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The Administrative Record Staff

Phase I IM/IRA Decision Document for Operable Unit 7 Present Landfill

Draft Report
August 24, 1995

Text

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

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Executive Summary

The Operable Unit (OU) 7 Draft Phase I Interim Measure/Interim Remedial Action (IM/IRA) Decision Document presents the proposed alternative for closure of OU 7 As agreed to bv the U S Department of Energy U S Environmental Protection Agency and Colorado Department of Public Health and Environment the alternative implemented as the interim action will also constitute the final action for OU 7 Also as agreed to bv the agencies this IM/IRA Decision Document in conjunction with the OU 7 Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report constitutes the OU 7 Closure Plan Several other maintenance and remedial actions are planned at OU 7 including implementing a leachate accelerated action constructing a slurry wall on the north side of the landfill and abandoning groundwater-monitoring wells within the landfill

OU 7 is located in the Rocky Flats buffer zone north of the industrial area and consists of four Individual Hazardous Substance Sites (IHSSs) associated with historic operation of the landfill The four IHSSs include IHSS 114 the Present Landfill IHSS 203 Inactive Hazardous Waste Storage Area, and IHSSs 167 2 and 167 3 Sprav Evaporation Areas The Present Landfill has operated primarily as a municipal waste facility for Rockv Flats since 1968 The landfill is used for office trash, construction debris scrap metal dried sanitary sewage sludge and other waste Historically the landfill has received incidental hazardous waste including containers partially filled with paint or solvents oil filters and metal cuttings coated with hydraulic oil The IHSSs associated with the landfill include an area southwest of the landfill (IHSS 203) used in 1986 and 1987 as a hazardous waste storage area for drums of liquid and solid waste The other two IHSSs are spray evaporation areas southeast of the landfill which received spray waters from the East Landfill Pond periodically between 1975 and 1994

This Phase I IM/IRA Decision Document summarizes the results from two separate field investigations at OU 7 and provides the resultant interpretation of the nature and extent of contamination This information is then used to quantify the risk to human health and the environment present at OU 7 Because OU 7 is being closed under a presumptive remedy approach a comprehensive baseline risk assessment was not necessary The presumptive remedy allows a comparison of all exposure pathways to the pathways that will be addressed by the presumptive remedy This document concludes that the presumptive remedy, containment will address all potential pathways with the exception of surface water and sediment in the East Landfill Pond and surface soils in spray evaporation areas The pathways not addressed by the presumptive remedy were subjected to a focused risk assessment process This risk assessment consisted of comparing the maximum site concentrations to preliminary remediation goals quantification of exposure and toxicity

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values, and comparison to applicable or relevant and appropriate requirements (ARARs) No risks above the acceptable ranges were identified in the pathways not addressed by the proposed remedy

The following Remedial Action Objectives (RAOs) were established for the Present Landfill closure, in accordance with EPA guidance

1 Prevent direct contact with landfill contents
2 Minimize infiltration and resulting contaminant leaching to groundwater
3 Control surface-water run-off and erosion
4 Control landfill gas (treat as needed)
5 Remediate wetland areas (as needed)

These RAOs form the basis for identification of appropriate remedial action alternatives for the site Section 5 of this report describes the nine alternatives initially identified as supportive of the RAOs As per EPA guidance the nine alternatives were evaluated against three criteria effectiveness, implementability, and cost This initial screening process eliminated five of the alternatives from further consideration Four alternatives were carried through the detailed screening of alternatives

The four alternatives evaluated in the detailed analysis of alternatives, presented in Section 6, include the following

Alternative 1 No Action
Alternative 5 Single-Barrier Flexible Membrane Cover (FMC)
Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover
Alternative 9 Composite-Barrier FMC and Clay Cover

It is assumed that the slurry wall maintenance action, scheduled for fiscal year 1996 is complete Alternative 1, the no-action alternative, is retained as a baseline for comparison in accordance with EPA guidance The only difference between the other three alternatives is in the composition of the soil layer beneath the FMC Alternative 5 includes common soil for bedding, Alternative 7 includes soils with a lower permeability, and Alternative 9 includes a thicker clay barrier layer rather than soil

The detailed analysis of alternatives uses nine criteria to evaluate each alternative The nine criteria are the following

1 Overall protection of human health and the environment
2 Compliance with ARARs
3 Long-term effectiveness and permanence
4 Reduction of toxicity, mobility, and volume through treatment
5 Short-term effectiveness
6 Implementability

7 Cost
8 Regulatory agency acceptance
9 Community acceptance

After evaluating each of the alternatives against the nine criteria a comparative analysis was performed to evaluate the alternatives relative to each other This comparison is described and quantified via a weighted ranking system which is presented in Section 6 Alternative 7 emerged from this multi-step evaluation process as the preferred alternative for the OU 7 remedial action Alternative 7 achieves the site RAOs and ranks consistently well according to the nine criteria

Alternative 7 consists of a single-barrier FMC underlain by a 12-inch soil layer with a permeability of 1E-05 cm/sec and a geocomposite gas-collection system The FMC is covered with a lateral drainage layer and a 36-inch vegetative layer Existing institutional controls are maintained including limited site access and new fencing around the cover is provided The slurry wall maintenance action is assumed to be completed This document also presents a post-closure monitoring plan for OU 7 Post-closure monitoring will be conducted for 30 years and will include semiannual upgradient and downgradient groundwater-monitoring wells quarterly gas monitoring and annual cover surveys and facility inspections

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1 Introduction

The Rocky Flats Environmental Technology Site is located in northern Jefferson County, Colorado approximately 16 miles northwest of Denver (Figure 1-1), and comprises approximately 6 550 acres of land in Sections 1 through 4 and 9 through 15 of Township 2 South Range 70 West, 6th Principal Meridian Major buildings are located within the industrial area which encompasses approximately 400 acres (Figure 1-2) The industrial area is surrounded by a buffer zone of approximately 6,150 acres

Rocky Flats is a government-owned contractor-operated facility in the nationwide nuclear weapons production complex The former mission at Rocky Flats was to produce components for nuclear weapons from plutonium, uranium, and non-radioactive materials The current mission is to manage wastes and materials and to clean up and convert the Rocky Flats site to beneficial use in a manner that is safe environmentally and socially responsible physically secure, and cost effective

This report addresses investigations at operable unit (OU) 7 which is located north of the industrial area on the western end of No Name Gulch and encompasses approximately 44 acres (Figure 1-2) OU 7 is one of 16 OUs at Rocky Flats Each OU is made up of a number of individual hazardous substance sites (IHSSs) OU 7 comprises the Present Landfill (IHSS 114) Inactive Hazardous Waste Storage Area (IHSS 203), East Landfill Pond Pond Area Spray Field (IHSS 167 2), and South Area Spray Field (IHSS 167 3) Figure 1-3 is a 1991 photograph that shows the landfill, pond, and adjacent spray evaporation areas

The preliminary assessment performed under the U S Department of Energy (DOE) Environmental Restoration program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination (DOE 1986) Additional information regarding historical plant operations, production activities, past waste disposal practices at Rocky Flats, and previous investigations not directly related to OU 7 are provided in the OU 7 Phase I Work Plan (DOE 1991a)

Hazardous constituents have been released (42 USC 9601 Section 101(22)) at Rocky Flats as a result of the production of nuclear weapons components processing of radioactive substances, and fabrication of metals A two-phase process was developed to remove these constituents A Phase I Resource Conservation and Recovery Act (RCRA) facility investigation/remedial investigation (RFI/RI) was conducted at OU 7 from November 1992 through April 1993 to characterize the site physical features, describe contaminant sources and determine the nature and extent of contamination in soils resulting from such releases A Phase II RFI/RI was subsequently planned to

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characterize the nature and extent of contamination in surface water, groundwater, and air and evaluate contaminant migration pathways

These activities were initiated pursuant to an Interagency Agreement (IAG) among the DOE, the U S Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) dated January 22, 1991 (DOE 1991b), which is currently being revised The IAG addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues that pertain to the site CDPHE is the lead regulatory agency for the IAG program at OU 7

The focus of investigations at OU 7 changed due to the adoption of a presumptive-remedy strategy for streamlined site characterization and site remediation by DOE, CDPHE, and EPA. As a result of this strategy, the Phase I RFI/RI Report and revised Phase I Work Plan were combined into a single document, the Final Work Plan Technical Memorandum for OU 7 (OU 7 Final Work Plan) (DOE 1994a), which was approved in September 1994 Supplemental fieldwork under the OU 7 Final Work Plan was conducted from October 1994 through January 1995 Findings of the supplemental Phase I field investigation are presented in this report

In accordance with a resolution of the Senior Executive Committee of the IAG in April 1994 (DOE 1994b), two interim measure/interim remedial actions (IM/IRAs) were directed for OU 7 These include a separate IM/IRA for collection of leachate at the seep above the East Landfill Pond and an IM/IRA for closure of the Present Landfill The seep collection IM/IRA is being implemented before closure as an accelerated action (Section 1 3 1) The landfill closure IM/IRA is addressed in this report.

1 1 Purpose of Report

This Phase I IM/IRA Decision Document (IM/IRA DD) presents the proposed alternative for landfill closure. The alternative addresses all source areas with risk levels greater than 1E-06 or a hazard index greater than 1 As agreed by DOE, CDPHE, and EPA, the interim action will be the final action for closure of OU 7 The Phase I IM/IRA DD and the Phase I RFI/RI Report constitute the OU 7 Closure Plan (CDPHE 1992) The IM/IRA DD was prepared in accordance with paragraphs 15 and 150 of the IAG (DOE 1991a) It is consistent with guidance in the preamble to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (55 Federal Register 8704) and is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements (6 CCR 1007-3 Part 265) DOE has prepared a draft Proposed Plan in accordance with Section I B 9 of the IAG (DOE 1991a), and it is included as an attachment to the IM/IRA DD The IM/IRA DD and the Proposed Plan will undergo a single public involvement program

1 2 Organization of Report

The IM/IRA DD is divided into 10 sections as follows

Section 1, Introduction, discusses the purpose and organization of the report Other maintenance or remedial actions at the Present Landfill are described, and the project approach is presented

Section 2 Site Characteristics, describes the physical characteristics and operational history of OU 7, describes site-specific geology hydrology and ecology, including sensitive habitats and endangered species, and summarizes the nature and extent of contamination in all media Information included in this section is from both the Phase I RFI/RI (DOE 1994a) and the additional Phase I field investigation

Section 3 Development of Remedial Action Objectives to Reduce Site Risks outlines the preliminary objectives of the remedial action, presents a conceptual site model for defining risks, summarizes the results of focused risk assessments for various environmental media, assesses compliance with applicable or relevant and appropriate requirements (ARARs), and presents final remedial action objectives (RAOs)

Section 4, Identification and Screening of Technologies, identifies and screens response actions and technologies that satisfy the RAOs Screening is based on an evaluation of effectiveness implementability and cost Favorable technologies are retained for consideration in the development of alternatives

Section 5, Development of Alternatives, describes the general components of the alternatives developed, presents nine alternatives, summarizes the results of the alternatives screen using effectiveness implementability, and cost and presents the four alternatives retained for detailed analysis

Section 6 Detailed Analysis of Alternatives, presents an evaluation of the four alternatives using the nine CERCLA criteria (overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, reduction of toxicity mobility and volume through treatment, short-term effectiveness, implementability costs, regulatory agency acceptance, and community acceptance) and recommends the best alternative for final selection by CDPHE and EPA

Section 7, Recommended Alternative, describes the proposed action, outlines design requirements, presents the conceptual design for the proposed action, and describes the process for developing the Title II design The conceptual design includes the proposed grading plan, surface-water control, proposed cover section seepage control, gas control, ancillary facilities, and estimated costs

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Section 8, Closure and Post-Closure Plans, details the plans that will be carried out during the closure and post-closure care periods to meet regulations stipulated in CHWA, 6 CCR 1007-3 Parts 265 11 and 265 117-120, respectively The closure plan describes the facility, extent of operations, notification requirements, construction activities, decontamination procedures, groundwater monitoring, ancillary closure activities, emergency response, closure certification requirements, and a schedule for closure The post-closure plan addresses permit requirements and describes routine inspection activities, gas monitoring, groundwater monitoring, the point-of-compliance, and the post-closure certification.

Section 9, Environmental Assessment, includes an evaluation of the impacts of the remedial action on human health, wildlife and vegetation, sensitive habitats and endangered species, wetlands and floodplains, air quality, surface-water quality, groundwater quality, irreversible and irretrievable resources, transportation, and cultural resources Cumulative impacts are examined. Impacts of the preferred alternative are compared to the no-action alternative

Section 10, References, presents references cited in the report.

The draft Proposed Plan for OU 7 Present Landfill Area is included as a separate attachment

Supporting data are included in the appendices to the report Appendix A presents borehole geologic logs in LOGGER format from the supplemental Phase I field investigation Appendix B contains drawdown recovery test data and analytical solutions from the supplemental Phase I field investigation Appendix C contains input parameters, results, and a summary of the groundwater modeling. Appendix D presents the screening-level ecological risk assessment for the leachate seep and surface water and sediment in the East Landfill Pond Appendix E contains input parameters, results, contaminant distribution maps, and a summary of the contaminant-transport modeling Appendix F presents settlement estimates. Appendix G presents input parameters, results, and a summary of the HELP modeling Appendix H provides estimated costs and assumptions Appendix I provides gas-emission estimates. Appendix J provides annual soil-loss calculations

1.3 Other Maintenance and Remedial Actions

Several other actions are planned at OU 7, including implementing a leachate accelerated action, constructing a slurry wall on the north side of the landfill, and abandoning groundwater-monitoring wells within the landfill (Figure 1-4)

1 3 1 Leachate Accelerated Action

The Seep Collection IM/IRA is being implemented before closure as an accelerated action A passive seep collection and treatment system is proposed as an accelerated action to eliminate discharge of F039 RCRA-listed waste from the leachate seep to the East Landfill Pond (Figure 1-4) The action was proposed in the Modified Passive Seep Collection and Treatment Proposed Action Memorandum (PAM) (DOE 1995a) which was submitted to CDPHE and EPA on June 15 1995 The PAM includes a description of the interception and passive treatment components of the system and a conceptual design Leachate will be intercepted with perforated pipe and directed to a tank containing carbon-based granular media that will separate the F039 waste from seep water F039 waste will be absorbed by the carbon-based media Treated water will be discharged directly to the East Landfill Pond The modified PAM was approved by CDPHE and EPA on June 27 1995 The system will be fully operational within six months

1 3 2 Slurry Wall Maintenance

A slurry wall will be constructed on the north side of the landfill as a maintenance action undertaken by DOE to address the failure of the existing groundwater-intercept system and north slurrv wall (Figure 1-4) Failure of the existing system is evidenced by (1) insignificant differences in heads in wells that straddle the existing groundwater-intercept system (2) groundwater modeling which shows that inflow occurs on the north side of the landfill (3) as-built diagrams which reveal that sections of the system were not keyed into bedrock and (4) as-built diagrams which show that minimum slopes could allow sediment buildup and blockage within the pipe drain

The new slurry wall will reduce groundwater inflow leachate generation and outflow at the seep Therefore it is an integral part of the remedial action recommended in this report The length of the slurry wall is estimated at 2 000 feet The slurry wall will be keyed into weathered bedrock consisting of siltstones and claystones of the undifferentiated Arapahoe and Laramie Formations Depth of the slurry wall varies with the depth of weathered bedrock and ranges from 15 to 30 feet Hydraulic conductivity ot the weathered bedrock is 4E-07 centimeters per second (cm/sec)

CDPHE and EPA approved DOE's proposal to construct the slurry wall as a maintenance action in May 1995 Construction of the slurry wall will occur in fiscal year 1996 This allows for monitoring the effectiveness of the wall and taking any necessary corrective actions prior to capping

1 3 3 Well Abandonment

Twenty-six of the 54 existing monitoring wells in OU 7 that are sampled quarterly as RCRA-compliance wells or sitewide groundwater-protection wells will be abandoned (Figure 1-4) This action was proposed in a January 13, 1995, letter from DOE to CDPHE and EPA (DOE 1994c) CDPHE and EPA approved the well abandonment proposal on February 13, 1995 (CDPHE 1995) Well abandonment was proposed on the basis that the purpose of each well has been fulfilled, the wells fall under the footprint of the landfill cap, the presence of the wells would compromise the integrity of the cap because holes would have to be cut in the synthetic liner, and unequal compaction of the fill material around the wells would potentially cause differential settlement of the cap Well abandonment will be performed in 1996

1.4 Project Approach–the Presumptive Remedy

Presumptive remedies are preferred technologies for common categories of sites developed by EPA based on historical data from successful remedial actions at similar sites The objective of the presumptive remedy approach is to streamline the site investigation and remedial action selection and reduce the cost and time required to implement the remedial action The presumptive remedy approach was adopted by DOE, CDPHE and EPA in May 1994 (EG&G 1993a, DOE 1994d) Letter approval was received from CDPHE in October 1994 (CDPHE 1994)

The approach was used to streamline the supplemental Phase I field investigation, which focused on gathering data for design of the presumptive remedies and assessment of contamination in groundwater downgradient of the landfill As a result of this strategy, a comprehensive baseline risk assessment was no longer required Use of the presumptive remedy also limited the need for initial identification and screening of alternatives for the corrective measures study/feasibility study (CMS/FS), or IM/IRA, and allowed the acceleration of the schedule for implementing remedial actions and achieving final closure

The presumptive remedy for CERCLA municipal landfill sites is containment (EPA 1993a) Containment technologies are generally appropriate for municipal landfills because the waste poses a relatively low long-term threat and the volume and heterogeneity of the waste make treatment impracticable Although the majority of the waste accepted at OU 7 is considered a municipal waste, some hazardous waste components have been detected in the leachate, indicating the presence of hazardous materials in the waste Therefore, the specific criteria used for the landfill cover design are based on a RCRA Subtitle C facility The containment presumptive remedy consists of the following

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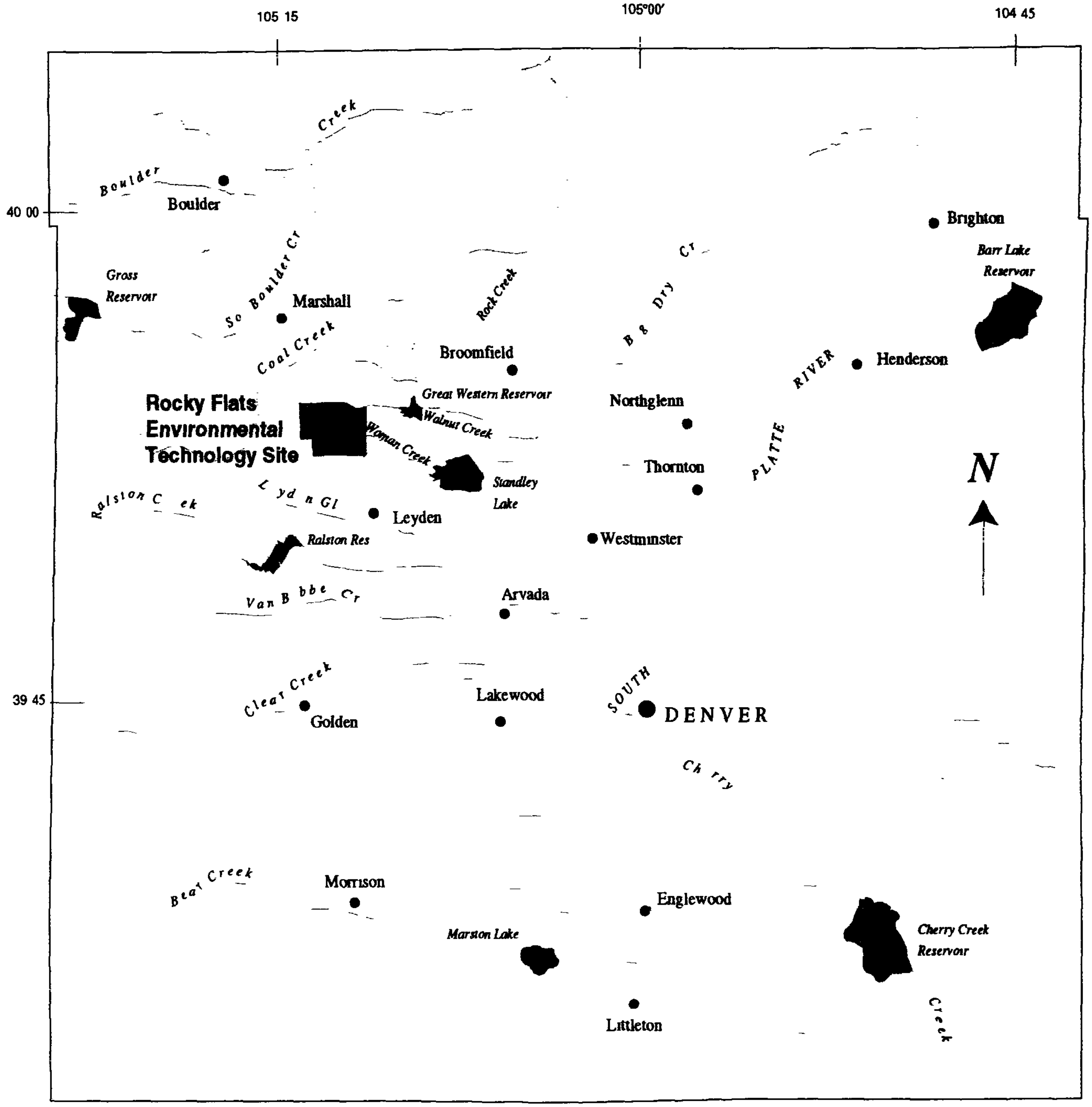
- Institutional controls
- Landfill cap (RCRA Subtitle C equivalent)
- Landfill gas control (and treatment if needed)
- Leachate collection (and treatment if needed)
- Source area groundwater control

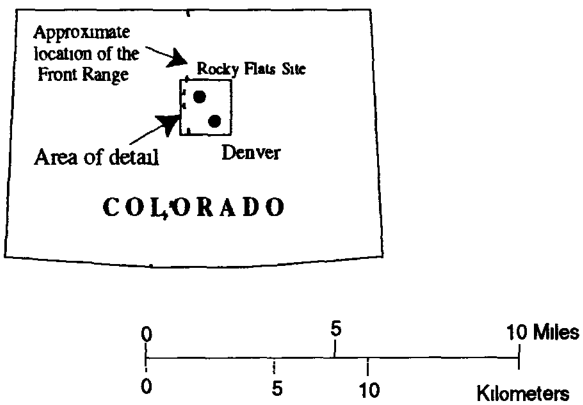
The presumptive remedy limits the alternatives that require detailed analysis to the components listed above Characterization of the waste material within the landfill is not necessary for selecting a response action Response actions selected for individual sites include only those components necessary based on site-specific conditions (EPA 1993a) The containment presumptive remedy addresses all pathways associated with the source

Potentially affected media and exposure pathways outside the landfill are generallv addressed separately However a response action for potentially affected media and exposure pathways outside the source area will be selected together with the presumptive remedy to develop a comprehensive response For OU 7 potentially affected media include the following

- Surface water in the East Landfill Pond
- Sediments in the East Landfill Pond
- Surface soils in spray evaporation areas
- Subsurface geologic materials downgradient of the landfill
- Groundwater downgradient of the landfill

The nature and extent of contamination in potentially affected media is addressed in Section 2 A focused risk evaluation and an ARARs comparison for these media are presented in Section 3





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Rocky Flats Environmental Technology Site
Golden Colorado

Location of the Rocky Flats Environmental Technology Site

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 1 1

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Figure 1-3
Present Landfill and East Landfill Pond (June 1991)

control generation and migration of leachate (Figure 2-1) The groundwater-intercept system is a clay barrier (not a slurry wall) on the outside wall of the leachate-collection trench with a perforated pipe outside the barrier to carry groundwater to the groundwater-intercept system discharge points (Figure 2-2)

Between 1977 and 1981 the leachate-collection trench and the West Landfill Pond were buried beneath waste during landfill expansion In 1982, two soil-bentonite slurry walls were constructed near the eastern end of the landfill to prevent groundwater migration into the expanded landfill area These slurry walls were tied into the north and south arms of the groundwater-intercept system and extend approximately 900 feet from the points of intersection (Figure 2-1) Based on as-built drawings, the slurry walls vary in depth from 10 to 20 feet There is no known waste disposal outside of the clay barrier or the slurry walls (DOE 1994a)

Effectiveness of landfill structures was evaluated in 1994 for the Phase I RFI/RI using historical groundwater-elevation data along a number of transects These data indicate that the groundwater-intercept system is functioning effectively except on the northwest side of the landfill (DOE 1994a)

As-built diagrams were reviewed for the IM/IRA DD Approximately 275 feet of the leachate-collection system trench along the northwest side and 400 feet of the trench along the southwest side of the landfill are not keyed into bedrock These diagrams establish a possible pathway that allows groundwater to flow into the landfill on the northwest side Another possible pathway is desiccation cracking of the clay layer Any blockage in the drain outside the clay barrier would further reduce the effectiveness of the intercept system Because there is a groundwater divide just south of the landfill the head on the south side of the landfill is fairly low and the groundwater-intercept system appears to be functioning even though it is not keyed into bedrock

2 1 5 Spray Evaporation Areas (IHSSs 167 2 and 167 3)

Spray evaporation of water from the East Landfill Pond to maintain the stored volume at 75-percent capacity (approximately 5,500 000 gallons) began in September 1975 Spray evaporation was discontinued in 1994 Two discrete spray areas have been identified (Figure 2-1) the Pond Area Spray Field (IHSS 167 2) on the north bank of the pond and the South Area Spray Field (IHSS 167 3) on the south bank of the pond These IHSSs were originally in OU 6 but were transferred to OU 7 in 1994 (DOE 1994a) Dimensions of the spray fields are approximately 100 feet by 460 feet for IHSS 167 2 and 120 feet by 440 feet for IHSS 167 3 Surface soils in spray evaporation areas are potentially contaminated by pond water Surface soils downgradient of the

East Landfill Pond dam are downwind and thus potentially affected by spray activities in these areas

2 1 6 OU 6 Trenches (IHSSs 166 1, 166 2, and 166 3)

OU 6 trenches A, B, and C (IHSSs 166 1, 166 2, and 166 3) are located southeast of the landfill (Figure 2-1) Trenches A and B received uranium- and/or plutonium-contaminated sludge from the sewage treatment plant (Building 995) from approximately 1964 to 1974 The materials placed in Trench C are not known, but it is probable that sewage sludge was also placed in this trench (DOE 1992a) More information regarding the history of these IHSSs is presented in the Phase I RFI/RI Work Plan for Operable Unit 6 - Walnut Creek Priority Drainage (DOE 1992b)

2.2 Geology

The geology at OU 7 is a function of the regional tectonic setting and local depositional and erosional conditions Geologic data used to characterize OU 7 were compiled from previous landfill investigations (Rockwell International 1988a, DOE 1991a), existing geologic characterization reports (EG&G 1992a, EG&G 1995a), U.S Geological Survey publications (Spencer 1961, Van Horn 1972), Colorado School of Mines reports (Weimer 1976), data from the Phase I RFI/RI field investigation (DOE 1994a), and data from the supplemental Phase I field investigation. A summary of the general geologic framework, description and distribution of surficial and bedrock geologic units, description of geotechnical properties, and description of pond sediments are presented in the following sections Geologic borehole logs from the additional Phase I field investigation are presented in Appendix A Geologic borehole logs from the Phase I RFI/RI are presented in the OU 7 Final Work Plan (DOE 1994a)

2 2 1 General Geologic Framework

Rocky Flats is located on an eastward-sloping plain just east of the Colorado Front Range The surface cover is composed of a series of coalescing alluvial fans developed during the Pleistocene The Present Landfill is located near the eastern extent of the alluvial-fan deposits The alluvial fans were deposited on a broad, gently sloping erosional surface, or pediment, which is underlain by more than 10,000 feet of gently dipping (less than 2 degrees) Pennsylvanian to Upper Cretaceous sedimentary rocks

Dissection of the gravel-capped pediment has occurred by headward erosion and planation along eastward-flowing streams and their tributaries Fluvial processes have formed moderately steep hillsides adjacent to the stream drainages, with the steepest slopes formed along the tops of the incised drainages The landfill at OU 7 is located in No Name Gulch at the western limit of headward erosion and pediment dissection Waste material has been placed on top of the bedrock and fills the valley to the top of

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the pediment at approximately 6,000 feet Some waste material is mounded above the top of the pediment in the center of the landfill Waste material is confined laterally by the leachate-collection trench and slurry walls and by the bedrock slopes of the valley

Figure 2-3 presents a generalized stratigraphic section that shows the vertical sequence of surficial deposits and bedrock Surficial and bedrock geologic units that influence groundwater flow include the Rocky Flats Alluvium and the underlying Arapahoe and Laramie Formations Also important is the artificial fill material of the landfill, which is not shown on the figure The Fox Hills Sandstone occurs at a depth of approximately 700 to 800 feet, which is too deep to be affected by the landfill As such it is not described

2 2 2 Description of Geologic Units

Surficial material consists of Quaternary alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, alluvial deposits of the valley-fill alluvium, and artificial fill (Figure 2-4) All surficial deposits are part of the upper hydrostratigraphic unit (UHSU) at Rocky Flats, which is discussed in more detail in Section 2 3

The Rocky Flats Alluvium caps the divides north and south of No Name Gulch and was deposited as a series of coalescing alluvial fans on the pediment Thickness of the Rocky Flats Alluvium is 25 to 30 feet on the northwest west, and southwest sides of the landfill and 10 to 15 feet on the divides north and south of the East Landfill Pond The Rocky Flats Alluvium is composed of reddish-brown to yellowish-brown, well graded, coarse gravel in a clayey-sand matrix Pebbles and cobbles are composed of quartzite, granite, and gneiss Maximum pebble size ranges from 1 to 3 inches in diameter Caliche which is a porous calcium carbonate cement, was described in drill cores from the divides north and south of the East Landfill Pond These zones may be discharge points for alluvial groundwater along the hillsides above the pond

Colluvium covers the hillsides between the pediment on which the Rocky Flats Alluvium is deposited and the No Name Gulch drainage and East Landfill Pond Colluvial materials have been deposited by slope wash and downward creep of alluvial material and bedrock The colluvium is 1 to 5 feet thick on the slopes around the East Landfill Pond and below the dam The colluvium consists of brown, structureless clay with some sand and a trace of gravel Soil development has occurred and roots are present down to depths of 3 feet

Valley-fill alluvium is present in the No Name Gulch drainage below the East Landfill Pond and is derived from reworked alluvial material and bedrock The alluvium is 3 to 8 feet thick in the OU 7 area and becomes thicker downstream to the east The alluvium consists of brown laminated to structureless clay with lenses of gravel Gravels have a sandy-silt matrix that is often iron-stained

Artificial fill and disturbed surficial material are present within the boundaries of the landfill, which includes IHSS 203 and the asbestos-disposal areas Thickness of the artificial fill, which includes waste and interim-soil cover, ranges from approximately 5 to 45 feet Artificial fill is thickest near the centerline of the valley and thinnest around the perimeter of the landfill, inside the surface-water diversion ditch An actively slumping area occurs in the artificial-fill material on the northeast side of the landfill Seeps were observed along the slope in this area.

Bedrock unconformably underlies the surficial deposits and consists of claystones, siltstones, and fine-grained sandstones of the undifferentiated Upper Cretaceous Arapahoe and Laramie Formations (Figure 2-3)

In general, the base of the Arapahoe Formation, which unconformably overlies the Laramie Formation, is marked by the presence of medium-grained to conglomeratic sandstones composed of well-rounded, frosted, quartz sand grains with pebbles of chert, rock fragments, and ironstone The lowermost 20 feet of the Arapahoe Formation are shown underlying the Rocky Flats Alluvium on the divides north and south of No Name Gulch on geologic maps of Rocky Flats (EG&G 1992a, EG&G 1995a) However, sandstones exhibiting the distinctive characteristic of the basal Arapahoe Formation or No 1 sandstone (Figure 2-3) are not exposed at the surface nor in any of the drill cores from OU 7 The contact between the Arapahoe and Laramie Formations is difficult to interpret in the absence of the marker or No 1 sandstone bed Therefore, in this report, the Arapahoe and Laramie Formations are undifferentiated. However, in the No Name Gulch drainage, the elevation of the bedrock is low enough that the bedrock is likely Laramie Formation

The Laramie Formation is approximately 600 to 800 feet thick The lower 300 feet is composed of laterally extensive sandstones, kaolinitic claystones, and coal beds The upper 300 to 500 feet consist primarily of olive-gray and yellowish-orange claystones Four sandstone units (designated as the No 2, No 3, No 4, and No 5 sandstones) have been identified in the bedrock beneath the No 1 sandstone and are considered upper Laramie Formation (Figure 2-3) (EG&G 1992a, EG&G 1995a) Where present, the sandstones are olive-gray, very fine-grained, subangular, well-sorted, locally calcareous, silty, and clayey Because they lie within claystones and are not in hydraulic connection with either the No 1 sandstone or the surficial deposits, the No 2 through No 5 sandstones are not considered significant migration pathways for potential contaminants to groundwater (DOE 1994a)

The bedrock at OU 7 is composed of gray to brown, structureless claystones containing a trace of carbonaceous material and occasional thin interbeds of siltstone and, less frequently, fine-grained sandstone Sandstones are composed of gray, very fine to fine-grained, subangular to subrounded, well-sorted, quartzose sand Sandstones are

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frequently interbedded with siltstones These coarser-grained units vary from 10 to 30 feet thick

2 2 3 Distribution of Geologic Units

Geologic units beneath the landfill waste consist of a thin covering of colluvium on hillsides and valley-fill alluvium in the No Name Gulch drainage, both underlain by the Laramie Formation Lithologies of the colluvium are clays and silts Lithology of the valley-fill alluvium is gravelly, clayey sand Lithologies of the Laramie Formation are typically limited to claystones and siltstones Laramie Formation sandstones (sometimes referred to as the No 2 through No 5 sandstones) were identified in well 0886 (at a depth of 59 feet) located near the East Landfill Pond, well 6487 (25 feet) located within the landfill and wells 4187 (81 feet), B207089 (31 feet), B207189 (70 feet) and 53094 (60 feet) located in No Name Gulch downgradient of the dam

Fine-grained sandstones subcrop beneath the alluvium only at well location B207089 (31 feet) which is downgradient of the dam This sandstone pinches out approximately 500 feet downstream and is not present at well 4287 Shallow sandstones (present within 15 feet of the contact between alluvium and bedrock) were encountered in wells 6487 (25 feet), located within the landfill on the south side, and B206789 (8 feet), located on the southwest shore of the pond Based on a 2-degree regional dip these shallow sandstones will not subcrop in the OU 7 area and are not preferential pathways for migration of contaminants (DOE 1994a) Other Laramie Formation sandstones are present at depths where there is no hydraulic connection with surficial deposits

Geologic units on the groundwater divides adjacent to the landfill consist of Rocky Flats Alluvium underlain by the undifferentiated Arapahoe and Laramie Formations Lithologies of the Rocky Flats Alluvium are clayey gravels and sands Lithologies of the undifferentiated Arapahoe and Laramie Formations are typically limited to claystones and siltstones Laramie Formation sandstones were identified in wells 0986, 70293, 70593, and 70893 at depths of 50 to 125 feet below ground surface All of these wells are located upgradient of the landfill

A possible fault was identified in the OU 7 area during the Sitewide Geoscience Characterization Study (EG&G 1995a) The inferred fault, which is more than 2 miles long, trends northeast-southwest and cuts across OU 7 east of the landfill face near the edge of the East Landfill Pond (Figure 2-4) The fault plane dips to the west Displacement along the fault is reported to be 25 to 50 feet, based on structural offset of a marker bed (EG&G 1995a) A trench excavated across the northern end of the fault revealed a wide fracture zone in the bedrock, however, the fractures appeared to decrease with depth The surficial deposits were not offset suggesting that movement had not occurred since their deposition (EG&G 1995a)

2 2 4 Geotechnical Properties of Geologic Units

Selected samples from subsurface boreholes drilled near the alignment of the proposed slurry wall were tested to determine geotechnical properties of soils developed in alluvium and colluvium at these locations. Samples of soils developed in alluvium from boreholes 53494 and 53594 and soils developed in colluvium from boreholes 52794 and 53694 were submitted for testing (Figure 2-5) Tests performed included natural moisture content in accordance with the standard method designated by the American Society for Testing and Materials (ASTM) D2216, grain-size distribution using sieve and hydrometer testing in accordance with standard method ASTM D422, Atterberg limits in accordance with standard method ASTM D4318, and specific gravity in accordance with standard method ASTM D854.

