibrated model "realizations" for the full range of radioactive and hazardous constituents identified at the MWL including: a wide range of radionuclides, a wide range of metals and inorganic compounds including beryllium, nickel, chromium, sodium, lithium, and the range of volatile organic compounds already demonstrated to have been escaped from the MWL. A comprehensive list of radionuclides, metals and volatile organic compounds can be found in what is identified in the CMIP at p. 4-2 as "[a] detailed MWL waste inventory, by pit and trench, … provided in the Environmental Restoration Project "Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996" (SNL 1998)."

<u>SNL Response</u>: The constituents modeled were chosen conservatively because of their high relative mobility and/or larger quantity identified in the inventory.

4. The FTM fails to identify or address fate and transport dynamics associated with the potential for formation of mobile, potential hazardous compounds by radiolysis - the process by which radionuclides can mix with non-radioactive constituents and form new compounds – to occur among waste constituents of the MWL.

<u>SNL Response</u>: Radiolysis is the molecular decomposition of a substance as a result of radiation. The modeling of constituents (amount and characteristics) formed as a result of radiolysis is highly uncertain and speculative. In addition, radiolysis is more likely to occur from high-level radioactive waste, rather than the low-level waste disposed of at the MWL.

5. The "triggers" identified in the FTM fail to include monitoring mechanisms to reflect either human intrusion, biological transport, or the waste constituents identified at the MWL, but not considered in the FTM.

<u>SNL Response</u>: Our recommended triggers include surface-concentration measurements for radon gas and tritium in soil pore water. Specific details on long-term monitoring of the MWL will be addressed in the MWL Long-Term Monitoring and Maintenance Plan (LTMMP). The LTMMP will be developed in consultation with the NMED following implementation of the final

remedy at the site, and is scheduled for completion in 2008.

The FTM fails to identify means to monitor, model and assure the effectiveness of institutional controls or the consequences of the failure of such passive site protection measures.

SNL Response: Institutional controls or the consequences of the failure of such passive protection measures are not appropriate for inclusion in the FTM. The Long-Term Monitoring and Maintenance Plan (LTMMP) will address these issues.

> **The FTM fails to provide a risk assessment/performance assessment analysis in its evaluation of the potential for release of contaminants from the MWL. RECOMMENDATION: In order for the FTM to be fully "comprehensive," NMED should require that the FTM be revised and expanded to address each of the areas of incompleteness identified above.**

SNL Response: Our study does provide a risk-based performance-assessment analysis using relevant regulatory performance standards as metrics (e.g., dose, groundwater concentrations). Probabilistic, uncertainty analyses are performed to develop distributions of scenario results that are compared against the metrics. Sensitivity analyses are also performed to identify the most important parameters and processes that impact the simulated performance metrics. Standard conversion factors (U.S. EPA slope factors) can be used to convert dose (which is reported in our analysis) to risk of cancer incidence or fatality.

C. Areas addressed inadequately in the FTM:

1. **The FTM relies on data regarding releases of radionuclides, heavy metals and VOCs ("volatile organic compound") from the Phase 1 and Phase 2 RCRA Feasibility Investigation (RFI) gathered 1993 – 1995. FTM at 14. No new data gathering was conducted. No new data gathering is proposed to calibrate or verify the modeling conducted**.

SNL Response: Our analysis also uses information and results from site studies conducted by Wolford (1997, 1998), WERC (2001), Peace et al. (2002), Peace et al. (2003), and Peace and Goering (2005).

Data gathering continues at the MWL, and will continue into the future under the long-term monitoring program. Currently, groundwater is sampled on an annual basis at the site, and analyzed for a wide suite of potential contaminants, including volatile organic compounds, tritium, and uranium. Sandia's Environmental Monitoring Program collects soil and vegetation samples along the MWL perimeter annually (since 1980). The soil and vegetation samples are analyzed for tritium and gamma-emitting radionuclides.

Data collected during long-term monitoring at the MWL will be used to update the fate and transport model for the site on a 5-year basis, and to re-evaluate the likelihood of contaminants reaching groundwater.

RECOMMENDATION: The NMED should require that SNL conduct a monitoring program to verify the accuracy of the model parameters and model results identified in the FTM. This program should include sampling of the vadose zone at and beneath the MWL to determine if the FTM's predictions and assumptions accurately reflect conditions at the MWL.

SNL Response: The FMT used realistically conservative data and sensitivity analyses to identify potential data gaps that additional data would be needed to fill. No additional data needs were identified during this process.

The NMED Class 3 Permit Modification for the MWL requires Sandia to develop a Long Term Monitoring and Maintenance Plan (LTMMP) for the MWL within 180 days after NMED's approval of the Corrective Measures Implementation Report. The LTMMP will be developed in consultation with the NMED, and will provide details of the monitoring program for the MWL, and triggers for the site. Data collected during long-term monitoring at the MWL will be used to evaluate the continued effectiveness of the remedy selected for the MWL. These data will also be used to update the fate and transport model for the site every 5 years, as required by the State of New Mexico Final Order, dated May 26, 2005.

2. **The FTM appears to have failed to identify or consider either the mechanisms for deterioration of waste containers or the consequences of the deterioration of waste containers in any manner during development of the input parameters and assumptions for its VOC, heavy metal and radionuclide models, with the single exception of the radon model runs in which radium-226 containers were determined to deteriorate in 1,000 years**.

SNL Response: This assertion is incorrect as all constituents were assumed to be exposed in the landfill WITHOUT containment. For the analysis of radon-222 transport, we assumed the source of anthropogenic radon-222 (radium-226) was contained in sealed sources.Up to 100% of these sealed sources were assumed to be exposed (broken) in the realizations.

The failure to address container deterioration systematically in the FTM results in the model using inappropriate, non-conservative assumptions about the "source terms" of waste constituents. The MWL waste containers, or the MWL waste containers SNL is aware of, include 55-gallon drums, plastic bags and other short-lived containers with an identifiable lifespan that is very short, a few decades in the case of 55-gallon drums, compared to the extremely long-lived hazards associated with the MWL contents other than tritium and cobalt-60.

The failure to address the limits on the durability containers due to deterioration mechanisms and resulting contaminant releases ignores a primary critique of SNL's data presented at the December 2004 MWL Public Hearing, as identified by the Hearing Officer, that SNL studies and models to date have failed to address the inevitable deterioration of waste containers.

RECOMMENDATION: To reflect the intent of the Hearing Officer as stated in her Final Report and Proposed Final Order, the FTM should be revised to identify and address fate and

transport dynamics that would occur as a result of the deterioration of all VOC, heavy metal and radionuclide containers at the MWL.

Also, the FTM's analysis of potential radon movement should be revised to both identify mechanisms that would result in deterioration of the radium-226 containers and conduct model realizations for container deterioration faster than the 1000-year period reported such as deterioration within 100-years of disposal.

3. **The FTM concludes that PCE, the one organic compound modeled in the FTM, would reach groundwater for all 100 model runs ("realizations") with the majority of the model runs showing PCE reaching groundwater within 50 years**.

The FTM states: "Figure 22 [on p. 55] shows the simulated PCE concentrations in the groundwater as a function of time for all 100 realizations. **The majority of the realizations show the aquifer concentrations peaking before 50 years**. **Depending on the time of disposal, this corresponds to peak concentrations occurring by 2010 – 2040.** [emphasis added]. To date, no detectable amounts of PCE have been found in the groundwater at the MWL. This is still consistent with the simulations which show a large amount of variability in the simulated concentrations resulting from uncertainty included in the input parameters." FTM at pp. 54-55. Figure 22 is attached these comments as APPENDIX A.

Thus, the FTM confirms that a volatile organic compound already shown to have escaped from the MWL, tetrachloroethylene (PCE), is likely to reach the groundwater aquifer within 50 years in most model runs. This finding should serve as a basis for NMED to focus a substantially higher degree of attention on the need for a corrective measure at the MWL that can be demonstrated to effectively control releases of VOCs.

Figure 23 in the FTM shows the concentration of PCE anticipated in the groundwater by the model realizations. This figure shows that the vast majority of the realizations – about 80% - show PCE levels in the groundwater in the range of 1 – 5 micrograms per liter, equivalent to parts per billion. Prediction of those concentrations of PCE reaching the groundwater represent a prediction of significant contamination as PCE is not naturally occurring and therefore **zero** PCE would be predicted to have reached groundwater if no PCE were already shown to have escaped from the MWL. Figure 23 is attached to these comments in APPENDIX A.

SNL Response: In contrast to the statement above, only 30% (not 80%) of the realizations results in groundwater concentrations ranging from 1 – 5 micrograms per liter. Only 1% of all the realizations show a groundwater concentration that exceeds the regulatory metric of 5 micrograms per liter.

The FTM shows that PCE reaches groundwater based on data from previously detected releases of VOCs at the MWL as, the FTM notes: "Although no quantitative estimates of the volumes of these contaminants disposed of in the MWL exist, soil samples provide an estimate of the extent and concentration of the region contaminated with VOCs at the MWL." FTM at p. 52.

<u>SNL Response</u>: No PCE has been detected in the groundwater at the MWL. The quote above refers to measured values of PCE in soil-gas samples taken at 10 and 30 feet below the surface.

The lack of information about this highly mobile contaminant in the MWL inventory, or the form and condition of containers used for disposal of PCE and other VOCs and SVOCs, prevents SNL from conducting analyses based on accurate estimates of the amount of VOCs and SVOCs in the MWL. The lack of recent or current VOC and SVOC monitoring data since the 1993 Phase 2 RFI prevents SNL from accurately reflecting the current extent of VOC and SVOC releases from the MWL in the FTM.

<u>SNL Response</u>: The extent of contamination by VOCs and SVOCs in subsurface soils at the MWL was characterized during the Phase 2 RFI. Concentrations of contaminants were found to be at low levels, below risk thresholds, and the MWL was proposed for No Further Action in 1996. Because the nature and extent of contamination had been adequately characterized during the Phase 2 RFI, and because contaminant levels were so low, monitoring was not continued for VOCs and SVOCs in soil.

There is little information about PCE in the MWL inventory because only small quantities of solvents such as PCE were disposed of at the site (primarily on rags and contaminated equipment).

See response below.

As SNL has no information available about the VOC waste volume and disposal practices the FTM used the: "[M]aximum measured gas concentration (5,900 ppb) … as a minimum value in a uniform distribution increasing to ten times this value to develop a range of equilibrium aqueous concentrations." FTM at p. 52. In other words, since the MWL permittee acknowledges that it has no information on the amount or form of the PCE (and other VOCs and SVOCs) in the landfill or how the containers they were disposed in have aged, the model used the amount of VOCs and SVOCs more than a decade ago that had already leaked from the landfill for the "source term."

<u>SNL Response</u>: The maximum inventory for PCE was increased (from the minimum value estimated from measured values) by a factor of 10; with this distribution, the simulation results fell within the range of measured values in 1993 at 10 and 30 feet below the subsurface. This calibrated the model for the latent period between emplacement (which is unknown) until the time of measurement in 1993.

This method of identifying the "source term" for the PCE FTM does not account for the likelihood that the amount of PCE, and other VOCs, leaking from waste containers may have increased significantly since 1993 when the VOC releases used to develop the FTM were detected.

The FTM only modeled one organic compound, PCE, though a dozen VOCs and SVOCs were demonstrated to have been released from the landfill by 1995. In spite of the demonstration that PCE would reach groundwater within 50 years in all model realizations, the FTM failed expand

its modeling study to address the fate and transport of other organics detected in the Phase 2 RFI monitoring data.

<u>SNL Response</u>: PCE was chosen conservatively because of its relatively large Henry's Constant and relatively high mobility. Because results showed that PCE could reach the groundwater, all other VOCs that have been measured in the soil gas at the site have been marked as "triggers" for monitoring in the groundwater.

Similarly the FTM fails to identify or present model realizations for the decay products of PCE and the other VOCs and SVOCs demonstrated to have escaped the MWL in 1993. This is particularly problematic as at least one decay product of PCE, vinyl chloride, has a maximum contaminant level (MCL) established by EPA of 2 ppb, less than the proposed trigger level of 2.5 ppb proposed for PCE in the FTM at p. 62. See EPA "National Primary Drinking Water Regulations" at http://www.epa.gov/safewater/contaminants/dw_contamfs/vinylchl.html.

<u>SNL Response</u>: PCE was modeled as a proxy for all VOCs, including its decay products. Biodegradation of PCE (and TCE) to vinyl chloride in groundwater would occur only under anaerobic conditions, which do not exist at the MWL.

As no information is presented in the FTM regarding fate and transport model realization data for any PCE decay product, no information is presented regarding concentrations of any decay products in groundwater that may have been predicted by the FTM model realizations.
The FTM should be revised to correct inconsistencies in data presented regarding PCE releases from the MWL. The FTM states that the maximum PCE detected in 1993 was <u>5,900 ppb</u> at p. 52, but lists the maximum concentration of PCE in 1993 as <u>5,200 ppb</u> on Figure 21 at p. 53.

<u>SNL Response</u>: The numbers reported are correct. Figure 21 shows the maximum concentration measured at 10 feet, which was 5,200 ppb. Figure 22 shows the maximum concentration measured at 30 feet, which was 5,900 ppb. The higher of the two values was used for inventory calibration.

RECOMMENDATION: Because PCE was shown to reach groundwater in all model realizations within approximately 50 years, the FTM should be revised to include model realizations reflecting future movement of all VOCs and SVOCs found to have been released from the landfill in 1993. These additional models and model realizations should be revised to include consideration of the decay products of PCE and the other VOC s and SVOCs that were shown to have escaped the MWL by 1993. Decay products modeled should include any decay products, such as vinyl chloride, that may have MCLs as low or lower than that established for PCE.

The FTM should be revised to reflect the potential for container deterioration to have resulted in significant additional VOC and SVOC releases from the MWL at rates well beyond the "ten times" indicated in the FTM at p. 52. As substantial additional deterioration of VOC and SVOC containers is likely to have occurred since 1993, it is reasonable for the FTM to be revised to include consideration of VOC and SVOC source terms 100x and 1000x the maximum values detected in the vadose zone in 1993 for all VOCs and SVOCs detected at the landfill. Model

realizations considering source terms 100 – 1000 times concentrations detected in 1993 will allow the FTM to address the potential for additional releases since 1993 or releases not detected in 1993.

The FTM should be revised to include evaluation of the vapor phase transport mechanism attributed to the VOCs that reached the groundwater at the Chemical Waste Landfill at SNL. This revision should be included to ensure that the assumptions regarding PCE movement used in the FTM reflect real world conditions at as demonstrated at other landfills at SNL.

The FTM should be revised to include a VOC and SVOC detection and monitoring system to provide real world data to verify results of model realizations.

The NMED should request a revision of the FTM that corrects any inconsistencies in data used and presented in the FTM. The indication that the FTM authors may have understated the maximum PCE gas concentrations in 1993 by more than 10% (the difference between 5,900 and 5,200) in one of its models (as reflected in Figure 21) should serve as a basis for the NMED to require verification that the appropriate, higher value was used in the FTM. In addition, the NMED should require that SNL verify that model realizations were indeed conducted with using values "ten times" the 1993 maximum gas concentration of PCE as neither Figure 21 or any other portion of the FTM discussion of VOC model realizations appear to reflect the use of values "ten times" 1993 maximum gas concentrations asserted by the FTM at p. 52.

The NMED should consider requiring improvements in the Corrective Measure proposed for the MWL to prevent future releases of VOCs and SVOCs from the MWL as the FTM (and a 1995 Argonne National Laboratory study cited in the FTM, as discussed below) demonstrates the high probability of VOCs reaching groundwater beneath the MWL at values at or near applicable maximum contaminant level standards.

SNL Response: See detailed responses above regarding these recommendations.

4. **The FTM identifies a 1995 Argonne National Laboratory [cited as Johnson 1995 in the FTM] report at p. 16 that showed that VOCs released from the MWL could reach the water approximately 250 years from the time of disposal. This study was not provided to NMED as part of either the Corrective Measures Study (CMS), Corrective Measure Implementation Plan (CMIP) or the references for either of those reports**.

The FTM at p. 16 states: "The [Argonne National Laboratory study report as Johnson, 1995] study also included screening calculations for aqueous-phase transport of PCE and TCE, and predicted that these VOCs could reach the water table approximately 250 years from time of disposal. No calculations were conducted for vapor-phase transport, which has proven to be the most significant transport mechanism for organic compounds in the vadose zone at nearby ER sites, including the Chemical Waste Landfill."

This 1995 study is cited as: “Johnson, R., D. Blunt, D. Tomasko, H. Hartmann, and A. Chan, 1995, A Human Health Risk Assessment for the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico, Argonne National Laboratory, Argonne, IL.” Though the FTM asserts that the Argonne Study used a “worst case scenario” approach, the failure of the 1995 Study to consider vapor-phase transport mechanisms, which has been shown to have resulted in VOCs escaping the Chemical Waste Landfill at SNL reaching the groundwater aquifer, appears to contradict that assertion.

The combination of the 1995 Argonne study with the FTM demonstrates that the high mobility of VOCs is not controlled by the proposed Corrective Measure at the MWL and the likelihood that VOCs will reach the groundwater aquifer beneath the MWL even if the currently approved Corrective Measure is installed at the MWL.

RECOMMENDATION: The NMED should require SNL to provide the agency with copies of the 1995 Argonne Study, review the Study, and consider its relevance regarding the adequacy of the Corrective Measure identified in the Permit Modification since SNL failed to present the Study to NMED or the public or consider it during the development of the Corrective Measure Study.

The NMED should review the Corrective Measure approved in the Permit Modification as the conclusions of the 1995 Argonne Report are contrary to the conclusions presented in the CMS and MWL hearing by SNL that contaminants such as VOCs *could not* reach groundwater at the MWL site. See statement “Contaminants are unlikely to reach groundwater …” CMS at 29.

SNL Response: Neither the Argonne National Laboratory report by Robert Johnson nor the early modeling results by Sandia National Laboratories provide any new information to the case, and details on these reports have been included in public documents for years. Both reports are discussed in depth in Section 5.6 of the Mixed Waste Phase 2 RCRA Facility Investigation Report (SNL/NM, 1996). In addition, the Argonne report was provided to WERC and to the public during the first WERC peer review of the MWL in 2001 (Reference No. 53, Appendix D, WERC 2001). The results of the Argonne National Laboratory study, and the modeling results by Sandia are also summarized in Appendix E of the Mixed Waste Landfill Corrective Measures Implementation Plan (SNL/NM, 2005).

The “trigger levels” identified in the FTM fail to provide for early detection and early response to releases prior to the exceedence of health–based standards. The proposed trigger levels fail to provide either early detection or early response as they are set at values at or near regulatory standards rather than at levels that would demonstrate the “edge of the plume,” which is the purpose of trigger levels as identified by the MWL Hearing Officer’s Final Report at pp. 35 – 40.

SNL Response: Triggers for contaminant releases to the surface were set at values that are orders of magnitude below values that were simulated to yield exceedances to regulatory metrics. The triggers for groundwater concentration were chosen to be half the MCLs. These values are considered conservative, as MCLs are typically health-based standards.

The trigger levels identified in the FTM are values that are well above background concentrations for the constituents identified and fail to identify levels that would demonstrate that the "edge of a plume" has reached a location of concern or that statistically significant increases in the concentration of contaminants have been detected by monitoring activities.

Exceedences of the proposed trigger levels identified in the FTM would demonstrate that significant and extensive contamination has already occurred, not conditions at the "edge of the plume," and would result in subsurface contamination that would be much more expensive to remedy than contamination detected at trigger levels set at concentrations exceeding background by a statistically significant value, such as 25% or 50%, above locally appropriate background values.

Though neither the Permit Modification or the Secretary's Final Order provide a specific definition for "trigger levels," several sources can be identified that demonstrate that the appropriate understanding of "trigger level" as identified in the MWL Hearing Officer's Final Report is a concentration of a constituent designated to "detect contamination" or the "edge of a plume," rather than an exceedence of a regulatory standard.

In her Final Report, the Hearing Officer identified an example of trigger levels as: "one trigger could be that if contaminants moved a specific distance deeper under the landfill, then this might result in NMED ordering future excavation" at p. 40.

At the MWL Public Hearing in December 2004, NMED's technical witness Willam Moats stated, "…triggers themselves would be designed around detection of contamination in the vadose zone and the groundwater." MWL Hearing Transcript at p. 1141.

RECOMMENDATION: To insure that trigger levels identify the "edge of a plume" and "detect contamination," rather than the exceedence of regulatory standards, the trigger levels applied to the monitoring systems at the MWL should be set at concentrations that reflect a significant increase above background values rather than at a concentrations that approach regulatory standards and are many times higher than background conditions. The location of the monitoring systems at which the trigger levels would apply should be beneath the landfill, but well above the groundwater level for the trigger levels to serve as an "early warning system" rather than confirmation of groundwater contamination by applying proposed trigger levels at an elevation at which groundwater is found as proposed in the FTM.

To provide "detection of contamination," trigger levels should be established at a level 25 – 50% above initial concentrations for contaminants of concern. Verification of contaminant concentrations when detected will provide assurance that values that exceed background concentrations by a significant amount are not anomalous or indicative of analytic error.

<u>SNL Response</u>: The trigger levels proposed in the MWL CMI Plan represent conservative values that were selected based on regulatory metrics. They were selected based on the objectives of minimizing false positive detections, while still protecting human health and the environment. The final trigger levels for the MWL will be selected in consultation with the NMED, and will be presented in Sandia's Long Term Monitoring and Maintenance Plan for the MWL.

5. **The trigger levels proposed in the FTM fail to identify trigger levels for waste constituents that apply at the edge of the MWL or in the vadose zone below the site but above the water table**.

The FTM lists recommended “trigger levels” in Section 4.2.1 at pp. 61 – 62. The list fails to include vadose zone trigger levels for contaminants identified in the MWL and only lists vadose zone trigger level for “infiltration” as measured by moisture content increase.

RECOMMENDATION: The FTM should be revised to provide for a vadose zone monitoring program that includes analysis of all of the constituents identified on pp. 61 – 62 and other constituents that may be identified based on these comments or other recommendation provided to the NMED to insure that all transport mechanisms, both anticipated and unanticipated, are addressed by the trigger levels implemented at the MWL.

SNL Response: The proposed vadose zone monitoring program consists of neutron moisture monitoring to assess changes in infiltration over time. Vadose zone monitoring parameters, frequencies and locations will be determined in consultation with the NMED during the development of the Long-Term Monitoring and Maintenance Plan (LTMMP).

6. **The FTM discussion of “Trigger Levels”’ does not address the degree to which monitoring for moisture content changes would reflect vapor phase movement of VOCs**.

Vapor phase movement of VOCs is noted as the mechanism for VOC transport to groundwater at the Chemical Waste Landfill at SNL. See quote from Johnson 1995, FTM at p. 16.

RECOMMENDATION: The FTM should identify effective technologies for detection of vapor phase movement of VOCs into the vadose zone beneath the MWL. These technologies should be included in an expanded monitoring system to provide for detection of VOC and SVOC releases from the MWL.

SNL Response: See detailed response to Comment No. 5, above.

7. **A broad range of sources of uncertainty in the FTM were identified by the FTM lead author Dr. Clifford Ho in a powerpoint presentation at a DOE-sponsored public meeting on the FTM in January 2006. The “uncertainty variables” identified by Dr. Ho included: waste inventory and size; thickness of cover and vadose zone; and transport parameters including: infiltration, adsorption coefficient, saturated conductivity, moisture content; tortuosity coefficients, and boundary-layer thickness.**

The FTM Report posted at on the NMED site does not identify the “uncertainty variables” in as clear and succinct a manner as the presentation by Dr. Ho and does not identify the range of

values use for each of the "uncertainty variables" parameters used in model realizations to account for those sources of uncertainty for each of the contaminants modeled.

RECOMMENDATION: The FTM should be revised to identify the full range of uncertainty variables associated with each of the constituents addressed in the FTM.

The FTM should be revised to identify the range of values used in model realizations to account for the uncertainty associated with each variable.

SNL Response: The report includes a description of all the uncertain variables and their ranges (see Tables 2-5 (pp. 26-29).

II. Corrective Measures Implementation Plan Comments and Recommendations

A. **The CMIP fails to effectively incorporate the content and findings of the FTM in either the evaluation or design of the Corrective Measure proposed for the MWL**.

While the CMIP includes the full text of the FTM as Appendix E in the CMIP as posted by NMED, the body of the CMIP does not appear to refer to or incorporate any of the information identified in the FTM in the substance of the CMIP.

Neither the "Regulatory Basis" (Section 3), "MWL Characteristics" (Section 4), "Technical Basis" (Section 5), "Vadose Zone Moisture Monitoring" (Section 7), "Conclusions" (Section 8) nor "References" (Section 9.0) sections of the CMIP identify or refer to the FTM or the data it contains.

RECOMMENDATION: The CMIP should be revised to incorporate the analyses and findings in the FTM - when it is determined to be comprehensive and meet the requirements of the Permit Modification and associated guidelines and regulations by NMED - in the design, operation and monitoring and maintenance plans proposed by the permittee for the MWL.

SNL Response: The objective of the CMI Plan was to present a detailed design of the remedy selected by the NMED for the MWL. The proposed design meets the full intent of RCRA Subtitle C regulations, which include minimizing water migration through the cover, minimizing maintenance and erosion, accommodating subsidence, and having a permeability less than or equal to that of the natural subsurface soils. The Fate and Transport model results do not show any need to modify the proposed design in the CMI Plan.

B. **The CMIP fails to provide a comprehensive or detailed long-term operation and maintenance plan for public comment or review**.

While the MWL Permit Modification requires the permittee to provide an operation and maintenance plan, the CMIP only provides information about vadose zone instrumentation and defers the presentation of information on the duration and frequency of the operation and maintenance plan until the conclusion of an unspecified consultation process with NMED. That approach is identified as the process for development of a MWL long-term monitoring and

maintenance plan. No aspects of a MWL monitoring program other than vadose zone monitoring are identified or addressed in the CMIP. See CMIP p. 7-1.

RECOMMENDATION: The CMIP should be revised to include a comprehensive long-term monitoring and maintenance program for public review and comment. The proposed long-term monitoring and maintenance program should include: all parameters to be monitored, all media – including air, soil, vadose zone, groundwater and biota (plants and animals); recommended limits of detection for analytic equipment to be use; frequency of sampling and analysis; quality control and quality assurance measures; monitoring and maintenance cost estimates; MWL cover inspections and maintenance activities; and measures to verify that all institutional control aspects of the proposed corrective measure are in place and enforced for the full closure and post-closure period at the MWL.

SNL Response: The NMED Class 3 Permit Modification for the MWL requires Sandia to submit a Long-Term Monitoring and Maintenance Plan to the NMED within 180 days after the NMED's approval of the CMI Report, following remedy implementation. Additional details on the proposed long-term monitoring and maintenance program will be presented in the Long Term Monitoring and Maintenance Plan, which will be developed in consultation with the NMED after implementation of the remedy.

C. The CMIP proposes only three vadose zone monitoring sites – boreholes - and does not provide a demonstration that such an arbitrary and limited number of instruments will provide comprehensive vadose zone monitoring.

The CMIP at p. 7-1 describes a vadose zone monitoring program that includes three access holes based on the "simplicity, low cost and long-term viability" of the approach. Unfortunately, the permittee did not consider it appropriate to provide a vadose zone monitoring program that is comprehensive enough to comply with the MWL Permit Modification or capable of monitoring the vadose zone beneath all of the MWL. This shortcoming in the CMIP is particularly significant in light of the FTM demonstrations that groundwater contamination due to VOC releases is inevitable as it occurs in all model realizations.

In its analysis, the CMIP fails to identify locations where contaminants from the MWL have been shown to have migrated from their point of disposal into the vadose zone in the Phase 2 RFI investigation nor does it correlate those locations with the three vadose zone monitoring sites in the CMIP. These locations are identified in the record of the MWL public hearing and include data from the "RFI Phase 2" conducted in the early 1990s.

No information is available on the extent of the migration of contaminants since the RFI Phase 2 investigations as such an investigation has not been required by NMED or attained and reported by SNL.

RECOMMENDATION: The CMIP should be revised to incorporate data from an investigation of the current extent of migration of contaminants into the vadose zone. The NMED should require SNL to conduct investigations using technologies such as ground penetrating radar and other geophysical methods to detect moisture distribution in addition to soil borings and other

methods to insure that the vadose zone monitoring program can be demonstrated to be comprehensive and addresses the full extent of vadose zone contamination beneath and adjacent to the MWL.

The CMIP should be revised to include additional vadose zone monitoring that is capable of providing a comprehensive capacity to detect contaminants released from the MWL.

In the alternative, the CMIP should be revised to demonstrate that the proposed vadose zone monitoring system is configured in a manner that can detect all potential routes of migration of contaminants, including volatile and semi-volatile organic compounds, identified beneath or adjacent to the MWL in the RFI Phase 2 investigation.

SNL Response: See response to Recommendation B above. Vadose zone monitoring will be addressed in more detail in the Long-Term Monitoring and Maintenance Plan (LTMMP), which will be developed following implementation of the remedy.

D. **The CMIP fails to address the technical literature related to bio-intrusion barriers or identify monitoring systems appropriate for detect of release associated with bio-intrusion into the MWL**.

An extensive body of technical literature has been developed on bio-intrusion barriers as well as releases of contaminants through vertebrates, invertebrates and plants that have been shown to have penetrated bio-intrusion barriers. This data was summarized in a report by a leading international expert on bio-intrusion barrier design and function prepared for Citizen Action New Mexico and presented to the NMED as part of its comments on SNL's proposed corrective measure at the MWL. This report, "Review of Sandia National Laboratories/New Mexico Evapotranspiration Cap Closure Plans for the Mixed Waste Landfill," by Tom Hakonson, Ph.D., Environmental Evaluation Services, LLC, is available at http://www.radfreenm.org/pages/hakonson_full.htm.

In his report, Dr. Hakonson's asserted that assumption that "tritium is now present in vegetation and animals that now occupy the MWL" was correct. He also cited investigations in which Sr-90, Cs-137 and Pu - all contaminants found at the MWL - have been discovered in animals occupying similar landfills containing mixed wastes and further states that biological transport of radioactive contaminants is likely to occur over time and increase over the long-term.

Information presented at the Mixed Waste Landfill Public Hearing in December 2004 by SNL confirms Dr. Hakonson's assertion regarding deer mice and vegetation at the MWL which show contamination with low levels of tritium and radon. See MWL Hearing Record Transcript at pp. 102 - 104 as noted in Hearing Officer Final Report at pp. 7 and 35.

Regarding biological transport of contaminants, Dr. Hakonson's report states: "Both plants and animals have the potential to transport buried waste to the ground surface. Plants do so via roots that can penetrate several meters into the landfill. Furthermore, most plant species have the capability to penetrate the relatively thin cover soil layer proposed for the MWL. This means that the term, "shallow rooted" as used by the SNL/NM ET cap designers is inappropriate given that the grass species that they propose to use to revegetate the ET cover all have the capability to

send roots several meters into the soil. If soil moisture penetrates beyond the existing rhizosphere, plant root distribution will extend downward to capture moisture at the deeper depths.

"Roots in contact with waste can incorporate soluble constituents and transport them to the ground surface. This uptake process is analogous to a one-way valve in that contaminants are pumped upward to above ground vegetation that eventually senesces and deposits associated contaminants on the ground surface. Burrowing by animals and insects also has the potential to access buried waste several meters below the ground surface. This can lead not only to chemical and radiation exposures to the organisms but also to physical transport of the waste upward in the soil profile and to the ground surface.

"This leads to what I believe is one of the more important deficiencies in the proposed MWL closure, namely the assumption that vertical and horizontal transport of site contaminants resulting from biological processes is not an important contributor to exposure pathways. My review suggests that relevant data from the MWL on contaminants in vegetation, animals, and soil cast to the surface by burrowing animals apparently do not exist. The reason biointrusion may be important is that it represents the major mechanism leading to vertical transport of contaminants to the ground surface and through the drying effect of plant transpiration on cover soils, plays a major role in the evolution of volatile contaminants from the ground surface. While vertical transport by biota may be small on a short time scale, over many decades these processes may become dominant in mobilizing buried waste.

"It is my opinion that the soil sampling done by SNL/NM in 1990 as a part of the Phase 2 RFI provides little information that can be used to answer questions about the effects of biointrusion in transporting MWL contaminants to the soil surface. The RFI soil sampling grid resulted in evenly spaced samples (i. e., that were non-randomly distributed), that provided coarse spatial resolution of contaminant concentrations, and that involved sampling locations that were recently disturbed such as Trench F where backfill was added just months before the soil samples were taken. Furthermore, those samples that were taken in 1990 represent a single snap shot in time and depending on the degree of past mechanical disturbances that occurred within the MWL boundaries, they may represent a snap shot with little elapsed time between soil surface disturbance and when the soil samples were taken.[emphasis added]."

RECOMMENDATION: The CMIP should be revised to include a thorough investigation and re-sampling of the soil at the MWL to identify bio-intrusion mechanisms and biological transport of contaminants, and consider the relationship of these findings of such investigations to the Corrective Measure for the MWL. The NMED should consider revisions to the Corrective Measure permitted for the MWL based on information concerning biological transport in Dr. Hakonson's report and sampling data collected from the flora and fauna at the MWL by SNL since biological transport of contaminants has occurred - and continues to occur - at the dump.

The implementation of a comprehensive sampling program designed to detect levels of radioactive contamination in plants and animals living at the MLW is strongly recommended as a part of the CMIP with appropriate trigger levels to be used to determine future corrective actions at the MWL.

<u>SNL Response</u>: The objective of the Corrective Measures Implementation (CMI) Plan was to present a detailed engineering design for the MWL remedy.

Biological transport is a potential mechanism for contaminant migration from the MWL. Tritium, the most mobile radionuclide disposed of in the MWL, has been detected at low levels in vegetation and small mammals at the MWL. The tritium levels measured to date are consistent with levels in the soil, and are not present at concentrations that represent a concern to environmental health. Tritium concentrations in soil and vegetation are decreasing over time due to radioactive decay and other natural processes.

The remedy selected by the NMED includes a rock biointrusion barrier. The intent of the rock barrier is to prevent any intrusion by burrowing animals, and it should restrict root growth so long as the underlying materials are relatively dry (Anderson and Forman, 2002). Care will be taken during long-term monitoring to prevent the establishment of deep-rooted species on the cover.

Additional details for long-term monitoring of biota will be presented in the MWL Long-Term Monitoring and Maintenance Plan (LTMMP), which will be developed in consultation with the NMED and completed once the MWL remedy has been implemented.

APPENDIX A

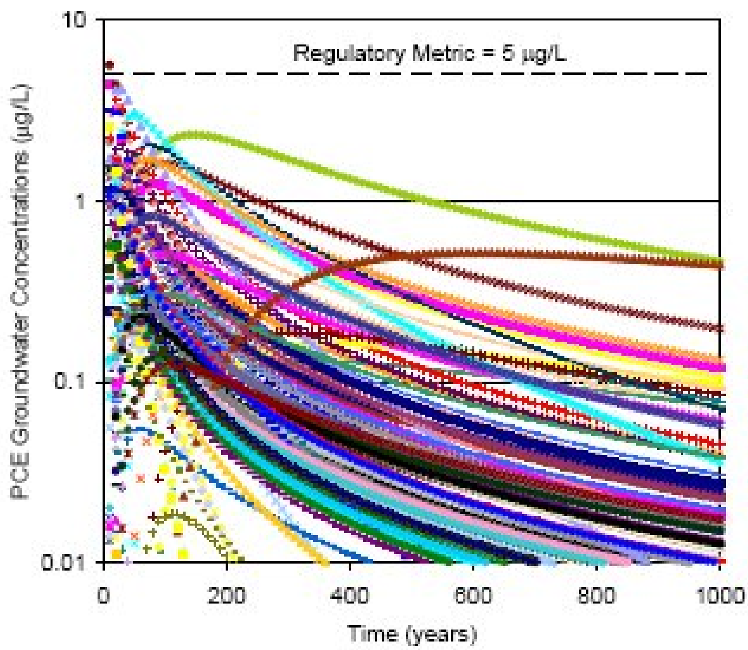

Figure 22. Simulated PCE groundwater concentrations for 100 realizations.

"Figure 22 shows the simulated PCE concentrations in the groundwater as a function of time for all 100 realizations. The majority of the realizations show the aquifer concentrations peaking before 50 years. Depending on the time of disposal, this corresponds to peak concentrations occurring by 2010 – 2040. So far, no detectable amounts of PCE have been found in the groundwater at the MWL. This is still consistent with the simulations, which show a large amount of variability in the simulated concentrations resulting from uncertainty included in the input parameters (see next section)." FTM at 54 –55.

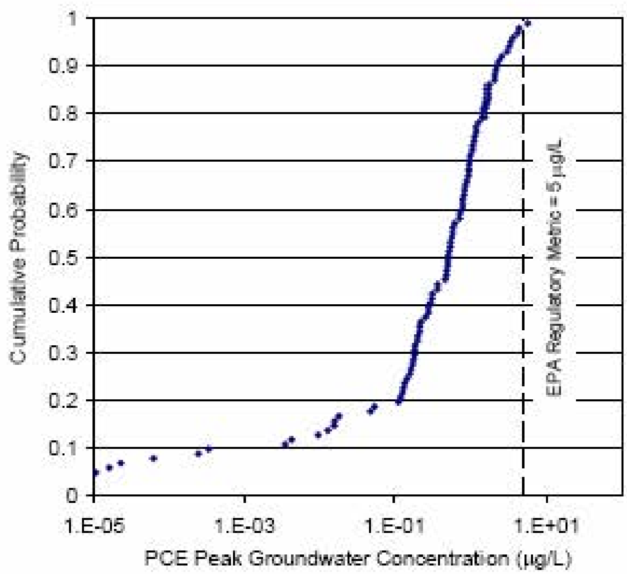

Figure 23. Cumulative probability for simulated PCE peak groundwater concentrations for 100 realizations.

<u>REFERENCES for DOE/SNL Responses</u>

Anderson, J.E. and A.D Forman, March 2002. *“The Protective Cap/Biobarrier Experiment. A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory,”* prepared by Stoller for U.S. Department of Energy – Idaho Field Office Environmental Surveillance, Education and Research Program, Contract DE-AC07-00ID13658, Idaho Falls, Idaho.

NMED, 2005. *“Final Order, State of New Mexico before the Secretary of the Environment in the Matter of Request for a Class 3 Permit Modification for corrective measures for the Mixed Waste Landfill, Sandia National Laboratories, Bernalillo County, New Mexico, EPA ID #5890110518,”* May 26, 2005.

Robinson, P. February 2006. *“Review of Sandia National Laboratories’ Mixed Waste Landfill Corrective Measures Implementation Plan and Fate and Transport Model,”* prepared on behalf of: Citizen Action, New Mexico by Paul Robison, Research Director, Southwest Research and Information Center, February 7, 2006.

Sandia National Laboratories/New Mexico (SNL/NM), November 2005. *"Mixed Waste Landfill Corrective Measures Implementation Plan,"* prepared at Sandia National Laboratories by J. Peace, T. Goering, C. Ho and M. Miller for the U.S. Department of Energy, Albuquerque, NM.

Sandia National Laboratories/New Mexico (SNL/NM), September 1996. *"Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico,"* report prepared by Sandia National Laboratories for the U.S. Department of Energy.

WERC, A Consortium for Environmental Education and Technology Development, *“Final Report, Independent Peer Review of the U.S. Department of Energy Sandia National Laboratories’ Mixed Waste Landfill,”* August 31, 2001.

Volume I

TAB 7

Notice of Public Dialogue on the Corrective Measures Implementation Plan for the Mixed Waste Landfill, November 2005

From: NMED/Kieling
To: Interested Citizen

Back of Tab 7

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505-6303
Telephone (505) 428-2500
Fax (505) 428-2567
www.nmenv.state.nm.us

BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

May 4, 2006

SUBJECT: NOTICE OF PUBLIC DIALOGUE ON THE CORRECTIVE MEASURES IMPLEMENTATION PLAN FOR THE U. S. DEPARTMENT OF ENERGY/SANDIA NATIONAL LABORATORIES' MIXED WASTE LANDFILL

Dear Interested Citizen:

The New Mexico Environment Department (NMED) will host a public dialogue to discuss technical issues related to the implementation of the vegetative soil cover for Sandia National Laboratories' Mixed Waste Landfill. The public dialogue will be held at the Los Griegos Health and Social Services Center, 1231 Candelaria Road, NW, from **9:00 a.m. to 5:00 p.m.**, on **May 25, 2006**. All members of the public are invited to attend this forum.

Enclosed is a public meeting notice providing additional information on the subject meeting. If you need further information regarding this forum please contact Mr. William Moats of my staff at (505) 284-5086.

Sincerely,

John E. Kieling
Program Manager
Permits Management Program
Hazardous Waste Bureau

MAY 25, 2006 PUBLIC DIALOGUE ON THE SANDIA NATIONAL LABORATORIES' CORRECTIVE MEASURES IMPLEMENTATION PLAN FOR THE MIXED WASTE LANDFILL

The public is invited to attend a forum on technical issues related to implementation of the vegetative soil cover of the Sandia National Laboratories Mixed Waste Landfill. The New Mexico Environment Department is hosting this public dialogue on Thursday, May 25, 2006 from 9:00 a.m. to 4:30 p.m. at the Los Griegos Health and Social Services Center located at 1231 Candelaria Road, NW. The documents related to this meeting are available at: http://www.nmenv.state.nm.us/HWB/snlperm.html under Mixed Waste Landfill. For further information regarding this meeting and the availability of documents, please contact the New Mexico Environment Department at (505) 428-2500.

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

PUBLIC MEETING NOTICE

NEW MEXICO ENVIRONMENT DEPARTMENT
HAZARDOUS WASTE BUREAU
Santa Fe, New Mexico
May 4, 2006

NOTICE OF PUBLIC DIALOGUE ON THE CORRECTIVE MEASURES IMPLEMENTATION PLAN FOR THE U. S. DEPARTMENT OF ENERGY/SANDIA NATIONAL LABORATORIES' MIXED WASTE LANDFILL

The New Mexico Environment Department (NMED) will host a public dialogue to discuss technical issues regarding the Corrective Measures Implementation (CMI) Plan for the U. S. Department of Energy/Sandia National Laboratories (SNL) Mixed Waste Landfill (MWL). A fate and transport model is included as part of the CMI Plan. The public dialogue will be held at the Los Griegos Health and Social Services Center, 1231 Candelaria Road, NW, from 9:00 a.m. to 5:00 p.m., on May 25, 2006. The public is invited to attend this forum on the technical issues related to the implementation of the vegetative soil cover.

The MWL occupies approximately 2.6 acres and is located in Technical Area III of Sandia National Laboratories, approximately 5 miles southeast of the Albuquerque International Sunport. Radioactive and mixed waste from SNL research facilities and off-site generators was disposed in the MWL from March 1959 to December 1988. Mixed waste has both radioactive and hazardous components. Approximately 100,000 cubic feet of radioactive waste containing 6,300 curies (Ci) of activity (at the time of disposal) were disposed of at the MWL.

On May 26, 2005, following a public hearing on the Corrective Measures Study for the landfill, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier as the remedy for the MWL. In addition, the DOE and Sandia were required to submit to the NMED for approval a CMI plan. The CMI Plan describes how the remedy will be implemented, including construction of the vegetative soil cover. The public meeting to be hosted by the NMED will focus on technical issues concerning the adequacy of the CMI Plan and the included fate and transport model. Both the plan and the model can be viewed on the NMED's web page at: http://www.nmenv.state.nm.us/hwb/snlperm.html under Mixed Waste Landfill.

For further information on this forum please contact Mr. William Moats of the New Mexico Environment Department at (505) 284-5086.

Any person with a disability requiring assistance or auxiliary aid to participate should contact Judy Bentley by 10 days prior to the meeting at the following address or phone number: New Mexico Environment Department, Room N-4030, P.O. Box 26110, 1190 St. Francis Drive, Santa Fe, New Mexico 87502-6110, (505) 827-9872. TDD or TDY users please access Ms. Bentley's number via the New Mexico Relay Network at 1-800-659-8331.

Volume I

TAB 8

Notice of 14 Day Public Comment Period for the Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005

From: NMED/Kieling
To: SNL/Wagner

Back of Tab 8

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

May 25, 2006

SUBJECT: NOTICE OF 14-DAY PUBLIC COMMENT PERIOD FOR SANDIA NATIONAL LABORATORIES' MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN (INCLUDING FATE AND TRANSPORT MODEL)

Dear Interested Citizen:

Enclosed is a **Public Notice** regarding the U. S. Department of Energy (DOE)/Sandia Corporation's (Permittees) Corrective Measures Implementation (CMI) Work Plan for the Sandia National Laboratories (SNL) Mixed Waste Landfill (MWL). The CMI Work Plan includes the results of a fate and transport model that predicts the future movement of contaminants at the MWL. This 14-day Public Comment Period is in addition to the earlier 60-day comment period that ended on February 2, 2006.

The DOE is owner, and with Sandia Corporation, co-operator of SNL. The Permittees are located at the following addresses: SNL, 1515 Eubank SE, Albuquerque, NM, 87123; and NNSA/DOE, Sandia Site Office, KAFB-East, Pennsylvania & H Street, Albuquerque, NM 87116.

The enclosed Public Notice provides locations where the CMI Work Plan and the associated fate and transport model may be reviewed by any member of the public. Comments on the CMI Work Plan will be received through **5:00 p.m.** on **June 8, 2006**.

Any person seeking additional information may contact:

Mr. William Moats
NMED - District 1 Albuquerque Office
5500 San Antonio NE
Albuquerque, NM 87109
E-mail: william.moats@state.nm.us
Telephone: (505) 222-9551

Mr. John E. Kieling, Program Manager
NMED - Hazardous Waste Bureau
2905 Rodeo Park Dr. East, Bldg 1
Santa Fe, NM 87505
E-mail: john.kieling@state.nm.us
Telephone: (505) 428-2500

Sincerely,

John E. Kieling
Program Manager
Permits Management Program
Hazardous Waste Bureau

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous Waste Bureau
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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

DERRITH WATCHMAN-MOORE
DEPUTY SECRETARY

PUBLIC NOTICE NO. 06-10

NEW MEXICO ENVIRONMENT DEPARTMENT
HAZARDOUS WASTE BUREAU
SANTA FE, NEW MEXICO
May 25, 2006

NOTICE OF 14-DAY PUBLIC COMMENT PERIOD FOR SANDIA NATIONAL LABORATORIES MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN (INCLUDING FATE AND TRANSPORT MODEL)

The federal Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901 to 6992(k), provides for the regulation of hazardous waste. Congress waived the immunity of the United States for actions brought under state hazardous and solid waste laws as well as under RCRA. Pursuant to Section 3006 of RCRA, 42 U.S.C § 6926, the U.S. Environmental Protection Agency (EPA) delegated to the New Mexico Environment Department (NMED), on April 16, 1985 by delegation numbers 8-31 and 8-32, the authority to enforce the Hazardous Waste Act (HWA) and its implementing regulations, the New Mexico Hazardous Waste Management Regulations (HWMR), 20.4.1 NMAC, in lieu of EPA enforcement through RCRA. NMED has maintained its delegation from EPA over hazardous waste management in New Mexico and from time to time has amended its state program to conform to statutory or regulatory changes in RCRA. The HWMR require corrective action at solid waste management units (SWMUs) where releases of hazardous waste or hazardous constituents have or may have occurred.

The U. S. Department of Energy, owner and operator, and Sandia Corporation, co-operator, (hereinafter referred to as the Permitees) have been issued a RCRA Permit for the Sandia National Laboratories (SNL) Facility, located in Bernalillo County, New Mexico, EPA ID# NM5890110518. The Permittees must comply with the HWA, the HWMR, and the SNL RCRA Permit and must conduct corrective action as necessary to protect human health and the environment.

On May 26, 2005, the NMED Secretary approved a final permit and ordered a final remedy for SNL's Mixed Waste Landfill. As part of these actions, the Permittees were required to submit to the NMED a Corrective Measures Implementation (CMI) Work Plan, which is to include a fate and transport model predicting the future movement of contaminants. The CMI Work Plan was submitted to the NMED on November 3, 2005 and includes a fate and transport model. Pursuant to the Secretary's order, the NMED is seeking public comment on the CMI Work Plan prior to making a final decision on whether to approve the plan.

LOCATION OF THE SNL FACILTY AND THE MWL

The Permittees are located at the following addresses: SNL, 1515 Eubank SE, Albuquerque, NM, 87123; and NNSA/DOE, Sandia Site Office, KAFB-East, Pennsylvania & H Street, Albuquerque, NM 87116. The Permittee's primary contact for this action is Mr. John Gould, NNSA/Sandia Site Office, DOE, at P.O. Box 5400, Albuquerque, NM 87185.

SNL is located within the boundaries of Kirtland Air Force Base (KAFB), south of Albuquerque in Bernalillo County, New Mexico. KAFB occupies 52,233 acres. SNL research and administration facilities occupy 2,842 acres and are divided into five Technical Areas (TAs), (designated 1 through 5) and several test areas. TA-1, TA-2, and TA-4 are separate research facilities in the north-central portion of KAFB. TA-3 and TA-5 are contiguous research facilities forming a 4.5-square-mile rectangular area in the southwestern portion of KAFB. TA-3 alone encompasses 2,000 acres.

The Mixed Waste Landfill (MWL) is located approximately 5 miles southeast of the Albuquerque International Sunport and 4 miles south of TA-1. The landfill occupies 2.6 acres in the north-central portion of TA-3.

FACILITY OPERATIONS

SNL, in operation since 1945, is engaged in research and development of conventional and nuclear weapons, alternative energy sources, and a wide variety of national security related research and development. As a result of these activities, SNL has generated hazardous, radioactive, mixed (those wastes containing both hazardous and radioactive components), and solid wastes. From 1945 to 1988 most of these wastes were disposed of at SNL at numerous locations, which have been classified by the NMED as Solid Waste Management Units (SWMUs) or Areas of Concern (AOCs). The SWMUs and AOCs include unpermitted landfills, septic-system drainfields and seepage pits, outfalls, waste piles, and test areas. Past waste management activities at SNL have caused the release of hazardous and radioactive contaminants into the environment. The Mixed Waste Landfill is classified as SWMU 76.

DESCRIPTION AND HISTORY OF THE MIXED WASTE LANDFILL

The MWL was opened as the "TA-3 low-level radioactive waste dump" in March 1959. The MWL accepted low-level radioactive waste and mixed waste from SNL research facilities and off-site generators from March 1959 to December 1988. Approximately 100,000 cubic feet of radioactive waste containing 6,300 curies (Ci) of activity (at the time of disposal) were disposed of at the MWL in unlined trenches and pits.

Investigations at the landfill indicate that tritium is the primary contaminant that has been released from the landfill. Results of a risk assessment prepared by the Permittees indicate that releases of contaminants from the MWL pose little risk to human health or the environment under an industrial land use scenario. Tritium activities at the MWL will decrease steadily with time due to its relatively short half-life of 12.3 years. Because of tritium's short half-life and in consideration of current activity levels, the NMED does not believe that tritium releases at the MWL pose a threat to groundwater, human health, or the environment.

REGULATORY BACKGROUND

NMED issued a RCRA Permit for storage of hazardous waste at SNL on August 6, 1992. On February 6, 2002, the Permittees applied to the NMED to renew their RCRA permit (the current Permit remains in effect until a final decision is made on the renewal request). On October 11, 2001, the NMED directed the Permittees to conduct a Corrective Measures Study (CMS) for the MWL because of concerns raised by the public. The CMS Work Plan was approved with conditions by the NMED on October 10, 2002.

After approval of the CMS Work Plan, the CMS was conducted by the Permittees to identify, develop, and evaluate corrective measures alternatives and to recommend a final remedy to be taken at the MWL. The results of the CMS were documented in a CMS Report following completion of the study; the report was transmitted to the NMED on May 21, 2003. The CMS Report was deemed complete by the NMED on January 5, 2004.

On January 23, 2004, the Permittees proposed a Class 3 modification of the SNL RCRA Permit, requesting that the NMED select a final remedy for the MWL. As part of a 60-day public notice and comment period initiated by the Permittees, a public meeting was held on February 26, 2004 in Albuquerque, New Mexico. Following completion of the Permittees public comment period, the NMED issued a public notice and began a public comment period starting August 11, 2004.

A public hearing on the selection of a final remedy for the MWL was held on December 2-3 and 8-9, 2005 in Albuquerque. The NMED public comment period was held from August 11, 2004 to December 2, 2004, and extended until December 9, 2004. Based on the administrative record and the Hearing Officer's Report, on May 26, 2005, the NMED Secretary approved a final permit and ordered a final remedy for SNL's Mixed Waste Landfill, selecting a vegetative soil cover with bio-intrusion barrier as the final remedy. In addition to selection of the final remedy, the final permit decision requires, among other deliverables, a CMI Work Plan. The CMI Work Plan must address the following:

a. A description of the selected remedy;
b. A description of the remediation system objectives;
c. An identification and description of the qualifications of key persons, consultants, and contractors that will be implementing the remedy;
d. Detailed engineering design drawings and systems specifications for all elements of the remedy;
e. A construction and construction quality assurance work plan;
f. An operation and maintenance plan;
g. The results of any remedy pilot tests, such as landfill cover test plots;
h. A schedule for submission to the Administrative Authority of periodic progress reports;
i. A schedule for implementation of the remedy;
j. A health and safety plan;
k. A comprehensive fate and transport model that studies and predicts future movement of contaminants in the landfill and whether they will eventually move further down the vadose zone and/or to groundwater; and
l. Triggers for future action that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy.

The Secretary's order requires that the NMED review, consider and respond to public comments prior to

approving certain documents related to the MWL, including the CMI Work Plan. The purpose of this public notice is for the NMED to solicit such public comment on the CMI Work Plan, including the fate and transport model. NMED requested public comment on the CMI Work Plan during a 60-day public comment period that ended on February 2, 2006 and is again requesting public comment during this 14-day public comment period.

PUBLIC REVIEW OF THE CORRECTIVE MEASURES WORK PLAN

The CMI Work Plan (including the fate and transport model) may be reviewed by any member of the public at the following locations during the public comment period:

NMED – Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505-6303
(505) 428-2500
Monday - Friday from 8:00 a.m. to 5:00 p.m.

NMED-District 1 Albuquerque Office
5500 San Antonio NE
Albuquerque, New Mexico 87109
(505) 222-9500
Monday - Friday from 8:00 a.m. to 5:00 p.m.

The CMI Work Plan, including the fate and transport model (as Appendix E), are also available electronically on the NMED website at: http://www.nmenv.state.nm.us/HWB/snlperm.html under Mixed Waste Landfill. A separate report, *SAND 2005-6888*, entitled *Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories*" is also included on the web page and contains much of the same information as that in Appendix E of the CMI Work Plan. Although the *SAND 2005-6888* report is included on the web page for convenience, the NMED is only seeking public comment on the CMI Work Plan, including Appendix E and all of the other appendices.

To obtain a copy of the CMI Work Plan or a portion thereof, in addition to further information, please contact Ms. Pam Allen at (505) 428-2500, or at the Santa Fe address given above. NMED will provide copies, or portions thereof, at a charge to the requester.

NMED issues this public notice on **May25, 2006,** to announce the beginning of a 14-day comment period that will end at **5:00 p.m., June 8, 2006**. Any person who wishes to comment should submit written or electronic mail (e-mail) comment(s) with the commenter's name and address to the respective address below. Only comments received on or before **5:00 p.m., June 8, 2006** will be considered.

John E. Kieling, Program Manager
Hazardous Waste Bureau - New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303
Ref: Sandia National Laboratories – MWL CMI Work Plan
E-mail: john.kieling@state.nm.us

Written comments must be based on the MWL CMI Work Plan (including the fate and transport model).

The NMED must ensure that the approved CMI Work Plan will be consistent with the New Mexico Hazardous Waste Management Regulations. All written comments submitted will become part of the

administrative record, will be considered in formulating a final decision, and may cause the CMI Work Plan to be modified. NMED will respond in writing to all significant public comment. The response will specify which provisions, if any, of the CMI Work Plan have been changed in the final decision, and the reasons for the change. This response will also be posted on the NMED website in addition to NMED notifying all persons providing written comments.

After consideration of all written public comments received, NMED will approve, or approve with modifications the CMI Work Plan. If NMED modifies the CMI Work Plan, the Permittees shall be provided by mail a copy of the modified CMI Work Plan and a detailed written statement of reasons for the modifications. The NMED will make the final decision publicly available and shall notify the Permittees by certified mail. All persons on the mailing list, or that provided written comments, or who requested notification in writing, will be notified of the final decision by mail.

The final decision will become effective immediately upon service of the decision to the Permittees, unless a later date is specified.

ARRANGEMENTS FOR PERSONS WITH DISABILITIES

Any person with a disability requiring assistance or auxiliary aid to participate in this process should contact Judy Bentley by 10 days prior to the end of the public comment period at the following address: New Mexico Environment Department, Room N-4030, P.O. Box 26110, 1190 St. Francis Drive, Santa Fe, New Mexico 87502-6110, (505) 827-9872. TDD or TDY users please access Ms. Bentley’s number via the New Mexico Relay Network at 1-800-659-8331.

Volume I

TAB 9

NOD (Part 1 and 2 Comments): Mixed Waste Landfill Corrective Measures Implementation Work Plan November 2005, and Requirement for Soil-Vapor Sampling and Analysis Plan

From: NMED/Bearzi
To: SNL/Wagner

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State of New Mexico
ENVIRONMENT DEPARTMENT
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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

CERTIFIED MAIL -- RETURN RECEIPT REQUESTED

November 20, 2006

Ms. Patty Wagner
Manager
Sandia Site Office/NNSA
U.S. Department of Energy
P. O. Box 5400, MS 0184
Albuquerque, NM 87185-5400

Mr. Les E. Shephard
Vice President
Energy, Information and Infrastructure Surety
Sandia National Laboratories
P. O. Box 5800, MS 0724
Albuquerque, NM 87185

RE: NOTICE OF DISAPPROVAL: MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION WORK PLAN, NOVEMBER 2005, AND REQUIREMENT FOR SOIL-VAPOR SAMPLING AND ANALYSIS PLAN SANDIA NATIONAL LABORATORIES EPA ID NM5890110518, HWB-SNL-05-025

Dear Ms. Wagner and Mr. Shephard:

The New Mexico Environment Department (NMED) has reviewed the subject Corrective Measures Implementation (CMI) Work Plan for the U.S. Department of Energy/Sandia Corporation's (Permittees) Mixed Waste Landfill (MWL) and has found a number of deficiencies.

The deficiencies are described in the comments below, which are divided into two parts based on subject. Comments in Part 1 are related to the construction plans and cover performance modeling. The Permittees shall address these comments within 30 days of receipt of this letter. Comments in Part 2 are related to the fate and transport model and monitoring triggers. The Permittees shall address the comments in Part 2 within 60 days of receipt of this letter.

Part 1, Comments on Landfill Construction Plans and Performance Modeling

The following comments shall be addressed by the Permittees within 30 days of receipt of this letter.

1. Executive Summary, Page iii, last bullet – Define the term "climax ecological community".

2. Section 2.1 – Provide a more detailed schedule that, at a minimum, indicates completion times for the following cover and project elements: subgrade, bio-intrusion barrier, native soil layer, topsoil layer, seeding, fencing, overall completion of project, and submittal of Corrective Measures Implementation (CMI) Report to NMED. As the actual start time is dependent on when the CMI Plan is approved, the completion times can be proposed as the number of days from the start time (assume the start time = 0 days).

3. Section 5.2.2.1.1, last paragraph – Describe the rainfall event that was simulated in the second *in situ* test.

4. Section 5.2.2.2, 1st paragraph on page 5-4 – Specify whether the degree of compaction was measured using the standard or modified proctor test.

5. Section 5.3.2.4, next to last sentence – This sentence refers to a sand layer with an initial water content of 0.036 cubic centimeters being used for a boundary condition. Normally, water content of soil is expressed as a percentage (of the ratio of the mass of water per the mass of solids, or in the case of volumetric water content the ratio of the volume of water to the total volume of soil). Confirm whether this value and unit of measurement are correct.

6. Section 5.7.1 – Specify the values used for the variables R, K, LS, VM and sources of the values used in the MUSLE equation to predict soil loss by water erosion.

7. Section 5.7.2 - Specify the values used for the variables I, k, C, l, V and sources of the values used in the WEQ equation to predict soil loss by wind erosion.

8. Section 7.0 – The NMED expects the vadose zone to be monitored for volatile organic compounds, tritium, and radon, in addition to soil moisture. The NMED may also require soil-gas monitoring to be conducted at depths other than at 173 feet, as implied by the Permittees in the second paragraph of Section 7.1. Monitoring details will need to be included in the long-term monitoring and maintenance plan, due within 180 days following approval of the CMI Report. No response is required at this time.

9. Figure 5-1 – Clarify which curves are representative of the PET data from the four National Weather Service stations in New Mexico and which are representative of the predicted PET data.

10. Appendix A, Construction Specifications, Section 02930, Reclamation seeding and Mulching, Part 3.1.2, #1 – Explain why the TA-3 borrow pits are not to be reseeded by the contractor, given that erosion of the borrow pits should be prevented.

11. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.3, #4 – The Permittees should consider changing the requirement that no proof rolling be conducted within 2 feet of any groundwater monitoring well, measuring device, or other placed surface. The NMED strongly suggests changing the requirement to preclude all heavy equipment from operating within 3 feet of wells or other measuring devices.

12. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.4, #8 and Part 3.3.6, #9 – Both of these sections contain language stating that nonconforming work shall be redone until the specifications are attained "or the Operator accepts the placement conditions". Please note that the NMED expects construction of the cover to comply substantially with the specifications in the approved CMI Plan. Failure to achieve the specifications in the approved CMI Plan, or obtain an NMED-approved change, could lead to disapproval of part or all of the constructed cover.

13. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.6 – The NMED strongly recommends that the Permittees add to the specifications for construction of the native soil layer a requirement for a minimum number of passes with compaction equipment.

14. Appendix B, Construction Quality Assurance Plan, Section 2.6.3, first sentence – Clarify what is meant by the first sentence: "The CQA Certifying Engineer is responsible for ....certifying the CQA document has been approved by the NMED". Did the Permittees intend, instead, to require that the CQA Certifying Engineer be responsible for certifying the results of the CQA Report that is to be submitted for NMED approval? If so, the first sentence should be revised to state "The CQA Certifying Engineer is responsible for certifying in a statement to the owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications". The next sentence of the paragraph explains further that the certification statement would normally be included in a CQA Report.

15. Appendix B, Construction Quality Assurance Plan, Section 8.7 – The Final Report must be submitted to the NMED as part of the CMI Report. The Final Report must include copies of all quality control data generated by the construction contractor as well as the quality assurance data generated by the CQA contractor.

16. Demonstrate with calculations and other information whether run-off and run-on controls have been adequately designed to handle peak precipitation events. Evaluate and discuss whether additional run-on controls should be constructed at locations further away from the landfill (e.g., at distances of 25 to 50 meters) to provide more protection for the cover from heavy rainfall events.

17. Identify the criteria to be applied to determine whether the establishment of vegetation on the final cover is acceptable, including, but not limited to, species diversity, plant survival, and the extent of ground cover. Explain how measurements will be conducted in the field to assess these criteria.

Part 2, Comments on the MWL Fate and Transport Model (Appendix E)

The following comments shall be addressed by the Permittees within 60 days of receipt of this letter. These comments concern Appendix E (Probabilistic Performance Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories) of the CMI Plan.

1. Section 2.1.2.2 -- The last paragraph of Section 2.1.2.2 states, "Present conditions were simulated by modeling infiltration through various thicknesses of an engineered cover, while future conditions were simulated by modeling infiltration through various thicknesses of soil under natural conditions (i.e., the 'natural analog')." This description implies that present and future conditions are simulated using different designs (in the near term an engineered cover which in the future eventually degrades to the conditions of natural soil). Section 3.4.2 states that the engineered soil cover reverts to the natural soil conditions around the landfill. Provide clarification in Section 2.1.2.2 regarding the evolving soil conditions within the cover. Explain what soil conditions are expected to evolve, why and when they will evolve, and what will they evolve to.

2. The first paragraph of Section 3.2.1 states that lead, cadmium, and radionuclides (except radon) were modeled using the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) and Multimedia Environmental Pollutant Assessment System (MEPAS) simulation tools. Section 3.2.2 states, "A separate model was used to model the transient transport of tritium at the MWL". The reader, however, does not learn until Section 3.7.1 that tritium was also modeled using FRAMES and MEPAS. Revise the text of Section 3.2.1 to indicate tritium was modeled using FRAMES and MEPAS, as well as the separate transient transport model.

The second paragraph of Section 3.2.1 indicates MEPAS is capable of computing contaminant fluxes for multiple routes, including radioactive decay and contaminant degradation. The paragraph states further that MEPAS was used only for the source-term and vadose-zone models, suggesting MEPAS was not used to model radioactive decay. In contrast, Section 3.2.2 indicates that the transient model for tritium and perchloroethene (PCE) accounts for contaminant decay. Clarify whether the modeling of radionuclide transport through the vadose zone at the MWL accounts for contaminant decay.

3. The first paragraph of Section 3.3 references Table E-2, which provides a summary of input parameters and distributions of constituents used in the modeling. Footnotes "b" and "d" reference an EPA fact sheet for tetrachloroethene; the fact sheet was reportedly accessed on the U.S. EPA website at www.epa.gov/WGWDW/dwh/t-voc/tetrachl.html, but it is not referenced in Section 6, References, of the report. The fact sheet was not available at the web address

provided, so the input parameters could not be verified. Provide the fact sheet as an attachment to the report and update the website address, if available, for the fact sheet. Also, revise Section 6 to include this fact sheet among the references. In addition, provide all other internet-referenced data as attachments to the report and cite these sources in Section 6.

4. Section 3.4.2, page E-35, 2nd paragraph – Explain why future infiltration rates would be less than current rates.

5. Section 3.6, Fate and Transport of Radon – Radon was modeled as originating from radium-226 sources. Explain why radon originating from the decay of depleted uranium was not incorporated into the radon fate and transport model.

6. Section 4, Pages E-59 and E-59a – Revise the trigger evaluation process to follow the corrective action process described in the Consent Order (April 29, 2004) if a trigger level is exceeded (step 3A), provided the Consent Order is still in force at the time the trigger level is exceeded. If the Consent Order has terminated, the trigger evaluation process should follow the standard RCRA corrective action process.

7. Section 3.3 -- The fourth paragraph of Section 3.3 discusses the dose via inhalation and dermal adsorption for gas-phase tritium, but a similar discussion is not presented for radon gas or gas-phase PCE. Clarify whether this dose discussion is applicable to all gas-phase constituents considered in the Report. If the dose discussion is only applicable to gas-phase tritium, then explain why this is the case. Alternatively, discuss inhalation and dermal adsorption doses for radon gas and gas-phase PCE.

8. Section 3.4.1 -- The first paragraph of Section 3.4.1 states the modeling study of water infiltration through the cover was "discretized by placing computational nodes at predetermined vertical spacing in a conceptual soil profile to evaluate the performance of a cover 3 ft in thickness." The model evaluated a soil profile that was actually 6 feet thick in order to avoid impacts due to boundary conditions, but these impacts and boundary conditions are not discussed. Thirty nodes were located within this 6-foot-thick soil profile. However, the discussion does not describe how or why the 30 node locations were predetermined within this soil profile. Explain the specific impacts caused by boundary conditions. Clarify how and why the computational node locations were predetermined.

The conceptual soil profile for the infiltration model, as discussed in Section 3.4.1, is presented side-by-side in Figure E-3 with nodal discretization used in the UNSAT-H model. As illustrated, the conceptual soil profile does not correspond to the components of the MWL soil cover cross-section. The soil profile illustration is dimensionless; i.e., it is not clear whether the soil profile is 6 feet thick. Also, only 23 of the 30 computational nodes within the cross-section are shown. In addition, the nodal depth locations can not be determined from the illustration. Revise the Figure E-3 conceptual model to clearly indicate the components of the MWL soil cover (i.e., subgrade layer, biointrusion barrier, native soil layer, topsoil layer, and vegetation) and their location relative to the MWL waste zone. Revise Figure E-3 to include a vertical scale for depth

(i.e., inches or feet below the cover surface) and the locations of all 30 computational nodes. Clarify the soil type specified for each component of the soil cover.

9. Section 4.2.2 -- Section 4.2.2 discusses the proposed neutron probe system for monitoring moisture content beneath the MWL. However, for the neutron probes to detect percolation through the soil cover, water will have to move through the bio-intrusion barrier, the waste zone, and a portion of the vadose zone prior to detection, which would be expected to require a considerable amount of time. The neutron probe system is thus more reliably a vadose-zone monitoring system rather than a tool to determine loss of integrity of the soil cover. If the Permittees want to monitor the cover for performance, the neutron probes should be placed just below the cover in the subgrade.

10. Figures -- Figures E-13, E-15, E-19, and E-24 present a graphical illustration of the sensitivity analyses performed for some of the constituents. The figures present histograms to compare ΔR^2 for constituent concentration and dose. Clarify why actual concentrations and doses were not presented in the sensitivity analyses.

11. General Comment on the Fate and Transport Model -- Compared to typical reports for modeling studies, the report as presented is brief, particularly when considering the complexity of using a Monte Carlo approach with multiple models, scenarios, and constituents of concern. In general, the report provides a narrative of a probabilistic model that is presented as a "black box." The report discusses the input parameters and selectively presents output results, but there is not adequate information to assess whether the "black box" is operating satisfactorily. The report does not present a discussion regarding software quality assurance – it is not known how well the various models work separately or together. Also, the report does not provide a critique of the modeling runs, except for an occasional qualitative statement. In contrast, a typical modeling report is a detailed and exhaustive presentation that addresses the conceptual development and construction of the model (e.g., the data quality objectives, the software code), the software quality assurance performed (including software validation and verification) to assess model performance both separately and when working together, the details regarding specific inputs and outputs for all runs of every scenario, and a quantitative analysis of the sensitivities of the input parameters, including an assessment of the bias of the model toward specific outputs. The report, however, does not provide this level of information. The Permittees must provide additional information to address the deficiencies mentioned above.

12. Provide information evaluating the risk to ecological receptors for tritium, radon, and radon daughter products, which are expected to be released to surface soil and the atmosphere.

13. Provide information evaluating the risk to human receptors for tritium, radon, and radon daughter products that would be expected to be released to surface soil and the atmosphere. Include external exposures.

14. The NMED expects surface soil surrounding animal borrows (including ant nests) to be monitored for radionuclides and metals. Develop triggers that are protective of both human health and the environment for radionuclides and metals in soil.

15. Develop triggers for tritium, radon, PCE and total VOCs as soil vapor. The NMED expects soil-gas in the vadose zone to be monitored for these constituents.

16. Table E-6 – The proposed trigger value for "infiltration" is 25% by volume. Specify whether "infiltration" means moisture content. Also, the proposed trigger is too high, as it likely represents conditions whereby there is near complete saturation of the soil.

17. Provide NMED a copy of the reference: Johnson et al (1995), *A Human Health Risk Assessment for the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico*, Argonne National Laboratories, Argonne, IL.