A summary of the geotechnical classification is presented in Table 2-1. Test results from boreholes 53494 and 53594 indicate that the shallow soils at these locations are classified as clayey sand, based on the Unified Soil Classification System (USCS) in accordance with standard method ASTM D2487-83 Test results from boreholes 52794 and 53694 indicate that the shallow soils at these locations are classified as fat clay, based on the USCS The clayey sand and fat clay determinations are generally consistent with soil descriptions of alluvium and colluvium, respectively

2 2 5 Description of Pond Sediments

Sediments have been accumulating in the East Landfill Pond since its construction in 1974 The source of contaminant loading to pond sediments includes the leachate seep and surface-water run-off from surrounding slopes. Sediment in the East Landfill Pond was sampled and characterized during the Phase I RFI/RI (DOE 1994a) The sediment ranges from 0 5 to 0 8 feet thick and consists of clay, silt, and organic matter The upper 0 2 to 0 5 feet consists of black silt and clay with very fine roots occurring in either thin mats or scattered throughout the core No bedding or lamination was visible The remaining 0 3 to 0 4 feet of core consists of very dark gray clay with some silt Very fine roots were observed but they decreased with depth. Olive-gray claystone of the Laramie Formation underlies the pond sediment.

2 3 Hydrology

The hydrology at OU 7 is a function of the general geologic framework, recharge and discharge conditions, physical properties of the aquifer materials, hydrodynamic conditions, and landfill structures Hydrogeologic data used to characterize OU 7 were compiled from previous landfill investigations (DOE 1991a), sitewide groundwater monitoring, assessment, and protection plans and reports (EG&G 1990, EG&G 1991, EG&G 1994a, EG&G 1995b, DOE 1992b, and DOE 1993a); and water-level measurement and hydraulic conductivity test activities of the Phase I RFI/RI (DOE

1994a) and supplemental field investigations Drawdown-recovery test data and analytical solutions from the supplemental Phase I field investigation are presented in Appendix B Additional information on the hydrogeology at OU 7 is presented in the OU 7 Final Work Plan (DOE 1994a)

2 3 1 Conceptual Flow Model

The conceptual flow model for OU 7 is illustrated in Figure 2-5 and encompasses surface-water hydrology, interactions between surface water and groundwater, and groundwater hydrology

- Surface-water hydrology components of the conceptual model include precipitation, evapotranspiration, pond evaporation, surface-water run-off, and engineered water transfers

- Interactions between surface-water flow and groundwater flow include infiltration/percolation, interflow seep flow at SW097, groundwater baseflow into the pond discharge from the existing groundwater-intercept system into the pond and seepage flow downward out of the pond

- Groundwater hydrology components include groundwater flow in surficial materials, seepage between surficial materials and weathered bedrock, groundwater flow in weathered bedrock, seepage between weathered bedrock and unweathered bedrock and groundwater flow in unweathered bedrock

Recharge discharge, and interactions between the surface-water and groundwater components of the conceptual model are presented briefly here and discussed in more detail in the following sections

Recharge or infiltration/percolation is a significant source of water to the landfill mass Groundwater inflow under or through the existing groundwater-intercept system is another significant source of water to the landfill These two sources of inflow are quantified in a water balance performed using numerical modeling, which is described in more detail in Section 2 3 5 and Appendix C Outflow from the landfill mass is funneled to the vicinity of the seep at SW097 where it exits the landfill as either seep flow or groundwater baseflow The East Landfill Pond collects surface-water run-off, seep flow and groundwater baseflow The dam acts as a barrier to the flow of groundwater in surficial materials Flow in weathered bedrock is much less than flow in surficial materials Some preferential flow paths most likely fractures exist in the weathered bedrock These preferential flow paths are potential contributors to the migration of contaminants in weathered bedrock Flow in unweathered bedrock is so small that any potential contaminant transport occurs by diffusion

2 3 2 Surface-Water Hydrology

Surface-water features resulting from historical interim response actions control surface-water hydrology Individual components of surface-water hydrology shown in the conceptual model (Figure 2-5) are described below

2 3 2 1 Surface-Water Features

A surface-water diversion ditch was constructed around the perimeter of the landfill in 1974 to divert surface-water run-off around the landfill and reduce the infiltration of surface water into the landfill, thereby reducing the volume of leachate discharging as seep flow (Figure 2-1) On the north side of the landfill, the ditch runs under a perimeter road through a small culvert and east into a small, natural drainage that eventually joins No Name Gulch below the East Landfill Pond dam On the south side of the landfill, the ditch runs east above the East Landfill Pond and drops into No Name Gulch below the dam. The diversion ditch is 2 to 3 feet deep, 5 feet wide at the bottom, and has a trapezoidal shape The slopes and floor of the ditch are composed of sparsely vegetated native-soil material

The East Landfill Pond covers approximately 2 5 acres (Figure 2-1) Pond water levels are controlled to prevent overflow into the spillway draining to No Name Gulch. Between 1975 and 1994, water volume was reduced to 75-percent capacity (approximately 5,500,000 gallons) by periodic spray evaporation Spray evaporation operations ceased in 1994 Approximately 1,000,000 gallons of water were transferred (or pumped) from the East Landfill Pond to the A-series ponds in fall 1994 Water was also transferred from the East Landfill Pond to the A-series ponds in May 1995

The pond water volume fluctuates seasonally but averages approximately 6,000,000 gallons (DOE 1994a) After water was transferred to the A-series ponds in fall 1994, the pond volume was reduced to approximately 5,000,000 gallons Recharge to the pond occurs from groundwater baseflow in surficial materials, leachate from the seep, and surface-water run-off from the landfill and surrounding slopes Discharge occurs by natural evaporation, seepage downward into weathered bedrock, seepage through the clay core of the dam, and engineered water transfers

2 3 2 2 Components of the Conceptual Flow Model

Surface-water hydrology components include precipitation, evapotranspiration, pond evaporation, surface-water run-off, and water transfers from the East Landfill Pond to the A-series ponds

Mean annual precipitation at Rocky Flats, including rainfall and snowmelt, is nearly 16 inches (DOE 1980) Approximately 40 percent of the annual precipitation falls during

April May, and June An additional 30 percent falls in July and August Approximately 19 percent falls during September October, and November The remaining 11 percent falls in December January, February, and March

Pond evaporation is estimated at 70 percent of the pan evaporation which ranges from 1 inch in December and January to 7 inches in September (DOE 1994a) Potential evapotranspiration, which includes both evaporation and transpiration by plants, varies in a pattern similar to that shown by pan evaporation Site-specific potential evapotranspiration data are not available At any given time, precipitation in excess of evapotranspiration will become surface-water run-off, infiltration, or interflow

Surface-water run-off from the landfill and from the area surrounding the pond are major contributors to pond water (DOE 1994a) Some portion of the run-off is diverted by the surface-water diversion ditch, while a significant fraction flows to the East Landfill Pond

As stated above water is periodically transferred to the A-series ponds to control the water level in the East Landfill Pond

2 3 3 Interactions Between Surface Water and Groundwater

Interactions between surface water and groundwater include infiltration/percolation, interflow seep flow at SW097 groundwater baseflow into the pond discharge from the existing groundwater-intercept system into the pond, and seepage flow downward out of the pond

Infiltration is the process by which precipitation moves downward into the soil and includes the flow within the unsaturated zone (Freeze and Cherry 1979) For purposes of the conceptual model, water that infiltrates reaches the groundwater table and recharges the groundwater in surficial materials Infiltration at OU 7 is assumed to be between 5 and 10 percent of the mean annual precipitation (or 0 8 to 1 6 inches)

Interflow is subsurface flow in the horizontal direction above the water table that is usually associated with storm events on hillsides Interflow may be a significant contributor to the variability of the flow at the seep (SW097)

Leachate presently discharges from a seep located at the base of the east face of the landfill (Figure 2-1) Seep flow varies throughout the year and has been estimated at 1 to 7 gallons per minute (gpm) A significant fraction of the groundwater flow from the landfill is funneled toward the seep The seep originates from the original stream channel in No Name Gulch that was filled in during construction and subsequent waste disposal in the landfill The seep is also directly downgradient of the West Landfill Pond dam which was breached before being covered with waste and interim soil cover

This breached dam may serve to further direct groundwater flow toward the seep As stated above, interflow is potentially a major source of the variability of the seep flow

An intermittent seep has been observed north of SW097 on the hillside just below the north asbestos-disposal area. This intermittent seep is most likely caused by saturated materials related to storm events Heavy surface-water run-off has been observed in this area following storm events Recent slumps have also been observed

Groundwater baseflow exists in surficial materials and weathered bedrock In surficial materials, the baseflow that does not intersect the ground surface at the seep is a source of recharge to the pond. The saturated thickness of the surficial materials at the edge of the East Landfill Pond is much less than the saturated thickness directly to the west in the landfill (Figure 2-6) This reduction in saturated thickness contributes to the formation of the seep (DOE 1994a) Evidence of preferential flow also exists The seep flows year-round while nearby alluvial well 0786 is often dry The groundwater modeling for the site also indicates that preferential flow occurs in the vicinity of the seep (Appendix C) In weathered bedrock, the potentiometric surface is below the bottom of the pond and the baseflow in the weathered bedrock is not expected to be a source of recharge to the pond

The existing groundwater-intercept system is configured to discharge either to the pond or to the discharge points east of the dam (Figure 2-1) Based on observations of no flow at the discharge points east of the dam, it is assumed that the system is currently discharging to the East Landfill Pond Discharge points to the pond are not visible at the ground surface

Water seeps from the pond into the weathered bedrock and through the weathered bedrock under the dam Some water also seeps through the dam core Flows are expected to be small based on the measured hydraulic conductivities in the weathered bedrock and the dam core (DOE 1994a, EG&G 1993b) This seepage is not effective in recharging the weathered bedrock downgradient of the pond The weathered bedrock wells (B206889 and B206989) directly below the dam consistently exhibit water levels 12 to 15 feet below the top of bedrock, indicating only partial saturation of weathered bedrock and a "perched" water table condition for surficial materials

The dam impedes groundwater flow in surficial materials Particle tracking shows that contaminants from the landfill are intercepted by the pond (Figure 2-7) (Appendix C) The chemical composition of groundwater downgradient of the dam is statistically different than groundwater in the vicinity of the East Landfill Pond (Section 2 5 8 contains a discussion of background comparisons and potential contaminants of concern [PCOCs]) The wells in surficial materials directly downgradient of the dam are often dry

2 3 4 Groundwater Hydrology

Groundwater flow at OU 7 occurs in the UHSU, which consists of surficial materials and weathered bedrock and, to a lesser extent, in the lower hydrostratigraphic unit (LHSU), which consists of discontinuous sandstone lenses in unweathered bedrock

2 3 4 1 Groundwater Flow in the UHSU

The UHSU, which corresponds to the uppermost 'aquifer' at Rocky Flats (DOE 1993a), is unconfined and consists of saturated unconsolidated surficial materials and weathered bedrock As described in Section 2 2 2 surficial materials include the Rocky Flats Alluvium colluvium valley-fill alluvium, and artificial fill Weathered bedrock is composed of undifferentiated Arapahoe and Laramie Formation claystones and siltstones Claystones predominate at OU 7

Groundwater flow in surficial materials is expected to be significantly greater than groundwater flow in either the weathered bedrock or the unweathered bedrock Hydraulic conductivities were measured at OU 7 during the Phase I RFI/RI and supplemental Phase I field investigation using drawdown-recovery tests Field procedures data analysis and results are presented in the OU 7 Final Work Plan (DOE 1994a) Drawdown-recovery test data and analytical solutions from the supplemental Phase I field investigation are included in Appendix B in this report In addition some slug tests were performed prior to the Phase I RFI/RI The results from all of these tests were used in calculating the geometric mean of hydraulic conductivities for surficial materials, weathered bedrock and unweathered bedrock The location, type of test, result and geometric mean of results are presented in Appendix B

The geometric mean of the measured hydraulic conductivities for the different geologic units are as follows (1) for surficial materials excluding artificial fill, the geometric mean is 1 6E-04 cm/sec or 0 47 feet/day (2) for artificial fill, the geometric mean is 6 7E-05 cm/sec or 0 19 feet/day, and (3) for all surficial materials combined, the geometric mean is 1 3E-04 cm/sec or 0 36 feet/day These hydraulic conductivity measurements are significantly greater than the measurements for weathered bedrock or unweathered bedrock The geometric mean of measured hydraulic conductivities in the weathered bedrock of the Laramie Formation is 4 0E-07 cm/sec or 0 0011 feet/day The geometric mean of measured hydraulic conductivities in unweathered bedrock is 6 4E-07 cm/sec or 0 0018 feet/day The individual hydraulic conductivities for each geologic unit are presented graphically in Figure 2-8

As described in the conceptual model above, sources of groundwater recharge to the UHSU include infiltration/percolation of precipitation, snowmelt storm run-off, and downward seepage from the East Landfill Pond Discharge occurs through evapotranspiration and surface seepage where the water table intersects the ground

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surface The level of groundwater rises annually in response to spring and summer recharge and declines during the remainder of the year

Groundwater in the UHSU generally flows to the east, however, localized flow follows topographic slopes toward the pond or toward the drainage below the dam Potentiometric surface maps for surficial materials and weathered bedrock for 2nd Quarter 1995 are presented in Figures 2-9 and 2-10, respectively The depth to groundwater in the UHSU is approximately 5 feet in No Name Gulch Groundwater flows to the east within the valley-fill alluvium, however, flow is intermittent Certain UHSU groundwater-monitoring wells east of the East Landfill Pond dam are often dry

The depth to groundwater within the landfill is approximately 20 feet at the western end, 16 feet in the middle, and 33 feet at the eastern end Relatively high water levels in the middle of the landfill result from groundwater inflow under the groundwater-intercept system on the north side, as shown by the potentiometric surface map in Figure 2-9 The lower portion of the landfill waste in the original No Name Gulch drainage is saturated in this area. Maximum thickness of saturated waste material is nearly 20 feet.

Groundwater flow in surficial materials in the vicinity of the landfill is divided into two components flow that is diverted by the existing groundwater-intercept system and slurry walls and flow that is not diverted by the existing groundwater-intercept system and slurry walls

Some fraction of the flow is diverted by the existing groundwater-intercept system and slurry walls Existing data indicate that the groundwater-intercept system and slurry walls are most effective in diverting groundwater on the west and south sides of the landfill (DOE 1994a) A groundwater divide between the No Name Gulch drainage and the North Walnut Creek drainage exists approximately 300 feet south of the south leachate-collection trench The presence of this groundwater divide limits the amount of available groundwater flow on the south side of the landfill and contributes to the effectiveness of the groundwater-diversion structures The saturated thickness of surficial materials is less on the south side of the landfill than on the north side

Some fraction of the flow is not diverted by the existing groundwater-intercept system and slurry walls This fraction is labeled "groundwater inflow under groundwater-intercept system" in Figure 2-5 but could also include flow through the groundwater-intercept system and flow through or under the existing slurry walls Existing data indicate that the groundwater-intercept system and slurry walls are least effective on the north side of the landfill (DOE 1994a)

Groundwater flowing out of the east boundary of the landfill is funneled to the seep area Some fraction discharges to the surface as seep water and the remainder enters the pond as groundwater baseflow Because the bottom of the pond rests directly on weathered bedrock and the dam is keyed into weathered bedrock the pond and dam interrupt the flow of contaminated groundwater from the landfill and impede its flow down No Name Gulch Figure 2-7 shows the flow paths of particles in groundwater over a 30-year time period Appendix C contains additional information and discussion of groundwater flow modeling and particle tracking

Seepage occurs between surficial materials and weathered bedrock Flow is expected to be mostly downward into the weathered bedrock based on measured water levels from well clusters The surficial materials and weathered bedrock are combined as the UHSU because evidence points to a hydraulic connection between the two layers (EG&G 1995b) However this connection is not evident in all well-cluster locations For some well clusters (e g 70093/70193), the potentiometric surfaces for surficial materials and weathered bedrock are almost identical and move together seasonally For other well clusters (e g , 70393/70493 and 4087/B206989) head differences in excess of 20 feet are consistently observed These head differences indicate that the weathered bedrock in this location is very tight and very little water flows through it In these locations, flow in surficial materials exists as a perched" water table over partially saturated weathered bedrock The water-level elevations presented in figures 2-9 and 2-10 illustrate this phenomena In all cases the water level in the weathered-bedrock well is lower than the water level in the surficial-material well, which indicates a consistent downward gradient for groundwater flow

Groundwater flow in weathered bedrock may be divided into two components flow through the matrix and flow through fractures or zones of high hydraulic conductivity

Based on the hydraulic conductivity measurements flow through the weathered bedrock matrix is expected to be approximately three orders of magnitude less than flow in surficial materials Weathered bedrock in the OU 7 vicinity consists almost exclusively of claystones The weathered siltstones and sandstones that are present elsewhere at the site are absent at OU 7 The basal Arapahoe or No 1 sandstone bed, which can be a significant water-bearing unit, is also absent

Preferential flow through weathered bedrock fractures or zones of higher hydraulic conductivity is potentially greater than flow through the weathered bedrock matrix These zones of higher hydraulic conductivity may be potential pathways for the migration of contaminants in weathered bedrock and are postulated to explain the apparent migration of certain contaminants in the weathered bedrock, such as nitrate/nitrite in wells B206889 and B206989 However higher hydraulic conductivities were not observed at OU 7 Based on all available analytical and hydraulic data, the extent of contamination and contaminant transport in the weathered bedrock is limited

Groundwater flow may occur along an inferred bedrock fault that cuts across the southeastern edge of the landfill (Figure 2-4) (EG&G 1995a) However, the fault does not offset or fracture the overlying alluvium, and potential groundwater flow along the fault would likely be restricted to bedrock Groundwater traveling along the fault zone would eventually discharge where the fault intersects the hillsides in No Name Gulch east of the landfill, therefore, it is likely that the fault does not serve as a source of inflow to the landfill

Seepage occurs between the weathered bedrock and unweathered bedrock This flow is expected to be in the downward direction Water-elevation data from well clusters consistently show water elevations in unweathered bedrock to be lower than water elevations in weathered bedrock. The magnitude of this flow is expected to be very small. Because of their low hydraulic conductivities, the claystones and siltstones that compose the majority of the unweathered bedrock act as an effective hydraulic barrier to downward migration of groundwater from the UHSU (EG&G 1995b).

2 3 4 2 *Groundwater Flow in the LHSU*

The LHSU at OU 7 is composed of individual siltstones and sandstones separated by fairly thick confining layers (aquitards) of claystone Flow rates are comparatively low in these lithologic units Fracturing is much less extensive in unweathered bedrock than in weathered bedrock LHSU wells at OU 7 are screened in clayey siltstones to silty fine-grained sandstones Calcite occasionally occurs as a pore-filling cement Sandstone lenses in the unweathered bedrock are thin and discontinuous and therefore, are not a major contributor to groundwater flow (EG&G 1992a, EG&G 1995a)

Hydraulic conductivities in these siltstones and sandstones are very low A sitewide evaluation of hydraulic conductivities of LHSU claystones, siltstones, and sandstones shows the geometric means to be within one order of magnitude (2 48E-07 cm/sec, 1 59E-07 cm/sec, and 5 77E-07 cm/sec, respectively) These values indicate that flow rates in the LHSU are only marginally impacted by changes in lithology Measured hydraulic conductivities at OU 7 are similar to these sitewide values with a geometric mean of 6 4E-07 cm/sec (Figure 2-8, Appendix B) Flow in unweathered bedrock is expected to be so small as to be negligible. Contaminant transport in unweathered bedrock is controlled primarily by diffusion because of the low linear groundwater velocities within the unit (EG&G 1995b) For these reasons, contaminant transport in the LHSU is expected to be negligible and is eliminated from further consideration

Riparian areas downgradient of the East Landfill Pond are poorly developed and lack extensive woody vegetation Relatively well-developed riparian areas of North Walnut Creek lie approximately one-half mile to the south (DOE 1995b)

2 4 2 Wildlife

Wildlife within OU 7 includes large and small mammals, birds, reptiles, amphibians, and aquatic macroinvertebrates

The most abundant large mammal is the mule deer White-tailed deer have also been infrequently observed Large carnivores present at Rocky Flats are the coyote red fox, gray fox striped skunk long-tailed weasel, badger, bobcat, and raccoon Eastern cottontails and white-tailed jackrabbits are also present Small mammals (rodents) present are the thirteen-lined ground squirrel, northern pocket gopher, hispid pocket mouse, silky pocket mouse, plains harvest mouse western harvest mouse deer mouse, Mexican woodrat house mouse prairie vole, meadow vole, meadow jumping mouse, and western jumping mouse (DOE 1980, DOE 1993b)

Common grassland birds at Rocky Flats include the western meadowlark, horned lark, vesper sparrow, grasshopper sparrow, western kingbird, and eastern kingbird Marshland areas support the sora rail common snipe song sparrow, red-winged blackbird, yellow-headed blackbird, common yellowthroat and song sparrow In addition, open water areas attract water birds such as the pie-billed grebe, double-crested cormorant great blue heron, black-crowned night-heron, green-winged teal, mallard, gadwall, killdeer, and spotted sandpiper Common birds of prey include the northern harrier, Swainson's hawk, red-tailed hawk American kestrel, great horned owl, and long-eared owl Occasionally, the bald eagle, rough-legged hawk, golden eagle, prairie falcon, and short-eared owl are observed (DOE 1994a)

The Rocky Flats site supports several species of reptiles and amphibians Snake species include the bullsnake, yellow-bellied racer, western terrestrial gartersnake, and prairie rattlesnake Western painted turtles are also present Amphibian species include the plains leopard frog, Woodhouse's toad, northern chorus frog, and tiger salamander

The East Landfill Pond apparently does not support fish and supports only a limited benthic macroinvertebrate community (DOE 1994a)

2 4 3 Sensitive Habitats and Endangered Species

Wetlands have been designated along the shoreline of the East Landfill Pond and in the pond itself by the U S Army Corps of Engineers (Figure 2-12) (COE 1994) Historically constant water levels in the pond have resulted in a well-established,

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vegetated littoral zone at the north, south, and west pond margins Cattails are the dominant emergent vegetation in these areas, and the area is used by common wetland wildlife species

The East Landfill Pond includes approximately 3 percent of the open water habitat and 6 percent of the available shoreline habitat at Rocky Flats, the adjacent wetland represents approximately 1 6 percent of the total (COE 1994) Since the pond was constructed only about 20 years ago, it is probably not a historically important component of the local ecosystem The pond apparently does not contain fish or crayfish populations Without a complex aquatic food web that includes upper-level aquatic consumers, the pond is a limited resource for aquatic-feeding wildlife Because the pond lacks predaceous fish such as bass, it may be a resource for breeding amphibians such as tiger salamanders, chorus frogs, and bullfrogs (Appendix D)

Slopes around the East Landfill Pond have been identified as potential habitat for the Preble's meadow jumping mouse (Figure 2-12) (DOE 1995b) The Preble's meadow jumping mouse has been petitioned for listing as a threatened or endangered species pursuant to the Endangered Species Act. The meadow jumping mouse currently receives protection as a non-game species under the Colorado Non-game, Endangered, or Threatened Species Conservation Act. The Preble's meadow jumping mouse is a subspecies of the meadow jumping mouse and, therefore, receives protection under state law

Three federally listed endangered wildlife species potentially occur at Rocky Flats the black-footed ferret, peregrine falcon, and bald eagle (ASI 1991) Potential habitat for several Colorado "Category 2" wildlife species occurs at Rocky Flats These are the ferruginous hawk, Preble's meadow jumping mouse, white-faced ibis, mountain plover, long-billed curfew, and swift fox (ASI 1991) Small size and lack of an appropriate prey base precludes OU 7 as an important habitat for these federally listed or Category 2 species (DOE 1994a) Four plant species potentially present at Rocky Flats include one federally listed threatened species, Ute lady's tresses, one Category 2 species, Colorado butterfly plant, and two species of concern in Colorado, forktip three-awn and toothcup None have been found at Rocky Flats (ASI 1991)

2.5 Nature and Extent of Contamination

The RI/FS RFI/CMS process for OU 7 was streamlined under the presumptive remedy framework Characterization of the contents of the landfill (waste material) is not necessary or appropriate for selecting a response action (EPA 1993a) Historical information and results from limited characterization efforts are presented in Section 2 1 for the Present Landfill, Inactive Hazardous Waste Storage Area, and asbestos-disposal areas Limited characterization of landfill gas and leachate was

2 3 5 Water Balance for the Landfill

As part of the surface-water hydrology investigations for the IM/IRA a water balance was performed for the landfill mass using MODFLOW (McDonald and Harbaugh 1991) model outputs for the no-action alternative Input parameters modeling runs results and a discussion of the results are included in Appendix C The model was calibrated using OU 7 data Inflows that contribute to leachate generation include recharge by infiltration/percolation of precipitation after evapotranspiration horizontal groundwater flow from the alluvium under or through the existing groundwater-intercept system (primarily on the north side) and under or through the existing north slurry wall and vertical groundwater flow upward from the weathered bedrock beneath the landfill Outflow is primarily horizontal flow at the seep

Conclusions from water-balance calculations indicate that approximately 60 percent of the inflow is groundwater from the alluvium and 40 percent is recharge by infiltration of precipitation (the potential error in water balance calculations is approximately 5 percent) Most of the groundwater inflow (87 percent) occurs on the north side of the landfill Contributions from the west side (6 percent) and the south side (7 percent) are relatively insignificant The water balance shows that both a cap and a slurry wall on the north side of the landfill would significantly reduce additional leachate generation DOE has proposed constructing a slurry wall in fiscal year 1996 as a maintenance action (Section 1 3 2) The water balance for the landfill mass is presented in Appendix C

2 4 Ecology

The buffer zone surrounding the industrial area at Rocky Flats generally supports a wide variety of native plant communities and wildlife However the areas in and around OU 7 have been subject to extensive physical disturbances associated with heavy equipment used for landfill operations and construction of the East Landfill Pond and groundwater-intercept system Ecological data used to characterize OU 7 were compiled from threatened and endangered species evaluations (ASI 1991), the Phase I RFI/RI field investigation (DOE 1994a) and the sitewide conceptual model (DOE 1995b) Additional ecological information is presented in the screening-level ecological risk assessment in Appendix D

2 4 1 Vegetation

Specific plant communities present within OU 7 include mesic and xeric mixed grassland disturbed area (developed or barren land), short marsh, wet meadow, and wetlands (Figure 2-11)

Mesic and xeric mixed grasslands are the most prevalent native habitat types at OU 7 These diverse plant community occurs on broad flat uplands, valley floors and hillsides (Figure 2-11) Differences in slope aspect, soil type disturbance and land-use history are reflected in differences in dominance of the various grasses and forbs characterizing these grasslands

Species richness was sampled along 2-meter by 50-meter belt transects within the mesic mixed grassland (DOE 1994a) Of the 106 species identified, 34 were graminoids, 63 forbs, 5 shrubs, and 4 cacti Of these, 68 percent were native perennial species, suggesting a possible trend toward a native grassland climax community Dominant grasses were western wheatgrass, Canada bluegrass, prairie junegrass and big bluestem Kentucky bluegrass, little bluestem, crested wheatgrass, sand dropseed blue grama, and needle-and-thread were also present Dominant forbs were diffuse knapweed Louisiana sage and Canada thistle Secondary forbs included prairie aster slimflower scurfpea, and klamath weed. Wild rose was the most commonly encountered shrub, and prickly pear the most common cactus encountered along transects within this habitat type

A belt transect sampled within the disturbed community contained 27 plant species· 7 grasses, 1 sedge, and 19 forbs (DOE 1994a) Native species constituted 70 percent of the community including all of the dominant grasses such as big bluestem blue grama Canada bluegrass and mountain muhly Narrowleaf sedge was also common The dominant forb was diffuse knapweed an introduced and aggressive weed that infests disturbed sites such as roadsides and waste areas Other forbs included Louisiana sage, hairy golden-aster, blazing star, western ragweed, and klamath weed Fringed sagebrush was the only shrub encountered in the disturbed community belt transect

A large section of OU 7 is developed land or barren land due to continuous earth moving at the landfill (Figure 2-11) Plants have little opportunity to germinate, grow, or establish in bare areas Most of the original topsoil has either been lost through wind and water erosion or buried in the landfill

Tall and short marsh occur in the area around the East Landfill Pond (Figure 2-11) Tall marsh occurs at the pond margins and is comprised of a near monoculture of broad-leaved cattail, which probably impacts establishment and growth of other hydrophytic plants The static water level, before the pond was subject to water transfers, probably promoted the persistence of the cattails The short marsh type occurs in the sprayed areas north and south of the pond where intermittent spray operations caused more variable hydrologic conditions The short marsh area is dominated by Baltic rush which prefers mesic to hydric conditions but will tolerate drier conditions Disturbed areas around the pond contain weedy species such as Canada thistle and western ragweed (DOE 1994a)

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performed during the Phase I RFI/RI and results are presented below Sampling efforts for the Phase I RFI/RI and supplemental Phase I field investigation were focused on characterizing areas where contaminant migration was suspected such as surface water and sediment in the East Landfill Pond surface soils in spray evaporation areas and subsurface geologic materials and groundwater downgradient of the landfill The nature and extent of contamination in these media are presented below

2 5 1 Methodology for Background Comparisons and PCOC Identification

Site-to-background comparisons were performed for metals radionuclides and indicator parameters using statistical tests recommended by Gilbert (EG&G 1994b) Statistical tests include the Gehan test slippage test quantile test t-test and hot-measurement test The hot-measurement test is a comparison of the maximum detection to the upper tolerance limit of the 99th percentile at the 99-percent confidence level ($UTL_{99/99}$) for background samples Results were presented for all media in the OU 7 Final Work Plan (DOE 1994a) Data from the sitewide Background Geochemical Characterization Report (EG&G 1993c) were used for background samples of sediment, groundwater, seep water, and surface water Data from soil samples collected in the Rock Creek drainage (DOE 1993b) were used for background samples of surface soils Metals radionuclides, and indicator parameters having elevated concentrations relative to background, as indicated by any one of the inferential statistical tests or the hot-measurement test, were identified as PCOCs Organic compounds were considered PCOCs if detected in samples from OU 7

For this report OU 7 data were aggregated in populations that reflect potential collection or treatment alternatives The following populations of data were evaluated landfill gas, leachate at the seep surface water in the East Landfill Pond, sediment in the pond, surface soils in the vicinity of spray evaporation areas, subsurface geologic materials (colluvium) downgradient of the landfill, subsurface geologic materials (weathered bedrock) downgradient of the landfill, groundwater in the vicinity of the East Landfill Pond upgradient of the dam, and groundwater downgradient of the dam

Specific data sets used for each medium include the following

- Landfill gas - 163 chemical-concentration measurements at 33 locations using field instruments that provide screening-level data (i e EPA Level II) one sampling event from Phase I RFI/RI
- Landfill gas - *in situ* soil-gas sampling, 67 samples collected at 33 locations, one sampling event from Phase I RFI/RI (EPA Level IV and V)
- Leachate at the seep (SW097) - monthly data (1990-1991), four months from Phase I RFI/RI (1992-1993) (EPA Level IV and V)

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- Surface water in the East Landfill Pond (SW098) - monthly data (1990-1991), four months from Phase I RFI/RI (1992-1993) (EPA Level IV and V)

- Sediments in the East Landfill Pond - three samples, one sampling event from Phase I RFI/RI (1993) (EPA Level IV and V)

- Surface soils in the vicinity of spray evaporation areas - 133 samples from 0 to 2 inches, 67 samples from 0 to 10 inches, one event from Phase I RFI/RI (1993), 12 samples from 0 to 2 inches, 4 samples from 0 to 10 inches, one event from supplemental Phase I field investigation (1994) (EPA Level IV and V)

- Subsurface geologic materials downgradient of the landfill - 21 samples from 2 boreholes (70993 and 71093), 7 from colluvium and 14 from weathered bedrock, one event from Phase I RFI/RI (1993) (EPA Level IV and V)

- Groundwater downgradient of the landfill in the vicinity of the pond and downgradient of the dam - quarterly data (1990-1994), four months from Phase I RFI/RI wells (1992-1993), one month from 1994 wells (EPA Level IV and V)

The nature and extent of contamination for these media is detailed below Landfill gas data were not evaluated statistically Environmental media characterized by other data sets were not investigated for this report because these media are upgradient or within the source Data sets not included are surface soils in IHSS 114 and IHSS 203, subsurface geologic materials upgradient of the landfill, surface-water discharge from the north and south groundwater intercepts, groundwater upgradient of the landfill, and groundwater within the landfill Information on contaminant distribution in these media can be found in the OU 7 Final Work Plan (DOE 1994a)

2 5 2 Landfill Gas

Gas flow through landfill waste and soils occurs in response to pressure gradients (i e , advective flow), concentration gradients (i e , diffusive flow), compaction and settling of wastes, barometric pressure changes, and displacement due to potentiometric surface fluctuations Advection of landfill gas is typically the predominant transport mechanism (EPA 1991a) Off-gassing pressures up to 0 44 pounds per square inch (lbs/in^2) were measured during the Phase I RFI/RI (DOE 1994a) Gas pressures exceeding approximately 0 05 lbs/in^2 indicate an advective, pressure-driven system (Emcon Associates 1982)

The composition of landfill-generated gases was evaluated on the basis of screening-level data on total combustible gases, methane, and carbon dioxide The composition of landfill gas at OU 7 is 45 to 70 percent methane and 20 to 40 percent carbon dioxide, indicating anaerobic conditions (DOE 1994a) Concentrations of methane and carbon dioxide are highest in the eastern portion of the landfill where wastes are thickest and most recently disposed In general landfill gases appear to be contained within the existing intercept system Concentrations of methane and carbon dioxide are relatively low, as expected, in the vicinity of the gas-venting wells Gas concentration maps and cross sections are included in the OU 7 Final Work Plan (DOE 1994a)

Concentrations of non-methane organic compounds (NMOCs) were determined by subtracting methane concentrations from the concentrations of total combustible gases As a result the reported concentrations of NMOCs may include minor amounts of inorganic gases such as hydrogen sulfide Concentrations of NMOCs range from 0 to 152 000 milligrams per liter (mg/L) and average 30,000 mg/L (DOE 1994a)

In situ soil-gas sampling was performed to characterize hazardous air pollutants (HAPs) in the unsaturated zone of the landfill Concentrations were reported as mg/L but no corresponding emission rates for generated gases were reported HAPs detected at the landfill include 1 2-dichloroethene, 1,1,1-trichloroethane, trichloroethene, methylene chloride, acetone, 2-butanone, toluene, xylene and hydrogen sulfide

2 5 3 Landfill Leachate at the Seep

The composition of landfill-generated leachate was evaluated on the basis of screening-level data collected during the Phase I RFI/RI and seep samples collected monthly during the Phase I RFI/RI and the 1990-1991 surface-water monitoring program Screening-level data were collected from 16 locations, 26 samples were collected Methane concentrations from screening-level data ranged from 0 0003 to 31 4 mg/L and typically approached the solubility limit of 35 mg/L at 17 degrees Celsius (Merck Index 1989) Methane concentrations at OU 7 are consistent with methane concentrations of 25 mg/L observed at other landfills (Beadecker and Back 1979)

Surface-water samples were collected from the seep at the base of the east face of the landfill (SW097 Figure 2-13) Background comparisons were performed to identify PCOCs using the Gilbert methodology (EG&G 1994b) Analytes detected in leachate at concentrations that exceeded background concentrations include metals, radionuclides, and indicator parameters VOCs and semivolatile organic compounds (SVOCs) were detected Concentration ranges detection limits detection frequencies, and PCOCs identified are presented in Table 2-2 Additional information is presented in the OU 7 Final Work Plan (DOE 1994a)

According to the Gilbert methodology (EG&G 1994b), professional judgment was used to eliminate certain analytes from the PCOC list (Table 2-2) Two rationales were used for the elimination of analytes (1) the analytes calcium magnesium, potassium, and sodium were eliminated because they are essential nutrients (EPA 1989a) and (2) other analytes were eliminated from consideration as PCOCs because of infrequent detection detection in method blanks, or detection in background samples

Alpha-BHC was eliminated as a PCOC because it was detected only once, the result was reported as zero, and the result was "J" qualified, which indicates that there was interference and the result is an estimated value Carbon disulfide, tetrachloroethene, and vinyl acetate were eliminated as PCOCs because they were infrequently detected, suggesting that the results are outliers and are not representative of the true population

Methylene chloride was eliminated as a PCOC for two reasons (1) many of the detections, including the maximum detection are 1990 data that were never validated and are "B" qualified (detected in laboratory blanks) and (2) methylene chloride is a common laboratory contaminant that was often detected in background groundwater samples Methylene chloride was detected in 26 of 100 samples, or 26 percent, in the background data set The maximum detection in background was 31 µg/L The $UTL_{99/99}$ for the background data set is 21 µg/L By contrast, methylene chloride was detected in 9 of 20 samples, or 45 percent, in the leachate data set The maximum detection in leachate was 190 µg/L

The following analytes are identified as PCOCs for leachate at a the seep

- Metals - antimony (20 µg/L), barium (645 µg/L), iron (81,005 µg/L), lithium (48 µg/L), manganese (1,623 µg/L), strontium (920 µg/L), and zinc (2,974 µg/L)
- Radionuclides - strontium-89,90 (1 35 picocuries per liter [pCi/L]), and tritium (393 pCi/L)
- SVOCs - 2,4-dimethylphenol (5 µg/L), 2-methylnaphthalene (16 µg/L), 4-methyphenol (4µg/L), acenaphthene (3 µg/L), bis(2-ethylhexyl)phthalate (5 µg/L), dibenzofuran (1 µg/L), diethyl phthalate (3 µg/L), fluorene (2 µg/L), naphthalene (18 µg/L), and phenanthrene (4 µg/L)
- VOCs - 1,1-dichloroethane (6 µg/L), 1,2-dichloroethene (4 µg/L), 2-butanone (12 µg/L), 2-hexanone (5 µg/L), 4-methyl-2-pentanone (11 µg/L), acetone (34 µg/L), benzene (2 µg/L), chloroethane (22 µg/L), chloromethane (5 µg/L), ethylbenzene (13 µg/L), o-xylene (6 µg/L), toluene (3 µg/L), total xylene (14 µg/L), trichloroethene (2 µg/L), and vinyl chloride (5 µg/L)
- Indicator parameters - nitrite (30 µg/L)

2 5 4 Surface Water in the East Landfill Pond

The composition of pond water was evaluated on the basis of surface-water monitoring samples collected monthly during the Phase I RFI/RI and the 1990-1991 surface-water monitoring program Surface-water samples were collected from station SW098, located in the central east section of the pond adjacent to the dam (Figure 2-13) Background comparisons were performed to identify PCOCs using the Gilbert

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methodology (EG&G 1994b) Analytes that were detected at concentrations or activities above background include metals and radionuclides, VOCs and SVOCs were detected, however, none of the VOCs or SVOCs were detected frequently Concentration ranges detection limits, detection frequencies and PCOCs identified are presented in Table 2-3 Only analytes that were detected are included in the table Additional information is presented in the OU 7 Final Work Plan (DOE 1994a)

Professional judgment was used to eliminate certain analytes from the PCOC list (Table 2-3) Again two rationales were used for the elimination of analytes (1) the analytes calcium, magnesium, potassium, and sodium were eliminated because they are essential nutrients (EPA 1989a) and (2) other analytes were eliminated from consideration as PCOCs because of infrequent detection detection in method blanks, or detection in background samples Acetone methylene chloride, and vinyl acetate were eliminated because they were infrequently detected, suggesting that the results are outliers and are not representative of the true population Acetone and methylene chloride were also detected in laboratory blanks (B qualified) and are common laboratory contaminants

The following analytes are identified as PCOCs for surface water in the East Landfill Pond

- Metals - arsenic (1 µg/L), lithium (79 µg/L), manganese (105 µg/L), molybdenum (20 µg/L), nickel (10 µg/L), strontium (476 µg/L) thallium (2 µg/L), and tin (41 µg/L)

- Radionuclides - americium-241 (0 007 pCi/L), strontium-89,90 (1 4 pCi/L), tritium (139 pCi/L) uranium-235 (0 1 pCi/L), and uranium-238 (1 1 pCi/L)

- SVOCs - bis(2-ethylhexyl)phthalate (5 µg/L) and di-n-butyl phthalate (5 µg/L)

2 5 5 Sediments in the East Landfill Pond

Sediment samples were collected at three locations in the pond to assess the impact of a potential point source of contamination from the seep and nonpoint run-off from the landfill Samples were analyzed for VOCs, SVOCs, radionuclides, metals, and inorganics (Figure 2-13) None of the radionuclides exceeded background $UTL_{99/99}$ values Three VOCs and several SVOCs were detected in pond sediments All SVOC results are estimated values below the quantitation limit ("J" qualified), however, they were not eliminated from the PCOC list Concentration ranges, detection limits detection frequencies qualifiers, and PCOCs identified are presented in Table 2-4 Only analytes that were detected are included in the table Additional information is presented in the OU 7 Final Work Plan (DOE 1994a)

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Professional judgment was used to eliminate certain analytes from the PCOC list (Table 2-4) The analytes calcium, magnesium, potassium, and sodium were eliminated as PCOCs because they are essential nutrients (EPA 1989a) Acetone was detected in the laboratory blank ("B" qualified) for the maximum detection, however, because it was detected in more than 50 percent of the samples, acetone was not eliminated from the PCOC list

The following analytes are identified as PCOCs for sediments in the pond

- Metals - zinc (106 mg/kg)
- SVOCs - acenaphthene (220 µg/kg), anthracene (240 µg/kg), benzo(a)anthracene (300 µg/kg), benzo(a)pyrene (293 µg/kg), benzo(b)fluoranthene (343 µg/kg), benzo(ghi)perylene (253 µg/kg), benzo(k)fluoranthene (230 µg/kg), benzoic acid (537 µg/kg), bis(2-chloroisopropyl)ethene (259 µg/kg), bis(2-ethylhexyl)phthalate (213 µg/kg), chrysene (29 µg/kg), fluoranthene (415 µg/kg), fluorene (251 µg/kg), indeno(1,2,3-cd)pyrene (247 µg/kg), phenanthrene (346 µg/kg), and pyrene (386 µg/kg)
- VOCs - 2-butanone (17 µg/kg), acetone (65 µg/kg), and toluene (307 µg/kg)

2 5 6 Surface Soils in Spray Evaporation Areas

Surface-soil samples were collected on a grid from the landfill eastward across the spray evaporation areas and surrounding slopes and downwind below the dam (Figure 2-14) Soil samples were collected at 133 locations from the 0- to 2-inch soil horizon and 67 locations from the 0- to 10-inch soil horizon during the Phase I RFI/RI (DOE 1994a) Soil samples were collected at 12 locations from the 0- to 2-inch soil horizon and 4 locations from the 0- to 10-inch soil horizon during the supplemental Phase I field investigation All samples were analyzed for metals and radionuclides

Background comparisons were performed to identify PCOCs using the Gilbert methodology (EG&G 1994b) Analytes that were detected at concentrations or activities above background concentrations or activities include metals, radionuclides, and indicator parameters Concentration ranges, detection limits, detection frequencies, qualifiers, and PCOCs identified are presented in Table 2-5 Only analytes that were detected are included in the table Additional information is presented in the OU 7 Final Work Plan (DOE 1994a)

Arsenic was detected in all samples and was frequently detected above background The maximum concentration of arsenic is 16 milligrams per kilogram (mg/kg) at a location southwest of the South Area Spray Field (SS702293, Figure 2-14) The maximum activity of americium-241 is 1 picocurie per gram (pCi/g) at a location on the hillslope south of the pond (SS703793, Figure 2-14) This area was regraded during routine maintenance at the landfill in September 1993 and falls under the proposed footprint of the landfill cap The maximum activity of radium-226 is 2 pCi/g at a location downwind of the spray evaporation areas below the dam (SS711193 Figure 2-14) Radium-226 was not detected in confirmation samples collected during the supplemental Phase I fieldwork

Professional judgment was used to eliminate calcium magnesium, potassium, and sodium as PCOCs because they are essential nutrients (EPA 1989a)

The following analytes are identified as PCOCs for surface soils in the vicinity of the East Landfill Pond

- Metals - antimony (4 mg/kg), barium (194 mg/kg), beryllium (1 mg/kg), cobalt (7 mg/kg), copper (17 mg/kg), lead (26 mg/kg), mercury (0 1 mg/kg), selenium (1 mg/kg) silver (1 mg/kg), strontium (48 mg/kg), thallium (0 2 mg/kg), vanadium (32 mg/kg), and zinc (56 mg/kg)

- Radionuclides - americium-241 (0 02 pCi/g), plutonium-239,240 (0 05 pCi/g), and radium-226 (1 pCi/g)

- Indicator parameters - nitrate/nitrite (4 mg/kg)

2 5 7 Subsurface Geologic Materials Downgradient of the Landfill

Subsurface geologic materials were sampled in two boreholes to characterize potential leachate-contaminated materials downgradient of the landfill (70993 and 71093) (Figure 2-15) Samples were collected at 2-foot increments in colluvium and 4-foot increments in weathered bedrock A total of 21 samples were collected, 7 from colluvium and 14 from bedrock All samples were analyzed for VOCs, SVOCs PCBs, metals radionuclides and indicator parameters (total organic carbon [TOC], nitrate, and sulfide)

Background comparisons were performed to identify PCOCs using the Gilbert methodology (EG&G 1994b) Analytes that were detected at concentrations or activities above background include metals radionuclides and indicator parameters in colluvium, and metals in weathered bedrock SVOCs and VOCs were detected Concentration ranges detection limits, detection frequencies, and PCOCs identified are presented in Table 2-6 Only analytes that were detected are included in the table Additional information is presented in the OU 7 Final Work Plan (DOE 1994a)

Professional judgment was used to eliminate calcium, magnesium, potassium, and sodium as PCOCs in colluvium and weathered bedrock because they are essential nutrients (EPA 1989a) All SVOC results are estimated values below the quantitation limit (J qualified), however, they were not eliminated from the PCOC list

1,1,1-trichloroethane was eliminated as a PCOC in weathered bedrock because it was detected only once, which suggests that the detection is an outlier and is not representative of the true population The result was also "J" qualified, indicating that it is an estimated value

The following analytes are identified as PCOCs for subsurface geologic material in colluvium downgradient of the landfill

- Metals - barium (230 mg/kg)
- Radionuclides - cesium-137 (0 584 pCi/g)
- SVOCs - chrysene (150 µg/kg), fluoranthene (189 µg/kg), phenanthrene (188 µg/kg), and pyrene (189 µg/kg)
- VOCs - 4-methyl-2-pentanone (17 µg/kg), toluene (850 µg/kg), and total xylenes (3 µg/kg)
- Indicator parameters - nitrate/nitrite (400 mg/kg)

The following analytes are identified as PCOCs for subsurface geologic material in weathered bedrock downgradient of the landfill

- Metals - arsenic (3 4 mg/kg), barium (97 mg/kg), cobalt (9 mg/kg), lead (22 mg/kg), manganese (275 mg/kg), strontium (97 mg/kg), and zinc (70 mg/kg)
- VOCs - toluene (309 µg/kg)

2 5 8 Groundwater Downgradient of the Landfill

Groundwater downgradient of the landfill is separated into two populations for data evaluation to assist in delineating areas where groundwater has been impacted by migration of landfill leachate (Figure 2-15) These populations are groundwater in the vicinity of the East Landfill Pond upgradient of the dam and groundwater downgradient of the dam Nine existing wells are screened across surficial material or weathered bedrock three near the East Landfill Pond and six downgradient of the dam Four wells are screened across unweathered bedrock sandstones or siltstones one near the pond and three downgradient of the dam Groundwater samples have been collected from the older wells since 1986 or 1989 and from the new wells since December 1994 Data from 1990 to 1995 were used in this report Appendix B lists the well locations, geologic formation the well is screened across, hydrostratigraphic unit, date the well was installed, and population for data aggregation (wells in the vicinity of the East Landfill Pond versus wells downgradient of the dam) Figure 2-15 shows the well locations and outlines the populations used for data aggregation

Background comparisons for inorganic analytes and radionuclides were performed on the two populations of UHSU groundwater to identify PCOCs using the Gilbert methodology (EG&G 1994b) Analytes that fail any of the tests are identified as PCOCs The results of the statistical tests for wells in the vicinity of the East Landfill Pond and downgradient of the dam are presented in Tables 2-7 and 2-8, respectively In addition to the inorganic analytes and radionuclides that fail the statistical tests, all VOCs and SVOCs detected in groundwater are considered PCOCs unless eliminated by professional judgment

Professional judgment was used to eliminate certain analytes from the PCOC list Two major rationales were used for the elimination of analytes (1) the analytes calcium, magnesium, potassium, and sodium were eliminated because they are essential nutrients (EPA 1989a) and (2) other analytes were eliminated from consideration as PCOCs because of infrequent detection, detection in method blanks, or detection in background samples

For the groundwater in vicinity of the East Landfill Pond (Table 2-7) 1,1-dichloroethane, acetone, benzene, chloroethane, ethylbenzene, toluene, and total xylenes were eliminated because infrequent detection suggests that the detection(s) are outliers Methylene chloride was eliminated for two reasons (1) many of the detections are 1990 data that were never validated and are B" qualified (detected in laboratory blanks) and (2) methylene chloride is a common laboratory contaminant that was often detected in background groundwater samples For the data set used for background comparisons, methylene chloride was detected in 43 of 298 samples or 14 percent of samples The maximum detection in background was 42 µg/L The $UTL_{99/99}$ for the background data set is 16 µg/L For the groundwater in vicinity of the East Landfill Pond, methylene chloride was detected in 7 of 51 samples, or 14 percent of samples The maximum detection in this data set was 8 µg/L The $UTL_{99/99}$ is 6 0 µg/L

For the groundwater downgradient of the dam (Table 2-8), antimony, benzene, and toluene were eliminated because infrequent detection suggests that the detection(s) are outliers Methylene chloride was eliminated for the same reasons stated above For the groundwater downgradient of the dam, methylene chloride was detected in 10 of 52 samples or 19 percent of samples The maximum detection of the methylene chloride in this data set was 12 µg/L The $UTL_{99/99}$ is 9 µg/L

The following are identified as PCOCs for the UHSU groundwater in the vicinity of the East Landfill Pond

- Metals - antimony (18 µg/L) lithium (207 µg/L) selenium (665 µg/L) silver (3 µg/L) and strontium (1 446 µg/L)

- Radionuclides - uranium-238 (32 63 pCi/L)
- SVOCs - bis(2-ethylhexyl)phthalate (4 µg/L)
- VOCs - carbon tetrachloride (2 µg/L), tetrachloroethene (2 µg/L), and trichloroethene (2 µg/L)
- Indicator parameters - chloride (155,699 µg/L), nitrate/nitrite (48,704 µg/L), orthophosphate (20 71 µg/L), and sulfate (621,840 µg/L)

The following are identified as PCOCs for the UHSU groundwater downgradient of the East Landfill Pond dam.

- Metals - lithium (100 µg/L) and strontium (1,355 µg/L)
- Radionuclides - strontium-89,90 (0 17 pCi/L)
- Indicator parameters - chloride (311,351 µg/L), fluoride (692 µg/L), nitrate/nitrite (7 7 µg/L), orthophosphate (30 14 µg/L), and sulfate (1,081,886 µg/L)

Background comparisons for inorganic analytes and radionuclides were performed on one population of LHSU groundwater to determine PCOCs The results of the statistical tests for LHSU wells downgradient of the landfill are presented in Table 2-9 Again, some analytes were eliminated by professional judgment Calcium, magnesium, potassium, and sodium were eliminated as PCOCs because they are essential nutrients (EPA 1989a) Acetone, chlorobenzene toluene, and total xylenes were eliminated as PCOCs because infrequent detection suggests that the detection(s) are outliers Methylene chloride was eliminated for the reasons stated above The PCOCs remaining for LHSU downgradient of the landfill are carbonate (6,000 µg/L) and orthophosphate (13 6 µg/L) Given the hydrology of the unweathered bedrock (Section 2 3 4 2) and the nature of these analytes, groundwater in the LHSU downgradient of the landfill will not receive further consideration

Table 2-1
Geotechnical Classification Test Results for Soil Samples

Borehole Number	Sample Number	Sample Depth (feet)	Description and USCS Soil Classification	Natural Moisture Content (ASTM D2216)	Grain-Size Distribution (ASTM D422)	Atterberg Limits (ASTM D4318)	Specific Gravity (ASTM D854)
53494	BH70405ST	0 to 12 6	Alluvium Clayey Sand (SC)	5 7%	Gravel 35% Sand 39% Silt 10% Clay 16%	PI = 14%	2 67
53594	BH70403ST	0 to 1 8	Alluvium Clayey Sand (SC)	8 0%	Gravel 25% Sand 40% Silt 17% Clay 18%	PI = 17%	2 64
53694	BH70401ST	0 to 2	Colluvium Fat Clay (CH)	13 9%	Gravel 0% Sand 8% Silt 30% Clay 62%	PI = 41%	2 52
52794	BH70407ST	0 to 2	Colluvium Fat Clay (CH)	21 2%	Gravel 22% Sand 10% Silt 23% Clay 45%	PI = 44%	2 65

Definitions

ASTM American Society for Testing and Materials
USCS Unified Soil Classification System
PI plasticity index
% percent

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Table 2-2
Analytes Detected in Leachate at the Seep (SW097)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals										
Aluminum	10 30,000	16/19	29	26,900	—	—	2,629	39,136	pCi/L	
Antimony	0 05 60	4/18	14	60 4	—	A	20	20,054	pCi/L	1
Arsenic	0.7 10	8/16	1.4	3	B	—	3	3,485	pCi/L	
Barium	0 02 50,000	19/19	297	1,550	—	—	645	63,510	pCi/L	2
Beryllium	0.2 5	2/18	0.2	1.4	—	JA	1	1,702	pCi/L	
Cadmium	0 1 - 16.5	4/18	1	7.6	—	—	3	1,760	pCi/L	
Calcium	14.5 - 100,000	19/19	[illegible]	212,000	—	—	[illegible]	[illegible]	pCi/L	1,2,3
Chromium	2 4 27 5	7/18	2	28.6	—	—	9	3,328	pCi/L	
Cobalt	0 02 50	10/18	2 7	19 1	B	—	11	16,936	pCi/L	
Copper	2 4 25	8/18	2	94 9	—	—	12	8,281	pCi/L	
Iron	4 7 30,000	19/19	61,300	155,000	—	—	81,005	16,477	pCi/L	2
Lead	0.8 2,000	14/18	1 5	11	—	V	5	1,482	pCi/L	
Lithium	2 2,000	15/19	34	107	—	V	48	35,577	pCi/L	2
Magnesium	[illegible]	19/19	[illegible]	[illegible]	—	—	[illegible]	[illegible]	pCi/L	2,3
Manganese	1 10,000	19/19	1320	2,490	—	—	1,623	3,024	pCi/L	2
Mercury	0.02 0.2	1/18	0 1	0.26	—	—	0.1	58.9	pCi/L	
Molybdenum	5.7 200	8/18	4	28.5	B	—	21	32,559	pCi/L	
Nickel	0.02 40	5/18	5	31	—	V	12	13,306	pCi/L	
Potassium	[illegible]	19/19	[illegible]	11,700	—	—	[illegible]	[illegible]	pCi/L	2,3
Selenium	1.1 5	2/18	1 1	7	W	—	2	1,710	pCi/L	
Silver	2.6 25	8/18	2.7	16 7	—	—	5	3,388	pCi/L	
Sodium	10 - 50,000	19/19	[illegible]	110,000	—	V	[illegible]	[illegible]	pCi/L	1,2,3
Strontium	3.5 10,000	17/19	814	1,370	—	—	920	241,118	pCi/L	2
Tin	10 200	8/18	11	243	—	—	48	33,576	µg/L	

Table 2-2
Analytes Detected in Leachate at the Seep (SW097)

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Vanadium	3 2 10 000	12/19	3 1	211	–	–	25	16 634	µg/L	
Zinc	1 8 10 000	19/19	857	16 000	–	.	2 974	3 708	µg/L	1 2
Pesticides										
alpha BHC	0 05 0 28	1/3	0	0	I	–	0 06	–	µg/L	4 5
Radionuclides										
Americium 241	0 0 013	16/16	0 000404	0 02121	–	V	0 007	0 03	pCi/L	
Cesium 137	0 47 1	14/14	0 21	0 6057	J	–	0 15	2 1	pCi/L	
Gross alpha	1 5 7 4	8/8	0 8918	6 639	–	V	2 9	29	pCi/L	
Gross beta	1 69 11 5	8/8	3 753	17	–	V	10	31	pCi/L	1,2,6
Plutonium 238	0 01 0 01	2/2	0 000465	0 00222	J	A	0 00088	0 025	pCi/L	
Plutonium 239	0 003 0 003	1/1	0 009	0 009	.	.	0 009	–	pCi/L	
Plutonium 239/240	0 0 013	16/16	0 001	0 01606	-	A	0 007		pCi/L	
Radium 226	0 03 0 03	1/1	0 58	0 58	-	A	0 58	17	pCi/L	
Strontium-89,90	0 21 1	9/9	0 66	4 06	–	V	1 35	4 9	pCi/L	1,2
Strontium 90	0 2 0 59	3/3	0 5442	1 1	–	–	0 7	-	pCi/L	
Tritium	155 450	19/19	185 4	1,500	–	A	393	732	pCi/L	2
Uranium 233, 234	0 1 0 6	12/12	0 0238	4 2	B	A	0 8	–	pCi/L	
Uranium 235	0 0 6	12/12	-0 012	0 084	J	A	0 03	0 3	pCi/L	
Uranium 238	0 086 0 6	12/12	0 03914	3 76	–	A	1	1 8	pCi/L	
Semivolatile Organic Compounds										
2 4 Dimethylphenol	10	1/5	3	3	J	A	5		µg/L	4
2 Methylnaphthalene	10	5/5	12	23	-	V	16	–	µg/L	4

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Table 2-2
Analytes Detected in Leachate at the Seep (SW097)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4-Methylphenol	10	3/5	2	4	J	–	4	–	µg/L	4
Acenaphthene	10	5/5	2	3	J	A	3	–	µg/L	4
Bis(2-ethylhexyl)phthalate	10 12	1/5	2	2	J	A	5	8	µg/L	4
Dibenzofuran	10	5/5	1	2	J	A	1	–	µg/L	4
Diethyl phthalate	10	4/5	1	3	J	A	3	8	µg/L	4
Fluorene	10	5/5	2	3	J	A	2	–	µg/L	4
Naphthalene	10	5/5	14	22	–	V	18	–	µg/L	4
Phenanthrene	10	5/5	4	5	J	A	4	–	µg/L	4
Volatile Organic Compounds										
1,1-Dichloroethane	5	17/20	2	10	–	V	6	–	µg/L	4
1,2-Dichloroethene	5	10/20	2	14	–	V	4	3	µg/L	4
2-Butanone	10	8/19	6	78	–	V	12	19	µg/L	4
2-Hexanone	10	1/20	1	10	–	V	5	–	µg/L	4
4-Methyl-2-Pentanone	10	5/20	10	87	J	A	11	–	µg/L	4
Acetone	10	10/20	10	220	–	A	34	29	µg/L	4
Benzene	5	11/20	1	2	J	–	2	3	µg/L	4
Carbon disulfide	5	1/20	6	6	–	–	6	4	µg/L	4,5
Chloroethane	10	15/20	10	57	–	V	22	–	µg/L	4
Chloromethane	10	2/20	4	7	J	A	5	–	µg/L	4
Ethylbenzene	5	19/20	1	18	–	–	13	–	µg/L	4
Methylene chloride	5	9/20	3	190	B	–	14	21	µg/L	4,5
o-Xylene	5	3/4	5	8	–	–	6	–	µg/L	4
Tetrachloroethene	5	2/20	1	1	J	–	2	3	µg/L	4,5

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Table 2-2
Analytes Detected in Leachate at the Seep (SW097)

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Toluene	5	19/20	5	88		—	38	3	µg/L	4
Total xylenes	5	19/20	1	25	J	A	14	3	µg/L	4
Trichloroethene	5	11/20	1	4	J	·	2	3	µg/L	4
Vinyl acetate	10	1/19	10	49	—	·	7	—	µg/L	4 5
Vinyl chloride	10	5/20	3	11	—	V	5	-	µg/L	4
Indicator Parameters										
Bicarbonate as $CaCO_3$	1000 10 000	15/15	554 000	705 000	—	V	595 800	·	µg/L	
Carbonate as $CaCO_3$	1000 10 000	2/9	0	0	—		3 889	-	µg/L	
Chloride	100 50 000	14/14	1800	66 300	-	V	53 650	64 366	µg/L	
Cyanide	10 20	1/14	1 5	36 8		·	9	252	µg/L	
Dissolved organic carbon	1 000 1 000	4/4	14 000	27 000		JA	18 750	16 997	µg/L	
Fluoride	100- 200	12/12	390	540	·	V	469 2	643	µg/L	
Nitrate/nitrite	20 200	6/10	20	870	—	V	263	3 130	µg/L	
Nitrite	20 20	6/9	20	63	—	V	30 33	1 576	µg/L	2
Oil and grease	200- 11 100	4/12	800	42 100	—	V	7 013	14 681	µg/L	
Orthophosphate	10 200	3/10	50	150		-	60 9	210	µg/L	
pH		5/5	6 8	7 3	-	—	7	—	pH	
Phosphorus	50- 1 000	9/9	95	1 380	—		387	272	µg/L	
Silica	400 2 000	3/3	7 400	43 000		-	19 567	36 561	µg/L	
Silicon	7 3 2 000	13/13	7 060	44 000	-	—	13 547	16 293	µg/L	
Solids nonvolatile suspended	5 000 5 000	6/6	10 000	199 000	—		83 167	·	µg/L	
Sulfate	200 25 000	5/14	200	29 600	·	V	5 084	41 114	µg/L	
Total dissolved solids	10 000	15/15	470 000	870 000	—		729 333	372 696	µg/L	
Total organic carbon	1 000 1 000	3/3	19 000	24 500	·	V	20 833	21 993	µg/L	

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Table 2-2
Analytes Detected in Leachate at the Seep (SW097)

Analyte	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total suspended solids	4 000 5,000	12/12	10 000	250 000	—	—	144 887	157 368	μg/L	

Notes

All analytes are total analytes unless otherwise noted.
For non-detects, one-half the detection limit is used in calculating the mean result.

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be PCOC by inferential statistics test(s).
3 Analyte not considered a PCOC because it is a nutrient.
4 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
5 Analyte not considered a PCOC because of infrequent detection and/or detection in blanks or background samples.
6 Analyte not considered a PCOC because it is not a measure of a single contaminant.
Analyte removed from consideration as PCOC.

Data Qualifiers

— data qualifier or validation field in database is blank.
B for inorganics, reported value is < CRDL but > IDL (estimated value).
B for organics, analyte is also detected in blank; for common lab contaminants include as detection if blank result > 10 times detection limit; for all other organics include if blank result > 5 times detection limit.
B for radionuclides, constituent also detected in blank whose concentration was > minimum detectable activity
J for organics, interference with target peak (estimated value).
J for organics, data indicate presence of compound but below detection limit (estimated value).
U for inorganics and organics, analyte analyzed but not detected at the quantitation limit.

Data Validation Codes

— data qualifier field in database is blank.
A acceptable result.
JA acceptable result (for estimated value).
V valid result.

Definitions

PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99-percent confidence level
CRDL contract-required detection limit
IDL instrument detection limit
μg/L micrograms per liter

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Table 2-3
Analytes Detected in Surface Water in the East Landfill Pond (SW098)

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	Background UTL 99/99 Concentration	Units	PCOC
Metals										
Aluminum	10 200	16/22	30 4	271	–	-	75	39 136	µg/L	
Antimony	0 05 500	2/22	8	16 9	B		22	20 054	µg/L	
Arsenic	0 7 10	9/21	0 9	2 2	-	V	1	3 485	µg/L	2
Barium	0 02 200	22/22	16	250	-	V	172	63 510	µg/L	
Beryllium	0 2 5	1/22	0 5	0 7	–	JA	1	1 702	µg/L	
Cadmium	0 1 5	1/22	1	2 1	–	JA	1	1 760	µg/L	
Calcium	14 3 5 000	22/22	3 180	55 000	–	V	39 972	56 909	µg/L	2 3
Cesium	5 2 500	2/23	33	50	B	–	211	475 272	µg/L	
Chromium	2 4 20	2/22	2	10 9	–	–	3	3 328	µg/L	
Copper	2 1 25	8/22	2	16		JA	5	8 281	µg/L	
Iron	4 3 100	22/22	16 3	1 150		V	507	16 477	µg/L	
Lead	0 8 20	7/21	0 9	5 3		JA	2	1 482	µg/L	
Lithium	2 100	20/21	7 7	109	-		79	35 577	µg/L	2
Magnesium	0 1 5 000	22/22	4,270	48 300	–		39 349	1 156 026	µg/L	2 3
Manganese	1 15	21/22	2 5	430	–	V	105	3 024	µg/L	2
Mercury	0 2 0 2	3/22	0 1	0 54	–	V	0 1	58 9	µg/L	
Molybdenum	5 7 500	3/21	3	13 1	B	-	20	32 559	µg/L	2
Nickel	0 02 40	14/22	6 3	22	–	V	10	13 308	µg/L	2
Potassium	10 5 000	22/22	1 360	10 900	–	V	8 754	1 607 524	µg/L	2,3
Silicon	7 3 100	14/14	298	3670		V	2 302	16,293	µg/L	
Silver	2 5 30	3/22	2	4	-	JA	3	3 388	µg/L	
Sodium	10 5 000	22/22	19 900	196 000	–	–	161 177	39 331	µg/L	1,2 3

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Table 2-3
Analytes Detected in Surface Water in the East Landfill Pond (SW098)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Strontium	2 3 200	21/21	44 9	598	–	–	476	241 118	µg/L	2
Thallium	0 1 10	2/21	1	7 4	–	JA	2	6,503	µg/L	2
Tin	10-1 000	6/21	10	44 3	B	–	41	33,576	µg/L	2
Vanadium	2 50	5/22	2	9	B	–	4	16,834	µg/L	
Zinc	1 8 20	19/22	4	105	–	–	17	3 706	µg/L	
Radionuclides										
Americium-241	0 0.19	15/15	0.0005655	0.031	U	A	0.007	0 03	pCi/L	1,2
Cesium-137	0.23 1 16	11/11	-0.2323	0 1344	–	V	-0 06	2 1	pCi/L	
Gross alpha	2 - 6.66	11/11	-0.67	8	U	V	2	29	pCi/L	2,6
Gross beta	2.6 - 7.8	11/11	7.8	18	–	V	11	31	pCi/L	2,6
Plutonium-239	0 0.03	6/6	0	0.022	–	–	0 007		pCi/L	
Plutonium-239/240	0 0.01	11/11	-0.000364	0.023	–	A	0.004		pCi/L	
Radium-226	0.211 - 0.211	1/1	0.23	0.23	–	V	0.23	17	pCi/L	
Strontium-89,90	0.23 1	5/5	0.6695	1.924	–	A	1.4	4 9	pCi/L	2
Strontium-90	0.36 0.58	5/5	0 7064	1.208	–	V	1.02		pCi/L	
Tritium	160 480	20/20	10	257 6	J	V	139	732	pCi/L	2
Uranium-233, 234	0 - 0.232	9/9	0 7626	1 594	–	V	1 1		pCi/L	
Uranium-235	0 0.281	9/9	-0.01	0 3	–	A	0 1	0.3	pCi/L	1,2
Uranium-238	0.08 0.283	9/9	0.6996	1 964	–	A	1.1	1.8	pCi/L	1,2
Semivolatile Organic Compounds										
Bis(2-ethylhexyl)phthalate	9 11	1/8	1	1	J	A	5	8	µg/L	4
Di-n-butyl phthalate	9 11	1/8	1	1	J	A	5		µg/L	4

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Table 2-3
Analytes Detected in Surface Water in the East Landfill Pond (SW098)

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Volatile Organic Compounds										
Acetone	10	1/21	6	12	B	—	6	29	µg/L	4 5
Methylene chloride	5	3/21	4	8	B	—	3	21	µg/L	4 5
Vinyl acetate	10	1/20	10	80	—	—	9		µg/L	4 5
Indicator Parameters										
Bicarbonate as $CaCO_3$	1 000 10 000	16/16	213 000	489 000		V	391 063		µg/L	
Carbonate	10 000 10 000	1/4	10 000	15 300		V	7 575	10 987	µg/L	
Carbonate as $CaCO_3$	1 000 10 000	9/12	0	76 500	—	V	28 167		µg/L	
Chloride	200- 25 000	16/16	137 000	190 000	—	-	164 875	64 366	µg/L	
Dissolved organic carbon	1 000 2 000	6/6	21 900	32 400	—	V	27 250	16 997	µg/L	
Fluoride	100 200	15/15	590	890	—		770	643	µg/L	
Nitrate	100	1/3	100	200	—	JA	100		µg/L	
Nitrate/nitrite	20 100	6/13	20	320		JA	80	3 130	µg/L	
Oil and grease	200 7 100	3/14	400	800		—	2 289	14 681	µg/L	
Orthophosphate	10 50	2/11	40	40	—	-	27 73	210	µg/L	
pH	—	4/4	8 2	8 3	—		8 2	—	pH	
Phosphorus	50 1 000	3/10	50	638	B	-	96	272	µg/L	
Silica	400 2 000	5/5	2 300	12 000	—	—	6 360	36 561	µg/L	
Solids nonvolatile suspended	50 00 5 000	2/6	5 000	12 000	—	V	4 667	—	µg/L	
Sulfate	500 10 000	16/16	7 000	25 600		V	16 031	41 114	µg/L	
Total dissolved solids	10 000	16/16	230 000	814 000	—	V	705 125	372 696	µg/L	

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Table 2-3
Analytes Detected in Surface Water in the East Landfill Pond (SW098)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total organic carbon	1 000 2 000	6/6	26,000	51 000	—	—	33,633	21,993	µg/L	
Total suspended solids	4 000 5,000	3/11	4,000	4 900 000	—	—	448 864	157,368	µg/L	

Notes

All analytes are total analytes unless otherwise noted.
For non-detects, one-half the detection limit is used in calculating the mean result.