18. Table E-6, the proposed trigger levels for 1,1,1-TCA, ethylbenzene, styrene, toluene, and total xylenes in groundwater are set too high. For these unnatural constituents, the levels of detection normally achieved by laboratories are much lower than groundwater standards set by the New Mexico Water Quality Control Commission (WQCC). The trigger levels can be set to much lower levels, and still allow for a given trigger level to be sufficiently above the limit of detection such that the constituent can be readily quantified with a high degree of confidence. Additionally, trigger levels should be set well below WQCC standards or below U. S. Environmental Protection Agency Maximum Contaminant Levels so that there will be time to react to prevent unacceptable levels of contamination should any trigger levels be exceeded.

19. Propose some additional monitoring to be conducted at locations within the landfill where contaminants were detected at their highest levels during the RFI. These locations should be subject to the same triggers as those proposed as points of compliance in Table E-6.

20. Expand the listing of proposed monitoring triggers in Table E-6, giving consideration of the following table:

Environmental Medium	**Monitoring Parameters**	**Main Potential Receptors**	**Sampling Points**
Air	radon, tritium	humans	landfill perimeter and interior stations
Surface Soil	radon, tritium, other radionuclides, metals	humans and ecological receptors	landfill perimeter, interior stations, and animal burrows located on cover
Subsurface Soil	moisture	humans via groundwater	neutron probe monitoring wells
Subsurface Soil Gas	radon, tritium, VOCs	humans via groundwater	beneath landfill
Groundwater	tritium, radon, isotopic uranium,VOCs	humans	down gradient groundwater monitoring wells

Radionuclides (other than radon and tritium) and metals should be the same as those listed in Table E-2. VOCs should include PCE, all organic constituents listed in Table E-6, and all other organic constituents normally detected by method 8260. NMED reserves the right to require additional monitoring pending review of the long-term monitoring and maintenance plan to be submitted later by the Permittees and pending receipt and review of public input of this latter mentioned plan.

General Comments and Requirements for Soil-Gas Sampling

As the Permittees are aware, most site characterization data for the MWL (other than groundwater data) dates before the mid 1990's. Because the rupturing of containers and the leaking of their contents could have occurred since the mid 1990's, the NMED requires more current soil-gas data to help resolve this issue. The Permittees shall therefore collect and analyze active soil-gas samples taken at depths of 10 and 30 feet at a minimum of three locations within the landfill where previous sampling has detected the highest soil-gas concentrations in the past. The soil-gas samples shall be analyzed for volatile organic compounds, tritium, and radon. Pursuant to Section VI.A of the Order on Consent (April 29, 2004), the Permittees shall provide for approval to the NMED within 30 days of receipt of this letter a work plan to conduct the active soil-vapor sampling described above. The work plan shall be prepared in accordance with Section X.B of the Consent Order.

Please contact William Moats of my staff at (505) 222-9551 if you have any questions.

Sincerely,

James P. Bearzi
Chief
Hazardous Waste Bureau

JPB:wpm

cc: J. Kieling, NMED, HWB
W. Moats, NMED, HWB
L. King, EPA-Region 6 (6PD-N)
J. Gould, DOE/NNSA/SSO, MS 0184
P. Freshour, SNL, MS 1087
File: Reading and SNL, 2006

Volume I

TAB 10

NMED Responses to Public Comments on the Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

From: NMED/Kieling
To: Interested Citizen

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BILL RICHARDSON
GOVERNOR

RON CURRY
SECRETARY

November 21, 2006

SUBJECT: NMED RESPONSES TO PUBLIC COMMENTS ON THE SANDIA NATIONAL LABORATORIES' MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

Dear Interested Citizen:

On November 3, 2005, Sandia National Laboratories (SNL) submitted to the New Mexico Environment Department (NMED) for approval a Corrective Measures Implementation (CMI) Plan pursuant to Sections IV.D and XI of the Compliance Order on Consent (April 29, 2004), and the Secretary's Final Order (May 26, 2005), *In the Matter of Request for a Class 3 Permit Modification for Corrective Measures for the Mixed Waste Landfill, Sandia National Laboratories, Bernalillo County, New Mexico, EPA ID No. NM5890110518.*

A public meeting was conducted on the technical merits of the CMI Plan on May 25, 2006. A public comment period was held from December 9, 2005 to February 7, 2006, and from May 25, 2006 to June 8, 2006. NMED's responses to public comment on the CMI Plan are available at the NMED web page at *http://www.nmenv.state.nm.us/hwb/snlperm.html* under Mixed Waste Landfill.

NMED's review of the CMI Plan has revealed several deficiencies that must be corrected before implementation of the CMI work. The letter addressing these deficiencies is available on the NMED web page as noted above.

Sincerely,

John E. Kieling
Program Manager
Permits Management Program
Hazardous Waste Bureau

Index of Public Comments Received:
Sandia National Laboratories Mixed Waste Landfill Corrective Measures Implementation Plan
November 2006

Commenter ID	Date of Letter or e-mail	Association/Commenter
A	1/25/06 (rec'd 1/27/06)	Citizen, Donna Detweiler
B	1/28/06 (rec'd 1/31/06)	Citizen, Floy J. Barrett
C	1/28/06 (rec'd 1/31/06)	Citizen, David M. Brugge
D	1/28/06 (rec'd 1/31/06)	Citizen, Maurice Weisberg, MD
E	Not dated (rec'd 2/06/06)	Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Dorelen Bunting and Janet Greenwald
F	2/06/06 (rec'd 2/06/06)	Loretto Community of Catholic Sisters and Co-members, Penelope McMullen
G	2/07/06 (rec'd 2/07/06) (rec'd 5/03/060	Citizen, John Tauxe, Ph.D., PE
H	2/07/06 (rec'd 2/07/06)	Citizen Action New Mexico, Susan Dayton (Comments compiled by Paul Robinson, Southwest Research and Information Center)
I	6/07/06 (rec'd 6/07/06) Meeting 7/19/06	Citizen Action New Mexico, Susan Dayton (Comments compiled by Paul Robinson, Southwest Research and Information Center)
J	6/08/06 (rec'd 6/08/06) Meeting 7/19/06	Citizen, Robert H. Gilkeson
K	6/08/06 (rec'd 6/08/06)	Nuclear Watch of New Mexico, Scott Kovac (Comments compiled by Paul Robinson, Southwest Research and Information Center; and Robert H. Gilkeson)
L	6/08/06 (rec'd 6/08/06)	Citizens for Alternatives to Radioactive Dumping, Janet Greenwald
M	6/08/06 (rec'd 6/08/06)	Embudo Valley Environmental Monitoring Group, Sheri Kotowski (Comments compiled by Paul Robinson, Southwest Research and Information Center; and Robert H. Gilkeson)
N	6/08/06 (rec'd 6/08/06)	Concerned Citizens for Nuclear Safety, Joni Arends

Commenter ID	Date of Letter or e-mail	Association/Commenter
O	6/08/06 (rec'd 6/08/06)	Citizen, Jamie Wells
P	5/30/06	Citizen, Krishan Wahi
Q	6/08/06 (rec'd 6/08/06)	Citizen, Willard Hunter

NMED Response to Public Comments on the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan November 2006

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
A **D**	**Citizen, Donna Detweiler** **Citizen, Maurice Weisberg, MD**	Groundwater Contamination	The commenter was concerned regarding possible contamination of groundwater resulting from releases from the MW, particularly contamination of the Burton Well serving the Kirtland Addition neighborhood. Commenter stated that the fate and transport model (FTM) indicates contamination may reach groundwater in as little as 50 years. The commenter believes there is "much good housing stock here," an apparent reference to the Kirtland Addition neighborhood, and expresses concern that it will be condemned as unlivable in the future. The commenter stated that the protection of the integrity of our aquifers is a matter of urgent national security for public health and economic stability. The commenter referenced the National Academy of Science, which reported in 2000 that most of the nuclear bomb sites will never be cleaned up enough to allow public access to the land and the plan for guarding these sites cannot guarantee the safety of the public.	R1	The low levels of contaminants released from the Mixed Waste Landfill (MWL) have not caused groundwater to become contaminated beneath the landfill and are unlikely to cause groundwater contamination in the future. The fate and transport model (FTM) recently completed by Sandia predicts little chance that groundwater contamination will occur. None of the modeled radionuclides and heavy metals was simulated by the FTM to reach groundwater during the 1,000-year performance period or the extended 10,000-year period. Tritium is the primary radiological contaminant released from the landfill. Both the FTM and modeling done by the WERC predict that the tritium released into the vadose zone will not contaminate groundwater. Furthermore, the FTM suggests that concentrations of perchloroethene (PCE) will peak in less than 50 years for the majority of the model runs. While only 1% of the model runs indicates that PCE concentrations will exceed the regulatory maximum contaminant level (MCL) of 5µg/L, the modeled contamination should have already occurred. Groundwater monitoring during the past 16 years has not detected contaminants in groundwater from the MWL at any level. This is strong evidence that the FTM may be overly conservative. Of the 100 runs, about 40% resulted in predicted PCE concentrations that were below the level of detection. Given that the FTM is conservative (e.g., it ignores dilution of PCE once groundwater is reached; is one-dimensional and thus allows only vertical migration of PCE; it uses PCE source levels up to 10 times that of the maximum level actually detected; the

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
			The commenter is also concerned about the leaching of radioactive materials from the MWL and their transport through the vadose zone to groundwater. The commenter references the SNL Chemical Waste Landfill and the Liquid Waste Disposal System as sources of groundwater contamination through a similar pathway. Additionally, the commenter is concerned that liquid waste was disposed in the MWL prior to 1972 and that it has leached from the MWL to groundwater. The commenter also states that tritium is expected to contaminate groundwater is less than ten years, and that it is well known that all landfills leak in wet or dry areas, especially if they are unlined and in porous or sandy soils. The commenter also states that movement of nuclear debris through soil is more rapid than DOE and the nuclear labs have maintained. Contaminants like Sr-90, tritium, and PCE move rapidly in plumes, and that plutonium has different rates of migration depending on local geologic conditions and preferred pathways.		low levels of contaminants released from the MWL have not caused groundwater contamination over the 57-year life of the landfill,) the NMED believes that PCE will not reach groundwater at any detectable level. Although vapor phase migration has played an important role in the contamination of groundwater at the Chemical Waste Landfill, aqueous transport was the dominant mode of migration of contaminants at the Liquid Waste Disposal System (LWDS). Thus, the LWDS site is dissimilar to the MWL. The CWL is also different in that the maximum VOC concentrations of soil gas observed at the Chemical Waste Landfill were several orders of magnitude higher than that detected at the MWL. NMED agrees that all landfills are expected to leak contaminants. However, not all releases pose threats to human health and the environment. PCE and tritium can migrate rapidly in the vadose zone in the vapor phase, and have done so at the MWL. However, as has been mentioned numerous times by the NMED, the levels of PCE and tritium detected at the MWL do not pose significant risk to human health and the environment. Plutonium and Sr-90 migrate with water. The cover proposed for the MWL will reduce the amount of water percolating through the landfill, and thus will prevent the migration of Sr-90 and plutonium. Furthermore, based on what is known about the inventory, it is highly unlikely that there is a sufficient amount of plutonium and Sr-90 in the landfill to threaten groundwater. As mentioned previously, none of the modeled radionuclides and heavy metals was simulated by the FTM to reach groundwater during the 1,000-year performance period or the extended 10,000-year period. See also NMED response R5.

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**		The commenter states the FTM concluded that contaminants from the MWL will reach Albuquerque's sole-source aquifer within 50 years. The commenter considers the seriousness of potentially contaminated drinking water and states that the FTM and the Corrective Measure Implementation Plan are dangerously inadequate.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter states the model concludes that PCE, the only organic compound modeled, would reach groundwater for all 100 model runs ("realizations") with the majority of the model runs showing PCE reaching groundwater within 50 years.		
A	**Citizen, Donna Detweiler**	Excavation as a remedy	The commenter would like to see the waste removed and disposed elsewhere away from a large population area.	R2	The NMED previously held a public comment period and public hearing regarding the corrective measures study (CMS) conducted for the MWL. After carefully considering public comment and evidence presented at the public hearing, the Secretary determined that the MWL should be immediately stabilized using a vegetative cover with bio-intrusion barrier in order that Albuquerque's groundwater be protected, to ensure protection of human heath and the environment from radiation emanating from waste in the landfill, and to protect workers from needless exposure to radiation. While groundwater beneath the landfill is not contaminated by releases from the landfill, and likely will never be, the DOE is
B	**Citizen, Floy J. Barrett**		The commenter stated that the people of New Mexico deserve to have the laboratories of this state comply with every possible safety procedure. The commenter believes the MWL model for containment does not insure long-term safety of groundwater and soil.		

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
			The commenter also stated there is still time to continue to study and reassess the issues noted by the commenter. The commenter also stated NMED has an obligation to require that Sandia National Laboratories complete reassessments.		required to monitor both the landfill and the groundwater to ensure a timely response in the unlikely event of significant contaminant migration or groundwater contamination. The final order signed by the Secretary requires that the effectiveness of the cover and the feasibility of excavation be re-evaluated every five years; the FTM is also to be updated. The vegetative soil cover with bio-intrusion barrier is feasible to implement, will maintain a low and thus acceptable level of risk to the public, workers, and the environment, is a proven reliable and effective technology, and will further reduce waste mobility. The remedy will prevent wastes from endangering our citizens, our ground water, and our environment by minimizing the infiltration and percolation of moisture into the landfill, by preventing the intrusion of small animals into waste, and by shielding people and the environment from harmful radiation. There is no new information in the FTM that suggests that the NMED should defer approval of the CMI Plan. The FTM's prediction that there is only a small chance that groundwater will become contaminated at levels exceeding regulatory standards corroborates and validates NMED's existing testimony presented at the hearing held on the Corrective Measures Study. Hence, there is no new information generated by the FTM that would form the basis for a different remedy for the landfill. The results instead strongly support the NMED's chosen remedy (cover with bio-intrusion barrier) as an acceptable alternative that is protective of human health and the environment.
C	**Citizen, David M. Brugge**		The commenter states that he had heard that the plan considered economy over safety.		
D	**Citizen, Maurice Weisberg, MD**		The commenter supports the excavation of all mixed wastes buried in unlined, unregulated, and unpermitted pits and trenches and their transfer for storage in hardened facilities above ground. The commenter also referenced Dr. Arjun Makhijani, of the Institute of Energy and Environmental Research (IEER), who supports excavating buried nuclear waste sites as a priority for shipment to a repository.		
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**		The commenter supports the excavation of the MWL and development of a comprehensive clean up plan to contain the waste in a safer area.		
H	**Citizen Action**		The commenter requests that NMED		

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
	New Mexico, Susan Dayton (Comments compiled by Paul Robinson, Southwest Research and Information Center)		consider requiring improvements in the Corrective Measure proposed for the MWL to prevent future releases of VOCs and SVOCs.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter states that NMED should defer final approval of Mixed Waste Landfill CMI Plan pending review of a remedy based on new information in the FTM and additional information provided in response to NMED queries.		
Q	**Citizen, Willard Hunter**		The commenter states that he has rarely seen a more proud organization than SNL and notes that he is a former employee. The commenter states, however, that money should be spent on proper waste disposal. The commenter also states that DOE has experience with clean-up alternatives, including rehabilitation of nuclear waste sites, which could be applied to the MWL.		

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B **C** **D**	**Citizen, Floy J. Barrett** **Citizen, David M. Brugge** **Citizen, Maurice Weisberg, MD**	Bio-transport of contaminants	The commenter is concerned that Sandia's FTM is not comprehensive and does not consider biological transport of contaminants. The commenter states that biological transport of contaminants is not limited to reptiles, mammals, birds, and amphibians. The commenter believes that invertebrates, surface and subsurface flora, fungi, molds, bacteria, and other species should be considered. The commenter suggests that the model should address soil bacteria and possibly viruses that become airborne during windy drought conditions at the MWL area. The commenter also suggested that the agent responsible for valley fever may mutate in the MWL area. The commenter stated that biotransport of radioactive contaminants is likely to occur over time and increasingly over the long term. The commenter also referenced Dr. Peter Montague, director of Rachel's Environment and Health Weekly, who indicated 5 or 6 reasons why dirt caps and vegetative covers fail. Among the problems are deep root systems extending as much as 20-30 feet below the surface, burrowing	R3	The model did not address biological transport. The NMED questions whether source terms and biological transport rates can be reasonably and realistically estimated to generate meaningful results. Models, even as powerful as the ones used for the MWL FTM, have limitations. It is unreasonable to expect the Permittees to evaluate the migration of contaminants caused by what might be thousands of individual species of fungi, mold, bacteria, viruses, and microbes that can be found at the MWL site. NMED agrees that burrowing animals and roots can cause the migration of contaminants to the ground surface. Once on the surface, such contaminants can continue to migrate by the activities of other animals, wind erosion, and surface-water erosion/solution. In the case of the MWL, bio-intrusion, even by ants, is not expected to play a major role in the migration of contaminants because the wastes are relatively insoluble and the debris items mostly large in size. Analytical results of surface-soil samples have demonstrated that since closure of the landfill and the beginning of its operation in 1958, the bio-transport of contaminants has been essentially nonexistent as contaminants migrating by this method, if any, have not been detected above background conditions. Given that the bio-transport of contaminants has not been an important factor for the migration of contaminants in the past, the required bio-intrusion barrier should limit even more so the ability of burrowing animals to bring debris contaminated with chemical and radiological constituents (such as radon-222, radium-226, and uranium-238) to the surface. The barrier should also help limit root penetration which would otherwise assist in the movement of tritium to the surface. As a matter of precaution, the NMED nevertheless intends to require the Permittees to monitor surface soil, including animal burrows and ant mounds.

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			rodents and insects, erosion, and cave-ins due to collapsing wastes, drums, and debris.		The NMED believes that the rock intrusion barrier will be very effective in preventing animals from burrowing into the landfill. After subgrade preparation, the actual depth to waste will average about two times the thickness of the cover.
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**		The commenter states the FTM needs to be revised to consider possible transport of contaminants through animals and plants. The commenter also states the FTM needs to be revised to consider the ineffectiveness of a rock bio-intrusion barrier.		It is common practice to construct bio-intrusion barriers from rock; an exhaustive search of the literature concerning the design of rock bio-intrusion barriers is unnecessary. Monitoring systems will be justified and their designs presented in the long-term monitoring and maintenance plan. After a long-term monitoring plan is approved, additional surface-soil sampling will be conducted and the level of risk re-evaluated at a minimum of every five years.
G	**Citizen, John Trauxe, Ph.D., PE**		The commenter believes that the most significant oversight in the contaminant transport modeling of the MWL is the lack of any contributions to transport by biotic activity. The commenter believes this should have been identified in the preliminary exercise of identifying significant features, events, and processes affecting contaminant transport at the site. The commenter notes that recent work at other DOE sites (including Los Alamos National Laboratory and Nevada Test Site) has found that biotic activity in the form of plant uptake and redistribution of contaminants and animal translocation of bulk (contaminated) materials can be significant or even dominant modes of contaminant transport. The commenter states that		

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			in arid environments, plants tend to extend roots to significant depths in search of water, while ants have been found to construct nests to depths of several meters. The commenter believes that a cap thickness of a meter is ineffective at keeping these biota out of the waste in the MWL. The commenter also notes that the model document includes the development of a method for predicting the ground surface flux of radon-222 (^{222}Rn) above the MWL, as a linear function of the concentration of its parent, radium-226 (^{226}Ra), at depth in the MWL. The commenter believes this model is fine under the assumption that all the ^{226}Ra stays at depth, but notes that if biotically-induced transport of waste materials is included as a contaminant transport process, the ^{226}Ra parent material (as well as its parents, such as uranium-238 [^{238}U]) will move into the cap itself and onto the ground surface. The commenter notes that this does not fit the current radon diffusion model assumptions, and suggests that this modeling must employ more sophisticated techniques. The commenter also states that decay cascades can produce		

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			significant doses, and should not be neglected in the dose assessment process. The commenter notes that when coupled with biotic processes in the cap, there is a possibility of bringing radionuclides to the surface. In a May 3, 2006 e-mail to the NMED, the commenter repeats his concern that bio-transport may be significant and that the rock bio-intrusion barrier will not prevent ants and roots from penetrating to depths below the barrier. He also repeats that radionuclides can be brought to the surface by bio-transport, and that the decay products of such radionuclides may pose a threat.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter stated that the FTM is not comprehensive with respect to the potential for releases including vadose zone and groundwater contamination due to transport not considered in the model, including mechanisms such as biological transport of contaminants through the ground surface, human intrusion, and movement of contaminants by wind/air. The commenter also stated that the fate and transport model does not address biological transport of		

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			contaminants resulting from plant and animal uptake of contaminants and subsequent dispersion of soil, plant and animal material by wind. The commenter believes this information is required for a comprehensive model. The commenter also states that the CMI plan does not address the technical literature related to bio-intrusion barriers or identify monitoring systems appropriate for detection of releases associated with bio-intrusion into the MWL. The commenter requests revision of the CMI plan to include a thorough investigation and re-sampling of the soil at the MWL to identify bio-intrusion mechanisms and biological transport of contaminants, and consider the applicability of findings of such investigations to the Corrective Measure for the MWL.		
O	**Citizen, Jamie Wells**		The commenter recommends establishing a program to monitor plants and animals to ensure bioaccumulation and/or transportation of constituents of concern from the MWL do not occur.		

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B **C** **F** **G**	**Citizen, Floy J. Barrett** **Citizen, David M. Brugge** **Loretto Community of Catholic Sisters and Co-members, Penelope McMullen** **Citizen, John Trauxe, Ph.D., PE**	Human intrusion and institutional controls	The commenter is concerned that Sandia's FTM is not comprehensive and does not consider human intrusion. The commenter believes that human intrusion into the MWL is a serious issue requiring further consideration. The commenter suggested there is potential for terrorist explosion in or adjacent to the MWL, which would effectively create a "dirty bomb." The commenter states FTM needs to be revised to consider the comprehensive modeling of institutional controls against human intrusion. The commenter believes that a reasonable potential future receptor scenario includes a residence built directly on top of the MWL. The commenter notes that with ongoing development in the Albuquerque area and a precedent of residential construction on old landfills (e.g., Love Canal, New York), this would trigger the analysis of additional exposure pathways as well, such as exposure to indoor air with its elevated concentrations of gaseous radionuclides and volatile organic compounds (VOCs).	R4	The model does not address human intrusion. Institutional controls will be implemented to prevent human intrusion onto and into the landfill. Under EPA regulations, there is no requirement that a facility must assume a loss of institutional controls and evaluate the construction and occupation of a residence constructed on a landfill. This is a reasonable approach as land zoned as industrial tends to remain industrial. Moreover, should SNL choose to change the land use, enforceable provisions in SNL's RCRA permit require public notice and NMED approval of any cleanups that would need to be conducted, given the new land use. Although the NMED can not say with certainty whether a terrorist act could be successfully launched against the landfill, the MWL site is undoubtedly more secure than most landfills given the nature of the classified work that takes place within Technical Area 3, and is a far less desirable target compared to other facilities at KAFB and SNL.. NMED intends to enforce institutional controls through the Permittees' permit as long as such controls are needed. The FTM makes predictions concerning the future migration of contaminants from the landfill. The model does not make regulatory decisions regarding the implementation of institutional controls, ensuring such controls remain in force in the future, and what must be done in the event of a failure of the remedy.

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H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		In a May 3, 2006 e-mail to the NMED, the commenter repeats his concern that one should assume a loss of institutional controls and that structures could be built on the landfill in the future. The commenter stated that the FTM is not comprehensive with respect to the potential for releases including vadose zone and groundwater contamination due to transport not considered in the model, including human intrusion. The commenter also stated that the FTM does not address transport of contaminants resulting from human intrusion associated with accidental events and the eventual failure of the land use restriction portions of the institutional controls proposed by Sandia for the MWL. The commenter believes this information is required for a comprehensive model. The commenter also stated that the FTM does not identify means to monitor, model and assure the effectiveness of institutional controls or the consequences of the failure of such passive site protection measures.		

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Q	**Citizen, Willard Hunter**		The commenter states that he is concerned regarding the level of security provided for the MWL.		
B **E** **F**	**Citizen, Floy J. Barrett** **Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Dorelen Bunting and Janet Greenwald** **Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**	Model does not consider all waste types present in the landfill	The commenter is concerned that Sandia's FTM is not comprehensive and does not consider beryllium and metallic sodium as potential contaminants of concern. The commenter is also concerned that Sandia's FTM is not comprehensive and does not consider appropriate "trigger levels" for all contaminants in the known inventory. The commenter supports consideration of all the contaminants for trigger levels. The commenter states the FTM needs to be revised to consider the modeling of all hazardous chemicals and volatile organic compounds known or suspected to be in the MWL.	R5	The model generally considers only those waste types that have the highest potential for migration and pose an unacceptable risk to the environment. The modeled waste types are chiefly those that are known to occur in large amounts in the landfill, and/or those that migrate easily in the vapor phase. There are hundreds of waste types in the landfill that occur in small quantities and most of these waste types have limited ability to migrate in the absence of water. It would be a poor use of time and money for the Permittees to model and develop triggers for all waste types when in reality few, if any, are likely to pose unacceptable risk to the environment. Based on the inventory, beryllium, sodium, lithium, and probably all SVOCs do not occur in sufficient quantities in the landfill such that if released they would pose unacceptable risk. For this reason, MNED does not believe it necessary to include them with the important waste types that should be modeled. The FTM utilized PCE as a surrogate VOC due to its presence in the MWL as the VOC with the highest *average* concentration in soil vapor, its greater mobility in the environment, and its tendency to migrate downward towards groundwater. A constituent with a greater maximum concentration than PCE is not necessarily a potentially more significant problem because the constituent may not be as mobile, as abundant, or toxic as PCE.

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			The commenter also states the FTM needs to be revised to consider the modeling of all potential new compounds which could be formed as a result of mixing radionuclides with non- radioactive materials.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter stated that the FTM is not comprehensive with respect to the modeling for the complete suite of radionuclides and daughter products, metals, and volatile and semi-volatile organic compounds in the known inventory of the MWL, including beryllium, nickel, chromium, sodium, lithium, and the range of volatile organic compounds (VOCs) present at the MWL.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter recommends that an enhanced version of the FTM be run for the full range of VOCs identified in soil in the MWL RFI Phase 2 Report including, but not limited to dichloro-difluoromethane; trichloroethene; 1,1,1-trichlorethane (TCA), toluene, ethylbenzene, xylene, 1,1,2-tri-chloro-trifluoroethane, dichloroethyne, acetone, isopropyl ether, 1,1-dichloroethene and styrene. The MWL RFI Phase 2 Report identifies dichloro-difluoromethane concentrations of 29,000 ppb at 10 feet and 21,500 ppb at 30 feet at Fig. 4.5 – 16 and Fig. 4.5-22, which		

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			are 4-5 times higher than the concentrations of PCE detected at those depths in the same report.		
B	**Citizen, Floy J. Barrett**	Triggers associated with the model do not include monitoring plants, animals, and humans	The commenter is concerned that Sandia's FTM is not comprehensive and does not consider animals, plants, and humans as "triggers."	R6	Triggers are not included for the monitoring of plants, animals, and humans because there are no regulatory standards under RCRA for comparison, and more useful triggers can be established for surface soil by using conventional methods that consider human and ecological risk factors. This is why surface soils rather than plant, animals, and humans, will be monitored for contaminants. Additionally, the NMED can not require the monitoring of humans if the people involved do not wish to be subjected to testing.
E	**Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Dorelen Bunting and Janet Greenwald**		The commenter believes that plants and animals, if found to be contaminated, should be considered a trigger.		
O	**Citizen, Jamie Wells**		The commenter recommends establishing human population level triggers and corrective actions if these trigger are reached.		
B	**Citizen, Floy J. Barrett**	Risk Assessment	The commenter is concerned that Sandia's FTM is not comprehensive and does not consider conducting a risk assessment for the FTM that includes all waste types buried at the MWL, not just the risk posed by tritium as currently considered by	R7	Risk assessments for the MWL are found in the Phase II RCRA Facility Investigation and the Corrective Measures Study Reports. The purpose of the FTM is to predict the future movement and fate of contaminants from the landfill. Although the FTM makes comparisons to regulatory standards which are based on human health risk assessment, the FTM is not a risk assessment.

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			the assessment.		See also NMED response R5 concerning the issue that the FTM does not consider all waste types present in the landfill.
E	**Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Dorelen Bunting and Janet Greenwald**		The commenter requests consideration of all contaminants in the MWL when calculating the risk to the surrounding community.		
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**		The commenter states the FTM needs to be revised to consider performing a risk assessment for all waste types buried in the MWL.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter stated that FTM does not provide a risk assessment/performance assessment analysis in its evaluation of the potential for release of contaminants from the MWL.		
B	**Citizen, Floy J. Barrett**	New data is needed for model input	The commenter is concerned that FTM is not comprehensive and uses data that are outdated. Commenter believes new data should be gathered to verify the validity of the	R8	Groundwater data has been collected through April 2006, and several sampling events were conducted in the early to late 1990's to characterize surface soil for radionuclides, metals, and tritium emissions.

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			modeling.		Additional data, including soil and soil vapor data, will be acquired once the long-term monitoring and maintenance plan is approved and implemented. Cover construction and preparation of a long-term monitoring and maintenance plan must be completed so that new monitoring data can be obtained to update the FTM as required by the NMED Secretary's Order.
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**		The commenter states FTM needs to be revised to consider recent data to verify the validity of FTM, since the data used are outdated by at least 10 years.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter states that the model relies on data regarding releases of radionuclides, heavy metals, and volatile organic compounds from the Phase 1 and Phase 2 RCRA Feasibility Investigation (RFI) gathered in 1993 – 1995. The commenter states that no new data was gathered or proposed to calibrate or verify the modeling.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter recommends implementation of a subsurface sampling program to identify distribution of VOCs detected in the MWL RFI Phase 2 Report to verify and/or refine FTM model results, applying appropriate QA/QC methods including split sampling with NMED incorporating duplicates and blank samples to verify analytic accuracy.		
O	**Citizen, Jamie Wells**		The commenter recommends verification of the FTM after acquiring new data.		

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C	**Citizen, David M. Brugge**	Duration of NMED oversight	The commenter acknowledges New Mexico's oversight is limited to the effects that are predictable during the next 30 years. The commenter suggests that the State should review the threat of adverse impacts on water, air, and safety within the Mesa del Sol development area and possibly impacts to land values, even though the critical stages of these threats are beyond the 30-year oversight period. The commenter suggests that impacts to land values will prevent the University of New Mexico from receiving the full benefit of the Mesa del Sol development. The commenter suggests that the university and the State may have potential liability for any damages.	R9	The NMED intends to enforce controls on the MWL for as long as they are needed. The NMED considered the future migration of contaminants when selecting the remedy for the MWL, and did not limit its consideration of this matter to a 30 year period, as many contaminates could take hundreds of years to reach groundwater. The NMED considered the types and amounts of waste known or suspected to be buried in the landfill, the potential for waste and waste constituents to migrate and their pathways, the levels and risk of current releases of contaminants, and the geologic, hydrologic, and climatic conditions present at the MWL. Using this information, and an assessment of the current and expected future risk, the NMED concluded that the MWL did not pose a current or future threat to human health and the environment. The FTM validates this conclusion.
C **E**	**Citizen, M. Brugge** **Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive Dumping, Dorelen Bunting and Janet Greenwald**	Endorses comments made by Citizen Action	The commenter states that he agrees with all comments made by Citizen Action. The commenter supports the comments submitted by Citizen Action concerning the MWL at Sandia National Laboratories and specifically the FTM.	R10	See NMED responses to Citizen Action Comments, Commenter identification "H" and "I".

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K	**Nuclear Watch of New Mexico, Scott Kovac** (Comments compiled by Paul Robinson, Southwest Research and Information Center; and Robert H. Gilkeson)		The commenter states that Nuclear Watch of New Mexico endorses the recommendations of the comments submitted to NMED by Citizen Action.		
L	**Citizens for Alternatives to Radioactive Dumping, Janet Greenwald**		The commenter states that Citizens for Alternatives to Radioactive Dumping endorses Citizen Action's recommendations concerning the MWL.		
M	**Embudo Valley Environmental Monitoring Group, Sheri Kotowski**		The commenter states that the Embudo Valley Environmental Monitoring Group endorses the recommendations of the comments submitted to NMED by Citizen Action.		
N	**Concerned Citizens for Nuclear Safety, Joni Arends**		The commenter states that the CMI Plan should be denied until all recommendations made by Citizen Action are resolved to Citizen Action's satisfaction.		
E	**Albuquerque Center for Peace and Justice and Citizens for Alternatives to Radioactive**	Vadose zone Monitoring	The commenter believes that contaminants in the vadose zone should be a trigger.	R11	The NMED agrees that soil gas in the vadose zone should be monitored for tritium, radon, and VOCs. The NMED will require the Permittees to develop triggers for soil gas for these radiological and chemical constituents, and include them in the long-term monitoring and maintenance plan. This plan is due 180 days following approval of the CMI Report.

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	Dumping, Dorelen Bunting and Janet Greenwald				The NMED has no authority to enforce DOE Orders, but does have the authority under State law to require the installation of vapor monitoring wells at the MWL. If the commenter believes that requirements of DOE Orders are not being met, the commenter should direct these particular concerns to the DOE.
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter states that the model does not identify trigger levels for waste constituents that apply at the edge of the MWL or in the vadose zone below the site, but above the water table.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter recommends establishment of a shallow (less than 50 foot depth) subsurface monitoring program in the vadose zone for detection of VOCs as part of long-term a maintenance and monitoring plan and apply triggers at those sites.		
J.	**Citizen, Robert H. Gilkeson**		The commenter states that the wells are not installed and are needed in the unsaturated strata beneath the landfill to monitor the levels of toxic volatile contaminants (e.g., PCE, TCE, TCA, etc.) and tritium that are released over time from the landfill. The commenter also indicates that		

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			monitoring wells in the vadose zone are required by DOE Order 450.1 for early identification of the release of contamination from the MWL.		
O	**Citizen, Jamie Wells**		The commenter recommends conducting characterization of the site to understand the current situation of the landfill inventory before conducting work, including vadose zone sampling.		
F	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen**	Long-term monitoring	The commenter states the FTM needs to be revised to consider a plan for monitoring, testing and dealing with contaminants that may show up in the future. The commenter also states the CMI plan should be revised to include full long-term monitoring and maintenance program for public review and comment.	R12	The Secretary's Order requires the Permittees to submit a long-term monitoring and maintenance (LTM) plan within 180 days after approval of the Corrective Measures Implementation Report. The monitoring plan will be designed after the remedy is completed and, thus, the end state of the landfill is known. This is an entirely appropriate sequence. The FTM is not a long-term monitoring and maintenance plan, nor was it intended to be one. The Order states that the long-term monitoring and maintenance plan shall be subject to public review and comment.
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter stated that the "triggers" identified in the model do not include monitoring mechanisms to reflect either human intrusion, biological transport, or the waste constituents identified at the MWL. The commenter also states that the model discussion of "Trigger Levels"' does not address the degree to which monitoring for moisture content changes would reflect vapor		The scope of the monitoring, sampling and analysis, quality control, frequency, triggers, and the technologies to be utilized are to be detailed in the long-term monitoring and maintenance plan. However, sampling and analysis will be required for a wide range of potential contaminants, and will not be limited to just tritium. Sampling will include animal burrows and ant mounds to assess bio-transport of contaminants, if any. The plan will include monitoring of air, surface soil, subsurface soil gas, and groundwater, but not the monitoring of plants and animals unless required by the DOE (see NMED response R6). The plan must contain contingency procedures should the remedy fail to be protective.

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			phase movement of VOCs. The commenter requests that the model identify technologies that could be used to monitor moisture content. The commenter is also concerned that the CMI plan does not provide a comprehensive or detailed long-term operation and maintenance plan for public comment or review. The commenter requests that the CMI plan include a long-term monitoring and maintenance program that addresses: all parameters to be monitored, all media – including air, soil, vadose zone, groundwater and biota (plants and animals); recommended limits of detection for analytic equipment to be used; frequency of sampling and analysis; quality control and quality assurance measures; monitoring and maintenance cost estimates; MWL cover inspections and maintenance activities; and measures to verify that all institutional control aspects of the proposed corrective measure are in place and enforced for the full closure and post-closure period at the MWL. The commenter also states that the CMI plan proposes only three vadose zone monitoring boreholes and does not provide a demonstration that this number of		See also NMED response R8 above concerning the acquisition of new data. The monitoring of moisture content of subsurface soil by the neutron probe method will not detect VOCs. Soil-gas monitoring is done by different means. The three monitoring stations for subsurface soil moisture content are adequate for their purpose. However, the NMED does not consider the monitoring of deep subsurface soil for moisture content to be the most important type of monitoring that should be done at the MWL; it is only one component of a comprehensive monitoring strategy. The effectiveness of the CMI Plan does not rely on the LTM Plan. In fact, the opposite is true. Furthermore, as pointed out by comments from Citizen Action, the CMI Plan does not include much of the essential elements of a LTM Plan. Simply put, the CMI Plan is not a LTM Plan, and it is not intended to be a LTM Plan. As mentioned before, the end state of the landfill must be known before the LTM plan can be finalized. The NMED suggests that commenters may wish to resubmit their comments during the public comment period to be held in the future for the LTM Plan, as many of the suggestions are relevant, and should be considered in the development of the final LTM Plan. Replacement wells can be installed through a vegetative soil cover without risking damage to the cover, as such covers are by nature of simple design.

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			instruments will provide comprehensive vadose zone monitoring.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)		The commenter states that NMED should revise its MWL "Permit Modification" to require submittal, review, and approval of a LTM Plan on a schedule parallel to the schedule for the remaining portions of the CMI Plan rather than deferring the submittal of the LTM Plan until 180 days following completion of the construction of the corrective measure. The commenter also states that the effectiveness of the CMI Plan is dependent on the implementation of the LTM Plan. The commenter states that the CMI Plan already provides substantial information regarding critical portions of the LTM Plan, including trigger levels and moisture monitoring systems. The commenter also indicates that the LTM Plan should include, but not be limited to: • Bio-monitoring program, including establishment of bio-monitoring triggers at a significant increase over background to establish baseline and identify bio-accumulation, if any, in plant, animal and		

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			insects species in and around the MWL for as long as the waste remains in place. The commenter proposes that this program should include the identification of specific species to be monitored, frequency of sampling, and type of contaminants to be monitored [radiological, volatile organic compounds (VOCs), and heavy metals]. • Require SNL/DOE to establish and maintain site access controls and use restrictions as identified in the CMS and Administrative Order on Consent Based immediately. • Vadose zone monitoring of VOCs, moisture, and an appropriate suite of radionuclides and metals to verify model outputs; establishment of a statistically defensible baseline; and consideration of continuous monitoring. • Reinstalled monitoring wells before any cover is installed to insure that drilling equipment does not damage the evapotranspirative cover for the MWL.		
O	**Citizen, Jamie Wells**		The commenter recommends developing, establishing, and		

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			approving a Long-Term Monitoring and Maintenance Plan before construction of the cover.		
F **G** **H**	**Loretto Community of Catholic Sisters and Co-members, Penelope McMullen** **Citizen, John Trauxe, Ph.D., PE** **Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Container deterioration	The commenter states the FTM needs to be revised to consider the analysis of possible deterioration of each type of "container" for each type of waste buried in the MWL. The commenter believes that transport and fate of tetrachloroethylene (or perchloroethylene, PCE) is modeled reasonably, including decay from biotic degradation, but notes that future releases of PCE from as-yet unbreached containers was not performed. The commenter stated that the FTM is not comprehensive with respect to the physical state of containers for the full range of contaminants at the MWL. The commenter also states that the model does not appear to identify or consider either the mechanisms for deterioration of waste containers or the consequences of the deterioration of waste containers during development of the input parameters and assumptions for its	R13	The model assumes known releases from the landfill are available to migrate, except for sealed radium-226 sources where the model considered various degrees of container leakage. The number of intact containers in the MWL that contain fluids is unknown; however, the inventory suggests that the quantity of such containers is probably not large. NMED believes that many of the steel containers within the landfill have or will eventually rust. Any liquids contained within the containers could migrate from the landfill if conditions are appropriate; however, this does not necessarily mean that any release would pose a risk to human health and the environment. It also does not mean that the landfill would need to be excavated to mitigate a release. Due to uncertainty associated with the inventory, NMED recognizes that continued monitoring is necessary to ensure protection of human health and the environment. New data from monitoring will be used to update the results of the FTM and to screen for any unexpected releases, should any occur.

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I **O**	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center) **Citizen, Jamie Wells**		VOC, heavy metal and radionuclide models, with the exception of the radon model runs in which radium-226 containers were determined to deteriorate in 1,000 years. The commenter recommends the identification, compilation, and review of container deterioration data applicable to containers identified at or likely to have been disposed of at the MWL including information from other SNL, Lockheed, and DOE sites to determine container patterns applicable to the MWL. The commenter recommends conducting research and testing to understand and model container decay in the landfill.		
G	**Citizen, John Tauxe, Ph.D., PE**	General comment on fate and transport model	The commenter stated that the general approach taken by the fate and transport model is proper and commendable. The commenter stated the model is aimed at identifying appropriate locations and properties or constituents for long-term monitoring, and that the stochastic (probabilistic) modeling provides information for performing a sensitivity analysis, which in turn informs the monitoring program. The commenter believes this is an example of appropriate application	R14	NMED agrees that the general approach using a probabilistic model, as opposed to a deterministic model, is appropriate. The probabilistic modeling approach taken by Sandia is likely the only way that any reasonable model could be generated for the MWL and attempt to account for uncertainties. However, because of the myriad of assumptions and input parameters that could be chosen, there will always be questions that can be raised about the results. However, no matter the results of the model, the NMED will only rely on empirical data acquired from monitoring the landfill to evaluate the remedy's effectiveness.

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			of stochastic modeling, but also noted that several technical flaws (presented below) bring the overall results into question.		
G	**Citizen, John Tauxe, Ph.D., PE**	Modeled inventory distributions	The commenter states that the uncertainty distribution for the inventory of radionuclides in the MWL is undefended, applying a uniform distribution with a minimum at the values reported in SNL (1993) (from the document references) and a maximum of only twice the minimum. Commenter notes that no justification for this distribution is provided in the document, and believes the distribution is narrow based on the uncertainties regarding the inventory that are apparent in the source document. The commenter believes it is highly unlikely that all inventory constituents share the exact same uncertainty distribution, so the uniform (x,2x) distribution seems *ad hoc*. The commenter notes that inventory uncertainty is often the greatest source of modeling uncertainty at other DOE sites and suggests that a more thorough analysis of these distributions should be performed. The commenter repeats this comment in additional comments sent to the NMED by e-mail, May 3, 2006.	R15	The uniform distribution (for the radionuclides considered by the model) was used because there is no indication within the inventory to indicate that each radionuclide required its own uncertainty distribution. Additionally, the quantities of radionuclides disposed of in the landfill are better known than the amounts of chemical constituents. Comparative analyses were performed between simulated and measured soil levels for tritium and PCE, and modeling results matched reasonably the actual levels found in the field. Also, sensitivity analyses indicated that the inventory parameter was not the most significant factor in mobility of radionuclides.

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G	**Citizen, John Tauxe, Ph.D., PE**	External radiation exposure	The commenter notes that external exposures from radionuclides in the ground surface and near surface was overlooked in the model and that this is a potentially significant exposure pathway. The commenter believes this exposure should be included with inhalation of gases and particulates and incidental ingestion of soils by potential future receptors that would have access to the site.	R16	Only tritium and radon are expected to penetrate the cover. Based on characterization studies, existing activity levels of tritium and radon are sufficiently low that they do not pose unacceptable risk to human health and the environment, accounting for both external exposure and ingestion. Because of radioactive decay, the levels of radionuclides seen currently at the surface are unlikely to increase in the future. See also NMED response R4.
G	**Citizen, John Tauxe, Ph.D., PE**	Modeling time	The commenter notes that the period of performance for the model is 1,000 years, but suggests that modeling for peak dose analysis should be done to provide perspective on the long-term significance of waste disposal.	R17	None of the modeled radionuclides and heavy metals was simulated to reach groundwater during the 1,000-year performance period or the extended 10,000-year period. However, the model predicts that aquifer concentrations of PCE will peak in less than 50 years for the majority of the model runs. NMED believes 10,000 years is sufficient and is consistent with conservative model calculations done for other facilities (e.g. Waste Isolation Pilot Plant).
G **H**	**Citizen, John Tauxe, Ph.D., PE** **Citizen Action New Mexico, Susan Dayton** (Comments	PCE degradation products	The commenter notes that PCE decay products are not modeled and yet can be significant sources of cancer risk. The commenter states that some of these decay products have higher hazard indices than that of PCE, and cancer risk from them should be included in the model, as well as consideration of variable biodegradation rates, which will vary with location in the model. The commenter states that the model also does not identify or present model realizations for the decay products of PCE and the other VOCs	R18	The FTM assumes that the entire inventory of PCE was released at one time. Consequently, phased future releases are not considered, as this would be a less conservative approach.. In addition, long-term monitoring parameters proposed by SNL include several PCE breakdown products. Given the low levels of PCE expected to reach the water table according to the model, and the low levels of PCE that actually exists, the NMED believes that PCE degradation products will likely not be of concern. See also NMED response R5.

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	compiled by Paul Robinson, Southwest Research and Information Center)		and semi-volatile compounds (SVOCs) that were known to have escaped the MWL in 1993.		
G	**Citizen, John Tauxe, Ph.D., PE**	Model should be realistic in all assumptions	The commenter notes that the model indicates it is conservative in its assumptions, but this philosophy was applied inconsistently between groundwater infiltration and surface water runoff pathways. When one is modeled conservatively, the other is not conservative, if the pathways are linked to the same conditions. The commenter recommends abandoning the attempt to be "conservative" in favor of trying to be realistic in all assumptions.	R19	Whenever the precipitation rate exceeds the infiltration rate, surface-water runoff occurs. In the case of infiltration rate (in this case, the term is used interchangeably with "percolation rate"), the minimum value of the range is based on present-day climate, while the maximum value assumes climate change will occur, based on history, and is based on about twice as much precipitation as currently received at the MWL. The maximum and minimum values chosen for the infiltration rate appear to be realistic. The NMED agrees that assumptions should be realistic, but strives to be conservative, and therefore more protective.
G	**Citizen, John Tauxe, Ph.D., PE**	Monitoring locations	The commenter notes that the model document proposes monitoring of tritium and radon at the site boundary. The commenter, however, suggests that more valuable and interesting data will be obtained by monitoring these constituents on the MWL as they emanate from the cover. The commenter believes monitoring on the MWL cover will provide a more immediate and sensitive indication of gas emanation than can be provided by monitoring at the boundary.	R20	The NMED agrees with this comment. Some monitoring should be done at stations located on the cover. Monitoring stations will be considered in detail in the long-term monitoring and maintenance plan to be submitted by SNL at a later date.

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G	**Citizen, John Tauxe, Ph.D., PE**	Sensitivity analysis	The commenter notes that the sensitivity analysis performed for the FTM attempts to identify those model parameters and processes that most influence the results and recommends them for future monitoring. The commenter believes, however, that the sensitivity analysis is *ad hoc*, rather than comprehensive. The commenter recommends performance of a comprehensive sensitivity analysis and that the inventory distributions should be revisited, or if this was done, that sufficient details be provided for the reader to understand the method.	R21	The sensitivity analyses consider all parameters, but the results of these analyses, which are graphically presented in figures, only present the parameters with statistical significance. NMED also believes that additional details may be needed in the explanation of the sensitivity analyses, as presently explained in Section 2.2.1 of the report. The comment will be considered further after Sandia submits additional information for the FTM.
G	**Citizen, John Tauxe, Ph.D., PE**	Cover design	In a May 3, 2006 e-mail to the NMED, the commenter states "In these arid environments, the best cap is a simple monofill of natural materials such as the alluvium surrounding the MWL. The trick is to make it thick enough to act as a sponge for episodic infiltrating water, and encourage plant growth to keep it dry. Specification of a RCRA Subtitle C type cap is misguided. The optimal cap should be based on performance, not on a rigid design".	R22	The proposed cover (cap) is essentially a monofill as suggested by the commenter. Performance modeling was conducted to arrive at a design intended to limit infiltration to no more than 2.5-3 mm/year.
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul	Convening a technical discussion group	The commenter requests that NMED convene a "technical discussion group" to serve as a public meeting to provide a forum for interested stakeholders regarding the adequacy	R23	NMED convened such a group on May 25, 2006, at the Los Griegos Health and Social Services Center in Albuquerque, New Mexico. The public was given an opportunity at the meeting to discuss any technical issues about the MWL CMI Plan that interested them. NMED also opened another 14-day public

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	Robinson, Southwest Research and Information Center)		of the FTM and the CMI plan. The commenter recommends that this technical discussion group include representatives of the permittee, the NMED, and members of the public who have expressed an interest in the studies conducted by Sandia and/or submitted comments to the NMED on the CMI plan and/or the FTM. The commenter also recommends convening this technical discussion group prior to determining that the CMI plan and the FTM are either "comprehensive" or complete".		comment period on that day, giving the public even more opportunity for input. The NMED, facility representatives from DOE and SNL, and members of the public were in attendance. The NMED had not taken any final action with the CMI Plan or FTM prior to this meeting.
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	1995 Argonne study and report on MWL	The commenter states that the model identifies a 1995 Argonne National Laboratory report [cited as Johnson 1995 in the FTM] at p. 16 that showed that VOCs released from the MWL could reach the water approximately 250 years from the time of disposal. This study was not provided to NMED as part of the CMS, CMI plan, or the references for either of those reports. The commenter states that NMED should require Sandia to provide the agency with copies of the 1995 Argonne study, review the study, and consider its relevance regarding the adequacy of the Corrective Measure identified in the Permit Modification since Sandia did not present the study to NMED or the public or consider it during the development of the CMS.	R24	NMED will request SNL to provide a copy of the 1995 Argonne National Laboratory study for review. However, the model does not change the result of site characterization studies completed for the landfill. See also NMED response R1.

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			The commenter requests that NMED review the Corrective Measure approved in the Permit Modification as the conclusions of the 1995 Argonne Report are contrary to the conclusions presented in the CMS and Sandia's MWL hearing, i.e., that contaminants such as VOCs could not reach groundwater at the MWL site.		
H **I**	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center) **Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson,	Trigger levels set too high	The commenter states that the “trigger levels” identified in the model do not provide for early detection and early response to releases prior to the exceedance of health–based standards. The commenter states that the proposed trigger levels do not provide either early detection or early response as they are set at values at or near regulatory standards, rather than at levels that would demonstrate the “edge of the plume.” The commenter suggests trigger levels that provide “detection of contamination,” which would be established at a level 25–50% above initial concentrations for contaminants of concern. The commenter recommends establishment of trigger levels for agency and public notification and initiating responsive action at values 50% - 100% above background and/or 50% above detection limit for	R25	The trigger levels for releases to the atmosphere as proposed are orders of magnitude less than the modeled values that would result in noncompliance with regulatory standards or DOE Orders. The proposed trigger levels for groundwater constituents mostly are set at one-half of their corresponding MCL values; a few constituents are set at one-half the New Mexico Water Quality Control Commission standards in cases where MCLs do not exist. The NMED will require that the trigger levels for the latter constituents be set to lower levels.

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	Southwest Research and Information Center)		VOCs identified in 1993-4 and technogenic radionuclides, and an appropriate suite of metals and naturally-occurring radionuclides		
H **I**	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center) **Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson,	Uncertainties in the fate and transport model	The commenter states that a broad range of sources of uncertainty in the model were identified by the model's lead author Dr. Clifford Ho in a PowerPoint presentation at a DOE-sponsored public meeting on the model in January 2006. The "uncertainty variables" identified by Dr. Ho included: waste inventory and size; thickness of cover; and vadose zone and transport parameters including: infiltration, adsorption coefficient, saturated conductivity, moisture content; tortuosity coefficients, and boundary-layer thickness. The commenter suggests that the model should be revised to identify the full range of uncertainty variables associated with each of the constituents addressed in the FTM, as well as to identify the range of values used in model realizations to account for the uncertainty associated with each variable. The commenter also recommends a revised and expanded FTM to address the range of parameters associated with "model uncertainties/sensitivities" – including vadose zone profile (Kd),	R26	Tables E-2 through E-5 of Appendix E present the variables used in the FTM and their respective range in values. The range in values for each variable is intended to address uncertainty through use of the Monte Carlo approach, whereby many runs of the FTM are made to create many outcomes based on the use of different combinations of input parameters. The results of each model run are equally probable, and the collection of results yields a cumulative probability distribution that can be compared to performance objectives or to assess risk. The commenters did not specify which of the variables were considered by them to be problematic, and for what reason. The NMED believes that the range of the variables shown in tables E-2 through E-5 are reasonable and comprehensive given the dimensions of the landfill; the geologic, hydrologic, and climatic conditions of the landfill; and what is known of the inventory and current releases of contaminants.

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	Southwest Research and Information Center)		half-life (degradation), inventory of VOCs, as identified at FTM p. 57.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Relationship between the cover design and fate and transport model	The commenter states that the CMI plan does not effectively incorporate the content and findings of the model in either the evaluation or design of the Corrective Measure proposed for the MWL. The commenter requests revision of the CMI plan to incorporate the analyses and findings in the model when it is determined to be comprehensive and meet the requirements of the permit modification and associated guidelines and regulations by NMED.	R27	Regulations for permitted and interim status landfills require closure of a landfill to meet certain performance standards, including minimizing over the long term the migration of liquids through a closed landfill (for example, 40 CFR 264.310). Using these regulations as guidance for the MWL (the MWL is not a permitted or interim status landfill), the cover design is based on the results of performance modeling, not the FTM. Performance modeling is conducted to predict how much moisture can infiltrate into and percolate through the cover over a specified period of time for various proposed cover designs. The FTM predicts the future migration of contaminants, based in part on using the results of the landfill performance model that was done for the MWL. If the FTM had predicted a high chance that groundwater would become contaminated, the Permittees could conduct further performance modeling in an attempt to improve the cover design to eliminate the predicted threat. However, because the FTM predicts little chance that groundwater contamination will occur at levels exceeding a regulatory standard, no design changes are warranted.
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	PCE concentrations in error	The commenter states "The FTM states that the maximum PCE detected in 1993 was 5900 ppb at pg.52, but lists the maximum concentration of PCE in 1993 as 5200 ppb on Figure 21 at pg. 53".	R28	The comment may be incorrectly citing site information. The maximum PCE concentration for 1993 data (at 30 feet) is shown correctly as 5900 ppb on Figure E-21. The maximum PCE concentration of 5200 ppb (at 10 feet) is shown on Figure E-20.

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I J	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center) **Citizen, Robert H. Gilkeson**	New wells are needed	The commenter recommends that the ground water monitoring wells at the MWL be replaced with wells that meet regulatory standards, including RCRA standards capable of meeting applicable data quality objectives and providing reliable and verifiable water quality and soil column data. The commenter also recommends that NMED conduct an independent analysis of the effectiveness of the monitoring wells to identify the occurrence of VOCs and other constituents of concern, including those modeled in the FTM. In a meeting on July 19, 2006, the commenter repeated that new wells should be installed at the MWL to replace wells impacted by drilling mud and additives. The commenter states that the strategy to leave chemical and radioactive waste at the Sandia mixed waste landfill and to assure protection of the regional aquifer by long-term monitoring of the existing set of monitoring wells is unacceptable because of the poor quality of the water samples produced from the wells. The commenter believes there are many important factors for why the wells do not meet the regulatory	R29	The NMED disagrees with this comment and believes that groundwater data obtained from the monitoring wells at the Mixed Waste Landfill (MWL) are generally representative of formation water (see also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*). A total of seven ground-water monitoring wells have been installed at the MWL (BW1, MW1, MW2, MW3, MW4, MW5, and MW6). Wells MW1, MW5 and MW6 were installed using the air-rotary casing hammer (ARCH) method. Well MW4 was drilled using sonic resonant technology; whereas, wells BW1, MW2 and MW3 were completed via the mud rotary drilling method. In the above mentioned report, groundwater data from the mud rotary wells (BW1, MW2, and MW3) were compared to corresponding data from wells completed by other drilling methods (MW1 and MW4) and to background hydrochemistry data representative of the Kirtland Air Force Base area. The results of this effort finds that the mud rotary wells, in addition to the other wells at the MWL, yield representative groundwater samples and that comments to the contrary are incorrect. The groundwater data representing water quality at the MWL can be relied upon for characterization purposes and remedy selection. There is no evidence that the hydrochemistry of groundwater samples from MWL monitoring wells has been significantly impacted by the use of drilling mud or additives. Just because drilling mud or additives have the *potential* to adversely impact water quality results does not mean that this has actually happened at the MWL. Decades of monitoring well installations around the world through a variety of methods show that with proper well development, wells drilled by the mud rotary method or other methods are capable of yielding representative water samples.

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N	**Concerned Citizens for Nuclear Safety, Joni Arends**		requirements for detection monitoring: • Drilling additives with well known chemical properties to mask the detection of contamination were allowed to invade the strata that surround the wells. • The drilling additives lowered the permeability of the strata surrounding the wells so that the wells produce stagnant water that was in contact for a long period of time with the strata affected by the drilling additives. In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic. The commenter recommends that NMED deny the CMI Plan, including the FTM, until such time as the recommendations made by Citizen Action are resolved to their satisfaction. The commenter states that issues related to the quality of the groundwater monitoring data must be resolved before NMED provides any type of approval of the CMI Plan. The commenter also recommends that the issues and comments raised		Although the practice is somewhat dated, it is clear that one commenter is referring to saturated hydraulic conductivity (Ksat) when using the term permeability. Note that the NMED responses will use the term "Ksat" rather than the less precise and dated term "permeability", as the latter term is often confused with a different physical property of rock formations. Because of the depth to the water table (about 460 feet), nearly all drilling methods capable of being successfully employed at the MWL will impact to some degree and at least temporarily the pristine environment of the saturated zone. This is because at minimum, for the common drilling methods either water or air must be injected to lubricate and/or cool the drill bit, and to transport cuttings to the surface. While desirable to have ideal and pristine conditions, one must accept the natural conditions that exist at sites and the limits of technology, and their influence on data quality objectives. The development of wells is a standard practice intended to restore the natural properties of the saturated zone to the extent *reasonably* possible. The NMED believes that wells that are properly and timely developed, including those installed using the mud rotary method, can yield representative water samples. The monitoring of groundwater in any given well over several years is also standard practice to allow for the restoration of water quality. A number of the wells at the MWL have sampled periodically for more than a decade. Although not prohibited by regulation, the NMED discourages the use of the mud rotary method for well installations because of its *potential* impacts on water quality and formation properties. A report prepared by the NMED in 1993 on the MWL monitoring well network makes this point, and subsequently, other wells completed at the MWL have been installed by other drilling methods. No evidence has been provided that the Ksat of the sediments surrounding any well at

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			by Robert H. Gilkeson must be addressed by Sandia National Laboratories and NMED prior to any type of approval of the CMI Work Plan is made by NMED. The commenter states that Concerned Citizens for Nuclear Safety has been involved with groundwater issues at Los Alamos National Laboratory (LANL) for many years. As the Department of Energy (DOE) owns both LANL and Sandia, the commenter was not surprised to learn that the same types of problems exist at Sandia as at LANL.		the MWL has been decreased by drilling mud or additives. The low Ksat of the sediments surrounding the shallower wells drilled by any method was expected given the geologic logs indicate that silty fine-grained sands make up the uppermost part of the saturated zone. Wells MW1 and MW4, drilled using the ARCH method without using drilling mud or additives (beyond water and air) also encountered the same silty sands as the wells drilled by the mud rotary method. These latter wells are also low yield wells due to the low Ksat of the saturated sediments they are screened in. There are no regulatory requirements or technical reasons that mandate that wells be screened only in high Ksat strata. In fact, such a requirement at the MWL would mean that the uppermost aquifer (i.e., the geologic unit that, in the event of a release, would be affected first) would go unmonitored. NMED strongly disagrees with this approach. The FTM predicts little chance of groundwater contamination. Soil and soil vapor data collected during the RCRA Facility Investigation demonstrate that there is no significant contamination in the vadose zone beneath the MWL. Given the latter, it is inconceivable that groundwater contamination is being masked by drilling additives when there is no expression of that contamination in the vadose zone. The vadose zone must be significantly contaminated before one would expect any groundwater contamination to be present, a condition which simply does not occur at the MWL. Because the well network is reliable, the NMED will not require replacement of wells except on a case-by-case basis as wells become useless for sampling due to the dropping water table. Note that not all wells are likely to be replaced after going dry, and that the NMED may choose different locations to install replacement wells.

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I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	New geophysical surveys needed	The commenter recommends that NMED require a revised set of geophysical surveys of the MWL to update and enhance the Phase 2 data to provide detailed information about the shape, distribution and content of containers in the MWL, the distribution of metals and other materials in landfill, and otherwise expand knowledge of inventory. This updated geophysical baseline should include replication of geophysical investigations in the RFI Phase 2 Report with contemporary equipment and analytic capabilities, as well as conduct of additional geophysical analyses including, but not limited to, sonar, ground penetrating radar, and magnetic resonance.	R30	Geophysical surveys are conducted chiefly to determine the trenches/pits and boundaries of a landfill by locating buried metal. The MWL and the trenches contained within it have been adequately characterized by geophysical surveys conducted during the Phase 2 RCRA Facility Investigation. There is no need to conduct other geophysical surveys of the MWL. Individual containers could not be well delineated, even with the benefit of the latest geophysical methods.
O	**Citizen, Jamie Wells**		The commenter recommends conducting characterization of the site to understand the current situation of the landfill inventory before conducting work, including: • Noninvasive geophysical characterization using magnetic resonance and radar, and the latest instrumentation, which has a higher data resolution and different frequencies (older instrumentation use one frequency) than when the previous geophysical surveys were performed. The		

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			commenter suggests that this data should be maintained in the appropriate format so they can be used in the future as refinements in technology and algorithms advance in this field. This could assist in a better understanding of the waste and containers.		
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Model input data	The commenter recommends full disclosure of FTM model input data.	R31	Tables E-2 through E-5 of Appendix E present the variables used in the FTM and their respective range in values.
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	VOC levels modeled	The commenter recommends that enhanced FTM realizations include considerations of VOC concentrations 100x and 1000x the concentrations identified in soil the MWL RFI Phase 2 Report.	R32	The model assumed PCE concentrations up to 10 times that of the maximum level actually detected. Inputs to the FTM should be not only conservative, but also reasonable and realistic. If PCE levels were increased to 100 to 1000 times of the maximum actually detected, the model would undoubtedly predict significant groundwater contamination for a much larger percentage of modeling runs. There is no basis to model such high concentrations based on the actual releases of VOCs reported in the Phase 2 RCRA Facility Investigation Report.
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson,	Other models of VOC fate and transport	The commenter recommends the identification and submittal to NMED and review of other models of VOC movement conducted by Sandia for other waste sites at SNL including, but not limited to, the	R33	Modeling must be done on a site by site basis, as every site generally has different source terms, and geologic, hydrologic, and climatic conditions. Sandia has modeled vapor-phase migration of VOCs at the Chemical Waste Landfill. The modeling results have been

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	Southwest Research and Information Center)		Chemical Waste Landfill, Liquid Waste Disposal System, and Lurance Canyon sites located at SNL.		submitted to and have been reviewed by the NMED. However, the FTM is more appropriately tailored for the MWL as it utilizes site-specific information to the extent possible.
O	**Citizen, Jamie Wells**		The commenter recommends validation of the FTM by using the code at other sites selected by the NMED.		Contaminant migration at the Liquid Waste Disposal System was primarily by aqueous-phase transport. This is probably also true for contaminant migration at the Lurance Canyon Burn Site. Neither of these sites is a close match with the MWL with respect to the conditions mentioned above, thus the modeling done for these sites would not be particularly useful for the MWL.
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Run-on/run-off controls	The commenter recommends locating run-off and run-on collection and diversion canals and swales approximately 25 to 50 meters away from the perimeter of cover system to manage flows from peak precipitation events.	R34	This point was considered and discussed during the Technical Discussion Public Meeting sponsored by NMED on May 25, 2006. NMED declined to act on this recommendation, because due to a 3,000-foot long sled track located east of the MWL, overland flow of surface water would be mostly prevented by the sled track from reaching the eastern edge of the future landfill cover. The sled track is elevated above the surrounding ground surface and thus acts as a barrier to westerly directed surface water flow.
I	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Wind erosion	The commenter recommends including an erosion resistant layer (armor) to reduce wind erosion effects.	R35	This point was considered and discussed during the Technical Discussion Public Meeting sponsored by NMED on May 25, 2006. The topsoil used for the cover will include a 25 percent mix of gravel that will help reduce wind and water erosion prior to vegetation becoming established on the cover. The topsoil/gravel mix is an erosion resistant layer. Further enhancements to the cover to deal with this issue are therefore unnecessary.
I	**Citizen Action New Mexico, Susan Dayton**	Defining seeding success	The commenter recommends identifying specific vegetative cover standards for determination of re-	R36	The NMED agrees with this comment. NMED will require SNL to define the criteria that will be used to assess whether vegetation of the cover has been successfully accomplished.

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	(Comments compiled by Paul Robinson, Southwest Research and Information Center)		vegetation success including, but not limited to, species diversity, plant survival, and ground cover parameters.		
I **K** **M**	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center) **Nuclear Watch of New Mexico, Scott Kovac** **Embudo Valley Environmental Monitoring Group, Sheri Kotowski**	Endorses comments made by Robert Gilkeson	The commenter presented recommendations submitted by Robert H. Gilkeson to the NMED. The commenter states that Nuclear Watch of New Mexico endorses the recommendations of the comments submitted to NMED by Robert H. Gilkeson. The commenter states that the Embudo Valley Environmental Monitoring Group endorses the recommendations of the comments submitted to NMED by Robert H. Gilkeson.	R37	See NMED responses to Robert Gilkeson Comments, commenter identification "J".
J	**Citizen, Robert H. Gilkeson**	Sampling procedures	The wells are sampled with procedures that strip from the water the volatile chemical solvent contaminants that are known to be	R38	Several of the wells at the MWL are constructed such that their screens straddle the water table. This is a common practice that is effective for monitoring the uppermost part of the saturated zone and to account for potential seasonal variations in water

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			released from the landfill (e.g., PCE, TCE, and TCA). The wells are sampled with procedures that expose the water to oxygen and therefore, many metal and radioactive contaminants known to be disposed of at the landfill are hidden from being detected. The commenter states that the collection of water samples after the wells are purged dry is unacceptable because of aeration and oxidation of the water that trickles into the wells, and therefore, a loss of many contaminants from the water and especially volatile solvents. The commenter suggests that PCE, one of the parameters for compliance monitoring, is a volatile solvent that will be stripped from the groundwater that recharges into the wells after they are purged dry. It is essential for the monitoring wells at the Sandia mixed waste landfill to provide a continuous flow of water for monitoring of sensitive water parameters with a closed flow-through cell with the collection of water samples after the sensitive parameters stabilize and during the continuous flow of water. In a July 19, 2006 meeting with the		levels and contaminant concentrations. The surface of the water contained in any given well is in contact with air (and thus oxygen). The formation water at the water table surrounding the wells is also in contact with air. No matter what sampling procedures are employed, some of the water that flows into the wells will have been exposed to oxygen in air. Not all of the wells at the MWL are low yield wells (will purge dry). Additionally, applicable regulations or guidance do not state that low yield wells are unacceptable. It is a standard EPA procedure to purge low yield wells dry, and then to collect water samples from them as soon as possible after they have sufficiently recovered. Low yield wells at the MWL are now sometimes taking days to recover after being purged dry. The fact that it takes so much time for the wells to recover indicates that the groundwater flow into these wells is not turbulent, hence there is less concern that appreciable volatile organic compounds are being stripped from the water samples. In the case of the MWL, it is known from soil-gas surveys and subsurface soil samples that volatile organic compounds are unlikely to reach groundwater, especially at detectable levels. This has been confirmed by the FTM. Regardless, the pumping and sampling procedures employed by Sandia are appropriate, and in fact are a necessity given the natural conditions that exist at the MWL. The majority of the wells at the MWL are "low yield wells" because the saturated sediments that they intercept have low Ksat – Ksat is a physical property that essentially is a measure of how easy groundwater can flow through the aquifer. The NMED and EPA both recognize that low yield wells exist in the real world and sometimes that the desired ideal sampling conditions can not be obtained. Because low yield wells are a reality, and contamination is not always in high Ksat zones, the sampling of low yield wells is not prohibited by regulation and procedures for sampling them are found in EPA guidance. See also NMED response R29.

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			NMED, the commenter repeated his comments on this topic.		As mentioned previously, in order to conduct a technically sound groundwater investigation at the MWL, SNL has had to construct some wells such that their well screens straddle the water table. The wells must monitor the water at the water table no matter the Ksat of the sediments that are encountered there. Sediments at the water table beneath the MWL have low Ksat. At the MWL, because the water does not flow into the wells easily because of low Ksat, the wells are purged dry even though the purging rate is only about 1 gallon per minute or less. Also, because the water does not flow into the wells easily, it may take several days before sufficient amounts of water will recharge the well to allow the collection of samples. Depending on the well, the time it takes for recovery has increased from a few hours to days as water levels have dropped over the years. Although ideal sampling procedures can not be achieved with the low yield wells at the MWL, no-purge sampling conducted at TA-V and the Tijeras Arroyo leads NMED to conclude that volatile organic compounds would still be detected.
J **O**	**Citizen, Robert H. Gilkeson** **Citizen, Jamie Wells**	Regulatory requirements for wells	The commenter indicates that the existing network of monitoring wells at the Sandia mixed waste landfill does not meet the requirements of the RCRA Statute, the NMED Sandia Consent Order, or the DOE Orders for the detection of contamination released from the waste buried in the landfill. In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic. The commenter recommends conducting characterization of the	R39	NMED disagrees with this comment and believes that the monitoring wells at the MWL substantively meet regulatory requirements under the New Mexico Hazardous Waste Management Regulations, requirements pursuant to the Sandia Consent Order issued April 29, 2004, and guidance issued by the U. S. Environmental Protection Agency. NMED has no authority to enforce DOE Orders, and so considers them irrelevant to a state-enforced cleanup action. The Mixed Waste Landfill is subject to corrective action under the New Mexico Hazardous Waste Management Regulations, 20.4.1 NMAC, which for the most part incorporate federal regulations promulgated under the Resource Conservation and Recovery Act (RCRA). NMED has negotiated a Consent Order with Sandia and the U. S. Department of Energy which contains groundwater monitoring well installation, development, purging,

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			site to understand the current situation of the landfill inventory before conducting work, including groundwater monitoring that meets 40 CFR 264 Subpart F.		and sampling requirements that is consistent with the New Mexico regulations and guidance. The EPA and the NMED have published guidance on how to properly construct monitoring wells and to collect and analyze groundwater samples. The monitoring wells at the MWL and the sampling procedures employed at the landfill by Sandia meet both NMED and EPA regulatory requirements, guidance, and requirements of the Consent Order. Neither the Consent Order nor any other applicable standard prohibits the installation of wells using the mud rotary method or any other method. The Consent Order appropriately requires development of a well to create an effective filter pack, correct damage to the formation caused by drilling, remove fine particles from the formation near the borehole, and assist in restoring water quality. The Consent Order applies to wells installed after the effective date of the Order. The existing wells at the MWL were all installed prior to this date. When new wells are installed at the MWL as replacement wells, they would need to meet the requirements of the Consent Order, provided the Order is still in effect at that time. Although the regulatory requirements of 20.4.1.500 NMAC incorporating 40 CFR 264 Subpart F can be used as guidance, nearly all of the requirements of Subpart F do not apply to the MWL because it is not a permitted unit. Instead, the landfill is regulated as a Solid Waste Management Unit subject to corrective action pursuant to 20.4.1.500 NMAC incorporating 40 CFR 264.101. Although not required by regulation, Sandia commonly uses flow-through cells while purging to measure certain field parameters (pH, temperature, and specific conductance). See also NMED responses R5 and R40.

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J	**Citizen, Robert H. Gilkeson**	Wells are set in sediments with low hydraulic conductivity	The commenter states that the wells are not installed in the aquifer strata with high permeability – the strata where the highest levels of contamination are expected and the strata that are fast pathways for horizontal travel of contaminated groundwater over great distance. The commenter states that there is a fundamental requirement of RCRA Subpart F is for the monitoring wells to be installed in the geologic strata that have a sufficient permeability to provide a continuous flow of groundwater with a minimum of drawdown of the water level in the well during the collection of groundwater samples. In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic.	R40	NMED agrees that groundwater will travel faster in strata with higher Ksats (given the hydraulic gradient is constant), and that such lithologic units have the potential to transport contaminants most quickly. However, as indicated above, most of the wells at the MWL are constructed such that their screens straddle the water table in order to monitor the uppermost water in the saturated zone (first water), regardless of the Ksat of the sediments that make up that part of the aquifer. If contamination is not detected in the uppermost zone of saturation at the MWL, then contamination is unlikely to occur at deeper levels where Ksat values at the MWL tend to be higher. Groundwater in lithologic units having low Ksat values (like aquitards) will still flow if subject to a hydraulic gradient (the normal case) and thus these units are subject to becoming contaminated. Based on slug tests, typical Ksat values for sediments in the uppermost part of the saturated zone at the MWL range from about 10^{-7} to 10^{-5} cm/s. These are relatively low Ksat values. As previously stated, some of the regulatory requirements of 20.4.1.500 NMAC incorporating 40 CFR 264 Subpart F may be considered useful guidance. However, the bulk of the requirements of Subpart F do not apply to the MWL because it is not a permitted unit. Instead, the landfill is regulated as a Solid Waste Management Unit pursuant to corrective action under 20.4.1.500 NMAC incorporating 40 CFR 264.101. The regulations in Subpart F do not mandate that monitoring wells be installed in geologic strata with high Ksat. The regulations also do not require that wells be capable of supplying water at rates that will minimize drawdown. The regulations do not specifically address Ksats or drawdown because sediments exhibiting high Ksat and that are capable of supporting low drawdown conditions at high pumping rates simply do not occur at all sites. See also NMED response R29.

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J	**Citizen, Robert H. Gilkeson**	PCE standard	The commenter states "Because of health concerns, the Environmental Protection Agency (EPA) has set the Drinking Water Standard for PCE at a Maximum Contaminant Level (MCL) of 5 ug/L (5 parts per billion). In addition, because of the danger to health, the EPA has set a Maximum Contaminant Level Goal of ZERO for the presence of PCE in groundwater".	R41	The EPA drinking-water MCL for PCE is 5 µg/L, and is an enforceable standard. The EPA MCL goal of 0 (zero) is not a standard, and therefore is not enforceable.
J	**Citizen, Robert H. Gilkeson**	Iron and Turbidity	With regard to well MW1, the commenter states "The water that recharged the well and was collected for the analytical suite had a turbidity slightly higher than the recommended upper limit of 5 NTUs in the RCRA guidance. The elevated turbidity may be responsible for the large difference between total iron and dissolved iron. However, the microbial processes greatly increase the level of colloidal iron in the groundwater and the high level of colloidal iron is probably the cause of both the high turbidity and the high level of total iron".	R42	The commenter provides no evidence that large volumes of iron precipitates are present in the sediments surrounding well MWL-MW1, and are plugging up formation materials, reducing their Ksat. MW1 was drilled using the ARCH method without the use of organic drilling additives. A reducing environment does not occur in the groundwater (See NMED response R29). See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*. Although the turbidity of the groundwater samples from MW1 (median of 6.59 NTU) is slightly higher than 5 NTU, it causes no significant problems. At Sandia, the turbidity of samples of natural spring water is often much higher; obviously, the springs have not been impacted by organic drilling additives. Water samples from well MW1 yield a median total iron concentration of 0.24 mg/L and a median dissolved iron concentration of 0.11 mg/L. These are background levels. At MW1, the turbidity of the water and the moderately higher levels of total iron observed are caused by suspended sediment

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					and corrosion of the stainless steel well screen. The suspended sediment occurs in the well because the filter pack is too coarse to prevent the finest particles of formation material from entering the well, and because small pieces of corroded well screen are suspected to be present in the well, mixed in with sediment. Higher turbidity can cause higher concentrations of metals to be detected in groundwater because suspended sediments contain much higher concentrations of metals compared to water. The metals in the suspended sediments, including iron, are leached into the water sample when the sample is preserved with nitric acid, elevating the amounts of metals beyond that actually present in formation water.
J	**Citizen, Robert H. Gilkeson**	Nickel and Turbidity	With regard to MW1, the commenter states "In addition, nickel is at an anomalous high level in the water produced from the well. The nickel may have been leached from the stainless steel well screen. Nevertheless, the high nickel values are evidence that the water produced from the well is from a stagnant zone surrounding the well screen and is not representative of the groundwater in the aquifer".	R43	The moderately high nickel levels seen in groundwater samples from this well are likely derived from leaching of the stainless-steel well screen. This is based on the fact that soil sample results from borings completed under the landfill do not indicate the existence of nickel contamination in the vadose zone. Although some groundwater adjacent to and down gradient of the well may be contaminated with dissolved nickel from leaching of the well screen, the zone of dissolved nickel is likely to be almost negligible in extent given the very small average linear velocity of the groundwater. Furthermore, whenever any low yield well is purged, it is not possible to remove all water that is present within the well. Even if purged dry, some stagnant water in the sump and below the level of the pump intake will remain in the well. For MW1, some stagnant water containing dissolved nickel will be trapped in the well below the pump intake and will mix with larger amounts of fresh formation water entering the well during recovery. Because there is no way to avoid this, water samples from MW1 will always contain moderately high levels of nickel for the rest of the life of the well.

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J	**Citizen, Robert H. Gilkeson**	Problems with wells at Los Alamos Laboratories (LANL)	The commenter states "The effects of the bentonite clay and the organic additives to mask the detection of contamination is a concern for the monitoring wells installed at the Los Alamos National Laboratory (LANL). See Appendix A with particular attention to reports A-4 and A-5 by the EPA and the DOE IG for the mud rotary monitoring wells at LANL". In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic.	R44	SNL and LANL are two different sites. Just because a problem may exist for some LANL monitoring wells does not mean that the same problem exists for wells at SNL. The MWL is over 60 miles from LANL, so problems with wells at LANL are not relevant to issues of groundwater monitoring at the MWL. The most significant problems with wells at LANL involve complexly-built wells in complex geology with small multiple screens which were not adequately developed. In contrast, wells at the MWL are simpler, constructed in relatively simple geology, have larger screens, and except for MW4, have but one screened interval. See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*.
J	**Citizen, Robert H. Gilkeson**	Separating screened intervals, MW4	The commenter states "Well MW4 has two screened intervals with each screen having a length of 20 feet. The rehabilitation of MW4 shall include installation of a low-flow submersible pump between two inflatable packers to restrict the interval of aquifer strata that produce water from the well".	R45	The lower screened interval is currently always separated from the upper screened interval by an inflatable packer, including during times of sampling.
J	**Citizen, Robert H. Gilkeson**	Eh and dissolved oxygen levels, MW5 and MW6	The commenter states "For the water produced from well MW5, the Eh and dissolved oxygen levels are much lower than the levels measured in the background groundwater. Furthermore, the water produced from MW6 has a negative Eh and a low level of dissolved oxygen. The	R46	The negative Eh values from the one sampling event quoted by the commenter are almost certainly errors. Eh measurements for water samples collected at the MWL are typically made using a flow-through cell. Wells MW5 and MW6 were drilled using the air rotary casing driven (ARCH) method. Organic drilling additives were not used to complete these wells. The hydrochemistry of

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			negative Eh and presence of dissolved oxygen do not occur together in groundwater and show the need to improve the measurement procedures with monitoring a continuous flow of water from the well using a closed flow-through cell". In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic.		groundwater water samples obtained from both wells are indicative of oxidizing conditions, not reducing conditions. The median Eh values for MW5, MW6, and BW1 are 78.6, 129.0, and 141.8 millivolts, respectively. The median dissolved oxygen values for MW5, MW6, and BW1 are 2.49, 2.43, and 6.8 mg/L, respectively. Both Eh and dissolved oxygen are lower for MW5 and MW6 because the groundwater encountered in these wells occurs deeper in the aquifer. Deeper groundwaters are typically older groundwaters, and older groundwaters tend to have lower dissolved oxygen levels and lower Eh compared to younger groundwaters. See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*.
J	**Citizen, Robert H. Gilkeson**	Iron and manganese concentrations, MW5	The commenter states "An additional indication that well MW5 does not produce representative water is that the concentrations of iron and manganese are much higher than the concentrations measured in the background well MWL-BW1. The elevated iron and manganese levels in well MW5 may be due to chemical processes from the organic drilling additives. As explained above, the chemical processes will create iron coatings on the aquifer strata that have enhanced properties to remove contaminants of concern for the compliance monitoring from the groundwater produced from well MW5. The coatings also lower the	R47	Although well MW5 was drilled using the air rotary casing driven method without the use of drilling mud or organic additives, sodium-bentonite grout inadvertently infiltrated the filter pack and screen of the well during installation. The median concentrations of total iron (0.133 mg/L) and manganese (0.116 mg/L) of water samples collected from MW5 are representative of background levels. Organic additives were not used to construct the well, thus, the levels of iron and manganese do not represent the reduction of iron and manganese minerals. Moderately oxidizing conditions are present in the well, not reducing conditions, as demonstrated by a median dissolved oxygen concentration of 2.49 mg/L, as well as the presence of nitrate and sulfate in water samples. NMED therefore concludes that the grout was successfully removed prior to placing the well into service. See NMED report by Moats, Mayerson, and Salem, 2006,

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			permeability of the strata that surround the well screen".		entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*.
J	**Citizen, Robert H. Gilkeson**	Zinc concentrations	The commenter states "The zinc data for water samples collected from the mixed waste landfill monitoring wells in April 2005 are summarized below. The NMED Approved Background Value for total zinc and dissolved zinc is 260 ug/L (parts per billion). Note that the total zinc concentrations measured in the seven monitoring wells are over an order of magnitude lower than the NMED approved natural background concentration of total zinc in groundwater. Of more importance are the very low levels of dissolved zinc in the groundwater produced from the monitoring wells. The very low dissolved zinc levels are evidence that the wells are surrounded by a reactive contaminant capture barrier that prevents the wells from producing representative water samples: 1). for the *in situ* groundwater chemistry, and 2). for the presence of contamination from waste released	R48	NMED disagrees. The zinc levels are representative of background concentrations and are consistent with those seen in groundwater samples from numerous wells and springs located across the Kirtland Air Force Base area. The median values of total and dissolved zinc detected in water samples from BW1, MW2, and MW3 (wells drilled by the mud rotary method) are higher than the median value for samples collected from MW1 (drilled using the ARCH method). Additionally, the median values of total zinc detected in water samples from BW1, MW2, and MW3 are generally higher than the median values representing water samples from MW4 , MW5, and MW6 (drilled by sonic resonant or ARCH methods). These statistics are opposite of what would be the case if reducing conditions were prevalent in the wells as suggested by the commenter. The wells do not need to be replaced. See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*. See also NMED response R29.

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			from the mixed waste landfill. The low levels of dissolved zinc and the low permeability of the strata surrounding the monitoring wells are evidence of the need to replace the wells."		
J	**Citizen, Robert H. Gilkeson**	Well development	The commenter states "The ASTM guidance for successful well development does not guarantee that all or even most of the drilling fluids are removed from the aquifer strata that are in contact with groundwater samples that are collected from the monitoring wells for contaminant analyses. The small diameter of the Sandia monitoring wells, the great depth of the wells, the short screen length, the small slot size of the screen openings, and the small size of the filter pack sediments that surround the well screen are factors that prevent removal of most of the bentonite clay muds and drilling fluids that are entrained into the aquifer strata".	R49	Proper well development can remove much, and ideally, nearly all drilling fluids. However, small amounts of drilling fluids would be expected to remain in the formation and filter pack following even the best efforts to develop a well. However, the drilling fluids that remain after proper well development must have limits to their ability to adsorb contaminants. Many water-supply wells are drilled using the mud rotary method because it is readily available and cost-effective. According to the commenter's position, which NMED disagrees with, one would never expect to see VOC or metal contaminants in the groundwater at such wells because of the unlimited capabilities of these reactive barriers to adsorb these contaminants. Unfortunately, this is not true as there are many examples of water-supply wells were groundwater contamination with VOCs or metals have been detected, and in fact, Safe Drinking Water Act compliance is based in many cases on samples from wells installed in such a manner. The installation of wells to depths of hundreds of feet always has an affect on water quality. This is one reason why the NMED typically requires sampling and analysis of groundwater over a period of several years. For example, it is well known that the introduction of air in the saturated zone using the air rotary drilling method can remove (air sparge) VOCs from groundwater in the vicinity of wells, and thus it may take several quarterly sampling events before VOCs will be detected in the groundwater. Water sampling has been conducted at the MWL

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					for as much as 16 years for some wells. NMED disagrees with the argument that the diameter, depth, screen lengths, and screen slot size of the wells, and the grain size of the filter packs conspire to prevent the removal of drilling fluids. The diameters of monitoring wells at the MWL are not especially small, but instead are typical for wells installed to depths of several hundred feet or more. The wells are as deep as they need to be in order to monitor the groundwater at the water table. The screen lengths of the wells (20 feet), with originally typically 15 feet of saturated length, are typical of monitoring wells employed throughout New Mexico (with dropping water levels at the MWL, the saturated portion of the screened intervals have actually decreased since the wells were installed). In fact, rather than being short, the screen lengths of the MWL wells are on the large end of the range recommended by EPA guidance. The slot size of the well screens, typically 0.010 inch for the older wells, is common among wells installed in the KAFB area. There is also nothing particularly unusual about the filter pack dimensions for wells located at the MWL. In the case of the MWL, the NMED believes that the low Ksats of the aquifer sediments presented the biggest challenge with respect to adequately developing the wells. Based on well development records, considerable effort was made to properly develop the wells at the MWL, and this effort was successful.
J	**Citizen, Robert H. Gilkeson**	Drilling fluids plugging saturated zone	The commenter states "The features of the Sandia monitoring wells at the mixed waste landfill that prevent the recovery of most of the drilling fluids that have invaded the aquifer strata where screens are installed include 1). because of the great depth to the	R50	NMED disagrees that drilling fluids are easy to emplace within the saturated zone surrounding the well, but at the same time, are nearly impossible to remove. If this were the case, no well anywhere in the world over a few hundred feet deep could ever be used to monitor groundwater. Drilling fluids that enter sediments in the vadose zone are of less importance than those penetrating the saturated zone, because

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			water table of the regional aquifer, the mud rotary drilling method operated as a powerful injection pump for invasion of the bentonite clay into the strata that surround the well screens, 2). the great depth of the monitoring wells limits the pumping energy for development, 3). the small inside diameter for well casing of 4.5 inches limits the size (power) of submersible pumps, 4). the short length of the well screens, 5). the small spacing of 0.01 inch for the slots on the well screens, and 6). the medium-grained sand in the filter pack that surrounds the well screens. Factors 2 through 6 restrict the energy for recovering the drilling fluids compared to the much greater energy of the mud rotary drilling method for invading the strata with the drilling additives". In a July 19, 2006, meeting with the NMED, the commenter repeated his comments on this topic.		the former fluids will not impact groundwater quality. Although the column of drilling mud above the saturated zone is large and can exert considerable pressure, there is a limit to the rate, and thus the extent, that drilling mud can penetrate into the saturated zone. Drilling mud, like water, can only migrate into the saturated zone as fast as the Ksat allows, this being the Ksat *for mud with respect to the formation materials* (not the Ksat for water). The Ksat for mud will be lower than that of water because Ksat is inversely proportional to the viscosity of a fluid, and mud has a higher viscosity than water. Thus, the mud will advance into the formation at a slower rate than if the fluid was water assuming other hydraulic properties remain constant. As mentioned previously, proper well development can remove much of the drilling fluids which penetrate into the saturated zone. Following displacement of the drilling mud from a well once well construction begins, the groundwater will apply hydraulic pressure against the drilling mud that has penetrated into the formation. As a consequence, pressure exerted by groundwater will help force drilling mud out of the formation and back into the well where it can be removed by development. As development continues, dilution of the mud by the groundwater will continuously lower its viscosity, further assisting in the removal of mud from the formation. The key is timely and effective development, which was accomplished at the MWL. The commenter implies that a large region surrounding the wells would be invaded by drilling mud. The rate at which drilling mud was able to penetrate the saturated zone in the uppermost part of the aquifer was estimated by the NMED to be only 8.6 cm/hour. The calculations for this figure are based on a Ksat of 10^{-6} cm/s, a hydraulic gradient of 475 feet, a porosity of 25%, density of drilling mud of 1.2 g/cm^3, a dynamic viscosity for drilling mud of 30 cp, and a dynamic viscosity of water (at 20

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					°C) of 1 cp. At the calculated rate, it would take 11.6 hours for the drilling mud to advance 1 meter into the saturated zone.
J	**Citizen, Robert H. Gilkeson**	Turbidity too high, MW3	The commenter states "An additional problem is that the water produced from well MW-3 is at a turbidity level three times greater than the maximum level allowed in the RCRA guidance".	R51	NMED disagrees. The median turbidity value for groundwater samples from MW3 is 2.99 NTU, which is less than the maximum recommended value of 5 NTU.
J	**Citizen, Robert H. Gilkeson**	Negative Eh and purging, MW4	The Commenter states "… the chemical data show that the water produced from the well has a negative Eh and is possibly anaerobic instead of the high positive Eh and aerobic chemistry of the background groundwater at well BW1. For well MW4, the measurements that show dissolved oxygen in the water with negative Eh are in conflict and show the need to improve the methods that are used for measuring these sensitive water parameters. The trend in Eh and dissolved oxygen measurements show that the necessary amount of groundwater was not purged from the well before samples were collected for the analytical suite. In a July 19, 2006 meeting with the NMED, the commenter repeated his comments on this topic.	R52	The median Eh of groundwater samples from MW4 is 285 millivolts; whereas the median Eh of samples from BW1 is 141.8 millivolts. Thus, the median Eh of water samples from MW4 actually exceeds that from BW1, opposite of what was argued by the commenter. The commenter did not consider all the relevant data. Well MW4 was drilled using the sonic resonant method, and without using organic drilling additives. As organic drilling additives were not used, a reducing groundwater environment would not be expected, and is not present. See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*. Because of potential errors in Eh measurements (see response R46), some SNL personnel may need more training or may need to exercise more care in obtaining Eh measurements, as negative Eh measurements should not be expected from water samples collected at the MWL.

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J	**Citizen, Robert H. Gilkeson**	Wells improperly located relative to groundwater flow direction	In a meeting with NMED on July 19, 2006, the commenter expressed concern that the MWL wells are worthless for samples because the groundwater flows from east to west.	R53	There are two newer wells, not considered by the commenter, located west of the landfill that were installed by the Permittees and required by the NMED. These wells were installed primarily with the intent to augment the monitoring well network with respect to determining the direction and gradient of groundwater flow. There is also an additional well drilled beneath Trench D, and three older wells located along the west-central boundary, and near the northwestern and northeastern corners of the landfill. These older wells were placed in these positions because early regional water levels were taken into account, suggesting north-directed groundwater flow. However, it is noteworthy that the northern part of the landfill is especially important from an environmental perspective because this is the portion of the landfill known to have had the most disposal of liquid and tritium wastes, and also where the highest concentrations of VOCs in soil gas have been detected. The older wells are therefore situated at very useful locations.
J	**Citizen, Robert H. Gilkeson**	Major ion chemistry is not reliable	In a meeting with NMED on July 19, 2006, the commenter expressed concern water samples are not reliable for major ion chemistry, as well as contaminants because sensitive water parameters have not stabilized.	R54	The NMED disagrees with this comment. Piper and stiff diagrams show that all major ions have maintained consistent concentrations throughout the 16 years of monitoring done at the MWL. See also the NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*.
J	**Citizen, Robert H. Gilkeson**	Sampling procedures are not the same as those specified by the LANL Consent Order.	In a meeting with NMED on July 19, 2006, the commenter expressed concern the sampling procedures employed at the MWL do not meet those required by the LANL Consent Order, and thus do not meet industry standards.	R55	The groundwater sampling methods employed at the MWL meet substantively guidance issued by the EPA and NMED. Industry follows guidance issued by the EPA. The wells are purged prior to sampling. Eh, pH, specific conductance, and temperature are generally measured during purging and sampling, and using a flow-through cell.

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
					The LANL Consent Order controls activities at LANL, not the MWL.
J	**Citizen, Robert H. Gilkeson**	Downward trends for Eh	In a meeting with NMED on July 19, 2006, the commenter states that most wells are trending to lower values of Eh which indicates a chemistry affected by drilling additives or contamination from the mixed waste dump.	R56	The NMED disagrees with this comment. There are no notable trends in Eh values for any water samples from MWL wells. See also NMED report by Moats, Mayerson, and Salem, 2006, entitled *Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories*.
P	**Citizen, Krishan Wahi**	Delay not protective	The commenter recommends approval of the CMI Plan recognizing that parameter and model uncertainty can be reduced, but not eliminated, no matter how much money is spent. The commenter states that more complicated facilities use the principle of ALARA (as low as reasonably achievable) to provide the balance in protecting human health. The commenter states that indefinite delays do not contribute to public health and safety.	R57	The NMED agrees that it is not possible to remove all uncertainty with respect to site investigations and models based upon them. The NMED also agrees that indefinite delays are not protective of human health and the environment. NMED is cognizant of strategies that dwell on uncertainty to undermine any scientific conclusions. Such strategies have been effective at delaying Congressional action on climate change that could be costly to industry. Of course, the scientific community is unanimous in its concurrence that global warming is a reality, despite the uncertainties in science. NMED believes this is a useful analogy in considering comments about uncertainly in scientific results.
Q	**Citizen, Willard Hunter**	Seismic threat	The commenter is concerned that the potential for a seismic threat does not appear to be addressed by the CMI Plan and the FTM. The commenter indicates that DOE requires new seismic design requirements in SNL buildings and questions why similar seismic	R58	Analogous, but not controlling, environmental regulations would not prohibit the construction of a hazardous waste landfill at the MWL site based on seismic threat because there is no evidence of Holocene fault movement within 200 feet of the site. The vegetative soil cover to be employed at the MWL, being a simple design of essentially a monolithic layer, would be expected to survive intact if an earthquake occurred nearby.

Commenter ID	Commenter / Association	Topic Area	Comment Summary	NMED Response Number	NMED Response
			analysis does not apply to the MWL.		
H	**Citizen Action New Mexico, Susan Dayton** (Comments compiled by Paul Robinson, Southwest Research and Information Center)	Sampling of landfill surface	The commenter also states that a consultant working for Citizen Action opined that sampling of the landfill surface was not random and grid locations too coarse, and that some sampling occurred over the most recent trenches dug at the MWL.	R59	The NMED disagrees with the comment that adequate surface-soil sampling was not done and was not random. This issue was dealt with in much detail during the hearing on the MWL Corrective Measures Study. A grid of random spacing and orientation was placed over the landfill surface. Analytical results of the surface soil sampling detected plutonium in surface soil which was caused by undocumented spills from containers of mixed waste stored on the landfill's surface. The levels of plutonium contamination found on the surface of the MWL do not pose unacceptable risk to human health or the environment.

Volume I

TAB 11

Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill
(referenced as part of 11/21/2006 NMED Responses to Public Comments on Corrective Measures Implementation Plan)

From: NMED/Moats et. al
To: Interested Citizen

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Evaluation of the Representativeness and Reliability of Groundwater Monitoring Well Data, Mixed Waste Landfill, Sandia National Laboratories

New Mexico Environment Department/Hazardous Waste Bureau
By: William P. Moats, David L. Mayerson[1], and Brian L. Salem
November 2006

Introduction

The Mixed Waste Landfill (MWL) was operated by Sandia National Laboratories (SNL), whose research facilities are within the area occupied by Kirtland Air Force Base (KAFB). The MWL was operated for land disposal from 1959 to 1988, and included at various times throughout its operational history disposal of radioactive, hazardous, and mixed wastes. It is comprised of two contiguous areas - the classified and the unclassified waste areas - which together occupy approximately 2.6 acres in the north-central portion of Technical Area 3. During operation of the MWL, classified wastes were buried in small pits, and unclassified wastes were disposed in seven trenches. SNL estimates that the landfill received a total of approximately 100,000 cubic feet of waste containing about 6,300 curies of activity at the time of disposal (SNL, 09/1996).

The MWL is subject to corrective action as a solid waste management unit (SWMU) under the New Mexico Hazardous Waste Management Regulations 20.4.1.500 NMAC, incorporating 40 CFR 264.101. Under the regulatory framework mandated by these regulations, and upon consideration of the Corrective Measures Study for the MWL (SNL, 05/2003), the Secretary of the New Mexico Environment Department (NMED) ordered construction of an evapotranspiration cover with bio-intrusion barrier over the landfill, and the subsequent development and implementation, upon NMED approval, of a long-term monitoring and maintenance plan (NMED, 05/26/2005).

Public comments submitted to NMED on the MWL Corrective Measures Implementation Plan (SNL, 11/2005) include concerns that the groundwater samples from the existing MWL monitoring wells have not yielded representative hydrochemical data due to the effects of residual drilling mud and organic additives. Commenters assert that residual organic additives can induce the formation of iron and manganese precipitates, which, like residual drilling mud, can remove (adsorb) contaminants from the groundwater before they enter a well bore and can reduce the local aquifer permeability in the vicinity of a well. Additionally, commenters maintain that residual organic additives may cause localized reducing conditions around a well bore, which is expressed by low values of Eh, nitrate, and sulfate; undetectable values of dissolved oxygen, and elevated concentrations of ammonia, sulfide, manganese and iron. They maintain that all of these circumstances exist at the MWL.

[1] Now employed with the NMED Ground Water Quality Bureau

The concerns expressed by the public were based in part upon groundwater investigations conducted at Los Alamos National Laboratory (LANL), where these circumstances were found to be true in some monitoring wells (LANL, 11/2005). Given the seriousness of these concerns relative to the NMED Hazardous Waste Bureau's (Bureau) mission and statutory mandates, the Bureau conducted a detailed study of the quality of groundwater data derived from MWL monitoring well samples. This document reports the results of that study.

Purpose

The purpose of this report is to evaluate whether or not groundwater samples from the MWL monitoring wells have produced metals and general chemistry concentration and field parameter data that are reliable and representative of groundwater underlying the MWL. NMED has relied upon these data, in part, to determine the appropriate remedy for the MWL. Other information was considered in the remedy selection process, including the waste inventory (types, amounts, and migration potential and pathways of waste) geologic and climatic conditions, current levels of chemical and radiological contaminants released into the vadose zone, surface soil, and the atmosphere, and short and long term risk to human health and the environment. These facets are not addressed in this study.

Background

The MWL overlies unconsolidated sediments within the Albuquerque Basin that generally can be grouped into two major lithologic units. The upper unit, the Alluvial Fan (AF) Facies, is composed chiefly of medium-grained to fine-grained sediments that are derived from the erosion of Precambrian and Paleozoic rocks forming the uplands east of the landfill. The unit generally becomes finer-grained with depth, and forms the uppermost portion of the saturated zone beneath the MWL. The AF Facies is characterized by low saturated hydraulic conductivity (10^{-7} cm/s), especially in its lower parts (Goering et al., 12/2002).

Underlying the AF Facies are somewhat coarser-grained fluvial sediments believed to have been deposited by an ancestral Rio Grande. This lower unit, the Ancestral Rio Grande (ARG) Facies, is characterized by saturated strata having a larger degree of lateral continuity and having hydraulic conductivities about two orders of magnitude higher than those of the AF Facies (Goering et al., 12/2002).

A total of seven groundwater monitoring wells have been installed at the MWL to monitor whether or not underlying groundwater has been affected by any contamination emanating from the MWL. Wells BW1, MW1, MW2, and MW3 each have a single well screen, and are all completed within the AF Facies (Goering et al., 12/2002). Well MW4 is installed in an angled borehole, and was completed with two well screens that are 20 feet apart and which are separated by a removable packer (Goering et al., 12/2002). The uppermost screen of this well is completed in the AF facies, while the lower screen is completed across the boundary of the AF facies and the underlying ARG Facies. Monitoring well MW5 is also completed across this facies boundary, while MW6 is

screened wholly within the ARG facies (Goering et al., 12/2002). Both MW5 and MW6 are completed with single screens. All of the groundwater underlying the MWL is within the low total dissolved solids (low-TDS) hydrochemical facies as described by Moats and Winn (01/1995).

Nitrate concentrations from MW4 groundwater samples are lower than those observed in groundwater samples from the four monitoring wells that are completed solely within the AF facies (*i.e.*, BW1, MW1, MW2, and MW3), and are very similar to the corresponding analyte data from MW5 and MW6 (see Appendices A and B). The presence of nitrate in the shallower facies groundwater is attributed to contamination from septic systems within the vicinity of Tech Area 3 (IT, 04/1999, cited in Goering et al., 12/2002), as no significant nitrate sources from the MWL are known to exist. This difference in nitrate concentrations between the upper screened zone of MW4 and the other shallow wells may be indicative of small hydrochemical differences related to local areas of lower hydraulic conductivity within the AF facies (Goering, 09/21/2006).

Three drilling methods were used to install monitoring wells at the MWL: mud rotary, air-rotary casing hammer (ARCH), and sonic resonance. According to SNL records, the mud rotary method, which utilizes drilling mud, drilling additives, or both was employed only in the installation of MWL monitoring wells BW1, MW2, and MW3, all of which are completed in the AF Facies (Ecology and Environment, 12/1989). These three wells will be collectively referenced herein as the *mud rotary wells*.

Bentonite drilling mud is composed primarily of the clay mineral montmorillonite, $(Na, Ca)(Al, Mg)_6(Si_4O_{10})_3(OH)_2 \cdot nH_2O$. Bentonite drilling muds also contain other minor components. For example, LANL found drilling mud could include various leachable components such as sulfate, uranium, and fluoride (LANL, 11/2005, Table A-10). The presence of residual drilling mud or additives in a well bore or surrounding aquifer material can affect the properties of groundwater samples. For example, in some cases, alkalinity levels of groundwater contaminated with organic drilling additives may be higher than those of formation water due to the oxidation of organic matter to form bicarbonate.

The only documented drilling additives that have been used in installation of the mud rotary wells are soda ash (Na_2CO_3), sodium carboxymethylcellulose (CMC: used to stabilize drilling fluid), and lost circulation material (Ecology and Environment, 12/1989, p. 3-3). Soda ash was used in the redrilling of BW1 and MW3 (Ecology and Environment, 12/1989, p. 3-4)[2], and was added to increase the pH of the mud when the viscosity could not be controlled by simple water addition. Lost circulation material (*e.g.*, ground fragments and pieces of cedar wood and cellophane) was used only in drilling BW1 (Ecology and Environment, 12/1989, p. 3-4 and Appendix D). CMC was used in the drilling of all three mud rotary wells to control water loss, increase viscosity, and

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[2] A typographic error on this page of the referenced report identifies the former as <u>M</u>W1; however Sections 4.1 and 4.4 and Appendix D drilling fluid reports clearly indicate that this well should have been identified as <u>B</u>W1.

inhibit clay swelling. Because of the properties of CMC, it was expected to be easily flushed from the borehole during well development.

Data on the construction of all MWL monitoring wells are summarized in Table 1. Well MW4 was drilled by the sonic resonance method (SNL, 12/07/1992), with the introduction of potable water during well installation (Goering, 07/17/2006). For wells installed using the ARCH method (MW1, MW5, and MW6), only air and potable water were introduced during installation (Ecology and Environment, 12/1989; SNL, 12/07/2000; and SNL, 10/19/2000). However, according to field notes, small quantities of sodium-bentonite grout infiltrated into the filter pack and well screen of MW5 during construction of this particular well.

Compared to the variability of regional background water quality in the low-TDS hydrochemical facies, minor hydrochemical differences exist in the relative concentrations of major ions between groundwater from the AF facies and that of the underlying ARG Faces. Stiff diagrams are commonly used as a means for the rapid comparison of the abundance of major ions between groundwater samples due to their distinctive graphical shapes. Figure 1 represents groundwater data from a sampling event conducted in April 2001 at the MWL. It shows that ARG Facies groundwater has relatively higher concentrations of magnesium (Mg), calcium (Ca), sodium (Na) plus potassium (K), alkalinity (bicarbonate and carbonate), and chloride (Cl) compared to groundwater from the AF Facies. Overall, groundwater from both facies is similar, as shown by a Piper trilinear diagram of major ion chemistry of groundwater samples from all MWL monitoring wells (Figure 2; Goering et al., 12/2002). Piper diagrams are useful for comparing water samples based on their proportions of major ions, and are especially useful for revealing whether or not mixing of groundwater from different sources is occurring. The Piper diagram in Figure 2 indicates that groundwater from both the AF and ARG Facies can be classified as a calcium-sodium bicarbonate water.

Time series concentration plots (Appendix B) show that groundwater alkalinity, sodium and sulfate concentrations have remained stable since sampling began at the MWL. Piper and stiff diagrams prepared by Goering et al. (12/2002) for sampling events conducted from 1993 -2001 further demonstrate that the overall hydrochemistry of groundwater at the MWL has remained generally stable over the time period for which groundwater data are available.

Based on analysis of soil samples from investigational boreholes as well as passive and active soil-gas surveys (SNL, 09/1996), detectable contaminant releases from the MWL are limited to low levels of tritium, radon, and volatile organic compounds in the vadose (*i.e.,* unsaturated) zone. Cadmium has been detected at low concentrations in the vadose zone, but only along the western boundary of the landfill. The fate and transport model of Ho et al (11/2005) predicts that groundwater is unlikely to be affected in the future by any of these contaminants occurring in the vadose zone. The results of up to 14 years of groundwater monitoring conducted at the MWL further support this conclusion.

Data sources

Available historical groundwater hydrochemical and field parameter data for each of the MWL groundwater monitoring wells were compiled from periodic SNL groundwater monitoring data reports (Goering et al., 12/2002; Lyon and Goering, 01/ 2006) and an NMED study (Moats and Winn, 01/1995). Appendix A presents a tabular compilation of available historical data for the analytes used in this evaluation.

Background hydrochemistry, which is used for comparison purposes with corresponding data from the monitoring wells, is taken from a comprehensive study of background groundwater quality throughout the area encompassed chiefly by Kirtland Air Force Base (KAFB), which includes the SNL research facilities (Moats and Winn, 01/1995). Only uranium concentration data are taken from a separate background study (IT Corporation, 03/1996).

Data analysis method

For this study, NMED has modified an effective method utilized by LANL in a similar investigation of the quality of LANL groundwater monitoring data (LANL, 11/2005). The LANL study employed a tiered assessment strategy in which selected key analyte concentrations from the three most recent groundwater sampling events were compared to local background concentrations. The specific analytes used were chosen considering common effects on groundwater samples from the presence of residual drilling mud and organic drilling additives (see Figure 3 for an overview of the LANL process). These effects, if they exist, would be shown by analyte concentrations that are either decreased or increased in comparison to corresponding regional background values by the adsorption or desorption of specific chemical species, by localized alteration of reduction-oxidation (redox) conditions, or both.

The NMED tiered evaluation method is shown as modifications to the LANL process in Figures 4 and 5. Data flag codes used to indicate that data reliability or representativeness may be compromised by the potential presence of residual drilling mud, additives, or both are explained in Table 5. An additional modification to the LANL process is the use of the median concentration values from the entire data set for any specific analyte where possible. This is a major enhancement of the LANL process, as use of median values allows for assessment of the reliability and representativeness of the *entire* data set for the subject wells, while discounting the effects of extreme (*i.e.*, very high or low) data values. For analytical results that are reported by the laboratory as below the analytical detection limit (DL), the NMED generally has used a value equal to one-half the value of the DL in the calculation of the median value. Because all concentration values for ammonia are reported as below the DL, no median concentration has been calculated for this analyte.

As an additional check on data reliability beyond that built into the LANL process, the NMED compared the median value of each analyte for each mud rotary well to the median values for the same analytes from groundwater samples from wells MW1 and

MW4. As stated above, these two wells are completed in the same AF facies, but were drilled without the use of mud or organic additives. Thus, neither of the two wells can possibly demonstrate any of the possible adverse effects of residual drilling mud and or organic additives, including the formation of iron or manganese precipitates that could mask the measurement of groundwater contaminants. Both of these wells should therefore provide analytical data that are representative of aquifer hydrochemistry. For purposes of this study, the NMED assumed that the median analyte concentration from a given mud rotary well that is within one standard deviation of the corresponding median from *either* MW1 or MW4 is strongly indicative of acceptable data representativeness and reliability. The range representing +/- one standard deviation from the median value of a given constituent will be hereinafter referred to as the *target comparison range*. However, small differences outside of the target comparison range do not automatically imply that samples from a well are not representative or reliable, as the background range for any given groundwater constituent generally encompasses an even larger degree of variance. For example, alkalinity in the low-TDS facies ranges from 101.0 to 291.0 mg/L, with a median of 169.5 mg/L and a standard deviation of 52.8 mg/L (Moats and Winn, 01/1995). This establishes a target comparison range of 116.7 to 222.3 mg/L, which excludes the maximum and minimum background values for alkalinity. In such cases, additional analysis may be required to decide whether or not any suspect data are representative and reliable.

As mentioned above, the LANL evaluation process is predicated on inferred geochemical and biochemical interactions among residual drilling mud and/or additives, groundwater, and aquifer materials. However, in some cases the LANL process used different groundwater constituents from those used by the NMED for the MWL. For NMED's examination of the MWL mud rotary wells, the LANL method was modified to utilize extant MWL groundwater data. For example, very little data for strontium are available for the MWL for use as a possible indicator of adsorption onto residual bentonite (see Figure 4, Tier 2.1-2). However, cadmium could be expected to be significantly adsorbed by residual bentonite, as the average adsorption coefficient for cadmium (560 mL/g) is about the same order of magnitude as that for strontium (110 mL/g) (LANL, 11/2005, Table 4-4, p. 62). Cadmium was therefore substituted for strontium in the NMED evaluation. Similarly, there are no analytical data for analytes specified in the LANL Tier 2.2-1 evaluation process available for MWL monitoring wells (see Figure 5), other than ammonia. However, oxidation of residual organic drilling additives would be expected to increase the level of alkalinity (LANL, 11/2005, p. 15). NMED has therefore substituted this analyte in this part of the tiered evaluation method.

MWL monitoring well samples have occasionally yielded low concentrations of acetone. Most of these detections are below the laboratory practical quantitation limit, and are associated with the detection of acetone concentrations in blank samples, which would be indicative of laboratory contamination. Therefore, acetone concentration data were not used in the evaluative process (see Figure 5, Tier 2.2-1).

The NMED further modified the LANL process by evaluating total, rather than dissolved, metal concentrations. With the exception of dissolved zinc, generally no more than four

analyses for any dissolved metals analyte exist. Use of total metal concentrations could overestimate the effect of desorption (see Figure 4, Tier 2.1-1) and Fe/Mn reducing conditions (see Figure 5, Tier 2.2-2), thus producing overly conservative assessments. On the other hand, use of the total metal concentrations could underestimate the effect of adsorption (see Figure 4, Tier 2.1-2) if the turbidity of a sample appreciably exceeds 5 NTU.

Although MW1 should provide sample data that are representative of background hydrochemistry in the AF facies, the concentration of total nickel in MW1 groundwater samples has shown a marked increase over time (see Figure 6). This is inferred to indicate progressive corrosion of the stainless steel well screen in this well (Goering et al., 12/2002). In addition to nickel, stainless steel commonly is comprised of iron and chromium. Therefore total iron concentrations from MW1 groundwater samples were not used in evaluating the mud rotary well sample data (see Table 4, Tier 2.2-2: redox conditions -- iron/manganese reducing conditions evaluation; and Table 6).

For MW4, the majority of post-05/23/1994 groundwater sample data are derived from samples from the upper screen, which also samples the AF Facies. However, data from earlier groundwater samples were composites of groundwater from both screens, with groundwater hydrochemistry from the lower more-conductive ARG facies presumably dominant (Goering, 09/21/2006). Nevertheless, groundwater data from MW4 represent a reasonable comparison to correlative data from the mud rotary wells.

As noted above, sodium-bentonite grout inadvertently infiltrated into the filter pack and screen of MW5 during well installation. Based on review of the field notes documenting well construction, it appears that much of the grout was removed prior to completing installation, and that all of the grout residing at the bottom of the well was removed prior to well development. Any remaining smaller amounts of grout within the filter pack should have been fairly easy to evacuate during well development.

If any appreciable grout is still present within the filter pack of MW5, there is a potential that the sodium bentonite contained within the grout could adsorb contaminants in a fashion similar to bentonite drilling mud. The percentage of bentonite in the grout that was used in the construction of MW5 is unknown, but bentonite grouts typically contain 2 to 6% sodium-bentonite by weight (U. S. Environmental Protection Agency, 03/1991). Grout is made chiefly from Portland cement, which is a mixture of various calcium silicates and calcium aluminates and subordinate amounts of hydrated calcium sulfate. Calcium and aluminum are major constituents of sodium-bentonite drilling mud, and, as mentioned previously, sulfate was found to be a leachable constituent of drilling mud made from bentonite mined from Wyoming, the most common source of bentonite used in well installations in the United States (LANL 11/2005).

Because grout is composed chiefly of Portland cement rather than drilling mud, various groundwater constituents in samples from MW5 were specifically evaluated as indicators of the presence of grout. In this case, it is assumed that the presence of grout is strongly indicated in MW5 water samples if all of the median concentrations of calcium, total

aluminum, and sulfate exceed their respective regional background concentrations (Table 9, Tier 3.1). As an additional check, the adsorption of metals was evaluated with the same process used for bentonite drilling mud (Table 9, Tier 3.2), except that total barium was substituted for total cadmium. NMED made this substitution because the levels of cadmium detected in MW5 groundwater samples are significantly less than the detection limit used to establish background, so meaningful comparisons using cadmium are not possible. Dissolved zinc data are not evaluated as such data are not available for water samples from MW5.

Finally, relative to other wells at the MWL, the general hydrochemistry of samples from MW5 should be most comparable to that of samples from MW6, as both of these latter wells are screened at least in part in the ARG Facies. The stiff diagrams shown in Figure 1 are useful for making this comparison.

Discussion

A major objective of this study is to determine whether localized reducing conditions may have become established in well bores by the oxidation of residual organic drilling additives (see Figure 5, tier 2.2-2.). In natural settings, the redox potential of groundwater tends to decrease as groundwater moves along its flow path. Water in the form of rain or snow initially contains appreciable levels of dissolved (free) oxygen due to the interaction of precipitation with the atmosphere. In recharge areas exhibiting sandy or gravelly soils, cavernous limestone, or fractured bedrock, levels of dissolved oxygen can remain high over considerable distances along the flow path of a groundwater system. In the KAFB/SNL area, groundwater commonly contains free oxygen at concentrations exceeding 2 mg/L (Moats and Winn, 01/1995), which is considered here to be indicative of moderate levels of dissolved oxygen (the lower limit of detection for dissolved oxygen is typically about 0.1 mg/L).

Because the solubility of dissolved oxygen in water is low, and because oxygen is not easily replaced in subsurface environments, oxidation of only a small amount of organic matter can consume all of the free oxygen in groundwater. If not sufficiently removed via well development, residual organic drilling additives can take the place of natural organic matter and supply nutrients to oxygen-consuming bacteria. The consumption of dissolved oxygen by bacterially-catalyzed reactions can deplete oxygen levels in groundwater to those below the level of detection. However, once the free oxygen has been consumed, reactions with other constituents in groundwater can cause further decreases in redox potential of the groundwater.

In a closed system, the oxidation of organic matter first consumes free oxygen, then is followed by a reduction of nitrate and manganese oxide. These reactions may be followed, in turn, by the reduction of ferric iron minerals. After sufficiently negative redox levels have been reached, sulfate can be reduced to H_2S and HS^-, along with the reduction of organic matter to carbon dioxide (CO_2) and methane (CH_4). However, in most groundwater systems, groundwater does not undergo all of the above redox stages

due to limitations on the availability of nutrients and conditions that allow bacteria to thrive.

Contaminants migrating from the MWL have not been detected in the groundwater beneath the landfill (Goering et al, 12/2002). Furthermore, the fate and transport model completed for the MWL shows that concentrations of contaminants in the vadose zone beneath the MWL are sufficiently low that groundwater is unlikely to be impacted in the future (SNL, 11/2005). Although contaminants do not occur in the groundwater presently (aside from nitrate from septic tanks as previously discussed), the ability of the MWL wells to provide high quality water samples useful for the detection of any unexpected future contamination is of paramount importance.

Tables 2 through 8 present the NMED's evaluation of the quality of MWL groundwater monitoring data using the tiered evaluation method. Wells MW1, MW4, and MW6 do not require further assessment because these wells were not installed with the mud rotary method. Although MW5 was also not installed using the mud rotary method, the quality of water samples from this well was assessed in this study due to the accidental intrusion of sodium-bentonite grout into the well's filter pack and screen. Additional assessment was therefore necessary for mud rotary wells BW1, MW2, and MW3, and ARCH well MW5.

For the mud rotary wells, the median concentrations of all of the analytes examined fall within the expected regional background ranges (Tables 3 and 4). Therefore, no data quality flags (Table 5) are assigned to any of these analytes. This part of the tiered evaluation process shows that there are no bentonite mud components in groundwater samples from the mud rotary wells, and similarly, that there is no evidence of adsorption of groundwater contaminants. This part of the evaluation also suggests that reducing conditions do not exist in the mud rotary wells.

Comparisons of median analyte values of the mud rotary wells to correlative values for MW1 and MW4 are shown in Tables 6 and 7. Analytes with median values that fall outside of the target comparison ranges for MW1 or MW4 are shown in Table 8. Of all of the analytes evaluated, only the median values for alkalinity (for MW3) and nitrate (for BW1, MW2, and MW3) fail to meet the target comparison ranges for both MW1 and MW4.

Relatively higher levels of alkalinity are expected in groundwater adversely affected by drilling mud. Higher alkalinity concentrations are also expected for groundwater subject to severely reducing conditions, such as those caused by the oxidation of organic matter, including organic drilling additives. However, the median value for alkalinity for the MW3 groundwater samples is actually less than the target comparison ranges for both MW1 and MW4. This, combined with the lack of other bentonite leaching indicators (Tier 2.2-1), strongly suggests that residual drilling mud is not affecting the quality of water samples collected from MW3. Additionally, the lower alkalinity in groundwater samples from this well, as well as moderate concentrations of sulfate and nitrate, high

levels of dissolved oxygen, and nondetectable levels of ammonia indicate that reducing conditions are not present within the well bore.

In general, higher values of nitrate are indicative of high redox potential. The median values for nitrate from MW2 and MW3 samples are slightly lower than the target comparison range for MW1. The median values of nitrate for samples from all three mud rotary wells are higher than the target comparison range for MW4. For all of the mud rotary wells, the levels of nitrate detected in water samples are relatively high compared to the background concentration of 4 mg/L and the median value for nitrate in the low-TDS facies (1.065 mg/L, Moats and Winn, 01/1995). These data, as well as moderate to high concentrations of dissolved oxygen, moderate levels of sulfate, and nondetectable levels of ammonia, further indicate that low redox conditions are not present in the groundwater at any of the mud rotary wells.

For the three mud rotary wells, the median values for total iron as compared to MW4, and the median values for total manganese as compared to both MW1 and MW4, are within their respective target comparison ranges, demonstrating that iron and manganese are not being dissolved into the groundwater as a result of reducing conditions. It is therefore no surprise that the formation of iron and manganese precipitates is not evident at any of the mud rotary wells. The median values for sulfate and ammonia (all non-detects) for these three wells are also within their respective target comparison ranges for both MW1 and MW4, further demonstrating that highly reducing conditions are not present in any of the mud rotary wells.

For ARCH well MW5, comparison of the median values for sulfate, calcium, and total aluminum to their respective maximum regional background concentrations indicate that grout contamination is not present in the well (see Table 9, Tier 3.1). Additionally, comparison of the median values for uranium, total zinc, and total barium to minimum regional background levels suggest that adsorption of contaminants is not taking place. Finally, Figure 1, as well as the series of stiff diagrams in Goering et al (12/2002), show that the general hydrochemistry of water samples from MW5 matches that of groundwater samples collected from MW6, providing yet further evidence that MW5 water samples are free from grout contamination.

Conclusions

MWL wells MW1, MW4, and MW6 were completed without the use of drilling muds and organic drilling additives. Water samples from these wells provide data that are reliable and representative of the hydrochemistry of the aquifer beneath the landfill. Evaluation of groundwater analytical data from MWL mud rotary well samples confirms that these data are not compromised. Therefore, none of the data examined is assigned a qualifying data flag. This study further shows that there are no bentonite drilling mud components that adversely affect sample chemistry in groundwater samples from the mud rotary wells, that there is no evidence of adsorption of groundwater contaminants or evidence of reducing conditions, and that grout contamination was adequately removed from ARCH well MW5 before the well was placed into service.

Nitrate in MWL groundwater samples is attributed to the oxidation of ammonia from Tech Area 3 septic systems. In particular, the consistent detection of relatively high concentrations of nitrate and moderate to high levels of dissolved oxygen in groundwater samples from the mud rotary wells provides strong evidence that localized reducing (low redox) conditions do not exist in the vicinity of these wellbores. Otherwise, concentrations of these analytes would be markedly lower or altogether absent under the slightest reducing conditions. The totality of evidence indicates that the three monitoring wells that were installed with mud rotary method (BW1, MW2, and MW3), and ARCH well MW5 have yielded reliable and representative hydrochemical data.

The NMED encourages the use of monitoring well installation methods that avoid potential impacts to groundwater quality. The NMED will evaluate new or replacement groundwater monitoring wells associated with the MWL long-term monitoring and maintenance plan in light of this recommendation. Nevertheless, the results of the tier evaluation process show that there are no adverse effects in any of the mud rotary wells caused by the presence of residual drilling mud and organic drilling additives. Thus, development of the mud rotary wells at the MWL was adequate, and the quality of water samples retrieved from these wells is representative of general aquifer chemistry.

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Figure 1: Stiff Diagrams of Major Ion Chemistry for all MWL Wells, April 2001
(Goering et al., 12/2002, Figure 4-14)

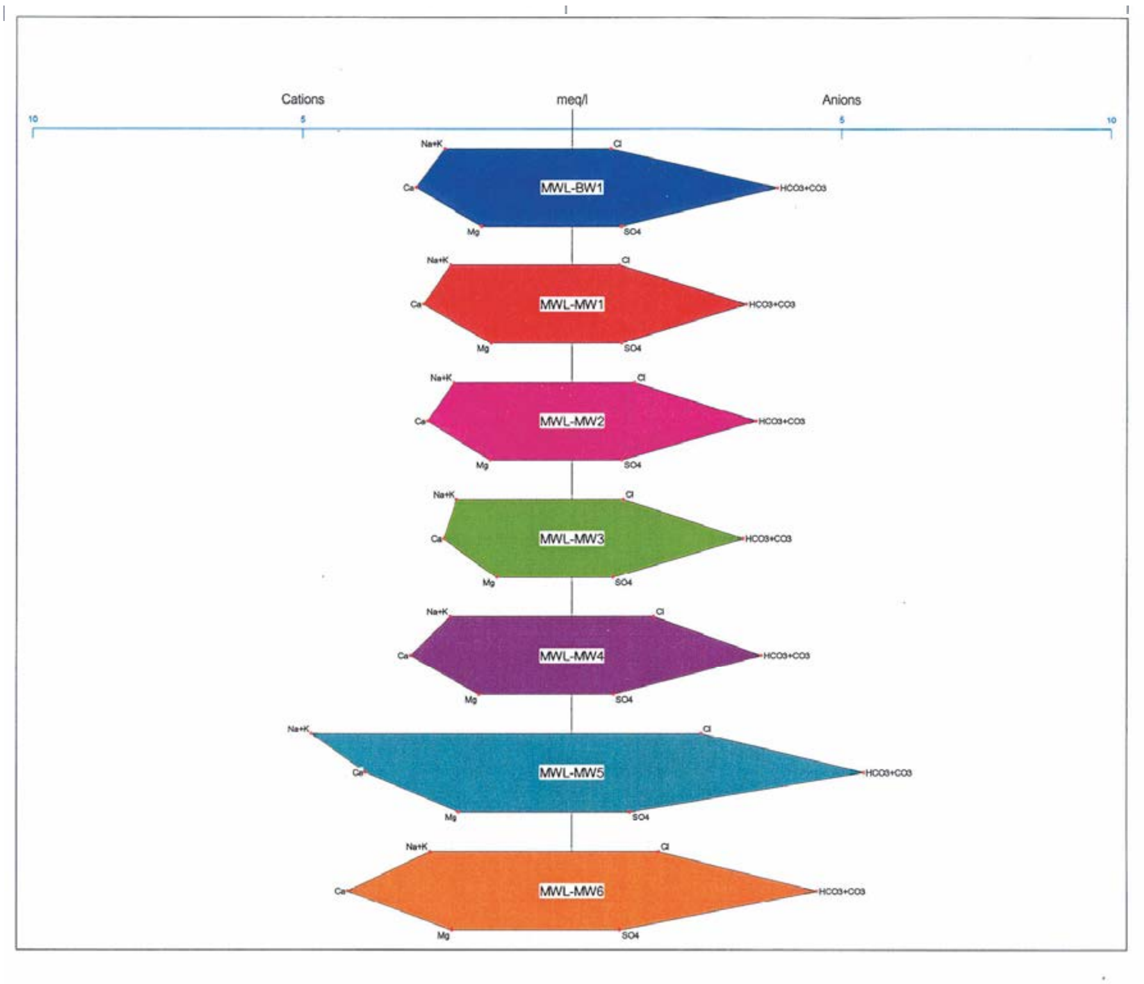


Figure 2: Piper trilinear diagram of major ion chemistry for all MWL wells, April 2001
(Goering et al, 12/2002, Figure 4-7)

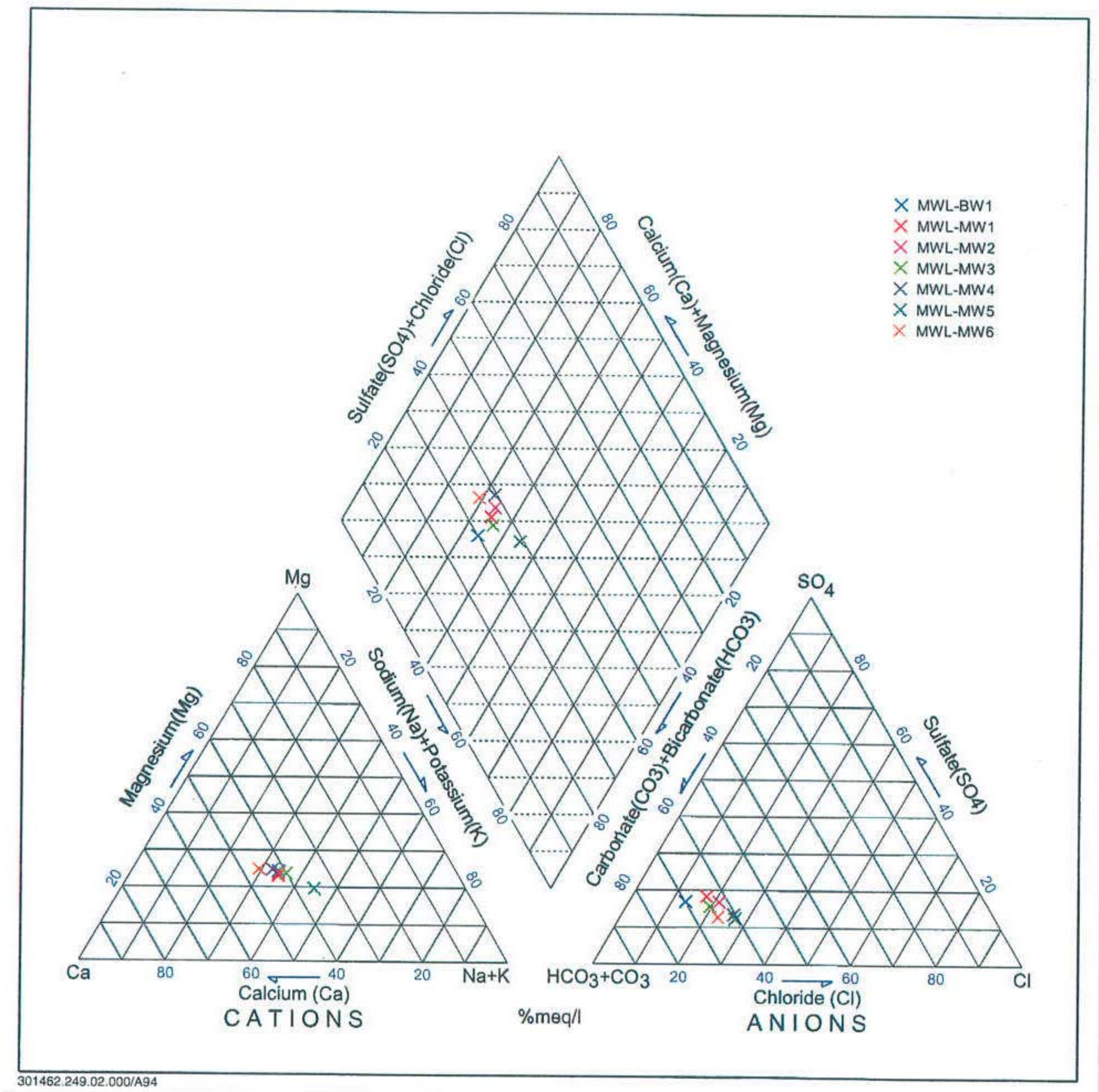


Figure 3: Overview of LANL evaluation process for monitoring well groundwater sample representativeness and reliability
(LANL, 11/2005, figure 4-1)

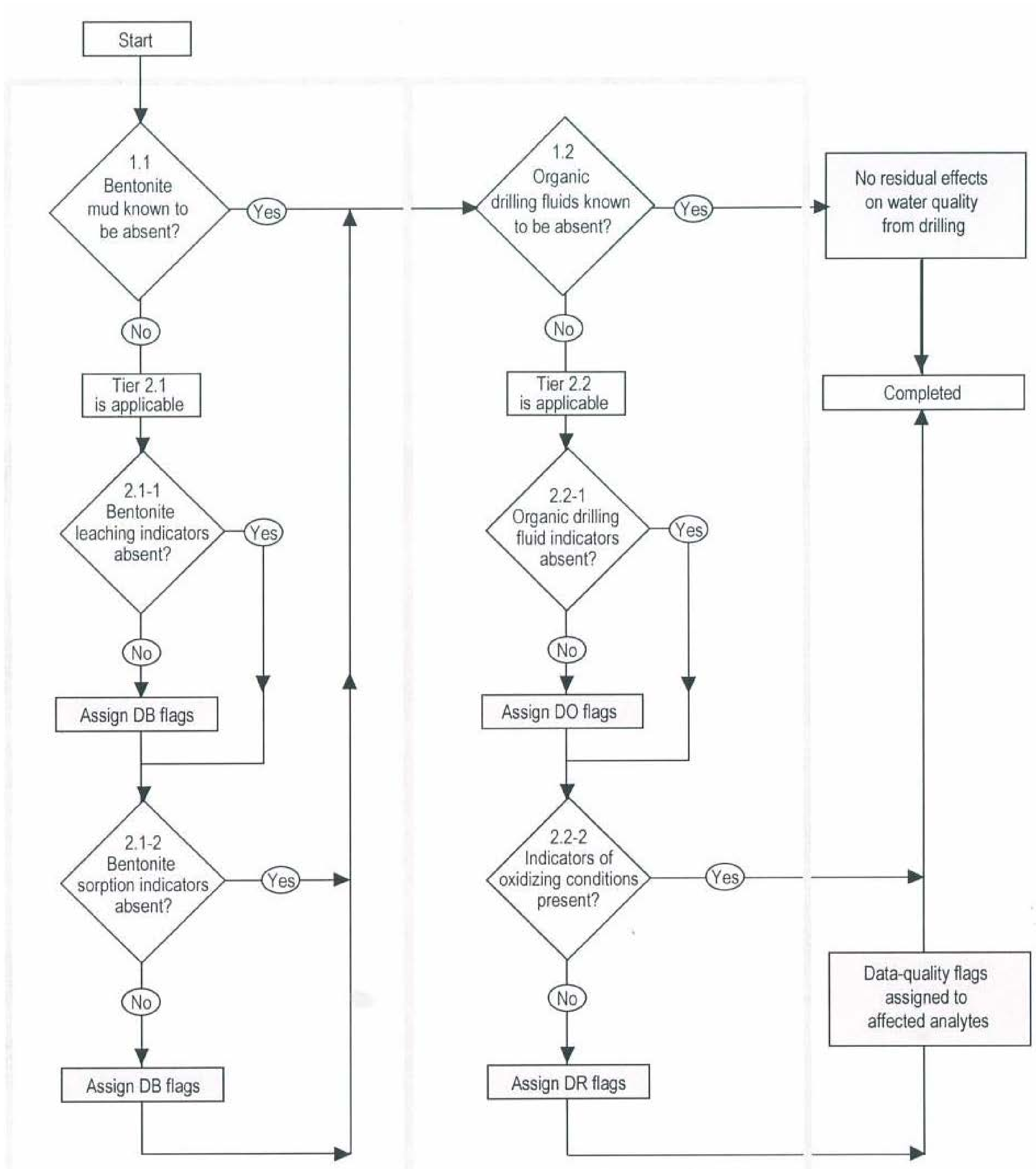


Figure 4: NMED modification of LANL Tier 2.1 evaluation process
(Modified from LANL, 11/2005, figure 4-3)

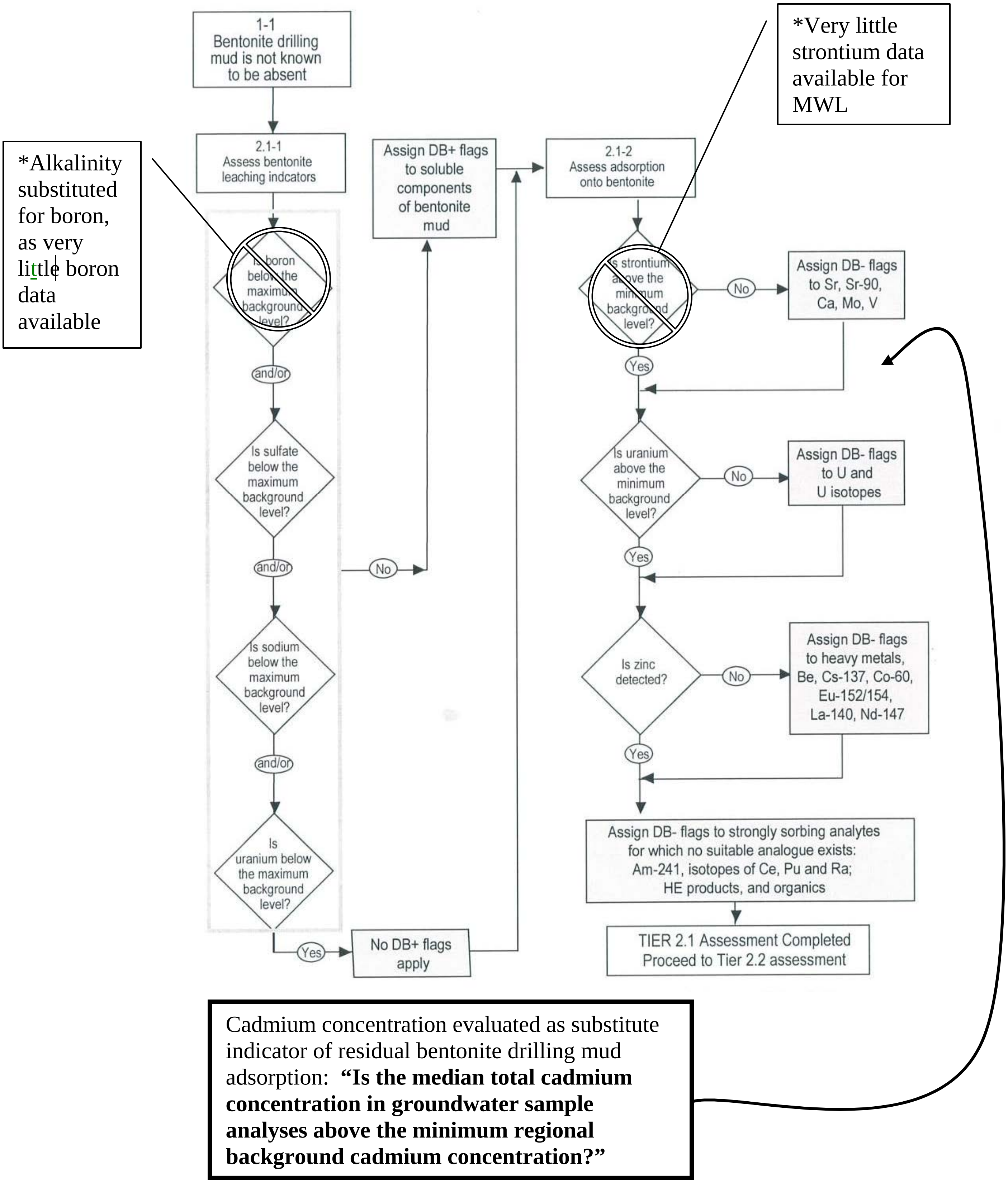


Figure 5: NMED modification of LANL Tier 2.2 evaluation process
(Modified from LANL, 2005, figure 4-10)

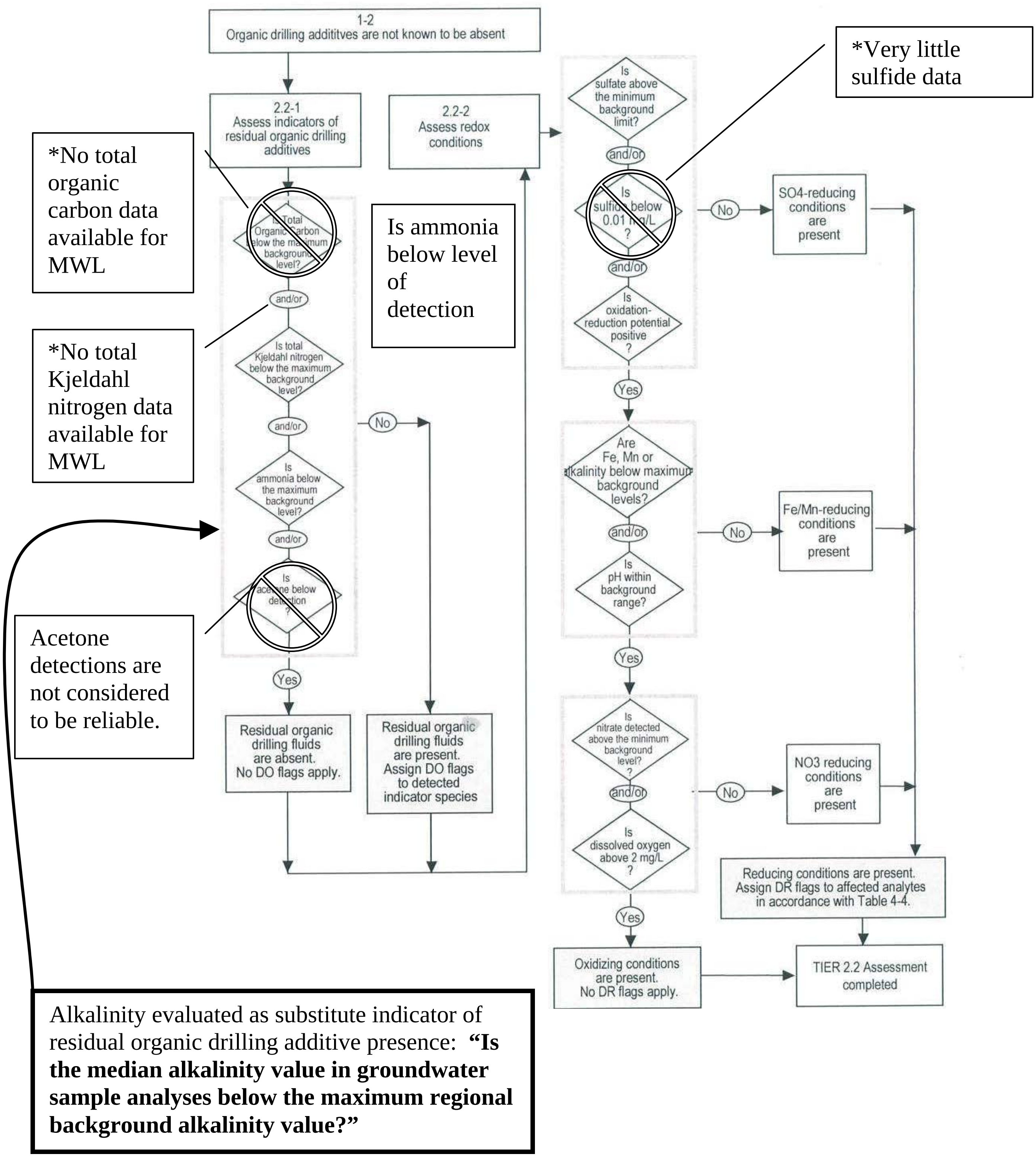


Figure 6: MWL--total nickel concentrations in groundwater samples vs. time

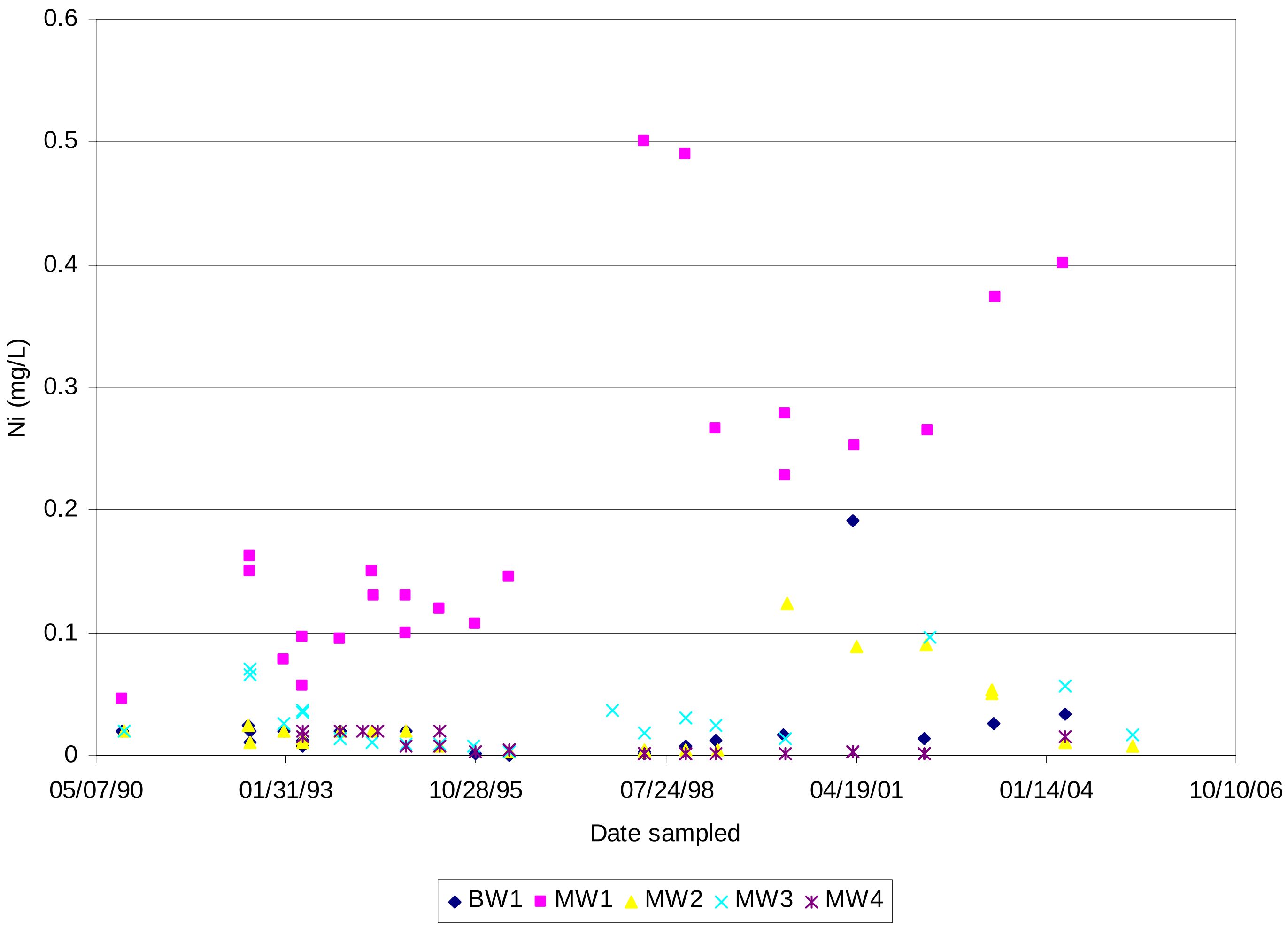


Table 1: MWL Monitoring well construction details

	BW1	MW1	MW2	MW3	MW4	MW5	MW6
Drilling method	mud rotary	air-rotary casing hammer	mud rotary	mud rotary	sonic resonance	air-rotary casing hammer	air-rotary casing hammer
Sedimentary facies at well screen	alluvial fan	alluvial fan	alluvial fan	alluvial fan	**top screen**: alluvial fan **bottom screen:** alluvial fan/ancestral Rio Grande	alluvial fan/ancestral Rio Grande	Ancestral Rio Grande
Screen interval (feet above mean sea level)	4930.53-4910.53	4923.12-4903.12	4923.71-4903.71	4927.67-4907.67	4904.75-4881.86 4861.97-4842.08	4881.15-4861.15	4864.46-4844.46
Date of completion	1989	1988	1989	1989	1993	2000	2000
Additional notes	Background monitoring well for MWL, located cross-gradient	cross-gradient	cross-gradient	down-gradient	6º angle well from vertical with dual completion. Sited beneath Trench D.	downgradient	downgradient