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be PCOC by inferential statistics test(s).
3 Analyte not considered a PCOC because it is a nutrient.
4 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
5 Analyte not considered a PCOC because of infrequent detection and/or detection in blanks or background samples.
6 Analyte not considered a PCOC because it is not a measure of a single contaminant.
▒ Analyte removed from consideration as PCOC.

Data Qualifiers

— data qualifier or validation field in database is blank.
B for inorganics, reported value is < CRDL but > IDL (estimated value).
B for organics, analyte is also detected in blank; for common lab contaminants include as detection if blank result > 10 times detection limit; for all other organics include if blank result > 5 times detection limit.
J for inorganics, value > IDL but control sample analysis not within control limits (estimated value).
J for organics, data indicate presence of compound but below detection limit (estimated value).
U for inorganics and organics, analyte analyzed but not detected at the quantitation limit.

Data Validation Codes

— data qualifier field in database is blank.
A acceptable result.
JA acceptable result (for estimated value).
V valid result.

Definitions

CRDL contract-required detection limit
IDL instrument detection limit
PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99-percent confidence level

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Table 2-4
Analytes Detected in Sediment in the East Landfill Pond

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL Concentration*	Units	PCOC
Metals											
Aluminum	7 7 12	2/2	12,300	16,600	..	V	SED70193	14,450	29,600	mg/kg	
Arsenic	0 32 0 42	3/3	2 7	5	–	V	SED70193	4	67	mg/kg	
Barium	1 6 2 5	3/3	174	215	–	V	SED70093	198	795	mg/kg	
Beryllium	0 22 0 34	3/3	0 81	1 5	–	JA	SED70193	1 2	2 6	mg/kg	
Calcium	7 5 11 7	2/2	6,290	7,850	-	V	SED70193	7,070	80,900	mg/kg	3
Chromium	0 64 0 99	3/3	12 3	17 5	..	V	SED70193	14 7	29 5	mg/kg	
Cobalt	0 64 0 99	3/3	5 7	7 6	.	V	SED70093	6 8	.	mg/kg	
Copper	0 71 1 1	3/3	11 2	18 6		V	SED70193	16	175 4	mg/kg	
Iron	1 8 2 8	2/2	11,600	15,400	-	V	SED70193	13,500	143,900	mg/kg	
Lead	2 5 3 8	3/3	21 6	33 7	–	V	SED70193	29 7	261 1	mg/kg	
Lithium	0 83 1 3	2/2	6 1	9 9	–	V	SED70193	8	–	mg/kg	
Magnesium	9 5 14 8	2/2	2,170	3,250	–	V	SED70193	2,710	6,470	mg/kg	3
Manganese	0 59 0 91	2/2	147	186	–	V	SED70193	167	.	mg/kg	
Nickel	2 7 4 2	3/3	9 3	15 3	–	V	SED70093	12 7	35 2	mg/kg	
Potassium	190 295	2/2	1,350	2,640	–	V	SED70193	1,995	3,227	mg/kg	3
Selenium	0 3 0 5	3/3	0 41	1 1		JA	SED70193	0 8	5 2	mg/kg	
Silicon	1 8 2 8	2/2	226	344		V	SED70193	285	-	mg/kg	
Silver	0 88 1 4	1/3	0 88	0 88	–	JA	SED70293	0 7	.	mg/kg	
Sodium	15 23 4	2/2	286	447	–	V	SED70193	367	2,127	mg/kg	3
Strontium	1 3 2 1	2/2	43 5	61 5	--	V	SED70193	52 5	356	mg/kg	
Tin	4 1 6 3	1/3	5 3	5 3	.	V	SED70293	3 8	.	mg/kg	
Vanadium	0 78 1 2	3/3	28 8	41	–	V	SED70193	34	86	mg/kg	
Zinc	0 59 0 91	3/3	49.2	187	-	V	SED70093	106	148	mg/kg	1

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Table 2-4
Analytes Detected in Sediment in the East Landfill Pond

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Radionuclides											
Americium-241	0 0021 0.0041	3/3	0 00452	0 01789	–	A	SED70093	0.01151	–	pCi/g	
Cesium-137	0	3/3	0.2863	0 732	X	–	SED70093	0.458	3 51	pCi/g	
Gross alpha	2.5 3.1	3/3	11 4	16.42	–	V	SED70193	14.6	–	pCi/g	
Gross beta	1.90 2.1	2/3	27 76	28.94	–	V	SED70093	28.3	–	pCi/g	
Plutonium-239/240	0 0067 0.015	3/3	0.007202	0 09628	–	A	SED70093	0.04480	–	pCi/g	
Strontium-89,90	0 042 0.074	3/3	0 1148	0.2386	–	V	SED70093	0 171	–	pCi/g	
Uranium-233,-234	0.042 0.096	3/3	0.9126	1 136	–	A	SED70093	1 022	–	pCi/g	
Uranium-235	0.05 0.062	3/3	0.05464	0.07362	–	A	SED70193	0.06158	–	pCi/g	
Uranium-238	0 056 - 0 076	3/3	0.8104	1 396	–	A	SED70093	1 16	–	pCi/g	
Semivolatile Organic Compounds											
Acenaphthene	450 790	1/3	100	100	J	A	SED70093	220	–	µg/kg	2
Anthracene	450 790	1/3	160	160	J	A	SED70093	240	–	µg/kg	2
Benzo(a)anthracene	450 790	1/3	340	340	J	A	SED70093	380	–	µg/kg	2
Benzo(a)pyrene	450 790	1/3	320	320	J	A	SED70093	293	–	µg/kg	2
Benzo(b)fluoranthene	450 790	1/3	460	470	J	A	SED70093	343	–	µg/kg	2
Benzo(ghi)perylene	450 790	1/3	200	200	J	A	SED70093	253	–	µg/kg	2
Benzo(k)fluoranthene	450 790	1/3	130	130	J	A	SED70093	230	–	µg/kg	2
Benzoic acid	2,200 - 3,900	3/3	260	870	J	A	SED70093	537	–	µg/kg	2
Bis(2-chloroisopropyl)ether	450 790	1/3	47	47	J	A	SED70093	259	–	µg/kg	2
Bis(2-ethylhexyl)phthalate	450 790	1/3	80	80	J	A	SED70093	213	–	µg/kg	2
Chrysene	450 790	1/3	310	310	J	A	SED70093	290	–	µg/kg	2
Fluoranthene	450 790	2/3	79	830	–	V	SED70093	415	–	µg/kg	2
Fluorene	450 790	1/3	92	92	J	A	SED70093	217	–	µg/kg	2

Table 2-4
Analytes Detected in Sediment in the East Landfill Pond

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background $UTL_{99/99}$ Concentration*	Units	PCOC
Indeno(1,2,3-cd)pyrene	450 790	1/3	180	180	J	A	SED70093	247	—	µg/kg	2
Phenanthrene	450 790	2/3	73	630	J	A	SED70093	346	—	µg/kg	2
Pyrene	450 790	2/3	74	750	J	A	SED70093	386		µg/kg	2
Volatile Organic Compounds											
2 Butanone	13 24	1/3	13	35	—	V	SED70093	17		µg/kg	2
Acetone	13 24	2/3	63	130	B	V	SED70193	68		µg/kg	2
Toluene	10 33	3/3	180	440	-	V	SED70293	307	—	µg/kg	2
Indicator Parameters											
% solids	0 1	4/4	42 1	75 8	—	V	SED70293	54 4	—	%	
pH	0 2	3/3	6 7	7 2	—	V	SED70193	7	—	pH	
Total organic carbon	500	3/3	7,800	9,400	X	V	SED70293	8,367	-	mg/kg	

Notes

* Background $UTL_{99/99}$ concentrations for seep sediment data. There are no background data for pond sediments
1 Analyte determined to be PCOC by hot measurement test.
2 All detected organic analytes are PCOCs unless eliminated through professional judgment.
3 Analyte not considered a PCOC because it is a nutrient.

Data Qualifiers

__ data qualifier field in database is blank.
B for organics, analyte is also detected in blank for common lab contaminants include as detection if blank result > 10 times detection limit for all other organics include if blank result > 5 times detection limit.
J for organics data indicate presence of compound but below detection limit (estimated value)
X for inorganics (pre 1992) detection limit greater than normal sample matrix interference

Data Validation Codes

__ data qualifier field in database is blank.
A acceptable result.
JA acceptable result (for estimated value)
V valid result.

Definitions

PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99 percent confidence level

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Table 2-5
Analytes Detected in Surface Soils in the Vicinity of Spray Evaporation Areas

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals											
Aluminum	3 7 40	216/216	5,100	24,400	–	V	SS700493	12,006	25,879	mg/kg	
Antimony	3 7 14.5	6/215	3 7	9 1	–	V	SS719693	4	–	mg/kg	1
Arsenic	0.14 2 6	216/216	1.2	15.7	–	V	SS702293	5	13	mg/kg	1
Barium	0.34 40	216/216	30	1120	–	V	SS705193	194	532	mg/kg	1
Beryllium	0 06 1	161/216	0.36	1.5	–	V	SS120894	1	5 0	mg/kg	2
Cadmium	0 5 1 7	13/215	0 5	1 5	–	V	SS710493	0	5	mg/kg	
Calcium	2.1 - 1,000	215/215	1,880	84,800	–	V	[illegible]	8,872	18,859	mg/kg	1,2,3
Chromium	0 47 3.3	216/216	4.3	24 7	–	V	SS700493	13	28	mg/kg	
Cobalt	0.49 10	201/216	2.8	16.2	–	V	SS712093	7	24	mg/kg	2
Copper	0 47 5	216/216	7 1	640	–	V	SS121394	17	30	mg/kg	1,2
Iron	0.58 - 20	216/216	4,390	59,800	–	V	SS121694	13,515	29,052	mg/kg	1,3
Lead	0 16 17.2	216/216	6.4	167	–	V	SS708893	26	62	mg/kg	1
Lithium	0.58 20	64/91	1.9	16.4	–	V	SS121094	8	22	mg/kg	
Magnesium	5.8 - 1,000	215/215	821	7,910	–	V	SS700[illegible]	2,[illegible]	7,718	mg/kg	1,3
Manganese	0 16 3	215/215	20.9	1,370	–	V	SS700593	215	2,100	mg/kg	
Mercury	0.076 0 17	21/219	0.05	0 14	–	V	SS708893	0.1	–	mg/kg	1
Molybdenum	1.2 49	16/92	1 4	4 1	–	V	SS702993	1	37	mg/kg	
Nickel	1.2 8	215/216	4.6	23.8	–	V	SS121394	12	27	mg/kg	
Potassium	96.8 - 1,000	216/216	495	5,520	–	V	[illegible]	1,[illegible]	5,[illegible]	mg/kg	3
Selenium	0.23 - 1	115/204	0.23	2.9	–	V	SS121594	1	1.4	mg/kg	1,2
Silicon	1.3 2 1	76/76	93.7	628	–	V	SS705393	267	3,542	mg/kg	
Silver	0 51 2	66/215	0.53	3	–	V	SS709593	1	–	mg/kg	1
Sodium	5.8 - 1,000	194/216	22.5	1,280	–	V	SS709293	128	1,052	mg/kg	1,3
Strontium	0.33 40	92/92	22.2	80.6	–	V	SS720193	48	113	mg/kg	2
Thallium	0.31 2	4/212	0 31	2 1	–	V	SS121594	0.2	2.0	mg/kg	1

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Table 2-5
Analytes Detected in Surface Soils in the Vicinity of Spray Evaporation Areas

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background $UTL_{99/99}$ Concentration	Units	PCOC
Tin	3 1 40	5/92	3 1	10	—	V	SS708993	3	70	mg/kg	
Vanadium	0 6 10	216/216	9 7	86 2	-	V	SS705293	32	60	mg/kg	1
Zinc	0 42 4	216/216	21 5	113		V	SS120894	56	99	mg/kg	1,2
Radionuclides											
Americium 241	0 0 033	200/200	0	1 076	·	V	SS703793	0 02	0 058	pCi/g	1,2
Cesium 134	0 0 12	66/66	0 381	0 12		V	SS120594	0 02		pCi/g	
Cesium 137	0 0 26	210/210	0 0722	2 27		V	SS700893	0	3 5	pCi/g	
Gross alpha	1 1 9	214/214	7 2	29	·	V	SS120794	15	43	pCi/g	
Gross beta	1 8 5 3	202/202	17 71	42	·	V	SS120794	26	53	pCi/g	
Plutonium 239/240	0 0 06	196/196	0 00101	0 4692	--	V	SS704293	0 05	0 13	pCi/g	1,2
Radium 226	0 0 51	106/106	0 4355	1 787	—	V	SS711193	1	1 5	pCi/g	1,2
Radium 228	0 0 98	132/132	0 7629	2 597	-	V	SS704493	1 6	4 8	pCi/g	
Strontium 89,90	0 02 0 5	214/214	0 004	1 017	—	V	SS708993	0 2	2 1	pCi/g	
Uranium 233, 234	0 0 3	213/213	0 5558	1 5	—	V	SS702593	0 9	1 8	pCi/g	
Uranium 235	0 0 3	213/213	0 0305	0 12	-	V	SS701993	0	0 187	pCi/g	
Uranium 238	0 0 3	213/213	0 5589	1 626		V	SS708293	0 9	2	pCi/g	
Indicator Parameters											
% solids	0 1 0 1	200/200	29 5	91 4	-	V	SS720093	75	129 3	%	
Nitrate/nitrite	0 5 1	164/216	0 68	45	—	V	SS710893	4	9 6	mg/kg	1,2
Total organic carbon	0 05 500	187/216	0 05	54,000	--	V	SS701193	10,700	..	mg/kg	

Notes

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be PCOC by inferential statistics test(s)
3 Analyte not considered a PCOC because it is a nutrient.

Data Validation Codes

V alid result

Definitions

PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99 percent confidence level

Data Qualifiers

— data qualifier or validation field in database is blank

Table 2-6
Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill

Colluvial Material (Qc)											
Metals											
Aluminum	6 9 7.8	7/7	10,400	16,100	—	V	71093	12,657	27,862	mg/kg	
Arsenic	0.24 0.36	7/7	3 3	7 9	—	V	70993	6	9	mg/kg	
Barium	1 4 1 6	7/7	91 4	624	—	JA	71093	230	465	mg/kg	1
Beryllium	0.2 0.22	7/7	0 74	1.2	—	JA	70993	1	25	mg/kg	
Calcium	6.7 - 7.8	7/7	5,620	7,350	—	V	71093	8,464	31,368	mg/kg	2
Chromium	0 56 0.64	7/7	11.2	16.9	—	V	71093	13.2	37	mg/kg	
Cobalt	0 56 0.64	7/7	5.6	10 9	—	V	71093	9	17	mg/kg	
Copper	0 63 0 72	7/7	12.6	17 7	—	V	71093	15	33	mg/kg	
Iron	1 6 1 9	7/7	12,300	18,400	—	V	71093	14,486	38,544	mg/kg	
Lead	2 2.8	7/7	16.5	27 9	—	JA	71093	23	32	mg/kg	
Lithium	0 74 0.84	7/7	6.1	9 9	—	V	71093	8	23	mg/kg	
Magnesium	8.4 - 9.6	7/7	1,500	3,560	—	V	71093	2,323	7,473	mg/kg	2
Manganese	0.52 - 0.59	7/7	108	262	—	V	70993	198	753	mg/kg	
Nickel	2 4 2.7	7/7	13.1	18.4	—	V	71093	15.2	42	mg/kg	
Potassium	169 - 192	7/7	[illegible]	1,760	—	V	71093	1,254	3,175	mg/kg	2
Selenium	0.26 0 34	7/7	0 34	0.74	—	JA	70993	0.52	7	mg/kg	
Silicon	1.6 1 8	7/7	315	659	—	JA	71093	410	—	mg/kg	
Sodium	13.3 - 15.8	7/7	85.6	312	—	V	70993	378	3,004	mg/kg	2
Strontium	1.2 1.4	7/7	49.9	107	—	V	71093	67	142	mg/kg	
Tin	3.6 4.1	5/7	3.7	8.9	—	JA	71093	5.6	626	mg/kg	
Vanadium	0 69 0 79	7/7	20 6	43.6	—	V	71093	28.4	73	mg/kg	
Zinc	0 52 0.59	7/7	55	72.2	—	V	71093	61	133	mg/kg	

Table 2-6
Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Radionuclides											
Americium 241	0	6/6	0 001197	0 0143	J	A	71093	0 0061	–	pCi/g	
Cesium 137	0 1 0 1	6/6	0 0142	0 2386	–	–	71093	0 0584	0 1	pCi/g	1
Gross alpha	0 8 3 4	6/6	8 03	16 8	-	V	70993	13 6	65	pCi/g	
Gross beta	2 3 2 5	6/6	21 88	26 18	·	V	70993	24 0	40	pCi/g	
Plutonium 239/240	0 0 016	4/4	0 002438	0 01842	J	A	70993	0 01076	–	pCi/g	
Radium 226	0 5	6/6	0 8443	1 083	·	–	70993	0 974	2	pCi/g	
Radium 228	0 5	6/6	1 322	1 859	–	–	70993	1 623	3	pCi/g	
Strontium-89,90	0 04 0 06	6/6	0 1022	0 4153	J	A	71093	0 1852	1 2	pCi/g	
Tritium	450 450	6/6	97 59	301 5	J	V	70993	170 1	456	pCi/g	
Uranium 233, 234	0 029 0 081	6/6	0 7916	1 166	–	A	71093	0 97	–	pCi/g	
Uranium 235	0 0 042	6/6	0 02566	0 05357	J	A	70993	0 03664	0 2	pCi/g	
Uranium 238	0 0 057	6/6	0 961	1 233	-	A	71093	1 06	2	pCi/g	
Semivolatile Organic Compounds											
Chrysene	380 440	1/7	43	43	J	A	70993	180	–	µg/kg	3
Fluoranthene	380 440	1/7	110	110	J	A	70993	189	–	µg/kg	3
Phenanthrene	380 440	1/7	100	100	J	A	70993	188		µg/kg	3
Pyrene	380 440	1/7	110	110	J	A	70993	189	–	µg/kg	3
Volatile Organic Compounds											
4 Methyl 2-pentanone	12 14	1/5	12	58	–	V	70993	17		µg/kg	3
Toluene	12 64	5/5	160	2,000	–	V	70993	850	–	µg/kg	3
Total xylenes	6 7	1/5	2	2	J	A	70993	3		µg/kg	3

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Table 2-6
Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill

Indicator Parameters											
% solids	0.1	7/7	73.9	85.6	—	V	71093	81	—	%	
Nitrate	1	2/5	1	2	—	JA	70993	1	—	mg/kg	
Nitrate/nitrite	1	3/6	1	20,000	—	V	71093	4,801	66	mg/kg	1
Total organic carbon	0.06	5/5	500	21,000	—	V	71093	8,540	—	mg/kg	
pH	0.2	7/7	7.8	8.4	—	V	70993	8.1	—	pH	
Weathered Bedrock Material (KaKl-w)											
Metals											
Aluminum	5.8 7.5	11/11	5,320	7,880	—	V	70993	7,035	43,375	mg/kg	
Arsenic	0.19 1.4	11/11	1.3	11.4	—	V	70993	3.4	10	mg/kg	1
Barium	1.2 1.5	11/11	24.5	254	—	JA	71093	97	205	mg/kg	1
Beryllium	0.16 - 0.21	11/11	0.53	1.1	—	JA	71093	1	9	mg/kg	
Cadmium	0.49 0.64	4/11	0.49	1.5	—	V	71093	0.5	—	mg/kg	
Calcium	[illegible]	11/11	[illegible]	[illegible]	—	V	[illegible]	[illegible]	[illegible]	mg/kg	1.2
Chromium	0.48 - 0.61	11/11	6.4	10.6	—	V	71093	8	52.7	mg/kg	
Cobalt	0.48 0.61	11/11	2.2	21	—	V	71093	9	17	mg/kg	1
Copper	0.53 0.68	11/11	13.2	24.3	—	V	71093	19	44	mg/kg	
Iron	1.4 - 1.8	11/11	4,880	24,800	—	V	71093	13,893	36,178	mg/kg	
Lead	1 2.3	11/11	12.6	31.2	—	JA	70993	22	26	mg/kg	1
Lithium	0.62 0.8	11/11	3.4	10	—	V	70993	7	24	mg/kg	
Magnesium	[illegible]	11/11	[illegible]	[illegible]	—	V	[illegible]	[illegible]	[illegible]	mg/kg	2
Manganese	0.44 0.57	11/11	20.2	896	—	JA	71093	275	706	mg/kg	1
Mercury	0.08 0.11	2/11	0.08	0.18	—	JA	70993	0.1	—	mg/kg	
Nickel	2 2.6	11/11	3.1	36.2	—	V	71093	17	52	mg/kg	
Potassium	143 - 164	11/11	[illegible]	[illegible]	—	V	[illegible]	[illegible]	[illegible]	mg/kg	2
Selenium	0.23 0.3	7/11	0.27	1.9	—	JA	71093	0.8	—	mg/kg	

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Table 2-6
Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL99/99 Concentration	Units	PCOC
Silicon	13 17	11/11	224	1200	-	JA	71093	589	-	mg/kg	
Silver	0 66 0 85	2/11	0 66	0 89		V	71093	0 5	62	mg/kg	
Sodium	11 3 14 5	11/11	256	939	–	V	70993	495	2,804	mg/kg	2
Strontium	1 1 3	11/11	46 6	197	-	V	71093	97	32 2	mg/kg	1
Thallium	0 26 0 34	2/11	0 28	0 66	–	JA	71093	0 2	–	mg/kg	
Tin	3 1 3 9	4/11	3 1	9 4	–	JA	70993	3 5	629	mg/kg	
Vanadium	0 59 0 75	11/11	10 3	29 2	-	V	71093	19	91	mg/kg	
Zinc	0 44 0 57	11/11	41 9	84 4	-	JA	71093	70	68	mg/kg	1
Radionuclides											
Americium 241	0	11/11	0 000329	0 009491	J	A	70993	0 00289	–	pCi/g	
Cesium 137	0 1	11/11	0 0344	0 01489	J		70993	0 0039	–	pCi/g	
Gross alpha	1 9 3 4	11/11	5 615	14 18	–	V	70993	10 8	-	pCi/g	
Gross beta	2 3 2 6	11/11	21 21	25 64	–	V	71093	23 7		pCi/g	
Plutonium 239/240	0 0 016	8/8	0	0 007367	J	A	71093	0 003372		pCi/g	
Radium 226	0 5	11/11	0 9136	1 312	-	-	70993	1 13	2 5	pCi/g	
Radium 228	0 5	11/11	1 048	1 584		–	70993	1 360	-	pCi/g	
Strontium 89,90	0 04 0 05	11/11	0 02282	0 8017	J	A	71093	0 1849	2 6	pCi/g	
Tritium	440 450	11/11	37 7	309 2	J	V	70993	80 2		pCi/L	
Uranium 233, 234	0 021 0 055	11/11	0 7383	1 408	–	A	70993	1 016		pCi/g	
Uranium 235	0 0 046	11/11	0 00387	0 1053	J	A	70993	0 0527	-	pCi/g	
Uranium 238	0 0 033	11/11	0 8527	1 309		A	70993	1 12	–	pCi/g	
Volatile Organic Compounds											
1,1,1 Trichloroethane	6	1/11	2	2	J	A	70993	3	–	µg/kg	3, 4
Toluene	6 110	11/11	120	580	–	JA	70993	309	-	µg/kg	3

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Table 2-6
Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill

Analyte	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Indicator Parameters											
% solids	0.1 0 1	11/11	82.7	89 4	—	V	71093	87	—	%	
Total organic carbon	0 05	3/11	500	2,600	—	V	71093	700	—	mg/kg	
pH	0.2	11/11	7.6	8.6	—	V	71093	8	—	pH	

Notes

Sample locations are 70993 and 71093

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte not considered a PCOC because it is a nutrient.
3 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
4 Analyte not considered a PCOC because of infrequent detection and/or detection is in blanks or background samples.

Data Qualifiers

__ data qualifier or validation field in database is blank.
J for inorganics, value > IDL but control sample analysis not within control limits (estimated value)
J for organics, data indicate presence of compound but below detection limit (estimated value).
V valid result.

Data Validation Codes

__ data qualifier field in database is blank.
A acceptable result.
JA acceptable result (for estimated value).

Definitions

Qc Quaternary colluvium
KaKl(w) weathered undifferentiated Cretaceous Arapahoe and Laramie formations
PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99-percent confidence level

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Table 2-7
Analytes Detected in UHSU Groundwater in the Vicinity of the East Landfill Pond

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Metals											
Aluminum	16 200	7/7	217	635	–	V	B206789	385	26 324	µg/L	
Antimony	17 60	1/7	14	58	B	Y	B206789	18	52	µg/L	1
Arsenic	2 10	1/7	1	2 7	..	V	B206789	1	8	µg/L	
Barium	9 200	4/7	16 1	22	B	Y	B206789	16	311	µg/L	
Calcium	17 5 000	7/7	151 000	167 000	–	V	B206789	158 000	148,662	µg/L	1 2 3
Cesium	20 1 000	1/6	23	45	B	Y	B206789	122	866	µg/L	
Chromium	3 10	2/7	2	17	–	JA	B206789	4	192	µg/L	
Copper	2 25	1/7	2	8	B	Y	B206789	4	42	µg/L	
Iron	5 100	7/7	238	527	–	V	B206789	383	32 398	µg/L	
Lead	1 5	2/7	1	1 2	B	V	B206789	1	20	µg/L	
Lithium	2 100	7/7	186	225		Y	B206789	207	177	µg/L	1 2
Magnesium	36 5 000	7/7	40 700	44 900	–	V	B206789	42 500	33 725	µg/L	1,2 3
Manganese	1 15	5/7	2 8	9 7	–	V	B206789	6 3	643	µg/L	
Nickel	10 40	1/7	3	11 1	B	Y	B206789	5	101	µg/L	
Potassium	620 5 000	6/7	3 640	3 760	B	V	B206789	3 489	5 243	µg/L	2 3
Selenium	0 5	7/7	488	815	+	JA	B206789	665	131	µg/L	1 2
Silicon	13 100	6/6	5 950	7 170	–	V	B206789	6 447	62 830	µg/L	
Silver	4 10	1/7	2	10 9	N	JA	B206789	3	7	µg/L	1 2
Sodium	21 5 000	7/7	139,000	148 000	-	V	B206789	144 429	147 829	µg/L	1,2 3
Strontium	1 200	7/7	1 360	1 560	–	V	B206789	1 446	1 110	µg/L	1 2
Thallium	2 10	1/7	1	1	B	V	B206789	1	9	µg/L	
Tin	18 200	1/7	10	19 2	B	V	B206789	12	170	µg/L	
Vanadium	3 50	3/7	2 9	8 9	BE	JA	B206789	5	71	µg/L	

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Table 2-7
Analytes Detected in UHSU Groundwater in the Vicinity of the East Landfill Pond

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	3 20	4/7	9.1	52 7	—	JA	B206789	19.3	184	µg/L	
Radionuclides											
Americium-241	0.01	1/1	-0.433	-0.433	J	—	B206789	-0 433	0.04	pCi/L	
Gross alpha	9.2	1/1	53.9	53 9	—	V	0786	53.9	391	pCi/L	
Gross beta	8.6	1/1	29.4	29.4	—	V	0786	29 4	221	pCi/L	
Plutonium-239/240	0.01	2/2	0.001108	0.004	—	A	B206789	0.003	—	pCi/L	
Radium-226	0 06 0 5	2/2	0.35	0.52	—	A	B206789	0 44	1.29	pCi/L	
Tritium	210 - 840	28/28	164 49541	388	J	V	0786	82	13,413	pCi/L	
Uranium-233,-234	0	1/1	49.32	49.32	—	A	B206889	49.32	—	pCi/L	
Uranium-235	0 07	1/1	2.62	2 62	—	A	B206889	2 62	5.2	pCi/L	
Uranium-238	0 07 0 18	2/2	29.81	35.45	—	A	B206889	32.63	114	pCi/L	2
Semivolatile Organic Compounds											
Bis(2-ethylhexyl)phthalate	10	1/2	3	3	J	A	B206789	4	—	µg/L	4
Volatile Organic Compounds											
1,1-Dichloroethene	0.1 - 10	1/51	0.1	0.6	—	Y	0786	2	8	µg/L	4,5
Acetone	10 - 100	2/51	4	25	B	—	B206889	6	18	µg/L	4,5
Benzene	0.1 - 10	2/51	0.1	0.5	J	A	B206889	2	8	µg/L	4,5
Carbon tetrachloride	0.2 10	2/51	0.2	7.11	—	Y	B206889	2	516	µg/L	4
Chloroethane	0.4 - 10	2/51	0.4	3	J	A	0786	2	—	µg/L	4,5
Ethylbenzene	0.2 - 10	1/51	0.2	0.3	J	A	B206889	2	—	µg/L	4,5
Methylene chloride	0.1 - 10	7/51	0.1	8	B	—	B206889	2	16	µg/L	4,5
Tetrachloroethene	0 1 10	1/51	0.1	0 769	—	Y	B206889	2	44	µg/L	4
Toluene	0.1 - 10	1/51	0.1	3	J	A	B206889	2	4	µg/L	4,5

Table 2-7
Analytes Detected in UHSU Groundwater in the Vicinity of the East Landfill Pond

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Total xylenes	0 5 10	1/46	0 5	3	J	A	B206889	3	3	µg/L	4 5
Trichloroethene	0 1 10	1/51	0 1	1 43	–	Y	B206889	2	38	µg/L	4
Indicator Parameters											
Bicarbonate as $CaCO_3$	1 000 10 000	21/21	135 000	860 000	–	V	0786	316 225	-	µg/L	
Carbonate as $CaCO_3$	1 000 10 000	4/13	0	1 430	B	V	B206789	1 264	–	µg/L	
Chemical oxygen demand	5 000 10 000	9/10	10 000	55 000		Y	0786	24 456	–	µg/L	
Chloride	200 25 000	21/21	59 000	460 000		V	B206889	155 697	63 635	µg/L	1 2
Fluoride	100 200	20/20	300	1 900		V	0786	692	2 024	µg/L	
Nitrate/nitrite	20 200 000	34/38	20	290 000	-	JA	B206889	4 8704	55 685	µg/L	1 2
Orthophosphate	10 50	4/7	10	30	-		B206789	20 71	53	µg/L	2
pH	–	2/2	7 1	7 7	-		B206789	7 4	–	pH	
Silica	400 2 000	8/8	5 500	25 000	–	JA	B206789	9 000	35 735	µg/L	
Sodium fluoride	100	1/1	520	520	–	V	B206789	520		µg/L	
Sodium sulfate	20 000	1/1	524 000	524 000	–	V	B206789	524 000		µg/L	
Solids nonvolatile suspended	5 000	1/1	29 000	29 000	-	JA	B206889	29 000	-	µg/L	
Sulfate	2 000 250 000	20/20	170 000	1 600 000		V	B206889	621 840	613 607	µg/L	1 2
Total dissolved solids	5 000 14 000	21/21	1 140 000	3 700 000		V	B206889	1 521 476		µg/L	
Total organic carbon	1 000 5 000	14/14	3 000	22 000	–	V	0786	8 975		µg/L	
Total suspended solids	4 000 5 000	19/20	5 000	590 000	–	–	B206789	63 675	1 402 588	µg/L	

Table 2-7
Analytes Detected in UHSU Groundwater in the Vicinity of the East Landfill Pond

Notes

All analytes are total analytes unless otherwise noted.
Organic analytes with zero hits are not reported.
Metal analytes with zero hits are reported.
All radionuclide results are considered hits.
The minimum result may be a hit or not a hit.
The maximum detection may only be a hit.
In calculating the mean, one-half of the detection limit is used for those results that are not hits.

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be PCOC by inferential statistics test(s).
3 Analyte not considered a PCOC because it is a nutrient.
4 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
5 Analyte not considered a PCOC because of infrequent detection and/or detection in blanks or background samples.

Data Qualifiers

— data qualifier field in database is blank.
\+ correlation coefficient for matrix spike analysis is less than 0.995 (estimated value).
B for inorganics, reported value is < CRDL but > IDL (estimated value).
B for organics, analyte is also detected in blank; for common lab contaminants include as detection if blank result > 10 times detection limit; for all other organics include if blank result > 5 times detection limit.
E for inorganics, value is an estimate due to interference (estimated value).
J for inorganics, value > IDL but control sample analysis not within control limits (estimated value).
J for organics, data indicate presence of compound but below detection limit (estimated value).
N for inorganics, spiked sample recovery is not within control limits (estimated value).

Data Validation Codes

— data qualifier or validation field in database is blank.
A acceptable result.
JA acceptable result (for estimated value).
V valid result.
Y analytical results in validation process.