Table 2: Tier 1-1 evaluation

MWL monitoring well	Bentonite mud and/or soda ash known to be absent?	Organic drilling fluids (e.g., CMC) known to be absent?	Outcome
BW1	no		Tier 2.1 is applicable
MW1	yes	yes	no residual effects on water quality from drilling
MW2	no		Tier 2.1 is applicable
MW3	no		Tier 2.1 is applicable
MW4	yes	yes	no residual effects on water quality from drilling
MW5	yes	yes	no residual effects on water quality from drilling, but grout infiltrated filter pack and screen during well installation
MW6	yes	yes	no residual effects on water quality from drilling

Table 3: Tier 2.1 evaluation
(See Figure 4)

Tier 2.1-1: desorption

MWL monitoring well	Median sulfate concentration from groundwater sample analyses (mg/L)	Is the median sulfate concentration in groundwater sample analyses below the maximum regional background concentration (*i.e.*, 124.7 mg/L at 95% confidence level [Moats and Winn, 1995])?	DB flag?
BW1	43.5	yes	none
MW2	41.1	yes	none
MW3	39.2	yes	none

MWL monitoring well	Median total sodium concentration from groundwater sample analyses (mg/L)	Is the median total sodium concentration in groundwater sample analyses below the maximum regional background total sodium concentration (*i.e.*, 74.0 mg/L at 95% confidence level [Moats and Winn, 1995])?	DB flag?
BW1	52.8	yes	none
MW2	49.6	yes	none
MW3	50.7	yes	none

Table 3 continued

Tier 2.1-1: desorption (concluded)

MWL monitoring well	Median total uranium concentration from groundwater sample analyses (mg/L)	Is the median total uranium concentration in groundwater sample analyses below the maximum regional background total uranium concentration? (*i.e.*, 0.0149 mg/L [IT Corporation, March, 1996])?	DB flag?
BW1	0.0066	yes	none
MW2	0.0066	yes	none
MW3	0.0055	yes	none

MWL monitoring well	Median alkalinity (as $CaCO_3$) value from groundwater sample analyses (mg/L)	Is the median alkalinity value in groundwater sample analyses below the maximum regional background alkalinity value (*i.e.*, 289.5 mg/L at 95% confidence level [Moats and Winn, 1995])?	DB flag?
BW1	229	yes	none
MW2	200	yes	none
MW3	191	yes	none

Table 3 continued

Tier 2.1-2: adsorption

MWL monitoring well	Median total uranium concentration from groundwater sample analyses (mg/L)	Is the median total uranium concentration in groundwater sample analyses above the minimum background total uranium concentration, (*i.e.*, 0.0005 mg/L [IT Corp., 03/1996])?	DB flag?
BW1	0.0066	yes	none
MW2	0.0066	yes	none
MW3	0.0055	yes	none

MWL monitoring well	Median total cadmium concentration from groundwater sample analyses (mg/L)	Is the median total cadmium concentration in groundwater sample analyses above the minimum background total cadmium concentration (*i.e.*, <0.001 mg/L [Moats and Winn, 1995])?	DB flag?
BW1	0.0025	yes	none
MW2	0.001	yes	none
MW3	0.002	yes	none

Table 3 concluded

Tier 2.1-2: adsorption (concluded)

MWL monitoring well	Median total zinc concentration (mg/L)	Is total zinc detected?	DB flag?
BW1	0.046	yes	none
MW2	0.071	yes	none

MW3	0.030	yes	none

MWL monitoring well	Median dissolved zinc concentration (mg/L)	Is dissolved zinc detected?	DB flag?
BW1	0.040	yes	none
MW2	0.037	yes	none
MW3	0.038	yes	none

Table 4: Tier 2-2 evaluation
(See Figure 5)

Tier 2.2-1: indicators of residual organic drilling additive

MWL monitoring well	Median alkalinity (as $CaCO_3$) value from groundwater sample analyses (mg/L)	Is the median alkalinity value in groundwater sample analyses below the maximum regional background alkalinity value (*i.e.*, 289.5 mg/L as $CaCO_3$ at 95% confidence level [Moats and Winn, 1995])?	DO flag?
BW1	229	yes	none
MW2	200	yes	none
MW3	191	yes	none

MWL monitoring well	Ammonia value from groundwater sample analyses (mg/L)	Is ammonia below the level of detection?	DO flag?
BW1	< 0.1	yes	none
MW2	< 0.1	yes	none
MW3	< 0.1	yes	none

Table 4 continued

Tier 2.2-2: redox conditions—sulfate reducing conditions evaluation

MWL monitoring well	Median sulfate concentration from groundwater sample analyses (mg/L)	Is the median sulfate concentration in groundwater sample analyses above the minimum regional background sulfate concentration (*i.e.*, 22.0 mg/L [Moats and Winn, 1995])?	DR flag?
BW1	43.5	yes	none
MW2	41.1	yes	none
MW3	39.2	yes	none

MWL monitoring well	Median Eh value from groundwater sample analyses	Is the Eh value positive?	DR flag?
BW1	141.8	yes	none
MW2	151.0	yes	none
MW3	144.5	yes	none

Table 4 continued

Tier 2.2-2: redox conditions—iron/manganese reducing conditions evaluation

MWL monitoring well	Median total iron concentration from groundwater sample analyses (mg/L)	Is the median total iron concentration in groundwater sample analyses below the maximum regional background total iron concentration (*i.e.*, *8*.570 mg/L at 95% confidence level [Moats and Winn, 1995])?	DR flag?
BW1	0.05	yes	none
MW2	0.09	yes	none
MW3	0.24	yes	none

MWL monitoring well	Median total manganese concentration from groundwater sample analyses (mg/L)	Is the median total manganese concentration in groundwater sample analyses below the maximum regional background total manganese concentration (*i.e.*, 0.100 mg/L [Moats and Winn, 1995])?	DR flag?
BW1	0.005	yes	none
MW2	0.005	yes	none
MW3	0.01	yes	none

MWL monitoring well	Median pH value from groundwater sample analyses	Is the median pH value in groundwater sample analyses below the maximum regional background pH value (*i.e.*, 7.9 at 95% confidence level [Moats and Winn, 1995])?	DR flag?
BW1	7.62	yes	none
MW2	7.55	yes	none
MW3	7.65	yes	none

Table 4 concluded

Tier 2.2-2: redox conditions—nitrate reducing conditions evaluation

MWL monitoring well	Median nitrate concentration from groundwater sample analyses (mg/L, as nitrogen)	Is the median nitrate concentration in groundwater sample analyses above the minimum regional background nitrate concentration (*i.e.*, <0.100 mg/L, as nitrogen [Moats and Winn, 1995])?	DR flag? (*n.b.*, Presence suggests reducing conditions do not exist in wellbore vicinity)
BW1	5.68	yes	none
MW2	3.83	yes	none
MW3	4.03	yes	none

MWL monitoring well	Median dissolved oxygen concentration from groundwater sample analyses	Is the median dissolved oxygen concentration in groundwater sample analyses above 2 mg/L?	DR flag?
BW1	6.8	yes	none
MW2	3.9	yes	none
MW3	7.29	yes	none

Table 5: Validation flag codes to indicate that analyte concentrations may not be reliable or representative of groundwater predrilling conditions
(LANL, 11/2005, Table 4-3)

Flag	Definition	Applicable Tier
DB+	Analyte concentration may be elevated above that in predrilling groundwater due to leaching from bentonite drilling mud	2.1
DB-	Analyte concentration may be less than that in predrilling groundwater due to adsorption onto residual bentonite drilling mud	2.1
DB	[Uranium and uranium isotopes] Analyte concentration may not be the same as that in predrilling groundwater due to effects of residual bentonite drilling mud, but nature of effect is indeterminate	2.1
DO+	Analyte concentration may be elevated above that in predrilling groundwater due to presence of residual organic drilling fluids	2.2
DR+	Analyte concentration may be elevated above that in predrilling groundwater due to reducing conditions caused by residual organic drilling fluids	2.2
DR-	Analyte concentration may be less than that in predrilling groundwater due to reducing conditions caused by residual organic drilling fluids	2.2
DR	Analyte concentration may not be representative of that in predrilling groundwater due to reducing conditions caused by residual organic drilling fluids, but nature of effect is indeterminate	2.2

Table 6: Comparison of mud rotary well median analyte values to target comparison ranges for MW1

Is the median analyte concentration in groundwater sample analyses within 1 standard deviation of the median analyte concentration in groundwater sample analyses from **MW1**?							
Analyte	MW1 target comparison range (i.e., +/- 1 standard deviation) [mg/L except Eh and pH]	**BW1**		**MW2**		**MW3**	
		median value [mg/L except Eh and pH]	comparison result	median value [mg/L except Eh and pH]	comparison result	median value [mg/L except Eh and pH]	comparison result
alkalinity [as $CaCO_3$]	192 – 230	229	yes	200	yes	191	**no**
ammonia	all analyses below detection limit	all analyses below detection limit	yes	all analyses below detection limit	yes	all analyses below detection limit	yes
cadmium (total)	0 – 0.0094	0.0025	yes	0.001	yes	0.0019	yes
dissolved oxygen	6.05 – 7.03	6.8	yes	3.9	**no**	7.29	**no**
Eh	99.3-242.9	141.8	yes	151.0	yes	144.5	yes
iron (total)	not used	0.05		0.09		0.24	
manganese (total)	0.0048 – 0.0172	0.005	yes	0.005	yes	0.010	yes
nitrate (as nitrogen)	4.65 – 5.74	5.68	yes	3.83	**no**	4.03	**no**
pH	7.32 – 7.73	7.62	yes	7.55	yes	7.65	yes
sodium (total)	48.2 – 52.8	52.8	yes	49.6	yes	50.7	yes
sulfate	39.1 – 48.3	43.5	yes	41.1	yes	39.2	yes
uranium (total)	0.0036 – 0.0068	0.0066	yes	0.0066	yes	0.0055	yes
zinc (total)	0 – 0.034	0.046	**no**	0.071	**no**	0.030	yes
zinc (dissolved)	0.003 – 0.014	0.040	**no**	0.037	**no**	0.038	**no**

Table 7: Comparison of mud rotary well median analyte values to target comparison ranges for MW4

Is the median analyte concentration in groundwater sample analyses within 1 standard deviation of the median analyte concentration in groundwater sample analyses from **MW4**?

Analyte	MW4 target comparison range (i.e., +/- 1 standard deviation) [mg/L except Eh and pH]	**BW1**		**MW2**		**MW3**	
		median value [mg/L except Eh and pH]	comparison result	median value [mg/L except Eh and pH]	comparison result	median value [mg/L except Eh and pH]	comparison result
alkalinity [as $CaCO_3$]	198.1 – 254.6	229	yes	200	yes	191	**no**
ammonia	all analyses below detection limit	all analyses below detection limit	yes	all analyses below detection limit	yes	all analyses below detection limit	yes
cadmium (total)	0 – 0.0019	0.0025	**no**	0.001	yes	0.0019	yes
dissolved oxygen	insufficient data	6.8		3.9		7.29	
Eh	190.4-380.0	141.8	**no**	151.0	**no**	144.5	**no**
iron (total)	0.0042 – 0.276	0.05	yes	0.09	yes	0.24	yes
manganese (total)	0 – 0.056	0.005	yes	0.005	yes	0.010	yes
nitrate (as nitrogen)	1.3 – 2.4	5.68	**no**	3.83	**no**	4.03	**no**
pH	7.01 – 7.45	7.62	**no**	7.55	**no**	7.65	**no**
sodium (total)	40.2 – 66.0	52.8	yes	49.6	yes	50.7	yes
sulfate	32.4 – 44.6	43.5	yes	41.1	yes	39.2	yes
uranium (total)	0.0056 – 0.0067	0.0066	yes	0.0066	yes	0.0055	**no**
zinc (total)	0 – 0.49	0.046	yes	0.071	yes	0.030	yes
zinc (dissolved)	insufficient data	0.040		0.037		0.038	

Table 8: Mud rotary well median analytes exhibiting concentrations outside of target comparison range from MW1 and/or MW4

	Mud rotary well affected					
Analyte	BW1	MW2	MW3	Issue	Failure to MW1?	Failure to MW4?
alkalinity			X	Median value is greater than one standard deviation below the comparative median value	X	X
cadmium (total)	X			Median value is greater than one standard deviation above the comparative median value		X
dissolved oxygen		X	X	Median value is greater than one standard deviation above or below the comparative median value	X	N/A
Eh	X	X	X	Median value is greater than one standard deviation below the comparative median value		X
nitrate		X	X	Median value is greater than one standard deviation above or below the comparative median value	X	X
pH	X	X	X	Median value is greater than one standard deviation above the comparative median value		X
uranium (total)			X	Median value is greater than one standard deviation below the comparative median value		X
zinc (total)	X	X		Median value is greater than one standard deviation above the comparative median value	X	
zinc (dissolved)	X	X	X	Median value is greater than one standard deviation above the comparative median value	X	N/A

Note: N/A means not analyzed.

Table 9: Indicator Constituents of Grout Contamination and Adsorption

Tier 3.1 Indicator Constituents of Grout Contamination

MWL monitoring well	Median sulfate concentration from groundwater sample analyses (mg/L)	Is the median sulfate concentration in groundwater sample analyses less than the maximum regional background sulfate concentration **(*i.e.,*** 124.7 mg/L at 95% confidence level [Moats and Winn, 1995]**)**?	Presence of Grout Indicated?
MW5	54.5	yes	no

MWL monitoring well	Median total calcium concentration from groundwater sample analyses (mg/L)	Is the median total calcium concentration in groundwater sample analyses less than the maximum regional background total calcium concentration (*i.e.*, 105.1 mg/L at 95% confidence level [Moats and Winn, 1995]**)**?	Presence of Grout Indicated?
MW5	79.5	yes	no

MWL monitoring well	Median total aluminum concentration from groundwater sample analyses (mg/L)	Is the median total aluminum concentration in groundwater sample analyses less than the maximum regional background total aluminum concentration? (*i.e.*, 3.6 mg/L [Moats and Winn, 1995]**)**?	Presence of Grout Indicated?
MW5	0.029	yes	no

Table 9 continued

Tier 3.2 Indicators of Adsorption

MWL monitoring well	Median total uranium concentration from groundwater sample analyses (mg/L)	Is the median total uranium concentration in groundwater sample analyses greater than the minimum background total uranium concentration, (*i.e.*, 0.0005 mg/L [IT Corp., 03/1996]**)**?	DB flag?
MW5	0.0094	yes	none

MWL monitoring well	Median total zinc concentration (mg/L)	Is total zinc detected?	DB flag?
MW5	0.0057	yes	none

MWL monitoring well	Median total barium concentration from groundwater sample analyses (mg/L)	Is the median total barium concentration in groundwater sample analyses greater than the minimum background total barium concentration (*i.e.*, <0.100 mg/L **[**Moats and Winn, 1995]**)**?	DB flag?
MW5	0.134	yes	none

Appendix A: MWL monitoring well groundwater analytical data for wells BW1, MW1, MW3, and MW4

Alkalinity (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
04/26/93			207.7		
04/26/93			200		
04/27/93		215.7			
04/27/93		220			
04/27/93				193.4	
04/27/93				197	
04/28/93	233				
04/28/93	257.3				
04/28/93	291				
04/30/93					231.7
11/08/93			208		
11/09/93		211			
11/09/93				193	
11/10/93	229				
11/11/93					218
10/24/94			185		
10/25/94		207			
10/25/94				177	
10/27/94	217				
10/28/94					234
03/14/95	230				
04/17/95			196		
04/17/95				182	
04/19/95		226			
04/19/95					266
04/19/95					267
10/16/95			199		
10/16/95				191	
10/20/95		234			
10/20/95					257
10/20/95					276
10/23/95	229				
04/15/96			195		
04/15/96				182	
04/16/96	212				
04/16/96					
04/18/96		220			
04/18/96					217
04/13/99	199				
04/05/01					215
04/06/01	233				
04/08/01				194	
04/13/01		198			
04/23/01			209		

Date sampled	BW1	MW1	MW2	MW3	MW4
04/15/02	246				
04/16/02					208
04/16/02					221
04/24/02			201		
04/30/02		191			
05/08/02				212	
04/08/03			204		
04/16/03					238
04/21/03		187			
04/22/03				186	
04/16/04		178			
04/20/04	214				
04/20/04					189
04/22/04				169	
04/26/04			187		
04/15/05	192				
04/19/05					185
count	13	11	11	11	14
Median values	229	211	200	191	226.35
1 STANDARD DEVIATION	26.76115	18.83997	8.43768	12.24745	28.28613
-1 STANDARD DEVIATION	202.2389	192.16	191.5623	178.7526	198.0639
+1 STANDARD DEVIATION	255.7611	229.84	208.4377	203.2474	254.6361

Ammonia (mg/L)

N.B., all analytical results are reported as below detection limit, except sample result for MW4 dated 5/31/94 (1.3 mg/L) which is likely erroneous.

Date sampled	BW1	MW1	MW2	MW3	MW4
11/08/93			0.05		
11/09/93		0.05			
11/09/93				0.05	
11/10/93	0.05				
11/10/93	0.05				
11/11/93					0.05
03/14/94					0.05
05/02/94			0.05		
05/03/94		0.05			
05/03/94				0.05	
05/04/94		0.05			
05/31/94					1.3
10/24/94			0.05		
10/25/94		0.05			
10/25/94		0.05			
10/25/94				0.05	
10/27/94	0.05				
10/27/94	0.05				
10/28/94					0.05
03/14/95	0.1				
10/16/95				0.0085	
10/20/95		0.0085			
10/20/95					0.0085
10/20/95					0.0085
10/23/95	0.009				
04/15/96			0.0085		
04/15/96				0.0085	
04/15/96				0.01	
04/16/96	0.009				
04/18/96		0.0085			
04/18/96					0.0085
04/18/96					0.0085
count	7	7	4	6	8
Median values	0.05	0.05	0.05	0.03	0.02925
1 STANDARD DEVIATION	0.030865	0.02025	0.02075	0.022463	0.450794
-1 STANDARD DEVIATION	0.019135	0.02975	0.02925	0.007537	-0.42154
+1 STANDARD	0.080865	0.07025	0.07075	0.052463	0.480044

Date sampled	BW1	MW1	MW2	MW3	MW4
DEVIATION					

Cadmium (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
09/27/90	0.0025				
09/27/90	0.0025				
09/27/90		0.046			
09/28/90			0.0025		
09/28/90				0.0025	
01/24/91	0.0025				
01/24/91	0.0025				
01/24/91		0.0025			
01/28/91			0.0025		
01/28/91				0.0025	
04/02/91			0.0025		
04/02/91				0.0025	
05/07/91	0.0025				
05/07/91	0.0025				
05/07/91		0.0025			
07/31/91		0.0025			
08/01/91			0.0025		
08/05/91				0.0025	
08/06/91	0.0025				
08/06/91	0.0025				
10/14/91			0.0025		
10/15/91		0.0025			
10/15/91				0.0025	
10/16/91	0.0025				
10/16/91	0.0025				
10/16/91	0.0025				
07/27/92			0.0025		
07/27/92			0.00025		
07/28/92		0.0025			
07/28/92		0.0006			
07/28/92				0.0025	
07/28/92				0.0024	
07/29/92	0.00025				
07/29/92	0.0025				
01/18/93			0.016		
01/19/93		0.0086			
01/19/93				0.029	
01/20/93	0.031				
01/20/93	0.023				
04/26/93			0.0025		
04/26/93			0.0008		
04/27/93		0.0005			
04/27/93		0.00025			
04/27/93				0.0025	

Date sampled	BW1	MW1	MW2	MW3	MW4
04/27/93				0.0014	
04/28/93	0.00025				
04/28/93	0.0025				
04/28/93					0.0025
04/28/93					0.0025
04/28/93					0.0025
11/08/93			0.0025		
11/09/93		0.0025			
11/09/93				0.0025	
11/10/93	0.0025				
11/10/93	0.0025				
11/10/93					0.0025
03/14/94					0.0025
05/02/94			0.0025		
05/02/94				0.0025	
05/03/94		0.0025			
05/04/94		0.0025			
05/31/94					0.0025
10/24/94			0.0025		
10/25/94		0.0025			
10/25/94		0.0025			
10/25/94				0.0025	
10/27/94	0.0025				
10/27/94	0.0025				
10/28/94					0.0025
04/17/95			0.0025		
04/17/95				0.0025	
04/19/95		0.0025			
04/19/95					0.0025
04/19/95					0.0025
10/16/95				0.0002	
10/20/95		0.00013			
10/20/95					0.00093
10/23/95	0.00012				
04/15/96			0.00017		
04/16/96	0.00005				
04/18/96		0.00005			
04/18/96				0.00005	
04/18/96					0.00005
04/28/96	0.00028				
04/23/97		0.00057			
04/23/97					0.00031
04/24/97			0.00065		
04/24/97				0.00046	
10/15/97		0.000105			
10/15/97		0.000105			

Date sampled	BW1	MW1	MW2	MW3	MW4
10/15/97				0.00022	
10/16/97			0.00045		
10/17/97	0.00024				
10/17/97					0.00035
03/31/98	0.0003				
03/31/98	0.00011				
04/01/98		0.000105			
04/01/98					0.0001
04/01/98					0.0001
04/01/98					0.0003
04/02/98			0.00032		
04/02/98			0.00025		
04/02/98				0.00011	
11/05/98	0.00011				
11/06/98		0.00086			
11/06/98			0.00028		
11/06/98				0.00011	
11/06/98					0.00026
11/06/98					0.00011
04/12/99				0.00011	
04/13/99	0.00011				
04/14/99		0.00011			
04/14/99					0.00025
04/19/99			0.00023		
04/06/00	0.00032				
04/07/00					0.00066
04/13/00				0.00064	
04/14/00		0.0012			
04/14/00		0.00032			
04/24/00			0.0011		
04/05/01					0.00033
04/05/01					0.00037
04/06/01	0.00067				
04/08/01				0.00011	
04/13/01		0.00013			
04/23/01			0.0004		
04/15/02	0.000578				
04/16/02					0.000126
04/16/02					0.000126
04/24/02			0.000488		
04/30/02		0.000387			
05/08/02				0.00111	
04/08/03			0.0152		
04/14/03	0.000181				
04/16/03					0.00309
04/16/03					0.00304

Date sampled	BW1	MW1	MW2	MW3	MW4
04/21/03		0.00222			
04/22/03				0.000508	
09/09/03		0.00168			
09/09/03			0.000502		
09/09/03					0.0017
04/16/04		0.000096			
04/20/04	0.000134				
04/20/04					0.000966
04/22/04				0.00036	
04/26/04			0.00013		
04/26/04			0.000143		
count	34	31	28	26	28
Median values	0.0025	0.0012	0.00095	0.0019	0.000795
1 STANDARD DEVIATION	0.006282	0.008165	0.003892	0.005517	0.001146
-1 STANDARD DEVIATION	-0.00378	-0.00696	-0.00294	-0.00362	-0.00035
+1 STANDARD DEVIATION	0.008782	0.009365	0.004842	0.007417	0.001941

Dissolved oxygen (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
04/28/93	6.8				
04/16/03		6.19			
04/20/03	6.16				
04/20/03					2.66
04/22/03				7.29	
04/26/03			3.9		
08/31/04		6.89			
09/01/04	7.99				
count	3	2	1	1	1
Median values	6.8	6.54	3.9	7.29	2.66
1 STANDARD DEVIATION	0.928673	0.494975	----	----	----
-1 STANDARD DEVIATION	5.871327	6.045025	----	----	----
+1 STANDARD DEVIATION	7.728673	7.034975	----	----	----

Eh (mV)

Date Sampled	BW1	MW1	MW2	MW3	MW4
01/18/93			86		
01/19/93		95		131	
01/20/93	109				
04/26/93			135		
04/27/93		162		112	
04/28/93	121				
11/08/93			39		
11/09/93		61		67	
11/10/93	85				
11/11/93					97
03/14/95	113				
04/17/95			279	279	
04/19/95		317			294
04/15/96			105	88	
04/16/96	77				
04/18/96		72			73
04/23/96					351
04/28/96	306				
04/23/97		146			
04/24/97			278	270	
10/15/97		228			317
10/16/97			235	230	
10/17/97	134				
03/31/98	217				
04/01/98		246			239
04/02/98			240	239	
11/05/98	201				
11/06/98		271	151	158	285
01/19/99		102			
01/20/99	120		130	117	
01/21/99					341
04/12/99				130	
04/13/99	168				
04/14/99		125			222
04/19/99			170		
04/06/00	194				
04/07/00					231
04/13/00				186	
04/14/00		224			
04/24/00			169		

Date Sampled	BW1	MW1	MW2	MW3	MW4
10/31/00					250
11/01/00	136				
02/07/01					195
02/09/01					192
04/06/01	200				
04/08/01				225	
04/13/01		180			
04/23/01			110		
11/13/01					301
04/16/02					334
04/24/02			204		
04/30/02		134			
05/08/02				128	
04/08/03			154.7		
04/14/03	123				
04/16/03					104.6
04/21/03		145.8			
04/22/03				253.2	
09/08/03		250.6			
09/09/03			220.8		376
04/16/04		222.9			
04/20/04	313				409.9
04/22/04				214	
04/26/04			144.3		
08/31/04		170.1			
09/01/04	157.3				
11/15/04	254.8				
11/16/04		215.7			
02/16/05	147.6				
02/21/05		172.1			
04/11/05		263.3			
04/12/05			75.6		
04/13/05				56	
04/06/06					290.5
04/10/06			68.3		
04/12/06		75.7			
04/13/06				83.6	
04/18/06	42.8				
count	20	22	19	18	19
Median values	141.8	171.1	151	144.5	285

1 Standard Deviation)	71.9670	71.8301	70.2655	73.1214	94.6265
-1 Standard Deviation	69.8329	99.2698	80.7344	71.3785	190.373
+1 Standard Deviation)	213.767	242.930	221.265	217.621	379.626

Iron (total) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
01/24/91	0.28				
01/24/91	0.05				
01/24/91	0.05				
01/24/91	0.05				
01/24/91		0.44			
01/24/91		0.05			
01/28/91			0.85		
01/28/91			0.05		
01/28/91				0.05	
01/28/91				0.05	
04/01/91	0.02				
05/02/91			0.2		
05/02/91			0.05		
05/02/91				0.24	
05/02/91				0.05	
05/07/91	0.05				
05/07/91	0.05				
05/07/91	0.1				
05/07/91	0.05				
05/07/91		0.76			
05/07/91		0.05			
07/01/91	0.05				
07/01/91			0.05		
07/01/91				0.25	
07/31/91		0.71			
07/31/91		0.05			
08/01/91			0.085		
08/01/91			0.05		
08/05/91				0.25	
08/05/91				0.1	
08/06/91	0.05				
08/06/91	0.05				
08/06/91	0.05				
08/06/91	0.05				
10/14/91			0.12		
10/14/91			0.05		
10/15/91		0.49			
10/15/91		0.05			
10/15/91				0.14	
10/15/91				0.05	
10/16/91	0.05				
10/16/91	0.05				
10/16/91	0.05				
10/16/91	0.05				

Date sampled	BW1	MW1	MW2	MW3	MW4
07/27/92			0.1		
07/27/92			0.05		
07/28/92		0.19			
07/28/92		0.05			
07/28/92				1.3	
07/28/92				0.05	
07/29/92	0.23				
07/29/92	0.05				
07/29/92	0.05				
07/29/92	0.05				
01/18/93			0.045		
01/19/93				0.37	
01/20/93	0.058				
01/20/93	0.09				
04/26/93			0.05		
04/26/93			0.06		
04/27/93		0.05			
04/27/93		0.05			
04/27/93		0.118			
04/27/93				0.38	
04/27/93				0.315	
04/27/93				0.033	
04/28/93	0.121				
04/28/93	0.055				
04/28/93	0.15				
04/28/93					0.14
04/28/93					0.12
04/30/93					0.21
04/30/93					0.05
11/08/93			0.05		
11/09/93		0.22			
11/09/93				0.12	
11/10/93	0.054				
11/10/93	0.041				
11/11/93					0.1
03/14/94					0.1
05/02/94			0.048		
05/03/94		0.11			
05/03/94				0.25	
05/04/94		0.048			
05/31/94					0.036
10/24/94			0.05		
10/25/94		0.058			
10/25/94		0.05			
10/25/94				0.078	
10/27/94	0.057				

Date sampled	BW1	MW1	MW2	MW3	MW4
10/28/94					0.15
03/14/95	0.07				
04/17/95			0.024		
04/17/95				0.071	
04/19/95		0.094			
04/19/95					0.07
04/19/95					0.098
10/16/95				0.266	
10/20/95		0.565			
10/20/95					0.0134
10/20/95					0.0161
10/23/95	0.321				
04/15/96			0.273		
04/15/96				0.0608	
04/15/96				0.0608	
04/16/96	0.0462				
04/18/96		0.0051			
04/18/96		0.272			
04/18/96					0.011
04/18/96					0.0051
08/27/98		0.26			
08/27/98		1.8			
04/12/99				0.0993	
04/13/99	0.0967				
04/14/99		0.583			
04/14/99					0.0917
04/19/99			0.18		
04/19/99			0.0906		
04/14/00		0.96			
04/05/01					0.486
04/05/01					0.304
04/06/01	1.82				
04/08/01				0.248	
04/13/01		0.409			
04/23/01			0.169		
04/15/02	0.0304				
04/16/02					0.199
04/16/02					0.248
04/24/02			0.357		
04/30/02		0.272			
05/08/02				0.731	
04/08/03			0.31		
04/08/03			0.399		
04/14/03	0.115				
04/16/03					0.299
04/16/03					0.303

Date sampled	BW1	MW1	MW2	MW3	MW4
04/21/03		0.464			
04/22/03				0.669	
04/16/04		0.886			
04/20/04	0.271				
04/20/04					0.206
04/22/04				1.1	
04/26/04			0.21		
04/26/04			0.204		
04/11/05		0.697			
04/11/05		0.135			
04/12/05			0.235		
04/13/05				0.473	
04/15/05	0.2				
04/19/05					0.303
04/19/05					0.318
04/06/06					0.441
04/10/06			0.377		
04/12/06		1.67			
04/12/06		1.64			
04/13/06				0.422	
04/18/06	0.361				
count	40	34	29	29	25
Median values	0.05	0.24	0.0906	0.24	0.14
1 Standard deviation	0.285691	0.488327	0.173678	0.314261	0.135825
-1 STANDARD DEVIATION	-0.23569	-0.24833	-0.08308	-0.07426	0.004175
+1 STANDARD DEVIATION	0.335691	0.728327	0.264278	0.554261	0.275825

Manganese (total) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
01/24/91	0.005				
01/24/91		0.019			
01/28/91			0.016		
01/28/91				0.005	
05/02/91			0.005		
05/02/91				0.005	
05/07/91	0.005				
05/07/91	0.005				
05/07/91		0.015			
07/01/91	0.005				
07/01/91			0.005		
07/01/91				0.005	
07/31/91		0.019			
08/01/91			0.005		
08/05/91				0.005	
08/06/91	0.005				
08/06/91	0.005				
10/14/91			0.005		
10/15/91		0.017			
10/15/91				0.005	
10/16/91	0.005				
10/16/91	0.005				
07/27/92			0.005		
07/28/92		0.005			
07/28/92				0.005	
07/29/92	0.005				
07/29/92	0.005				
01/18/93			0.005		
01/19/93		0.011			
01/19/93				0.005	
01/20/93	0.005				
01/20/93	0.005				
04/26/93			0.005		
04/26/93			0.005		
04/27/93		0.0095			
04/27/93				0.047	
04/27/93				0.056	
04/27/93				0.056	
04/28/93	0.005				
04/28/93	0.0098				
04/30/93					0.16
11/08/93			0.005		
11/09/93		0.005			
11/09/93				0.0043	

Date sampled	BW1	MW1	MW2	MW3	MW4
11/10/93	0.005				
11/10/93	0.005				
11/11/93					0.04
05/02/94			0.0089		
05/03/94		0.012			
05/03/94				0.012	
05/04/94		0.0078			
05/31/94					0.094
10/24/94			0.005		
10/25/94		0.011			
10/25/94				0.021	
10/27/94	0.005				
10/27/94	0.005				
10/28/94					0.045
04/17/95			0.0025		
04/17/95				0.0025	
04/19/95		0.0025			
04/19/95					0.028
04/19/95					0.027
10/16/95			0.00787		
10/16/95				0.013	
10/20/95		0.0128			
10/20/95					0.0284
10/20/95					0.0295
10/23/95	0.00955				
04/15/96			0.0121		
04/15/96				0.00341	
04/16/96	0.0019				
04/18/96		0.0109			
04/18/96					0.0166
04/18/96					0.016
04/12/99				0.0228	
04/13/99	0.00238				
04/14/99		0.00793			
04/14/99					0.00959
04/19/99			0.00802		
04/06/00	0.0324				
04/05/01					0.0198
04/05/01					0.0179
04/08/01				0.00983	
04/13/01		0.00655			
04/23/01			0.00197		
04/15/02	0.00535				
04/16/02					0.022
04/16/02					0.0212
04/24/02			0.00197		

Date sampled	BW1	MW1	MW2	MW3	MW4
04/30/02		0.00646			
05/08/02				0.00429	
04/08/03			0.00183		
04/08/03			0.00223		
04/14/03	0.00081				
04/16/03					0.00589
04/16/03					0.00609
04/21/03		0.00599			
04/22/03				0.0105	
04/16/04		0.0172			
04/20/04	0.00479				
04/20/04					0.00187
04/22/04				0.0157	
04/26/04			0.00278		
04/26/04			0.00279		
04/11/05		0.019			
04/12/05			0.0005		
04/12/05			0.00415		
04/13/05				0.0259	
04/15/05	0.00282				
04/19/05					0.00457
04/19/05					0.00483
04/06/06					0.00844
04/10/06			0.00551		
04/12/06		0.0236			
04/12/06		0.0232			
04/13/06				0.0771	
04/18/06	0.0054				
count	27	22	25	23	21
Median values	0.005	0.011	0.005	0.00983	0.0198
1 STANDARD DEVIATION	0.005582	0.0062	0.003395	0.020799	0.036183
-1 STANDARD DEVIATION	-0.00058	0.0048	0.001605	-0.01097	-0.01638
+1 STANDARD DEVIATION	0.010582	0.0172	0.008395	0.030629	0.055983

Nickel (total) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
09/27/90	0.02				
09/27/90	0.02				
09/27/90		0.046			
09/28/90			0.02		
09/28/90				0.02	
07/17/92	0.025				
07/17/92			0.025		
07/27/92			0.01		
07/28/92		0.15			
07/28/92		0.162			
07/28/92				0.066	
07/28/92				0.07	
07/29/92	0.01				
07/29/92	0.02				
01/18/93			0.02		
01/19/93		0.078			
01/19/93				0.026	
01/20/93	0.02				
01/20/93	0.02				
04/26/93			0.014		
04/26/93			0.01		
04/27/93		0.097			
04/27/93		0.057			
04/27/93				0.037	
04/27/93				0.035	
04/28/93	0.01				
04/28/93	0.012				
04/28/93	0.0075				
04/28/93					0.016
04/28/93					0.02
11/08/93			0.02		
11/09/93		0.095			
11/09/93				0.014	
11/10/93	0.02				
11/10/93	0.02				
11/10/93					0.02
03/14/94					0.02
05/02/94			0.02		
05/02/94				0.011	
05/03/94		0.15			
05/04/94		0.13			
05/31/94					0.02
10/24/94			0.02		

Date sampled	BW1	MW1	MW2	MW3	MW4
10/25/94		0.1			
10/25/94		0.13			
10/25/94				0.0098	
10/27/94	0.02				
10/27/94	0.02				
10/28/94					0.0082
04/17/95			0.0075		
04/17/95				0.0093	
04/19/95		0.12			
04/19/95					0.02
04/19/95					0.0082
10/16/95				0.00799	
10/20/95		0.107			
10/20/95					0.00307
10/23/95	0.00196				
04/15/96			0.00342		
04/16/96	0.0004				
04/18/96		0.145			
04/18/96				0.00367	
04/18/96					0.004
04/18/96					0.004
10/15/97				0.0362	
03/31/98	0.0029				
03/31/98	0.00114				
04/01/98		0.5			
04/01/98					0.00114
04/01/98					0.00114
04/01/98					0.0008
04/02/98			0.00351		
04/02/98			0.005		
04/02/98				0.018	
11/05/98	0.00719				
11/06/98		0.49			
11/06/98			0.00449		
11/06/98				0.031	
11/06/98					0.00189
11/06/98					0.00159
04/12/99				0.0251	
04/13/99	0.0128				
04/14/99		0.266			
04/14/99					0.00093
04/19/99			0.00531		
04/06/00	0.0165				
04/07/00					0.00155
04/13/00				0.0141	
04/14/00		0.279			

Date sampled	BW1	MW1	MW2	MW3	MW4
04/14/00		0.228			
04/24/00			0.124		
04/05/01					0.00355
04/05/01					0.00355
04/06/01	0.191				
04/13/01		0.252			
04/23/01			0.0882		
04/15/02	0.0136				
04/16/02					0.00172
04/16/02					0.00115
04/24/02			0.0897		
04/30/02		0.265			
05/08/02				0.0961	
04/08/03			0.0512		
04/08/03			0.0529		
04/14/03	0.0266				
04/21/03		0.374			
04/16/04		0.401			
04/20/04	0.0332				
04/20/04					0.0159
04/22/04				0.056	
04/26/04			0.0105		
04/26/04			0.0106		
04/12/05			0.00802		
04/13/05				0.0173	
count	25	23	23	20	23
Median values	0.02	0.15	0.014	0.02255	0.00355

Nitrate (as nitrogen) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
10/14/91			5.1		
10/15/91		5.5			
10/15/91				4.3	
10/16/91	5.6				
10/16/91	5.6				
07/29/92	5.4				
04/26/93			4.6		
04/26/93			4.5		
04/27/93		5.5			
04/27/93		5.0			
04/27/93				4	
04/27/93				3.7	
04/28/93	5.7				
04/28/93	5.4				
11/08/93			4.9		
11/09/93		5.4			
11/09/93				4.2	
11/10/93	5.9				
11/10/93	5.8				
11/11/93					1.9
03/14/94					1.5
05/02/94			4.70		
05/03/94		5.0			
05/03/94				3.9	
05/04/94		5.2			
05/31/94					1.2
10/24/94			4.90		
10/25/94		5.2			
10/25/94		5.2			
10/25/94				4.3	
10/27/94	5.6				
10/27/94	5.7				
10/28/94					0.6
10/31/94	5.7				
04/17/95			5.00		
04/17/95				4.7	
04/19/95		5.5			
04/19/95					0.14
04/19/95					0.15
04/15/96			4.65		
04/15/96				4.05	
04/15/96				4.05	
04/16/96	5.65				
04/18/96		5.2			

Date sampled	BW1	MW1	MW2	MW3	MW4
04/18/96					1.89
04/18/96					1.92
04/28/96	5				
04/23/97		5.2			
04/23/97					1.2
04/24/97			3.70		
04/24/97				2.8	
10/15/97		4.9			
10/15/97		5.1			
10/15/97					1.81
10/16/97			3.93		
10/16/97				4.05	
10/17/97	5.75				
03/31/98	6.08				
04/01/98		5.4			
04/01/98					1.71
04/01/98					1.92
04/02/98			3.44		
04/02/98				3.56	
11/05/98	5.36				
11/06/98		5.4			
11/06/98			4.00		
11/06/98				4.4	
11/06/98					2
11/06/98					2.05
11/06/98					2.05
04/12/99				4.08	
04/13/99	6.15				
04/14/99		5.2			
04/14/99					1.9
04/19/99			3.72		
04/06/00	5.55				
04/07/00					2
04/13/00				4.15	
04/14/00		4.5			
04/14/00		4.4			
04/24/00			3.45		
04/05/01					1.59
04/05/01					1.61
04/06/01	6.75				
04/08/01				2.59	
04/13/01		3.0			
04/23/01			3.35		
04/15/02	5				
04/16/02					1.85
04/16/02					1.75

Date sampled	BW1	MW1	MW2	MW3	MW4
04/24/02			2.20		
04/30/02		4.8			
05/08/02				3.75	
04/08/03			2.58		
04/14/03	5.7				
04/16/03					1.63
04/16/03					1.75
04/21/03		4.7			
04/22/03				3.7	
04/16/04		5.2			
04/20/04	5.9				
04/20/04					1.85
04/22/04				2.25	
04/26/04			2.75		
04/26/04			1.58		
04/12/05			1.83		
04/13/05				3.25	
04/15/05	2.82				
04/19/05					1.94
04/19/05					1.94
count	22	22	20	20	26
Median values	5.675	5.195	3.825	4.025	1.83
1 STANDARD DEVIATION	0.712971	0.547111	1.091544	0.628916	0.537181
-1 STANDARD DEVIATION	4.962029	4.647889	2.733456	3.396084	1.292819
+1 STANDARD DEVIATION	6.387971	5.742111	4.916544	4.653916	2.367181

pH

Date sampled	BW1	MW1	MW2	MW3	MW4
09/27/90	7.67				
09/27/90		7.49			
09/28/90			6.91		
09/28/90				7.59	
01/24/91	7.57				
01/24/91		7.46			
01/28/91			7.15		
01/28/91				7.9	
05/02/91			7.47		
05/02/91				7.46	
05/07/91		7.26			
07/31/91		7.34			
08/01/91			7.74		
08/05/91				7.51	
08/06/91	7.34				
10/14/91			7.84		
10/15/91		7.43			
10/15/91				7.57	
10/16/91	7.4				
01/13/92			8.05		
01/14/92				7.79	
01/15/92	7.65				
07/27/92			7.65		
07/28/92		7.33			
07/28/92				7.68	
07/29/92	7.45				
01/18/93			7.44		
01/19/93		7.45			
01/19/93				7.68	
01/20/93	7.52				
04/26/93			7.63		
04/27/93		7.6			
04/27/93				7.8	
04/28/93	7.62				
04/28/93	7.56				
04/28/93					7.23
11/08/93			7.36		
11/09/93		7.19			
11/09/93				5.58	
11/10/93	7.46				
11/11/93					7.16
04/28/94	7.75				
05/02/94			7.67		
05/03/94		7.67			

Date sampled	BW1	MW1	MW2	MW3	MW4
05/03/94				8.06	
05/04/94		7.59			
10/24/94			7.68		
10/25/94				7.69	
10/27/94	7.57				
10/28/94					7.25
03/14/95	7.63				
04/17/95			7.97		
04/17/95				7.88	
04/19/95		7.35			
04/19/95					7.21
10/16/95			7.6		
10/16/95				7.44	
10/20/95		7.54			
10/20/95					7.11
10/23/95	7.76				
04/15/96			7.39		
04/15/96				7.65	
04/16/96	7.53				
04/18/96		7.51			
04/18/96					7.23
04/18/96					7.09
04/28/96	7.66				
04/23/97		7.35			
04/24/97			7.46		
04/24/97				7.79	
10/15/97		7.45			
10/15/97					7.21
10/16/97			7.36		
10/16/97				7.57	
10/17/97	7.62				
03/31/98	7.43				
04/01/98		7.37			
04/01/98					6.92
04/02/98			7.16		
04/02/98				7.37	
11/05/98	7.62				
11/06/98		7.46			
11/06/98			7.04		
11/06/98				7.58	
11/06/98					7.11
01/20/99	8.17				
01/20/99			7.64		
01/20/99				7.81	
01/21/99					6.97
04/12/99				7.64	

Date sampled	BW1	MW1	MW2	MW3	MW4
04/13/99	7.68				
04/14/99		7.36			
04/14/99					7.3
04/19/99			7.49		
04/06/00	8.06				
04/07/00					7.23
04/13/00				7.72	
04/14/00		7.57			
04/14/00		7.57			
04/24/00			7.44		
10/31/00					7.29
11/01/00	7.4				
02/07/01					6.96
02/09/01					7.1
04/05/01					7.3
04/06/01	7.49				
04/08/01				7.57	
04/13/01		7.34			
04/23/01			7.35		
11/13/01					7.24
04/15/02	7.68				
04/16/02					7.2
04/24/02			7.44		
04/30/02		7.63			
05/08/02				7.87	
04/08/03			7.52		
04/14/03	7.98				
04/16/03		7.83			7.5
04/16/03					7.5
04/20/03					7.88
04/21/03		7.73			
04/22/03				7.4	
04/22/03				7.89	
04/26/03			7.93		
09/08/03		7.8			
09/09/03			7.57		
09/09/03					7.7
04/16/04		7.83			
04/20/04	8.06				
04/26/04			7.73		
08/31/04		8.19			
09/01/04	7.81				
11/15/04	8.02				
11/16/04		7.73			
02/16/05	8.21				
02/21/05		7.65			

Date sampled	BW1	MW1	MW2	MW3	MW4
04/11/05		7.75			
04/12/05			7.85		
04/13/05				7.1	
04/15/05	7.51				
04/19/05					7.07
04/06/06					7.39
04/10/06			7.78		
04/12/06		7.64			
04/13/06				7.56	
04/18/06	7.24				
count	32	32	30	28	25
Median values	7.62	7.525	7.545	7.645	7.23
1 STANDARD DEVIATION	0.242766	0.207255	0.269015	0.438812	0.219507
-1 STANDARD DEVIATION	7.377234	7.317745	7.275985	7.206188	7.010493
+1 STANDARD DEVIATION	7.862766	7.732255	7.814015	8.083812	7.449507

Sodium (total) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
01/24/91		50.2			
01/28/91			56.5		
01/28/91				55.4	
04/01/91	51				
04/01/91		50.3			
04/02/91			55.4		
04/02/91				55.3	
10/14/91			55.1		
10/15/91		50.7			
10/15/91				55.9	
10/16/91	57				
01/15/92	49.1				
04/26/93			45.7		
04/26/93			55.4		
04/27/93		45.7			
04/27/93		52.8			
04/27/93				45.7	
04/27/93				55.5	
04/28/93	54.7				
04/28/93	46.9				
04/28/93	47.4				
04/30/93					46.9
11/08/93			55.4		
11/09/93		50.9			
11/09/93				51.5	
11/10/93	56				
11/11/93					46.2
10/24/94			53.9		
10/25/94		53.6			
10/25/94				53.2	
10/27/94	56.9				
10/28/94					67.1
03/14/95	51				
04/17/95			46.8		
04/17/95				49.9	
04/19/95		52.1			
04/19/95					80.7
04/19/95					75.9
10/16/95			47.9		
10/16/95				49.2	
10/20/95		52.2			
10/20/95					76.6
10/20/95					78.5

Date sampled	BW1	MW1	MW2	MW3	MW4
10/23/95	56.6				
04/15/96			49.5		
04/15/96				50.8	
04/16/96	55.5				
04/18/96		49.4			
04/18/96					53.1
04/05/01					49.9
04/05/01					48.9
04/06/01	52.5				
04/08/01				47.1	
04/13/01		50.1			
04/23/01			49.6		
04/15/02	54.2				
04/16/02					49.1
04/16/02					48.9
04/24/02			52.7		
04/30/02		53.0			
05/08/02				50.6	
04/08/03			49.4		
04/08/03			54.8		
04/14/03	52				
04/16/03					56.9
04/16/03					56
04/21/03		49.8			
04/22/03				50.7	
04/16/04		46.7			
04/20/04	52.8				
04/20/04					49.7
04/22/04				45.5	
04/26/04			46.9		
04/26/04			46.8		
04/12/05			47.9		
04/13/05				47.2	
count	15	14	17	15	15
Median values	52.8	50.5	49.6	50.7	53.1
1 STANDARD DEVIATION	3.345459	2.257503	3.845624	3.583494	12.93361
-1 STANDARD DEVIATION	49.45454	48.2425	45.75438	47.11651	40.16639
+1 STANDARD DEVIATION	56.14546	52.7575	53.44562	54.28349	66.03361

Sulfate (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
09/27/90	45.1				
09/27/90	43.9				
09/27/90		43.1			
09/28/90			44.7		
09/28/90				44.1	
01/24/91	41.7				
01/24/91	43.4				
01/24/91		42.3			
01/28/91			41.3		
01/28/91				41.1	
04/01/91	43.2				
05/02/91			45.2		
05/02/91				42.7	
05/07/91	42.6				
05/07/91	42.8				
05/07/91		42.4			
07/31/91		41.0			
08/01/91			41.2		
08/05/91				38.6	
08/06/91	43.3				
08/06/91	44.3				
10/14/91			42.7		
10/15/91		43.1			
10/15/91				40.0	
10/16/91	44.8				
10/16/91	44.6				
01/15/92	58.9				
07/27/92			38.4		
07/28/92		40.6			
07/28/92				37.5	
07/29/92	42.8				
07/29/92	42.5				
01/18/93			22.5		
01/19/93		22.9			
01/19/93				21.1	
01/20/93	23.9				
01/20/93	23.8				
04/26/93			47.3		
04/26/93			39		
04/27/93		43.7			
04/27/93		43.0			
04/27/93				39.7	
04/27/93				39.0	

Date sampled	BW1	MW1	MW2	MW3	MW4
04/28/93	43				
04/28/93	46.7				
04/28/93	46.7				
04/28/93					46.7
04/30/93					38.7
11/08/93			40.5		
11/09/93		41.9			
11/09/93				38.3	
11/10/93	43.5				
11/10/93	43.6				
11/11/93					34.8
03/14/94					49.6
05/02/94			40.5		
05/03/94				38.0	
05/04/94		43.7			
05/31/94					34.2
10/24/94			42.9		
10/25/94		45.4			
10/25/94		46.0			
10/25/94				40.5	
10/27/94	42.5				
10/27/94	42.7				
10/28/94					43.9
03/14/95	52				
04/17/95			42.4		
04/17/95				41.0	
04/19/95		44.4			
04/19/95					49.8
04/19/95					49.7
10/16/95			41.3		
10/16/95				39.1	
10/20/95		46.6			
10/20/95					52.2
10/20/95					52
10/23/95	46.9				
04/15/96			41.2		
04/15/96				39.3	
04/15/96				39.3	
04/16/96	42.7				
04/18/96		44.4			
04/18/96					35.5
04/18/96					35.7
04/05/01					37.1
04/05/01					37.1
04/06/01	44				
04/08/01				36.3	

Date sampled	BW1	MW1	MW2	MW3	MW4
04/13/01		44.3			
04/23/01			44.3		
04/15/02	47.1				
04/16/02					38.3
04/16/02					38.2
04/24/02			40.9		
04/30/02		45.6			
05/08/02				38.4	
04/08/03			41		
04/14/03	44.7				
04/16/03					41.5
04/16/03					42.5
04/21/03		44.9			
04/22/03				40.4	
04/16/04		45.0			
04/20/04	43.9				
04/20/04					42.4
04/22/04				36.9	
04/26/04			37.3		
04/26/04			37.5		
04/11/05		41.9			
04/12/05			33.7		
04/13/05				37.4	
04/15/05	42.2				
04/19/05					36.7
04/19/05					36.6
04/06/06					35.5
04/10/06			38.6		
04/12/06		43.6			
04/12/06		44.2			
04/13/06				39.2	
04/18/06	42.2				
count	32	23	22	22	22
Median values	43.45	43.7	41.1	39.15	38.5
1 STANDARD DEVIATION	6.079407	4.604608	4.95244	4.300239	6.089841
-1 STANDARD DEVIATION	37.37059	39.09539	36.14756	34.84976	32.41016
+1 STANDARD DEVIATION	49.52941	48.30461	46.05244	43.45024	44.58984

Uranium (total) (ug/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
10/24/94			7.84		
10/25/94		1.34			
10/25/94		5.48			
10/25/94				4.82	
10/27/94	5.09				
04/17/95			6.64		
04/17/95				5.49	
04/19/95					6.17
04/19/95					6.5
04/05/01					5.37
04/05/01					5.53
04/06/01	5.9				
04/08/01				4.61	
04/13/01		5.27			
04/15/02	6.63				
04/16/02					6.24
04/16/02					6.19
04/24/02			6.72		
04/30/02		5.09			
05/08/02				5.68	
04/08/03			6.48		
04/08/03			6.78		
04/14/03	6.61				
04/16/03					6.45
04/16/03					6.52
04/21/03		5.12			
04/22/03				5.86	
04/16/04		5.45			
04/20/04	7.19				
04/20/04					5.12
04/22/04				5.55	
04/26/04			6.07		
04/26/04			6.2		
04/12/05			6.54		
04/13/05				5.14	
count	5	6	8	7	9
Median values	6.61	5.195	6.59	5.49	6.19
1 STANDARD DEVIATION	0.809308	1.617415	0.536828	0.463383	0.528772
-1 STANDARD DEVIATION	5.800692	3.577585	6.053172	5.026617	5.661228

Date sampled	BW1	MW1	MW2	MW3	MW4
+1 STANDARD DEVIATION	7.419308	6.812415	7.126828	5.953383	6.718772

Zinc (total) (mg/L)

Date sampled	BW1	MW1	MW2	MW3	MW4
09/27/90	0.096				
09/27/90	0.074				
09/27/90	0.097				
09/27/90	0.086				
09/28/90			0.18		
09/28/90			0.094		
09/28/90				0.029	
09/28/90				0.01	
07/27/92			0.094		
07/27/92			0.01		
07/27/92			0.105		
07/28/92		0.021			
07/28/92		0.01			
07/28/92		0.018			
07/28/92				0.06	
07/28/92				0.01	
07/28/92				0.071	
07/29/92	0.055				
07/29/92	0.01				
07/29/92	0.041				
07/29/92	0.01				
07/29/92	0.062				
01/18/93			0.075		
01/18/93			0.069		
01/19/93		0.01			
01/19/93				0.074	
01/20/93	0.11				
01/20/93	0.12				
04/26/93			0.01		
04/26/93			0.069		
04/26/93			0.073		
04/27/93		0.011			
04/27/93		0.0089			
04/27/93		0.038			
04/27/93				0.03	
04/27/93				0.036	
04/27/93				0.014	
04/28/93	0.036				
04/28/93	0.033				
04/28/93	0.045				
04/28/93					0.086
04/28/93					0.031
04/30/93					0.012

Date sampled	BW1	MW1	MW2	MW3	MW4
04/30/93					0.01
11/08/93			0.054		
11/09/93		0.016			
11/09/93				0.03	
11/10/93	0.048				
11/10/93	0.04				
11/11/93					0.0057
03/14/94					2.1
05/02/94			0.098		
05/03/94		0.017			
05/03/94				0.019	
05/04/94		0.016			
05/31/94					0.14
10/24/94			0.068		
10/25/94		0.028			
10/25/94		0.024			
10/25/94				0.043	
10/27/94	0.037				
10/28/94					0.07
03/14/95	0.04				
04/17/95			0.014		
04/17/95				0.0068	
04/19/95		0.0044			
04/19/95					0.07
04/19/95					0.069
10/16/95				0.018	
10/20/95		0.00673			
10/20/95					0.0597
10/20/95					0.0618
10/23/95	0.0636				
04/15/96			0.104		
04/15/96				0.011	
04/15/96				0.011	
04/16/96	0.0197				
04/18/96		0.00636			
04/18/96					0.0172
04/18/96					0.0179
08/27/98		0.023			
08/27/98		0.023			
04/12/99				0.0809	
04/13/99	0.0241				
04/14/99		0.00394			
04/14/99		0.00394			
04/14/99					0.507
04/19/99			0.0833		
04/14/00		0.023			

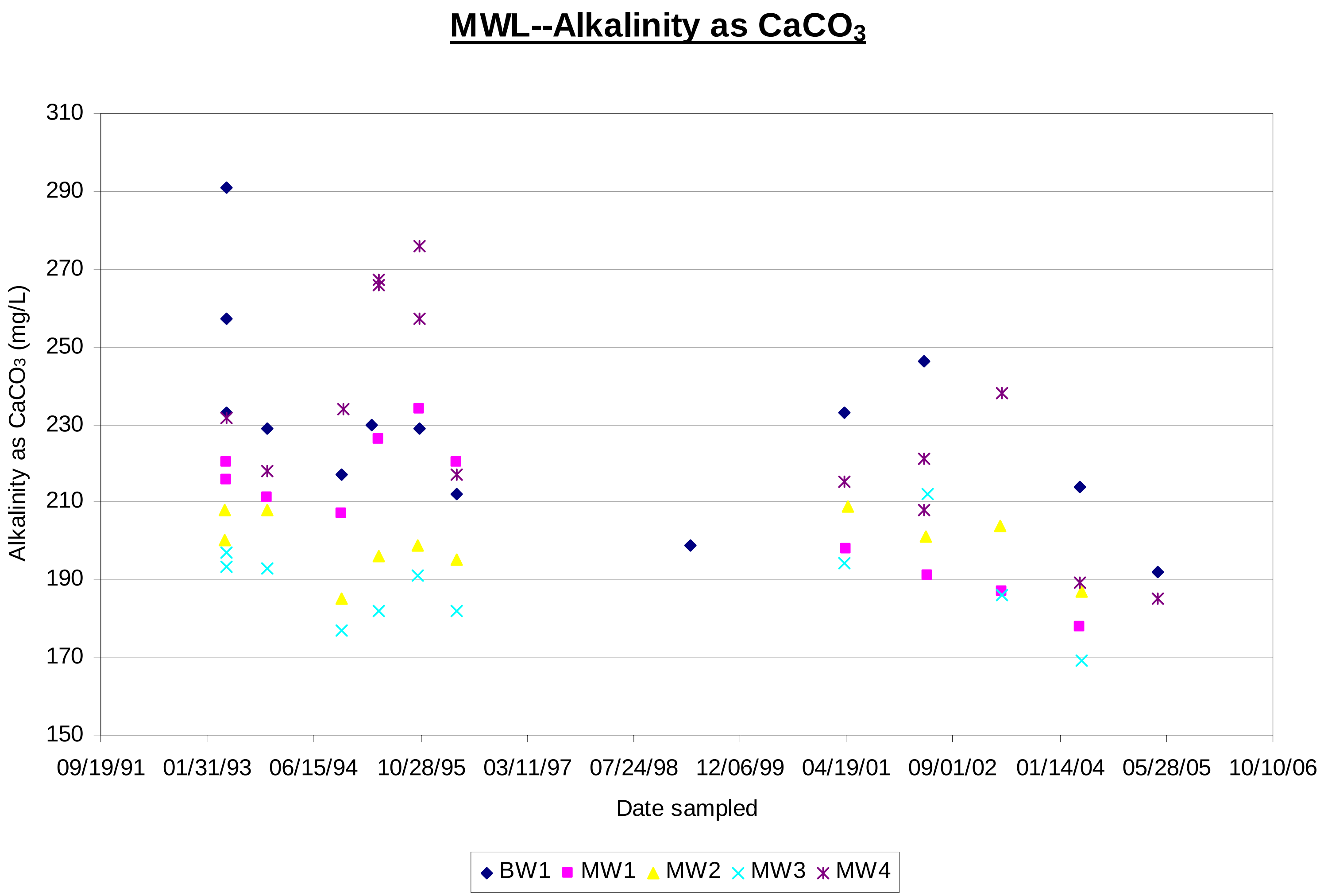
Date sampled	BW1	MW1	MW2	MW3	MW4
04/05/01					0.452
04/05/01					0.441
04/06/01	0.255				
04/08/01				0.0195	
04/13/01		0.0257			
04/23/01			0.0224		
04/15/02	0.214				
04/16/02					0.118
04/16/02					0.0969
04/24/02			0.0798		
04/30/02		0.0587			
05/08/02				0.25	
04/08/03			0.167		
04/08/03			0.159		
04/14/03	0.035				
04/16/03					0.0704
04/16/03					0.0705
04/21/03		0.0922			
04/22/03				0.02	
04/16/04		0.017			
04/20/04	0.0551				
04/20/04					0.0258
04/22/04				0.0576	
04/26/04			0.019		
04/26/04			0.0214		
04/11/05		0.0127			
04/11/05		0.0111			
04/12/05			0.0245		
04/13/05				0.0484	
04/15/05	0.0222				
04/19/05					0.023
04/19/05					0.0225
04/06/06					0.0197
04/10/06			0.0286		
04/12/06		0.0111			
04/12/06		0.0105			
04/13/06				0.126	
04/18/06	0.0455				
count	27	28	24	23	25
Median values	0.0455	0.016	0.071	0.03	0.069
1 STANDARD DEVIATION	0.056875	0.018312	0.049163	0.053245	0.423607
-1 STANDARD	-0.01138	-0.00231	0.021837	-0.02324	-0.35461

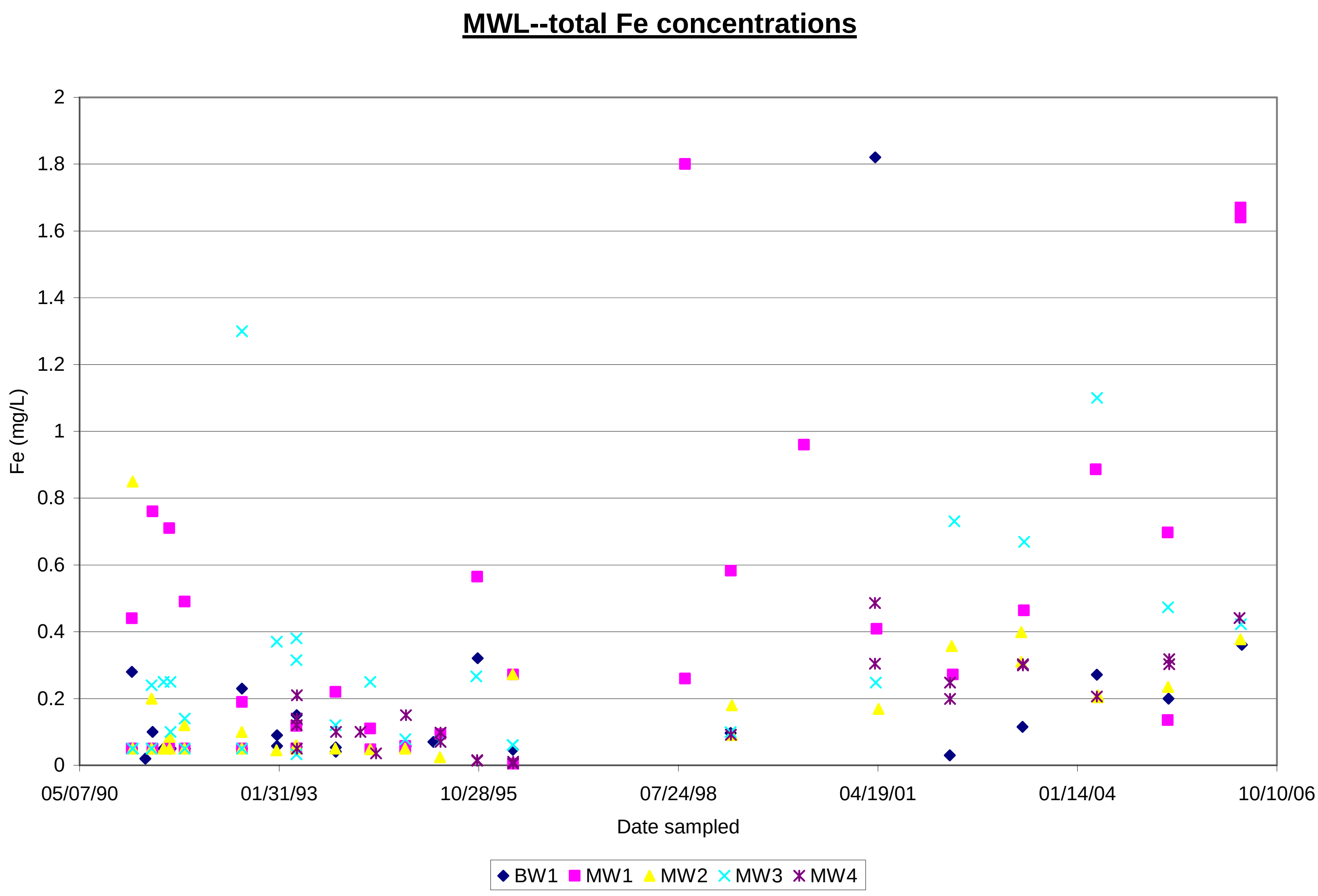
Date sampled	BW1	MW1	MW2	MW3	MW4
DEVIATION					
+1 STANDARD DEVIATION	0.102375	0.034312	0.120163	0.083245	0.492607

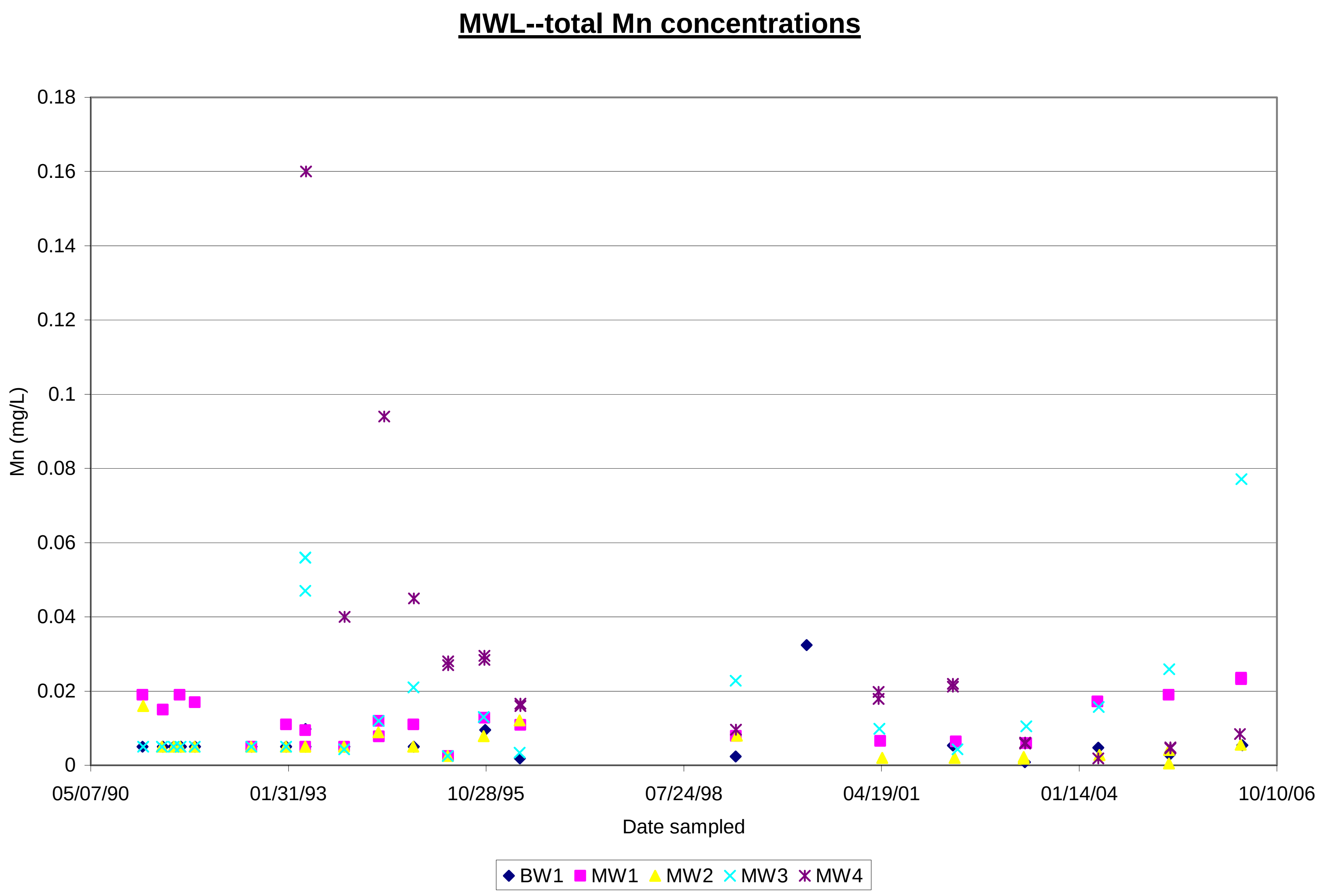
Zinc (dissolved) (mg/L)

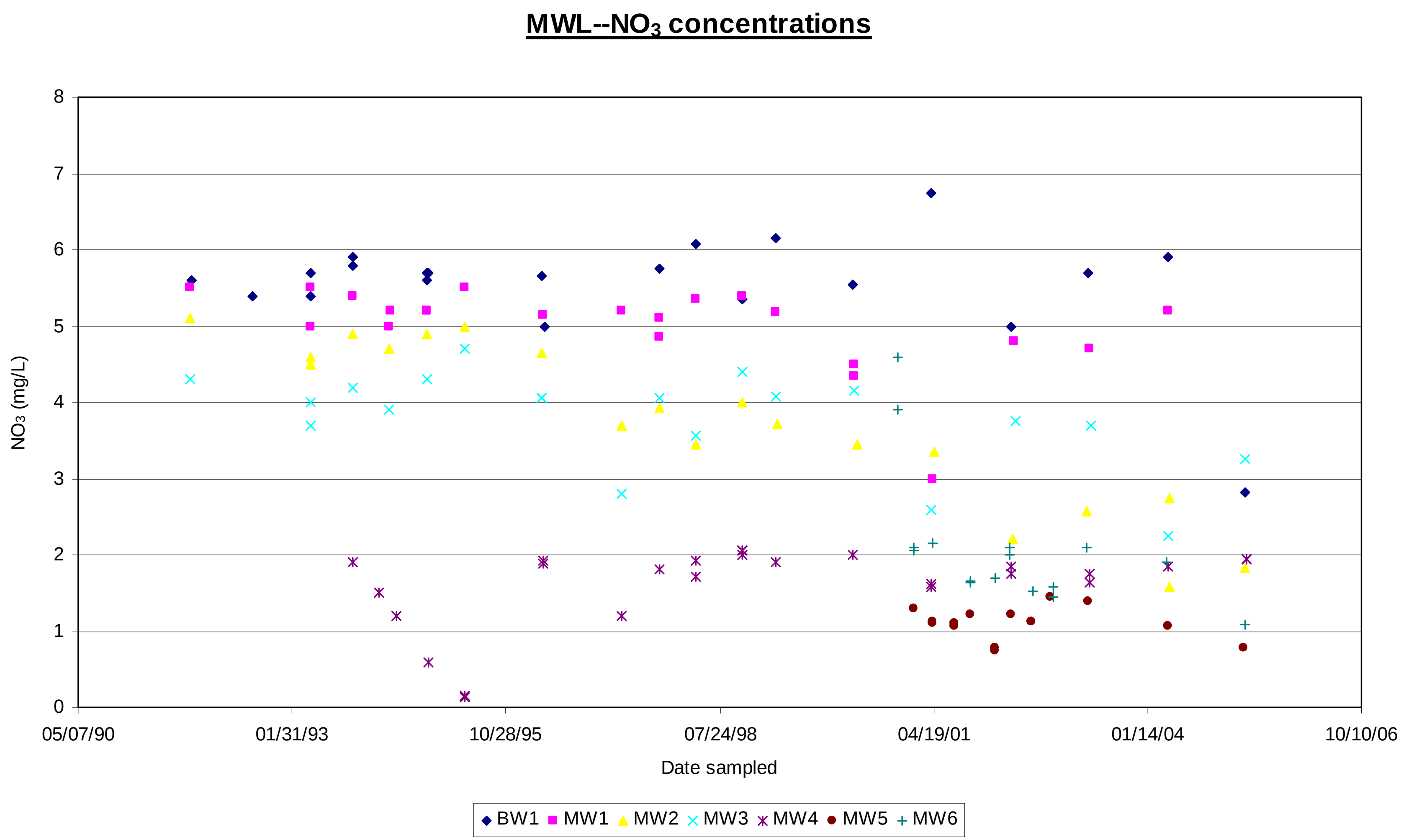
Date sampled	BW1	MW1	MW2	MW3	MW4
01/19/93		0.01			
01/20/93	0.11				
01/20/93	0.12				
04/28/93	0.012				
11/09/93		0.016			
11/10/93	0.048				
11/10/93	0.04				
05/03/94		0.017			
05/04/94		0.016			
10/27/94	0.037				
03/14/95	0.04				
04/19/95		0.0044			
10/20/95		0.00673			
10/23/95	0.0636				
04/16/96	0.0197				
04/18/96		0.00636			
04/12/99				0.0687	
04/13/99	0.015				
04/14/99					0.461
04/19/99			0.0657		
04/11/05		0.00513			
04/12/05			0.00886		
04/13/05				0.00658	
count	10	8	2	2	1
Median values	0.04	0.008365	0.03728	0.03764	0.461
1 STANDARD DEVIATION	0.037479	0.005341	0.040192	0.043925	----
-1 STANDARD DEVIATION	0.002521	0.003024	-0.00291	-0.00629	----
+1 STANDARD DEVIATION	0.077479	0.013706	0.077472	0.081565	----

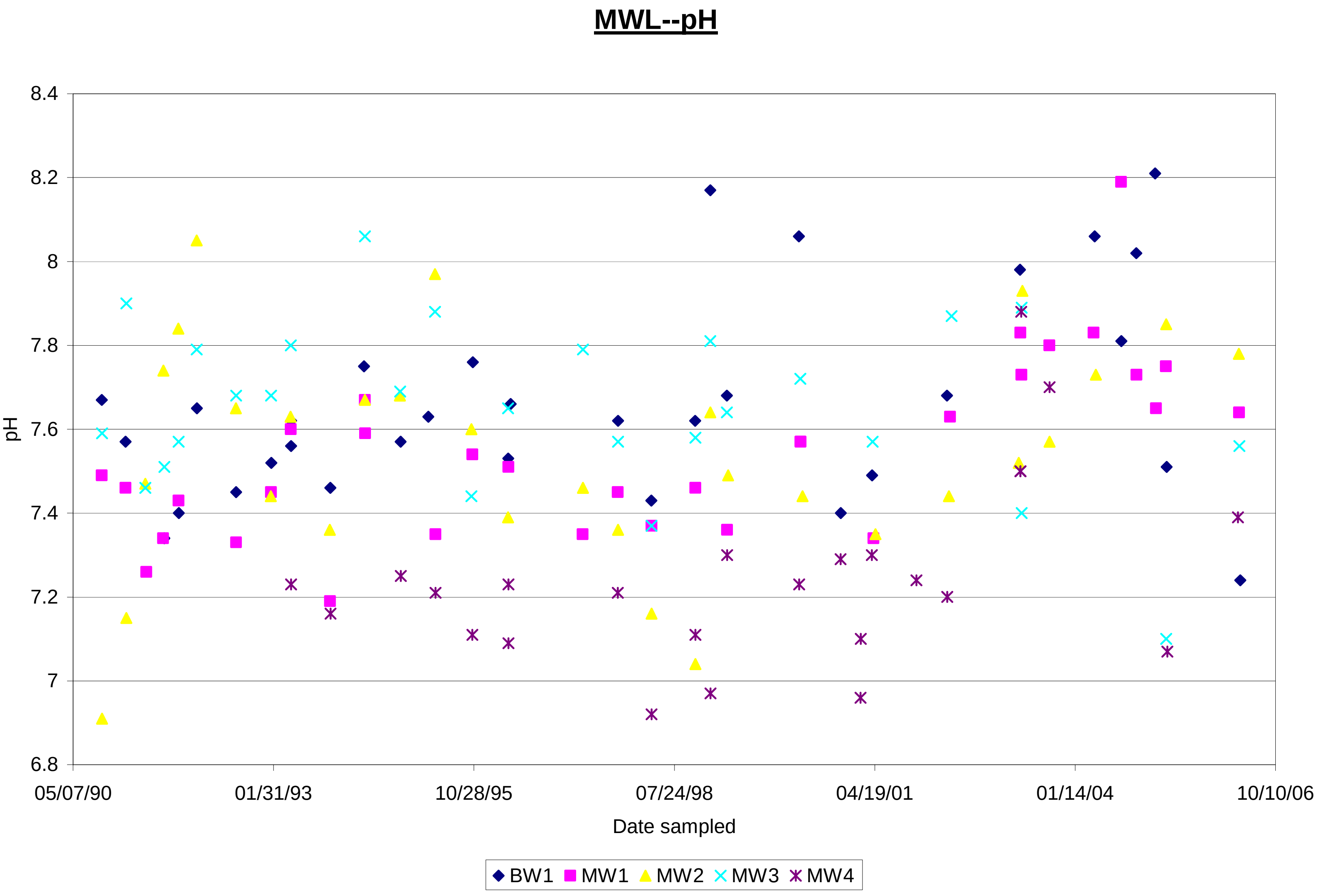
Appendix B: time-series analytical data plots

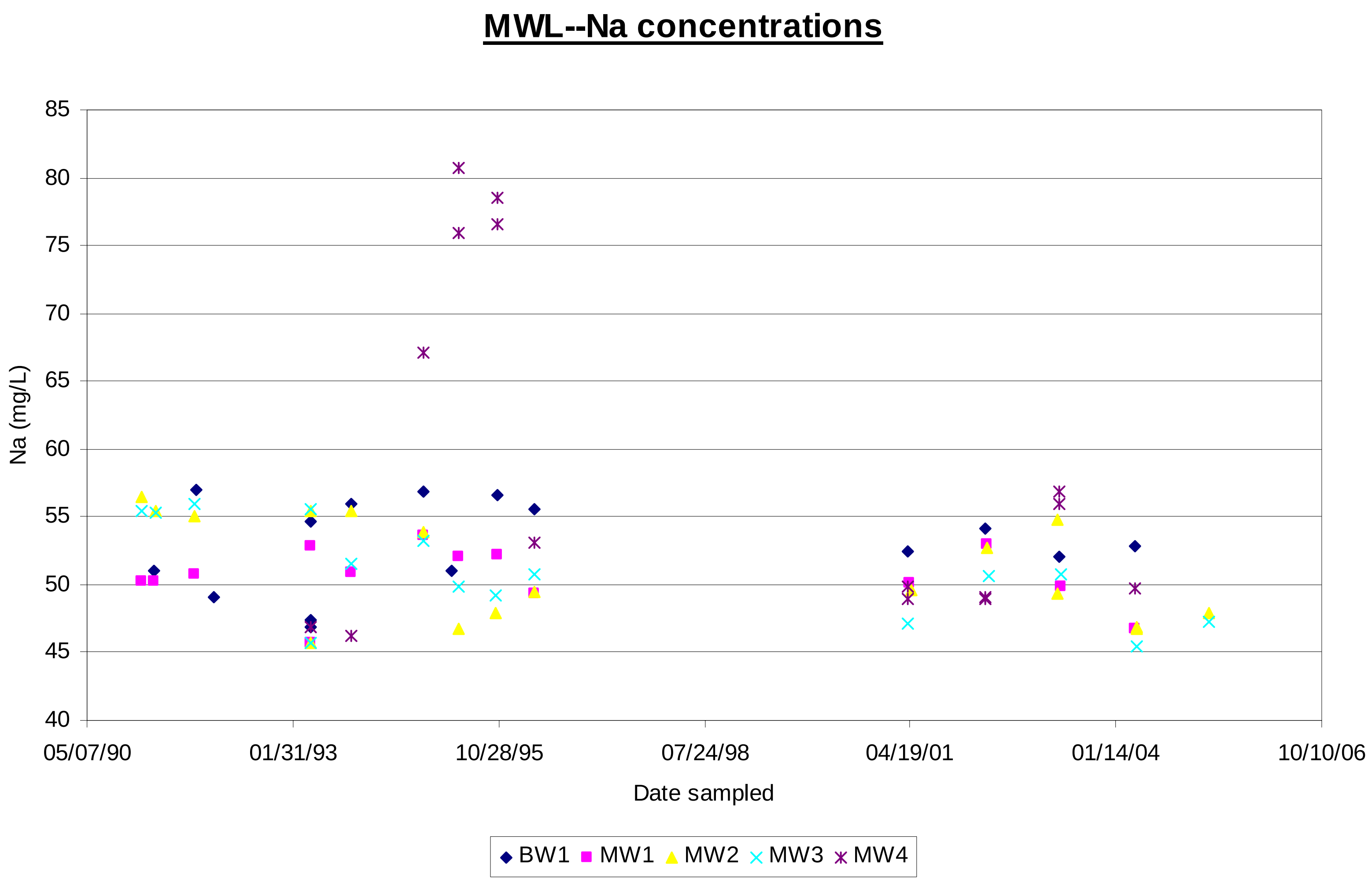

MWL--Alkalinity as CaCO3
Alkalinity as CaCO3 (mg/L)
310
290
270
250
230
210
190
170
150
09/19/91
01/31/93
06/15/94
10/28/95
03/11/97
07/24/98
12/06/99
04/19/01
09/01/02
01/14/04
05/28/05
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4

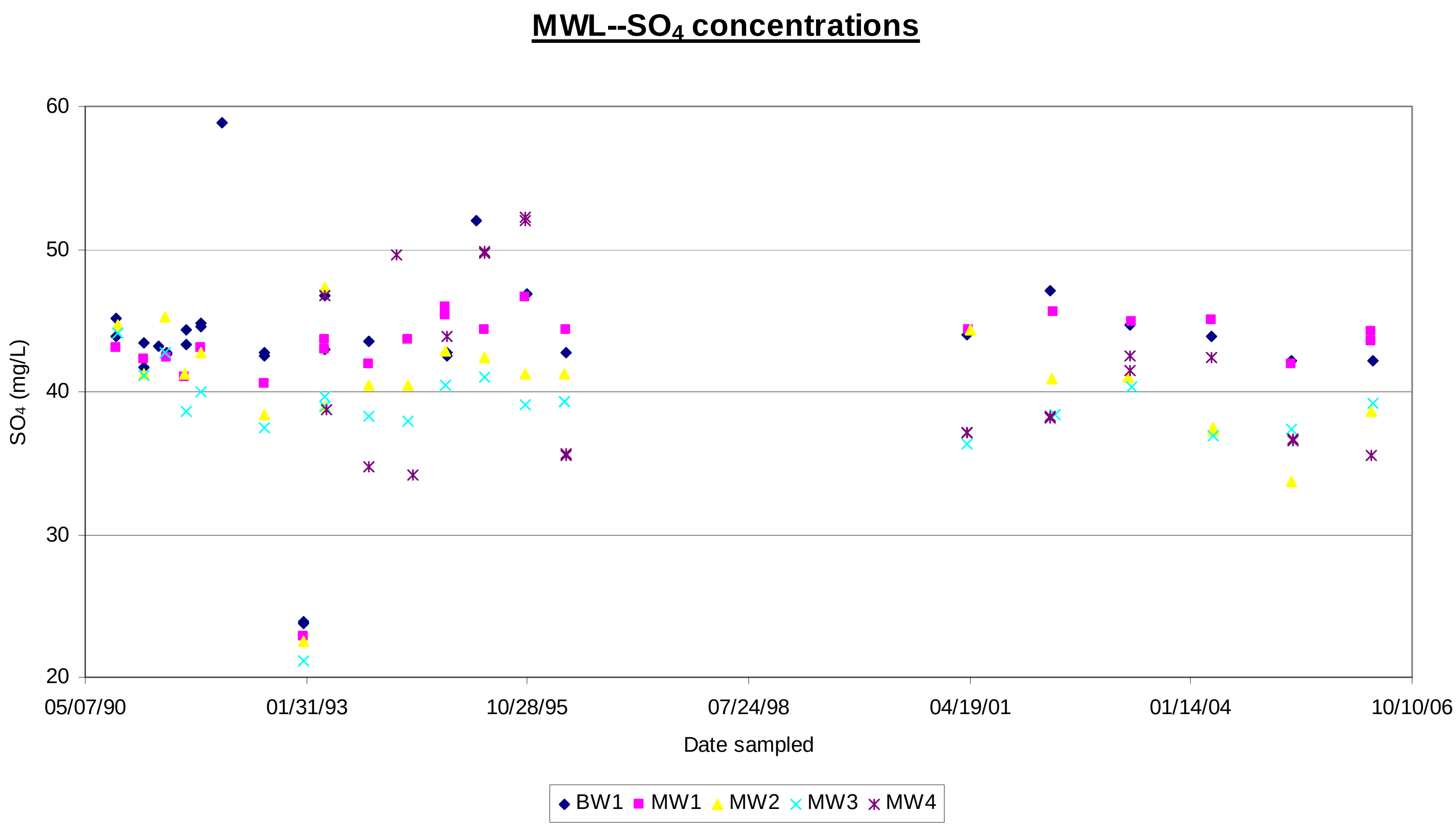

MWL--total Fe concentrations
Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4

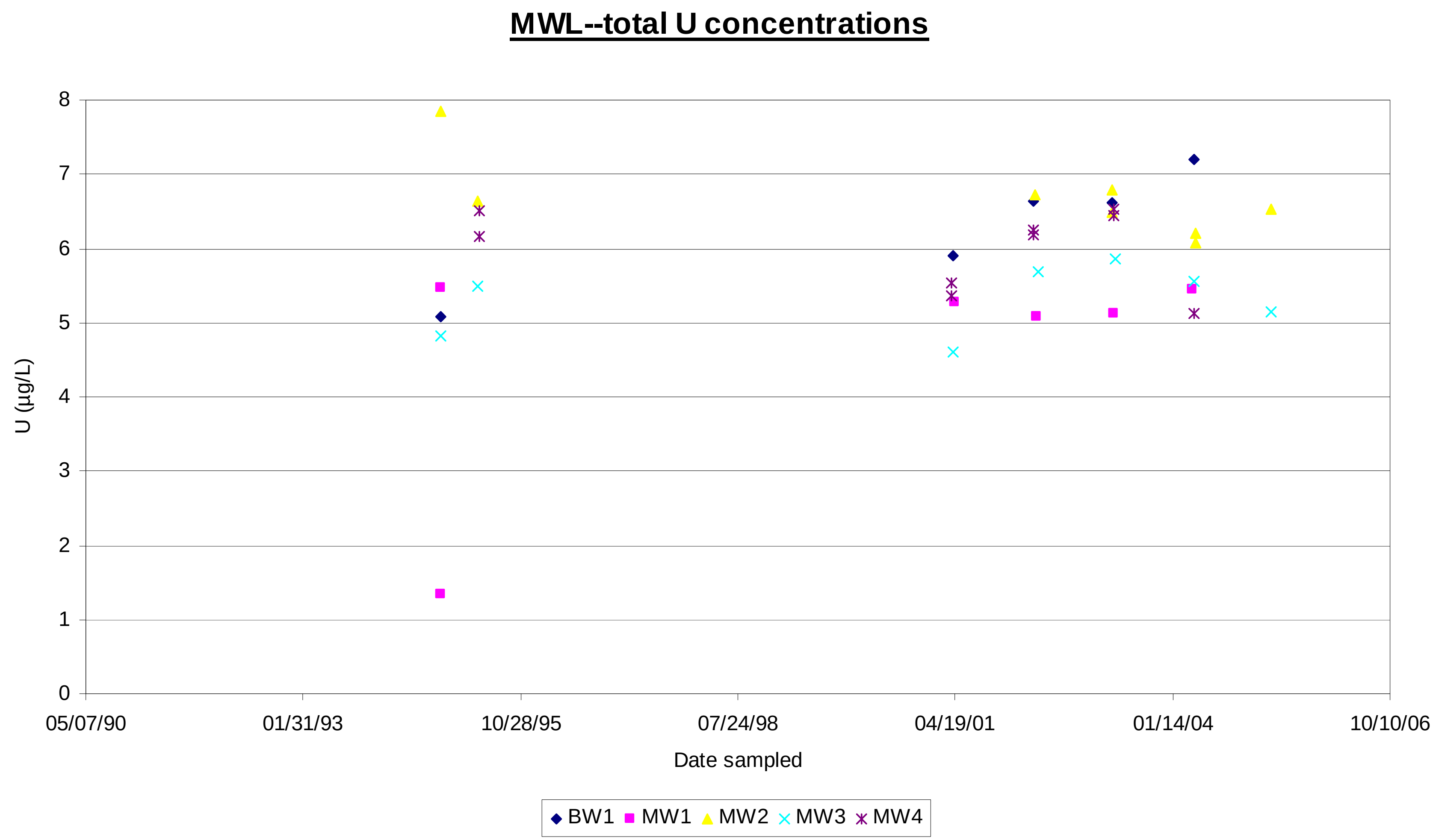

MWL--total Mn concentrations
Mn (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4

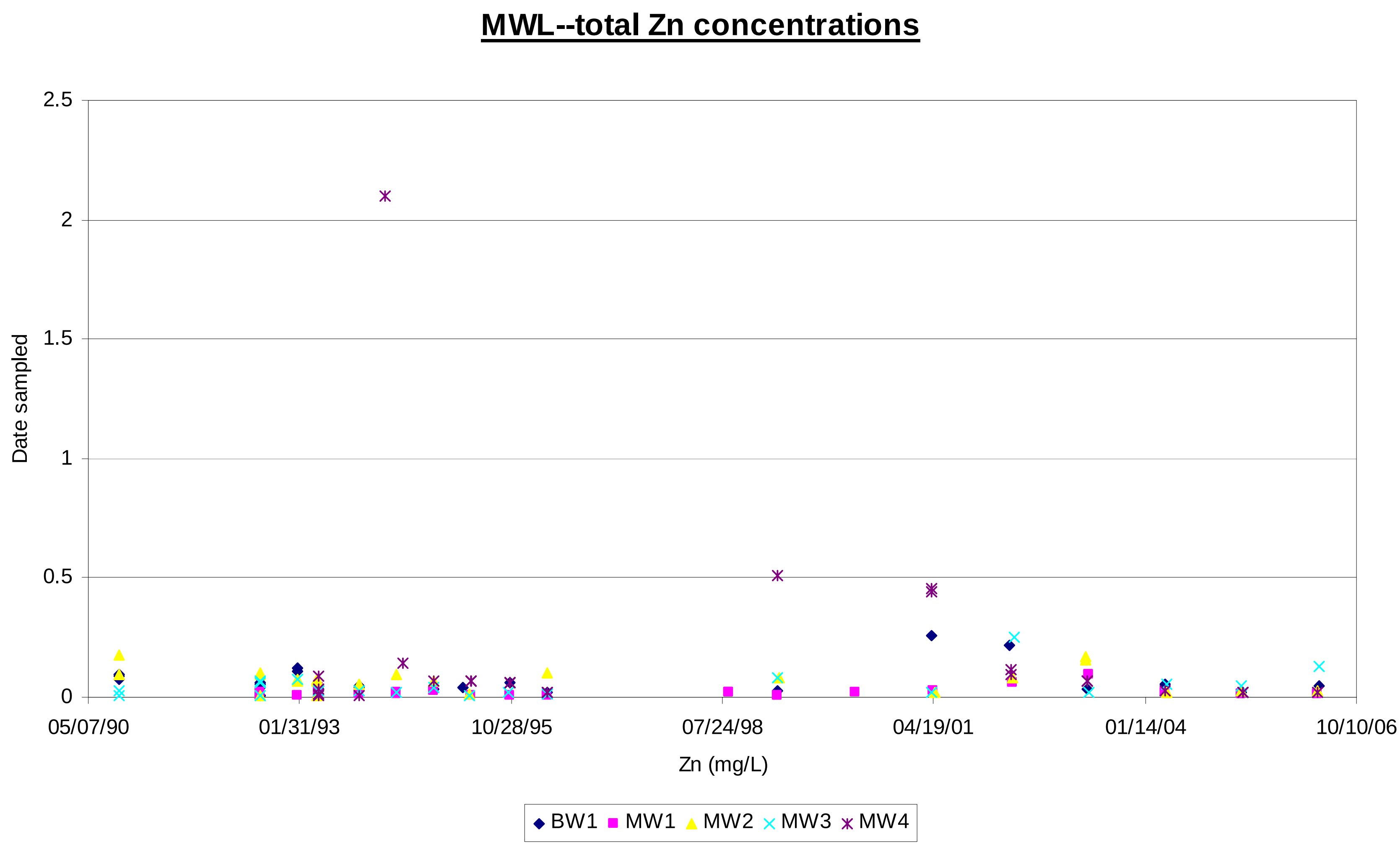

MWL--NO_3 concentrations
8
7
6
5
4
3
2
1
0
NO_3 (mg/L)
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4
MW5
MW6

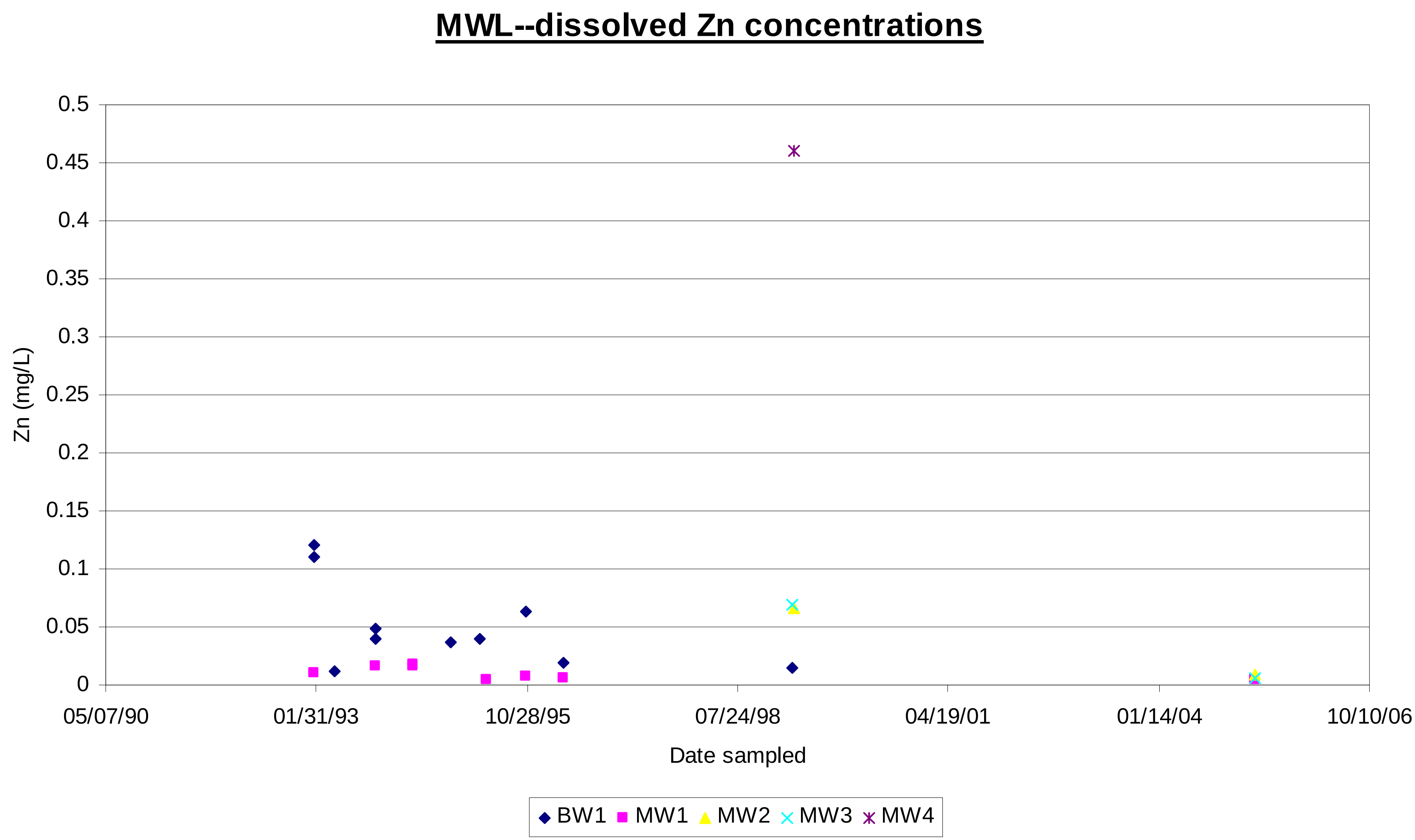

MWL--pH
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
pH
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4


MWL--Na concentrations
Na (mg/L)
85
80
75
70
65
60
55
50
45
40
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4


MWL--SO4 concentrations
60
50
40
30
20
SO4 (mg/L)
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4


MWL--total U concentrations
U (µg/L)
8
7
6
5
4
3
2
1
0
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4


MWL--total Zn concentrations
2.5
2
1.5
1
0.5
0
Date sampled
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Zn (mg/L)
BW1
MW1
MW2
MW3
MW4


MWL--dissolved Zn concentrations
Zn (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
05/07/90
01/31/93
10/28/95
07/24/98
04/19/01
01/14/04
10/10/06
Date sampled
BW1
MW1
MW2
MW3
MW4

Appendix C: Groundwater monitoring data for MW5

Groundwater Monitoring Data for MW5

Sample Date	Calcium mg/L	Aluminum (total) mg/L	Sulfate mg/L	Barium (Total) mg/L	Uranium (Total) mg/L	Zinc (Total) mg/L
01/17/01		0.136	56.8	0.133		0.0092
01/17/01						
04/16/01		0.0766	52.0	0.134	9.23	0.00577
04/16/01		0.0911	52.4		9.03	0.00632
07/24/01		0.0172		0.133		0.00572
07/24/01		0.0172				0.0051
10/08/01	77.7	0.063	50.6	0.146	9.53	0.0124
01/30/02	73.3	0.0509	55.8	0.149	9.56	0.00839
01/30/02	72.7	0.0562	55.2	0.151	9.91	0.00774
04/17/02	84.1	0.0172	56.8	0.141	9.37	0.00392
07/23/02	79.5	0.0239	52.5	0.132	8.86	0.00362
07/23/02	78.9	0.0344	54.2	0.130	8.86	0.00366
10/15/02	84.6	0.00454	57.0	0.134	9.44	0.00525
04/09/03	88	0.0111	56.8	0.129	9.53	0.00513
04/21/04	86.8	0.00454	54.3	0.133	9.58	0.00514
04/06/05		0.0413	46.7			0.0173
04/14/06		0.0244	54.7			0.0077

Volume I

TAB 12

DOE/Sandia Responses to NOD Part 1 Comments and Submittal of Soil-Vapor Sampling and Analysis Plan: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

From: SNL/Wagner
To: NMED/Bearzi

Back of Tab 12

Notes for Volume I, Tab 12:

The document included herein includes reference to a sampling and analysis plan that was appended to the "Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005," developed in response to a November 2006 request by NMED to obtain more current soil-gas volatile organic compound (VOC) and tritium data, and to sample for possible radon emissions at the Mixed Waste Landfill (Justification Binder Volume I, Tab 9). The sampling and analysis plan, entitled "Appendix A, Sampling and Analysis Plan for Soil Gas Volatile Organic Compounds, Tritium, and Radon at the Mixed Waste Landfill" and dated December 2006 can be found in Justification Binder Volume II, Tab 1.

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

DEC 2 1 2006

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Road East
Building 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the Department of Energy (DOE) and Sandia Corporation, DOE is submitting a response to the Notice of Disapproval (NOD): Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005 and Requirements for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories, EPA ID NM5890110518, HWB-SNL-05-025. The enclosed responses address Part 1 comments. We have also enclosed a Soil-Vapor Sampling and Analysis Plan as directed by the NOD. Our response to Part 2 comments will be submitted under separate cover.

In our opinion, we do not consider our response to Part 1 and the soil-vapor plan as major documents in the corrective measures process and look forward to a timely review. It is our expectation that approval of this submittal will allow the start of the cover construction process. Sub-grade preparation activities are nearing completion and maintaining the experienced field crew is critical to that process.

If you have any questions, please contact me at (505) 845-6036 or Joe Estrada of my staff at (505) 845-5326.

Sincerely,

Kimberly A Davis for
Patty Wagner
Manager

Enclosures

DEC 1 1 2008

cc w/enclosures:
W. Moats, NMED (via Certified Mail)
J. Kieling, NMED, Santa Fe
L. King, USEPA, Region VI (via Certified Mail)
T. Skibitski, NMED-OB
T. Longo, NNSA/NA-56/HQ, GTN
UNM Zimmerman Library

cc w/o enclosure:
M. Reynolds, NNSA/SSO
J. Gould, NNSA/SSO
A. Blumberg, SNL/NM, Org. 11100, MS 0141
P. Freshour, SNL/NM, Org. 6765, MS 1087
D. Miller, SNL/NM, Org. 6765, MS 0718
D. Schofield, SNL/NM, Org. 6765, MS 1087
T. Goering, SNL/NM, Org. 6765, MS 1087
S. Griffith, SNL/NM, Org. 6765, MS 1087
M. J. Davis, SNL/NM, Org. 6765, MS 1087
Records, Center, SNL/NM, Org. 6765, MS 1087

Sandia Corporation
Albuquerque, New Mexico
December 15, 2006

DOE/Sandia Responses to NMED's "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005"

Comment Set 1

INTRODUCTION

This document responds to the first set of comments received in a letter from the New Mexico Environment Department (NMED) to the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) on November 24th, 2006 regarding the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan for Sandia National Laboratories (SNL). The letter is entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005, and Requirement for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories" [EPA ID NM5890110518, HWB-SNL-05-025].

The NMED letter contains two sets of comments, divided based on subject. The first set is entitled, "Part 1, Comments on Landfill Construction Plans and Performance Modeling". The second set is entitled, "Part 2, Comments on the MWL Fate and Transport Model (Appendix E)". The NMED letter also includes a request for a Soil-Gas Sampling Plan to obtain more current soil gas data.

This response document provides the first set of NMED comments, and DOE/Sandia's responses. NMED comments are listed in boldface, followed by the DOE/Sandia response, written in normal font under "Response". This document also contains a sampling and analysis plan (SAP) requested by NMED to obtain more current data on volatile organic compounds (VOCs), tritium, and radon at the MWL. The SAP is presented in Appendix A.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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Part 1. Comments on Landfill Construction Plans and Performance Modeling

1. -- Executive Summary, Page iii, last bullet -- Define the term "climax ecological community".

<u>Response:</u> The term "climax ecological community" is a term for a late or final stage in the development of an ecological community in which the composition of plants and animals is relatively stable and well-matched to environmental conditions. In the case of the MWL, the climax ecological community would be classified as Desert Grassland (Dick-Peddie, 1992), under current climatic conditions.

2. Section 2.1 -- Provide a more detailed schedule that, at a minimum, indicates completion times for the following cover and project elements: subgrade, bio-intrusion barrier, native soil layer, topsoil layer, seeding, fencing, overall completion of project, and submittal of Corrective Measures Implementation (CMI) Report to NMED. As the actual start time is dependent on when the CMI Plan is approved, the completion times can be proposed as the number of days from the start time (assume the start time = 0 days).

<u>Response:</u> A detailed schedule for the cover construction activities is presented below. Subgrade preparation activities should be completed by December 31, 2006. The cumulative schedule assumes approval to install the cover is received at start time T=0 days (T_0). Assumptions include the following:

1) NMED approves the SAP for soil gas VOCs, tritium, and radon at the MWL within fifteen days of receiving the document, allowing rapid implementation of the soil gas sampling activities.

2) DOE/SNL complete the soil gas and tritium sampling activities by mid-January, and cover construction activities are initiated shortly thereafter, allowing the current MWL field crew and heavy equipment to be retained.

3) The cover start time T_0 assumes full NMED approval of the MWL cover design presented in the CMI Plan (SNL/NM November 2005), as well as approval of the DOE/SNL responses to the Part 1 NOD comments.

TASK	Task Duration (Working Days)	Cumulative Time From T_0 (Calendar Days)
Receive Approval To Install Cover (T_0)	**0 days**	**0**
Screen Native Soils at the Borrow Areas	50 days	78
Extend MWL-MW4 Well Casing; Service Pump and Packer	20 days	44
Haul and Place Bio-Intrusion Barrier Rock	45 days	62
Haul Native Soil from Borrow Areas to MWL	30 days	47
Place Native Soil Layer	50 days	132
Procure 3/8" Crushed Gravel for Topsoil Layer	20 days	103
Stockpile Topsoil	14 days	93
Blend 3/8" Gravel with Topsoil	15 days	118
Haul and Place Topsoil Layer	30 days	190
Seed Cover and Surrounding Area	10 days	204
Install Fencing	10 days	218
Demobilize	20 days	225
Overall Completion of the Cover Construction Project	209 days	225
Submit Corrective Measures Implementation Report to NMED	130 days[2]	407

[1]Subgrade preparation should be completed by 12/31/2006
[2]180 calendar days

3. Section 5.2.2.1.1, last paragraph -- Describe the rainfall event that was simulated in the second in situ test.

Response: A short-duration rainfall-simulation study was undertaken in 1998 to estimate evapotranspiration rates following natural rainfall events, and to provide infiltration and percolation data useful for fitting unsaturated models (SNL, April 1999; Wolford, 1998). A 10 ft by 10 ft plot was established approximately 100 ft northwest of the MWL IP test plot, located approximately 500 ft west of the MWL. A neutron access tube was installed in the center of the plot, and initial moisture contents were measured using gravimetric samples and neutron logging prior to initiating the rainfall event.

The simulated rainfall event consisted of applying 80 gallons (303 liters) of water, equal to 1.28 inches over 100 ft2, to the plot over a period of 38 minutes during the afternoon of August 20, 1998. The water was distributed uniformly over the plot by subdividing the plot into 4 quarters, and sprinkling from a hose for known time periods on each section of the plot.

The soil within the plot was subsequently sampled at 3-inch depth increments between August 20 1998 and September 30, 1998 to obtain soil-water content values over time following application of the water. The data collected were used to fit infiltration and unsaturated flow parameters, as well as to estimate evapotranspiration rates for modeling

purposes. Additional details on the artificial rainfall experiment simulated in the second in situ test are presented in Wolford, 1998.

4. Section 5.2.2.2, 1st paragraph on page 5-4 -- Specify whether the degree of compaction was measured using the standard or modified proctor test.

Response: The degree of compaction was measured using Standard Proctor tests. The results are tabulated in Attachment C of Appendix A, "Geotechnical Report", in the document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL September 1999).

5. Section 5.3.2.4, next to last sentence —This sentence refers to a sand layer with an initial water content of 0.036 cubic centimeters being used for a boundary condition, Normally, water content of soil is expressed as a percentage (of the ratio of the mass of water per the mass of solids, or in the case of volumetric water content the ratio of the volume of water to the total volume of soil). Confirm whether this value and unit of measurement are correct.

Response: The units for initial water content in the next-to-last sentence in Section 5.3.2.4 were incorrect. This sentence should read, "Instead, a coarse sand layer with an initial water content of 0.036 cm^3/cm^3 was used for its lower boundary condition".

The text in this section has been revised accordingly.

6. Section 5.7.1 -- Specify the values used for the variables R, K, LS, VM and sources of the values used in the MUSLE equation to predict soil loss by water erosion.

Response: The calculation set for potential soil loss from the MWL cover using the Modified Universal Soil Loss Equation (MUSLE) was originally presented in Appendix D of the document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL/NM September 1999). A copy of this calculation set, entitled "Erosion and Slope Stability Calculations", is included as Attachment 1 to this NOD response. This calculation set includes copies of the tables and figures from which the variables R, K, LS, and VM were determined.

References used to prepare this calculation set include

- Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. KHera, February, 1998.
- AGRA, Mixed Waste Landfill Cover, Tabulation of Test Results performed by AGRA Earth & Environmental on May 17, 1999.

Values used for the variables and sources for the values are shown in the table below.

Parameter	Variable	Value	Additional Information
Rainfall Factor	R	35	Determined from isoerodent map of the western United States, illustrating average annual values of the rainfall factor, R. See Figure 1, Sheet 9 of Attachment 1.
Soil Erodibility Factor	K	0.44	Approximate value of K, based on a loamy very fine sand with organic content < 0.5%. See tabulation of AGRA test results, Table 1, Sheet 10 of Attachment 1; K determined from Table 2, Sheet 12, of Attachment 1.
Topographic Factor for Cover (2% slope)	LS	0.28	See Sheets 5 and 6 of Attachment 1.
Topographic Factor for Sideslope (16.7% slope)	LS	1.32	See Sheets 5 and 6 of Attachment 1.
Erosion Control Factor for Cover (no vegetation)	VM	0.06	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See Sheet 7 and Sheet 14 of Attachment 1.
Erosion Control Factor for Sideslope (no vegetation)	VM	0.11	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See Sheet 7 and Sheet 14 of Attachment 1
Erosion Control Factor for Cover and Sideslope (vegetation established)	VM	0.01	Assumes that vegetation is established on both the cover and side-slopes 12 months after seeding, and assumes that one-half the straw mulch remained. See Sheet 8 and Sheet 15 of Attachment 1.

7. Section 5.7.2 -- Specify the values used for the variables I, k, C, L, V and sources of the values used in the WEQ equation to predict soil loss by wind erosion.

<u>Response:</u> The calculation set for potential soil loss from the MWL cover using the Wind Erosion Equation (WEQ) was originally presented in Appendix D of the document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL/NM September 1999). A copy of this calculation set, entitled "Erosion and Slope Stability Calculations", is presented as Attachment 2 to this NOD response. This calculation set includes copies of the tables and figures from which the variables I, k, C, L, and V were determined.

References used prepare this calculation set include

- Natural Resources Conservation Service (NRCS) National Agronomy Manual, 190-V-NAM, 2nd Ed., Part 502, March 1988.

- 2) N.P. Woodruff and F.H. Siddaway, 1965. "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, No. 5, Pages 607-608.

Values used for the variables and sources for the values are shown in the table below.

Parameter	Variable	Value	Additional Information
Soil Erodibility Index for Cover (2% slope)	I	134 tons/acre/year	Based on erodibility index for a loamy very fine sand, as determined by AGRA test results. See Sheet 2, 9 and 11 of Attachment 2.
Soil Erodibility Index for Sideslope (16.7% slope)	I	188 tons/acre/year	Based on erodibility index for a loamy very fine sand, as determined by AGRA test results. See Sheets 3, 9 and 11 of Attachment 2.
Total Surface Roughness (Cover and Sideslope)	k	1.0	Based on the assumption that the engineered cover and sideslopes will be smooth and without ridges. See Sheets 3, 4, 13 and 14 of Attachment 2.
Climatic Factor	C	120	Index of the relative erosivity by geographic location. See Sheets 5 and 15 in Attachment 2.
Unsheltered Distance (Cover)	L	524 ft	Field length along the prevailing wind direction. See Sheets 5 and 15 of Attachment 2.
Unsheltered Distance (Sideslope)	L	25 ft	Field length along the prevailing wind direction. See Sheets 5 and 15 of Attachment 2.
Vegetative Cover Factor (Cover)	V	4,500 small grain equivalent	Assumes no vegetation was yet established; that straw mulch had been applied to the cover and side-slopes at 2 tons/acre, and that the mulch was crimped into soils with a disk. See
Vegetative Cover Factor (Sideslope)	V	3,200 small grain equivalent	Assumes vegetation is established on cover and sideslopes 12 months after seeding, and one half the straw mulch remains. Also assumes that 400 small grain equivalent of native grass is established on cover and sideslopes.

8. Section 7.0 -- The NMED expects the vadose zone to be monitored for volatile organic compounds, tritium, and radon, in addition to soil moisture. The NMED may also require soil-gas monitoring to be conducted at depths other than at 173 feet, as implied by the Permittees in the second paragraph of Section 7.1. Monitoring details will need to be included in the long-term monitoring and maintenance plan, due within 180 days following approval of the CMI Report. No response is required at this time.

Response: DOE/Sandia are proposing a robust soil-gas monitoring system for long-term monitoring at the MWL. The soil-gas monitoring system will serve as an early-warning system to protect groundwater from potential migration of contaminants. Additional information regarding the proposed monitoring, including the parameters and depths to be monitored, will be included in the DOE/Sandia responses to the second set of comments within this NOD (Part 2). Further details will be included in the Long Term Monitoring and Maintenance Plan (LTMMP), to be submitted within 180 days of the NMED's approval of the MWL CMI Report.

9. Figure 5-1 -- Clarify which curves are representative of the PET data from the four National Weather Service stations in New Mexico and which are representative of the predicted PET data.

Response: The PET curves for the Cochiti, Elephant Butte, Socorro, and Bosque del Apache National Weather Service Stations are delineated by wider lines and have no symbols. The curves representing the PET data predicted by HELP-3 are delineated by much narrower

lines, and have symbols identifying the monthly PET values predicted by the model.

10. Appendix A, Construction Specifications, Section 02930, Reclamation seeding and Mulching, Part 3.1.2, #1 -- Explain why the TA-3 borrow pits are not to be reseeded by the contractor, given that erosion of the borrow pits should be prevented.

Response: Once the MWL cover has been constructed and the TA-3 borrow pits are no longer required for environmental restoration activities, they may be transferred over to Sandia Facilities for continued use at Sandia. However, if the TA-3 borrow pits are not needed by Facilities, they will be seeded and reclaimed as described in Appendix A, Construction Specifications, Section 02930, Reclamation Seeding and Mulching.

11. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.3, #4 -- The Permittees should consider changing the requirement that no proof rolling be conducted within 2 feet of any groundwater monitoring well, measuring device, or other placed surface. The NMED strongly suggests changing the requirement to preclude all heavy equipment from operating within 3 feet of wells or other measuring devices.

Response: The requirement will be changed to preclude all heavy equipment from operating within 3 feet of any monitoring well or measuring device.

12. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.4, #8 and Part 3.3.6., #9 -- Both of these sections contain language stating that nonconforming work shall be redone until the specifications are attained "or the Operator accepts the placement conditions". Please note that the NMED expects construction of the cover to comply substantially with the specifications in the approved CMI Plan. Failure to achieve the specifications in the approved CMI Plan, or obtain an NMED-approved change, could lead to disapproval of part or all of the constructed cover.

Response: Sandia fully expects to construct the MWL cover to meet all specifications identified in the CMI Plan. If these specifications cannot be met for any reason, the NMED will be informed of these discrepancies and a mutually-acceptable corrective action will be determined and implemented.

13. Appendix A, Construction Specifications, Section 02200, Earthwork Part 3.3.6 -- The NMED strongly recommends that the Permittees add to the specifications for construction of the native soil layer a requirement for a minimum number of passes with compaction equipment.

Response: Part 3.3.6 of Section 02200 describes the installation of the native soil layer. Item 5 of Part 3.3.6 states that for each lift "The Contractor shall compact to not less than 90 percent of maximum dry density at -2 to +2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing)." Item 9 of the same section further states that "Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full depth of the lift and recompacted until the specifications are attained or the Operator accepts the

placement conditions."

With the requirement that the lifts be compacted, and tested to meet a specified compaction, it is not necessary to count the number of passes of compaction equipment, as long as the construction specifications are met.

14. Appendix B, Construction Quality Assurance Plan, Section 2.6.3, first sentence — Clarify what is meant by the first sentence: "The CQA Certifying Engineer is responsible for...certifying the CQA document has been approved by the NMED". Did the Permittees intend, instead, to require that the CQA Certifying Engineer be responsible for certifying the results of the CQA Report that is to be submitted for NMED approval? If so, the first sentence should be revised to state "The CQA Certifying Engineer is responsible for certifying in a statement to the owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications". The next sentence of the paragraph explains further that the certification statement would normally be included in a CQA Report.

Response: The first sentence will be revised to state "The CQA Certifying Engineer is responsible for certifying in a statement to the owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications."

15. Appendix B, Construction Quality Assurance Plan, Section 8.7 -- The Final Report must be submitted to the NMED as part of the CMI Report. The Final Report must include copies of all quality control data generated by the construction contractor as well as the quality assurance data generated by the CQA contractor.

Response: The Construction Quality Assurance Plan will include all quality control data generated by the construction contractor as well as quality insurance data generated by the CQA contractor. The Construction Quality Assurance Plan will be submitted to the NMED as part of the CMI Report.

16. Demonstrate with calculations and other information whether run-off and run-on controls have been adequately designed to handle peak precipitation events. Evaluate and discuss whether additional run-on controls should be constructed at locations further away from the landfill (e.g., at distances of 25 to 50 meters) to provide more protection for the cover from heavy rainfall events.

Response: Calculations have been prepared regarding the adequacy of the run-off and run-on controls for handling peak precipitation events. The complete calculation set and supporting exhibits are presented in Attachment 3. The calculation results are summarized below.

The site will be graded such that runoff from the site flows north, west and east. There is a high point on the north side of the site that prevents flow from running onto the site. Two swales will be provided to carry the flow to the north or the south. This may be seen in Exhibit 1: Mixed Waste Landfill Final Cover Grading Plan", included in the complete

calculation set (Attachment 3).

The watershed basin draining onto the site has been delineated and is shown on Exhibit 2 of Attachment 3. It is divided in to a north basin and a south basin that drain to the north and south swales respectively.

Runoff was calculated using the City of Albuquerque Development Process Manual (City of Albuquerque 2006) criteria for the 100 year –6 hour storm. The north basin generates 24 cfs and the north swale has the capacity for 79 cfs. The south basin generates 6.5 cfs and the capacity of the south swale is 58 cfs.

The swales are therefore sized with abundant capacity to prevent flow from entering the site and to carry the runoff around the site.

The general drainage pattern in this area is a gentle slope to the west. After the flow is discharged from the site, it drains westward and no additional controls are needed. Exhibit 2 shows the topography up to a minimum of 200 feet beyond the site to illustrate this.

17. Identify the criteria to be applied to determine whether the establishment of vegetation on the final cover is acceptable, including, but not limited to, species diversity, plant survival, and the extent of ground cover. Explain how measurements will be conducted in the field to assess these criteria.

Response: Establishment of the desired vegetation community on the MWL cover is anticipated to be the result of a successional process. Ecological succession is a generally predictable pattern of orderly changes in the composition or structure of an ecological community. Succession on the MWL will be initiated by the formation of this new, unoccupied habitat on the cover.

The MWL cover will be seeded with grass species that have been identified as native to the surrounding area. These grasses will eventually out-compete the weedy plants that dominate early in plant community succession. The final cover soil has been collected from the local area in order to provide the correct growing substrate for the seeded plant species. This soil is expected to contain a significant amount of weed seed, including large amounts of *Salsola tragus* seeds, commonly known as Russian thistle or tumbleweed. No supplemental watering is planned for the MWL, although supplemental watering is widely recommended to facilitate establishment of native plants in a chosen area. Due to a large amount of weed seeds and no supplemental watering, the early succession period is anticipated to be long.

Mature Plant Community Criteria

Vegetation on the MWL cover will be surveyed by a qualified biologist on a regular basis. This survey will include:

- Identification of any barren areas
- Identification of all plant species present on the cover

- Quantification of plant species present on the cover

Plant species will be identified according to their scientific names. Plant species will be quantified by determining the percent cover of each actively photosynthesizing species contained within a one-meter by one-meter survey quadrat. These quadrat survey locations will vary across the cover at the time of each inspection in order to best reflect plant cover across the MWL.

The mature, secondary plant community will be achieved when greater than 50% of the photosynthesizing foliar coverage is comprised of grass species native to the general TA-III area.

General Comments and Requirements for Soil-Gas Sampling

As the Permittees are aware, most site characterization data for the MWL (other than groundwater data) dates before the mid 1990's. Because the rupturing of containers and the leaking of their contents could have occurred since the mid 1990's, the NMED requires more current soil-gas data to help resolve this issue. The Permittees shall therefore collect and analyze active soil-gas samples taken at depths of 10 and 30 feet at a minimum of three locations within the landfill where previous sampling has detected the highest soil-gas concentrations in the past. The soil-gas samples shall be analyzed for volatile organic compounds, tritium, and radon. Pursuant to Section VI.A of the Order on Consent (April 29, 2004), the Permittees shall provide for approval to the NMED within 30 days of receipt of this letter a work plan to conduct the active soil-vapor sampling described above. The work plan shall be prepared in accordance with Section X.B of the Consent Order.

Response: A work plan has been developed which presents plans for sampling and analysis of soil gas at six locations within or adjacent to the MWL, and at two background locations. Soil gas samples will be collected at depths of 10 and 30 feet, and analyzed for VOCs. Soil samples will be collected from the same locations and depths, and analyzed for tritium in soil moisture. Samples for analysis of radon are difficult to obtain from soil gas samples; instead, radon sampling is proposed to be conducted along the MWL perimeter once the MWL cover has been completed.

The sampling and analysis plan for soil gas VOCs and tritium and radon is presented in Appendix A.

References

City of Albuquerque, 2006, "Albuquerque Development Process Manual", October 2006 Revision, published by American Legal Publishing Corporation, 432 Walnut Street, Cincinnati, Ohio 45202.

Dick-Peddie, W.A. 1992, "New Mexico Vegetation Past, Present and Future." University of New Mexico Press, Albuquerque, NM. 244 pp.

Sandia National Laboratories/New Mexico (SNL/NM), September, 1999, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico", prepared for US DOE by Sandia National Laboratories Environmental Restoration Project, Albuquerque, New Mexico, September 23, 1999.

Sandia National Laboratories/New Mexico (SNL/NM), November 2005. "Mixed Waste Landfill Corrective Measures Implementation Plan", prepared at Sandia National Laboratories by J. Peace, T. Goering, C. Ho and M. Miller for the U.S. Department of Energy, Albuquerque, NM.

Wolford, R.A., 1998, Preliminary unsaturated flow modeling and related work performed in support of the design of a closure cover for the Mixed Waste Landfill. Prepared by GRAM, Inc. for the Mixed Waste Landfill Cover Project, Environmental Restoration Program, Organization 6135. Sandia National Laboratories, Albuquerque, NM, November 10, 1998.

Attachment 1

Universal Soil Loss Calculations for the MWL Cover

Using the

Modified Universal Soil Loss Equation (MUSLE)

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Purpose:

Determine the soil loss due to sheet and rill erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Modified Universal Soil Loss Equation (MUSLE). This calculation only presents potential loss.

References:

1. Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. Khera, February, 1998.
2. AGRA, Mixed Waste Landfill Cover, Tabulation of Test Results performed by AGRA Earth & Environmental on May 17, 1999.

Soil Loss Calculations

Modified Universal Soil Loss Equation (MUSLE):

$$A = RK(LS)(VM)$$

Where:

A = Average annual soil loss (Tons/Acre/yr.)

R = Rainfall factor

K = Soil erodibility factor

LS = Topographic factor

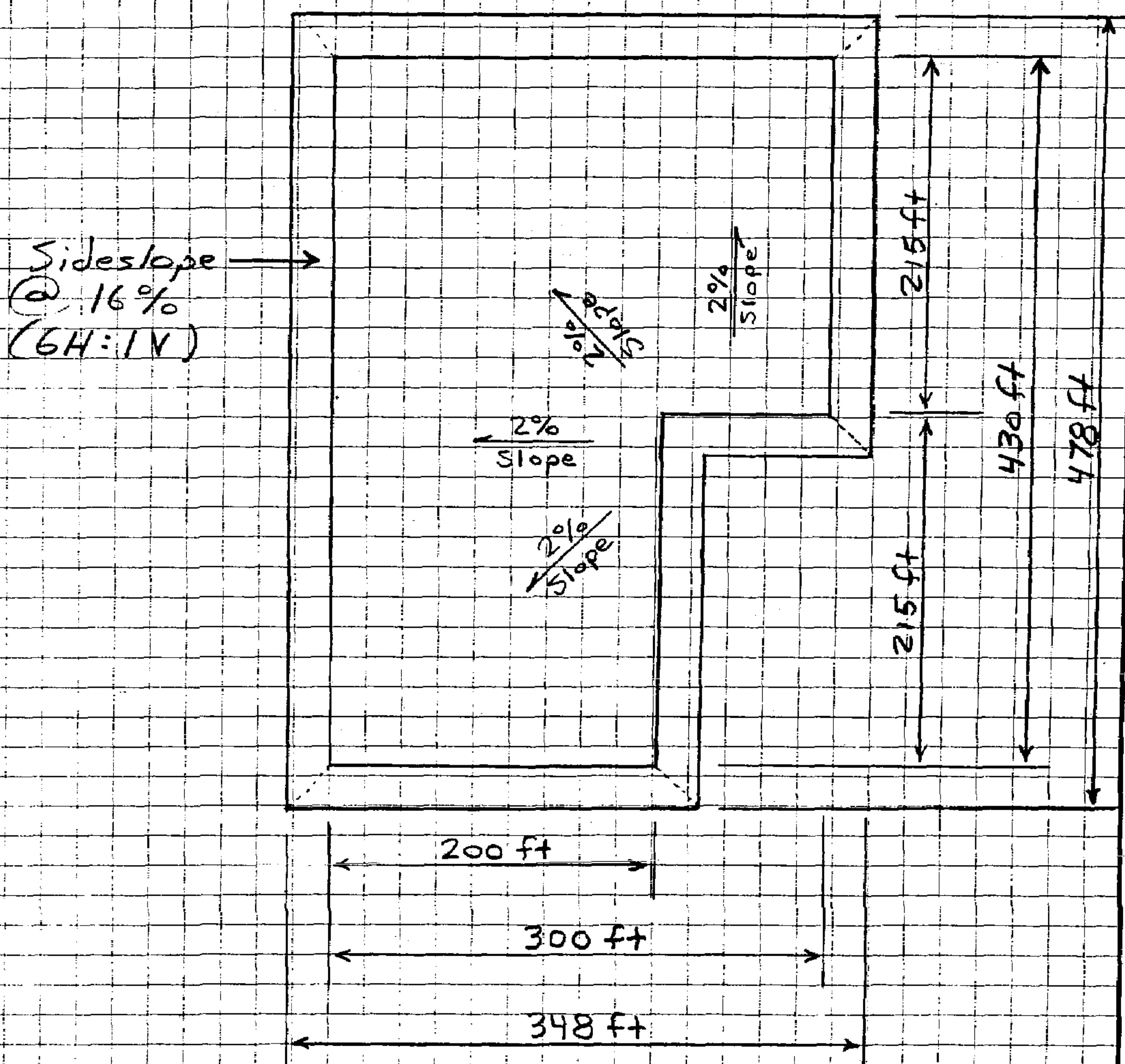
VM = Erosion control factor

GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Plan View Cover



GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Area of Cover

$$A_c = (200\,ft \times 215\,ft) + (200\,ft \times 215\,ft) + (100\,ft \times 215\,ft)$$

$$= 107{,}500\,ft^2$$

$$= 107{,}500\,ft^2 / 43{,}560\,ft^2/Acre$$

$$= \underline{\underline{2.47\ Acres}}$$

Area of Sideslopes

$$A_{SS} = (24\,ft \times 478\,ft) + (24\,ft \times 200\,ft) + (24\,ft \times 239\,ft) + (24\,ft \times 100\,ft) + (24\,ft \times 215\,ft) + (24\,ft \times 324\,ft)$$

$$= 37{,}344\,ft^2 / 43{,}560\,ft^2/Acre$$

$$= \underline{\underline{0.86\ Acres}}$$

Total Area of Cover and Sideslopes

$$A_{TOT} = A_c + A_{SS}$$

$$= 2.47\ Acres + 0.86\ Acres$$

$$= \underline{\underline{3.33\ Acres}}$$

By: M. McVey	Date: 8/19/99	Title: Potential Soil loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

1) Determine rainfall factor, R:
From Figure 1 (Sheet 9)
⟹ R = 35

2) Determine soil erodibility factor, K:
- From Tabulation of AGRA Test Results, Table 1 (Sheet 10), USCS Classifation = SM
- USDA classification for SM with sand fraction > 70% is loamy sand, Figure 2 (Sheet 11).
- Percent passing #170 sieve indicates that sand fraction is predominantly fine to very fine.

⟹ Loamy very fine sand

From Table 2 (Sheet 12), K for a loamy very fine sand with organic content < 0.5%
= 0.44

K = 0.44

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

3) Determine topographic factor, LS:

$$LS = \frac{(L/72.6)^m (65s^2 + 450s + 650)}{(s^2 + 10{,}000)}$$

where:

L = Slope length (See sheet 13)

s = slope steepness (%)

m = exponent

0.20 for s < 1

0.30 for 1 ≤ s < 3

0.40 for 3 ≤ s < 5

0.50 for 5 ≤ s < 10

0.60 for s ≥ 10

$$LS_{(2\%)\,\text{Cover}} = \frac{(327/72.6)^{0.3} (65(2)^2 + 450(2) + 650)}{(2)^2 + 10{,}000}$$

$$= \underline{\underline{0.28}}$$

for:

L = 327 ft

s = 2%

m = 0.30

GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

$$LS_{(16.7\%)\ \text{Sideslopes}} = \frac{(24/72.6)^{0.6}\left(65(16.7)^2 + 450(16.7) + 650\right)}{(16.7)^2 + 10{,}000}$$

$$= \underline{\underline{1.32}}$$

for:

L = 24 ft (See sheet 13)

S = 16.7%

m = 0.60

MUSLE:

$$A = RK(LS)(VM)$$

$$A_{(2\%\ \text{Cover})} = 35(0.44)(0.28)(VM)$$

$$= \underline{\underline{4.31(VM)}}$$

$$A_{(16.7\%\ \text{Sideslopes})} = 35(0.44)(1.32)(VM)$$

$$= \underline{\underline{20.33(VM)}}$$

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

4) Determine erosion control factor, VM:

Case 1 : No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimpted into soils with disk.

From Table 3 (Sheet 14)

$\Longrightarrow VM_{(2\%\ Cover)} = 0.06$

$\Longrightarrow VM_{(16.7\%\ Sideslopes)} = 0.11$

For 2% Cover Slope

$A = 4.31(0.06) = 0.26$ Tons/acre/yr.

For 16.7% Sideslopes

$A = 20.33(0.11) = 2.24$ Tons/acre/yr.

$$\text{Total Soil Loss} = \frac{(0.26\ Tn/Ac/Yr)(2.47\ Ac) + (2.24\ Tn/Ac/Yr)(0.86\ Ac)}{2.47\ Ac + 0.86\ Ac}$$

$= 0.77$ Tons/Acre/yr. $<$ 2 Tons/Acre/yr.

OK

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; ½ straw mulch remains.

From Table 4 (Sheet 15)

$\Rightarrow$ VM = 0.01

For 2% Cover Slope

A = 4.31 (0.01) = 0.04 Tons/Acre/yr.

For 16.7% Sideslopes

A = 20.33 (0.01) = 0.2 Tons/Acre/yr.

$$\text{Total Soil Loss} = \frac{(0.04\ \text{Tn/Ac/yr.})(2.47\ \text{Ac}) + (0.2\ \text{Tn/Ac/yr.})(0.86\ \text{Ac})}{2.47\ \text{Ac} + 0.86\ \text{Ac}}$$

= 0.08 Tons/Acre/yr. < 2 Tons/Acre/yr.

OK

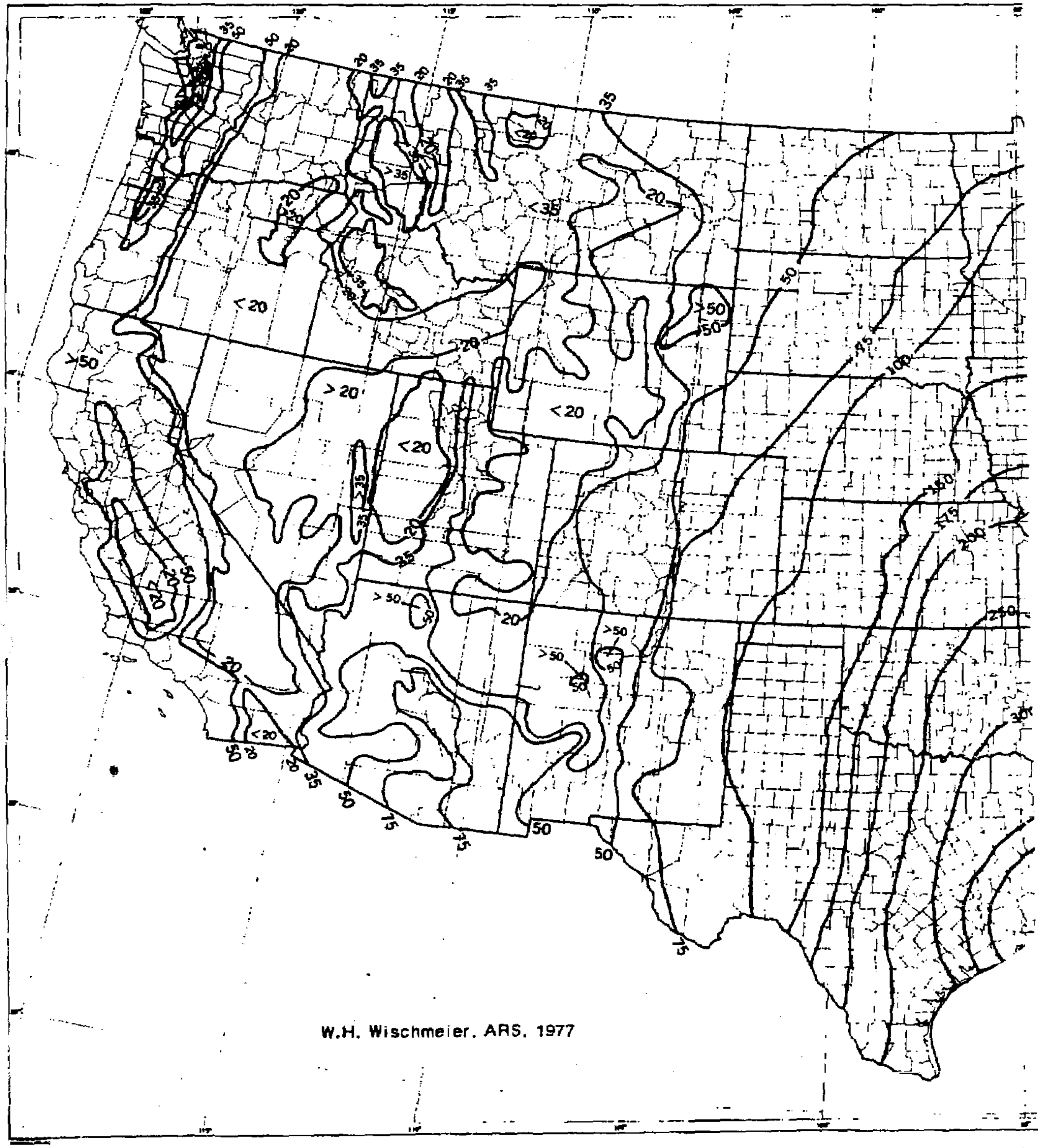


Figure 1 —Iso-erodent map illustrating average annual values of the rainfall factor, R.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

PROJECT: Mixed Waste Landfill Cover

DATE: 05/17/99

SOURCE: SNL

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
Composite MWL-A1	0"-2'	ML	NV	NP	58	64	82	85	87	89	95	98	99	100		4.5	4557
Composite MWL-1B	2'	SM	NV	NP	25	35	56	73	79	87	95	99	100			4.3	4560
Native Soil	1 of 3	SM	NV	NP	24	35	68	74	78	83	90	94	97	100		4.8	4565
Native Soil	2 of 3	SM-SC	22	6	31	42	70	75	78	84	91	96	98	100		6.2	4566
Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	88	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

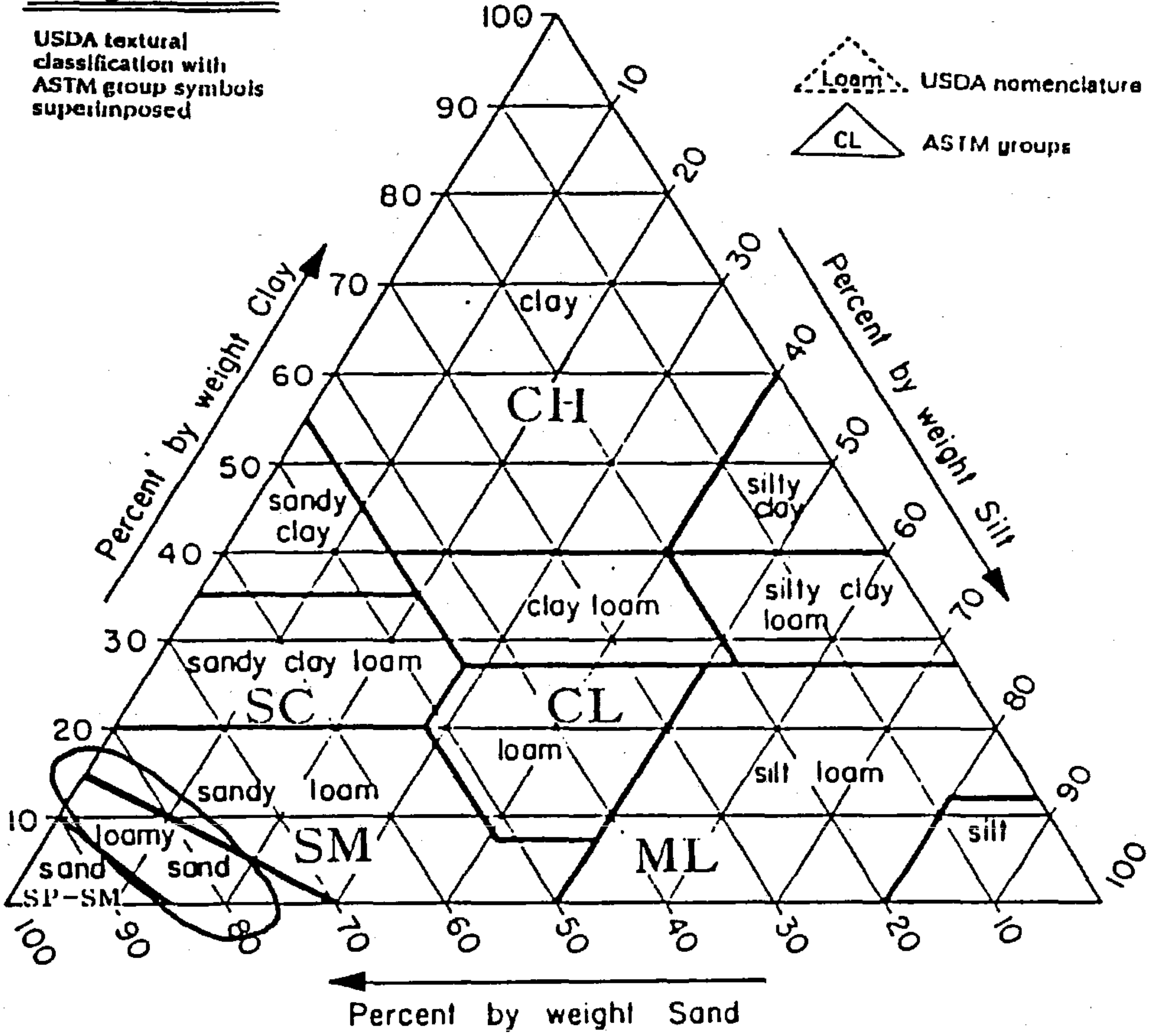
SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

Figure 2.