Definitions

CRDL contract-required detection limit
IDL instrument detection limit
PCOC potential contaminant of concern
$UTL_{99/99}$ upper tolerance limit of the 99th percentile at the 99-percent confidence level

Table 2-8
Analytes Detected in UHSU Groundwater Downgradient of the Dam

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background $UTL_{99/99}$ Concentration	Units	PCOC
Metals											
Aluminum	200	7/8	141	3 080		–	4287	938	26 324	µg/L	
Antimony	60	1/8	8	66 8	–	JA	B207089	17	52	µg/L	1 5
Arsenic	10	1/8	1	1 9	B	-	4287	1	8	µg/L	
Barium	200	7/8	27 5	94 5	B	·	4287	45	311	µg/L	
Cadmium	5	2/8	1	2 4	B	V	B207089	1	4	µg/L	
Calcium	5 000	8/8	77 800	149 000	–	V	B207089	127 400	148 662	µg/L	1 2 3
Chromium	10	5/8	2 5	18		V	B207089	7	192	µg/L	
Copper	25	2/8	3 5	9 4	B	–	4287	4	42	µg/L	
Iron	100	8/8	124	2 890		–	4287	888	32 398	µg/L	
Lead	3 5	2/8	1	2 6	B	–	4287	1	20	µg/L	
Lithium	100	8/8	13 5	138	–	V	B207089	100	177	µg/L	2
Magnesium	5 000	8/8	11 300	44 100	–	V	B207089	34 313	33 725	µg/L	1,2 3
Manganese	15	8/8	14 1	109	–	V	B207089	47	643	µg/L	
Molybdenum	200	2/8	2	7 3	B	V	B207089	4	204	µg/L	
Nickel	40	4/8	4	8 4	B	–	4287	6	101	µg/L	
Potassium	5 000	8/8	1,290	6 730	–	V	B207089	5 194	5 243	µg/L	1,2 3
Selenium	5	1/8	1	1	B	JA	B207089	1	131	µg/L	
Silicon	100	4/4	2 720	13 300	N	JA	4287	5 615	62 830	µg/L	
Silver	10	2/7	2	3 2	B	·	4287	2	7	µg/L	
Sodium	5 000	7/7	23,200	465 000	–	V	B207089	330,300	147,829	µg/L	1,2 3
Strontium	200	7/7	412	1 870		V	B207089	1 355	1 110	µg/L	1 2
Tin	200	2/7	10	20 2	B	V	B207089	12	170	µg/L	
Vanadium	50	5/7	5	32 1	B	-	4287	13	71	µg/L	

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Table 2-8
Analytes Detected in UHSU Groundwater Downgradient of the Dam

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	20	5/7	11.3	33.4	—	V	B207089	22.1	184	µg/L	
Radionuclides											
Americium-241	0 0.03	23/23	0	0.012	—	A	B207089	0.005	0.04	pCi/L	
Cesium-134	2.21	1/1	0.64	0.64	—	—	B207089	0.64		pCi/L	
Cesium-137	0.6 2.37	10/10	-0.486	0.4296	J	A	B207089	0	1.1	pCi/L	
Gross alpha	4.8 74.07	2/2	0	19	—	Y	B207089	10	391	pCi/L	
Gross beta	10 21.82	2/2	3.46	13	—	Y	B207089	8	221	pCi/L	
Plutonium-238	0.00814 0.01	2/2	0.002316	0.01164	—	—	B207089	0.00898	0.04715	pCi/L	
Plutonium-239/240	0 0.087	25/25	-0.000272	0.009	J	V	B207089	0.002	—	pCi/L	
Radium-226	0.096	1/1	0.64	0.64	B	Y	B207089	0.64	1.29	pCi/L	
Strontium-89,90	0.25 1.6	4/4	-0.14	0.49	—	A	4287	0.17	1.2	pCi/L	2
Strontium-90	0	1/1	1.31	1.31	—	—	B207089	1.31	—	pCi/L	
Tritium	0 820	37/37	141	400	U	—	B207089	97	13,413	pCi/L	
Uranium-233,-234	0 0.61	4/4	2.8	20.09	—	A	4087	7.8	—	pCi/L	
Uranium-235	0 0.74	4/4	0.062	0.7962	—	A	4287	0.456	5.2	pCi/L	
Uranium-238	0 0.61	4/4	1.5	13.23	—	A	4087	5	114	pCi/L	
Volatile Organic Compounds											
[illegible]	0.1 - 5	[illegible]	0.1	0.1	J	—	[illegible]	[illegible]	[illegible]	µg/L	4.5
[illegible]	0.1 - 5	[illegible]	0.1	[illegible]	B	—	[illegible]	[illegible]	10	µg/L	4.5
[illegible]	0.1 - 5	[illegible]	0.1	1	[illegible]	—	[illegible]	[illegible]	4	µg/L	4.5

Table 2-8
Analytes Detected in UHSU Groundwater Downgradient of the Dam

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background $UTL_{99/99}$ Concentration	Units	PCOC
Indicator Parameters											
Ammonia	30 100	5/14	80	214		Y	B207089	75	-	µg/L	
Bicarbonate as $CaCO_3$	1 000 10 000	32/32	38 000	670 000	·	V	B207089	311 825	–	µg/L	
Carbonate as $CaCO_3$	1 000 10 000	8/24	0	12 000	-	V	4087	1 764	–	µg/L	
Chemical oxygen demand	0 10 000	13/16	4 800	21 000	-	V	4287	10 048	·	µg/L	
Chloride	200 100 000	29/29	12 000	530 000	–	V	B207089	311 351	63 635	µg/L	1 2
Cyanide	5 100	2/22	1	5 6	B	V	B207089	8	12	µg/L	
Fluoride	0 100	32/32	230	3 400	–	–	4087	692	2 024	µg/L	1
Nitrate/nitrite	20 2 800	32/35	20	72 000	–	V	B206989	7 714	55 685	µg/L	1 2
Orthophosphate	10 50	12/21	6	150	-	JA	4287	30 14	53	µg/L	1 2
pH	0 1	3/3	7 6	7 73	–	Y	B207089	7 7	·	pH	
Silica	400	10/10	2 600	9 000	·	·	4087	4 460	35 735	µg/L	
Specific conductivity	1	2/2	3 105 2	3 110	·	Y	B207089	3108		µmhos/cm	
Sulfate	1 000 100 000	32/32	33 000	19 000 000			B207089	1 081 886	613 607	µg/L	1 2
Total dissolved solids	5 000 14 000	32/32	280 000	5 100 000		V	B206989	1 529 688	–	µg/L	
Total organic carbon	1 000 5 000	15/17	190	10 500	-	Y	4087	4 190		µg/L	
Total suspended solids	4 000 5 000	30/32	4 000	442 000	–	V	4287	74 484	1 402 588	µg/L	

Notes

All analytes are total analytes unless otherwise noted
Organic analytes with zero hits are not reported
Metal analytes with zero hits are reported
All radionuclide results are considered hits
The minimum result may be a hit or not a hit.
The maximum detection may only be a hit.
In calculating the mean one half of the detection limit is used for those results that are not hits

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be PCOC by inferential statistics test(s)
3 Analyte not considered a PCOC because it is a nutrient.
4 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
5 Analyte not considered a PCOC because of infrequent detection and/or detection in blanks or background samples

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Table 2-8
Analytes Detected in UHSU Groundwater Downgradient of the Dam

Data Qualifiers

__	data qualifier or validation field in database is blank.
B	for inorganics, reported value is < CRDL but > IDL (estimated value).
B	for organics, analyte is also detected in blank, for common lab contaminants include as detection if blank result > 10 times detection limit, for all other organics include if blank result > 5 times detection limit.
J	for inorganics, value > IDL but control sample analysis not within control limits (estimated value).
J	for organics, MS data indicate presence of compound but below detection limit (estimated value).
N	for inorganics, spiked sample recovery is not within control limits (estimated value)
U	for inorganics and organics, analyte analyzed but not detected at the quantitation limit.

Data Validation Codes

__	data qualifier field in database is blank.
A	acceptable result.
JA	acceptable result (for estimated value).
V	valid result.
Y	analytical results in validation process.

Definitions

CRDL	contract-required detection limit
IDL	instrument detection limit
PCOC	potential contaminant of concern
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level

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Table 2-9
Analytes Detected in LHSU Groundwater Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL[illegible] Concentration	Units	PCOC
Metals											
Aluminum	200	1/1	2 490	2 490	N	JA	4187	2 490	13 788	µg/L	
Antimony	60	1/1	28 1	28 1	B	JA	4187	28 1	1 269	µg/L	
Barium	200	1/1	387	387		V	4187	387	1 424	µg/L	
Calcium	5 000	1/1	108 000	108 000	--	V	4187	108 000	127 687	µg/L	2
Chromium	10	1/1	60 7	60 7	-	V	4187	60 7	1 210	µg/L	
Cobalt	50	1/1	3 1	3 1	B	V	4187	3 1	1 237	µg/L	
Copper	25	1/1	16 9	16 9	B	V	4187	16 9	1 338	µg/L	
Iron	100	1/1	2 400	2 400		JA	4187	2 400	18 339	µg/L	
Lead	3	1/1	4 4	4 4	–	V	4187	4 4	22	µg/L	
Lithium	100	1/1	91 9	91 9	B	V	4187	91 9	150	µg/L	
Magnesium	5 000	1/1	26 200	26,200	-	V	4187	26,200	28 140	µg/L	2
Manganese	15	1/1	121	121	·	V	4187	121	615	µg/L	
Molybdenum	200	1/1	24	24	B	V	4187	24	1 241	µg/L	
Nickel	40	1/1	48 4	48 4	–	V	4187	48 4	1 266	µg/L	
Potassium	5 000	1/1	6,220	6 220	–	V	4187	6,220	8 801	µg/L	2
Selenium	5	1/1	3	3	B	V	4187	3	5	µg/L	
Sodium	5 000	1/1	437 000	437 000	–	V	4187	437 000	659 404	µg/L	2
Strontium	200	1/1	1 470	1 470	–	V	4187	1 470	1 725	µg/L	
Vanadium	50	1/1	11 6	11 6	B	V	4187	11 6	1 274	µg/L	
Zinc	20	1/1	52 6	52 6	E	JA	4187	52 6	1 401	µg/L	

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Table 2-9
Analytes Detected in LHSU Groundwater Downgradient of the Landfill

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Radionuclides											
Americium-241	0.00377 0 01	4/4	0	0 00696	—	Y	59094	0.004	0 072	pCi/L	
Cesium-137	1	1/1	0.3585	0 3585	J	—	B207189	0.3585	1 05	pCi/L	
Gross alpha	1	1/1	8.4	8.4	—	V	0686	8.4	133	pCi/L	
Gross beta	2.9	1/1	5.4	5.4	—	V	0686	5.4	110.7	pCi/L	
Plutonium-238	0.01 0.0119	3/3	-0.00257	0.002145	J	—	B207189	0.00007	—	pCi/L	
Plutonium-239/240	0 0 01	4/4	0.0006231	0.01192	—	A	B207189	0.006	—	pCi/L	
Radium-226	0.5	1/1	1.5	1 5	—	—	4187	1.5	—	pCi/L	
Tritium	200 910	26/26	173	300	U	V	B207189	31	1,779	pCi/L	
Uranium 233, 234	0 14	1/1	3.24	3.24	—	A	4187	3.24	—	pCi/L	
Uranium-235	0.06	1/1	0.08	0 08	—	A	4187	0.08	0.27	pCi/L	
Uranium-238	0.13	1/1	1.2	1.2	—	A	4187	1.2	—	pCi/L	
Volatile Organic Compounds											
Acetone	10 - 100	[illegible]	4	10	B	—	[illegible]	[illegible]	12	µg/L	[illegible]
[illegible]	[illegible]	[illegible]	0.2	1	J	—	4187	[illegible]	—	µg/L	[illegible]
[illegible]	[illegible]	[illegible]	0.1	16	—	V	[illegible]	[illegible]	12	µg/L	[illegible]
Toluene	[illegible]	[illegible]	0.1	[illegible]	J	A	[illegible]	[illegible]	—	µg/L	[illegible]
[illegible]	[illegible]	1/40	1	[illegible]	J	A	4187	[illegible]	4	µg/L	[illegible]
Indicator Parameters											
Ammonia	30.0 100	2/4	100	513	—	Y	4187	170	—	µg/L	
Bicarbonate as $CaCO_3$	1 000 10 000	38/38	1 000	180 000	—	V	0686	116,371	—	µg/L	
Carbonate	1 000 10,000	2/8	1 000	23,000	—	V	0686	8,000	17 826	µg/L	1
Carbonate as $CaCO_3$	1 000 10,000	19/30	0	220,000	—	V	B207189	30,122	—	µg/L	

Table 2-9
Analytes Detected in LHSU Groundwater Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Location of Maximum Detection	Mean	Background UTL Concentration	Units	PCOC
Chemical Oxygen Demand	5 000 10 000	10/10	5 000	37 000	–	V	4187	14 470	–	µg/L	
Chloride	200 50 000	36/36	12 000	1 100 000			4187	572 823	532 358	µg/L	
Fluoride	100	37/37	300	1 500	–	V	0886	792 4	2 303	µg/L	
Nitrate/nitrite	20 5 000	35/38	20	2 400	–	V	0886	1 287	4 180	µg/L	
Nitrite	20 5 000	1/3	20	250	–	–	4187	920	4 859	µg/L	
Orthophosphate	10 50	2/13	10	80	–	–	4187	13 46	51	µg/L	1
pH		2/2	8 8	12	–		B207189	10	–	pH	
Silica	400	15/15	2 300	6 200			0886	3 460	12 145	µg/L	
Sodium fluoride	100	1/1	650	650		V	4187	650	–	µg/L	
Sodium sulfate	10 000	1/1	53 000	53 000		V	4187	53 000		µg/L	
Solids nonvolatile suspended	5 000	1/1	138 000	138 000		JA	B207189	138 000		µg/L	
Specific conductivity	10	2/2	490	3 300	–	Y	4187	1 895		µmhos/cm	
Sulfate	2 000 10 000	37/37	6 000	79 000	–	JA	B207189	27 908	992 074	µg/L	
Total dissolved solids	10 000 14 000	38/38	230 000	2 000 000	–	V	4187	1 241 658	2 059 573	µg/L	
Total organic carbon	1 000 5 000	11/13	1 000	4 120	–	Y	0886	2 105		µg/L	
Total suspended solids	4 000 5 000	36/37	5 000	450 000	–	V	0886	137 122	2 956 564	µg/L	

Notes

All analytes are total analytes unless otherwise noted.
Organic analytes with zero hits are not reported
Metal analytes with zero hits are reported
All radionuclide results are considered hits.
The minimum result may be a hit or not a hit.
The maximum detection may only be a hit.
In calculating the mean one half of the detection limit is used for those results that are not hits
Because of the small number of site samples inferential statistics were not performed Only the hot measurement test was used to compare site data to background data.

Table 2-9
Analytes Detected in LHSU Groundwater Downgradient of the Landfill

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte not considered a PCOC because it is a nutrient.
3 All detected organic analytes are considered PCOCs unless eliminated by professional judgment.
4 Analyte not considered a PCOC because of infrequent detection and/or detection in blanks or background samples.

Data Qualifiers

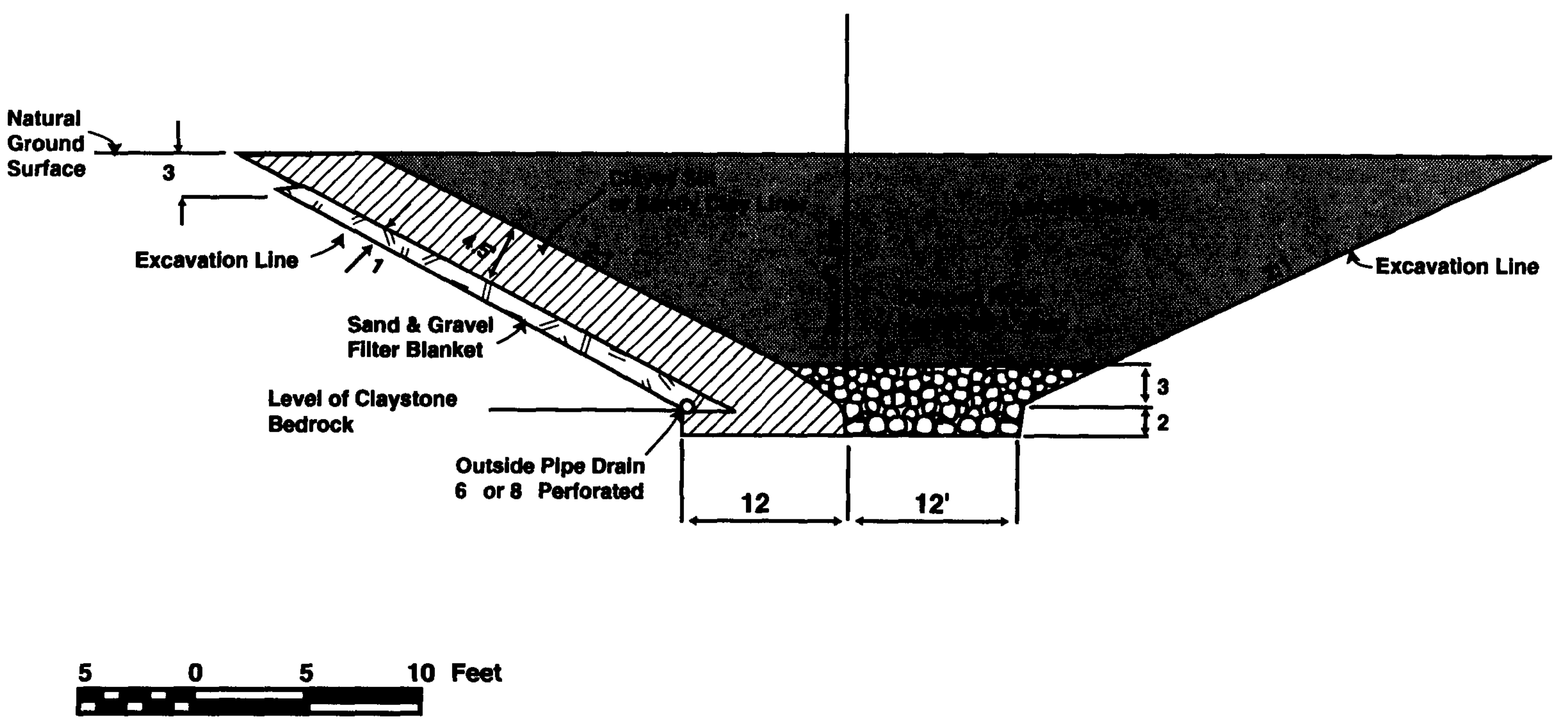
—	data qualifier or field validation field in database is blank.
—	for inorganics, duplicate analysis is not within control limits (estimated value)
B	for inorganics, reported value is < CRDL but > IDL (estimated value).
B	for organics, analyte is also detected in blank, for common lab contaminants include as detection if blank result > 10 times detection limit, for all other organics include if blank result > 5 times detection limit.
E	for inorganics, value is an estimate due to interference (estimated value).
J	for inorganics, value > IDL but control sample analysis not within control limits (estimated value).
J	for organics, data indicate presence of compound but below detection limit (estimated value).
N	for inorganics, spiked sample recovery is not within control limits (estimated value).

Data Validation Codes

—	data qualifier field in database is blank.
A	acceptable result.
JA	acceptable result (for estimated value).
V	valid result.
Y	analytical results in validation process.

Definitions

CRDL	contract-required detection limit
IDL	instrument detection limit
PCOC	potential contaminant of concern
$UTL_{99/99}$	upper tolerance limit of the 99th percent confidence level



Adapted from Rockwell International 1982

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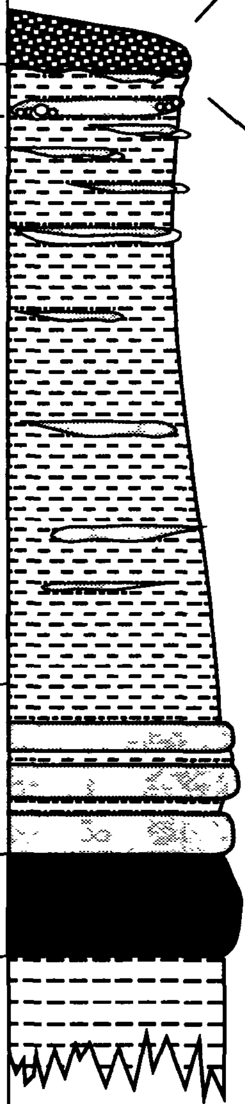
Typical Existing Groundwater-Intercept System Section

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 2 2

G95ESVM/IRA DD OU 7/Leachate Section 2510 III

Age	Formation	Thickness (feet)
Quaternary	Rocky Flats Alluvium/ Colluvium	0 30
Cretaceous	Arapahoe Formation	0 20
	Laramie Formation	600-800 upper interval 300 500 lower interval 300
	Fox Hills Sandstone	90-140
	Pierre Shale and older units	



Clayey Sandy Gravels – reddish brown to yellowish brown matrix grayish orange to dark gray poorly sorted angular to subrounded cobbles coarse gravels coarse sands and gravelly clays varying amounts of caliche

Claystones Silty Claystones and Sandstones – light to medium olive gray with some dark olive-black claystone silty claystone and fine-grained sandstone weathers yellowish orange to yellowish brown a mappable light to olive gray medium- to coarse grained frosted sandstone to conglomeratic sandstone occurs locally at the base (Arapahoe marker bed or No 1 sandstone)

Claystones Silty Claystones, Clayey Sandstones and Sandstones – kaolinitic light to medium gray claystone and silty claystone and some dark gray to black carbonaceous claystone thin (2) coal beds and thin discontinuous very fine to medium-grained moderately sorted sandstone interval (No 2 through No 5 sandstones)

Sandstones Claystones and Coals – light to medium gray fine to coarse grained moderately to well sorted silty immature quartzose sandstone with numerous claystones and subbituminous coal beds and seams that range from 2 to 8 thick)

Sandstones – grayish orange to light gray calcareous fine-grained subrounded glauconitic friable sandstone

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Source EG&G 1992a

G95\ES\IMIRA DD OU 7\Gen Strat 2501 mdw

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Generalized Stratigraphic Section

Phase I IM/IRA DD | Operable Unit No 7
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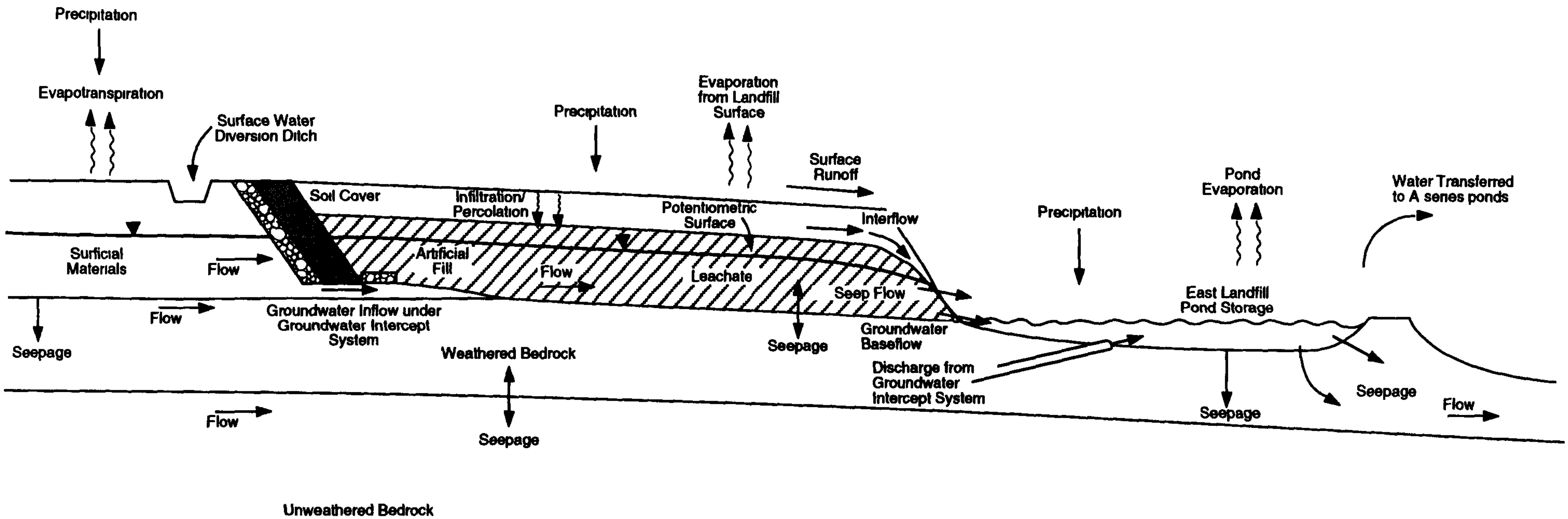
Present Landfill Area Cross Section



Not to scale

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Conceptual Flow Model for OU 7

Phase I IM/IRA DD	Operable Unit No 7
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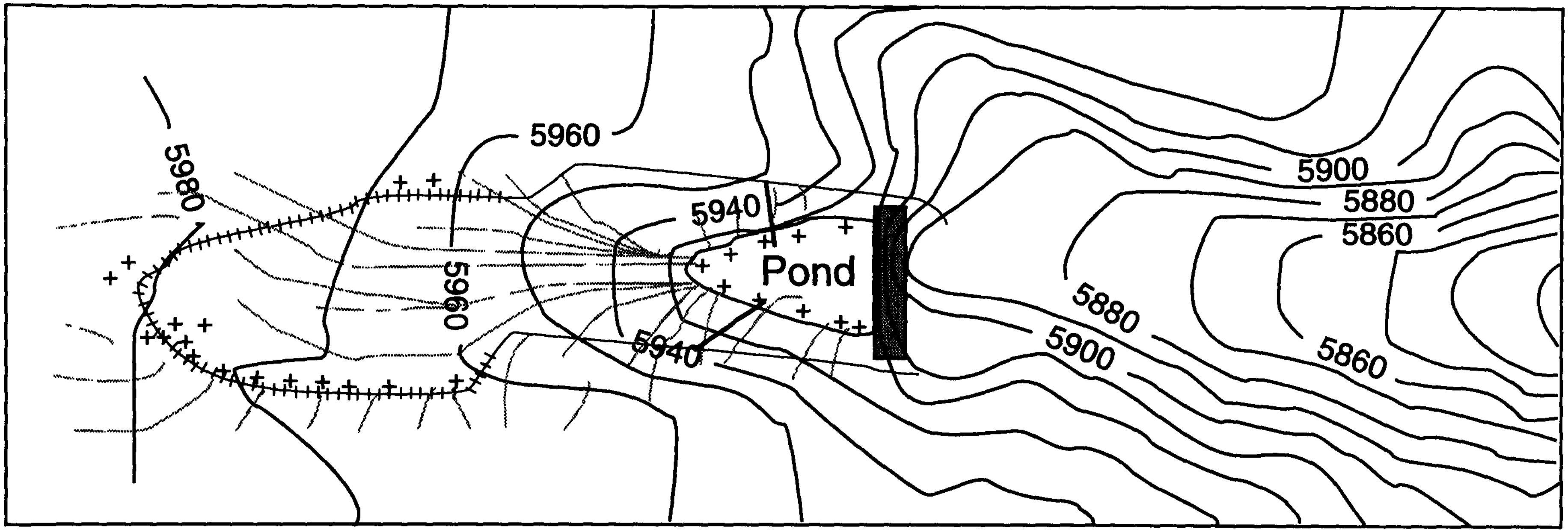
G95ES\IMIRA DD OU 7\Conceptual flow model 2510



(perforated line symbol)	Existing groundwater intercept system, perforated
(solid line symbol)	Existing groundwater intercept system, nonperforated
(shaded box symbol)	Dam (low hydraulic conductivity)
+	Particle entering boundary

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Groundwater Flowpaths from the Landfill

Phase I IM/IRA DD — Operable Unit No 7

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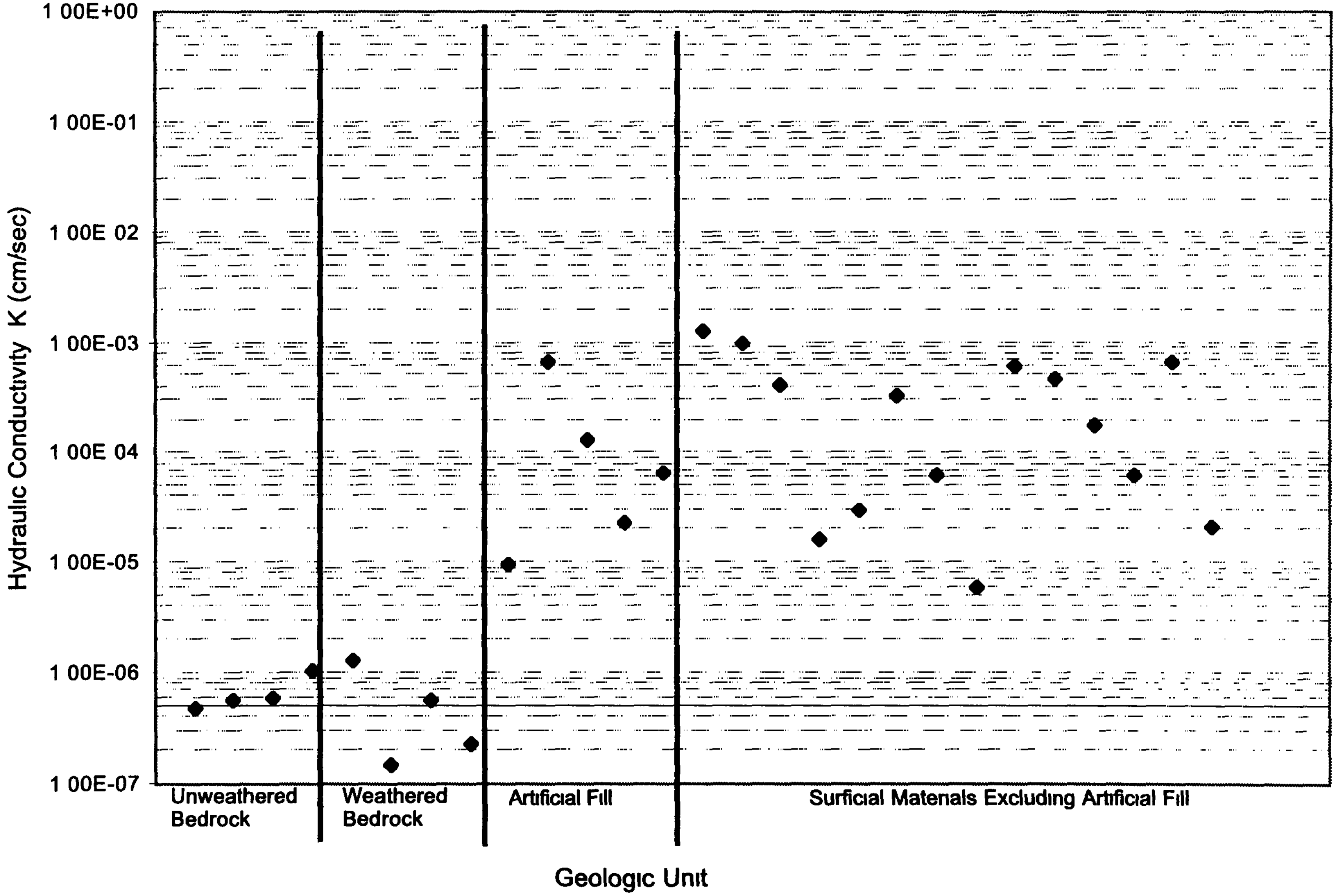
G95ESUM/IRA DD OU 7GW Flowpaths 2510.ill

Figure 2-8
Hydraulic Conductivity Measurements for Each Geologic Unit



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3 Development of Remedial Action Objectives to Reduce Site Risks

This section presents the process used to develop RAOs or response actions Preliminary RAOs are identified for each medium risks are defined using a conceptual site model, potential exposure pathways associated with each medium are identified and risks to human health and the environment are evaluated using a focused or streamlined risk assessment approach as recommended in EPA guidance for presumptive remedies (EPA 1993a) Compliance with ARARs is assessed by comparing chemical-specific ARARs for surface water and groundwater to mean concentrations detected at OU 7 and by identifying location-specific and action-specific ARARs Final RAOs are developed by eliminating preliminary RAOs for which there is no risk to the potential receptor, analytes do not exceed ARARs, or the exposure pathway is incomplete Final RAOs are used for the identification and screening of technologies presented in Section 4

3 1 Preliminary Remedial Action Objectives

In order to meet the overall objective of protecting human health and the environment under CERCLA (EPA 1991a) preliminary RAOs were developed for each medium RAOs are medium-specific or operable unit-specific goals for protecting human health and the environment (EPA 1988)

RAOs for presumptive remedy components of OU 7 (the landfill), which will remain a long-term waste management area, are specified in EPA guidance and include the following (EPA 1993a)

- Prevent direct contact with landfill contents
- Minimize infiltration and resulting contaminant leaching to groundwater
- Control surface-water run-off and erosion
- Control landfill gas (treat as needed)
- Collect and treat leachate at the source (as needed)
- Control groundwater at the source to contain the plume

RAOs for the other components at OU 7 may include the following as needed

- Remediate surface water in the East Landfill Pond (as needed)
- Remediate sediments in the East Landfill Pond (as needed)
- Remediate wetland areas (as needed)
- Remediate surface soils in spray evaporation areas (as needed)
- Remediate subsurface geologic materials downgradient of the landfill (as needed)
- Remediate groundwater downgradient of the landfill (as needed)

To evaluate alternatives in terms of overall protection of human health and the environment, the manner in which site risks identified in the conceptual site model are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls was considered (EPA 1991a) Containment will accomplish RAOs for the presumptive remedy components at OU 7 by addressing all pathways associated with the source RAOs for the other components will be evaluated in terms of exposure pathways, risk, and compliance with ARARs in the following sections The anticipated future land use for the area surrounding the landfill is open space (EPA 1995a) There are no plans for future development of groundwater for any use at OU 7 Also, existing information shows that there is only limited availability of groundwater downgradient of the landfill (Section 2 3)

3 2 Conceptual Site Model for Defining Risks

Data collected during the Phase I RFI/RI, presented in the OU 7 Final Work Plan (DOE 1994a) and summarized in Section 2, were used to develop a conceptual site model The model identifies the suspected sources, contaminant release and transport mechanisms, exposure points or affected media, and exposure routes (Figure 3-1)

Contaminant sources include solid and liquid hazardous and nonhazardous wastes in the Present Landfill, soils in IHSS 203 where hazardous wastes were stored, and asbestos in the asbestos-disposal areas Mechanisms for contaminant releases include the following

- Erosion of interim cover material exposing landfill contents directly, or release of landfill contents by erosion and run-off
- Volatilization of landfill gas
- Leachate seep discharge to the East Landfill Pond
- Spray evaporation of pond water
- Leaching of contaminants into the groundwater

Primary transport mechanisms are movement of landfill gas, movement with surface-water run-off, movement with the leachate seep, and movement with groundwater Spray evaporation activities ceased in 1994, therefore, continued releases are no longer occurring by this mechanism.