USDA textural classification with ASTM group symbols superimposed



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Sheet 12 of 15

Example 12.3

A landfill in south New Jersey is designed to have a cover with a slope of 5% of a top plateau extending from a central ridge (high point) for a distance of 300 ft. Beyond this distance, the cover slopes down to the toe at a grade of $1V$ on $4H$. The upper cover component is loamy sand with 2% organic content. Grass is the only means of erosion control. Determine the expected soil loss from sheet flow.

Solution: From Figure 12.7, $R = 200$. From Table 12.9, $K = 0.1$. From Eq. 12.21:

LS (top plateau), $m = 0.4$

$LS = (300/72.6)^{0.4}(65 \times 25 + 450 \times 5 + 650)/(25 + 10{,}000) = 0.794$

LS (side slope), $m = 0.6$

$LS = (500/72.6)^{0.6}(65 \times 625 + 450 \times 25 + 650)/(625 + 10{,}000) = 15.73$

To determine the soil loss, we begin by using Eq. 12.20 for the top plateau:

$$A = 200(0.1)(0.79)(VM) = 15.8(VM)$$

From Table 12.8, the VM factors are 0.4, for grass seedings less than 2 months old, 0.05 for those 2 to 12 months old, and 0.01 for those over 12

Table 2.

Approximate values of factor K for USDA textural classification

Texture class	Organic matter content <0.5% K	2% K	4% K
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
→ Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13–0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

Source: Lutten et al., 1979

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
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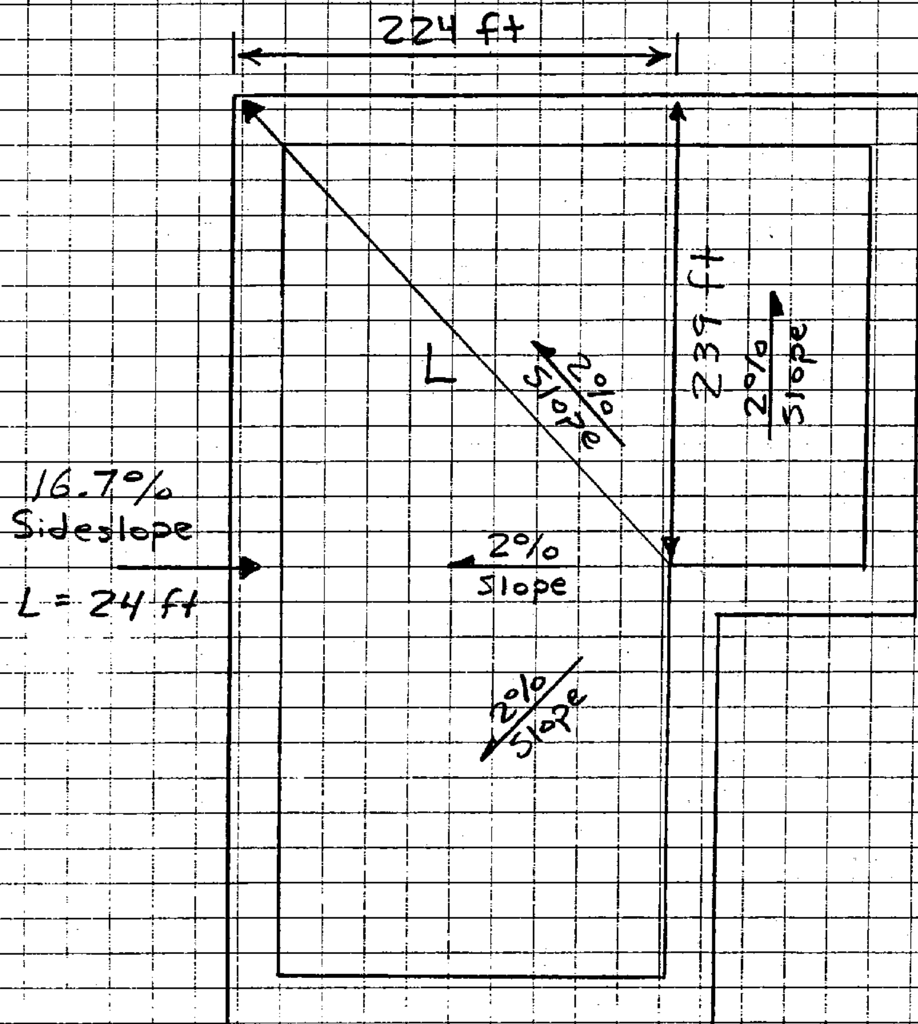

For 2% Cover Slope

L = 327 ft

For 16.7% Sideslopes

L = 24 ft

Straw or hay mulches applied to steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana, tests on a 20% slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil losses of 12 t/A when 5 in. of simulated rain was applied at 2.5 in./hr on a 35-ft plot (Wischmeier and Meyer, 1973). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective.

Table IV presents approximate C values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed to be applicable.

Soil loss ratios for many conditions on SLB, construction, and developmental areas can be obtained from Table IV if good judgment is exercised in comparing the surface conditions with those of specified agricultural conditions. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influence of unpredictable random variables and experimental error. The percentages listed for Table V are the best available averages for a wide variety of specified agricultural conditions, only a few of which might be applicable to SLB systems. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily more accurately represent the true average for that locality. Small samples are more subject to bias by random variables and experimental error than are larger samples.

Table 3.

MULCH FACTORS AND LENGTH LIMIT[S] FOR CONSTRUCTION SLOPES[a]

Type of Mulch	Mulch Rate (Tons/Acre)	Land Slope (%)	Factor C	La[...] Li[...] (
None	0	all	1.0	.
Straw or hay,	1.0	1-5	0.20	2
tied down by	1.0	6-10	0.20	1
anchoring and				
tacking	1.5	1-5	0.12	3
equipment[c]	1.5	6-10	0.12	1
2% Cover Slope →	2.0	1-5	0.06	4
	2.0	6-10	0.06	2
	2.0	11-15	0.07	1
16.7% Sideslopes →	2.0	16-20	0.11	1
	2.0	21-25	0.14	
	2.0	26-33	0.17	
	2.0	34-50	0.20	
Crushed stone, ¾ to 1½ in	135	<16	0.05	2
	135	16-20	0.05	[illegible]
	135	21-33	0.05	
	135	34-50	[illegible]	
	240	<21	0.02	3
	240	21-33	0.02	2
	240	34-50	0.02	1
Wood chips	7	<16	0.08	
	7	16-20	0.08	
	12	<16	0.05	1
	12	16-20	0.05	1
	12	21-33	0.05	[illegible]
	25	<16	0.02	2
	25	16-20	0.02	1
	25	21-33	0.02	1
	25	34-50	0.02	[illegible]

[a]From Meyer and Ports (1976). Developed by an int[er]agency workshop group on the basis of field experience a[nd] limited research data.

[b]Maximum slope length for which the specified mulch r[ate] is considered effective. When this limit is exceeded, eithe[r a] higher application rate or mechanical shortening of t[he] effective slope length is required.

[c]When the straw or hay mulch is not anchored to the soil, [C] values on moderate or steep slopes of soils having K val[ues] greater than 0.30 should be taken at double the values giv[en] in this table.

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Table 12.8
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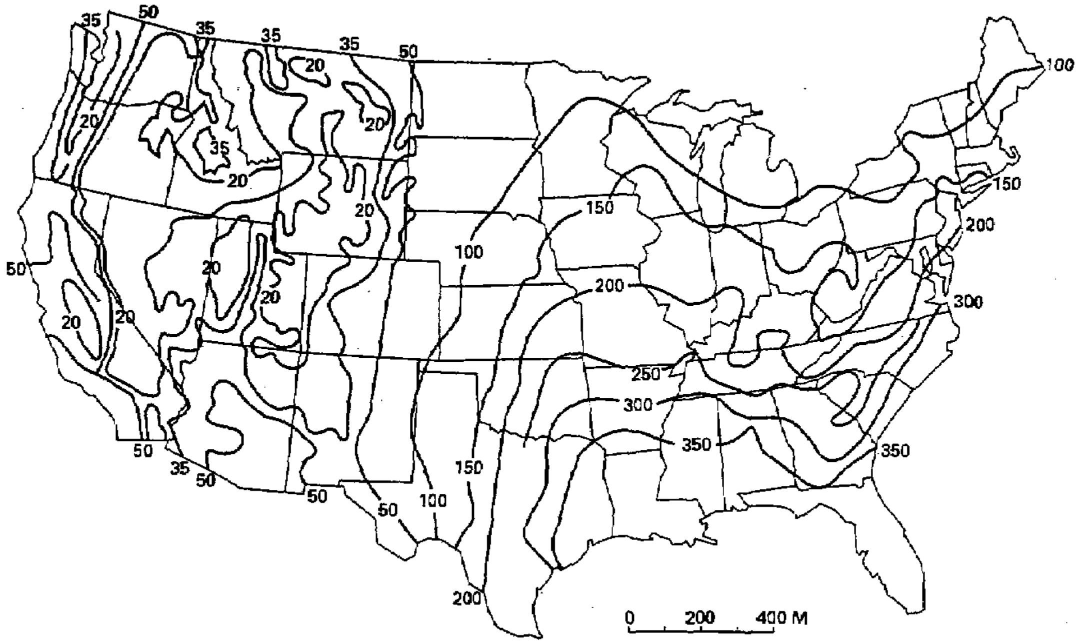

Figure 12.7 Average annual rainfall—erosivity factor R

Table 4.

Typical VM factor values

Condition	VM factor
Bare soil condition	
Freshly disked, 6–8 in.	1.0
After one rain	0.89
Loose, 12 in. thick	
Smooth	0.9
Rough	0.8
Compacted bulldozer scraped up and down	1.3
Same except roots raked	1.2
Compacted bulldozer scraped across slope	1.2
Rough irregular tracked in all directions	0.9
Seed and fertilize fresh	0.9
Same after 6 months	0.54
Compacted fill	1.24–1.71
Saw dust, 2 in. deep disked in	0.61
Dust binder	
605 gal/acre	1.05
1210 gal/acre	0.29–0.78
Hydromulch (wood fiber slurry), fresh	
1000 lb/acre	0.05
1400 lb/acre	0.01–0.02
Seedings	
Temporary, 0–60 days	0.4
After 60 days	0.05
Permanent, 0–60 days	0.4
2–12 months	0.05
After 12 months	0.01
Excelsior blanket with plastic net	0.04–0.1

Attachment 2

Potential Soil Loss

From the MWL Cover

By Wind Erosion

GRAM, Inc. Calculation Sheet Sheet 1 of 20

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

Purpose:

Determine the soil loss due to wind erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Wind Erosion Equation (WEQ). This calculation only presents potential loss.

References:

Natural Resources Conservation Service (NRCS) National Agronomy Manual, 190-V-NAM, 2nd Ed., Part 502, March 1988.

N.P. Woodruff and F.H. Siddaway, 1965. "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, No. 5, pages 602-608.

Method of Analysis:

Standard engineering hand calculations using the Wind Erosion Equation (WEQ).

$$E = f[(IKC)LV]$$

where:

E = estimated average annual soil loss (Tons/Acre/yr.)

I = soil erodibility index

K = ridge roughness factor

C = climatic factor

L = unsheltered distance

V = vegetative factor

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

1) Determine soil erodibility index, I:
- From Tabulation of AGRA Test Results, Table 1 (Sheet 9), USCS Classification is SM.
- USDA classification for SM with sand fraction > 70% is loamy sand (Sheet 10).
- Percent passing #170 sieve indicates that the sand fraction is predominantly fine to very fine.

Soil classification ⟹ Loamy very fine sand

From Table 2 (Sheet 11) for a loamy very fine sand ⟹ I = 134 Tons/Acre/yr.

__For 2% Cover Slope__

I = 134 Tons/Acre/yr.

- Knoll erodibility adjustment: Adjustments of the "I" factor for knolls is used where windward facing slopes are less than 500 ft long and the increase in slope gradient from the adjacent upwind landscape is 3% or greater.

Since the windward facing slopes are > 500 ft long and < 3%, no adjustment to the soil erodibility index, I, is warranted for the 2% cover slope.

I = 134 Tons/Acre/yr.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For the 16.7% Sideslopes

$I = 134$ Tons/Acre/yr.

Knoll erodibility adjustment: Since the 6:1 (16.7%) sideslopes are < 500 ft long and the windward facing slopes are > 3%, the knoll erodibility adjustment is warranted.

Max slope change = 16.7% (6:1)

From Table 3 (Sheet 12):

Adjustment to I = 1.4 multiplier

Therefore: $I = 134(1.4) = 188$

$I = 188$ Tons/Acre/yr.

2) Determine the total surface roughness, K:

$K = K_{rd}$ (ridge roughness) x K_{rr} (random roughness)

K_{rd}

Because the cover is man-made, it is assumed that the cover and sideslopes will be smooth and without ridges.

From Figure 2 (Sheet 13): $K_r = 0$

Since $K_r = 0 \implies K_{rd} = 1.0$

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

K_{rr}

Random roughness (rr) is the non-oriented surface roughness that is sometimes referred to as cloddiness. Cloddiness is usually created by the action of tillage implements.

From Table 4 (Sheet 14):

For drill, double disk ⇒ rr = 0.4 inches

For 2% Cover Slope

rr = 0.4 inches

I = 134

From Figure 3 (Sheet 14) ⟹ $K_{rr} = 1.0$

For 16.7% Sideslopes

rr = 0.4 inches

I = 188

From Figure 3 (Sheet 14) ⟹ $K_{rr} = 1.0$

Total Surface Roughness for the 2% Cover Slope and the 16.7% Sideslopes

$K = K_{rd} \times K_{rr} = (1.0)(1.0)$

$K = 1.0$

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

3) Determine the climatic factor, C:

The climatic factor is an index of the relative erosivity by geographic location.

From Figure 4 (Sheet 15) ⟹ C = 120

4) Determine the unsheltered distance, L:

The unsheltered distance is the field length along the prevailing wind direction.

For 2% Cover Slope

From Figure 5 (Sheet 16) ⟹ L = 524 ft

For 16.7% Sideslopes

From Figure 6 (Sheet 17) ⟹ L = 25 ft

5) Determine the vegetative cover factor, V:

The effect of vegetative cover in the WEQ is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent in pounds per acre of small grain residue in reference condition (small grain equivalent - Sge).

Case 1: No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimped into soil with disk.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

2 Tons/Acre (straw mulch) = 4,000 lbs/Acre (Small grain residue)

From Figure 7, using the flat winter wheat residue 10" long randomly distributed reference line (because straw mulch will be lying flat on landfill cover surface)

$\Longrightarrow$ V = 4,500 Sge (small grain equivalent)

Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; 1/2 straw mulch remains.

1 Ton/Acre (1/2 straw mulch remains) = 2,000 lbs/Acre (Small grain residue)

From Figure 7: 2,000 lbs/Acre small grain residue

$\Longrightarrow$ V = 2,800 Sge (small grain equivalent)

12 months after seeding, 400 Sge* of native grass is established on the cover and sideslopes.

* 400 Sge is a conservative estimate from New Mexico state Agronomist, Mike Sporcic. The estimate is based upon a two year decomposition routine contained in a revised USLE equation for grain straw decomposition in contact with soil.

$\Longrightarrow$ V = 2,800 Sge + 400 Sge = 3,200 Sge

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

6) Determine the average annual soil loss, E:

For 2% Cover Slope

From Table 5 (Sheet 19)

for: C = 120

I = 134

K = 1.0

L = 524 ft

Case 1:

V = 4,500 Sge

⟹ E = 0 Tons/Acre/yr.

Case 2:

V = 3,200 Sge

⟹ E = 0 Tons/Acre/yr.

GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For 16.7% Sideslopes

From Table 6 (Sheet 20)

for: $C = 120$

$I = 188$

$K = 1.0$

$L = 25$ ft

Case 1:

$V = 4{,}500$ Sge

$\Longrightarrow$ $E = 0$ Tons/Acre/yr.

Case 2:

$V = 3{,}200$ Sge

$\Longrightarrow$ $E = 0$ Tons/Acre/yr.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

PROJECT: Mixed Waste Landfill Cover

DATE: 05/17/99

SOURCE: SNL

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
Composite MWL-A1	0'-2'	ML	NV	NP	58	64	82	85	87	89	95	98	99	100		4.5	4557
Composite MWL-1B	2'	SM	NV	NP	25	35	56	73	79	87	95	99	100			4.3	4560
Native Soil	1 of 3	SM	NV	NP	24	35	68	74	78	83	90	94	97	100		4.8	4565
Native Soil	2 of 3	SM-SC	22	6	31	42	70	75	78	84	91	96	98	100		6.2	4566
Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	88	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

AGRA Earth & Environmental

Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

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Figure 1.

USDA textural classification with *ASTM group symbols* superimposed

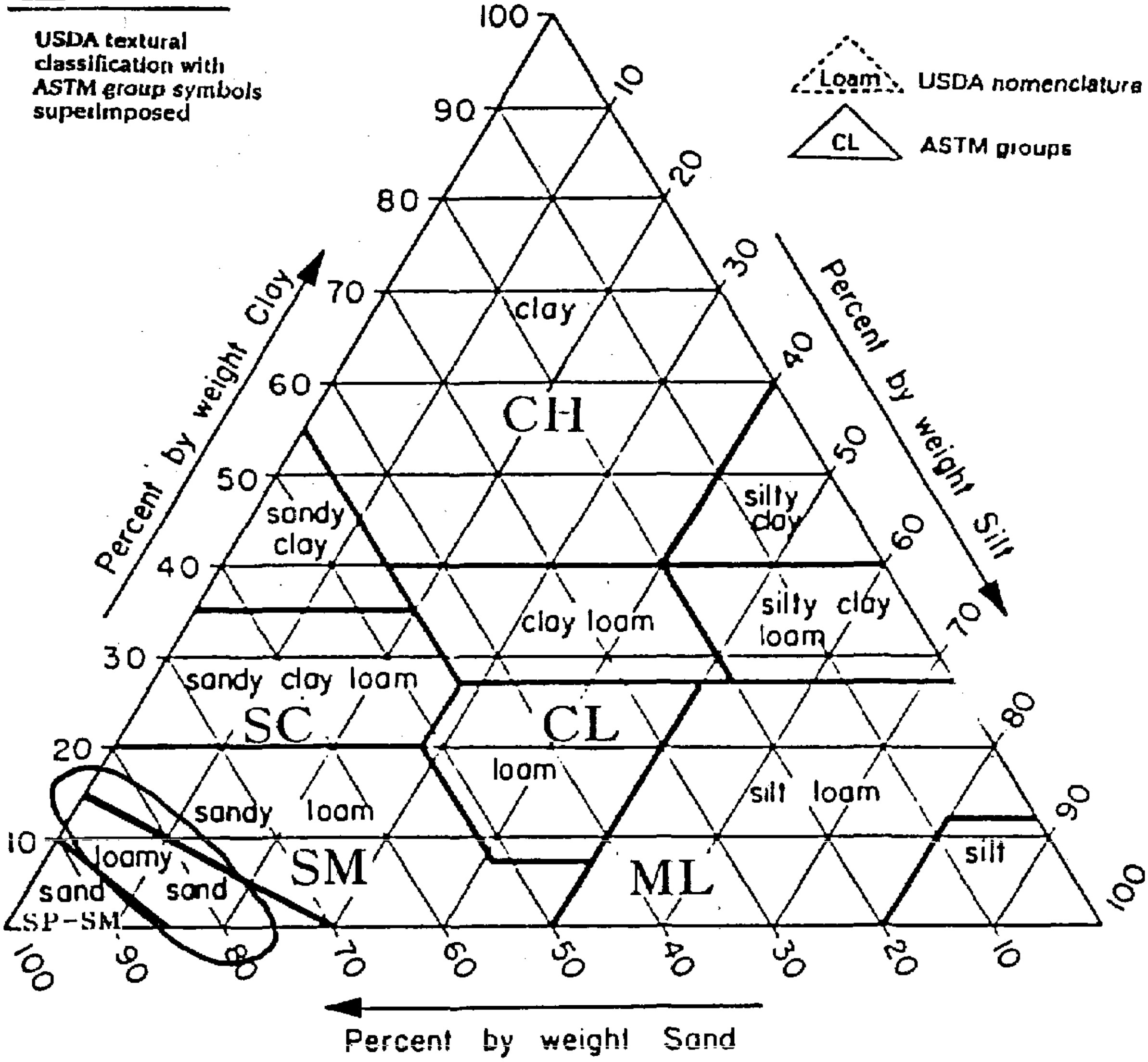


TABLE 2.

WIND ERODIBILITY GROUPS and SOIL ERODIBILITY INDEX

Predominant Soil Texture Class of Surface Layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (I) (Tons/Acre/Year)[1]
Very fine sand, fine sand, sand, or coarse sand	1	310[2] 250 220 180 160
Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials	2	134
Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	3	86
Clay, silty clay, noncalcareaous clay loam, or silty clay loam with more than 35 % clay	4	86
Calcareous loam and silt loam, or calcareous clay loam and silty clay loam	4L	86
Noncalcareous loam and silt loam with less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials	5	56
Noncalcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay	6	48
Silt, non-calcareous silty clay loam with less than 35% clay, and fibric organic soil material	7	38
Soils not susceptible to wind erosion due to coarse surface fragments or wetness	8	---

[1] The soil erodibility index is based on the relationship of dry soil aggregates greater then .84 mm to potential soil erosion.

[2] The "I" factors for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an I of 220 as an average figure. For coarse sand with gravel, use a low figure. For no gravel and very fine sand, use a higher figure.

TABLE 3. KNOLL ERODIBILITY ADJUSTMENT FACTOR FOR I

Slope Change in Prevailing Wind Erosion Direction	A Knoll Adjustment to I	B Increase at Crest Area Where Erosion Is Most Severe
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10	3.6	6.8
10 - 15*	2.0	--
16.7% * 15 - 20	1.4	--
20 +	1.0	--

*Factors above 10% slope change based on NRCS judgment. No research data available.

To adjust the "I" factor for knoll erodibility the "I" factor for the soil on the windward facing part of the knoll is multiplied by the factor shown in Column A of Table 3. Column B in the same table shows the increased erodibility near the crest (upper 1/3 of the slope), where the effect is most severe. This adjustment applies only to that portion of the knoll exposed to the prevailing wind erosion direction.

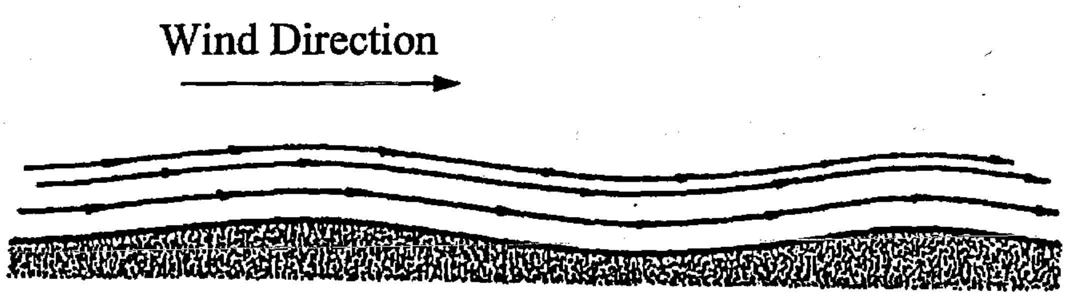
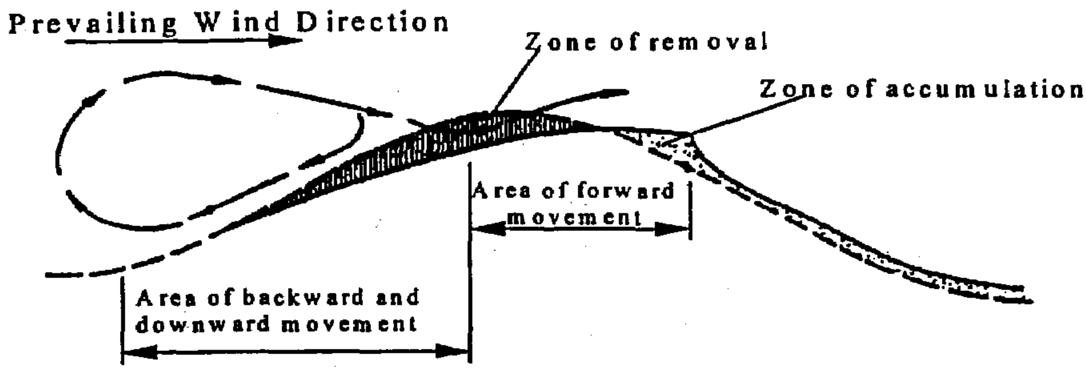


Figure 4. Wind Flow Pattern over Level to Rolling Terrain

On level fields or on rolling terrain where slopes are longer and slope changes are less than those used to describe a knoll, the wind flow pattern tends to conform to the surface and do not exhibit the flow constriction typical of knolls, as illustrated in Figure 4.



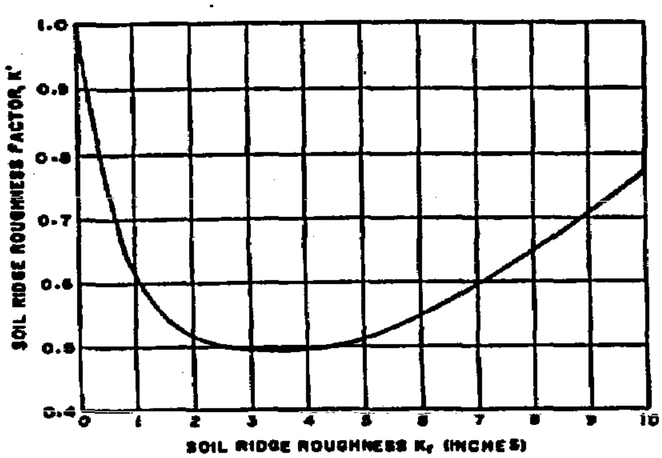
Soil Movement on Ridges

<u>Information Needed to Determine the "K" Factor for Ridge Roughness</u>

- Angle of Deviation
    * Prevailing wind erosion direction
    * Ridge-furrow direction
- Ridge Height
- Ridge Spacing

The "K" factor is based on a standard ridge height to ridge spacing ratio of 1:4. Calibrations of wind tunnel studies led to the development of this curve that relates ridge-furrow roughness to the "K" factor.

This curve is the basis for the "K" factor tables found in Exhibit 502.62 in the National Agronomy Manual and in the Field Office Technical Guide.



$$K_r = \frac{4h^2}{s}$$

K 2.0 /

where:
h = ridge height in inches
s = ridge spacing (inches) measured in the wind erosion direction

Figure 2. Graph to determine soil ridge roughness factor K from soil ridge roughness Kr.

Table 4. Random Roughness Values for "Core" Field Operations[1]

Field Operations	Random Roughness (in)	Field Operations	Random Roughness (in)
Chisel, sweeps	1.2[2]	Fertilizer applicator, anhydrous knife	0.6
Chisel, straight points	1.5	Harrow, spike	0.4
Chisel, twisted shovels	1.9	Harrow, tine	0.4
Cultivator, field	0.7	Lister	0.8
Cultivator, row	0.7	Manure injector	1.5
Cultivator, ridge till	0.7	Moldboard plow	1.9
Disk, one way	1.2	Mulch treader	0.4
Disk, heavy plowing	1.9	Planter, no-till	0.4
Disk, tandem	0.8	Planter, row	0.4
Drill, double disk	0.4	Rodweeder	0.4
Drill, deep furrow	0.5	Rotary hoe	0.4
Drill, no-till	0.4	Vee ripper	1.2
Drill, no-till into sod	0.3		

[1] These values are typical and representative for operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may vary by cropping region, farming practice, soil texture, or other conditions.

[2] These values may be used in WEQ for random roughness. However, the use of the random roughness photos in Agriculture Handbook 703 is preferable.

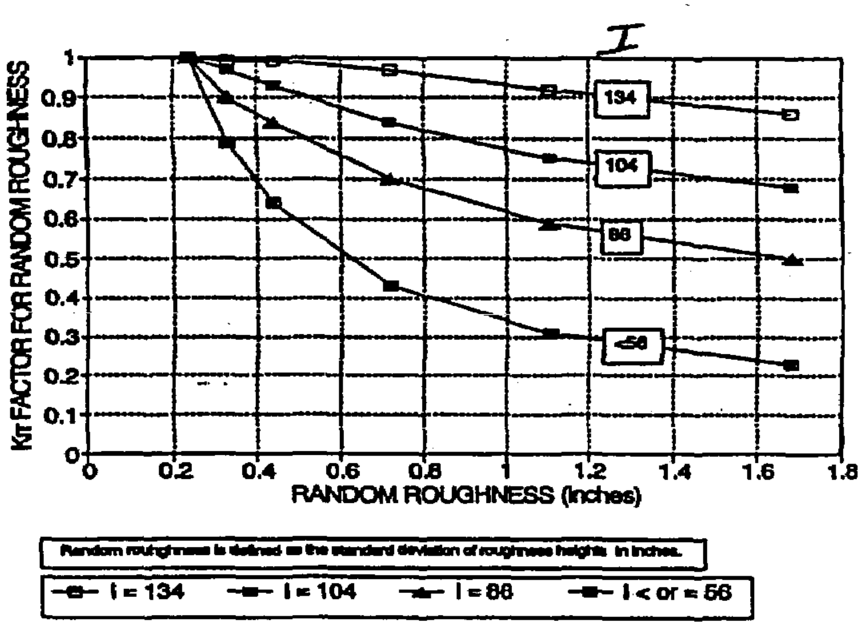


Figure 3. Graph to Determine K_{rr} from Random Roughness and "I" Factor Values

Annual "C" Values
Of The Wind Erosion Equation
New Mexico

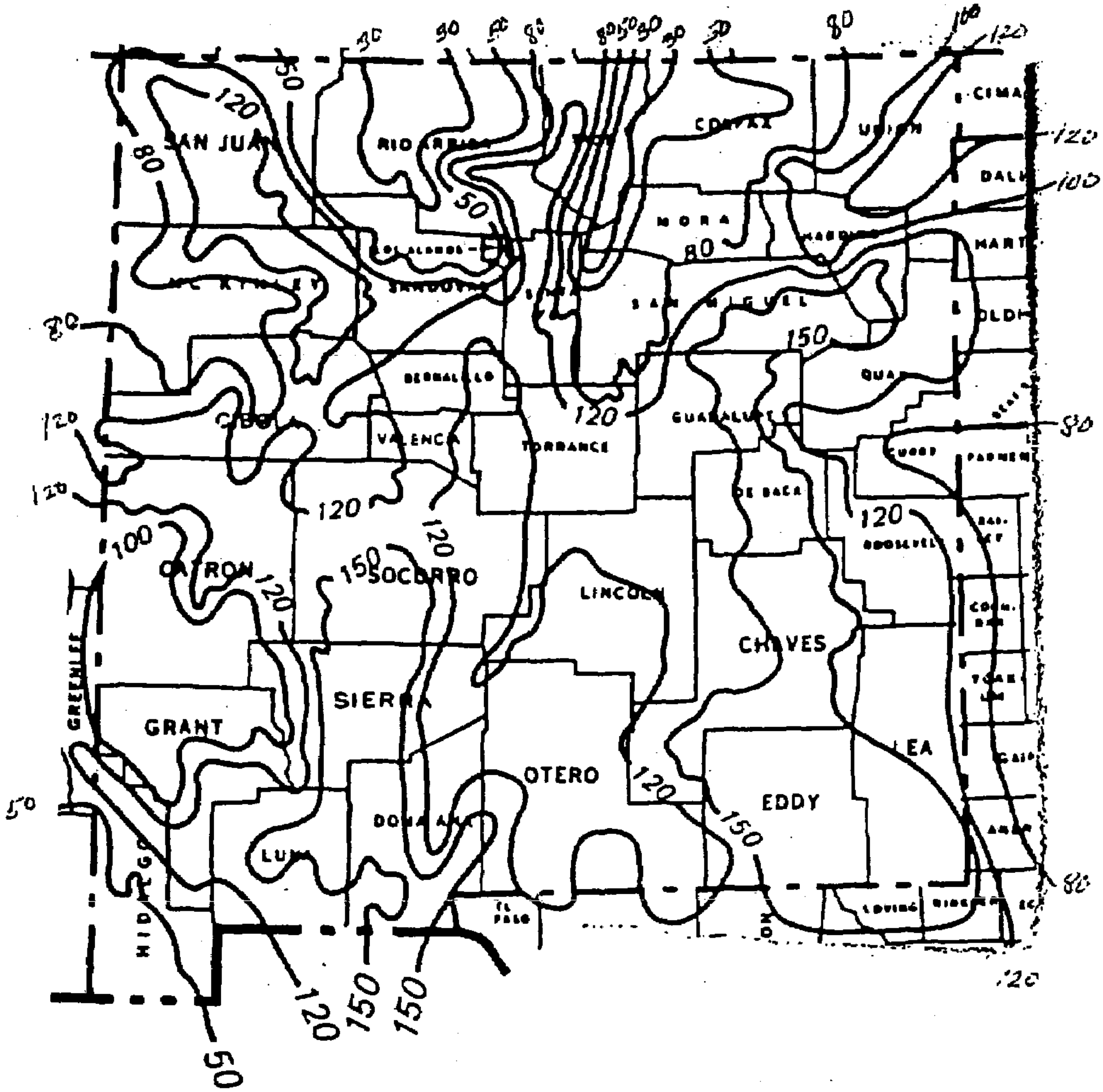


Figure 4.

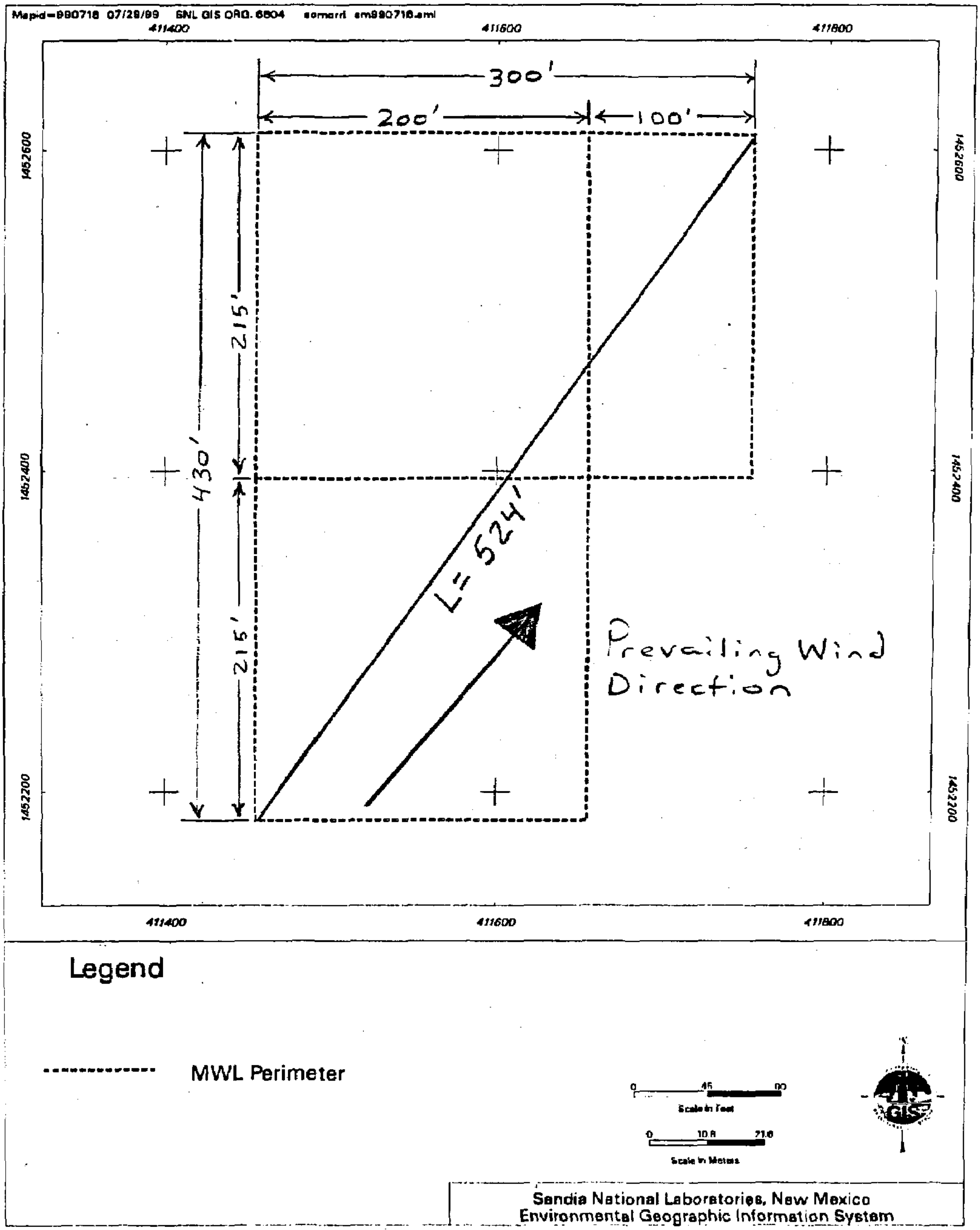


Figure 5. Unsheltered distance, L, for the 2% Cover Slope

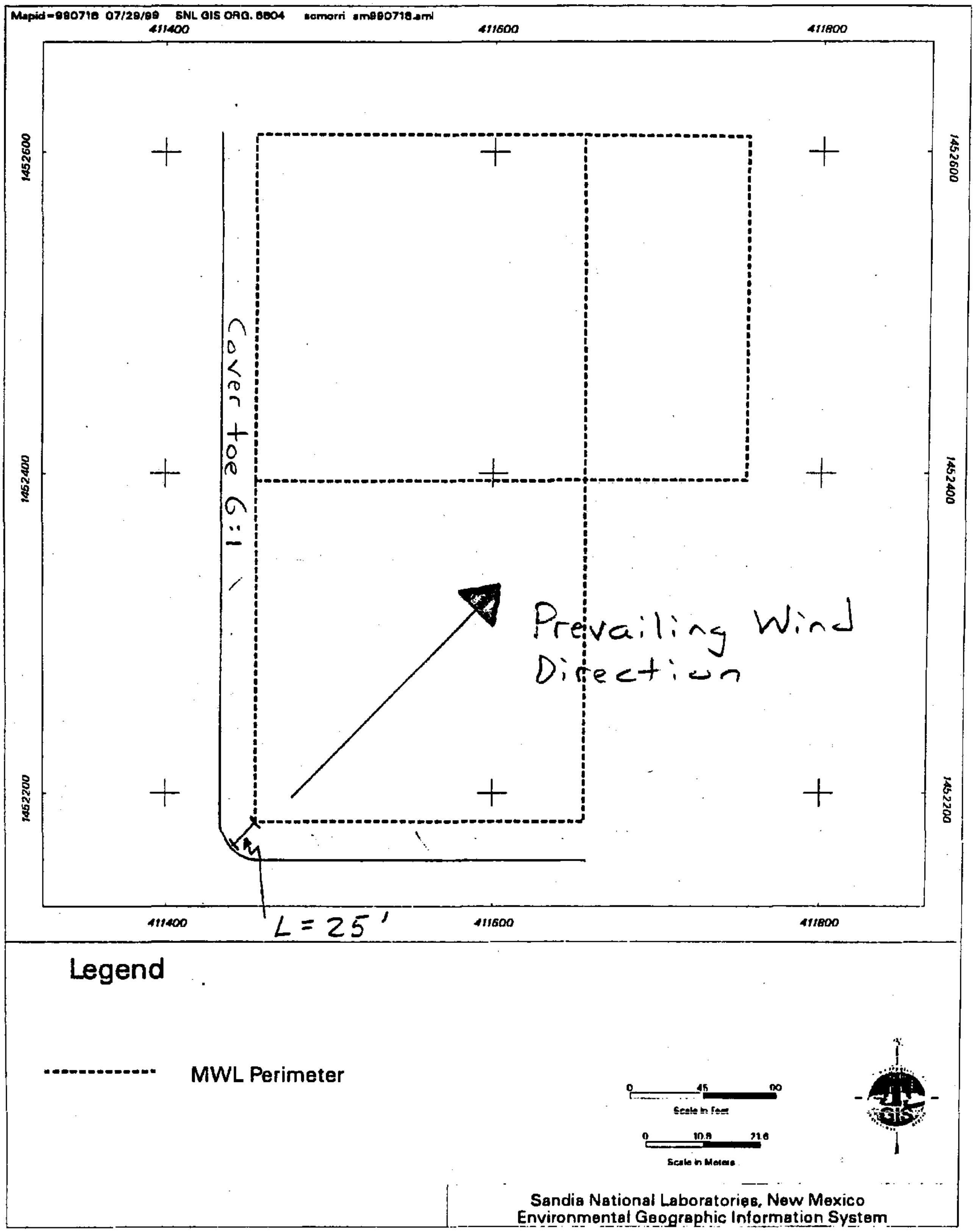


Figure 6. Unsheltered distance, L, for the 16.7% Sideslopes

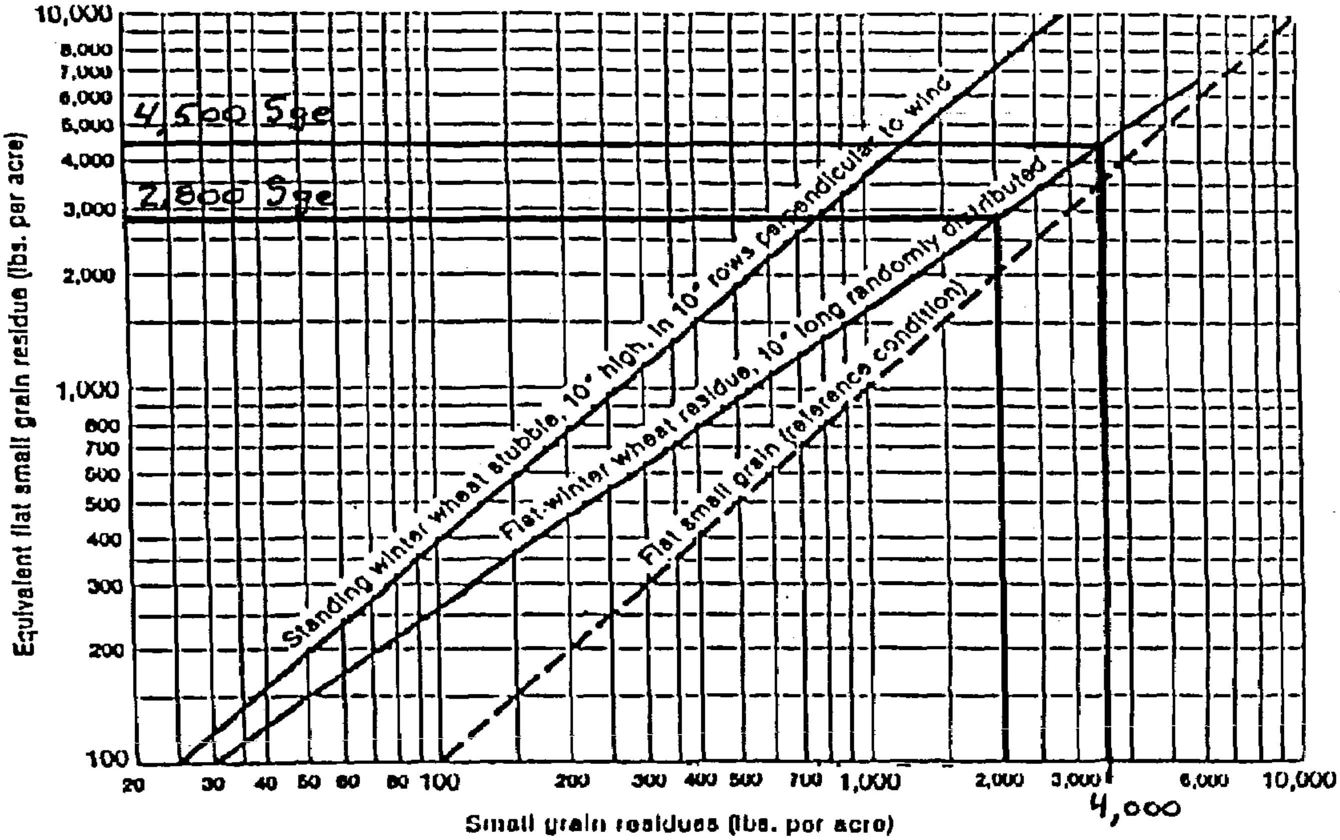
GETATIVE COVER "V"

ıd Erosion Equation E = ƒ[(IKC)LV]

;etative Cover Factor "V"

: effect of vegetative cover in the Wind Erosion Equation is expressed by relating the . 1, amount, and orientation of vegetative material to its equivalent in pounds per acre of ıll grain residue in reference condition (SGe).

Flat Small Grain Equivalents of Small Grain Residues
(Use for wheat, barley, rye and oats)



Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Source: Lyles and Allison—Trans. ASAE 1981, 24 (2): 405-406.
Residues are washed, air dried, and placed as described for wind tunnel tests.

Figure 7.

e Reference Condition

: term Flat Small Grain Equivalent (SGe) is based on a reference condition (dotted line Figure 6) developed from wind tunnel research. It is defined as:

10-inch stalks of small grain lying parallel to the wind arranged in rows

Table 5. C=120, I=134, k=1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998 — C = 120 — I = 134

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
8000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
6000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
4000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
3000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
2000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
1000	153.2	137.4	116.2	95.5	65.4	45.4	27.4	17.1	10.8	5.8	3.2	0.7	0.4
800	151.0	135.3	114.3	93.7	64.0	44.3	26.6	16.5	10.5	5.5	3.0	0.6	0.3
524' > 600	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	0.0
400	137.4	122.7	102.8	83.3	55.9	37.6	22.1	13.3	8.3	4.2	2.2	0.2	
300	131.6	117.2	97.9	78.9	52.5	34.9	20.3	12.1	7.4	3.7	1.9	0.2	
200	120.2	106.7	88.5	70.5	46.1	29.9	17.0	9.8	5.9	2.8	1.4	0.1	
150	111.5	98.7	81.3	64.2	41.4	26.3	14.6	8.3	4.9	2.3	1.1	0.1	
100	104.4	92.1	75.5	59.1	37.6	23.4	12.8	7.1	4.1	1.9	0.9	0.1	
80	98.5	86.7	70.7	54.9	34.6	21.2	11.4	6.3	3.6	1.6	0.7	0.1	
60	88.7	77.7	62.8	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4	0.0	
50	82.8	72.4	58.2	44.2	26.9	15.7	8.1	4.2	2.3	1.0	0.3		
40	77.5	67.5	54.0	40.7	24.5	14.0	7.1	3.6	2.0	0.7	0.0		
30	69.3	60.1	47.7	35.4	20.9	11.6	5.7	2.8	1.5	0.5			
20	57.9	49.8	38.9	28.3	16.1	8.5	4.0	1.9	0.9	0.0			
10	43.2	36.8	28.1	19.7	10.6	5.1	2.3	1.0	0.3				

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998 — C = 120 — I = 134

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.1	4.9	2.6	0.2	
8000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
6000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
4000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
3000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
2000	143.2	128.0	107.6	87.7	59.3	40.4	23.9	14.6	9.1	4.7	2.5	0.2	
1000	137.3	122.6	102.7	83.3	55.8	37.6	22.1	13.3	8.2	4.2	2.2	0.2	
800	132.5	118.1	98.7	79.7	53.1	35.4	20.6	12.3	7.5	3.8	2.0	0.2	
600	126.6	112.7	93.8	75.2	49.7	32.7	18.8	11.1	6.7	3.3	1.7	0.1	
400	118.1	104.8	86.7	69.0	44.9	29.0	16.4	9.5	5.6	2.7	1.3	0.1	
300	112.0	99.1	81.7	64.5	41.6	26.4	14.8	8.4	4.9	2.3	1.1	0.1	
200	104.1	91.9	75.3	58.9	37.5	23.3	12.8	7.1	4.1	1.9	0.9	0.1	
150	96.6	85.0	69.2	53.7	33.6	20.5	11.0	6.0	3.4	1.5	0.7	0.1	
100	88.7	77.8	62.9	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4		
80	83.1	72.6	58.4	44.4	27.1	15.8	8.2	4.3	2.3	1.0	0.3		
60	74.3	64.7	51.6	38.7	23.1	13.0	6.6	3.3	1.8	0.7			
50	69.8	60.6	48.0	35.7	21.1	11.7	5.8	2.9	1.5	0.6			
40	64.8	56.1	44.2	32.6	18.9	10.3	5.0	2.4	1.3				
30	57.2	49.3	38.4	27.9	15.8	8.3	3.9	1.8	0.9				
20	48.8	41.8	32.1	22.9	12.6	6.3	2.9	1.3	0.4				
10	35.4	29.9	22.4	15.3	8.0	3.6	1.5	0.5					

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 19 of 20

Table 6. C = 120, I = 180, K = 1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998; C = 120; I = 180

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
8000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
6000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
4000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
3000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
2000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
1000	214.0	194.7	169.2	145.0	106.1	81.0	53.0	36.5	25.1	15.3	9.5	2.4	1.6
800	211.0	191.8	166.5	142.5	103.9	79.1	51.5	35.3	24.2	14.7	9.1	2.2	1.5
600	206.0	187.1	162.1	138.2	100.4	75.8	49.1	33.4	22.8	13.7	8.4	2.0	1.3
400	196.7	178.3	153.8	130.5	93.9	70.0	44.8	30.1	20.3	12.0	7.2	1.7	1.1
300	190.0	172.0	148.0	124.9	89.3	65.9	41.9	27.8	18.6	10.8	6.4	1.5	1.0
200	179.0	161.6	138.4	116.0	81.9	59.5	37.3	24.3	16.0	9.1	5.3	1.2	0.6
150	167.2	150.5	128.2	106.5	74.2	52.8	32.5	20.8	13.5	7.4	4.2	0.9	0.5
100	156.0	140.0	118.6	97.6	67.1	46.9	28.4	17.8	11.4	6.1	3.4	0.7	0.4
80	147.3	131.9	111.2	90.9	61.8	42.5	25.4	15.6	9.8	5.1	2.8	0.6	0.0
60	135.7	121.1	101.4	82.0	54.9	36.8	21.6	13.0	8.0	4.0	2.1	0.2	↓
50	127.8	113.7	94.7	76.1	50.3	33.2	19.1	11.3	6.9	3.4	1.7	0.1	
40	119.7	106.2	88.0	70.1	45.8	29.6	16.8	9.7	5.8	2.8	1.4	0.1	
25' > 30	109.5	96.8	79.6	62.7	40.3	25.4	14.1	8.0	4.7	2.2	1.0	0.1	
20	94.6	83.1	67.6	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4	0.0	
10	72.7	63.2	50.3	37.6	22.4	12.6	6.3	3.2	1.7	0.6	0.0	↓	↓

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR — JANUARY, 1998; C = 120; I = 180

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
8000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
6000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
4000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
3000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
2000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
1000	189.6	171.6	147.6	124.6	89.0	65.7	41.7	27.7	18.5	10.7	6.4	1.5	1.0
800	186.4	168.5	144.8	122.0	86.8	63.8	40.3	26.6	17.7	10.2	6.0	1.4	0.7
600	182.7	165.1	141.6	119.0	84.4	61.6	38.8	25.5	16.9	9.6	5.7	1.3	0.7
400	174.1	156.9	134.1	112.0	78.7	56.6	35.2	22.8	14.9	8.4	4.8	1.1	0.6
300	167.3	150.6	128.3	106.6	74.3	52.9	32.6	20.8	13.5	7.5	4.2	0.9	0.5
200	153.1	137.3	116.1	95.4	65.3	45.3	27.3	17.0	10.8	5.7	3.2	0.7	0.4
150	143.3	128.1	107.7	87.8	59.4	40.5	24.0	14.7	9.2	4.7	2.5	0.2	
100	134.1	119.6	100.0	80.8	54.0	36.1	21.1	12.6	7.8	3.9	2.0	0.2	
80	126.3	112.3	93.5	75.0	49.5	32.5	18.7	11.0	6.7	3.3	1.7	0.1	
60	114.9	101.8	84.1	66.6	43.2	27.6	15.5	8.9	5.3	2.5	1.2	0.1	
50	108.3	95.8	78.7	61.9	39.7	25.0	13.8	7.8	4.5	2.1	1.0	0.1	
40	102.8	90.7	74.2	58.0	36.8	22.8	12.5	6.9	4.0	1.8	0.9	0.1	
30	94.5	83.1	67.5	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4		
20	79.5	69.4	55.6	42.1	25.4	14.6	7.5	3.9	2.1	0.8			
10	60.1	51.8	40.6	29.7	17.0	9.0	4.3	2.0	1.0				

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 20 of 20

Attachment 3

Calculations

Regarding

Run-Off and Run-On Controls

For the MWL Cover

NMED (NOD) COMMENT: "Demonstrate with calculations and other information whether run-off and run-on controls have been adequately designed to handle peak precipitation events. Evaluate and discuss whether additional fun-on controls should be constructed at locations further away from the landfill (e.g. at distances of 25 to 50 meters) to provide more protection for the cover from heavy rainfall events."

Response to NMED (NOD) Comment;

The site will be graded such that runoff from the site flows north, west and east. There is a high point on the north side of the site that prevents flow from running onto the site. Two swales will be provided to carry the flow to the north or the south. This may be seen in Exhibit 1: Mixed Waste Landfill Final Cover Grading Plan" attached.

The watershed basin draining onto the site has been delineated and is shown on Exhibit 2. It is divided in to a north basin and a south basin that drain to the north and south swales respectively.

Runoff was calculated using the City of Albuquerque DPM criteria for the 100 year –6 hour storm. Reference: DPM Criteria Attached. The north basin generates 24 cfs and the north swale has the capacity for 79 cfs. The south basin generates 6.5 cfs and the capacity of the south swale is 58 cfs.

The swales are therefore sized with abundant capacity to prevent flow from entering the site and to carry the runoff around the site.

The general drainage pattern in this area is a gentle slope to the west. So after the flow is discharged from the site, they drain westward and no additional controls are needed. Exhibit 2 shows the topography up to a minimum of 200 feet beyond the site to illustrate this.

URS

Job: Mixed Waste Landfill Project — Project No. ____ — Sheet ____ of ____

Description: Response to NMED Comment No. 16, — Computed by [signature] — Date 11 Dec. 06

Checked by HB PE — Date 11 Dec. 06

Reference

USE CITY of ALB. DRAINAGE METHOD

BASIN AREA

NORTH 297636 ft²

SOUTH 81997.54 ft²

TOTAL = 379633.54 SF ✓

Time of Concentration

Longest flow path

N = 964'

S = 616'

SLOPE sheet flow $\frac{97.2-91.7}{400} = .01375$ ft/ft

other $\frac{5391.7-5380}{564} = .02074$ ft/ft

$\text{Slope} = \frac{5388-5382}{616} = 0.0097$ ft/ft

Zone 3

LAND TREATMENT

⇒ SAY Type C possibly some type A is there but much of the area has been impacted by human activity

this is conservative

Time of Concentration

NORTH $t_c = L_1/V_1 + L_2/V_2 \ldots$

$V = K\sqrt{S*1000}$

$V_1 = .7\sqrt{.01375(100)} = 0.82$ ✓

$V_2 = 2\sqrt{.02074(100)} = 2.88$ ✓

$T_c = \left(400'/0.82\ \text{ft/sec} + 564'/2.88\ \text{ft/sec}\right) / (3600\ \text{sec/hour}) = 0.1899$ hrs = 11 min

URS

Job: Mixed Waste Landfill Project | Project No. ____ | Sheet ____ of ____
Description: Response to NMED Comment No. 16. | Computed by: SJ | Date: 11 Dec. 06
Checked by: HB PE | Date: 11 Dec. 06

Reference

SOUTH use $K = 2$

$$V = 2\sqrt{.0097(100)} = 1.97$$

$$T_c = \frac{616 \text{ ft}}{1.97 \frac{\text{ft}}{\text{sec}}} = 312.7 \text{ sec} = 5 \text{ min}$$

NORTH + SOUTH - Both < 12 min

Use TABLE A-9 for Qpeak-100

Zone 3 / L.T. C

NORTH 297636 ft^2 = 6.833 Ac

SOUTH 81997.54 ft^2 = 1.882 Ac

$$Q_{peak} \text{ NORTH} = 6.833\text{Ac}\left(3.45 \frac{\text{cfs}}{\text{Acres}}\right) = 23.6\text{cfs}$$

$$Q_{peak} \text{ SOUTH} = 1.882\text{ Ac}\left(3.45 \frac{\text{cfs}}{\text{Ac}}\right) = 6.5\text{cfs}$$

NORTH SWALE - Q100

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.02000	ft/ft
Discharge	23.60	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+40	5382.00
1+56	5381.00
1+86	5382.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+86, 5382.50)	0.030

Results

Normal Depth	0.63	ft
Elevation Range	5381.00 to 5388.00 ft	
Flow Area	7.25	ft²
Wetted Perimeter	22.88	ft
Top Width	22.84	ft
Normal Depth	0.63	ft
Critical Depth	0.64	ft
Critical Slope	0.01922	ft/ft
Velocity	3.26	ft/s
Velocity Head	0.16	ft
Specific Energy	0.80	ft
Froude Number	1.02	
Flow Type	Supercritical	

NORTH SWALE - Q100

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.63	ft
Critical Depth	0.64	ft
Channel Slope	0.02000	ft/ft
Critical Slope	0.01922	ft/ft

NORTH SWALE - CAPACITY

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.02000	ft/ft
Normal Depth	1.00	ft

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+40	5382.00
1+56	5381.00
1+86	5382.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+86, 5382.50)	0.030

Results

Discharge	79.35	ft³/s
Elevation Range	5381.00 to 5388.00 ft	
Flow Area	18.00	ft²
Wetted Perimeter	36.06	ft
Top Width	36.00	ft
Normal Depth	1.00	ft
Critical Depth	1.04	ft
Critical Slope	0.01631	ft/ft
Velocity	4.41	ft/s
Velocity Head	0.30	ft
Specific Energy	1.30	ft
Froude Number	1.10	
Flow Type	Supercritical	

NORTH SWALE - CAPACITY

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.00	ft
Critical Depth	1.04	ft
Channel Slope	0.02000	ft/ft
Critical Slope	0.01631	ft/ft

SOUTH SWALE - CAPACITY

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00900	ft/ft
Normal Depth	1.10	ft

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+24	5384.00
1+32	5383.90
1+39	5385.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+39, 5385.00)	0.030

Results

Discharge	57.58	ft^3/s
Elevation Range	5383.90 to 5388.00 ft	
Flow Area	15.25	ft^2
Wetted Perimeter	21.17	ft
Top Width	21.00	ft
Normal Depth	1.10	ft
Critical Depth	0.97	ft
Critical Slope	0.01529	ft/ft
Velocity	3.78	ft/s
Velocity Head	0.22	ft
Specific Energy	1.32	ft
Froude Number	0.78	
Flow Type	Subcritical	

SOUTH SWALE - CAPACITY

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.10	ft
Critical Depth	0.97	ft
Channel Slope	0.00900	ft/ft
Critical Slope	0.01529	ft/ft

SOUTH SWALE - Q100

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.00900	ft/ft
Discharge	6.50	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
1+00	5388.00
1+24	5384.00
1+32	5383.90
1+39	5385.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(1+00, 5388.00)	(1+39, 5385.00)	0.030

Results

Normal Depth	0.38	ft
Elevation Range	5383.90 to 5388.00 ft	
Flow Area	3.29	ft²
Wetted Perimeter	12.11	ft
Top Width	12.05	ft
Normal Depth	0.38	ft
Critical Depth	0.30	ft
Critical Slope	0.02186	ft/ft
Velocity	1.97	ft/s
Velocity Head	0.06	ft
Specific Energy	0.44	ft
Froude Number	0.67	
Flow Type	Subcritical	

SOUTH SWALE - Q100

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.38	ft
Critical Depth	0.30	ft
Channel Slope	0.00900	ft/ft
Critical Slope	0.02186	ft/ft

TABLE 22.3 B-1

VALUES OF MANNING'S n

	n
Reinforced Concrete Pipe	.013
Poured Concrete	.013
No-joint cast in place concrete pipe	.014
Reinforced Concrete Box	.015
Reinforced Concrete Arch	.015
Streets	.017
Flush Grouted Rip-Rap	.020
Corrugated Metal Pipe	.025
Grass Lined Channels (sodded & irrigated)	.025
Earth Lined Channels (smooth)	.030
Arroyo Channels	.030
Wire Tied Rip-Rap	.040
Medium Weight Dumped Riprap	.045
Grouted Rip-Rap (exposed rock)	.045
Arroyo Overbank	.045
Jetty Type Rip-Rap (D_{50} > 24")	.050

Following incorporation of review comments, the August, 1991 version of Section 22.2, Hydrology was released for use by the Drainage Design Criteria Committee. This version included the placement of the rainfall peak in this second hour of the design storm. Modifications to the Probable Maximum Flood procedures incorporated a "local storm" and a "general storm." A "Notice of Second Review" was published in the Albuquerque Journal and Tribune on August 31, 1991. The August, 1991 version has been accepted by the City, County and AMAFCA as an allowable procedure for hydrologic analysis and design of flood control structures.

The January, 1993 version of Section 22.2, Hydrology incorporates comments received since August, 1991. The version includes a procedure to evaluate basin hydrology for steep natural slopes, and some text revisions suggested by the USDA Soil Conservation Service. For most applications, there will be no computational differences between the January, 1993 version and the August, 1991 version. The text has been reformatted into seven (7) separately numbered parts, to simplify future revision of the document.

The pages which follow replaced all previous pages in the Hydrology Section of the DPM (Section 22.2, pages 2 through 21). Following a public review and comment period, the revised Section 22.2, Hydrology was approved by the City Engineer and the Mayor. In the City of Albuquerque, the revision became effective on April 7, 1993. Bernalillo County also adopted the revision as the standard for design of flood and drainage control, effective April 7, 1993. The revised Section 22.2, Hydrology is to be regarded as the principal reference for hydrologic design in the City of Albuquerque and Bernalillo County.

The Drainage Design Criteria Committee wish to acknowledge the assistance of the many individuals who reviewed the document. In particular we wish to thank Richard Leonard, Brian Burnett and Dwayne Sheppard for their work on the Committee.

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INTRODUCTION

There have been many methods used in Albuquerque and Bernalillo County to compute runoff volumes, peak flow rates and runoff hydrographs from drainage basins. Any methodology used should be based on measurable conditions, be as simple as possible and produce accurate reproducible results. The methods, graphs, and tables which follow will be used by the City of Albuquerque, Bernalillo County and AMAFCA staff in the review and evaluation of development plans and drainage management plans.

Two basic methods of analysis are presented herein:

a) **PART A** - describes a simplified procedure for smaller watersheds based on the Rational Method and initial abstraction/uniform infiltration precipitation losses. The procedure is applicable to watersheds up to 40 acres in size, but the procedure may be extended to include larger watersheds with some limitations.

b) **PART C** - describes a unit hydrograph procedure which uses a version of the U.S.D.A. Agricultural Research Service HYMO computer program, modified to utilize initial abstraction/uniform infiltration precipitation losses. The AHYMO computer program developed by the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), and the simplified input procedures available with this program, are also described. This procedure is applicable for small and large watersheds.

In addition to these procedures, **PART D** describes a modification of the **PART C** procedures to compute a Probable Maximum Flood. This has special application to the design of dams.

PART B describes the computation of time of concentration and time to peak which are used in PART A, PART C and PART D.

There may be conditions in which the procedures and analysis tools described in PART A, PART C or PART D are not applicable or optimal for design. **PART E** describes some additional analysis procedures and some criteria under which alternate procedures will be evaluated.

PART F contains a tabulated list of definitions of symbols used in this Section of the D.P.M. and a bibliography.

PART G contains the input and output files from the examples in PARTS C and D which utilize the HYMO computer program.

PART A - PROCEDURE FOR 40 ACRE AND SMALLER BASINS

A simplified procedure for projects with sub-basins smaller than 40 acres has been developed based on initial abstraction/uniform infiltration precipitation losses and Rational Method procedures. For this procedure, Bernalillo County has been divided into four (4) Precipitation Zones.

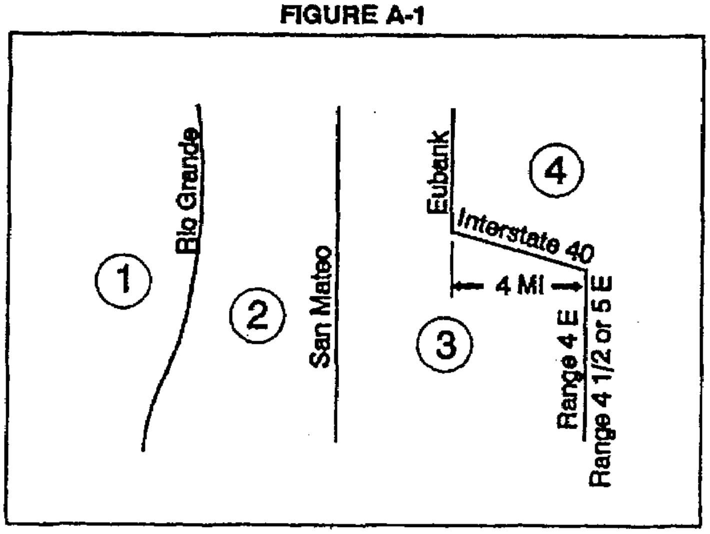
A.1 PRECIPITATION ZONES

Bernalillo County's four precipitation zones are indicated in TABLE A-1 and on FIGURE A-1.

TABLE A-1. PRECIPITATION ZONES

Zone	Location
1	West of the Rio Grande
2	Between the Rio Grande and San Mateo
3	Between San Mateo and Eubank, North of Interstate 40; and between San Mateo and the East boundary of Range 4 East, South of Interstate 40
4	East of Eubank, North of Interstate 40; and East of the East boundary of Range 4 East, South of Interstate 40

FIGURE A-1



Where a watershed extends across a zone boundary, use the zone which contains the largest portion of the watershed.

A.2 DESIGN STORM

The principal design storm is the 100-year 6-hour event defined by the NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Vol. IV - New Mexico. Assume an AMC II condition (a normally dry watershed). For design of retention or detention ponds, storms of 24-hour or longer duration many be required. The 24-hour event is defined by the NOAA Atlas 2. The 4-day and 10-day events can be obtained using the procedures in S.C.S. TSC Technical Note-Hydrology, PO-6 (Rev. 2) The 100-year 60-minute depth is computed by the following formula from Table 11 of NOAA Atlas 2:

$$P_{60} = 0.494 + 0.755 * (P_{360} * P_{360} / P_{1440}) \qquad \text{(a-1)}$$

TABLE A-2. DEPTH (INCHES) AT 100-YEAR STORM					
Zone	P_{60}	P_{360}	P_{1440}	P_{4days}	P_{10days}
1	1.87	2.20	2.66	3.12	3.67
2	2.01	2.35	2.75	3.30	3.95
3	2.14	2.60	3.10	3.95	4.90
4	2.23	2.90	3.65	4.70	5.95

The 2-year 60-minute depth is computed by the following formula from NOAA Atlas 2:

$$P_{60\text{-}2} = -0.011 + 0.942 * (P_{360\text{-}2} * P_{360\text{-}2} / P_{1440\text{-}2}) \qquad \text{(a-2)}$$

Based on fitting a logarithmic curve to the values in Table 12 of NOAA Atlas 2, the 12-minute (0.2 hour) depth was computed to be 50.24 percent of the 60-minute depth:

$$P_{12} = 0.5024 * P_{60} \qquad \text{(a-3)}$$

For certain applications (e.g., street drainage, low flow channels and sediment transport) storms of greater frequency than the 100-year storm must be considered. To estimate precipitation at return periods other than 100 years, multiply the 360-minute or 1440-minute 100-year precipitation amounts by the factors in TABLE A-3.

TABLE A-3. RETURN PERIOD FACTORS	
Return Period (years)	**Factor**
50	0.900
25	0.800
10	0.667
5	0.567
2	0.434

Example A-1

Find the 10-year, 6-hour storm depth for Zone 2.

$P_{360\text{-}10} = 2.35 * 0.667 = 1.57$ inches

Example A-2

Find the 2-year, 1-hour storm depth for Zone 3.

$P_{360\text{-}2} = 2.60 * 0.434 = 1.128$ inches

$P_{1440\text{-}2} = 3.10 * 0.434 = 1.345$ inches

$$P_{60\text{-}2} = -0.011 + 0.942 * (P_{360\text{-}2} * P_{360\text{-}2} / P_{1440\text{-}2})$$
$$= -0.011 + 0.942*(1.128*1.128/1.345)$$
$$= 0.880 \text{ inches}$$

A.3 LAND TREATMENTS

All land areas are described by one of four basic land treatments or by a combination of the four land treatments.

Land treatments are given in TABLE A-4.

TABLE A-4. LAND TREATMENTS	
Treatment	**Land Condition**
A	Soil uncompacted by human activity with 0 to 10 percent slopes. Native grasses, weeds and shrubs in typical densities with minimal disturbance to grading, groundcover and infiltration capacity.
B	Irrigated lawns, parks and golf courses with 0 to 10 percent slopes. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes greater than 10 percent and less than 20 percent.
C	Soil compacted by human activity. Minimal vegetation. Unpaved parking, roads, trails. Most vacant lots. Gravel or rock on plastic (desert landscaping). Irrigated lawns and parks with slopes greater than 10 percent. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes at 20 percent or greater. Native grass, weed and shrub areas with clay or clay loam soils and other soils of very low permeability as classified by SCS Hydrologic Soil Group D.
D	Impervious areas, pavement and roofs.
Most watersheds contain a mix of land treatments. To determine proportional treatments, measure respective subareas. In lieu of specific measurement for treatment D, the areal percentages in TABLE A-5 may be employed.	

TABLE A-5. PERCENT TREATMENT D (Impervious)	
Land Use	**Percent**
Commercial*	90
Single Family Residential N=units/acre, N≤6	$7*\sqrt{(N*N)+(5*N)}$ (a-4)
Multiple Unit Residential Detached* Attached*	 60 70
Industrial Light* Heavy*	 70 80
Parks, Cemeteries	7
Playgrounds	13
Schools	50
Collector & Arterial Streets	90
*Includes local streets	

TABLE A-5 does not provide areal percentages for land treatments A, B and C. Use of TABLE A-5 will require additional analysis to determine the appropriate areal percentages of these land treatments.