Contaminants in landfill gas may migrate into the atmosphere After contaminants from the leachate seep or from run-off have entered the East Landfill Pond, they may remain suspended or dissolved in surface water, be deposited in sediment at the bottom of the pond, be discharged to groundwater, or be taken up by plants or aquatic life in wetland areas After contaminants in water from the pond have been sprayed onto the surrounding slopes and have infiltrated the soil they may subsequently be leached out of the soil by run-off or infiltration/percolation or be dispersed by the wind

After contaminants have entered the groundwater, several migration pathways are possible Groundwater in the UHSU could discharge to surface water in the East Landfill Pond Groundwater in the UHSU could also migrate downgradient discharge to surface water in No Name Gulch, migrate with surface water to the confluence of No Name Gulch and North Walnut Creek, and eventually migrate offsite This migration pathway is not likely because groundwater modeling has shown that migration is slowed considerably or possibly even stopped by the dam Discharge from groundwater to surface water below the dam is not expected because the intermittent stream in No Name Gulch is a losing stream that discharges to groundwater Groundwater in the UHSU could migrate slowly downgradient remaining as groundwater This migration pathway is the most likely as shown by groundwater modeling Groundwater in the UHSU could also seep into the confining layers of the unweathered bedrock and eventually reach the sandstones of the LHSU However, hydraulic conductivity values for the confining layer are low and downward seepage is minimal (Section 2 3) Contaminants in groundwater may also be deposited in subsurface geologic materials downgradient of the landfill

VOCs detected in landfill leachate could be transported by seeps surface-water run-off or groundwater During transport, VOCs in groundwater may be subject to adsorption, hydrolysis, and biological degradation under aerobic or anaerobic conditions As stated above discharge from groundwater to surface water below the dam is not expected and contaminants are most likely absorbed or migrate within groundwater

Potential exposure pathways associated with OU 7 (Figure 3-1) include ingestion and dermal contact with waste materials, inhalation of dust, and physical hazards from the source, inhalation and explosion of landfill gas, inhalation and ingestion of and dermal contact with leachate from the seep and surface water and sediment from the East Landfill Pond inhalation and ingestion of dermal contact with and external irradiation from soils in spray evaporation areas and subsurface geologic materials downgradient of the landfill, and inhalation and ingestion of, and dermal contact with groundwater from wells downgradient of the landfill

Because the contents of the landfill IHSS 203, and the asbestos-disposal areas will be contained, the conceptual site model is most useful for identifying areas beyond the landfill that may pose a threat to human health or the environment Risks posed by these media are evaluated below

3 3 Evaluation of Risks

Baseline risk assessments evaluate the potential threat to human health and the environment in the absence of any remedial action and often provide both the basis for determining if remedial action is necessary and the justification for performing remedial actions Under the presumptive remedy approach, a quantitative baseline risk assessment is not necessary to evaluate if the containment remedy addresses pathways and contaminants of concern associated with the source Rather, all potential exposure pathways can be identified using the conceptual site model and compared to the pathways addressed by the containment presumptive remedy (EPA 1993a) For pathways not addressed by the containment presumptive remedy, a focused or streamlined risk assessment was performed The methodology for the focused risk assessment is described below

3 3 1 Methodology to Determine if a Response Action is Necessary

Leachate resulting from land-disposed hazardous wastes classified by more than one waste code under RCRA Subpart D or from a mixture of wastes classified under RCRA Subparts C and D is designated F039 RCRA-listed waste contained in groundwater (6 CCR 1007-3 Part 261) The method used to determine the hazardous waste classification and resultant treatment standards for various environmental media at OU 7 is shown in Figure 3-2 (DOE 1995c) The first step is to determine if land disposal of hazardous waste has occurred. The second step is to ascertain if leachate exists by application of the "derived from" rule The third step is to determine if multisource leachate (F039) exists And, the final step is to determine if the "contained in" policy applies to these environmental media If it does, the waste must meet standards or be remediated or treated to meet standards When standards are met, the media no longer "contains" listed waste

Only leachate within the landfill is considered F039 RCRA-listed waste. Leachate that discharges at the seep, surface water in the East Landfill Pond, pond sediments, surface soils in spray evaporation areas, and subsurface geologic materials and groundwater downgradient of the landfill constitute leachate "contained in" environmental media Therefore, risk-based analyses were performed to determine if these media pose a threat to human health or the environment

Methods used to evaluate chemical data for samples collected from these environmental media are shown in Figure 3-3 The methodology uses PCOCs previously identified following the Gilbert methodology (EG&G 1994b) and encompasses a focused risk assessment that includes a preliminary remediation goal (PRG) screen and risk calculations All organics detected were considered PCOCs

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The risk evaluation is used to determine if remediation of other (non-presumptive remedy) media is required

Land-use scenarios used for the PRG screen and the risk calculations were based on recommendations from the Future Land-Use Working Group (DOE 1995d) and include an open-space scenario for landfill leachate, surface water, sediment, and soil a construction-worker scenario for subsurface geologic materials, and a future onsite office-worker scenario for groundwater Residential uses have been eliminated from the future land-use plan (DOE 1995d)

Sitewide PRGs were developed for use in Rocky Flats environmental remediation activities for analytes that have toxicity criteria and are based on a target cancer risk of 1E-06 or a hazard index (HI) of 1 PRGs used in this report are from the Final Programmatic Risk-Based Preliminary Remediation Goals (DOE 1995e) Draft Programmatic PRGs for Rocky Flats Plant—Open Space (DOE 1995e), and Programmatic Preliminary Risk-Based Remediation Goals for RFETS (DOE 1995g) The maximum detected concentration of each PCOC as identified in Section 2 5, was compared to the PRG for that analyte If the maximum concentration of an analyte was less than the PRG the analyte was dropped from further consideration If the maximum detected concentration of an analyte was greater than the PRG, the analyte was evaluated in the focused risk assessment Maximum concentrations are used for the PRG screen to provide a conservative approach that is consistent with the CDPHE risk-based conservative screen (CDPHE/EPA/DOE 1994) performed prior to baseline risk assessments at Rocky Flats

None of the PCOCs in landfill leachate, surface water, sediment, or subsurface geologic materials failed the PRG screen, therefore, PCOCs in these media were dropped from further consideration Risks were estimated for PCOCs in surface soil and groundwater that failed the PRG screen using the 95 percent upper confidence limit of the mean concentration (UCL_{95}) Risks were calculated for incidental ingestion and particulate inhalation of, and external irradiation from surface soil by an open-space receptor and for groundwater ingestion by a future onsite office worker Risks were not calculated for dermal exposure to surface soils because the OU 7 surface-soil PCOCs included only metals and radionuclides and in accordance with EPA guidance, dermal exposure to metals and radionuclides cannot be quantified (EPA 1989a) Site-specific exposure factors and open-space exposure parameters were used to calculate risks (DOE 1995h, DOE 1995i) Environmental media with carcinogenic risks that fall below or within the EPA acceptable risk range of 1E-04 to 1E-06 and noncarcinogenic risks that are below the HI of 1 do not require a response action (EPA 1993a)

A screening-level ecological risk assessment was performed to determine if PCOCs in leachate surface water and sediment present an unacceptable toxicological risk to aquatic life and wildlife Exposure and toxicity of PCOCs in sediment and pond water to aquatic life are used to determine if conditions in the pond are adequate to support a functional aquatic habitat. Potential toxicity of leachate, pond water, and sediment to aquatic-feeding avian and mammalian wildlife species (mallards and raccoons) and to non-aquatic wildlife species (mule deer, coyotes, and Preble's meadow jumping mouse) was evaluated

Ecological exposures and risk estimations are based on the same data used to characterize the nature and extent of contamination (Section 2.5) and the potential human health risks presented below Risks were characterized by comparing chemical concentrations in abiotic media to literature-based benchmarks to determine if PCOCs are present in concentrations that could be toxic to aquatic life or wildlife (DOE 1995b, DOE 1995j) Conservative assumptions were adopted in developing benchmarks and estimating exposures to minimize the chance of underestimating risk Results are summarized below and presented in detail in Appendix D

3 3 2 Present Landfill, IHSS 203, and Asbestos-Disposal Areas

A quantitative risk assessment is not necessary for the source area. Potential exposure to soils and waste material in the Present Landfill, IHSS 203, and asbestos-disposal areas from direct contact, volatilization, and/or wind will be addressed by the presumptive remedy for source containment (Figure 3-4) The proposed landfill cover will prevent exposure to source materials In accordance with EPA guidance, it is not necessary or appropriate to estimate the risk associated with future residential land use because such use would be incompatible with the need to maintain the integrity of the containment system (EPA 1993a)

3 3 3 Landfill Gas

A quantitative risk assessment is not necessary for landfill gas Potential exposure to landfill gas will be addressed by the presumptive remedy for gas control (Figure 3-5) The proposed landfill cover will include a gas-venting layer Gas emissions will be contingent upon air-emission ARARs

3 3 4 Landfill Leachate at the Seep

A quantitative risk assessment is not necessary for leachate in the source area. However, a focused risk assessment was performed as a conservative measure to evaluate the potential risk from ingestion of leachate Potential exposure to landfill leachate will be addressed by the presumptive remedy for source containment (Figure 3-6) The proposed landfill cap will cover the seep area and prevent exposure to leachate, reduce contaminant leaching to groundwater, and ultimately reduce leachate

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generation and migration In addition, leachate will be intercepted and treated at the seep before closure as an accelerated action for OU 7

Potential human receptors are open-space recreational users A PRG screen was performed for landfill leachate (SW097) using an open-space exposure scenario (DOE 1995f) Results of the PRG screen are presented in Table 3-1 None of the 35 PCOCs from Section 2 5 3 Nature and Extent of Contamination in Landfill Leachate at the Seep, exceeded the PRGs for an open-space recreational user Therefore there is no risk to human health from inhalation or incidental ingestion of, or dermal exposure to leachate at the seep

Potential ecological receptors include terrestrial and avian wildlife A screening-level ecological risk assessment was performed to determine if PCOCs in leachate from the seep present an unacceptable toxicological risk to aquatic life and wildlife (Appendix D) Baseline risk estimates were based on the conservative assumption that receptors spend all of their time at the East Landfill Pond

Under these conditions, the HI was greater than 1 for mallards, raccoons and coyotes (mallard HI = 50 raccoon HI = 3, mule deer HI = 0 08, coyote HI = 3, Preble s meadow jumping mouse HI = 0 02) Risk to mallards is from potential exposure to naphthalene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate, and phenanthrene Risk to raccoons is from potential exposure to naphthalene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate and total xylenes Risk to coyotes is from potential exposure to naphthalene, 2-methylnaphthalene, phenanthrene, and barium

Hazard quotients for individual PCOCs and hazard indices are estimated for risks associated with no-observed-adverse-effects levels (NOAELs), risk is lower for exceeding lowest-observed-adverse-effects levels (LOAELs) Sources of uncertainty for ecological risk are the actual bioavailability of PCOCs, assumptions about frequency and duration of exposures and importance of the East Landfill Pond as a habitat resource (Appendix D) Because it was assumed that mallards, raccoons, and coyotes spend all of their time at the pond and drink exclusively from the seep, risks were conservatively overestimated

3 3 5 Surface Water in the East Landfill Pond

A focused or streamlined risk assessment is necessary for surface water in the East Landfill Pond because surface water is not a component of the presumptive remedy Potential exposure pathways identified in the conceptual site model can be used to determine affected media exposure routes and potential receptors (Figure 3-7) After contaminants from the leachate seep or from run-off have entered the East Landfill Pond they may remain suspended or dissolved in surface water be discharged to groundwater or be taken up by plants or aquatic life in wetland areas Potential exposure pathways evaluated include inhalation and incidental ingestion of, and dermal contact with surface water in the East Landfill Pond

Potential human receptors include open-space recreational users A PRG screen was performed for pond water (SW098) using an open-space exposure scenario (DOE 1995f) Results of the PRG screen are presented in Table 3-2 None of the 15 PCOCs from Section 2 5 4, Nature and Extent of Contamination in Surface Water in the East Landfill Pond, exceeded the PRGs for an open-space receptor, and, therefore, no risk assessment was performed There is no risk to human health from inhalation, incidental ingestion, or dermal exposure of surface water from the East Landfill Pond

Potential ecological receptors include aquatic life and terrestrial and avian wildlife A screening-level ecological risk assessment was performed to determine if PCOCs in pond water present an unacceptable toxicological risk to aquatic life and wildlife (Appendix D) Only one of the surface water PCOCs (manganese) exceeded state water quality standards or risk-based benchmarks The cumulative risk, expressed as the HI, also did not exceed 1 These data are consistent with whole effluent toxicity tests performed on water samples from the pond Results of the literature-based toxicity screen, laboratory toxicity testing, and preliminary risk calculation indicate that pond water represents negligible risk to aquatic life Baseline risk estimates were based on the conservative assumption that receptors spend all of their time at the pond

Using these assumptions, the HI was greater than 1 only for mallards (mallard HI = 10, raccoon HI = 0 3, mule deer HI = 0 01, coyote HI = 0 03, Preble's meadow jumping mouse HI = 0 03) Risk to mallards is from potential exposure to bis(2-ethylhexyl)phthalate and di-n-butyl phthalate Sources of uncertainty for ecological risk are the actual bioavailability of PCOCs, assumptions about frequency and duration of exposures, and importance of the East Landfill Pond as a habitat resource Because it was assumed that mallards spend all of their time at the East Landfill Pond, risk to mallards was conservatively overestimated

The East Landfill Pond includes approximately 3 percent of the open-water habitat and 6 percent of the available shoreline habitat at Rocky Flats, the adjacent wetland represents approximately 1 6 percent of the total wetland areas at Rocky Flats (COE 1994) Risks to vegetation were evaluated as part of the screening-level ecological risk assessment Risks to vegetation are minimal (Appendix D)

Since the East Landfill Pond was constructed only 20 years ago, it is probably not a historically important component of the local ecosystem (Appendix D). The pond apparently does not contain fish or crayfish populations. Without a complex aquatic food web that includes upper-level aquatic consumers, the pond is a limited resource for aquatic-feeding wildlife The pond area has been identified as potential habitat for one federal candidate species, Preble's meadow jumping mouse (DOE 1995b), but its occurrence there has not been confirmed It is possible that other state or federally protected species may use the pond area occasionally but the resources at the East Landfill Pond are not critical to any of them (DOE 1995j, Appendix D)

3 3 6 Sediments in the East Landfill Pond

A focused or streamlined risk assessment for sediment in the East Landfill Pond is necessary because pond sediment is not a component of the presumptive remedy Potential exposure pathways identified in the conceptual site model can be used to determine affected media exposure routes and potential receptors (Figure 3-7) After contaminants from the leachate seep or from run-off have entered the East Landfill Pond, they may be deposited in sediment at the bottom of the pond or be taken up by plants or aquatic life in wetland areas Potential exposure pathways evaluated include inhalation and incidental ingestion of and dermal contact with sediment from the East Landfill Pond Potential human receptors include open-space recreational users

A PRG screen was performed for pond sediment using an open-space exposure scenario (DOE 1995g) Results of the PRG screen are presented in Table 3-3 None of the 20 PCOCs from Section 2 5 5, Nature and Extent of Contamination in Sediments from the East Landfill Pond exceeded the PRGs for an open-space user, and, therefore, no risk assessment was performed There is no risk to human health from inhalation or incidental ingestion of or dermal contact with sediment from the East Landfill Pond

Potential ecological receptors include aquatic life and terrestrial and avian wildlife A screening-level ecological risk assessment was performed to determine if PCOCs in sediment present an unacceptable toxicological risk to aquatic life and wildlife (Appendix D) Baseline risk estimates were based on the conservative assumption that receptors spend all of their time at the East Landfill Pond The HI for exposure of aquatic life to sediments was greater than 1,100 PCOCs contributing most to risk estimates were fluorene, anthracene, chrysene benzo(b)fluoranthene, and barium Results of toxicity tests performed on pond sediments are not consistent with these results and indicate no toxicity to aquatic life (Appendix D)

Preliminary risk calculations based on exposure estimations appear to overestimate risks to aquatic life Based on these calculations, risk of toxicity to sediment-associated organisms appears to be high, but results of site-specific surface-water and sediment toxicity tests indicate no toxicity (Appendix D) In addition, many of the species present in sediment samples are moderately tolerant of polluted sediments suggesting that conditions in the pond are not as toxic as indicated by the hazard quotients Risk to aquatic life appears to be minimal (Appendix D)

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Using these assumptions, the HI was greater than 1 for raccoons, mule deer, coyotes, and Preble's meadow jumping mice (mallard HI = 0 8, raccoon HI = 6, mule deer HI = 3, coyote HI = 4, Preble's meadow jumping mouse HI = 3) Risk to raccoons is from potential exposure to aluminum, vanadium, and arsenic Risk to mule deer, coyotes, and Preble's meadow jumping mice is from potential exposure to aluminum (Appendix D) Again, sources of uncertainty are bioavailability of PCOCs, assumptions about exposures, and importance of the pond as a habitat resource Although there is risk to terrestrial wildlife, it is unlikely that receptors spend all of their time at the East Landfill Pond, and therefore, the risk is conservatively overestimated

3 3 7 Surface Soils in Spray Evaporation Areas

A focused risk assessment for surface soils in spray evaporation areas is necessary because surface soils are not a component of the presumptive remedy Potential exposure pathways identified in the conceptual site model can be used to determine affected media, exposure routes, and potential receptors (Figure 3-8) After contaminants in water from the pond have been sprayed onto the surrounding slopes and have infiltrated the soil, they subsequently may be leached out of the soil by run-off or infiltration/percolation or dispersed by the wind Potential exposure pathways include particulate inhalation, ingestion, dermal contact, and external irradiation

Potential human receptors are open-space recreational users Risks were calculated for PCOCs identified in the combined 0- to 2-inch and 0- to 10-inch soil horizons in the vicinity of the East Landfill Pond Samples were collected from the landfill eastward across the spray evaporation areas and surrounding slopes and downwind below the dam A PRG screen was performed for surface soil using an open-space scenario (DOE 1995f) Results of the PRG screen are presented in Table 3-4 The UCL_{95} for each PCOC that failed the PRG screen was used to estimate the risks of incidental ingestion and particulate inhalation of, and external irradiation from surface soil for an open-space recreational user Risks were not calculated for dermal exposure to surface soils because the surface-soil PCOCs included only metals and radionuclides and, in accordance with EPA guidance, dermal exposure to metals and radionuclides cannot be quantified (EPA 1989a)

The methodology used to evaluate the risks of exposure to surface soil was taken from Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A (EPA 1989a) and Part B (EPA 1991b) The open-space scenario assumes that a recreational user visits the open-space area 25 times per year Exposure parameters for each pathway are presented in Tables 3-5, 3-6, and 3-7 (DOE 1995h) Intake factors were calculated using the equations listed below

Incidental Ingestion

$$\text{Chemical Intake Factor (mg/kg-day)} = \frac{IR \times ME \times EF \times ED}{BW \times AT}$$

$$\text{Radionuclide Intake Factor (mg)} = IR \times ME \times EF \times ED$$

where
- IR = ingestion rate
- ME = matrix effect in the GI tract (absorption factor)
- EF = exposure frequency
- ED = exposure duration
- BW = body weight
- AT = averaging time

Particulate Inhalation

$$\text{Chemical Intake Factor (m}^3\text{/day)} = \frac{IR \times 1/PEF \times RF \times DF \times ET \times EF \times ED}{BW \times AT}$$

$$\text{Radionuclide Intake Factor (kg)} = IR \times 1/PEF \times RF \times DF \times ET \times EF \times ED$$

where
- IR = inhalation rate
- PEF = particulate emission factor (standard default [EPA 1991b])
- RF = respirable fraction (PM-10)
- DF = respiratory deposition factor
- ET = exposure time
- EF = exposure frequency
- ED = exposure duration
- BW = body weight
- AT = averaging time

External Irradiation

$$\text{Intake Factor (years)} = ET \times SF \times EF \times ED$$

where
- ET = gamma exposure time factor
- SF = gamma shielding factor
- EF = exposure frequency ratio
- ED = exposure duration

Cancer slope factors and reference doses were taken from Health Effects Assessment Summary Tables (HEAST) (EPA 1994a) and Final Programmatic Risk-Based Preliminary Remediation Goals (DOE 1995e) which includes a compilation of current toxicity factor information Risks were calculated for ingestion particulate inhalation

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and external irradiation Results of the risk calculations are presented in Tables 3-8, 3-9, and 3-10 Carcinogenic risk is within the acceptable risk range for incidental ingestion by a child (4E-06), incidental ingestion by an adult (2E-06), particulate inhalation (2E-11), and external irradiation (6E-09) Noncarcinogenic risk (hazard index) is below 1 for incidental ingestion by a child (HI = 0 008) and incidental ingestion by an adult (HI = 0 0009) These results indicate that there is no risk to human health from incidental ingestion, particulate inhalation, or external irradiation from surface soils in spray evaporation areas

3 3 8 Subsurface Geologic Materials Downgradient of the Landfill

A focused or streamlined risk assessment for subsurface geologic materials downgradient of the landfill is necessary because subsurface soils are not a component of the presumptive remedy Potential exposure pathways identified in the conceptual site model can be used to determine affected media, exposure routes, and potential receptors (Figure 3-9). After contaminants from the leachate seep into the groundwater, they may migrate downgradient and be deposited in subsurface geologic materials Potential exposure pathways evaluated include particulate inhalation, ingestion, dermal contact, and external irradiation

A PRG screen was performed for subsurface geologic materials using an onsite construction-worker exposure scenario (DOE 1995g). Results of the PRG screen are presented in Table 3-11 None of the 10 PCOCs in colluvium or 8 PCOCs in weathered bedrock from Section 2 5 7, Nature and Extent of Contamination in Subsurface Geologic Materials Downgradient of the Landfill, exceeded the PRGs for construction workers, and, therefore, no risk assessment was performed There is no risk to human health from particulate inhalation and ingestion of, dermal contact with, and external irradiation from subsurface soils downgradient of the landfill.

3 3 9 Groundwater Downgradient of the Landfill

A focused risk assessment for groundwater downgradient of the landfill is necessary because groundwater that has migrated away from the source area is not a component of the presumptive remedy After contaminants have entered the groundwater, they most likely migrate downgradient through the UHSU to the confluence of No Name Gulch and North Walnut Creek and potentially migrate offsite Groundwater modeling has shown that migration is slowed considerably or possibly even stopped by the dam Discharge from groundwater to surface water downgradient of the dam is not expected The intermittent stream in No Name Gulch is a losing stream that discharges to groundwater Discharge does occur to the pond During transport, contaminants in groundwater may be subject to adsorption, hydrolysis, and biological degradation under aerobic or anaerobic conditions

Potential exposure pathways associated with groundwater downgradient of the landfill include inhalation and ingestion of and dermal contact with groundwater from downgradient wells (Figure 3-10) As recommended by the Future Land-Use Working Group potential human receptors for groundwater are future onsite office workers Risks were calculated for PCOCs identified in UHSU groundwater from two populations wells in the vicinity of the East Landfill Pond upgradient of the dam and wells downgradient of the dam These populations were evaluated separately to determine the downgradient limit of contamination In the event that groundwater collection and treatment were needed, the system could be designed to collect only contaminated groundwater instead of all groundwater downgradient of the landfill

A PRG screen was performed for groundwater using a future onsite office-worker scenario The maximum detected concentration of each PCOC was compared to the PRG for that analyte (DOE 1995e) Results of the PRG screen are presented in Table 3-12 If the maximum detected concentration or activity of an analyte was less than the PRG the analyte was dropped from further consideration If the maximum detected concentration of an analyte was greater than the PRG, the analyte was evaluated in the risk assessment A focused human health risk assessment was performed for groundwater in both populations using a future onsite office-worker groundwater-ingestion scenario The UCL_{95} for each PCOC that failed the PRG screen was used to calculate the risks of groundwater ingestion

The methodology used to assess risks at OU 7 was taken from Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual, Part A (EPA 1989a) The future onsite office-worker scenario assumes that a worker ingests 1 liter of water per day for 250 days per year Exposure parameters are presented in Table 3-13 (DOE 1995h) Intake factors were calculated using the equations listed below

Groundwater Ingestion

$$\text{Chemical Intake Factor (L/kg-day)} = \frac{IR \times FI \times EF \times ED}{BW \times AT}$$

$$\text{Radionuclide Intake Factor (liters)} = IR \times FI \times EF \times ED$$

where

IR	=	ingestion rate
FI	=	fraction ingested from the contaminated source
EF	=	exposure frequency
ED	=	exposure duration
BW	=	body weight
AT	=	averaging time

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Oral cancer slope factors and oral reference doses were taken from HEAST (EPA 1994a) and Final Programmatic Risk-Based Preliminary Remediation Goals (DOE 1995e), which includes a compilation of current toxicity factor information Results of the risk calculations are presented in Table 3-14

The carcinogenic risk from ingestion of UHSU groundwater in the vicinity of the pond upgradient of the dam is within the acceptable risk range of 1E-04 to 1E-06 (1E-05), however, the noncarcinogenic risk is above the acceptable risk or HI of 1 (HI = 3) The primary contributor to noncarcinogenic risk is selenium (HI = 1.5)

The risks from ingestion of UHSU groundwater downgradient of the dam are within the acceptable risk range (carcinogenic risk less than 1E-06, noncarcinogenic risk, HI = 0 2) Therefore, there is no risk to future onsite office workers from ingestion of UHSU groundwater downgradient of the dam. There is some potential risk associated with ingestion of UHSU groundwater in the vicinity of the East Landfill Pond upgradient of the dam However, the potential exposure pathway associated with groundwater downgradient of the landfill is incomplete There are no plans to develop groundwater in the future, therefore, no one will be ingesting groundwater from wells

3 4 Compliance with ARARs

Pursuant to the IAG, onsite remedial actions at OU 7 must comply with all applicable RCRA and CHWA requirements and must also address CERCLA requirements (DOE 1991b) CERCLA Section 121(d), as amended by SARA, requires that, at a minimum, any remedial action achieve overall protection of human health and the environment and comply with ARARs Laws included under this ARARs umbrella include all federal environmental laws and state standards more stringent than their federal counterpart State regulations promulgated under federally authorized programs are considered federal requirements (EPA 1990a) Because Rocky Flats is a DOE facility, DOE orders apply with the same force as applicable federal regulations (EPA 1989b)

Laws and regulations identified as ARARs are either applicable or relevant and appropriate Applicable requirements are those "cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental laws, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (40 CFR Part 300 5) Relevant and appropriate requirements are defined as "those standards that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site" (40 CFR Part 300 5)

ARARs are used to create a framework for determining the health and risk-based limits for remedial action and to develop remedial alternatives Ultimately, it is necessary to demonstrate that the final remedy addresses all pathways and contaminants of concern, not just those that trigger the need for remedial action (EPA 1991a) Onsite actions must comply only with the substantive aspects of ARARs, offsite activities must adhere to both substantive and administrative requirements Substantive requirements include cleanup standards or levels of control, administrative requirements prescribe methods and procedures such as fees, permitting, inspection, and reporting requirements

There are three types of ARARs chemical-specific, location-specific, and action-specific This division is a convenient way to categorize regulations in a way that ties them to the remedial process The following sections identify potential ARARs for OU 7 by type of requirement In addition, guidance to be considered (TBC) is identified where appropriate TBCs are advisories, criteria, or guidance that may be useful in developing CERCLA remedies (40 CFR Part 300 400[g][3]) TBCs may be used to supplement promulgated standards when the meaning of those standards is ambiguous or when they do not address a particular situation

3 4 1 Potential Chemical-Specific ARARs

Chemical-specific ARARs identify acceptable limits for an amount or concentration of a chemical that may be present in the environment These standards usually take the form of health-based or risk-based numerical limitations that restrict ambient concentrations of various chemical substances above a threshold level All applicable or relevant and appropriate federal chemical-specific standards (e g , maximum contaminant levels [MCLs] and land disposal restrictions [LDRs] universal treatment standards) must be complied with when determining appropriate cleanup levels for landfill leachate, surface water in the East Landfill Pond and groundwater downgradient of the landfill State ARARs must also be complied with if they are promulgated and are more stringent than federal standards For chemicals that do not have associated federal or state potential ARARs the practical quantitation limit (PQL) cited in the regulations, or 10 times the EPA Contract Laboratory Program detection limit when no PQL is cited is proposed Table 3-15 presents potential chemical-specific ARARs for surface water Table 3-16 presents potential chemical-specific ARARs for groundwater There are no chemical-specific ARARs for sediments or surface soils

3 4 1 1 Landfill Leachate at the Seep

Mean concentrations of all analytes detected in landfill leachate at the seep were compared to the potential chemical-specific ARARs for surface water Mean concentrations of three metals (aluminum manganese, and zinc), two SVOCs

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(2-methylnaphthalene, naphthalene), and five VOCs (benzene, methylene chloride, tetrachloroethane, vinyl acetate, and vinyl chloride) exceed potential ARARs (Table 3-17) Of these, the maximum detection of tetrachloroethane is less than the ARAR, however, the mean exceeds the ARAR because one-half the detection limit was used for non-detects in calculating the mean result, and the detection limits vary and can be quite high Vinyl acetate was detected in only one of 19 samples, and although this detection exceeds the ARAR, the single detection suggests that this detection is an outlier and is not representative of landfill leachate. The maximum detection of methylene chloride is from 1990 These data were never validated and are "B" qualified, indicating that they were detected in the laboratory blank These data are not appropriate for an ARARs comparison, and therefore tetrachloroethane, vinyl acetate, and methylene chloride are not considered further

Seven analytes exceed ARARs in landfill leachate aluminum, benzene, manganese, 2-methylnaphthalene, naphthalene, vinyl chloride, and zinc

3 4 1 2 *Surface Water in the East Landfill Pond*

Mean concentrations of all analytes detected in surface water in the East Landfill Pond were compared to the potential chemical-specific ARARs for surface water Mean concentrations of one metal (manganese) and one VOC (vinyl acetate) exceed potential ARARs (Table 3-18) Vinyl acetate was detected in only one of 19 samples, and although this detection exceeds the ARAR, the low detection frequency suggests that this detection is an outlier and is not representative of surface water in the pond Sixty percent of the manganese detections exceed the ARAR for manganese

3 4 1 3 *Groundwater Downgradient of the Landfill*

Mean concentrations of all analytes detected in UHSU groundwater in individual wells downgradient of the landfill (in the vicinity of the pond and downgradient of the dam) were compared to the potential chemical-specific ARARs for groundwater Mean concentrations of one metal (selenium), four VOCs (1,1-dichloroethane, benzene, carbon tetrachloride, and tetrachloroethene), and three indicator parameters (fluoride, nitrate/nitrite, and sulfate) exceed potential ARARs (Table 3-19)

Of these, the maximum detections of 1,1-dichloroethane, benzene, and tetrachloroethene are less than their respective ARARs, however, the mean exceeds the ARAR because one-half the detection limit was used for non-detects in calculating the mean result Carbon tetrachloride was detected in two of 18 samples, and only one of these detections exceeds the ARAR, the low detection frequency suggests that this detection is an outlier and is not representative of contaminants from the landfill source Fluoride was detected in five samples in one well, one of the detections exceeds ARARs The low detection frequency and the limited spatial extent of fluoride suggests that this detection is an outlier and is not representative of contaminants from the landfill These data are not appropriate for an ARARs comparison and therefore 1 1-dichloroethane benzene tetrachloroethene carbon tetrachloride and fluoride are not considered further

Three analytes exceed ARARs in UHSU groundwater downgradient of the landfill nitrate/nitrite selenium and sulfate Selenium exceeds ARARs only in UHSU groundwater in the vicinity of the pond Nitrate/nitrite and sulfate exceed ARARs in UHSU groundwater in the vicinity of the pond and downgradient of the dam

Contaminant-transport modeling was performed to simulate the movement of contaminants in groundwater to evaluate the effect of potential releases and determine how far contaminants that currently exceed ARARs will travel downgradient after landfill closure Two-dimensional contaminant-transport modeling was performed using an analytical solution developed by Domenico and Robbins (1985) and coded into the TPLUME model (Golder Associates 1989) The input parameters and Surfer plots of outputs are presented in Appendix E Model simulations were performed for chloride selenium and sulfate in surficial materials and for chloride nitrate/nitrite selenium and sulfate in weathered bedrock Chloride was modeled because it is an indicator parameter for VOCs

For weathered bedrock a sensitivity analysis on hydraulic conductivity was performed Using the geometric mean hydraulic conductivity for weathered bedrock measured at OU 7 (4E-07 cm/sec) all of the modeled contaminants exhibited minimal movement (Appendix E Figures E8 through E11) At this hydraulic conductivity transport is controlled by diffusion The UCL_{95} of sitewide hydraulic conductivity values for weathered bedrock (5 6E-05 cm/sec) was used in another set of simulations These simulations exhibited more contaminant movement than the initial simulations but none of the simulated contaminant plumes reached downgradient well 53194 (Appendix E Figures E12 through E15) Based on these simulations and the flow regime in the weathered bedrock (Section 2 3) the weathered bedrock pathway is not considered to be complete with respect to human or environmental receptors

For surficial materials the contaminant modeling showed that ARARs would be exceeded for selenium and sulfate at downgradient well 53194 in 30 years if the dam were removed However there are several reasons why these modeling results are overly conservative

- Constant source versus declining source assumption The TPLUME model assumes a constant source of contamination over the entire period of the simulation Actual conditions at OU 7 indicate a declining source(s) If the landfill mass is the source of contaminants the proposed cap and slurry wall (to be performed as a maintenance action) will reduce groundwater flow through the landfill and contaminant transport out of the landfill For selenium, the source is suspected to be naturally occurring selenium dissolved from the soil matrix by groundwater unsaturated with respect to selenium This groundwater may be related to the spray evaporation of pond water Since the spray evaporation ended in 1994 this source should be reduced over time For sulfate and nitrate/nitrite the source is suspected to be either the buried sludges in IHSSs 166 1 and 166 3 or naturally occurring sulfate and nitrate released from the soil matrix Although the existing nitrate/nitrite data do not show any temporal trends the sulfate data show a slight but distinct decrease in concentrations over time

- Use of weathered-bedrock concentrations as source terms for surficial-materials modeling The TPLUME simulations for selenium and sulfate used weathered-bedrock concentrations as source terms for surficial-materials modeling because of data gaps for surficial materials This assumption is excessively conservative The measured potentiometric surfaces show a strong downward hydraulic gradient between the surficial materials and weathered bedrock in the vicinity of the dam with head differences of more than 20 feet. The measured concentrations of selenium and sulfate in surficial materials are much lower than the measured concentrations in the weathered bedrock

- Effect of the East Landfill Pond dam as a barrier to contaminant migration The TPLUME model assumes homogeneous, isotropic conditions and cannot account for hydraulic barriers As a result, the model does not take into account the effect of the dam as a barrier to contaminant migration As described in Sections 2 3 and 2 5 and Appendix C the dam has proven to be a significant barrier to groundwater flow and contaminant migration in surficial materials

Based on the flow modeling and particle tracking in Appendix C and the contaminant-transport modeling in Appendix E, contaminant migration down No Name Gulch is expected to be minimal Although the landfill has been operational for almost 30 years leachate migration has been insignificant. Wells 4287, 52894, and 53194 will be adequate to monitor groundwater quality downgradient of the landfill Exceedance of ARARs at these wells is not expected during the 30-year post-closure period The carcinogenic risk levels associated with the ingestion of groundwater by onsite office workers is less than 1E-06 The noncarcinogenic risk is above the acceptable risk or HI of 1 (HI = 3) However, the exposure pathway associated with the UHSU groundwater downgradient of the landfill is incomplete This risk should stay in the acceptable range over the 30-year post-closure monitoring period As the landfill cap and proposed slurry wall reduce leachate generation, migration, and contaminant loading the water quality in the monitoring wells will improve

Wells downgradient of the dam that meet potential ARARs for UHSU groundwater include 4287, 52894, and 53194

3 4 2 Potential Location-Specific ARARs

Location-specific ARARs identify requirements that apply because the site has a special quality related to geography or the presence of a protected resource These requirements may limit the remedial action that may be implemented or create the need for more stringent remedial efforts Potential location-specific ARARs for OU 7 are presented in Table 3-20 Location-specific ARARs most pertinent to OU 7 concern wetlands floodplains, and endangered species Also of concern are historic natural cultural or archaeological resources

3 4 2 1 Wetlands Requirements

Remedial actions at OU 7 will have to be implemented to minimize the destruction loss or degradation of wetlands (40 CFR 6 302[a]) As described in Section 2 4 3 wetlands have been designated along the shoreline and within the East Landfill Pond by the U S Army Corps of Engineers (Figure 2-12) (COE 1994) The wetland composes about 1 6 percent of the total wetlands at Rocky Flats The loss of wetland areas that fall under the proposed footprint of the landfill cover and injury to remaining wetland areas will be mitigated as needed

A wetlands assessment will be required under 40 CFR Part 6 The Clean Water Act (CWA) Section 404 (40 CFR Part 6) requires a permit for actions to dispose of dredge and fill material in waters of the United States Because the East Landfill Pond and pond margins have been designated as wetlands they are considered waters of the United States under the CWA Remedial actions will likely impact the pond, consequently, the CWA Section 404 permitting requirements and Executive Order 11990 have been identified as potential ARARs and substantive provisions must be met (Table 3-20)

3 4 2 2 Floodplain Requirements

The remedial action is not required to comply with the Floodplain Environmental Review Requirements in 10 CFR 1022 because the floodplains at Rocky Flats do not meet the definition in the regulation (DOE 1994e) Floodplains are defined in 10 CFR 1022 as the lowlands adjoining inland and coastal waters and relatively flat areas and flood prone areas of offshore islands including at a minimum that area inundated by a one percent or greater chance of flood in any given year ' The floodplains at Rocky Flats do not adjoin inland bodies of water nor are they relatively flat, flood prone areas Although the streams that flow through the site have a mappable 100-year floodplain these are not floodplains as defined in 10 CFR 1022, and therefore, floodplain requirements of 10 CFR 1022 do not apply

3 4 2 3 Threatened or Endangered Species Requirements

Riparian areas along No Name Gulch and the areas adjacent to the East Landfill Pond have been identified as potential habitat for Preble's meadow jumping mouse (Figure 2-12), which is protected under the Colorado Nongame, Endangered, or Threatened Species Conservation Act (CRS 33-2-101 to 107) This act is a potential ARAR for OU 7 Given the current protection of the Preble's meadow jumping mouse under state law, DOE's commitment to protect natural resources under the Natural Resource Trustee Memorandum of Understanding (DOE 1994f), and the potential for listing Preble's meadow jumping mouse under the Endangered Species Act, habitat mitigation will be performed as needed

3 4 2 4 Historic, Archaeological, and Cultural Resource Requirements

Compliance with federal and state laws designed to preserve areas with historical, natural, cultural, or archaeological value requires the identification of cultural resources and prehistoric or historic artifacts located at OU 7 An archaeological and historical study of the Rocky Flats area was conducted in 1989 (Burney *et al.* 1989) Cultural resource site density appears to be fairly low The study found some evidence of short-term prehistoric use such as camping, hunting, and scattered historic settlement, however, the rocky terrain and thin soils prevented more intense, long-term use of the area The historic preservation officer for the state of Colorado reviewed these findings and concluded that "there will be no effect on significant cultural resources by undertakings proposed" at Rocky Flats (CHS 1992)

3 4 3 Potential Action-Specific ARARs

Action-specific ARARs are management, performance, or treatment standards that are triggered by the particular activities selected to accomplish a remedy Action-specific requirements do not, in themselves, determine the remedial alternative; rather, they indicate how a selected alternative must be achieved Table 3-21 lists the potential federal and state action-specific ARARs that have been identified for OU 7 Table 3-22 lists standards and other guidance that have been identified as TBC Action-specific ARARs most pertinent to OU 7 are RCRA and CHWA closure requirements, air-emission requirements, delisting requirements, discharge requirements under the National Pollutant Discharge Elimination System (NPDES), and post-closure groundwater-monitoring requirements

3 4 3 1 Closure Requirements

Because records indicate that some hazardous waste was disposed at the landfill, it was designated as an interim status RCRA-regulated unit and was included in the Part B permit application for Rocky Flats (Rockwell International 1986) The Present Landfill is being closed under interim status regulations in accordance with Section I B 11 b of the IAG (DOE 1991a) CHWA and RCRA Subtitle C closure requirements are applicable because hazardous wastes were disposed in the Present Landfill after November 19 1980 which is the effective date of RCRA (EPA 1993a)

Two types of closure are allowed under RCRA Subtitle C clean closure and landfill closure The Present Landfill at OU 7 will be closed under landfill closure standards which require post-closure care and maintenance of the unit for at least 30 years after closure (EPA 1989c) Closure ARARs require that the landfill must be capped with a final cover designed and constructed to provide long-term minimization of migration of liquids, function with minimum maintenance promote drainage and minimize erosion accommodate settling and subsidence and have a permeability less than or equal to the natural subsoils present (6 CCR 1007 3 Part 265 310[a]) Post-closure care includes maintenance of the final cover and maintenance of a groundwater-monitoring system (6 CCR 1007-3 Parts 265 117 and 265 228[b])

3 4 3 2 Air-Emission Requirements

Closure of the Present Landfill could potentially trigger some air pollution control and permitting requirements Placement of the cap will require standard construction project dust-control measures The final capped facility could potentially release regulated quantities of VOCs and other regulated air pollutants An evaluation of applicable federal and Colorado regulations governing these types of facilities relative to air permitting is described below

Colorado Air Regulation No 1 requires new construction projects on sites over 1 acre in a non-attainment area to implement standard dust-control measures defined in the regulations The placement of the cap as part of a CERCLA action would meet the definition of new construction under Regulation No 1 Thus the requirements for dust control would be considered an ARAR under CERCLA Additionally, unpaved roadways with vehicle traffic of 150 vehicles per day (in a non-attainment area) and haul roads exceeding 40 haul loads or 200 vehicles per day are required to submit a control and abatement plan describing the control measures that will be taken to minimize such fugitive-dust generation Some standard dust-control measures are provided in Regulation No 1 and include basic activities such as application of dust suppressant covering hauled loads and daily compaction of the construction site, which should not greatly impact the planned activities

Air pollution control permits for sources in Colorado are issued by the Air Pollution Control Division of CDPHE Requirements are outlined in Colorado Air Quality Control Commission (CAQCC) Regulation No 3 and include requirements for operating permits and for prevention of significant deterioration (PSD) Facilities subject to these requirements must file an air pollutant emission notice (APEN) for each source or group of sources of uncontrolled emissions. Facilities that file an APEN must then determine whether they will require a construction permit under Part B of Regulation No 3 Applicability can be triggered in three ways

- For each potential emission point, a determination is made whether actual uncontrolled emissions of criteria pollutants (CO, NO_x, SO_2, particulates [PM-10], total suspended particulates [TSP], ozone [O_3], VOCs, lead, fluorides, H_2SO_4 mist, H_2S, total reduced sulfur, reduced sulfur compounds, and municipal waste combustion products) are above established *de minimis* levels Determinations are based on either actual measured data or on estimates developed by approved methods

- Colorado has developed its own system for estimating the actual uncontrolled emissions of a designated set of HAPs based on the location of the emission point, distance from the property line, height of the release point, and reporting "bin", or category, of the pollutant being evaluated If any HAPs are emitted above *de minimis* levels, the facility must file an APEN

- Specific categories of sources are required to file for permits based on standards developed for their operations No specific requirements for municipal solid-waste landfills currently exist in Colorado regulations, and there are no plans to include specific requirements for landfills until federal regulations are finalized

Thresholds for triggering required reporting and permitting activities are based on whether the source is located in an attainment or non-attainment area, as defined in the regulations Rocky Flats is located in a non-attainment area. The threshold limit requiring an APEN for uncontrolled emissions of criteria pollutants is 1 ton per year If it can be demonstrated that emissions of criteria pollutants from the entire facility are less than 1 ton per year, then no APEN is required As outlined in the NCP, only the substantive requirements must be met for onsite CERCLA responses (55 Federal Register 8756, March 8, 1990)

Requirements for air pollution control and permitting for landfills are contingent on the type of landfill operation At the federal level, landfills considered municipal solid-waste landfills have been the subject of a rulemaking process that resulted in a proposed rule (56 Federal Register 24468, May 30, 1991), a revision to the proposed rule (58 Federal Register 33790, June 21, 1993), and significant internal and external review and comment No final rule has been published at this time Hazardous waste landfills permitted under RCRA are not covered under the proposed rules but are subject to specific requirements at the time of closure in terms of cap design and other monitoring However there are no specific provisions in the RCRA treatment, storage and disposal facility regulations for air pollution controls

Based on this regulatory status no specific landfill air pollution control standards apply to OU 7

Closure of the landfill will require an APEN a construction permit development of a fugitive emission control plan and implementation of standard dust control procedures during construction Specific controls for gas emissions from the landfill after closure are not expected to be required based on estimated emission rates of NMOCs

3 4 3 3 Delisting Requirements

DOE proposes to delist landfill leachate which is considered F039 RCRA-listed waste contained in groundwater (EPA 1990a) Under the presumptive remedy it is proposed that the leachate be delisted (i e shown to be nonhazardous) and thus no longer subject to CHWA and RCRA Subtitle C hazardous waste regulations Instead, the leachate will be managed in accordance with CHWA and RCRA Subtitle D requirements which are ARARs for leachate If leachate or groundwater sampling during the post-closure period shows that the maximum allowed concentrations (MACs) are not being attained for delisting the leachate will be managed as Subtitle C hazardous waste and ARARs under Subtitle C will be met

The basis for delisting is that the leachate is not hazardous does not exhibit hazardous-waste characteristics and does not pose a threat to human health or the environment (Section 3 3 4) In addition the proposed remedy (landfill cap) will cover the seep area prevent exposure to leachate reduce contaminant leaching to groundwater and ultimately reduce leachate generation and migration (Section 2 3 5) A slurry wall will be constructed as a maintenance action to reduce groundwater inflow leachate generation and outflow at the seep In addition leachate will be collected and treated at the seep as an accelerated action before closure As the landfill dewaters leachate generation is reduced and a decrease in contaminant concentrations in leachate is expected As outlined in the NCP (55 Federal Register 8756 March 8 1990) only the substantive requirements of delisting must be met for onsite CERCLA responses

The substantive requirements of 40 CFR 260 20 and 260 22 are documented here and include a general discussion of why delisting is warranted concentrations of each constituent remaining comparison of actual concentrations to the MACs for specific constituents results of fate and transport modeling to show calculated concentrations at a receptor well and a contingency plan to address leachate that does not achieve delistable levels These requirements are outlined in A Guide to Delisting of RCRA Wastes for Superfund Remedial Responses (EPA 1990b) and clarified in Petitions to Delist Hazardous Wastes - A Guidance Manual (EPA 1993b) EPA guidance requires upgradient and downgradient groundwater-monitoring data for delisting decisions (EPA 1993b) Upgradient data are summarized in the OU 7 Final Work Plan (DOE

1994a) Downgradient data are presented in this report Statistical comparisons of upgradient data to downgradient data are presented in the Annual RCRA Groundwater Monitoring Report (EG&G 1994a)

Concentrations of contaminants in the leachate are presented in Tables 2-4 3-1 and 3-16 Concentrations of contaminants in groundwater downgradient of the leachate seep are presented in Tables 2-10 2-11 3-11 3-13, and 3-18 The text corresponding to these tables describes the nature and extent of contamination (Sections 2 5 3 and 2 5 8) risk evaluations (Sections 3 3 4 and 3 3 9), and compliance with potential chemical-specific ARARs (Section 3 4 1) Table 3-23 provides a comparison of maximum detected concentrations in leachate at the seep to MACs from the delisting guidance (EPA 1990b) The maximum detected concentration of only one analyte exceeds the MAC The maximum detection of 1,1-dichloroethane in leachate is 10 µg/L, the MAC is 2 524 µg/L However, the detection limit (5 µg/L) is also greater than the MAC The potential ARAR for 1,1-dichloroethane is 59 µg/L

Two-dimensional contaminant-transport modeling was performed using the methodology described previously The input parameters and Surfer plots of outputs are presented in Appendix E Model simulations were performed for 1 1-dichloroethane in surficial materials Well 53194 was used as the receptor well The contaminant modeling showed that the MAC for 1,1-dichloroethane would not be exceeded at downgradient well 53194 in 30 years As the landfill cap and proposed slurry wall reduce leachate generation, migration, and contaminant loading, the water quality in downgradient monitoring wells will improve As described in Sections 2 3 and 2 5 and Appendix C the dam has proven to be a significant barrier to groundwater flow and contaminant migration in surficial materials

In accordance with the requirements for delisting (EPA 1990b EPA 1993b) groundwater monitoring will be performed during the post-closure period to determine whether MACs for delisting have been attained A contingency plan will be developed to address leachate and groundwater that do not meet delistable levels

3 4 3 4 Discharge Requirements

Criteria and standards for NPDES (40 CFR Part 125) under the Clean Water Act and Colorado Water Quality Control Act are applicable under the IAG (DOE 1991b) Because OU 7 is an onsite CERCLA action, an NPDES permit is not required for discharges from the East Landfill Pond to No Name Gulch However, DOE will have to comply with the substantive provisions of these acts In the short term effluent limitations will be achieved through the accelerated action or leachate treatment system In the long term effluent limitations will be achieved with the final remedy or

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landfill cap After closure excess water in the East Landfill Pond will be discharged to No Name Gulch Discharge requirements will be negotiated with CDPHE and EPA

3 5 Final Remedial Action Objectives or Response Actions

Final RAOs were developed based on preliminary RAOs (Section 3 1) the conceptual site model for defining risks exposure pathways site risks potential ARARs and the presumptive remedy approach A quantitative risk assessment is not necessary to evaluate whether the containment remedy addresses all pathways and contaminants of concern associated with the source Rather all potential exposure pathways identified using the conceptual site model were compared to the pathways addressed by the containment presumptive remedy (EPA 1993a) Exposure pathways addressed by the presumptive remedy include direct contact with the source and exposure to leachate and landfill gas (Table 3-24)

For media not addressed by the presumptive remedy EPA guidance (EPA 1993a) states that an active response is not required if contaminant concentrations exceed chemical specific standards but the site risk is within the acceptable risk range for carcinogens (1E-04 to 1E-06) Risks were evaluated and an ARARs comparison was performed for these media A reasonably anticipated future land use the open-space scenario was used for evaluating risks from exposure to leachate surface water sediment and surface soils Onsite construction-worker and onsite office-worker scenarios were used for evaluating risks from exposure to subsurface geologic materials and groundwater downgradient of the landfill respectively Ultimately it is necessary to demonstrate that the final remedy addresses all pathways and contaminants of concern

3 5 1 Elimination of Preliminary RAOs

Preliminary RAOs were eliminated from the final response action because (1) there is no risk to the potential receptor (2) analytes do not exceed ARARs or (3) the exposure pathway is incomplete RAOs eliminated include the following

- Collect and treat leachate at the source
- Remediate surface water in the East Landfill Pond
- Remediate sediments in the East Landfill Pond
- Remediate surface soils in spray evaporation areas
- Remediate subsurface geologic materials downgradient of the landfill
- Control groundwater at the source to contain the plume
- Remediate groundwater downgradient of the landfill

The rationale for eliminating each of these RAOs is summarized in Table 3-24 and presented below

3 5 1 1 Collect and Treat Leachate at the Source

Potential exposure to landfill leachate will be addressed by the presumptive remedy for source containment (Table 3-24) The proposed landfill cap will cover the seep area and prevent exposure to leachate reduce leachate generation and migration and reduce contaminant loading to groundwater A slurry wall will be constructed as a maintenance action to reduce groundwater inflow, leachate generation, and outflow at the seep In addition, leachate will be collected and treated at the seep as an accelerated action for OU 7 before closure, even though leachate collection and removal activities are not required for closure of interim-status units (6 CCR 1007-3 Part 265 310)

Based on results of the PRG screen and ecological risk assessment, there is no associated risk to human health from landfill leachate. The cumulative risk for avian and terrestrial wildlife, expressed as the HI, was greater than 1 for mallards, raccoons, and coyotes Because it was assumed that these species spend all of their time at the East Landfill Pond, risk was overestimated. Based on results of an ARARs comparison seven analytes exceed ARARs in landfill leachate aluminum, benzene, manganese, 2-methylnaphthalene, naphthalene, vinyl chloride, and zinc Only one analyte (1 1-dichloroethane) is above MACs for delisting and the detection limit for 1 1-dichloroethane is greater than the MAC.

DOE proposes to monitor discharge from the passive leachate-treatment system until the landfill cover is constructed After the containment presumptive remedy is in place, the seep discharge point will be covered, approximately 94 percent of the source water will be eliminated (Section 2 3), and the pathway for exposure of human and ecological receptors to leachate will be incomplete

3 5 1 2 Remediate Surface Water in the East Landfill Pond

Based on results of the PRG screen, there is no associated risk to human health or terrestrial or aquatic organisms from surface water in the pond (Table 3-24) One of the surface water PCOCs exceeded state water quality standards or risk-based benchmarks (manganese) For ecological receptors the cumulative risk, expressed as the HI, was greater than 1 only for mallards Because it was assumed that mallards spend all of their time at the East Landfill Pond, risk to mallards was overestimated The pond exceeds only one potential ARARs for surface water (manganese)

DOE proposes to leave the portion of the pond and wetlands not covered by the cap in place The East Landfill Pond represents approximately 1.6 percent of the total wetland area at Rocky Flats (COE 1994) and has been identified as potential habitat for the Preble's meadow jumping mouse (DOE 1995b) The dam acts as a barrier to groundwater migration and is effective in preventing contaminants in groundwater from migrating down No Name Gulch

3 5 1 3 Remediate Sediments in the East Landfill Pond

Based on results of the PRG screen and the ecological risk assessment no response action is required for sediments in the East Landfill Pond because the sediments pose no risk to human health and minimal risk to aquatic life and wildlife (Table 3-24) DOE proposes to leave the pond sediments in place

3 5 1 4 Remediate Surface Soils in Spray Evaporation Areas

Because carcinogenic risks fall below or within the EPA acceptable risk range of 1E-04 to 1E-06 and noncarcinogenic risks are below the HI of 1 surface soils do not require a response action (Table 3-24) DOE proposes to leave the surface soils in the vicinity of spray evaporation areas undisturbed

3 5 1 5 Remediate Subsurface Geologic Materials Downgradient of the Landfill

Based on the PRG screen no response action is required for subsurface geologic materials downgradient of the landfill because the subsurface soils pose no risk to human health (Table 3-24) DOE proposes to leave the subsurface soils undisturbed

3 5 1 6 Control Groundwater at the Source to Contain the Plume

Source-area groundwater control to contain the plume will be addressed in several ways As described in Section 2 3 5 the presumptive remedy (landfill cap) and maintenance actions (slurry wall) will reduce inflow to the landfill by approximately 94 percent which will reduce the flow rate of the leachate seep The proposed landfill cap will cover the seep area reducing contaminant leaching to groundwater Groundwater modeling has shown that migration is likely slowed considerably or possibly even stopped by the dam Discharge from groundwater to surface water is not expected downgradient of the dam because the intermittent stream in No Name Gulch is a losing stream that discharges to groundwater Discharge does occur to the pond Groundwater in the UHSU may also seep down into the confining layers of the unweathered bedrock, however hydraulic conductivity values for the confining layer are low and downward seepage is minimal

3 5 1 7 Remediate Groundwater Downgradient of the Landfill

The carcinogenic risk from ingestion of UHSU groundwater in the vicinity of the pond upgradient of the dam is within the acceptable risk range of 1E-04 to 1E-06 (1E-05) however the noncarcinogenic risk is above the acceptable risk or HI of 1 (HI = 3) The primary contributor to noncarcinogenic risk is selenium (HI = 1 5) The risks from ingestion of UHSU groundwater downgradient of the dam are within the acceptable risk range (carcinogenic risk less than 1E-06 noncarcinogenic risk, HI = 0 2) Therefore there is minimal risk to future onsite office workers from ingestion of

UHSU groundwater The potential exposure pathway associated with UHSU groundwater downgradient of the landfill is incomplete because the containment presumptive remedy will eliminate approximately 94 percent of the source water and the seep discharge point will be covered, which eliminates the contaminant release/transport mechanism No plans are anticipated for the future development of groundwater for any use at OU 7, which eliminates the exposure route (Table 3-24)

Three analytes exceed ARARs in UHSU groundwater downgradient of the landfill nitrate/nitrite, selenium, and sulfate Selenium exceeds ARARs only in groundwater in the vicinity of the pond (Selenium was not detected in groundwater downgradient of the dam) Contaminant-transport modeling indicates that concentrations of selenium in groundwater will exceed ARARs at well 53194 in 30 years (Appendix E), however, the modeling neglected the effects of the dam, which would likely impede the migration of contaminants, and uses concentrations in weathered bedrock for surficial materials (Section 2.5 7) In addition, the pond area will be covered by the landfill cap, reducing the amount of recharge to groundwater in this area Nitrate/nitrite and sulfate exceed ARARs in groundwater in the vicinity of the pond and downgradient of the dam Contaminant-transport modeling indicates that concentrations of sulfate in groundwater will exceed ARARs at well 53194 in 30 years because the sulfate source appears to be downgradient of the dam (Appendix E) The groundwater modeling is excessively conservative because it assumes a constant source, uses concentrations in weathered bedrock for surficial materials, assumes homogeneous, isotropic conditions, and does not take into account the effect of the dam (Section 3 4 1 3)

Wells downgradient of the dam that meet potential ARARs for UHSU groundwater include 4287, 52894, and 53194 These wells are proposed as downgradient wells for the post-closure groundwater-monitoring system (6 CCR 1007-3 Part 265 90[a]) Samples collected from these wells are representative of groundwater quality downgradient of the landfill, and the wells are capable of detecting potential future releases from the landfill

3 5 2 Development of Final RAOs

Final RAOs that will be used for the identification and screening of technologies (Section 4) and the development of alternatives (Section 5) include the following

- Prevent direct contact with landfill contents
- Minimize infiltration and resulting contaminant leaching to groundwater
- Control surface-water run-off and erosion
- Control landfill gas (treat as needed)
- Remediate wetland areas (as needed)

Table 3-1
Preliminary Remediation Goal (PRG) Screen for Leachate at the Seep

PCOC	Maximum Detected Concentration	Location of Maximum	Open Space Surface Water PRG[1]	Units	Maximum > PRG[2]
Metals					
Antimony	60 4	SW097	13 600	µg/L	no
Barium	1 550	SW097	2 380 000	µg/L	no
Iron	155 000	SW097	—	µg/L	no
Lithium	107	SW097	681 000	µg/L	no
Manganese	2 490	SW097	170 000	µg/L	no
Strontium	1 370	SW097	20 400 000	µg/L	no
Zinc	16 000	SW097	10 200 000	µg/L	no
Radionuclides					
Strontium 89,90[3]	4 06	SW097	795	pCi/L	no
Tritium	1,500	SW097	823,000	pCi/L	no
Indicator Parameters					
Nitrite	63	SW097	3 410 000	µg/L	no
Semivolatile Organic Compounds					
2 4 Dimethylphenol	3	SW097	681 000	µg/L	no
2 Methylnaphthalene	23	SW097	—	µg/L	no
4 Methylphenol	4	SW097	—	µg/L	no
Acenaphthene	3	SW097	2 040 000	µg/L	no
Bis(2 ethylhexyl)phthalate	2	SW097	5 680	µg/L	no
Dibenzofuran	2	SW097	—	µg/L	no
Diethyl phthalate	3	SW097	27 300 000	µg/L	no
Fluorene	3	SW097	1 360 000	µg/L	no
Naphthalene	22	SW097	1 360 000	µg/L	no
Phenanthrene	5	SW097	—	µg/L	no
Volatile Organic Compounds					
1 1 Dichloroethane	10	SW097	3 410 000	µg/L	no
1 2 Dichloroethene	14	SW097	307 000	µg/L	no
2 Butanone	76	SW097	20 400 000	µg/L	no
2 Hexanone	10	SW097	—	µg/L	no
4 Methyl 2 pentanone	87	SW097	2 730 000	µg/L	no
Acetone	220	SW097	3 410 000	µg/L	no
Benzene	2	SW097	2 740	µg/L	no

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Table 3-1
Preliminary Remediation Goal (PRG) Screen for Leachate at the Seep

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chloroethane	57	SW097	—	µg/L	no
Chloromethane	7	SW097	6,110	µg/L	no
Ethylbenzene	18	SW097	3,410 000	µg/L	no
Toluene	88	SW097	6,810,000	µg/L	no
Total xylenes	25	SW097	68,100,000	µg/L	no
Trichloroethene	4	SW097	7,230	µg/L	no
Vinyl chloride	11	SW097	41.8	µg/L	no
o-Xylene[4]	8	SW097	68 100,000	µg/L	no

Notes

— no PRG is available

[1] PRGs are presented in Draft Programmatic PRGs for Rocky Flats Plant - Open Space (DOE 1995e).

[2] If the maximum detected concentration is greater than the PRG, the analyte is evaluated in a risk assessment. PRGs are developed for those analytes with toxicity criteria. Only analytes with PRGs are evaluated in a risk assessment. If no maximum detected concentrations exceed the PRG, a risk assessment is not performed.

[3] The PRG is for strontium-90 and daughter products because it is more conservative than the PRG for strontium-89.

The PRG is for total xylenes

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Table 3-2
Preliminary Remediation Goal (PRG) Screen for Surface Water in the East Landfill Pond

PCOC	Maximum Detected Concentration	Location of Maximum	Open Space Surface Water PRG[1]	Units	Maximum > PRG[2]
Metals					
Arsenic	2 2	SW098	45 4	µg/L	no
Lithium	109	SW098	681 000	µg/L	no
Manganese	430	SW098	170 000	µg/L	no
Molybdenum	13 1	SW098	170 000	µg/L	no
Nickel	22	SW098	681 000	µg/L	no
Strontium	598	SW098	20 400 000	µg/L	no
Thallium	7 4	SW098	—	µg/L	no
Tin	44 3	SW098	20 400 000	µg/L	no
Radionuclides					
Americium 241	0 031	SW098	136	pCi/L	no
Strontium 89 90[3]	1 924	SW098	795	pCi/L	no
Tritium	257 8	SW098	823,000	pCi/L	no
Uranium 235[4]	0 3	SW098	946	pCi/L	no
Uranium 238[5]	1 964	SW098	717	pCi/L	no
Semivolatile Organic Compounds					
Bis(2 ethylhexyl)phthalate	1	SW098	5 680	µg/L	no
Di n butyl phthalate	1	SW098	3 410 000	µg/L	no

Notes

— no PRG is available

PRGs are presented in Draft Programmatic PRGs for Rocky Flats Plant Open Space (DOE 1995e)

If the maximum detected concentration is greate than the PRG the analyte is evaluated in a risk assessment. PRGs are developed for those analytes with toxicity criteria. Only analytes with PRGs are evaluated n a risk assessment. If no maximum detected concentrations exceed the PRG a risk assessment is not performed

3 The PRG s for strontium 90 and daughter products because it s more conservati e than the PRG for strontium 89

The PRG is for uranium 235 and daughter products

5 The PRG is for uranium 238 and daughter products

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Table 3-3
Preliminary Remediation Goal Screen for Sediments in the East Landfill Pond

PCOC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals					
Zinc	167	SED70093	7 68E+05	mg/kg	no
Semivolatile Organic Compounds					
Acenaphthene	100	SED70093	4 61E+08	µg/kg	no
Anthracene	160	SED70093	2.30E+09	µg/kg	no
Benzo(a)anthracene	340	SED70093	2 45E+04	µg/kg	no
Benzo(a)pyrene	320	SED70093	2 45E+03	µg/kg	no
Benzo(b)fluoranthene	470	SED70093	2.45E+04	µg/kg	no
Benzo(ghi)perylene	200	SED70093	—	µg/kg	no
Benzo(k)fluoranthene	130	SED70093	2.45E+05	µg/kg	no
Benzoic acid	870	SED70093	3.07E+10	µg/kg	no
Bis(2-chloroisopropyl)ether	47	SED70293	2.56E+05	µg/kg	no
Bis(2-ethylhexyl)phthalate	80	SED70093	1.28E+05	µg/kg	no
Chrysene	310	SED70093	2 45E+06	µg/kg	no
Fluoranthene	830	SED70093	3.07E+08	µg/kg	no
Fluorene	92	SED70093	3.07E+08	µg/kg	no
Indeno(1 2 3-cd)pyrene	180	SED70093	2.45E+04	µg/kg	no
Phenanthrene	630	SED70093	—	µg/kg	no
Pyrene	750	SED70093	2.30E+08	µg/kg	no
Volatile Organic Compounds					
2 Butanone	35	SED70093	4.61E+09	µg/kg	no
Acetone	130	SED70193	7 68E+08	µg/kg	no
Toluene	440	SED70293	1.54E+09	µg/kg	no

Notes

— no PRG is available

[1] PRGs are presented in Programmatic Preliminary Risk-based Remediation Goals for RFETS-Open Space (DOE 1995f)

[2] If the maximum detected concentration is greater than the PRG the analyte is evaluated in a risk assessment. PRGs are developed for those analytes with toxicity criteria. Only analytes with PRGs are evaluated in a risk assessment. If no maximum detected concentrations exceed the PRG, a risk assessment is not performed.

Definitions

PCOC potential contaminant of concern

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Table 3-4
Preliminary Remediation Goal (PRG) Screen for Surface Soils in the Vicinity of Spray Evaporation Areas

PCOC	Maximum Detected Concentration	Location of Maximum	Open Space Soil PRG[1]	Units	Maximum > PRG[2]
Metals					
Antimony	9 1	SS719693	3 070	mg/kg	no
Arsenic	15 7	SS702293	10	mg/kg	yes
Barium	1 120	SS705193	535,000	mg/kg	no
Beryllium	1 5	SS120894	4 08	mg/kg	no
Cobalt	16 2	SS712093	461 000	mg/kg	no
Copper	640	SS121394	307 000	mg/kg	no
Lead	167	SS708893	—	mg/kg	no
Mercury	0 14	SS708693	2,310	mg/kg	no
Selenium	2 9	SS121594	38 400	mg/kg	no
Silver	3	SS709593	38 400	mg/kg	no
Strontium	80 6	SS720193	>1,000,000	mg/kg	no
Thallium	2 1	SS121594	—	mg/kg	no
Vanadium	86 2	SS705293	53,800	mg/kg	no
Zinc	113	SS120894	>1 000 000	mg/kg	no
Radionuclides					
Americium 241	1 076	SS703793	23 6	pCi/g	no
Plutonium 239/240	0 4692	SS704293	69 8	pCi/g	no
Radium 226[3]	1 787	SS711193	0 0247	pCi/g	yes
Indicator Parameters					
Nitrate/nitrite	45	SS710893	>1 000 000	mg/kg	no

Notes

— no PRG is available

1 PRGs are presented in Draft Programmatic PRGs for Rocky Flats Plant Open Space (DOE 1995e)

2 If the maximum detected concentration is greater than the PRG the analyte is evaluated the risk assessment (Tables 3 8 3 9 and 3 10) PRGs are developed for those analytes w th to icity criteria. Only analytes with PRGs are evaluated in the risk assessment.

3 The PRG is for radium 226 and daughter products

Table 3-5
Site-Specific Exposure Factors for Incidental Ingestion of Surface Soil[1]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ingestion Rate	IR	100	50	mg/visit
Matrix Effect in GI Tract (Absorption Factor)	ME	chemical specific[2]	chemical specific[2]	unitless
Exposure Frequency	EF	25	25	visits/year
Exposure Duration	ED	6	24	years
Body Weight	BW	15	70	kg
Averaging Time Noncarcinogen	ATN	2,190	8,760	days
Averaging Time Carcinogen	ATC	25,550	25,550	days

Notes

1 Exposure parameters are presented in Final Open-Space Exposure Parameters (DOE 1995b).
2 All absorption factors are 1 conservatively assuming 100 percent absorption.

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Table 3-6
Site-Specific Exposure Factors for Particulate Inhalation of Surface Soil[1]

Exposure Factor	Abbreviation	Reasonable Maximum Exposure (RME) Value Adult	Units
Inhalation Rate	IR	1 4	m^3/hour
Particulate Emission Factor	PEF	4 63E+10	m^3/kg
Respirable Fraction (PM 10)	RF	0 46	unitless
Respiratory Deposition Factor	DF	0 85	unitless
Exposure Time	ET	5 0	hours/visit
Exposure Frequency	EF	25	visits/year
Exposure Duration	ED	30	years
Body Weight	BW	70	kg
Averaging Time Carcinogen	ATC	25,550	days

Note

E posure parameters are presented in Final Open Space Exposure Parameters (DOE 1995h) and Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Part B (EPA 1991b)

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Table 3-7
Site-Specific Exposure Factors for External Irradiation from Surface Soil[1]

[illegible]	[illegible]	[illegible]	[illegible]
Gamma Exposure Time Factor	ET	0 2	unitless
Gamma Shielding Factor	SF	1 0	unitless
Exposure Frequency Ratio	EF	0.07	unitless
Exposure Duration	ED	30	years

Note

[1] Exposure parameters are presented in Final Open-Space Exposure Parameters (DOE 1995h).

Table 3-8
Potential Risks Associated with Incidental Ingestion of Surface Soil[1]
Open-Space Exposure Scenario

Child Exposure									
Carcinogens[2]	**UCL$_{95}$**		**Intake[3]**				**Oral Cancer Slope Factor[4]**		**Carcinogenic Risk**
Arsenic	5 5	mg/kg	0 039	mg/kg day	0 00000022	mg/kg day	1 75E+01	(mg/kg/day)$^{-1}$	4E 06
Radium 226	1 0	pCi/g	15 000	mg	16	pCi	2 95E 09	risk/pCi	5E 08
Total Carcinogenic Risk									**4E-06**
Noncarcinogens[2]	**UCL$_{95}$**		**Intake[3]**				**Chronic Reference Dose[4]**		**Hazard Quotient**
Arsenic	5 5	mg/kg	0 457	mg/kg-day	0 0000025	mg/kg day	3E 03	mg/kg day	0 008
Hazard Index									**0 008**
Adult Exposure									
Carcinogens[2]	**UCL$_{95}$**		**Intake[3]**				**Oral Cancer Slope Factor[4]**		**Carcinogenic Risk**
Arsenic	5 5	mg/kg	0 017	mg/kg day	0 000000092	mg/kg-day	1 75E+01	(mg/kg-day)$^{-1}$	2E 06
Radium 226	1 0	pCi/g	30 000	mg	31	pCi	2 95E 09	risk/pCi	9E 08
Total Carcinogenic Risk									**2E-06**
Noncarcinogens[2]	**UCL$_{95}$**		**Intake[3]**				**Oral Chronic Reference Dose[4]**		**Hazard Quotient**
Arsenic	5 5	mg/kg	0 049	mg/kg-day	0 00000027	mg/kg day	3E 03	mg/kg day	0 0009
Hazard Index									**0 0009**

Notes

1 Risks were calculated for those chemicals with oral toxicity criteria. Slight rounding may occur
2 PCOCs identified from the PRG screen (Table 3-4)
3 Exposure factors used to calculate intake for incidental ingestion of surface soil in an open space exposure scenario are presented in Table 3 5
Oral toxicity values are from DOE (1995c) and HEAST (EPA 1994a)

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Table 3-9
Potential Risks Associated with Particulate Inhalation of Surface Soil[1]
Open-Space Exposure Scenario

[illegible]	[illegible]		[illegible]		[illegible]		[illegible]
Arsenic	5 5	mg/kg	1 4E-12	mg/kg-day	1 51E+01	(mg/kg-day)[-1]	2E-11
Radium-226	1 04	pCi/g	4 6E-04	pCi	2.72E-09	risk/pCi	1E 12
Total Carcinogenic Risk							2E-11

Notes

1. Risks were calculated for those chemicals with inhalation toxicity criteria. Slight rounding may occur
2. PCOCs identified from the PRG screen (Table 3-4).
3. Exposure factors used to calculate intake for particulate inhalation of surface soil in an open-space exposure scenario are presented in Table 3-6.
4. Inhalation toxicity values are from DOE (1995c) and HEAST (EPA 1994a).

Table 3-10
Potential Risks Associated with External Irradiation from Surface Soil[1]
Open-Space Exposure Scenario

[illegible]	[illegible]		[illegible]		[illegible]		[illegible]
Radium-226	1 04	pCi/g	0.44	pCi-yr/g	1.31E-08	risk/yr per pCi/g soil	6E-09
Total Risk							6E-09

Notes

1. Risks were calculated for those chemicals with external exposure toxicity criteria. Slight rounding may occur.
2. PCOCs identified from the PRG screen (Table 3-4).
3. Exposure factors used to calculate intake for external irradiation from surface soil in an open-space exposure scenario are presented in Table 3-7
4. External exposure values are from HEAST (EPA 1994a).