Backyard retention ponds, and other small on-site ponding, may have the effect of reducing runoff from impervious areas. Where it can be clearly demonstrated that backyard and small on-site retention ponding currently exist, impervious and/or pervious areas which drain to such ponds ~~may~~ can be given credit towards their determination of peak rates of runoff and runoff volumes from the development. ~~considered to be in land treatment A. Application of backyard ponding is not normally applicable to more than 35 percent of the area in land treatment D (impervious). Allowance for backyard ponding will not be considered for new developments and future development.~~

A.4 ABSTRACTIONS

Initial abstraction is the precipitation depth which must be exceeded before direct runoff begins. Initial abstraction may be intercepted by vegetation, retained in surface depressions, or absorbed on the watershed surface. Initial abstractions are shown in TABLE A-6.

TABLE A-6. INITIAL ABSTRACTION (IA)	
Treatment	**Initial Abstraction (inches)**
A	0.65
B	0.50
C	0.35
D	0.10

Infiltration is the only significant abstraction after the initial abstraction. After initial abstraction is satisfied, treat infiltration as a constant loss rate as specified in TABLE A-7.

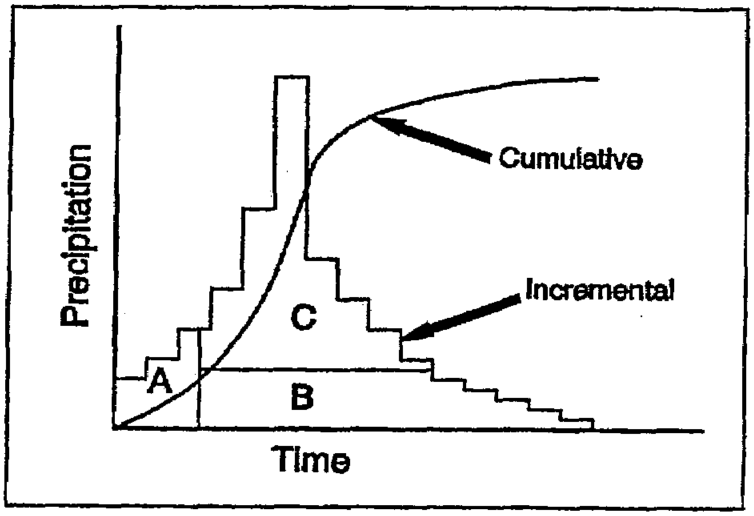
TABLE A-7. INFILTRATION (INF)	
Treatment	**Loss Rate (inches/hour)**
A	1.67
B	1.25
C	0.83
D	0.04*
* Treatment D infiltration rate is applicable from 0 to 3 hours; use uniform reduction from 3 to 6 hours, with no infiltration after 6 hours.	

Runoff from a previous event can saturate a channel bed, rendering it minimally pervious for several days. Do not anticipate additional bed losses for design purposes.

A.5 EXCESS PRECIPITATION & VOLUMETRIC RUNOFF

Excess precipitation, E, is the depth of precipitation remaining after abstractions are removed. Excess precipitation does not depend on watershed area. Excess precipitation is determined by subtracting the initial abstraction and infiltration from the design storm hydrograph. FIGURE A-2 illustrates the development of excess precipitation. The curved line plots cumulative precipitation. Precipitation intensities (in/hr) are shown as a histogram. Initial abstraction is area A. The horizontal line is at a height corresponding to the infiltration rate. Infiltration loss is area B. The remaining histogram, area C, is excess precipitation.

FIGURE A-2



Excess precipitation, E, by zone and treatment is summarized in TABLE A-8.

(NOTE: In this table and several tables which follow, corresponding values for 2- and 10- year storms are shown in brackets below each 100-year value)

TABLE A-8. EXCESS PRECIPITATION, E (INCHES) - 6 HOUR STORM

Zone	Treatment 100-YR [2-YR, 10-YR]			
	A	B	C	D
1	0.44 [0.00, 0.08]	0.67 [0.01, 0.22]	0.99 [0.12, 0.44]	1.97 [0.72, 1.24]
2	0.53 [0.00, 0.13]	0.78 [0.02, 0.28]	1.13 [0.15, 0.52]	2.12 [0.79, 1.34]
3	0.66 [0.00, 0.19]	0.92 [0.06, 0.36]	1.29 [0.20, 0.62]	2.36 [0.89, 1.50]

4	0.80 [0.02, 0.28]	1.08 [0.11, 0.46]	1.46 [0.27, 0.73]	2.64 [1.01, 1.69]

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To determine the volume of runoff,

1) Determine the area in each treatment, A_A, A_B, A_C, A_D

2) Compute the weighted excess precipitation, E

$$\text{Weighted E} = \frac{E_A A_A + E_B A_B + E_C A_C + E_D A_D}{A_A + A_B + A_C + A_D} \quad \text{(a-5)}$$

3) Multiply the weighted E by the watershed area.

$$V_{360} \text{ (as volume)} = \text{weighted E* } (A_A + A_B + A_C + A_D) \quad \text{(a-6)}$$

EXAMPLE A-3
Find the 100-year V_{360} for 30 acres in zone 1. Eight acres are treatment A, 10 acres are treatment B, 5 acres are treatment C, and 7 acres are treatment D.
Weighted E = ((8 * 0.44) + (10 * 0.67) + (5 * 0.99) + (7 * 1.97)) / 30 = 0.965 inches
Volume = (0.965 * 30) / 12 = 2.41 acre-ft. = V_{360}

For ponds which hold water for longer than 6 hours, longer duration storms are required to establish runoff volumes. Since the additional precipitation is assumed to occur over a long period, the additional volume is based on the runoff from the impervious areas only.

For 24-hour storms:

$$V_{1440} = V_{360} + A_D * (P_{1440} - P_{360}) / 12 \text{ in/ft} \quad \text{(a-7)}$$

For 4-day storms:

$$V_{4DAYS} = V_{360} + A_D * (P_{4DAYS} - P_{360}) / 12 \text{ in/ft} \quad \text{(a-8)}$$

For 10-day storms:

$$V_{10DAYS} = V_{360} + A_D * (P_{10DAYS} - P_{360}) / 12 \text{ in/ft} \quad \text{(a-9)}$$

EXAMPLE A-4
Find the 100-year 24-hour and 4-day runoff volume, V_{1440} and V_{4days}, for the area in Example A-3.
V_{360} = 2.41 acre-feet
V_{1440} = 2.41 + 7 ac * (2.66 - 2.20) / 12 = 2.68 acre-feet
V_{4DAYS} = 2.41 + 7 ac * (3.12 - 2.20) / 12 = 2.95 acre-feet

A.6 PEAK DISCHARGE RATE FOR SMALL WATERSHEDS

Small watersheds are less than or equal to 40 acres.

Peak Discharge

Using a 0.2-hour (12-minute) time of concentration, peak discharge, Q_P, per acre is the volume of excess precipitation in the heaviest 12-minute portion of the storm, divided by the time increment 12 minutes, and multiplied by an attenuation factor. The attenuation factor (0.59 for treatment A, 0.67 for treatment B, 0.75 for treatment C and 0.93 for treatment D) describes the effect of routing. Determine the peak discharge using the values in TABLE A-9, which have been adjusted to consider the effects of initial abstraction.

TABLE A-9. PEAK DISCHARGE (CFS/ACRE)

Zone	Treatment 100-YR [2-YR, 10-YR]			
	A	**B**	**C**	**D**
1	1.29 [0.00, 0.24]	2.03 [0.03, 0.76]	2.87 [0.47, 1.49]	4.37 [1.69, 2.89]
2	1.56 [0.00, 0.38]	2.28 [0.08, 0.95]	3.14 [0.60, 1.71]	4.70 [1.86, 3.14]
3	1.87 [0.00, 0.58]	2.60 [0.21,1.19]	3.45 [0.78, 2.00]	5.02 [2.04, 3.39]
4	2.20 [0.05, 0.87]	2.92 [0.38, 1.45]	3.73 [1.00, 2.26]	5.25 [2.17, 3.57]

To determine the peak rate of discharge,

1) Determine the area in each treatment, A_A, A_B, A_C and A_D.

2) Multiply the peak rate for each treatment by the respective areas and sum to compute the total Q_P.

$$\text{Total } Q_P = Q_{PA}A_A + Q_{PB}A_B + Q_{PC}A_C + Q_{PD}A_D \quad \text{(a-10)}$$

Example A-5
Find 100-year Q_P for 14 acres in zone 1. The four land treatments are: 3 acres in treatment A, 5 acres in treatment B, 2 acres in treatment C and 4 acres in treatment D.
Total Q_P = (1.29 * 3) + (2.03 * 5) + (2.87 * 2) + (4.37 * 4) = 37.24 cfs

3) Approximately the same results can be achieved by a Rational Method solution. The 0.2-hour (12-minute) peak intensities, I, are given in TABLE A-10 and Rational Method coefficients, C, are given in TABLE A-11.

$$\text{Total } Q_P = (C_A * I * A_A) + (C_B * I * A_B)$$

$$+ (C_C * I * A_C) + (C_D * I * A_D) \quad \text{(a-11)}$$

TABLE A-10. PEAK INTENSITY (IN/HR at t_c = 0.2 hour)

Zone	Intensity 100-YR [2-YR, 10-YR]
1	4.70 [1.84, 3.14]
2	5.05 [2.04, 3.41]
3	5.38 [2.21, 3.65]
4	5.61 [2.34, 3.83]

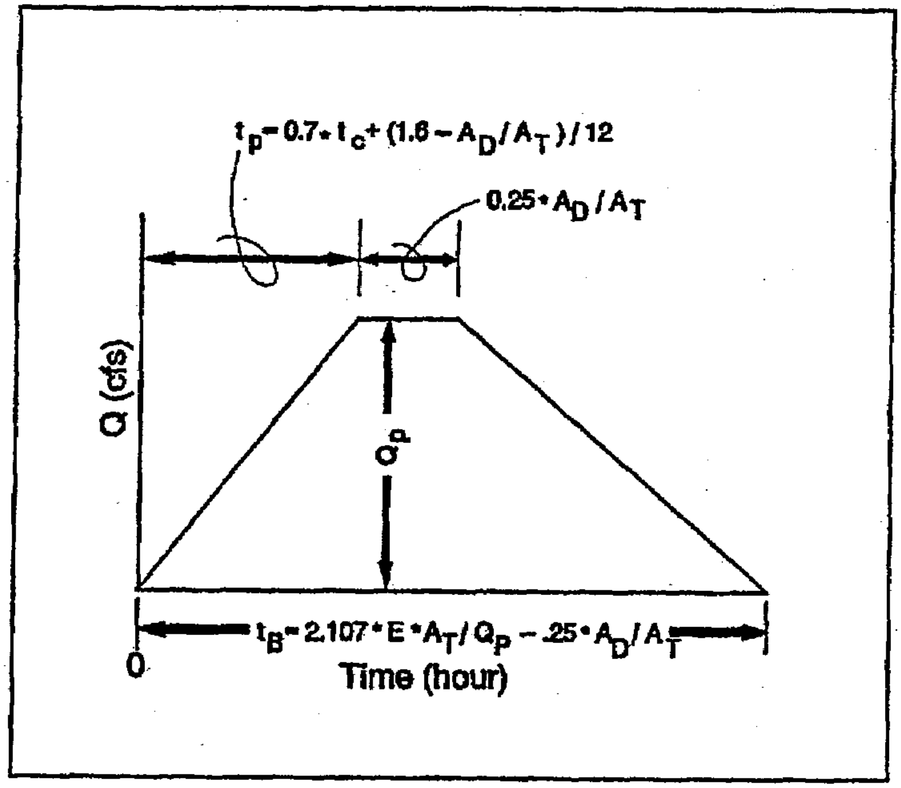
TABLE A-11. RATIONAL METHOD COEFFICIENT, C				
Zone	Treatment			100-YR [2-YR, 10-YR]
	A	B	C	D
1	0.27 [0.00, 0.08]	0.43 [0.02, 0.24]	0.61 [0.26, 0.47]	0.93 [0.92, 0.92]
2	0.31 [0.00, 0.11]	0.45 [0.04, 0.28]	0.62 [0.29, 0.50]	0.93 [0.91, 0.92]
3	0.35 [0.00, 0.16]	0.48 [0.10, 0.33]	0.64 [0.35, 0.55]	0.93 [0.92, 0.93]
4	0.39 [0.02, 0.23]	0.52 [0.16, 0.38]	0.66 [0.43, 0.59]	0.94 [0.93, 0.93]

(Note the quote from the <u>ASCE Manual and Report on Engineering Practice No. 37</u> (1969): The commonly reported Rational C values "are applicable for storms to 5- to 10-yr frequencies. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff." Thus higher C's realized under heavy precipitation might be expected.)

Example A-6
Recompute Example A-5 using the Rational Method.
Q = C I A
= (0.27 * 4.70 *3) + (0.43 * 4.70 * 5) + (0.61 * 4.70 * 2) + (0.93 * 4.70 * 4)
= 37.13 cfs

Continue the peak for 0.25 * A_D / A_T hours. When A_D is zero, the hydrograph will be triangular. When A_D is not zero, the hydrograph will be trapezoidal. FIGURE A-3 shows the hydrograph in graphic form.

FIGURE A-3



Example A-8
Determine the hydrograph for Example A-5.
A_T = 14.0 acres A_D = 4.0 acres t_C = 0.2 hour Q_P = 37.24 cfs
E = ((3 * .44) + (5 * .67) + (2 * .99) + (4 * 1.97)) / (3 + 5 + 2 + 4) = 1.038 inches
t_P = (0.7 * 0.2) + (1.6 - (4 / 14)) / 12) = 0.2495 hours
t_B = (2.017 * 1.038 * 14 / 37.24) - (0.25 * 4 / 14) = 0.7157 hours
Duration of peak = 0.25 * 4 / 14 = 0.0714 hours

PART B - TIME OF CONCENTRATION, LAG TIME, AND TIME TO PEAK

There is a delay, after a brief heavy rain over a watershed, before the runoff reaches its maximum. The length of time it takes for runoff from a watershed to reach an analysis point effects the peak runoff rate, with shorter times producing higher peak flow for a constant runoff volume. The velocity at which water can flow through a watershed and the length of flow path are used to determine the time factors. Time of concentration, lag time, and time to peak are three related watershed parameters that are used to determine peak rates of runoff.

B.1 DEFINITIONS

The three time parameters used are defined as follows:

time of concentration (t_c) = time it takes for runoff to travel from the hydraulically most distant part of the watershed basin to the basin outlet or point of analysis

Lag time (L_G) = time from the center of unit rainfall excess to the time that 50 percent of the volume of unit runoff from the drainage basin has passed the concentration point or point of analysis.

time to peak (t_p) = time from the beginning of unit rainfall excess to the time of the peak flow of the unit runoff hydrograph.

The three time parameters can be computed using the procedures identified in this section. The peak discharge rates and intensity factors identified in TABLES A-9 and A-10 (PART A) were computed using a time of concentration (t_c) of 0.2 hour. The procedures in Part C require the computation of time to peak (t_p) as specified herein.

B.2 COMPUTATION OF TIME OF CONCENTRATION

Three different equations are used to compute time of concentration (t_c) for larger watersheds. For subbasin reach lengths shorter than 4000 feet the SCS Upland Method is used; for subbasin reach lengths longer than 12000 feet the USDI Bureau of Reclamation lag time equation is used. A transition equation is used for subbasin reach lengths between 4000 and 12000 feet.

Consideration should be given to splitting large watersheds into smaller subbasins with reach lengths less than 4000 feet. Smaller subbasins will allow more accurate modeling of channels and basin topography, and should provide for greater modeling accuracy.

1). For subbasin reach lengths less than 4000 feet:

Compute time of concentration, t_c (hours), for the entire (pervious and impervious) watershed by the SCS Upland Method, the sum of the travel times in the subreaches comprising the longest flow path to the watershed outlet.

$$t_c = (L_1 / V_1 + L_2 / V_2 + \ldots + L_x / V_x) / 3600 \text{ sec/hour} \qquad \text{(b-1)}$$

and, $(L_1 + L_2 + \ldots + L_x) < 4000$ feet

where L_x is the subreach length (feet) and v is the velocity (feet/sec) in that subreach, as determined by the following equation:

$$v = K * \sqrt{(s * 100)} = 10 * K * \sqrt{(s)} \qquad \text{(b-2)}$$

where s is the slope in foot per foot, and K depends upon the conveyance condition, as shown in TABLE B-1. If t_C is computed to be less than 0.2 hours, use $t_C = 0.2$ hours.

TABLE B-1. CONVEYANCE FACTORS

K	Conveyance Condition
0.7	Turf, landscaped areas and undisturbed natural areas (sheet flow* only).
1	Bare or disturbed soil areas and paved areas (sheet flow* only).
2	Shallow concentrated flow (paved or unpaved).
3	Street flow, storm sewers and natural channels, and that portion of subbasins (without constructed channels) below the upper 2000 feet for subbasins longer than 2000 feet.
4	Constructed channels (for example: riprap, soil cement or concrete lined channels).

* Sheet flow is flow over plane surfaces, with flow depths up to 0.1 feet.
Sheet flow applies only to the upper 400 feet (maximum) of a subbasin.

For composite reaches, where this basin slope is uniform, the composite basin conveyance condition, K, can be computed using the following equation:

$$K = L / (L_1 / K_1 + L_2 / K_2 + \ldots + L_X / K_X) \qquad \text{(b-3)}$$

where $L = L_1 + L_2 + \ldots + L_X$

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For composite reaches where the basin slope is not uniform, the composite basin conveyance condition, K, can be computed using the following equation:

$$K = (L / \sqrt{s}) / (L_1 / (K_1 * \sqrt{s_1}) + L_2 / (K_2 * \sqrt{s_2}) + ... + L_x / (K_x * \sqrt{s_x})) \quad \text{(b-4)}$$

where: $L = L_1 + L_2 + ... + L_x$

and, $$s = (L_1 * s_1 + L_2 * s_2 + ... + L_x * s_x) / L \quad \text{(b-5)}$$

2.) For subbasin reach lengths between 4000 and 12000 feet:

Compute the time of concentration, t_C (hours), for the entire watershed using the following equation:

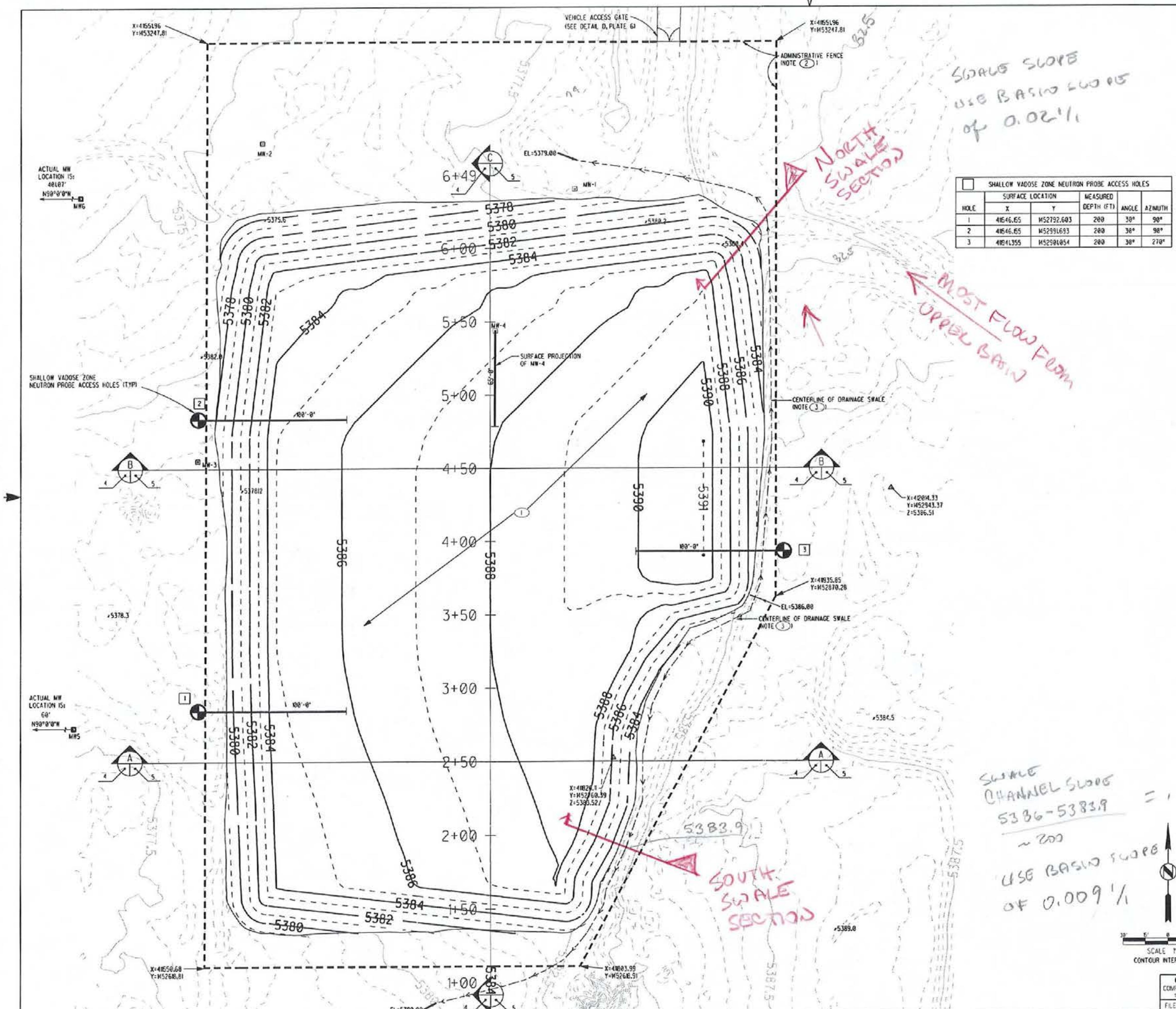
$$t_C = ((12000 - L) / (72000 * K * s^{0.5})) + ((L - 4000) * K_N * (L_{CA} / L)^{0.33} / (552.2 * s^{0.165})) \quad \text{(b-6)}$$

where:

K	=	Conveyance factor from TABLE B-1. For composite reaches, K is computed using equation b-3 or b-4.
L	=	distance of longest watercourse, in feet.
L_{CA}	=	distance along L from point of concentration to a point opposite centroid of drainage basin, in feet.
s	=	overall slope of L, in foot per foot. For composite reaches s is computed using equation b-5.
K_N	=	a basin factor based on an estimate of the weighted, by stream length, average Manning's n value for the principal watercourses in the drainage basin. For the Albuquerque area, values of K_N may be estimated from TABLE B-2.

TABLE B-2. LAG EQUATION BASIN FACTORS

K_N	Basin Condition
0.042	Mountain Brush and Juniper
0.033	Desert Terrain (Desert Brush)
0.025	Low Density Urban (Minimum improvements to watershed channels)
0.021	Medium Density Urban (Flow in streets, storm sewers and improved channels)
0.016	High Density Urban (Concrete and rip-rap lined channels)



SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES					
HOLE	SURFACE LOCATION X	SURFACE LOCATION Y	MEASURED DEPTH (FT)	ANGLE	AZIMUTH
1	41646.65	H52792.603	200	30°	90°
2	41646.65	H52991.693	200	30°	90°
3	41941.355	H52901.054	200	30°	270°

GENERAL NOTES

1. BORROW SITE FOR NATIVE SOIL LAYER FILL AND TOPSOIL LAYER IS APPROXIMATELY 1.5 MILES SOUTH OF THE PROJECT AREA.
2. NATIVE SOIL LAYER FILL SHALL BE OBTAINED FROM TA-3 BORROW PITS. APPROXIMATELY 13,200 CUBIC YARDS OF FILL SHALL BE REQUIRED FOR THE NATIVE SOIL LAYER. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). ANY GRADE STAKES USED ON THE PROJECT SHALL BE REMOVED AND BACKFILLED WITH COVER MATERIAL TO MEET CONSTRUCTION SPECIFICATIONS.
3. THE TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL LAYER SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). TOPSOIL SHALL BE ADMIXED 25 PERCENT BY VOLUME WITH 3/8-INCH CRUSHED GRAVEL (ASTM D448, SIZE *8). APPROXIMATELY 3,900 CY WILL BE REQUIRED FOR THE TOPSOIL LAYER.
4. BIOINTRUSION LAYER MATERIALS: THE BIOINTRUSION BARRIER MATERIAL SHALL BE CONSTRUCTED USING A GRADED ROCK RIPRAP. RIPRAP SIZE SHALL BE OF STONE SIZE SO THAT 50 PERCENT OF THE PIECES, BY WEIGHT, SHALL BE LARGER THAN THE D50 SIZE(4"). THE WELL GRADED MATERIAL SHALL BE A MIXTURE COMPOSED PRIMARILY OF LARGER STONE SIZES BUT WITH A SUFFICIENT MIXTURE OF OTHER SIZES TO FILL THE SMALLER VOIDS BETWEEN THE STONES. THE DIAMETER OF THE LARGEST STONE SIZE IN SUCH A MIXTURE SHALL BE 6" (1.5 TIMES) THE D50 SIZE OF 4". THE THICKNESS OF THE BIOINTRUSION BARRIER MATERIAL LAYER SHALL BE A MINIMUM OF 1' AND A MAXIMUM OF 1.25'.

   THE BIOINTRUSION LAYER SHALL BE OBTAINED FROM A LOCAL SUPPLIER AND STOCKPILED SOUTH OF THE SITE BY THE OPERATOR FOR THE CONTRACTOR'S USE.

KEYED NOTES

(1) THE FINAL COVER CONTOURS INDICATE TOP OF THE FINAL COVER.

(2) CONTRACTOR SHALL INSTALL AN ADMINISTRATIVE FENCE AROUND PERIMETER OF CONSTRUCTED LANDFILL COVER. ADMINISTRATIVE FENCE SHALL BE CONSTRUCTED ACCORDING TO DETAIL D, PLATE 6.

(3) CONTRACTOR SHALL CONSTRUCT A DRAINAGE SWALE IN ACCORDANCE WITH DETAIL C, PLATE 6. DRAINAGE SWALE SHALL BE CONSTRUCTED TO ENSURE POSITIVE DRAINAGE USING ELEVATIONS SHOWN ON THIS PLAN AS A GENERAL GUIDE.

SEEDING PLAN

1. SEEDING SHALL COMPLY WITH CONSTRUCTION SPECIFICATION 02930, RECLAMATION SEEDING AND MULCHING.
2. THE FOLLOWING SEED MIX SHALL BE USED FOR SEEDING OF THE FINAL GRADE, BORROW LOCATION, LAYDOWN AREAS, AND OTHER LOCATIONS IMPACTED BY CONSTRUCTION ACTIVITIES:

SEED SPECIES	SEEDING RATE PURE LIVE SEED (POUNDS PER ACRE)
BLACK GRAMA	6.0
GALLETA GRASS	8.0
RING MUHLY	3.0
SPIKE DROPSEED	3.0

ESTIMATED BORROW QUANTITIES	
TOPSOIL LAYER	3900 CY
BIOINTRUSION LAYER	4900 CY
NATIVE SOIL LAYER	13,200 CY

LEGEND

—5384.5—	EXISTING INDEX CONTOUR
- - -	EXISTING INTERMEDIATE CONTOUR
— — —	FINAL ADMINISTRATIVE FENCE
—5384.5—	FINAL COVER INDEX CONTOUR
- - -	FINAL COVER INTERMEDIATE CONTOUR
MW-4	GROUNDWATER MONITORING WELL
←—←—	DRAINAGE SWALE CENTERLINE
1	SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES
△	PROJECT BENCHMARKS

REV	DATE	DESCRIPTION	DWN	CKD	APP
B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

P.O. OR W.O. / PROJECT NO.

U.S. DEPARTMENT OF ENERGY
KIRTLAND AREA OFFICE
ALBUQUERQUE, NEW MEXICO

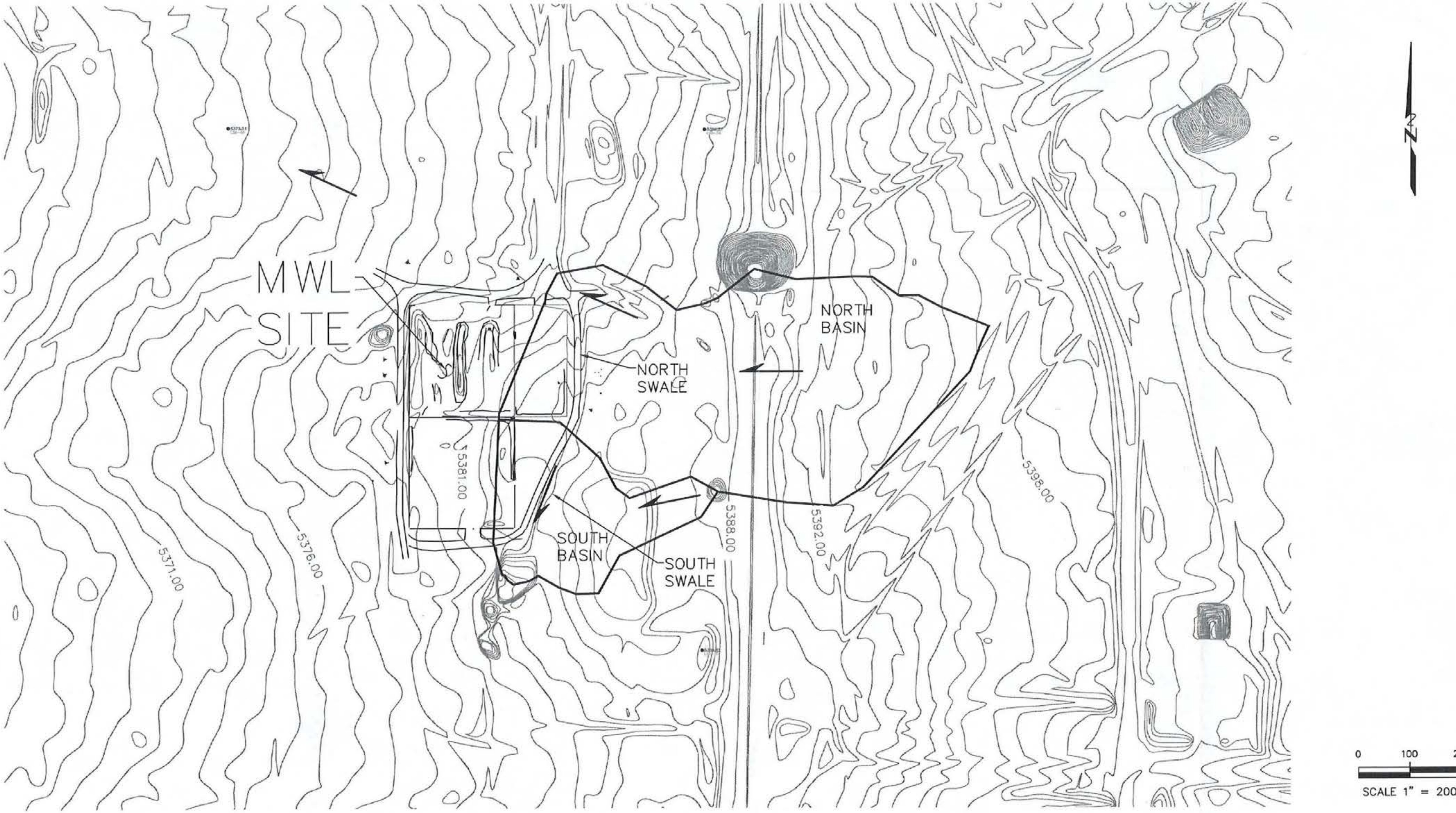
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

FINAL COVER

MIXED WASTE LANDFILL FINAL COVER GRADING PLAN

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./xx
DATE	07.29.05
SIZE	D
DRAWING NO./SHEET	999997/A6.91
PLATE	4

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823
FILE NAME: 99999746.91
REFERENCE FILES:



DIRECTION OF FLOW

BASIN BOUNDARY

URS
6501 AMERICAS PARKWAY N.E., SUITE 900
ALBUQUERQUE, NEW MEXICO 87110
(505) 855-7500 FAX: (505) 855-7555

TOPOGRAPHICAL MAP FOR MIXED WASTE EXHIBIT #2

MWL SITE

AS OF DECEMBER, 2006

SHEET 1 OF 1

Volume I

TAB 13

DOE/Sandia Responses to the NOD Part 2 Comments: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 (Includes submittal of the 2nd Edition of Appendix E, SAND2007-0170)

From: SNL/Wagner
To: NMED/Bearzi

Back of Tab 13

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

JAN 1 9 2007

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Road, East, Bldg. 1
Santa Fe, NM 87505

Dear Mr. Bearzi,

On behalf of the Department of Energy (DOE) and Sandia Corporation (Sandia), DOE is submitting the second response to the Notice of Disapproval (NOD): Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005 and Requirements for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories, EPA ID NM5890110518, HWB-SNL-05-025. In a letter dated December 21, 2006, we submitted responses to Part 1 comments and the required Soil Vapor Sampling and Analysis Plan.

Enclosed with this letter is an Errata sheet correcting a typographical error in the response to Part 1 Comment Number 15. In addition, the enclosure contains responses that address Part 2 comments.

As part of this response submittal, DOE and Sandia are presenting additional information on the monitoring trigger evaluation process. This information provides the basis for requirements to be established under the Long Term Monitoring and Maintenance Plan (LTMMP). Accordingly, this information is preliminary and will be finalized in the LTMMP which is required for submittal to the New Mexico Environment Department and subject to a public review and comment period.

If you have any questions regarding this submittal, please contact me at (505) 845-6036 or Joe Estrada of my staff at (505) 845-5326.

Sincerely,

Kimberly A Davis for

Patty Wagner
Manager

Enclosures (2)

JAN 1 9 2007

Received
JAN 2 6 2007
District I

cc w/enclosures:
W. Moats, NMED (via Certified Mail)
J. Kieling, NMED, Santa Fe
L. King, USEPA, Region VI (via Certified Mail)
T. Skibitski, NMED-OB
T. Longo, NNSA/NA-56/HQ, GTN
UNM Zimmerman Library

cc w/o enclosure:
M. Reynolds, NNSA/SSO, MS-0184
J. Gould, NNSA/SSO, MS-0184
A. Blumberg, SNL/NM, Org. 11100, MS- 0141
P. Freshour, SNL/NM, Org. 6765, MS-1089
D. Miller, SNL/NM, Org. 6765, MS -0718
C. Ho, SNL/NM, Org. 6313, MS- 0735
T. Goering, SNL/NM, Org. 6765, MS -1089
S. Griffith, SNL/NM, Org. 6765, MS-1089
M. J. Davis, SNL/NM, Org. 6765, MS-1089
Records, Center, SNL/NM, Org. 6765, MS-1089

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **DOE/Sandia Response to NMED's "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005" (Comment Set 2), January 2007**

Document authors: **Tim Goering, 6765 and Cliff Ho, 6313**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: Peter B. Davies 1/15/07

Peter B. Davies
Director
Nuclear Energy & Global Security Technologies
Division 6700
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico 87185
Operator

Date

and

Signature: Kimberly A Davis for 1/19/07

Patty Wagner
Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Date

ERRATA SHEET

Part 1, Comments on Landfill Construction Plans and Performance Modeling

Revised Response to Comment No. 15, Comment Set 1 (SNL December 2006):

15. Appendix B, Construction Quality Assurance Plan, Section 8.7 -- The Final Report must be submitted to the NMED as part of the CMI Report. The Final Report must include copies of all quality control data generated by the construction contractor as well as the quality assurance data generated by the CQA contractor.

Response: The Construction Quality Assurance **Report** will include all quality control data generated by the construction contractor as well as quality insurance data generated by the CQA contractor. The Construction Quality Assurance **Report** will be submitted to the NMED as part of the CMI Report.

Note: The original response incorrectly referred to the document as a Construction Quality Assurance Plan, rather than a Construction Quality Assurance Report.

Sandia Corporation
Albuquerque, New Mexico
January 15, 2007

DOE/Sandia Responses to NMED's "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005"

Comment Set 2

INTRODUCTION

This document responds to the second set of comments received in a letter from the New Mexico Environment Department (NMED) to the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) on November 24th, 2006 regarding the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan for Sandia National Laboratories (SNL). The letter is entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Work Plan, November 2005, and Requirement for Soil-Vapor Sampling and Analysis Plan, Sandia National Laboratories" [EPA ID NM5890110518, HWB-SNL-05-025].

The NMED letter contains two sets of comments, divided based on subject. The first set is entitled, "Part 1, Comments on Landfill Construction Plans and Performance Modeling". A response to the first set of comments was submitted by DOE/Sandia to NMED on December 21, 2006 (SNL December 2006). This document provides a correction for the response to Comment No. 15 in Comment Set 1 along with the DOE/Sandia response to the second set of comments, which are entitled, "Part 2, Comments on the MWL Fate and Transport Model (Appendix E)".

This document lists each NMED comment, and DOE/Sandia's response to that comment. The NMED comment is listed in boldface, followed by the DOE/Sandia response, written in normal font under "Response".

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Part 2. Comments on the MWL Fate and Transport Model (Appendix E)

1. Section 2.1.2.2 -- The last paragraph of Section 2.1.2.2 states, "Present conditions were simulated by modeling infiltration through various thicknesses of an engineered cover, while future conditions were simulated by modeling infiltration through various thicknesses of soil under natural conditions (i.e., the 'natural analog')." This description implies that present and future conditions are simulated using different designs (in the near term an engineered cover which in the future eventually degrades to the conditions of natural soil). Section 3.4.2 states that the engineered soil cover reverts to the natural soil conditions around the landfill. Provide clarification in Section 2.1.2.2 regarding the evolving soil conditions within the cover. Explain what soil conditions are expected to evolve, why and when they will evolve, and what will they will evolve to.

Response: Cover performance modeling was conducted in 2003 and 2004 using site-specific climate, hydrologic, and vegetation input parameters, and is discussed in depth the document entitled, "Calculation Set for Design and Optimization of Vegetative Soil Covers" (Peace and Goering 2005). This modeling effort simulated cover performance under present and future conditions using the same design, but slightly different soil hydraulic properties. A complete copy of this report is included on the CD as Attachment 1, under the subdirectory, "Supporting Documentation".

Soil hydraulic properties for modeling present conditions were determined by measuring soil hydraulic properties of an engineered cover test plot, while soil hydraulic properties for modeling future conditions were determined by measuring soil hydraulic properties of the natural analogue. Additional information on measurement of the soil hydraulic properties for both modeling scenarios is presented below.

Present Conditions – Engineered Cover Properties

Soil hydraulic properties for the engineered vegetative cover were determined by field and laboratory measurements conducted on an engineered cover test plot constructed at the IP Test Site west of the MWL. The engineered cover test plot was constructed to the same bulk density and initial moisture contents specified in the current MWL cover design. The test plot consisted of 6 feet of compacted native soil overlain by 9 inches of uncompacted native topsoil. The native soil layer was placed in 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. The native soil was compacted to not less than 90% maximum dry density at -3 to +2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing). A total of 13 lifts, excluding subgrade, were placed to complete construction of the engineered cover test plot. Additional details on the construction of the engineered cover test plot and the measurement of the soil hydraulic properties are presented in Section 4.2 of the document, "Calculation Set for Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico" (Peace and Goering 2005).

Field and laboratory tests were conducted on the soils of the engineered cover test plot to

measure the soil hydraulic and geotechnical properties used for performance modeling of the engineered cover. Because the engineered cover test plot was constructed to the same specifications as the proposed MWL cover using the same soil type, the soil hydraulic properties of the engineered test plot were considered representative of the proposed MWL cover. Thus, the modeling results from the engineered cover represent present conditions for the proposed MWL cover.

Future Conditions – Natural Analogue Properties

The soil hydraulic properties for the natural analogue were determined by field and laboratory measurements conducted on undisturbed soils near the IP test site west of the MWL. The soil hydraulic properties of the natural analogue are discussed in Section 6.5.3 of Peace and Goering (2005). The soil hydraulic properties of the natural analogue were considered representative of future conditions for reasons presented below.

Evolution of Soil Conditions within the Cover:

The MWL engineered cover will gradually evolve over time to a more natural system (i.e. the natural analogue) as vegetation is established, and natural processes gradually affect the properties of the cover. Pedogenic processes (i.e., soil evolution) will change soil physical and hydraulic properties that are fundamental to the performance of the engineered cover. Pedogenesis includes processes such as 1) hydraulic and mechanical redistribution of soil particles, affecting soil hydrologic properties (i.e. bulk density, porosity, and hydraulic conductivity); 2) formation of macropores for preferential flow associated with root growth, animal intrusion, and soil structural development; 3) secondary mineralization, deposition, and illuviation of fines, colloids, soluble salts, and oxides that can alter water storage and infiltration; and 4) soil mixing caused by freeze-thaw activity, animal burrows, and the shrink-swell action of expansive clays (Chadwick and Graham 2000).

Although vegetation will be established on the MWL cover within three to five years, the pedogenic processes discussed above will take many years for the engineered cover to evolve to, and perform like the natural analogue. Pedogenic processes are driven by climate, organisms, topographic relief, parent material, and time. Many interactions occur between water, air, temperature, microorganisms, plants, animals, and their residues, affecting the mineral material of the original soil and its position in the landscape. During its evolution, the soil profile slowly expands and deepens, developing characteristic discrete soil layers called horizons, while a steady-state balance is approached. One cannot predict when steady state (i.e. the natural analogue) is attained. For this reason, the soil properties of the natural analogue were considered, and used as modeling input parameters to assess the future performance of the MWL cover.

Cover Performance Modeling of Present Conditions versus Future Conditions

Cover performance modeling of both the engineered cover and the natural analogue was conducted using input parameters measured on the engineered cover and the natural

analogue, as described above. Present conditions were simulated by modeling cover performance assuming soil properties of the engineered cover. Future conditions were simulated by modeling cover performance assuming soil properties of the natural analogue. Table 1 presents the model input parameters for both the engineered cover and the natural analogue.

The modeling results confirm that under both current and future scenarios, the MWL cover will meet the EPA-prescribed technical equivalency criteria for RCRA landfills. These criteria are a net annual infiltration of 31.5 millimeter/yr, and an average infiltration rate of 1 X 10^{-7} cm/s or less (Peace and Goering 2005).

Table 1. UNSAT-H Code Input Parameters

Parameter	Natural Analogue		Engineered Cover		Source
	Input value	Unit(s)	Input value	Unit(s)	
Initial Head	17,200	cm	5620	cm	RETC Code
θ_s	0.39	Percent	0.35	Percent	RETC Code
θ_r	0.001	Percent	0.001	Percent	RETC Code
α	0.0309	cm^{-1}	0.022	cm^{-1}	RETC Code
n	1.19	(-)	1.26	(-)	RETC Code
ℓ	0.5	(-)	0.5	(-)	[a]
K_s	4.05×10^{-4}	cm/s	3.46×10^{-4}	cm/s	Field
Root Depth	80	cm	80	cm	Field
LAI Historical Precipitation	0.8 max	(-)	0.8 max	(-)	[b, c, d]
LAI Maximum Precipitation	1.2 max		1.2 max		
Growing Season	2–364	Julian Day	2–364	Julian Day	[b, c, d]
Percent Bare Area	81	Percent	81	Percent	Field
RLD coefficient *a*	0.5090	(-)	0.5090	(-)	Field
RLD coefficient *b*	-0.0630	(-)	-0.0630	(-)	Field
RLD coefficient *c*	0.0262	(-)	0.0262	(-)	Field
Ψ_w	30,000	cm	30,000	cm	[e, f, g]
Ψ_d	3000	cm	3000	cm	[h, i]
Ψ_n	30	cm	30	cm	[h, i]
PET coefficient *a*	0	(-)	0	(-)	[j]
PET coefficient *b*	0.52	(-)	0.52	(-)	[j]
PET coefficient *c*	0.5	(-)	0.5	(-)	[j]
PET lower limit *d*	0.0	(-)	0.0	(-)	[j]
PET upper limit *e*	3.7	(-)	3.7	(-)	[j]

[a]Maulem (1976)
[b]NMED (1998)
[c]Scurlock et al. (2001)
[d]Munk (2004)
[e]HDR Engineering (2000)
[f]ITRC (2003)
[g]Hillel (1998)
[h]Fayer (2000)
[i]Feddes et al. (1978)
[j]Ritchie and Burnett (1971)

α Air entry parameter
θ_r Residual moisture content
θ_S Saturated moisture content
Ψ_w Wilting point
Ψ_d Limiting point
Ψ_n Anaerobic
cm Centimeter(s)
K_S Saturated hydraulic conductivity
ℓ Mualem numerical parameter
LAI Leaf area index
max Maximum
n van Genuchten curve-fitting parameter
PET Potential evapotranspiration
RDL Root length density

2. The first paragraph of Section 3.2.1 states that lead, cadmium, and radionuclides (except radon) were modeled using the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) and Multimedia Environmental Pollutant Assessment System (MEPAS) simulation tools. Section 3.2.2 states, "A separate model was used to model the transient transport of tritium at the MWL". The reader, however, does not learn until Section 3.7.1 that tritium was also modeled using FRAMES and MEPAS. Revise the text of Section 3.2.1 to indicate tritium was modeled using FRAMES and MEPAS, as well as the separate transient transport model.

The second paragraph of Section 3.2.1 indicates MEPAS is capable of computing contaminant fluxes for multiple routes, including radioactive decay and contaminant degradation. The paragraph states further that MEPAS was used only for the source-term and vadose-zone models, suggesting MEPAS was not used to model radioactive decay. In contrast, Section 3.2.2 indicates that the transient model for tritium and perchloroethene (PCE) accounts for contaminant decay. Clarify whether the modeling of radionuclide transport through the vadose zone at the MWL accounts for contaminant decay.

Response: The text in Sections 3.2.1 and 3.2.2 has been clarified to indicate that FRAMES/MEPAS can only simulate liquid-phase transport of constituents such as tritium. A separate analytical model was used to simulate the gas and liquid-phase transport of tritium.

The use of source-term and vadose-zone models in MEPAS does not preclude radioactive decay. Constituent decay can occur in both the source-term and vadose-zone transport models. Text has been added to Section 3.2.1 to clarify this. The revised Probabilistic Performance Assessment Modeling Report is included in Appendix A.

3. The first paragraph of Section 3.3 references Table E-2, which provides a summary of input parameters and distributions of constituents used in the modeling. Footnotes "b" and "d' reference an EPA fact sheet for tetrachloroethene; the fact sheet was reportedly accessed on the U.S. EPA website at www.epa./WGWDW/dwh/t-voc/tetrachl.html, but it is not referenced in Section 6, References, of the report. The fact sheet was not available at the web address provided, so the input parameters could not be verified. Provide the fact sheet as an attachment to the report and update the website address, if available, for the fact sheet. Also, revise Section 6 to include this fact sheet among the references. In addition, provide all other internet-referenced data as attachments to the report and cite these sources in Section 6.

Response: There was a typo in the URL address for the PCE fact sheet. This has been corrected and all online references have been added to Section 6. PDF versions of these web pages are included in the attached CD (Attachment 1). The online references are listed in Section 6 as follows:

- U.S. EPA, Tetrachloroethylene (PCE) Online Fact Sheet:
  www.epa.gov/OGWDW/dwh/t-voc/tetrachl.html

- U.S. EPA, Cadmium Online Fact Sheet: www.epa.gov/safewater/dwh/t-ioc/cadmium.html

- U.S. EPA, Lead Online Fact Sheet: www.epa.gov/safewater/dwh/t-ioc/lead.html

- U.S. EPA, Henry's Constant Online Calculator: www.epa.gov/athens/learn2model/part-two/onsite/esthenry.htm)

4. Section 3.4.2, page E-35, 2nd paragraph -- Explain why future infiltration rates would be less than current rates.

Response: The cover performance modeling predicted the average infiltration rate through the engineered cover (representing present conditions) to be 1.18 X 10^{-9} cm/s for historical precipitation, and 5.34 X 10^{-9} cm/s for the maximum precipitation scenario (Peace and Goering 2005). The modeling predicted the average infiltration rate for the natural analogue (representing future conditions) to be 2.44 X 10^{-10} cm/s for the historical precipitation scenario, and 1.04 X 10^{-9} cm/s for the maximum precipitation scenario.

The difference in modeling results between the engineered cover (representing present conditions) and the natural analogue (representing future conditions) reflect variations in soil properties between the engineered cover and the natural analogue, as shown in Table 1. These include minor differences in saturated hydraulic conductivity (4.05 X 10^{-4} cm/s for the natural analogue, versus 3.46 X 10^{-4} cm/s for the engineered cover) and porosity, as indicated by the saturated moisture content (θ_s) of 0.39 for the natural analogue versus 0.35 for the engineered cover. These variations in soil properties are a result of the pedogenic processes discussed above (see Response to Comment No. 1), and result in a net increase in porosity and hydraulic conductivity. The increased porosity and hydraulic conductivity of the natural analogue facilitate evapotranspiration, resulting in a net decrease in infiltration rate for the natural analogue (i.e. future conditions).

***5.* Section 3.6, Fate and Transport of Radon -- Radon was modeled as originating from radium-226 sources. Explain why radon originating from the decay of depleted uranium was not incorporated into the radon fate and transport model.**

Response: Radon was included as a daughter product of uranium-238 in the FRAMES/MEPAS simulations, as discussed in Section 3.6.2.2 and 3.7.2.2. However, U-238 was not included as a source of radon for the gas-transport model detailed in Section 3.6.2.2 because the activity of Ra-226 (parent of Rn-222) resulting from the decay of uranium-238 is negligible (15 microCuries after the first 1,000 years) relative to the activity of Ra-226 assumed in the model (6-12 Curies). This has been clarified in the text.

6. Section 4, Pages E-59 and E-59a -- Revise the trigger evaluation process to follow the corrective action process described in the Consent Order (April 29, 2004) if a trigger level is exceeded (step 3A), provided the Consent Order is still in force at the time the trigger level is exceeded. If the Consent Order has terminated, the trigger evaluation process

should follow the standard RCRA corrective action process.

<u>Response:</u> To be consistent with the Compliance Order on Consent (NMED April 2004) between the NMED, the DOE, and Sandia Corporation, hereinafter referred to as the Consent Order, several minor modifications were made to the trigger evaluation process figure on Pages E-59 and E-59a. The Consent Order requires notification of the NMED in writing within 15 days after the discovery of any previously unknown release of a Contaminant from a SWMU or Area of Concern. For consistency with the Consent Order, Step 3B on Figure E-25 has been revised to state, "If verified, notify NMED ***in writing within 15 days*** and increase sampling frequency as negotiated with NMED".

In addition, the following line was added to Item 5 on Page E-59a, which explains the trigger evaluation process, ***"If the NMED determines that further investigation of the trigger exceedance is needed, NMED may require corrective action based on a finding that releases of contaminants have occurred, are occurring, or are likely to occur."***

The revised Trigger Evaluation Process is shown in Figure 1 below. All proposed monitoring triggers are considered preliminary at this point, and provide the basis for requirements to be established under the Long Term Monitoring and Maintenance Plan (LTMMP). Accordingly, this information is preliminary and will be finalized in the LTMMP which is required for submittal to NMED and subject to a public review and comment period.

7. Section 3.3 -- The fourth paragraph of Section 3.3 discusses the dose via inhalation and dermal adsorption for gas-phase tritium, but a similar discussion is not presented for radon gas or gas-phase PCE. Clarify whether this dose discussion is applicable to all gas-phase constituents considered in the Report. If the dose discussion is only applicable to gas-phase tritium, then explain why this is the case. Alternatively, discuss inhalation and dermal adsorption doses for radon gas and gas-phase PCE.

<u>Response:</u> Inhalation and dermal adsorption of gas-phase radon and PCE were not used as performance metrics in this analysis. Table 1 in Section 3.1 of the Performance Assessment Modeling Report summarizes the performance metrics that were used for these constituents. Text has been added to clarify this in the report. The inhalation dose is only applicable to gas-phase tritium because the enforceable regulatory metrics pertaining to radon and PCE do not use dose (surface flux is used for radon and groundwater concentration is used for PCE).

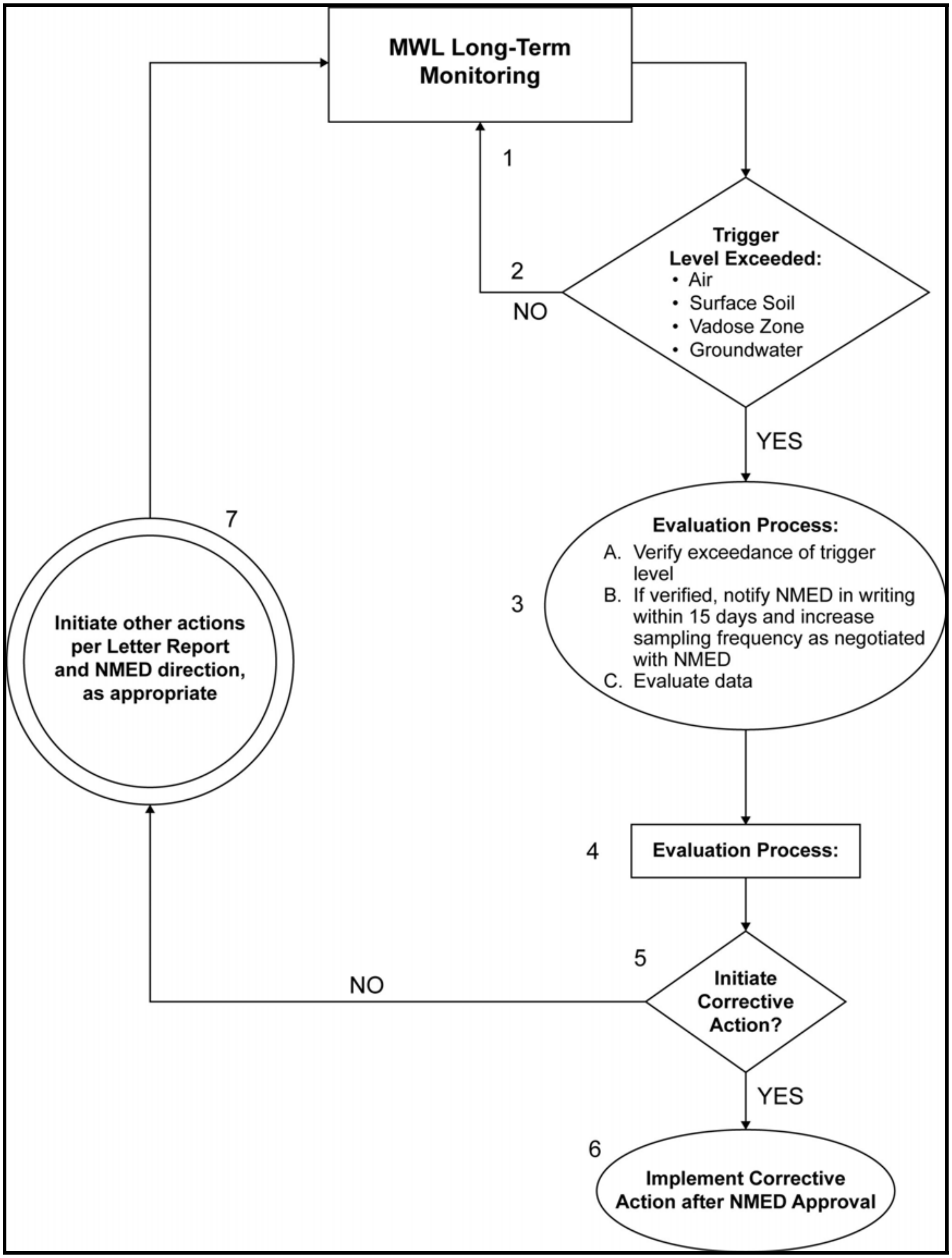


Figure 1. Trigger evaluation process for the Mixed Waste Landfill (revised)

8. Section 3.4.1 --The first paragraph of Section 3.4.1 states the modeling study of water infiltration through the cover was "discretized by placing computational nodes at predetermined vertical spacing in a conceptual soil profile to evaluate the performance of a cover 3 ft in thickness." The model evaluated a soil profile that was actually 6 feet thick in order to avoid impacts due to boundary conditions, but these impacts and boundary conditions are not discussed. Thirty nodes were located within this 6-foot-thick soil profile. However, the discussion does not describe how or why the 30 node locations were predetermined within this soil profile. Explain the specific impacts caused by boundary conditions. Clarify how and why the computational node locations were predetermined.

The conceptual soil profile for the infiltration model, as discussed in Section 3.4.1, is presented side-by-side in Figure E-3 with nodal discretization used in the UNSAT-H model. As illustrated, the conceptual soil profile does not correspond to the components of the MWL soil cover cross-section. The soil profile illustration is dimensionless; i.e., it is not clear whether the soil profile is 6 feet thick. Also, only 23 of the 30 computational nodes within the cross-section are shown. In addition, the nodal depth locations cannot be determined from the illustration. Revise the Figure E-3 conceptual model to clearly indicate the components of the MWL soil cover (i.e., subgrade layer, biointrusion barrier, native soil layer, topsoil layer, and vegetation) and their location relative to the MWL waste zone. Revise Figure E-3 to include a vertical scale for depth (i.e., inches or feet below the cover surface) and the locations of all 30 computational nodes. Clarify the soil type specified for each component of the soil cover.

<u>Response:</u> Section 3.4.1 presents only a conceptualization of the model used to predict water percolation through the cover. A detailed description of the model and extensive discussion of the input parameters, boundary conditions, and results are discussed in the document, "Calculation Set for Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico" (Peace and Goering, 2005). Additional information from this report is included below.

Node Locations:

The 30 node locations within this soil profile were carefully selected to minimize modeling computational requirements, yet yield accurate numerical results. Node spacing is very fine near the ground surface and becomes progressively larger with increased depth through the soil profile. The fine node spacing near the surface is necessary for an accurate numerical solution because very large and rapid changes in suction head occur as the surface dries and wets in response to evaporation and precipitation. Deeper in the soil profile, suction head changes are less dramatic and node spacing is increased. This spacing was selected to minimize numerical errors while maintaining reasonable execution times.

By code convention, nodal depths in the soil profile were assigned metric values. The node locations were "predetermined" within the soil profile to facilitate interpretation of modeling results. Node numbers 10, 14, 19, 22, and 26 were assigned depths of 30, 61, 91, 122 and 152 cm, respectively, to represent the lower boundary of covers 1,2,3,4 and 5 ft in thickness. Model output included flux across each nodal boundary; hence, the results could be used to optimize cover thickness for the remedy design.

Boundary Conditions:

Boundary conditions were selected to be conservative with regards to prediction of net percolation through the cover. Hence, predicted percolation values may be higher than actual percolation values. The water flow for the upper boundary (i.e., through the surface of the soil profile), is specified as an evaporation flux boundary and an infiltration boundary equivalent to hourly precipitation over a 24-hr period. The water flow for the lower boundary or the base of the soil profile at 6 ft is specified as a unit downward gradient —flow is always directed downward. A lower boundary specified as a unit gradient is conservative because in nature, movement of water is either upward or downward as the soil profile responds to precipitation, evaporation, and transpiration. Since hourly precipitation is designated and the model regards daily precipitation as occurring over a 24-hr period, all flow is directed downward through the soil profile.

Nodal Discretization versus Conceptual Soil Profile (Figure E-3):

The MWL cover was modeled as a lithologic monolayer to be conservative. A soil profile with uniform soil and hydrologic properties translates into a significant conservative estimate of liquid water flow, i.e. water flow is increased. If multiple layers are simulated, the water potential in the underlying layer must equal the water potential in the overlying layer before flow into the lower layer occurs. Multiple layering in performance modeling as well as multiple layers in nature attenuate the downward flow of liquid water (e.g., yielding multiple capillary barriers that slow water flow).

Figure E-3 does not show the actual components of the MWL soil cover (i.e., subgrade layer, biointrusion barrier, native soil layer, topsoil layer, and vegetation), because the model did not model each of these as individual components of the cover. Figure E-3 represents a conservative 3-ft thick, monolithic cover (i.e., the native soil layer, the topsoil layer, and the vegetation). The subgrade layer adds additional thickness to the lithologic monolayer represented by the modeled thicknesses of 4 and 5 ft. Although the biointrusion barrier was not modeled, its inclusion in the design does not adversely affect cover performance. In fact, the biointrusion barrier serves as a capillary break, further reducing the downward flow of water and adding additional conservatism to the estimate of net percolation by the model.

The figure has been revised to include a vertical scale for depth (i.e., feet below the cover surface) and the locations of all 30 computational nodes. However, to be true to the infiltration model, the biointrusion barrier, subgrade layer, and underlying wastes are not shown on the revised figure. The revised figure is shown below.

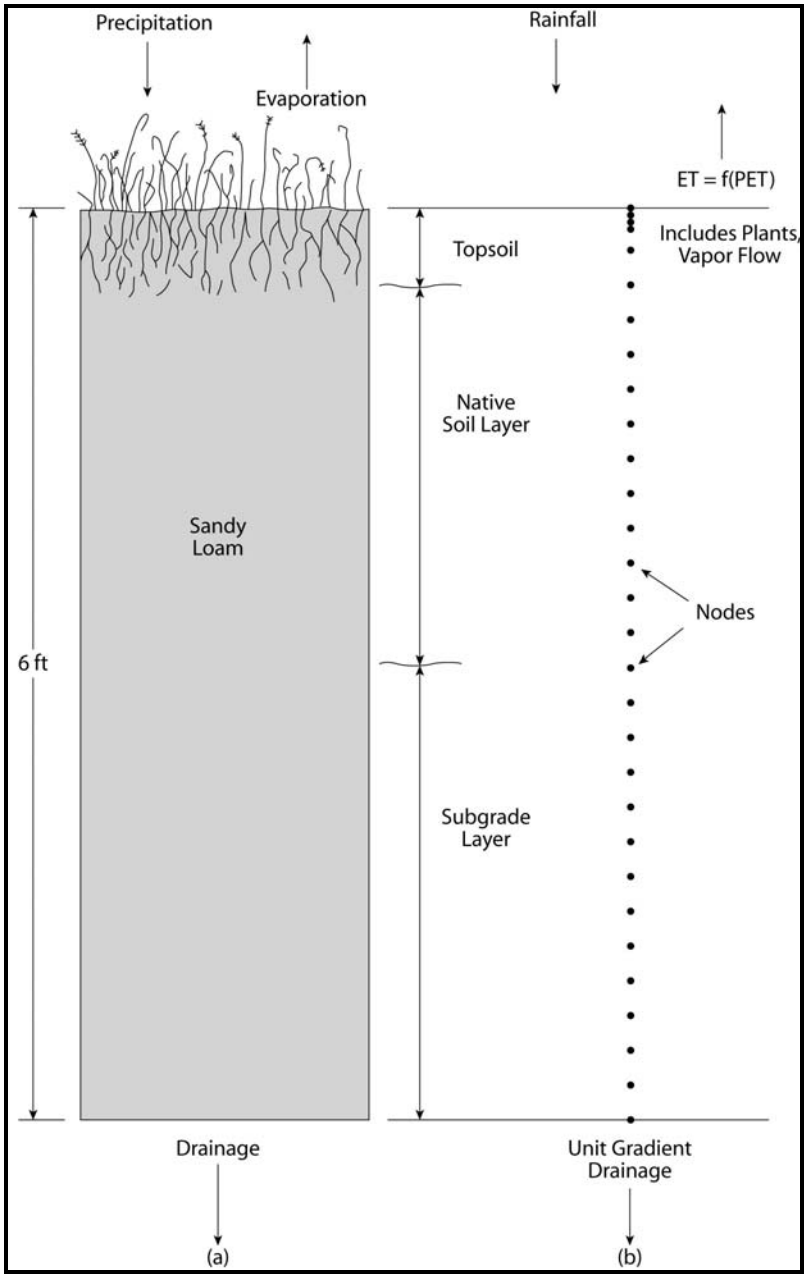


Figure 2. (a) Conceptual model for infiltration model. (b) Nodal discretization in UNSAT-H.

Soil Type Modeled:

The soil type modeled for the cover is a sandy loam.

9. Section 4.2.2 -- Section 4.2.2 discusses the proposed neutron probe system for monitoring moisture content beneath the MWL. However, for the neutron probes to detect percolation through the soil cover, water will have to move through the bio-

intrusion barrier, the waste zone, and a portion of the vadose zone prior to detection, which would be expected to require a considerable amount of time. The neutron probe system is thus more reliably a vadose-zone monitoring system rather than a tool to determine loss of integrity of the soil cover. If the Permittees want to monitor the cover for performance, the neutron probes should be placed just below the cover in the subgrade.

Response: Neutron probes installed immediately below the cover in the subgrade could be used to detect changes in moisture content as a result of infiltration through the cover. However, installation of horizontal neutron access tubes beneath the MWL to monitor moisture would yield limited additional monitoring benefits. The behavior of the cover design was evaluated at the engineered cover test plot constructed at the IP Test Site west of the MWL and is well understood. It is of more interest to monitor the vadose zone beneath the landfill to monitor potential migration of contaminants from the landfill. The proposed neutron probe system is suggested as part of the vadose zone monitoring system to be utilized for long-term monitoring of the landfill.

Installation of vertical neutron probe access holes through the MWL cover to monitor the subgrade is also not recommended. Access holes installed directly through the cover would increase the potential for preferential flow down the boreholes, and into the underlying wastes. In addition, increased vehicular traffic on the cover during monitoring activities could damage the vegetation growing on the cover, and would negatively affect bulk density and porosity of the cover. Increased traffic on the cover may also cause rutting and potential erosion of the cover itself.

The current neutron moisture monitoring system, consisting of three boreholes angled 30 degrees from vertical beneath the MWL, will be used to monitor the vadose zone beneath the landfill, and to indirectly monitor the cover performance. If infiltration through the cover were to significantly increase, the resulting percolation through the disposal cell would be detected by neutron moisture logging in the underlying vadose zone. The angled boreholes extend well beneath the lateral extent of the cover with depth, as shown in Plate 4 of the MWL CMI Plan, and will intercept any increased percolation through the cover. Additional details on use of the current neutron moisture monitoring system to monitor cover performance are included in the response to Comment No. 16, below.

10. Figures -- Figures E-13, E-15, E-19, and E-24 present a graphical illustration of the sensitivity analyses performed for some of the constituents. The figures present histograms to compare ΔR^2 for constituent concentration and dose. Clarify why actual concentrations and doses were not presented in the sensitivity analyses.

Response: Section 2.2.1 describes the stepwise linear rank-regression sensitivity analysis that was used in this study. In this approach, the actual concentrations and doses *are* used as performance metrics in the sensitivity analyses. The impact of the uncertainty of the input parameters on the simulated performance metrics (e.g., concentration, dose) is evaluated, and the relative impact is presented as ΔR^2 in Figures E-13, E-15, E-19, and E-24 Those

parameters with a large ΔR^2 have a greater correlation to the simulated performance metric; in other words, the simulated performance metric (e.g., concentration, dose) has a greater sensitivity to those parameters. Additional text has been added to Section 3.5.2.3 to clarify this.

11. General Comment on the Fate and Transport Model -- Compared to typical reports for modeling studies, the report as presented is brief, particularly when considering the complexity of using a Monte Carlo approach with multiple models, scenarios, and constituents of concern. In general, the report provides a narrative of a probabilistic model that is presented as a "black box." The report discusses the input parameters and selectively presents output results, but there is not adequate information to assess whether the "black box" is operating satisfactorily. The report does not present a discussion regarding software quality assurance -- it is not known how well the various models work separately or together. Also, the report does not provide a critique of the modeling runs, except for an occasional qualitative statement In contrast, a typical modeling report is a detailed and exhaustive presentation that addresses the conceptual development and construction of the model (e.g., the data quality objectives, the software code), the software quality assurance performed (including software validation and verification) to assess model performance both separately and when working together, the details regarding specific inputs and outputs for all runs of every scenario, and a quantitative analysis of the sensitivities of the input parameters, including an assessment of the bias of the model toward specific outputs. The report, however, does not provide this level of information. The Permittees must provide additional information to address the deficiencies mentioned above.

Response: The software and models that are used in this report are taken from widely used packages (e.g., FRAMES/MEPAS) or peer-reviewed journal articles. The report provides references for each model and software that is used (the gas-phase radon-transport model is derived in an appendix). These references contain the full description of each mathematical model and associated validation studies, and the report qualitatively summarizes the relevant features and processes that are utilized in the analysis. We felt that this was the best approach for this report; inclusion of this material in the report would have made the report extremely large and cumbersome to read.

We agree, however, that additional work and materials are needed to provide quality assurance for the models and software used in this particular study. With regard to model and software validation and verification, we have added additional documentation of tests that demonstrate the models and software were working properly and as intended (see "Model_Supplement_12-7-06.doc," included on the CD in Attachment 1). This supplement includes additional details regarding each of the models and software that were used in the analyses, and tests are performed to demonstrate the performance of each model. Links are provided to the Mathcad models (written in plain English and symbolic text) for the radon, tritium, and PCE transport models. In addition, all of the model input and output files have been made available on the CD.

With regard to "details regarding specific inputs and outputs for all runs of every scenario," the CD contains Excel files that contain the inputs and outputs for every realization that was simulated for each constituent. This information is summarized in the cumulative distribution

functions and plots presented in the report. We believe that presenting the input and output data for every realization in the report would be excessive, so we have included it on the CD instead.

Finally, with regard to "a quantitative analysis of the sensitivities of the input parameters," this has been done and is described in the sensitivity-analysis sections throughout the report for each constituent (see Sections 3.5.2.3, 3.6.2.3, 3.7.2.3, and 3.9.2.3).

12. Provide information evaluating the risk to ecological receptors for tritium, radon, and radon daughter products, which are expected to be released to surface soil and the atmosphere.

Response: Risk to ecological receptors from tritium, radon, and radon daughter products that would be expected to be released to surface soil and the atmosphere is anticipated to be negligible, and is typically not evaluated for ecological risk. The primary components of ecological risk from these radionuclides are due to ingestion and external exposure.

SNL current ecological risk assessment methodology, as agreed upon by NMED, does not account for inhalation as a primary pathway. Within the current SNL ecological risk assessment methodology, the inhalation pathway is considered to be a minor pathway in the overall contribution to ecological risk. Furthermore, ecological risks due to radiological contaminants have been minimal at other SNL sites when compared to human health radiological risk assessment concerns (i.e., the allowable dose is significantly higher for ecological receptors when compared to human receptors), and are anticipated to be negligible at the MWL as well. For this reason, evaluation of risk to ecological receptors was not included in the report.

13. Provide information evaluating the risk to human receptors for tritium, radon, and radon daughter products that would be expected to be released to surface soil and the atmosphere. Include external exposures.

Response: For tritium, calculation of risk to human receptors can be estimated from dose which was calculated in the fate and transport (F&T) modeling report. The maximum dose from tritium calculated in the F&T realizations was 18 mrem/year, while the average dose was 1.7 mrem/year. The risk from these tritium doses ranges from 1E-5 to 1E-6.

Regulatory-based metrics (e.g., dose, groundwater concentrations, and surface flux rate for radon) provide a more rigorous basis for performance-assessment calculations than risk. For this reason, risk from tritium to human receptors was not calculated in the F&T report.

Risk from radon and radon daughter products is implicit in the airborne concentrations provided in the EPA guidelines. Dose/risk from radon and radon daughter products are considered as one. The majority of dose/risk from exposure to radon and its daughter products comes from the daughter products, which are solids that may be deposited in lung tissue.

The estimate of risk from radon is subject to considerable uncertainty, and depends on a

myriad of variables affecting dose for a given exposure scenario. For example, risk from radon (and its daughter products) is a function of age, gender and whether or not one currently smokes, has smoked in the past, or has never smoked. Additional information on the risk to human receptors from radon (and radon daughter products) is presented in the document, "EPA Assessment of Risks from Radon in Homes", US EPA 2003 (*http://www.epa.gov/radon/images/402-r-03-003.pdf*). A copy of this document is included on the attached CD (Attachment 1) under the subdirectory, "Supporting Documentation".

14. The NMED expects surface soil surrounding animal borrows (including ant nests) to be monitored for radionuclides and metals. Develop triggers that are protective of both human health and the environment for radionuclides and metals in soil.

Response: Surface soil surrounding select animal burrows and ant nests was sampled prior to clearing and grubbing the site in order to obtain baseline environmental monitoring data. The data are being evaluated, and will be presented in a report to NMED on baseline environmental monitoring data for the MWL that is currently being drafted.

During long-term monitoring at the MWL, DOE/Sandia will monitor animal burrows and ant nests (ant hills). Current plans are to survey locations of animal burrows and ant hills by GPS on an annual basis, and to collect surface soil samples from animal burrows and ant hills every five years to ensure that contaminants have not been mobilized by biota. The soil samples will be analyzed for RCRA metals, gamma-emitting radionuclides, and gross alpha and gross beta activity.

Triggers proposed for RCRA metals concentrations in the surface soil samples are the NMED Industrial/Occupational Soil Screening Levels (NMED 2006). Triggers proposed for gamma-emitting radionuclides are the NMED-HWB Approved Background Values (Dinwiddie 1997).

A table summarizing all proposed monitoring triggers is included in the DOE/Sandia response to Comment No. 20, below.

Please note that the Consent Order includes the corrective action requirements for the MWL but contains no requirements for radionuclides or the radioactive portion of mixed waste. Thus, any triggers proposed for radionuclides are provided voluntarily, pursuant to the Consent Order. The voluntary inclusion of such radionuclide information shall not be enforceable and shall not constitute the basis for any enforcement because such information falls wholly outside the requirements of the Consent Order. Additional information on radionuclides and the scope of the Consent Order is available in Section III.A of the Consent Order. Throughout the remainder of this submittal, this paragraph will be referred to as the Consent Order note.

15. Develop triggers for tritium, radon, PCE and total VOCs as soil vapor. The NMED expects soil-gas in the vadose zone to be monitored for these constituents.

Response: In order to monitor soil vapor for contaminants, DOE/Sandia is proposing

installation of a robust monitoring system for sampling soil gas within the vadose zone at the MWL. The proposed vadose zone monitoring system would serve as an early warning system to protect groundwater, and would allow early detection of contaminants migrating through the vadose zone, before they impact groundwater quality. Soil gas samples would be analyzed for VOCs, but not for tritium or radon for reasons described below.

During the Phase 2 RCRA Facility Investigation (RFI) in the mid 1990s, extensive soil gas data were collected to determine the nature and extent of VOC contamination in near-surface soils at the site (SNL/NM 1996) with most of the samples collected from depths of 10 ft and 30 ft below ground surface. Although low concentrations of VOCs are present in the vadose zone at the MWL, they have not impacted groundwater quality based on sixteen years of groundwater monitoring data collected since 1990.

The proposed vadose zone monitoring system will provide updated data regarding VOC profiles with depth, and is proposed to consist of three Flexible Liner Underground Technologies (FLUTe™) sampling wells. The FLUTes™ are proposed to be constructed in vertical boreholes located immediately outside the perimeter of the MWL cover with the locations selected near areas where the highest concentrations of VOCs were detected during earlier studies at the MWL. Actual locations of the FLUTe™ boreholes will be selected in conjunction with NMED. Soil gas sampling ports are proposed to be installed in each FLUTe™ at depths of 50 ft, 100 ft, 200 ft, 300 ft, and 400 ft below ground surface.

Soil gas data collected from the FLUTes™ will be used to assess current VOC distributions with depth, and to monitor VOC concentrations over time, allowing early identification of any potential threats to groundwater. The VOC data from the FLUTes™ will also be used to update the MWL fate and transport model every five years, as required in the NMED Final Order (NMED 2005).

Triggers for Tritium and Radon

Analysis of FLUTe™ soil gas samples for tritium and radon is not recommended, as these are not routine analyses, and would yield data of limited value. Tritium and radon can be more directly monitored at ground surface, as described in Section 4.2.1 of the Performance Assessment Modeling Report. Because of tritium's high mobility, any significant releases of tritium would be readily detected in surface soils adjacent to the landfill, eliminating the need to sample tritium in soil gas. As discussed in the Performance Assessment Modeling Report, the proposed trigger for tritium in surface soils along the MWL perimeter is 20,000 pCi/L in soil moisture. Tritium concentrations measured in soil samples collected with depth during the Phase 2 RFI were relatively low below depths of 26 feet, pose minimal risk to human health, and have not impacted groundwater quality.

Radon will be monitored above ground surface along the MWL perimeter using track etch monitors (Section 4.2.1), with a proposed trigger value of 4 pCi/L in air. This technique is superior for analysis of radon flux over time, and will provide more useful information than time-discrete samples collected from the FLUTes™. Radon has not been detected above background levels in soils at the MWL, and any significant releases of radon in the near future are unlikely, due to the nature of the sealed sources containing radium-226, from which the

radon would emanate.

Please see Consent Order note provided in response to Comment No. 14.

Triggers for VOCs in the Vadose Zone

Triggers are proposed for PCE, TCE, and total VOCs in soil gas at the MWL. TCE has been detected in groundwater at other locations across SNL and Kirtland Air Force Base, and for this reason, a trigger is proposed for TCE, as well as PCE.

There are no regulatory limits for individual concentrations of volatile organic compounds in the vadose zone. DOE/Sandia propose trigger levels for TCE and PCE in soil gas based on a similar trigger proposed for the Chemical Waste Landfill (CWL). In the Post-Closure Care Plan for the CWL, a trigger of 20 ppmv was proposed for TCE in soil vapor samples collected from the deepest sampling ports (SNL September 2005). The CWL is located only 1.3 miles to the southeast of the MWL, and overlies similar hydrogeologic conditions, with similar depths to groundwater. Triggers protective of groundwater at the CWL should also be protective of groundwater at the MWL because of the similar hydrogeologic conditions at both sites.

DOE/Sandia propose triggers of 20 parts per million by volume (ppmv) for TCE and 20 ppmv for PCE for soil gas samples at the MWL. In addition, DOE/Sandia propose a trigger of 25 ppmv for total VOCs in soil gas samples at the MWL. These triggers, although not based on risk or regulatory limits, are sufficiently low to protect groundwater quality of the aquifer. All triggers would apply to samples collected from the deepest sampling port in each FLUTe™. Triggers would not apply to samples collected from shallower ports.

16. Table E-6 -- The proposed trigger value for "infiltration" is *25%* by volume. Specify whether "infiltration" means moisture content. Also, the proposed trigger is too high, as it likely represents conditions whereby there is near complete saturation of the soil.

<u>Response:</u> The trigger parameter actually applies to "moisture content" rather than "infiltration". The moisture content of the subsurface soil provides an indirect indication of the infiltration through the cover. The EPA-prescribed technical equivalence criteria for RCRA landfills is an average infiltration rate of 10^{-7} cm/s through the landfill cover, equivalent to a net annual infiltration of 31.5 mm of water per year through the cover. Assuming an average vertical hydraulic gradient of unity, an infiltration rate of 10^{-7} cm/s would result in an underlying moisture content of the soils to be approximately 23 percent by volume. A 23 percent volumetric moisture content is equal to 59 percent saturation, assuming an average soil porosity of 39 percent.

Figure 3 shows the relationship between unsaturated hydraulic conductivity and volumetric moisture content for 18 subsurface soil samples collected from the IP Test Site, located 500 ft west of the MWL. Assuming a vertical hydraulic gradient of unity, the infiltration rate through soil at a given moisture content is equal to the unsaturated hydraulic conductivity at that moisture content. Thus, by drawing a horizontal line across the graph at the EPA-prescribed infiltration rate of 10^{-7} cm/s through the cover, one can estimate the volumetric moisture content of the underlying soils, based on their soil moisture characteristic curves. This

moisture content is equivalent to the extrapolated moisture content at the x-intercept along the graph where the horizontal line meets the soil moisture characteristic curve.

Based on soil moisture characteristic data for MWL soils shown in Figure 3, moisture contents in underlying soils would range from approximately 18 percent by volume up to 28 percent by volume, and would average approximately 23 percent by volume, if infiltration through the MWL cover averaged the EPA-prescribed equivalence criterion of 10^{-7} cm/s.

For this reason, DOE/Sandia recommend using the average 23 percent volumetric moisture content of underlying soils as the trigger to indicate that the MWL cover is meeting the EPA-prescribed technical equivalency criteria for RCRA landfills. This 23 percent volumetric moisture content has a regulatory basis, and is considered a reasonable value for a trigger to indicate cover performance. Because the accuracy of the neutron logging tool is ± 2 percent volumetric moisture content, a 2 percent delta was originally added to the 23 percent value to ensure that readings at this level are not false positive interpretations, and the trigger was initially proposed at 25 percent by volume in the original Performance Assessment Modeling Report (Appendix E in SNL November 2005). However, because NMED considers the initially-proposed 25 percent moisture content value to be too high, DOE/Sandia suggest eliminating the 2 percent delta, with the final moisture content trigger set at 23 percent by volume. The proposed trigger of 23 percent by volume would apply to linear depths of 10 ft to 100 ft (vertical depths of 8.7 ft to 86.6 ft) along the neutron probe access holes in the vadose zone beneath the MWL. This interval is proposed as the "regulated interval" because it lies beneath the root zone, and yet is shallow enough that a response would be readily detected if there is a significant increase in infiltration through the cover.

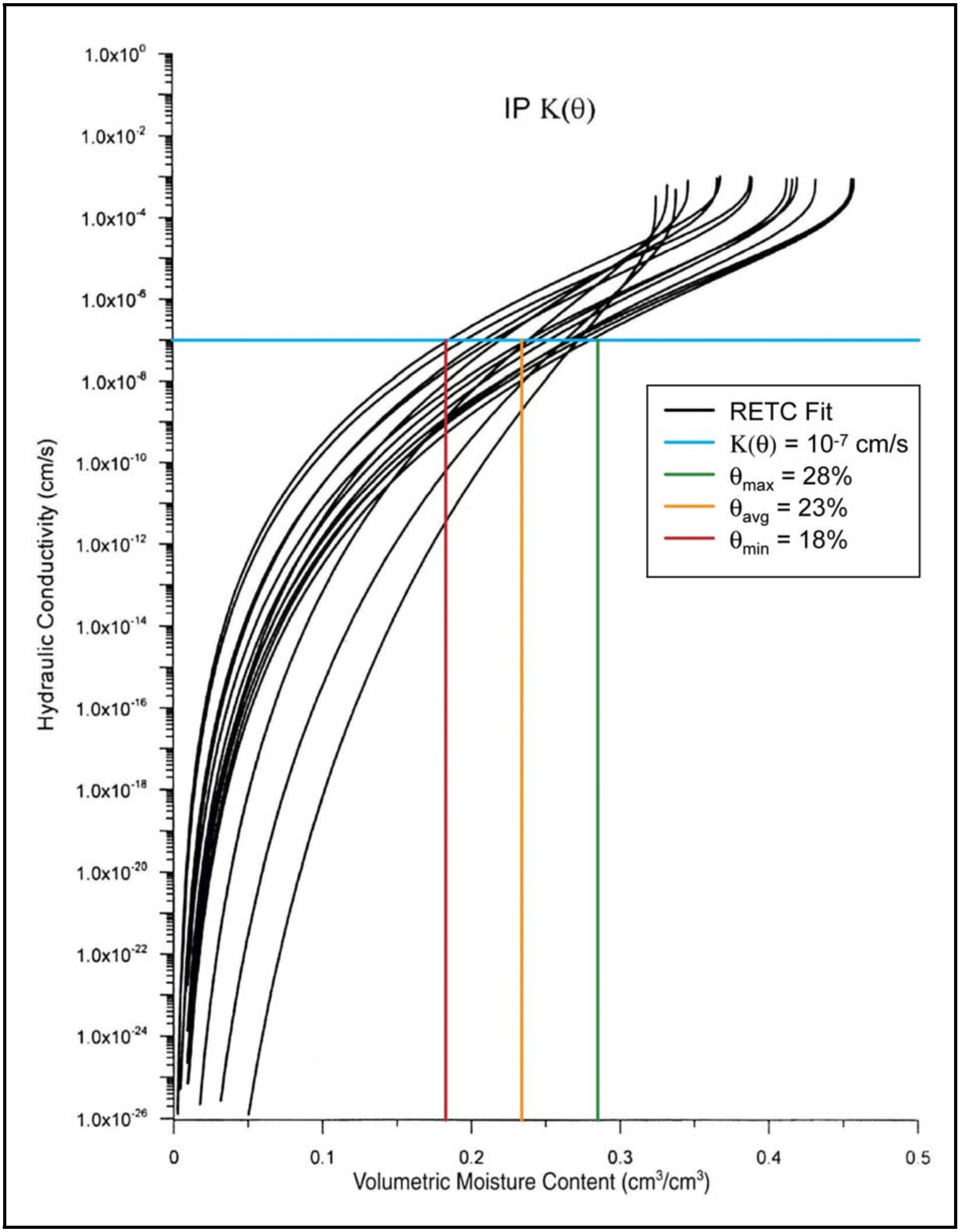


Figure 3. Relationship between unsaturated hydraulic conductivity and volumetric moisture content for 18 subsurface soil samples collected from the IP Test Site

17. Provide NMED a copy of the reference: Johnson et al (1995), *A Human Health Risk Assessment for the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico,* Argonne National Laboratories, Argonne, IL.

Response: This document is actually entitled, "A Preliminary Human Health Risk Assessment for the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico" by Johnson et al., 1995. A copy of this report is included on the attached CD, under the subdirectory "Preliminary Risk Assessment by Johnson et al".

18. Table E-6, the proposed trigger levels for 1,1,1-TCA, ethylbenzene, styrene, toluene, and total xylenes in groundwater are set too high. For these unnatural constituents, the levels of detection normally achieved by laboratories are much lower than groundwater standards set by the New Mexico Water Quality Control Commission (WQCC). The trigger levels can be set to much lower levels, and still allow for a given trigger level to be sufficiently above the limit of detection such that the constituent can be readily quantified with a high degree of confidence. Additionally, trigger levels should be set well below WQCC standards or below U. S. Environmental Protection Agency Maximum Contaminant Levels so that there will be time to react to prevent unacceptable levels of contamination should any trigger levels be exceeded.

Response: The proposed trigger levels for 1,1,1-TCA, ethylbenzene, styrene, toluene, and total xylenes in groundwater are regulatory-based, and are set at a value of one-half the EPA Primary Drinking Water Standard (MCL) (EPA 2003a) for each constituent. There is no technical or regulatory basis for further reducing these trigger levels (with respect to risk and human health), and DOE/Sandia are concerned that reductions in these triggers to even lower concentrations will result in more false positive detections for these constituents. There are often analytical difficulties with measuring extremely low concentrations of VOCs in groundwater.

Rather than lowering the trigger levels for VOCs in groundwater and increasing the risk of false positive detections, DOE/Sandia recommend installation of a robust vadose-zone monitoring system to allow early detection of any potential migration of VOCs through the vadose zone, well before they reach groundwater (see response to Comment No. 16). DOE/Sandia recommend keeping trigger levels for VOCs in groundwater at one-half the EPA Primary Drinking Water Standard, as proposed originally in Table E-6. DOE/Sandia also recommend expanding the list of triggers for VOC in groundwater to include triggers for all Target Compound List (TCL) VOCs analyzed using EPA Method 8260. See response to Comment No. 20, below.

19. Propose some additional monitoring to be conducted at locations within the landfill where contaminants were detected at their highest levels during the RFI. These locations should be subject to the same triggers as those proposed as points of compliance in Table E-6.

Response: Additional monitoring at locations within the landfill using intrusive techniques is not recommended, and could compromise the integrity of the cover. However, Appendix A to the first NOD Comment Set (SNL December 2006) presented a sampling and analysis plan

(SAP) for soil-gas volatile organic compounds, tritium, and radon at the Mixed Waste Landfill. Sampling locations were selected based on maximum concentrations of VOC contaminants detected during the Phase 2 RFI in the mid 1990s (SNL 1996). VOC concentrations will be measured at depths of 10 ft and 30 ft in a total of six boreholes in and around the MWL, and two background boreholes. The boreholes will be advanced using a GeoProbe in the same manner as was done during the Phase 2 RFI. Soil samples will also be collected at depths of 10 ft and 30 ft in each borehole for analysis of tritium concentrations in soil moisture. All sampling will be conducted prior to construction of the MWL cover.

If the upcoming sampling program within the MWL shows concentrations of VOC contaminants significantly elevated above concentrations detected during the Phase 2 RFI study, DOE/Sandia will open discussions with NMED on the potential need for additional intrusive monitoring activities within the landfill. However, at this time, DOE/Sandia suggest approaching this issue in a phased manner; if the data show no significant increases in contaminant concentrations, additional intrusive monitoring within the landfill is not recommended.

Additional monitoring for VOCs in soil gas is proposed using FLUTes™ installed around the perimeter of the MWL. The FLUTes™ are proposed to be located near areas of the landfill where contaminants were detected at their highest levels during the Phase 2 RFI. In order to protect the integrity of the cover and to minimize the potential for preferential flow down boreholes, the FLUTes™ are not planned to be installed directly through the cover of the landfill.

Monitoring of animal burrows and ant nests is also proposed for the MWL cover (see response to Comment No. 14). Samples of soil from the vicinity of animal burrows and ant nests on the MWL cover will be collected on a five-year basis and analyzed for RCRA metals, gross alpha and beta activity, and gamma-emitting radionuclides. Additional details on future monitoring activities will be included in the MWL Long Term Monitoring and Maintenance Plan.

20. Expand the proposed monitoring triggers in Table E-6, giving consideration of the following table:

Environmental Medium	Monitoring Parameters	Main Potential Receptors	Sampling Points
Air	**radon, tritium**	**humans**	**landfill perimeter and interior stations**
Surface Soil	**radon, tritium, other radionuclides, metals**	**humans and ecological receptors**	**landfill perimeter, interior stations, and animal burrows located on cover**
Subsurface Soil	**moisture**	**humans via groundwater**	**neutron probe monitoring wells**
Subsurface Soil Gas	**radon, tritium, VOCs**	**humans via groundwater**	**beneath landfill**
Groundwater	**tritium, radon, isotopic uranium, VOCs**	**humans**	**down gradient groundwater monitoring wells**

Radionuclides (other than radon and tritium) and metals should be the same as those listed in Table E-2. VOCs should include PCE, all organic constituents listed in Table E-6, and all other organic constituents normally detected by method 8260. NMED reserves the right to require additional monitoring pending review of the long-term monitoring and maintenance plan to be submitted later by the Permittees and pending receipt and review of public input of this latter mentioned plan.

Response: The proposed monitoring triggers in Table E-6 have been revised, based on NMED's requests presented in Comments No. 14, 15, 16, 18, and 20. The updated monitoring triggers are shown in Table 2. Based on NMED's recommendations, modifications to the proposed monitoring discussed in Appendix E (SNL November 2005) include the addition of the following:

- Collection of surface soil samples near animal burrows and ant nests, and analysis for RCRA metals, gamma-emitting radionuclides, gross alpha activity, and gross beta activity. Additional triggers are proposed for RCRA metals and gamma-emitting radionuclides. Please see Consent Order note provided response to Comment No. 14.

- Installation of a robust multi-level vadose zone sampling system for VOCs using FLUTe™ technology. This system will be used as an early-warning system to protect groundwater.

- Monitoring of the vadose zone to assess VOC profiles with depth. Triggers are proposed for TCE, PCE, and Total VOCs in soil vapor.

- Additional triggers are proposed for VOCs in groundwater. Triggers are proposed for all Target Compound List (EPA Method 8260) VOCs.

Table 2. Proposed Monitoring Triggers for the Mixed Waste Landfill.

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Air	Radon	Humans	4 pCi/L (measured by Track-Etch radon detectors)	MWL Perimeter	Average flux of radon-222 gas shall be less than 20 $pCi/m^2/s$ at the landfill surface (design standard)	EPA Action Threshold for radon in air (U.S. EPA 2005)
Surface Soil	Tritium	Humans and ecological receptors	20,000 pCi/L tritium in soil moisture	MWL Perimeter	Dose to the public via the air pathway shall be less than 10 mrem/yr	DOE Order 5400.5, 10 CFR 61 Subpart H, 40 CFR 141.66
Surface Soil	Cs-137	Humans and ecological receptors	0.664 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	Ra-226	Humans and ecological receptors	2.30 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	Th-232	Humans and ecological receptors	1.01 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	U-235	Humans and ecological receptors	0.16 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)
Surface Soil	U-238	Humans and ecological receptors	1.4 pCi/g	Animal burrows & ant nests on the cover	Radionuclide concentrations in soil shall not exceed NMED-Approved Maximum Background Concentrations	NMED-Approved Maximum Background Concentrations (Dinwiddie 1997)

Table 2 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Surface Soil	Arsenic	Humans and ecological receptors	17.7 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Barium	Humans and ecological receptors	100,000 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Cadmium	Humans and ecological receptors	56.4	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Chromium	Humans and ecological receptors	3400 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Lead	Humans and ecological receptors	800 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Mercury	Humans and ecological receptors	100,000 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Surface Soil	Selenium	Humans and ecological receptors	5680 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)

Table 2 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Surface Soil	Silver	Humans and ecological receptors	5680 mg/kg	Animal burrows & ant nests on the cover	RCRA metal concentrations in soil shall not exceed NMED Industrial/Occupational Soil Screening Levels	NMED Industrial/Occupational Soil Screening Levels (NMED 2006)
Subsurface Soil	Moisture Content	Humans via groundwater	23 percent by volume	Linear depths of 10 ft to 100 ft along neutron probe access holes beneath the MWL	Infiltration through the cover shall be less than the EPA-prescribed technical equivalence criterion of 31.5 mm/yr [10E-7 cm/s]	RCRA 40 CFR Part 264.301
Subsurface Soil Gas	PCE	Humans via groundwater	20 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Subsurface Soil Gas	TCE	Humans via groundwater	20 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Subsurface Soil Gas	Total Volatile Organic Compounds	Humans via groundwater	25 ppmv	Deepest FLUTe Sampling Port	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Uranium	Humans via groundwater	15 µg/L	Downgradient monitoring well locations	Uranium concentrations in groundwater shall not exceed the EPA MCL of 30 µg/L	EPA Primary Drinking Water Standard
Groundwater	1,1,1-Trichloroethane (1,1,1-TCA)	Humans via groundwater	100 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,1,2-Trichloroethane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,1-Dichloroethene	Humans via groundwater	3.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

Table 2 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Groundwater	1,2-Dichloroethane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	1,2-Dichloropropane	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Benzene	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Carbon tetrachloride	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Chlorobenzene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Ethyl benzene	Humans via groundwater	350 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Methylene chloride	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Styrene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Tetrachloroethene (PCE)	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Toluene	Humans via groundwater	500 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Trichloroethene (TCE)	Humans via groundwater	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

Table 2 (continued)

Environmental Medium	Monitoring Parameter	Main Potential Receptors	Proposed Trigger Value	Sampling Points	Performance Objective	Applicable Guideline or Regulation
Groundwater	Vinyl Chloride	Humans via groundwater	1.0 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Xylenes (Total)	Humans via groundwater	5,000 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	cis-1,2-Dichloroethene	Humans via groundwater	35 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Trans-1,2-Dichloroethene	Humans via groundwater	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Groundwater	Method 8260 VOCs with no MCLs	Humans via groundwater	EPA Region 6 Human Health Medium-Specific Screening Levels	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA Region 6 Human Health Medium-Specific Screening Levels	EPA Region 6 Human Health Medium-Specific Screening Levels

CFR = Code of Federal Regulations.
cm = Centimeter(s).
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
ft = Foot (feet).
L = Liter(s).
m = Meter(s).
m^2 = Square meter(s).
µg = Microgram(s).
MCL = Maximum contaminant level.
mm = Millimeter(s).
mrem = Millirem.
MWL = Mixed Waste Landfill.
pCi = Picocurie(s).
RCRA = Resource Conservation and Recovery Act.
s = Second(s).
TCA = Trichloroethane.
VOC = Volatile organic compound.
yr = Year(s).

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Volume I

TAB 14

Second NOD: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

From: NMED/Bearzi
To: SNL/Wagner

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October 10, 2008

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RE: NOTICE OF DISAPPROVAL: MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN, NOVEMBER 2005 SANDIA NATIONAL LABORATORIES, NM5890110518 SNL-05-025

Dear Ms. Wagner and Mr. Nimick:

The New Mexico Environment Department (NMED) has reviewed the U.S. Department of Energy/Sandia Corporation's (Permittees) responses to the NMED's Notice of Disapproval (NOD) issued on November 20, 2006 for the Sandia National Laboratories Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan. The Permittees responses were submitted in two parts, dated December 15, 2006, and January 19, 2007. Based on our review of these responses, NMED has identified several deficiencies that require additional information or resolution. The deficiencies are described in the comments below.

Part 1 Comments

1. In response to NOD Comment 17, Permittees state that "[t]he mature, secondary plant community will be achieved when greater than 50% of the photosynthesizing foliar coverage is comprised of grass species native to the general TA-III area". Russian thistle (tumbleweed) should not be allowed to be a part of the foliage on the cover and should not count as part of the foliar coverage used as a measure for acceptable establishment of

vegetation. NMED expects any tumbleweed that grows on the cover to be removed periodically as part of long-term maintenance.

2. Also in response to NOD Comment 17, the Permittees did not indicate the extent of foliar coverage that would represent acceptable establishment of vegetation on the final landfill cover. Propose a percentage of foliar cover relative to the total surface area of the landfill cover that will be considered as representative of acceptable establishment of foliage. Indicate also the size (in square feet) of any barren areas that would be considered unacceptable and would thus require re-seeding and/or other corrective measures to improve the foliar coverage of the barren areas.

Part 2 Comments

1. In response to NOD Comment 4, the Permittees state that future infiltration rates through the MWL cover (based on the natural analogue) would be less than the current infiltration rates (based on the engineered cover). This reduction in future infiltration rates presumably is due to increased evapotranspiration caused by increasing porosity and hydraulic conductivity of the landfill cap as it reverts to natural soil conditions. While this process may occur, it is not clear how this conclusion was reached. Clarify if the anticipated increase in evapotranspiration is based on empirical data (i.e., actual infiltration and/or groundwater recharge data from areas with natural soil), modeling simulations, or another method.

2. In response to NOD Comment 6, Section 4, Pages E-59 and E-59a, the Permittees indicate that monitoring triggers are considered preliminary and are to be finalized in the Long-Term Monitoring and Maintenance Plan (LTMMP). This is not an acceptable approach, as the NMED Secretary's Final Order issued on May 25, 2006 requires that the triggers be developed as part of the CMI Plan. The relevant part of the Final Order states: "As part of the Corrective Measures Implementation Plan that incorporates the remedy (described in the draft permit modification in Paragraph V.3), Sandia shall additionally include the following: ..., b) triggers for future action, that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy."

   Although the trigger levels and the environmental media that they apply to must be established as part of the CMI Plan, the specific methods, locations, and frequencies of monitoring, and other related details can be established through approval of the LTMMP. Trigger levels, once accepted by the NMED through its review and approval of the CMI Plan, must be incorporated into the proposed LTMMP.

   Additionally, the trigger evaluation process described in Section 4 and in Figure E-25 (of pages E-59 and E-59a), and as revised by the Permittees' response, is not an acceptable approach. In NOD Comment 6, and again through this Notice of Disapproval, the Permittees are instructed to revise the trigger evaluation process to follow the corrective

action process described in the Consent Order (April 29, 2004) if a trigger level is exceeded, provided the Consent Order is still in force at the time. If the Consent Order has terminated, the trigger evaluation process should follow the corrective action process described in the Facility Permit. The Permittees should repeat sampling to confirm if a trigger level has been exceeded. Repeat sampling should be the primary means to avoid implementation of corrective action based on false positives.

3. In NOD Comment 9, the NMED concluded that the neutron probes will only be able to evaluate soil moisture at depths in the vadose-zone that are considerably deeper than the base of the soil cover. Because it would take substantial time for moisture to move through the vadose zone to the depths of the neutron probe access tubes, and because the current design does not monitor for breakthrough of moisture from the cover to the waste, NMED does not agree that such moisture monitoring offers the best possible design for an early warning system. Thus, NMED will place more emphasis on other types of monitoring in the LTMMP. No response is required by the Permittees for this comment.

4. In NOD Comment 14, the Permittees indicate that soil samples from animal burrows and ant hills will be collected every five years. NMED believes that every five years is too long of an interval between sampling events given that the MWL remedy and fate and transport model are to be re-evaluated every five years in accordance with the Final Order. The Permittees' current proposal involves only one round of sampling results to be available for each five year re-evaluation. The Permittees must propose a sampling frequency with a shorter interval between sampling events.

5. In NOD Comment 15, NMED indicated that soil gas in the vadose zone was to be monitored for tritium, radon, PCE, and total VOCs. The Permittees plan to install a FLUTe™ vadose zone soil-gas monitoring system around the MWL for VOCs, and propose trigger levels of 20 parts per million by volume (ppmv) for trichloroethylene (TCE) and tetrachloroethylene (PCE), and 25 ppmv for total VOCs to ensure protection of groundwater. However, the Permittees did not agree to monitor for tritium or radon in soil gas on the basis that the data would be of limited value, and that NMED did not have the authority to require monitoring of these radioactive constituents. Note that the U. S. Environmental Protection Agency (EPA) and NMED regulates gross beta in groundwater through drinking water standards. Tritium and some isotopes of radon are beta emitters. Furthermore, NMED disagrees that the data would be of limited value, as NMED believes that concentration trends are useful indicators of contaminant migration. Thus, NMED expects the Permittees to monitor for tritium and radon in soil gas in the vadose zone. The Permittees must specify trigger levels for radon and tritium for soil gas in the vadose zone.

6. In NOD Comment 19, NMED asked that the Permittees propose additional monitoring points at locations (surface and subsurface) within the landfill where contaminants were detected at their highest levels during the RCRA Facility Investigation of the MWL. No additional sampling was proposed by the Permittees, chiefly on the basis that intrusive

monitoring techniques could possibly compromise cover integrity. However, NMED believes that additional monitoring points can be located within the landfill, and that such monitoring can be conducted without necessarily driving heavy vehicles over the landfill surface. The Permittees shall propose additional monitoring points at locations within the landfill where radon, tritium, and VOCs were detected at their highest levels during the RCRA Facility Investigation. These monitoring locations should consider air, surface soil, and subsurface soil as media to be monitored.

7. In NOD Comment 18, and in Table 2 of the Permittees' January 19, 2007, responses to the NOD for Comment 20, Permittees did not agree to lower the trigger levels for the VOCs 1,1,1-TCA, ethylbenzene, styrene, toluene, and total xylenes (in groundwater). The Permittees continue to propose trigger levels based on one-half of the value of EPA Primary Drinking Water Standards, and state that there are no regulatory or technical reasons for further reducing the trigger levels for these VOCs. The Permittees also argue that there are analytical difficulties with measuring low concentrations of VOCs in groundwater which could lead to false detections of contaminants.

   NMED finds that some of the proposed trigger levels are unacceptable because they fall within three general categories: a) they fail to take into account Consent Order (April 29, 2004) requirements for groundwater cleanup levels; b) they are erroneous; or c) they do not address all constituents of concern for the MWL. These deficiencies are discussed more specifically below. NMED also proposes alternative trigger levels for those considered to be unacceptable in the tables provided below.

   A. Consent Order Requirements for Cleanup Levels

   The Permittees assert that regulations do not require the cleanup of groundwater to concentrations that are below water quality standards; hence, setting trigger levels at one-half the water quality standard is adequate to protect groundwater. However, NMED may require corrective action at any solid waste management unit (SWMU) as necessary to protect human health and the environment from releases (20.4.1.500 NMAC incorporating 40 CFR 264.101). This is true even in cases where groundwater is known to be contaminated at levels below water quality standards. Additionally detection and prevention of the contamination of groundwater at any concentration should be the main goal of long-term monitoring at the MWL.

   Any given trigger level applicable to groundwater beneath the MWL should be based on the appropriate water quality standard, which in general will be the most stringent of a state or federal standard for the constituent of interest. Section VI.K.1.a of the Consent Order states that "[g]roundwater cleanup levels are based on the WQCC standards and the EPA MCLs for drinking water Contaminants. If both a WQCC standard and a MCL have been established for an individual substance, then the most stringent of the two levels shall be considered the cleanup level for that substance…If a WQCC standard or MCL has not been established for a specific substance, the EPA Region VI Human

Health Medium Specific Screening Level for tap water shall be used as the screening level".

The purpose of establishing trigger levels is to provide for early warning of any unexpected releases so that action can be taken to prevent groundwater contamination, and especially to prevent contamination from exceeding a water quality standard. Groundwater investigations can take considerable time to complete; often such investigations may take many years. Thus, to be useful as part of an early warning system, trigger levels are generally set much lower than their corresponding standards, and especially in cases where standards are much higher than laboratory analytical detection limits.

For these reasons, NMED believes one-half of a water quality standard is too high for a trigger level for a given groundwater constituent where the standard is greater than about 0.040 mg/L. In cases where the standard is greater than 0.040 mg/L, NMED proposes that the trigger level for a groundwater constituent should be set at one-quarter (25%) of the standard, which should be sufficiently higher than most detection limits such that false positives should be uncommon. However, in the case of naturally occurring constituents, it may be necessary to set the trigger level to corresponding background levels whenever 25% of the standard falls below the approved maximum background concentration for the area.

The trigger levels for 1,1,1-TCA; 1,1-dichloroethene, toluene, vinyl chloride, total xylenes, chlorobenzene, ethylbenzene, styrene; cis 1,2 – dichloroethene; trans 1,2-dichloroethene, and method 8260 VOCs in groundwater are not acceptable as they are not based on the lowest concentration of the applicable EPA MCL, WQCC standard, or if an applicable MCL or WQCC standard does not exist, the applicable EPA Region 6 Human Health Medium Specific Screening Level for tap (residential) water. NMED proposes alternate trigger levels for these constituents in the table below. The NMED's proposed alternate trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	**Parameter**	**NMED proposed trigger level**	**Comments**
Groundwater	1,1,1-TCA	0.015 mg/L	25% of WQCC standard (0.060 mg/L)
Groundwater	1,1-dichloroethene	0.0025 mg/L	50% of WQCC standard (0.005 mg/L)
Groundwater	toluene	0.1875 mg/L	25% of WQCC standard (0.750 mg/L)
Groundwater	vinyl chloride	0.0005 mg/L	50% of WQCC standard (0.001 mg/L)
Groundwater	total xylenes	0.155 mg/L	25% of WQCC standard (0.620 mg/L)

Groundwater	chlorobenzene	0.025 mg/L	25% of EPA MCL
Groundwater	ethylbenzene	0.175 mg/L	25% of EPA MCL
Groundwater	styrene	0.025 mg/L	25% of EPA MCL
Groundwater	cis 1,2 - dichloroethene	0.0175 mg/L	25% of EPA MCL
Groundwater	trans 1,2-dichloroethene	0.025 mg/L	25% of EPA MCL
Groundwater	method 8260 VOCs	50% of the most stringent of EPA MCL, WQCC standard, or EPA Region 6 Human Health Medium Specific Screening Level for tap water, as applicable. Trigger level to be set at 25% of standard if the standard is greater than 0.040 mg/L.	As explained in the column to the left.

B. Erroneous Trigger Levels

The trigger levels for cadmium and mercury in surface soil are not acceptable for the reasons indicated in the column for "Comments" in the following table. NMED also proposes alternate trigger levels for these constituents in the following table. The alternate trigger levels are based on NMED industrial/occupational soil screening levels. The NMED's proposed alternate trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	**Parameter**	**NMED proposed trigger level**	**Comments**
Surface soil	cadmium	564 mg/kg	Screening value was listed incorrectly in Table 2.
Surface soil	mercury	6.84 mg/kg	Screening value for methyl mercury is more conservative. Use of elemental mercury not supported

			by waste inventory.

C. Additional Metals of Concern at the MWL

For each given medium listed in the left-most column of the table below, add the following additional constituents and their corresponding trigger levels to Table E-6 of Appendix E of the CMI Plan. The trigger levels for soil are based on NMED industrial/occupational soil screening levels. The NMED's proposed additional trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	**Parameter**	**NMED proposed trigger level**
Surface soil	Copper	45,400 mg/kg
Surface soil	Nickel	22,700 mg/kg
Surface soil	Vanadium	1,140 mg/kg
Surface soil	Zinc	100,000 mg/kg
Surface soil	Cobalt	20,500 mg/kg
Surface soil	Beryllium	2,250 mg/kg
Groundwater	Chromium (total)	0.043 mg/L (background)
Groundwater	Cadmium	0.0025 mg/L (50% of EPA MCL)
Groundwater	Nickel	0.050 mg/L (25% of WQCC standard of 0.2 mg/L)
Groundwater	Dichlorodifluoromethane	0.0975 mg/L (25% EPA Region 6 screening level for compound)
Groundwater	tritium	4 mrem/year (EPA MCL)
Groundwater	radon	300 pCi/L (proposed EPA MCL)

The Permittees are required to address these comments within 60 days of receipt of this letter. Please contact William Moats of my staff at (505) 222-9551 if you have any questions.

Sincerely,

James P. Bearzi
Chief
Hazardous Waste Bureau

cc: J. Kieling, NMED, HWB

W. Moats, NMED, HWB
L. King, EPA-Region 6 (6PD-N)
J. Gould, DOE/NNSA/SSO, MS 0184
J. Cochran, SNL, MS 0719
File: Reading and SNL, 2008

Volume I

TAB 15

DOE/Sandia Responses to Second NOD: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

From: SNL/Davis
To: NMED/Bearzi

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ENTERED

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

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DEC 2008
NMED Hazardous
Waste Bureau

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Road East, Bldg. 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the Department of Energy/National Nuclear Security Administration (DOE/NNSA), and Sandia Corporation (Sandia), DOE/NNSA is submitting responses to comments received in a letter from the New Mexico Environment Department (NMED) to the U.S. Department of Energy and Sandia Corporation, dated October 10, 2008, regarding the Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill (MWL) at Sandia National Laboratories/New Mexico. The letter is entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005, Sandia National Laboratories, NM5890110518 SNL-05-025". This Notice of Disapproval (NOD) is a result of the NMED review of an earlier DOE/Sandia response to an NOD (dated November 20, 2006). The earlier response by the DOE/Sandia was submitted in two-parts dated December 15, 2006, and January 19, 2007. The NMED identified several deficiencies that required additional information or resolution.

Should you have any questions regarding our responses to the NOD, contact me at (505) 845-6036, or Joe Estrada of my staff at (505) 845-5326.

Sincerely,

Kimberly A. Davis
Acting Manager

Enclosure

cc w/enclosure:
W. Moats, NMED (Via Certified Mail)
L. King, EPA, Region 6 (Via Certified Mail)
T. Skibitski, NMED-OB (2 copies)
C. Wimberly, SSO
J. Gould, SSO
J. Lehr, NA-56, HQ/FORS

NOV 2 6 2008

Records Center, SNL/NM, Org. 6765, MS-1089
Zimmerman Library, UNM (c/o SNL/NM)

cc w/o enclosure:
T. Longo, NA-56, HQ/GTN
A. Blumberg, SNL/NM, Org. 11100, MS-0141
F. Nimick, SNL, Org. 6790, MS-0701
D. Miller, SNL/NM, Org 6765, MS-0718
J. Cochran, SNL/NM, Org. 6765, MS-0719
S. Griffith, SNL/NM, Org. 6765, MS-1089
B. Langkopf, SNL/NM, Org. 6765, MS-1089
D. Pellegrino, SSO
S. Lacy, SSO
M. Reynolds, SSO

AOP 95-45, 06

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **Responses to the "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories, NM5890110518 SNL-05-025"**

Document author: **Stacy Griffith, Department 06765**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: Francis B. Nimick   11/20/08
Date

Francis B. Nimick
Deputy Director to the
Nuclear Energy & Global Security Technologies
Division 6700
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico 87185
Operator

and

Signature: Kimberly A. Davis   11/26/08
Date

Kimberly Davis
Acting Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Sandia National Laboratories
Albuquerque, New Mexico
December 10, 2008

DOE/Sandia Responses to NMED "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories, NM5890110518 SNL-05-025"

INTRODUCTION

This document responds to comments received in a letter from the New Mexico Environment Department (NMED) to the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) dated October 10, 2008 regarding the Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill (MWL) at Sandia National Laboratories/New Mexico (SNL/NM). The letter is entitled "Notice of Disapproval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories, NM5890110518 SNL-05-025". This Notice of Disapproval (NOD) is a result of the NMED review of an earlier DOE/Sandia response to an NOD (dated November 20, 2006). The earlier response by the DOE/Sandia was submitted in two parts dated December 15, 2006, and January 19, 2007. The NMED has identified several deficiencies that required additional information or resolution. The deficiencies are listed in two parts.

This document lists each NMED comment, and the DOE/Sandia response to that comment. The NMED comment is listed in boldface, followed by the DOE/Sandia response, written in normal font under "Response".

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Part 1 Comments

Comment 1: In response to NOD Comment 17, Permittees state that "[t]he mature, secondary plant community will be achieved when greater than 50% of the photosynthesizing foliar coverage is comprised of grass species native to the general TA-III area". Russian thistle (tumbleweed) should not be allowed to be part of the foliage on the cover and should not count as part foliar coverage used as a measure for acceptable establishment of vegetation. NMED expects any tumbleweed that grows on the cover to be removed periodically as part of the long-term maintenance.

Response 1: DOE/Sandia offer a counterproposal that Russian-thistle, *Salsola tragus* (scientific name change from *Salsolsa kali*) be allowed as part of the foliage on the cover during the establishment of the mature, secondary plant community. Russian-thistle is a nonnative transitory species, but can be beneficial when rehabilitating disturbed sites. It is frequently an unwanted species on such sites, but disturbed sites often recover more quickly when Russian-thistle is left on-site because its presence accelerates the rate of revegetation (Howard, 1992).

Howard (1992) also states that if topsoil remains on the site, Russian-thistle roots are readily invaded by mychorrhizal fungi harbored in the soil. Russian-thistle does not form mychorrhizal associations, and fungal invasion results in the death of the infected root. The fungi consequently invade other Russian-thistle roots. Russian-thistle populations decline, but mycorrizal fungus populations increase and subsequently invade the mycorrhizal association-forming species which comprise the next stage of plant succession. These species usually flourish as a consequence of increased mychorrhizal fungus populations. If topsoil is gone, however, Russian-thistle can dominate disturbed sites for up to 10 years. Such sites benefit more from the addition of topsoil than the removal of Russian-thistle. This reference and further information on *Salsola* can be found at http://www.fs.fed.us/database/feis/plants/forb/salkal/all.html.

During the establishment of the mature, secondary plant community, the DOE/Sandia propose the use of supplemental watering in order to facilitate the development of the native plant species.

Comment 2: Also in response to NOD Comment 17, the Permittees did not indicate the extent of foliar coverage that would represent acceptable establishment of vegetation on the final landfill cover. Propose a percentage of foliar cover relative to the total surface area of the landfill cover that will be considered as representative of acceptable establishment of foliage. Indicate also the size (in square feet) of any barren areas that would be considered unacceptable and would thus require re-seeding and/or other corrective measures to improve the foliar coverage of the barren areas.

Response 2: As proposed in the Long-Term Monitoring and Maintenance Plan (LTMMP), the operational criteria for achieving successful revegetation for the MWL cover under average annual precipitation conditions are as follows:

- The proposed percentage of foliar cover relative to the total surface area of the landfill cover that will be considered as representative of acceptable establishment of foliage is 25 percent (i.e., 25 percent of the land surface is covered with living plants). Of the 25 percent total foliar coverage, 50 percent or greater comprises native perennial species and less than 50 percent comprises annual species (including nonnative, transitory species).

- No contiguous bare spots greater than 200 square feet (approximately 14 by 14 feet) would be acceptable, and such bare spots would require re-seeding and/or other corrective measures to improve the foliar coverage.

Part 2 Comments

Comment 1: In response to NOD Comment 4, the Permittees state that future infiltration rates through the MWL cover (based on the natural analogue) would be less than the current infiltration rates (based on the engineered cover). This reduction in the future infiltration rates presumably is due to the increased evapotranspiration caused by increasing porosity and hydraulic conductivity of the landfill cap as it reverts to natural soil conditions. While this process may occur, it is not clear how this conclusion was reached. Clarify if the anticipated increase in evapotranspiration is based on empirical data (i.e., actual infiltration and/or groundwater recharge data from areas with natural soil), modeling simulations, or another method.

Response 1: The anticipated increase in evapotranspiration is based on empirical data and site-specific data that were used in the Unsaturated Water and Heat Flow (UNSAT-H) code model simulations. Daily potential evapotranspiration (PET) values were calculated using the Hydrologic Evaluation of Landfill Performance (HELP) code Version 3 (Schroeder et al. 1994) with its embedded functions and database for Albuquerque, New Mexico (Peace and Goering, 2005). Site-specific data such as root depth, root length density, leaf area index, growing season and percent bare area were used in the vegetative input for the UNSAT-H code. Soil hydraulic properties used in the UNSAT-H code for the natural analogue and the engineered cover were obtained from site-specific empirical data obtained from the instantaneous profile (IP) test site that was located near the MWL.

Comment 2: In response to NOD Comment 6, Section 4, Pages E-59 and E-59a, the Permittees indicate that monitoring triggers are considered preliminary and are to be finalized in the Long-Term Monitoring and Maintenance Plan (LTMMP). This is not an acceptable approach, as the NMED Secretary's Final Order issued on May 25, 2006 requires that the triggers be developed as part of the CMI Plan. The relevant part of the Final Order states: "As part of the Corrective Measures Implementation Plan that incorporates the remedy (described in the draft permit modification in Paragraph V.3), Sandia shall additionally include the following: ..., b) triggers for future action, that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy."

Although the trigger levels and the environmental media that they apply to must be established as part of the CMI Plan, the specific methods, locations, and frequencies

of monitoring, and other related details can be established through approval of the LTMMP. Trigger levels, once accepted by the NMED through its review and approval of the CMI Plan, must be incorporated into the proposed LTMMP.

Additionally, the trigger evaluation process described in Section 4 and in Figure E-25 (of pages E-59 and E-59a), and as revised by the Permittees' response, is not an acceptable approach. In NOD Comment 6, and again through this Notice of Disapproval, the Permittees are instructed to revise the trigger evaluation process to follow the corrective action process described in the Consent Order (April 29, 2004) if a trigger level is exceeded, provided the Consent Order is still in force at the time. If the Consent Order has terminated, the trigger evaluation process should follow the corrective action process described in the Facility Permit. The Permittees should repeat sampling to confirm if a trigger level has been exceeded. Repeat sampling should be the primary means to avoid implementation of corrective action based on false positives.

Response 2: Revisions to trigger levels are discussed in Response 7, below.

In addition, DOE/Sandia would like to withdraw Section 4.1, Appendix E entitled "Trigger Evaluation Process from the CMI Plan". This section includes Figure E-25 entitled "Trigger Evaluation Process for the Mixed Waste Landfill". The methods by which the analytical data and any trigger level exceedances will be evaluated will be addressed in the revised LTMMP.

Comment 3: In NOD Comment 9, the NMED concluded that the neutron probes will only be able to evaluate soil moisture at depths in the vadose-zone that are considerably deeper than the base of the soil cover. Because it would take substantial time for moisture to move through the vadose zone to the depths of the neutron probe access tubes, and because the current design does not monitor for breakthrough of moisture from the cover to the waste, NMED does not agree that such moisture monitoring offers the best possible design for an early warning system. Thus, NMED will place more emphasis on other types of monitoring in the LTMMP. No response is required by the Permittees for this comment.

Response 3: No response required.

Comment 4: In NOD Comment 14, the Permittees indicate that soil samples from animal burrows and ant hills will be collected every five years. NMED believes that every five years is too long of an interval between sampling events given that the MWL remedy and fate and transport model are to be re-evaluated every five years in accordance with the Final Order. The Permittees' current proposal involves only one round of sampling results to be available for each five year re-evaluation. The Permittees must propose a sampling frequency with a shorter interval between sampling events.

Response 4: DOE/Sandia will revise this sampling frequency to occur annually, if these features are found to exist following the annual inspection and survey, and there is adequate sample volume.

Comment 5: In NOD Comment 15, NMED indicated that soil gas in the vadose zone was to be monitored for tritium, radon, PCE, and total VOCs. The Permittees plan to install a FLUTe™ vadose zone soil-gas monitoring system around the MWL for VOCs, and propose trigger levels of 20 parts per million by volume (ppmv) for trichloroethylene (TCE) and tetrachloroethylene (PCE), and 25 ppmv for total VOCs to ensure protection of groundwater. However, the Permittees did not agree to monitor for tritium or radon in the soil gas on the basis that the data would be of limited value, and that the NMED did not have the authority to require monitoring of these radioactive constituents. Note that the U.S. Environmental Protection Agency (EPA) and NMED regulates gross beta in groundwater through drinking water standards. Tritium and some isotopes of radon are beta emitters. Furthermore, NMED disagrees that the data would be of limited value, as NMED believes that concentration trends are useful indicators of contamination migration. Thus, NMED expects the Permittees to monitor for tritium and radon in soil gas in the vadose zone. The Permittees must specify trigger levels for radon and tritium for soil gas in the vadose zone.

Response 5: On November 13, 2008, the NMED clarified in a personal communication (Griffith, 2008) that DOE/Sandia will not be required to sample for radon and tritium in subsurface soil-vapor samples nor specify trigger levels for radon and tritium in soil vapor in the vadose zone. Thus, no response is required.

Comment 6: In NOD Comment 19, NMED asked that the Permittees propose additional monitoring points at locations (surface and subsurface) within the landfill where contaminants were detected at their highest levels during the RCRA Facility Investigation of the MWL. No additional sampling was proposed by the Permittees, chiefly on the basis that intrusive monitoring techniques could possibly compromise cover integrity. However, NMED believes that additional monitoring points can be located within the landfill, and that such monitoring can be conducted without necessarily driving heavy vehicles over the landfill surface. The Permittees shall propose additional monitoring points at locations within the landfill where radon, tritium, and VOCs were detected at their highest levels during the RCRA Facility Investigation. These monitoring locations should consider air, surface soil, and subsurface soil as media to be monitored.

Response 6: On November 5, 2008, the NMED clarified in a personal communication (Griffith, 2008) that the subsurface samples refer to soil-vapor samples collected in the subsurface. DOE/Sandia proposes to install two permanent soil-vapor sampling points within the landfill boundary. The LTMMP will be revised to include sample collection points within the landfill boundary (on the cover) for air, surface soil, and soil vapor.

Soil-vapor samples will not be analyzed for radon and tritium (see Response 5).

Trigger levels for constituents in soil vapor will apply only to samples collected from the deepest sample points (i.e. from the 400-foot sample ports of the FLUTe™ vadose zone soil-vapor monitoring system installed around the perimeter of the cover).

Comment 7: In NOD Comment 18, and in Table 2 of the Permittees' January 19, 2007, responses to the NOD for Comment 20, Permittees did not agree to lower the trigger levels for the VOCs 1,1,1-TCA, ethylbenzene, styrene, toluene, and total xylenes (in groundwater). The Permittees continue to propose trigger levels based on one-half of the value of EPA Primary Drinking Water Standards, and state that there are no regulatory or technical reasons for further reducing the trigger levels for these VOCs. The Permittees also argue that there are analytical difficulties with measuring low concentrations of VOCs in groundwater which could lead to false detections of contaminants.

NMED finds that some of the proposed trigger levels are unacceptable because they fall within three general categories: a) they fail to take into account Consent Order (April 29, 2004) requirements for groundwater cleanup levels; b) they are erroneous; or c) they do not address all constituents of concern for the MWL. These deficiencies are discussed more specifically below. NMED also proposes alternative trigger levels for those considered to be unacceptable in the tables provided below.

A. Consent Order Requirements for Cleanup Levels

The Permittees assert that regulations do not require the cleanup of groundwater to concentrations that are below water quality standards; hence, setting trigger levels at one-half the water quality standard is adequate to protect groundwater. However, NMED may require corrective action at any solid waste management unit (SWMU) as necessary to protect human health and the environment from releases (20.4.1.500 NMAC incorporating 40 CFR 264.101). This is true even in cases where groundwater is known to be contaminated at levels below water quality standards. Additionally detection and prevention of the contamination of groundwater at any concentration should be the main goal of long-term monitoring at the MWL.

Any given trigger level applicable to groundwater beneath the MWL should be based on the appropriate water quality standard, which in general will be the most stringent of a state or federal standard for the constituent of interest. Section VI.K.1.a of the Consent Order states that "[g]roundwater cleanup levels are based on the WQCC standards and EPA MCLs for drinking water Contaminants. If both a WQCC standard and a MCL have been established for an individual substance, then the most stringent of the two levels shall be considered the cleanup level for that substance...If a WQCC standard or MCL has not been established for a specific substance, the EPA Region VI Human Health Medium Specific Screening Level for tap water shall be used as the screening level.

The purpose of establishing trigger levels is to provide for early warning of any unexpected releases so that action can be taken to prevent groundwater contamination, and especially to prevent contamination from exceeding a water quality standard. Groundwater investigations can take considerable time to complete; often such investigations may take many years. Thus, to be useful as part of an early warning system, trigger levels are generally set much lower than their corresponding standards, and especially in cases where standards are much higher than laboratory analytical detection limits.

For these reasons, NMED believes one-half of a water quality standard is too high for a trigger level for a give groundwater constituent where the standard is greater than about 0.040 mg/L. In cases where the standard is greater than 0.040 mg/L, NMED proposes that the trigger level for a groundwater constituent should be set at one-quarter (25%) of the standard, which should be sufficiently higher than most detection limits such that false positives should be uncommon. However, in the case of naturally occurring constituents, it may be necessary to set the trigger level to corresponding background levels whenever 25% of the standard falls below the approved maximum background concentration for the area.

The trigger levels for 1,1,1-TCA; 1,1-dichloroethene, toluene, vinyl chloride, total xylenes, chlorobenzene, ethylbenzene, styrene; cis 1,2-dichloroethene; trans 1,2-dichloroethene, and method 8260 VOCs in groundwater are not acceptable as they are not based on the lowest concentration of the applicable EPA MCL, WQCC standard, or if an applicable MCL or WQCC standard does not exist, the applicable EPA Region 6 Human Health Medium Specific Screening Level for tap (residential) water. NMED proposes alternate trigger levels for these constituents in the table below. The NMED's proposed alternate trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	Parameter	NMED proposed trigger level	Comments
Groundwater	1,1,1-TCA	0.015 mg/L	25% of WQCC standard (0.060 mg/L)
Groundwater	1,1-dichloroethene	0.0025 mg/L	50% of WQCC standard (0.005 mg/L)
Groundwater	toluene	0.1875 mg/L	25% of WQCC standard (0.750 mg/L)
Groundwater	vinyl chloride	0.0005 mg/L	50% of WQCC standard (0.001 mg/L)
Groundwater	total xylenes	0.155 mg/L	25% of WQCC standard (0.620 mg/L)
Groundwater	chlorobenzene	0.025 mg/L	25% of EPA MCL
Groundwater	ethylbenzene	0.175 mg/L	25% of EPA MCL
Groundwater	styrene	0.025 mg/L	25% of EPA MCL
Groundwater	cis 1,2-dichloroethene	0.0175 mg/L	25% of EPA MCL
Groundwater	trans 1,2-dichloroethene	0.025 mg/L	25% of EPA MCL
Groundwater	method 8260 VOCs	50% of the most stringent of EPA MCL, WQCC	As explained in the column to the left.

		standard, or EPA Region 6 Human Health Medium Specific Screening Level for tap water, as applicable. Trigger level to be set at 25% of the standard if the standard is greater than 0.040 mg/L.	

B. Erroneous Trigger Levels

The trigger levels for cadmium and mercury in surface soil are not acceptable for the reasons indicated in the column for "Comments" in the following table. NMED also proposes alternate trigger levels for these constituents in the following table. The alternate trigger levels are based on NMED industrial/occupational soil screening levels. The NMED's proposed alternate trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	Parameter	NMED proposed trigger level	Comments
Surface soil	cadmium	564 mg/kg	Screening value was listed incorrectly in Table 2.
Surface soil	mercury	6.84 mg/kg	Screening value for methyl mercury is more conservative. Use of elemental mercury not supported by waste inventory.

C. Additional Metals of Concern at the MWL

For each given medium listed in the left-most column of the table below, add the following additional constituents and their corresponding trigger levels to Table E-6 of Appendix E of the CMI Plan. The trigger levels for soil are based on NMED industrial/occupational soil screening levels. The NMED's proposed additional trigger levels should be incorporated into Table E-6 of Appendix E of the CMI Plan.

Environmental Medium	Parameter	NMED proposed trigger level
Surface soil	Copper	45,400 mg/kg
Surface soil	Nickel	22,700 mg/kg
Surface soil	Vanadium	1,140 mg/kg

Surface soil	**Zinc**	**100,000 mg/kg**
Surface soil	**Cobalt**	**20,500 mg/kg**
Surface soil	**Beryllium**	**2,250 mg/kg**
Groundwater	**Chromium (total)**	**0.043 mg/L (background)**
Groundwater	**Cadmium**	**0.0025 mg/L (50% of EPA MCL)**
Groundwater	**Nickel**	**0.050 mg/L (25% of WQCC standard of 0.2 mg/L)**
Groundwater	**Dichlorodifluoromethane**	**0.0975 mg/L (25% EPA Region 6 screening level for compound)**
Groundwater	**tritium**	**4 mrem/year (EPA MCL)**
Groundwater	**radon**	**300 pCi/L (proposed EPA MCL)**

Response 7: DOE/Sandia applied the formula proposed by the NMED to determine the trigger levels for method 8260 VOCs in groundwater. The following table details the NMED proposed trigger levels for method 8260 VOCs in groundwater with an additional third column representing the DOE/Sandia agreement to apply those without a cited trigger value and includes a DOE/Sandia counterproposal for the following four (4) VOC trigger levels: bromodichloromethane, dibromochloromethane, cis-1,3-dichloropropene, and trans-1,3-dichloropropene.

Table 1. Proposed Trigger Levels for VOCs in Groundwater

Analyte	NMED Proposed Trigger Level (µg/L)	DOE/Sandia Counterproposal Trigger Level (µg/L)
1,1,1-Trichloroethane (1,1,1-TCA)	15	
1,1,2,2-Tetrachloroethane	5	
1,1,2-Trichloroethane	1	
1,1-Dichloroethane	12.5	
1,1-Dichloroethene	2.5	
1,2-Dichloroethane	2.5	
1,2-Dichloropropane	2.5	
2-Butanone (methyl ethyl ketone)	1775	
2-Hexanone	none	
4-methyl-, 2-Pentanone (Methyl isobutyl ketone)	500	
Acetone	1375	
Benzene	2.5	
Bromodichloromethane	0.09	0.9
Bromoform	4.25	
Bromomethane	4.25	
Carbon disulfide	250	
Carbon tetrachloride	2.5	
Chlorobenzene	25	
Chloroethane (ethyl chloride)	1.95	
Chloroform	25	
Chloromethane	48	
Dibromochloromethane	0.065	0.65
Ethyl benzene	175	
Methylene chloride	2.5	
Styrene	25	
Tetrachloroethene (PCE)	2.5	
Toluene	187.5	
Trichloroethene (TCE)	2.5	
Vinyl acetate	103	
Vinyl chloride	0.5	
Xylene	155	
cis-1,2-Dichloroethene	17.5	
cis-1,3-Dichloropropene (1,3-Dichloropropene)	0.2	2.0
trans-1,2-Dichloroethene	25	
trans-1,3-Dichloropropene	0.2	2.0

The proposed trigger levels for bromodichloromethane, dibromochloromethane, cis-1,3-dichloropropene, and trans-1,3-dichloropropene are less than the method detection limit of the contract analytical laboratory. Accordingly, the DOE/Sandia offer a counterproposal for these constituents based on the following considerations:

- The NMED triggers levels for these carcinogens were selected using the EPA Region 6 Human Health Medium Specific Screening Level for tap (residential) water per NMED Comment 7 criteria, which uses a target cancer risk of 1.0E-06.
- DOE/Sandia propose to adjust these triggers to use the target cancer risk of 1.0E-05 as presented in the NMED Soil Screening Levels (June 2006).

The revised triggers levels increase by an order of magnitude, as a result of using the higher target cancer risk.

In reference to the surface soil trigger levels listed in Comment 7, Table B, Erroneous Triggers Levels, the DOE/Sandia will apply the cadmium trigger level of 564 mg/kg in surface soil samples.

The trigger level value for methyl mercury as it appears in Comment 7 is assumed to be incorrect. DOE/Sandia will use a corrected value of 68.4 mg/kg for industrial/occupation soil (NMED Soil Screening Levels, June 2006).

The DOE/Sandia agree to apply the proposed trigger levels listed in Comment 7, Table C, Additional Metals of Concern at the MWL.

Volume I

TAB 16

Conditional Approval: Mixed Wasted Landfill Corrective Measures Implementation Plan, November 2005

From: NMED/Bearzi
To: SNL/Davis

Back of Tab 16

BILL RICHARDSON
Governor

DIANE DENISH
Lieutenant Governor

NEW MEXICO
ENVIRONMENT DEPARTMENT

Hazardous Waste Bureau

2905 Rodeo Park Drive East, Building 1
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Phone (505) 476-6000 Fax (505) 476-6030
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RON CURRY
Secretary

JON GOLDSTEIN
Deputy Secretary

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

December 22, 2008

Kimberly A. Davis
Acting Manager
Sandia Site Office/NNSA
U.S. Department of Energy
P.O. Box 5400 MS 0184
Albuquerque, NM 87185-5400

Francis B. Nimick
Deputy Director
Nuclear Energy & Global Securities Technologies
Sandia National Laboratories
P.O. Box 5800, MS 0701
Albuquerque, NM 87185

RE: CONDITIONAL APPROVAL
MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN, NOVEMBER 2005
SANDIA NATIONAL LABORATORIES, NM5890110518
SNL-05-025

Dear Ms. Davis and Mr. Nimick:

The New Mexico Environment Department (NMED) has reviewed the U.S. Department of Energy/Sandia Corporation's (Permittees) November 26, 2008 responses to NMED's second Notice of Disapproval (NOD) for the Sandia National Laboratories Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan. The MWL CMI Plan was originally submitted in November 2005. The NOD was the second addressing deficiencies in the CMI Plan, the first having been issued on November 20, 2006. The Permittees responded to these NODs on December 15, 2006 (Comment Response Set #1); January 19, 2007 (Comment Response Set #2); and, in the aforementioned response, on November 26, 2008.

The MWL CMI Plan is hereby approved, subject to the following conditions.

1. The Permittees must implement various changes proposed by the Permittees in their responses to the NODs. Specifically:

a. The proposal presented in the Permittees' November 26, 2008, response to comment #2 (Part 1 Comments) concerning what constitutes acceptable foliage cover must be incorporated into the Long-Term Monitoring and Maintenance Plan (LTMMP).

b. NMED agrees with the Permittees' withdrawal of Section 4.1, Appendix E and associated Figure E-25 from the CMI Plan. A new evaluation method for data and trigger levels must be incorporated into the LTMMP. NMED believes that a statistical approach could be designed that would be acceptable.

c. The proposal presented in the Permittees' November 26, 2008, response to comment #4 (Part 2 Comments) concerning the annual sampling of animal burrows and ant hills, must be incorporated into the LTMMP.

d. The proposal presented in the Permittees' November 26, 2008, response to comment #6 (Part 2 Comments) concerning the installation of two permanent soil-vapor sampling points and other sampling collection points for air, surface soil, and soil vapor located within the landfill boundary, must be incorporated into the LTMMP.

e. All of the trigger levels for all media need to be incorporated into the LTMMP. These trigger levels are found in the original submittal of the CMI Plan, Comment Response Set #2, and the Permittees' responses dated November 26, 2008 (Comment #7, Part 2 Comments). NMED accepts the Permittees' trigger levels in the November 26, 2008 responses for bromodichloromethane, dibromochloromethane; cis-1,3 dichloropropene, and trans-1,3 dichloropropene.

f. The Permittees must adhere to the construction schedule proposed in Comment Response Set #1 (see Comment #2 in Set #1). The Permittees may have an additional 90 days to complete any necessary contracts to begin construction of the cover.

g. The Permittees must implement the change to the CMI Plan under comment response 10 of Comment Response Set #1 concerning the seeding of borrow pits that are no longer needed.

h. The Permittees must implement the change to the CMI Plan under comment response 11 of Comment Response Set #1 concerning the use of heavy equipment within three feet of any monitoring well or measurement device.

i. The Permittees must implement the change to the CMI Plan under comment response 15 of Comment Response Set #1 concerning quality control data, and as corrected in Comment Response Set #2.

2. The Permittees provided evidence that tumbleweed may actually be helpful to establish other types of vegetation. However, the roots of tumbleweed plants can potentially extend to depths of about two meters. Such deep roots could reach the waste layer and provide a pathway for contaminants to migrate to the surface. The Permittees therefore may not allow tumbleweed to grow on the MWL cover. However, NMED accepts the Permittees' proposal to implement a supplemental watering plan as a means to help establish a mature plant community on the MWL cover. The method, timing, and amount of supplemental watering should be included in a revision of the LTMMP.

NMED has reconsidered its position as stated in its letter of October 10, 2008, and now agrees that radon and tritium would not have to be monitored in soil gas because of the difficulty in

obtaining sufficient quantities of gas for accurate measurements. Radon and tritium will be monitored in the groundwater and at the surface of the landfill through methods that are to be fully developed in the LTMMP.

Please contact William Moats of my staff at (505) 222-9551 if you have any questions.

Sincerely,

James P. Bearzi
Chief
Hazardous Waste Bureau

cc: J. Kieling, NMED, HWB
W. Moats, NMED, HWB
L. King, EPA-Region 6 (6PD-N)
J. Gould, DOE/NNSA/SSO, MS 0184
J. Cochran, SNL, MS 0719
File: Reading and SNL, 2008

Volume I

TAB 17

Replacement Pages for the Mixed Waste Landfill

Corrective Measures Implementation Plan, November 2005

From: SNL/Davis
To: NMED/Bearzi

Back of Tab 17

Notes for Volume I, Tab 17:

Only the DOE/SNL letter and explanation page regarding replacement pages submitted in response to the December 22, 2008 letter from NMED, "Conditional Approval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005" are included herein. The replacement pages included in this submission have been integrated into the "Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005," which can be found in Justification Binder Volume I, Tab 4.

National Nuclear Security Administration
Sandia Site Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

FEB 1 2 2009

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Road East, Bldg. 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the U.S. Department of Energy/National Nuclear Security Administration (DOE/NNSA) and Sandia Corporation (Sandia), DOE/NNSA is submitting requested changes in the form of replacement pages for the response to the letter from the New Mexico Environment Department (NMED) dated December 22, 2008 regarding the Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill at Sandia National Laboratories/New Mexico. The NMED letter is entitled "*Conditional Approval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories,* NM5890110518 SNL-05-025". This Conditional Approval is a result of the NMED review of earlier DOE/NNSA and Sandia responses to two Notice of Disapprovals (dated November 20, 2006, and November 26, 2008). Items in Part 1 of the NMED Conditional Approval letter (conditions g, h, and i) are to implement changes to the CMI Plan, specifically.

Other items in the NMED Conditional Approval letter (conditions Part 1a, b, c, d, e, f, and Part 2) are to be addressed in the Long-Term Monitoring and Maintenance Plan at a later date.

Sincerely,

Kimberly A. Davis
Acting Manager

FEB 1 2 2009

Enclosure

cc: (w/enclosure):
W. Moats, NMED (Via Certified Mail)
L. King, EPA, Region 6 (Via Certified Mail)
T. Skibitski, NMED-OB (2 copies)
Records Center, SNL/NM, MS 1089
Zimmerman Library, UNM (c/o SNL/NM)
J. Lehr, NA-56/HQ/FORS

cc: (w/o enclosure):
A. Blumberg, SNL/NM, MS 0141
F. Nimick, SNL/NM, MS. 0701
D. Miller, SNL/NM, MS 0718
J. Cochran, SNL/NM, MS 0719
S. Griffith, SNL/NM, MS 1089
B. Langkopf, SNL/NM, MS 1089
C. Daniel, SNL/NM, MS 1089
J. Gould, SSO
K. Agogino, SSO
C. Wimberly, SSO

AOP 95-45, 06

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **Replacement Pages for the Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories, NM5890110518 SNL-05-025", January 2009.**

Document author: **Stacy Griffith, Department 06765**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

Signature: Francis B. Nimick 1/26/09
Date

Francis B. Nimick
Deputy Director to the
Nuclear Energy & Global Security Technologies
Center 6700
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico 87185
Operator

and

Signature: Kimberly A. Davis
Date 2/12/09

Kimberly Davis
Acting Manager
U.S. Department of Energy
National Nuclear Security Administration
Sandia Site Office
Owner and Co-Operator

Sandia Corporation
Albuquerque, New Mexico
January 2009

Replacement Pages for the Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005

INTRODUCTION

The U. S. Department of Energy/National Nuclear Security Administration (DOE/NNSA), and Sandia Corporation (Sandia) is submitting requested changes in the form of replacement pages for the response to the letter from the New Mexico Environment Department (NMED) dated December 22, 2008 regarding the Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill (MWL) at Sandia National Laboratories/New Mexico (SNL/NM). The NMED letter is entitled "Conditional Approval: Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005 Sandia National Laboratories, NM5890110518 SNL-05-025". This Conditional Approval is a result of the NMED review of earlier DOE/NNSA and Sandia responses to two Notice of Disapprovals (dated November 20, 2006, and November 26, 2008). Items in Part 1 of the NMED Conditional Approval letter (conditions g, h, and i) are to implement changes to the CMI Plan, specifically.

The replacement pages for the CMI Plan are contained in this document and address conditions g, h, and i of Part 1 as listed below:

g. The Permittees must implement the change to the CMI Plan under comment response 10 of Comment Response Set #1 concerning the seeding of borrow pits that are no longer needed.

h. The Permittees must implement the change to the CMI Plan under comment response 11 of Comment Response Set #1 concerning the use of heavy equipment within three feet of any monitoring well or measurement device.

i. The Permittees must implement the change to the CMI Plan under comment response 15 of Comment Response Set #1 concerning quality control data, and as corrected in Comment Response Set #2.

The replacement pages contain an under-scored item (material that is being added or corrected). There may also be a strikethrough item (material to be omitted) in the case of replacement. There is a total of three replacement pages.

Other items in the NMED Conditional Approval letter (conditions Part 1a, b, c, d, e, f, and Part 2) are to be addressed in the Long-Term Monitoring and Maintenance Plan at a later date.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.