Table 3-11
Preliminary Remediation Goal (PRG)
Screen for Subsurface Geologic Materials Downgradient of the Landfill

PCOC	Maximum Detected Concentration	Location of Maximum	Construction Worker Subsurface Soil PRGs[1]	Units	Maximum > PRG[2]
Colluvial Material (Qc)					
Metals					
Barium	624	71093	1 24E+05	mg/kg	no
Radionuclides					
Cesium 137	0 2386	71093	—	pCi/g	no
Semivolatile Organic Compounds					
Chrysene	43	70993	1 70E+07	µg/kg	no
Fluoranthene	110	70993	7 10E+07	µg/kg	no
Phenanthrene	100	70993	—	µg/kg	no
Pyrene	110	70993	5 32E+07	µg/kg	no
Volatile Organic Compounds					
4 Methyl 2 pentanone	58	70993	1 42E+08	µg/kg	no
Toluene	2 000	70993	3 29E+05	µg/kg	no
Total xylenes	2	70993	9 81E+04	µg/kg	no
Indicator Parameters					
Nitrate/nitrite[3]	20,000	71093	2 84E+06	mg/kg	no
Weathered Bedrock Material (KaKl w)					
Metals					
Arsenic	11 4	70993	7 09E+01	mg/kg	no
Barium	254	71093	1 24E+05	mg/kg	no
Cobalt	21	71093	1 06E+05	mg/kg	no
Lead	31 2	70993		mg/kg	no
Manganese	3130	71093	8 86E+03	mg/kg	no
Strontium	939	70993	1 06E+06	mg/kg	no
Zinc	84 4	71093	5 32E+05	mg/kg	no
Volatile Organic Compounds					
Toluene	580	70993	3 29E+05	µg/kg	no

Notes

— no PRG s available

1 PRGs are presented n Programmatic Prel minary Risk based Remediation Goals for RFETS-Construction Worker (DOE 1995f)
If the maximum detected concentration is greater than the PRG the analyte is e aluated in a risk assessment PRGs are developed for those analytes with to city criteria Only analytes w th PRGs are e al ated n a risk assessme t. If no maximum detected concentrations exceed the PRG a risk assessment is not performed
PRG for nitrate because it is the dominant species

Definitions

PCOC potential contaminant of concern
Qc Quaternary colluvium
KaKl(w) w thered ndiff rent ted Cretaceous Arapahoe and Laramie Formations

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Table 3-12
Preliminary Remediation Goal (PRG) Screen for Groundwater Downgradient of the Landfill

PCOC	Maximum Detected Concentration	Location of Maximum	Residential Groundwater PRG[1]	Units	Maximum > PRG[2]
UHSU Groundwater in the Vicinity of the East Landfill Pond					
Metals					
Antimony	58	B206789	14.6	µg/L	yes
Lithium	225	B206789	730	µg/L	no
Selenium	815	B206789	182	µg/L	yes
Silver	10.9	B206789	182	µg/L	no
Strontium	1 580	B206789	21,900	µg/L	no
Radionuclides					
Uranium-238[3]	35.45	B206889	2.38	pCi/L	yes
Indicator Parameters					
Chloride	460,000	B206889		µg/L	no
Nitrate/nitrite[4]	290,000	B206989	58,400	µg/L	yes
Orthophosphate	30	B206789	—	µg/L	no
Sulfate	1,600,000	B206889	—	µg/L	no
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	3	B206789	6.07	µg/L	no
Volatile Organic Compounds					
Carbon tetrachloride	7 11	B206889	0.26	µg/L	yes
Tetrachloroethene	0 769	B206889	1.43	µg/L	no
Trichloroethene	1.43	B206889	2.55	µg/L	no
UHSU Groundwater Downgradient of the Dam					
Metals					
Lithium	138	B207089	730	µg/L	no
Strontium	1 870	B207089	21,900	µg/L	no
Radionuclides					
Strontium-89,90[5]	0.49	4287	1.32	pCi/L	no
Carbonate as $CaCO_3$	12,000	4087	—	µg/L	no
Indicator Parameters					
Chloride	530,000	B207089	—	µg/L	no
Fluoride	3,400	4087	2 190	µg/L	yes
Nitrate/nitrite[4]	72,000	B206989	58,400	µg/L	yes
Orthophosphate	150	4287	—	µg/L	no
Sulfate	19,000,000	B207089	—	µg/L	no

Notes

— no PRG is available

1 PRGs are presented in Final Programmatic Risk Based Preliminary Remediation Goals, Revision 2 (DOE 1995d).
2 *If the maximum detected concentration is greater than the PRG, the analyte is evaluated in the risk assessment* (Table 3-13). PRGs are developed for those analytes with toxicity criteria. Only analytes with PRGs are evaluated in the risk assessment.
3 The PRG is for uranium 238 and daughter products.
4 The PRG is for nitrate because it is the dominant species present.
5 The PRG is for strontium-90 and daughter products because it is more conservative than the PRG for strontium-89

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Table 3-14
Potential Risks Associated with Groundwater Ingestion[1]
Future Onsite Office Worker Exposure Scenario

UHSU Groundwater in the Vicinity of the East Landfill Pond							
Carcinogens[2]	**UCL$_{95}$**		**Intake[3]**		**Oral Cancer Slope Factor[4]**		**Carcinogenic Risk**
Carbon tetrachloride	2 7	µg/L	0 0000094	mg/kg day	1 3E 01	(mg/kg-day)$^{-1}$	1E 06
Uranium 238[4]	35	pCi/L	221,563	pCi	4 27E 11	risk/pCi	9E 06
Total Carcinogenic Risk							**1E-05**
Noncarcinogens[2]	**UCL$_{95}$**		**Intake[3]**		**Oral Chronic Reference Dose[4]**		**Hazard Quotient**
Antimony	32	µg/L	0 00031	mg/kg day	4E 04	mg/kg day	0 8
Carbon tetrachloride	2 7	µg/L	0 000026	mg/kg day	7E 04	mg/kg day	0 04
Nitrate/nitrite[5]	69,339	µg/L	0 68	mg/kg day	1 6E+00	mg/kg-day	0 4
Selenium	749	µg/L	0 0073	mg/kg-day	5E 03	mg/kg-day	1 5
Hazard Index							**3**
UHSU Groundwater Downgradient of the Dam							
Noncarcinogens[2]	**UCL$_{95}$**		**Intake[3]**		**Oral Chronic Reference Dose[4]**		**Hazard Quotient**
Fluoride	894	µg/L	0 0088	mg/kg-day	6E 02	mg/kg-day	0 1
Nitrate/nitrite[6]	12,849	µg/L	0 13	mg/kg day	1 6E+00	mg/kg day	0 08
Hazard Index							**0 2**

Notes

1. Risks were calculated for those chemicals with oral toxicity criteria. Slight rounding may occur
2. PCOCs identified from the PRG screen (Table 3 11)
3. Exposure factors used to calculate intake for groundwater ingestion in a future onsite office worker exposure scenario are presented in Table 3 12
4. Oral toxicity values are from (DOE 1995d) and HEAST (EPA 1994a)
5. The maximum detected concentration was used to calculate risk because the UCL$_{95}$ is greater than the maximum detected concentration
6. The oral chronic reference dose is for nitrate because it is the dominant species present.

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Table 3-13
Site-Specific Exposure Factors for Groundwater Ingestion[1]

Exposure Factor	Abbreviation	Reasonable Maximum Exposure (RME) Value	Units
		Adult	
Ingestion Rate	IR	1 0	L/day
Fraction Ingested from Contaminated Source	FI	1 0	unitless
Exposure Frequency	EF	250	days/year
Exposure Duration	ED	25	years
Body Weight	BW	70	kg
Averaging Time Noncarcinogen	ATN	9,125	days
Averaging Time Carcinogen	ATC	25,550	days

Note

[1] Exposure parameters are presented in Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment (DOE 1995g).

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Table 3-15
Potential Chemical-Specific ARARs for Surface Water

Analyte	ARAR/ TBC	Unit	Law/Regulation	Citation
Metals				
Aluminum	87	µg/L	Colorado Water Quality Standard AQ	5 CCR 1002-8 3 1 11
Antimony	300	µg/L	Practical Quantitation Limit (PQL)	
Arsenic	50	µg/L	SDWA MCL	40 CFR 141
Barium	1 000	µg/L	RCRA MCL	40 CFR 264 94
Beryllium	4	µg/L	Segment 4 & 5 Standard	Standard is 1-day average
Cadmium	TVS		Segment 4 & 5 Standard	
Chromium	50	µg/L	RCRA MCL	40 CFR 264 94
Cobalt	50	µg/L	Colorado Water Quality Standard AG	5 CCR 1002 8 3 1 11
Copper	TVS		Segment 4 & 5 Standard	
Lead	TVS		Segment 4 & 5 Standard	
Lithium	2 500	µg/L	Colorado Water Quality Standard AG	5 CCR 1002 8 3 1 11
Manganese	50	µg/L	Colorado Water Quality Standard	5 CCR 1002 8 3 1 11
Mercury	10	µg/L	Segment 4 & 5 Standard	
Nickel	125	µg/L	Segment 4 & 5 Standard	
Selenium	17	µg/L	Colorado Water Quality Standard	5 CCR 1002 8 3 1 11
Silver	50	µg/L	RCRA MCL	40 CFR 264 94
Tin	8 000	µg/L	PQL	
Vanadium	100	µg/L	Colorado Water Quality Standard AG	5 CCR 1002 8 3 1 11
Zinc	2 000	µg/L	Colorado Water Quality Standard AG	5 CCR 1002-8 3 1 11
Radionuclides				
Americium 241	30	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Cesium 137	3,000	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Plutonium-239/240	30	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Plutonium 238	30	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5

Table 3-15
Potential Chemical-Specific ARARs for Surface Water

Analyte	ARAR/TBC	Unit	Law/Regulation	Citation
Plutonium-239	30	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Radium 226	100	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Strontium-89,90	8	pCi/L	SDWA MCL	40 CFR 141
Tritium	1,000	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Uranium-233, 234	500	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Uranium-235	600	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Uranium-238	600	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Indicator Parameters				
Cyanide	200	µg/L	SDWA MCL	40 CFR 141
Fluoride	2,000	µg/L	Colorado Water Quality Standard, DW	5 CCR 1002-8, 3.1 11
Nitrate/nitrite	10,000	µg/L	SDWA MCL	40 CFR 141
Nitrite	500	µg/L	Segment 4 & 5 Standard	Standard is 1-day average
Sulfate	250,000	µg/L	Colorado Water Quality Standard, DW	5 CCR 1002-8 3.1 11
Volatile Organic Compounds				
1 1-Dichloroethane	58	µg/L	6 CCR 1007-3	Sec 268.43
1,2-Dichloroethene	70	µg/L	SDWA MCL	40 CFR 141
2-Butanone	280	µg/L	6 CCR 1007-3	Sec 268.43
2-Hexanone	50	µg/L	Practical Quantitation Limit (PQL)	6 CCR 1007-3, 264, App. IX
4-Methyl-2-pentanone	140	µg/L	6 CCR 1007-3	Sec 268 43
Acetone	280	µg/L	6 CCR 1007-3	Sec 268.43
Benzene	1	µg/L	Colorado Water Quality Standard, HH, DW, DW&F	5 CCR 1002-8, 3.1 11
Chloromethane	5.7	µg/L	Colorado Water Quality Standard DW&F	5 CCR 1002-8, 3.1 11
Ethylbenzene	57	µg/L	RCRA LDR	40 CFR 268.40
Methylene chloride	4 7	µg/L	Colorado Water Quality Standard, HH, DW&F	5 CCR 1002-8 3 1 11
Tetrachloroethene	1	µg/L	PQL	5 CCR 1002-8, 3 1 11

Table 3-15
Potential Chemical-Specific ARARs for Surface Water

Analyte	ARAR/ TBC	Unit	Law/Regulation	Citation
Toluene	1 000	µg/L	SDWA MCL	40 CFR 141
Total xylenes	10 000	µg/L	SDWA MCL	40 CFR 141
Tnchloroethene	2 7	µg/L	Colorado Water Quality Standard HH DW&F	5 CCR 1002 8 3 1 11
Vinyl acetate	5	µg/L	PQL	6 CCR 1007 3 264 App IX
Vinyl chlonde	2	µg/L	SDWA MCL	40 CFR 141
Semivolatile Organic Compounds				
2 Methylnaphthalene	10	µg/L	PQL	6 CCR 1007 3 264 App IX
2 4 Dimethylphenol	36	µg/L	RCRA LDR	40 CFR 268 40
Acenaphthene	520	µg/L	Colorado Water Quality Standard AQ CH	5 CCR 1002-8 3 1 11
Bis(2 ethylhexyl)phthalate	10	µg/L	PQL	5 CCR 1002 8 3 1 11
Dibenzofuran	10	µg/L	PQL	6 CCR 1007 3 264 App IX
Diethyl phthalate	200	µg/L	RCRA LDR	40 CFR 268 40
Fluorene	10	µg/L	PQL	5 CCR 1002 8 3 1 11
Naphthalene	10	µg/L	PQL	5 CCR 1002 8 3 1 11
Phenanthrene	10	µg/L	PQL	5-CCR 1002 8 3 1 11

Abbreviations

AG agricultural
AQ aquatic
CCR Colorado Code of Regulations
CFR Code of Federal Regulations
CH chronic
DW drinking water
DW&F drinking water and fish
HH human health
LDR Land Disposal Restrictions
MCL maximum contaminant level
PQL practical quantitation limit
RCRA Resource Conservation and Recovery Act
SDWA Safe Drinking Water Act
TVS table value standard

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Table 3-16
Potential Chemical-Specific ARARs for Groundwater

Analyte	Potential ARAR	Unit	Law/Regulation	Citation
Metals				
Antimony	300	µg/L	Practical Quantitation Limit (PQL)	6 CCR 1007-3, 264 App. IX
Arsenic	50	µg/L	SDWA MCL	40 CFR 141
Barium	1,000	µg/L	RCRA MCL	40 CFR 264 94
Beryllium	2	µg/L	PQL	6 CCR 1007-3, 264, App. IX
Cadmium	5	µg/L	SDWA MCL	40 CFR 141
Chromium	50	µg/L	RCRA MCL	40 CFR 264.94
Cobalt	10	µg/L	PQL	6 CCR 1007-3, 264 App IX
Copper	1,300	µg/L	MCLG	40 CFR 141 50-52
Lead	50	µg/L	RCRA MCL	40 CFR 264 94
Manganese	200 (AG)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1 11
Mercury	2	µg/L	SDWA MCL	40 CFR 141
Nickel	100	µg/L	SDWA MCL	40 CFR 141
Selenium	20	µg/L	PQL	6 CCR 1007-3, 264, App. IX
Silver	70	µg/L	PQL	6 CCR 1007-3, 264 App. IX
Thallium	400	µg/L	PQL	6 CCR 1007-3, 264 App IX
Tin	8,000	µg/L	PQL	6 CCR 1007-3 264, App. IX
Vanadium	40	µg/L	PQL	6 CCR 1007-3, 264 App. IX
Zinc	2 000 (AG)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1 11
Radionuclides				
Americium-241	1.2 (DW)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Cesium-137	120 (DW)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Plutonium-239/240	1 2 (DW,a)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Radium-226	4 (DW)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400.5
Strontium-89,90	8	pCi/L	SDWA MCL	40 CFR 141

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Table 3-16
Potential Chemical-Specific ARARs for Groundwater

Analyte	Potential ARAR	Unit	Law/Regulation	Citation
Tritium	20,000	pCi/L	SDWA MCL	40 CFR 141
Uranium 233, 234	20 (DW,b)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Uranium 235	24 (DW,b)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Uranium 238	24 (DW,b)	pCi/L	Radiation Protection of the Public and the Environment	DOE Order 5400 5
Total uranium	40	pCi/L	Colorado Water Quality Standard	5 CCR 1002-8, 3 1 11
Indicator Parameters				
Cyanide	200	µg/L	SDWA MCL	40 CFR 141
Fluoride	2 000 (DW)	µg/L	Colorado Water Quality Standard	5 CCR 1002 8 3 1 11
Nitrate/nitrite	10 000	µg/L	SDWA MCL	40 CFR 141
Sulfate	250 000 (DW)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3 1 11
Volatile Organic Compounds				
1 1 Dichloroethane	1	µg/L	PQL	6 CCR 1007 3 264 App IX
1 1 Dichloroethene	7	µg/L	SDWA MCL	40 CFR 141
1 1 1 Trichloroethane	200	µg/L	SDWA MCL	40 CFR 141
1 1 2 Trichloroethane	1	µg/L	PQL	6 CCR 1007 3 264 App IX
1 2 Dichloroethene	0 (cis) 100 (trans)	µg/L	SDWA MCL	40 CFR 141
1 2 Dichloropropane	1	µg/L	PQL	
1 4 Dichlorobenzene	75	µg/L	SDWA MCL	40 CFR 141
2 Butanone	10	µg/L	PQL	6 CCR 1007 3 264 App IX
2 Hexanone	50	µg/L	PQL	6 CCR 1007 3 264 App IX
4 Methyl 2 pentanone	50	µg/L	PQL	6 CCR 1007 3 264 App IX
Acetone	100	µg/L	PQL	6 CCR 1007 3 264 App IX
Benzene	1 (HH DW DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3 1 11
Bromodichloromethane	1	µg/L	PQL	6 CCR 1007 3 264 App IX
Bromoform	4	µg/L	Colorado Basic Standard for Groundwater	5 CCR 1002 8 3 11

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Table 3-16
Potential Chemical-Specific ARARs for Groundwater

Analyte	Potential ARAR	Unit	Law/Regulation	Citation
Carbon tetrachloride	1	µg/L	PQL	6 CCR 1007-3, 264, App IX
Chlorobenzene	100 (HH DW DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3.1 11
Chloroethane	5	µg/L	PQL	6 CCR 1007 3 Part 264 App IX
Chloromethane	5 7 (DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3 1 11
Chloroform	6	µg/L	Colorado Basic Standard for Groundwater	5 CCR 1002-8, 3.11
Ethylbenzene	680	µg/L	Colorado Basic Standard for Groundwater	5 CCR 1002-8, 3 11
Methylene chloride	4 7 (HH, DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1 11
Tetrachloroethene	1	µg/L	PQL	6 CCR 1007-3 264 App. IX
Toluene	1,000	µg/L	SDWA MCL	40 CFR 141
Total xylenes	10,000	µg/L	SDWA MCL	40 CFR 141
Trichloroethene	2 7 (HH, DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3 1 11
Trichlorofluoromethane	10	µg/L	PQL	6 CCR 1007-3, 264 App. IX
Vinyl acetate	5	µg/L	PQL	6 CCR 1007-3, 264 App IX
Vinyl chloride	2	µg/L	SDWA MCL	40 CFR 141
Semivolatile Organic Compounds				
1,4-Dichlorobenzene	75	µg/L	SDWA MCL	40 CFR 141
2-Chloronapthalene	10	µg/L	PQL	6 CCR 1007-3, 264 App. IX
2-Methylnaphthalene	10	µg/L	PQL	6 CCR 1007-3, 264 App. IX
2,4-Dimethylphenol	2,120 (AQ AC)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1.11
2,4,5-Trichlorophenol	10	µg/L	PQL	6 CCR 1007-3, 264, App IX
4-Nitrophenol	10	µg/L	PQL	6 CCR 1007-3, 264, App. IX
Acenaphthene	520 (AQ, CH)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1 11
Bis(2-ethylhexyl)phthalate	10	µg/L	PQL	6 CCR 1007-3, 264 App IX
Dibenzofuran	10	µg/L	PQL	6 CCR 1007-3 264 App IX
Di-n-butyl phthalate	2 700 (HH, DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8, 3.1 11

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Table 3-16
Potential Chemical-Specific ARARs for Groundwater

Analyte	Potential ARAR	Unit	Law/Regulation	Citation
Di n-octyl phthalate	30	µg/L	PQL	6 CCR 1007 3 264 App IX
Diethyl phthalate	23 000 (HH DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002 8 3 1 11
Dimethylphthalate	313 (DW&F)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3 1 11
Fluorene	10	µg/L	PQL	6 CCR 1007 3 264 App IX
Naphthalene	10	µg/L	PQL	6 CCR 1007 3 264 App IX
Pentachlorophenol	50	µg/L	PQL	6 CCR 1007 3 264 App IX
Phenanthrene	10	µg/L	PQL	6 CCR 1007 3 264 App IX
Phenol	2 500 (AQ CH)	µg/L	Colorado Water Quality Standard	5 CCR 1002-8 3 1 11
Pesticides				
Aroclor 1232	50	µg/L	PQL	
Aroclor 1242	50	µg/L	PQL	

Abbreviations

a f1 value of 1 E-03
AC acute
AG agricultural
AQ aquatic
b f1 value of 5 E-02
CCR Colorado Code of Regulations
CFR Code of Federal Regulations
CH chronic (30-day)
DW drinking water
DW&F drinking water and fish
HH human health
MCL maximum contaminant level
MCLG maximum contaminant level goal
PQL practical quantitation limit
RCRA Resource Conservation and Recovery Act
SDWA Safe Drinking Water Act
TVS table value standard

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Table 3-17
ARARs Comparison for Leachate at the Seep

Analyte	Detection Limit Range	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals										
Aluminum	10 - 50,000	18/19	19	29	28,900	—	—	2,829	87	µg/L
Antimony	0 05 60	4/18	0	14	60 4	—	A	20	300	µg/L
Arsenic	0 7 10	8/16	0	1 4	3	B	—	3	50	µg/L
Barium	0 02 50 000	19/19	1	297	1,550	—	—	645	1,000	µg/L
Beryllium	0.2 5	2/18	0	0.2	1.4	—	JA	1	4	µg/L
Calcium	14.5 100 000	19/19	0	126 000	212,000	—	—	151,737	TVS	µg/L
Chromium	2 4 27.5	7/18	0	2	29.6	—	—	9	50	µg/L
Cobalt	0 02 50	10/18	0	2.7	19 1	B	—	11	50	µg/L
Copper	2.4 25	8/18	0	2	94 9	—	—	12	TVS	µg/L
Lead	0.8 - 2 000	14/18	0	1.5	11	—	V	5	TVS	µg/L
Lithium	2 2,000	15/19	0	34	107	—	V	48	2,500	µg/L
Manganese	1 - 10,000	19/19	19	[illegible]	[illegible]	—	—	[illegible]	50	µg/L
Mercury	0.02 0.2	1/18	0	0.1	0.28	—	—	0 1	10	µg/L
Nickel	0 02 40	5/18	0	5	31	—	V	12	125	µg/L
Selenium	1 1 5	2/18	0	1 1	7	W	—	2	17	µg/L
Silver	2.6 25	8/18	0	2.7	16.7	—	—	5	50	µg/L
Tin	10 200	8/18	0	11	243	—	—	48	8,000	µg/L
Vanadium	3.2 10,000	12/19	1	3 1	211	—	—	25	100	µg/L
Zinc	1.8 10,000	19/19	18	567	16,000	—	[illegible]	2,274	2,000	µg/L
Radionuclides										
Americium-241	0 0.013	16/16	0	-0 000404	0.02121	—	V	0.007	30	pCi/L
Cesium-137	0 47 1	14/14	0	-0.21	0.6057	J	—	0 15	3,000	pCi/L
Plutonium-238	0.01	2/2	0	-0.000465	0.00222	J	A	0.00088	30	pCi/L

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Table 3-17
ARARs Comparison for Leachate at the Seep

Analyte	Detection Limit Range	Detection Frequency	Detections Exceeding ARARs	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean Result	ARAR	Units
Plutonium 239	0 003	1/1	0	0 009	0 009	—	—	0 009	30	pCi/L
Plutonium 239/240	0 0 013	16/16	0	0 001	0 01606	—	A	0 007	30	pCi/L
Radium 226	0 03	1/1	0	0 58	0 58	—	A	0 58	100	pCi/L
Strontium 89,90	0 21 1	9/9	0	0 66	4 06	—	V	1 35	8	pCi/L
Tritium	155 450	19/19	1	185 4	1,500	—	A	393	1,000	pCi/L
Uranium 233, 234	0 1 0 6	12/12	0	-0 0238	4 2	B	A	0 8	500	pCi/L
Uranium 235	0 0 6	12/12	0	-0 012	0 084	J	A	0 03	600	pCi/L
Uranium 238	0 086 0 6	12/12	0	0 03914	3 76	—	A	1	600	pCi/L
Semivolatile Organics										
2 4 Dimethylphenol	10	1/5	0	3	3	J	A	5	36	µg/L
2 Methylnaphthalene	10	5/5	5	12	23	—	V	16	10	µg/L
Acenaphthene	10	5/5	0	2	3	J	A	3	520	µg/L
Bis(2 ethylhexyl)phthalate	10 12	1/5	0	2	2	J	A	5	10	µg/L
Dibenzofuran	10	5/5	0	1	2	J	A	1	10	µg/L
Diethyl phthalate	10	4/5	0	1	3	J	A	3	200	µg/L
Fluorene	10	5/5	0	2	3	J	A	2	10	µg/L
Naphthalene	10	5/5	5	14	22	—	V	18	10	µg/L
Phenanthrene	10	5/5	0	4	5	J	A	4	10	
Volatile Organics										
1 1 Dichloroethane	5	17/20	0	2	10	—	V	6	59	µg/L
1 2 Dichloroethene	5	10/20	0	2	14	—	V	4	70	µg/L
2 Butanone	10	6/19	0	6	76	—	V	12	280	µg/L
2 Hexanone	10	1/20	0	1	10	—	V	5	50	µg/L
4 Methyl 2 pentanone	10	5/20	0	10	87	J	A	11	140	µg/L

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Table 3-17
ARARs Comparison for Leachate at the Seep

Acetone	10	10/20	0	10	220	—	A	34	280	µg/L
Benzene	5	11/20	4	1	[illegible]	J	—	2	1	µg/L
Chloromethane	10	2/20	1	4	7	J	A	5	5 7	µg/L
Ethylbenzene	5	19/20	0	1	18	—	—	13	57	µg/L
Methylene chloride	5	9/20	[illegible]	3	190	[illegible]	—	14	4.7	µg/L
Tetrachloroethene	5	2/20	0	1	1	J	—	[illegible][1]	1	µg/L
Toluene	5	19/20	0	5	88	—	—	38	1,000	µg/L
Total xylenes	5	19/20	1	1	25	J	A	14	10,000	µg/L
Trichloroethene	5	11/20	1	1	4	J	—	2	2 7	µg/L
Vinyl acetate	10	1/19	5	10	[illegible]	—	—	7[2]	5	µg/L
Vinyl chloride	10	[illegible]	[illegible]	[illegible]	[illegible]	—	V	6	2	µg/L
Indicator Parameters										
Cyanide	10 20	1/14	0	1.5	36.8	—	—	9	200	µg/L
Fluoride	100 200	12/12	0	390	540	—	V	489.2	2,000	µg/L
Nitrate/nitrite	20 200	6/10	0	20	870	—	V	263	10,000	µg/L
Nitrite	20	8/9	0	20	83	—	V	30.33	500	µg/L
Sulfate	200 25,000	5/14	0	200	29,800	—	V	5,084	250,000	µg/L

Notes

Shaded analytes indicate mean result exceeds ARAR.
All analytes are total analytes unless otherwise noted.
Analytes with zero detections are not reported.
For non-detects, one-half the detection limit is used in calculating the mean result.

[1] For tetrachloroethene, the maximum detection equals the ARAR, the mean exceeds the ARAR because one-half detection limit for non-detects exceeds the ARAR.
[2] For vinyl acetate one detection out of nineteen causes mean to exceed ARAR, suggests that one detection is outlier and should be discarded.

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Table 3-17
ARARs Comparison for Landfill Leachate

Data Qualifiers

	Data qualifier field in database is blank.
B	For inorganics reported value is < crdl but > idl (estimated value)
B	For organics analyte is also detected in blank for common lab contaminants include as detection if blank result > 10 times detection limit for all other organics include if blank result > 5 times detection limit.
B	For radionuclides constituent also detected in blank whose concentration was > minimum detectable activity
I	Organics interference with target peak (estimated value)
J	For organics ms data indicate presence of compound but below detection limit (estimated value)
U	For inorganics and organics analyte analyzed but not detected at the quantitation limit.
W	Inorganics post-digestion spike for gfaa analysis is out of control limits while sample absorbance is less than 50 percent of spike absorbance

Data Validation Codes

-	data validation field in database is blank
A	acceptable result
JA	acceptable result (for estimated value)
V	valid result

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Table 3-18
ARARs Comparison for Surface Water in the East Landfill Pond

Analyte	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals										
Aluminum	10 200	16/22	5	30.4	271	—	—	75	87	µg/L
Antimony	0.05 500	2/22	0	8	16.9	B	—	22	300	µg/L
Arsenic	0 7 10	9/21	0	0 9	2.2	—	V	1	50	µg/L
Barium	0 02 200	22/22	0	18	250	—	V	172	1,000	µg/L
Beryllium	0.2 5	1/22	0	0 5	0 7	—	JA	1	4	µg/L
Chromium	2.4 20	2/22	0	2	10.9	—	—	3	50	µg/L
Lithium	2 - 100	20/21	0	7.7	109	—	—	79	2,500	µg/L
Manganese	1 - 15	21/22	14	2.5	[illegible]	—	V	105	50	µg/L
Mercury	0.2	3/22	0	0 1	0.54	—	V	0 1	10	µg/L
Nickel	0 02 - 40	14/22	0	6.3	22	—	V	10	125	µg/L
Silver	2 5 30	3/22	0	2	4	—	JA	3	50	µg/L
Tin	10 1 000	6/21	0	10	44.3	B	—	41	8 000	µg/L
Vanadium	2 50	6/22	0	2	9	B	—	4	100	µg/L
Zinc	1.8 20	19/22	0	4	105	—	—	17	2,000	µg/L
Radionuclides										
Americium-241	0 0 19	15/15	0	0.0006655	0.031	U	A	0.007	30	pCi/L
Cesium-137	0.23 1 16	11/11	0	-0.2923	0.1344	—	V	-0.06	3,000	pCi/L
Plutonium-239	0 - 0.03	8/8	0	0	0.022	—	—	0.007	30	pCi/L
Plutonium-239/240	0 0.01	11/11	0	-0.000364	0.023	—	A	0.004	30	pCi/L
Radium-226	0.211	1/1	0	0.23	0.23	—	V	0.23	100	pCi/L
Strontium-89,90	0.23 1	5/5	0	0.8635	1.924	—	A	1 4	8	pCi/L
Tritium	160 460	20/20	0	19	257.8	J	V	139	1,000	pCi/L
Uranium-233, 234	0 0.232	9/9	0	0 7826	1 594	—	V	1 1	500	pCi/L

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Table 3-18
ARARs Comparison for Surface Water in the East Landfill Pond

Analyte	Detection Limit Range	Detection Frequency	Detections Exceeding ARARs	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean Result	ARAR	Units
Uranium-235	0 0 281	9/9	0	0 01	0 3	–	A	0 1	600	pCi/L
Uranium 238	0 08 0 263	9/9	0	0 6996	1 964	–	A	1 1	600	pCi/L
Semivolatile Organics										
Bis(2 ethylhexyl)phthalate	9 11	1/8	0	1	1	J	A	5	10	µg/L
Di n butyl phthalate	9 11	1/8	0	1	1	J	A	5		µg/L
Volatile Organics										
Acetone	10	1/21	0	6	12	B	–	6	280	µg/L
Methylene chloride	5	3/21	2	4	8	B	–	3	4 7	µg/L
Vinyl acetate	10	1/20	1	10	80	–	–	9[1]	5	µg/L
Indicator Parameters										
Fluoride	100 200	15/15	0	590	890	–	–	770	2 000	µg/L
Nitrate/nitrite	20 100	6/13	0	20	320	–	JA	80	10 000	µg/L
Sulfate	500 10 000	16/16	0	7 000	25 600	–	V	16 031	250 000	µg/L

Notes

Shaded analytes indicate mean result exceeds ARAR
All analytes are total analytes unless otherwise noted
Analytes with zero detections are not reported
For non-detects one half the detection limit is used in calculating the mean result.
[1] For vinyl acetate one detection out of nineteen causes mean to exceed ARAR suggests that one detection is outlier and should be discarded

Data Qualifiers

- – data qualifier field in database is blank
- B for inorganics reported value is < CRDL but > IDL (estimated value)
- B for organics, analyte is also detected in blank, for common lab contaminants include as detection if blank result > 10 times detection limit, for all other organics include if blank result > 5 times detection limit
- J for organics MS data indicate presence of compound but below detection limit (estimated value)
- U for inorganics and organics analyte analyzed but not detected at the quantitation limit

Data Validation Codes

- data validation field in database is blank
- A acceptable result
- JA acceptable result (for estimated value)
- V valid result

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Table 3-19
ARARs Comparison for Groundwater Downgradient of the Landfill

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6786 Summary Statistics											
Radionuclides											
Tritium	210 470	9/9	0	9	134.2	368	J	V	215	20,000	pCi/L
Volatile Organics											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.4 10	2/14	0	14	0.4	8	J	A	4	5	µg/L
Methylene chloride	0.1 5	4/14	0	14	0.1	3	J	A	2	4.7	µg/L
Indicator Parameters											
Fluoride	100	5/5	0	5	1,200	1 900	—	V	1,540	2,000	µg/L
Nitrate/nitrite	20 100	5/9	0	9	20	1,800	—	V	248.3	10,000	µg/L
Sulfate	2,000 5,000	5/5	0	5	170,000	250,000	—	V	210,000	250 000	µg/L
4087 Summary Statistics											
Radionuclides											
Americium-241	0.01	1/1	0	1	0.002	0.002	—	A	0.002	1.2	pCi/L
Plutonium-239/240	0	1/1	0	1	0.006	0.006	—	A	0.006	1.2	pCi/L
Tritium	259 650	5/5	0	5	0	260.8	J	V	169.4	20,000	pCi/L
Uranium-233,-234	0.36	1/1	0	1	20 09	20.09	—	A	20.09	20	pCi/L
Uranium-235	0.31	1/1	0	1	0.5933	0.5933	—	A	0.5933	24	pCi/L
Uranium-238	0.25	1/1	0	1	13.23	13.23	—	A	13.23	24	pCi/L
Volatile Organics											
Methylene chloride	0.2 5	2/8	0	8	0.2	2	J	—	2	4 7	µg/L
Indicator Parameters											
Fluoride	100	5/5	1	5	1,500	3,400	—	—	2,060	2,000	µg/L
Nitrate/nitrite	20 - 100	4/5	0	5	20	644	—	Y	305	10,000	µg/L
Sulfate	2,000 5,000	5/5	6	5	288,000	770,000	—	—	522,000	250,000	µg/L
4087 Summary Statistics											
Metals											
Arsenic	10	1/2	0	2	1 9	1.9	B	—	1	50	µg/L
Barium	200	2/2	0	2	79 6	94 5	B	—	87 1	1,000	µg/L
Chromium	10	2/2	0	2	6.9	9.5	B	—	8.2	50	µg/L
Copper	25	1/2	0	2	6 7	9.4	B	—	6.4	1,300	µg/L
Lead	3	2/2	0	2	1 1	2.8	B	—	1.9	50	µg/L
Manganese	15	2/2	0	2	58.7	59.8	E	—	59.3	200	µg/L
Nickel	40	2/2	0	2	7.1	8.4	B	—	7.8	100	µg/L
Silver	10	1/2	0	2	2	3.2	B	—	2	70	µg/L
Tin	200	1/2	0	2	11 5	11.5	B	—	12	8,000	µg/L
Vanadium	50	2/2	0	2	24 3	32.1	B	—	28.2	40	µg/L
Zinc	20	2/2	0	2	21.9	28.9	E	—	25.4	2,000	µg/L

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Table 3-19
ARARs Comparison for Groundwater Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Detections Exceeding ARARs	Number of Samples	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	ARAR	Units
Radionuclides											
Americium 241	0 0 01	4/4	0	4	0 00107	0 011	–	JA	0 005	1 2	pCi/L
Cesium 137	0 6 0 82	2/2	0	2	0 0334	0 38	–	A	0 17	120	pCi/L
Plutonium 239/240	0 0 01	4/4	0	4	0 0002529	0 004	–	A	0 002	1 2	pCi/L
Strontium 89,90	0 25	1/1	0	1	0 49	0 49	–	A	0 49	8	pCi/L
Tritium	216 7 520	6/6	0	6	84 9	390	–	–	128	20,000	pCi/L
Uranium 233, 234	0 61	1/1	0	1	4 078	4 078	–	A	4 078	20	pCi/L
Uranium 235	0 74	1/1	0	1	0 7962	0 7962		A	0 7962	24	pCi/L
Uranium 238	0 61	1/1	0	1	3 683	3 683	-	A	3 683	24	pCi/L
Volatile Organic Compounds											
Methylene chloride	0 1 5	1/9	0	9	0 1	1	J	V	2	4 7	µg/L
Indicator Parameters											
Fluoride	100	8/8	0	8	400	800	–	V	618 8	2 000	µg/L
Nitrate/nitrite	20 100	6/7	0	7	40	200	–	V	94 3	10 000	µg/L
Sulfate	2 000 5 000	8/8	0	8	33 000	79 221	–	V	48 253	250 000	µg/L
53194 Summary Statistics											
Radionuclides											
Americium 241	0 00436	1/1	0	1	0 006443	0 006443		Y	0 006443	1 2	pCi/L
Plutonium 239/240	0 0125	1/1	0	1	0 004633	0 004633	J	Y	0 004633	1 2	pCi/L
Tritium	384	1/1	0	1	14 34	14 34	J	Y	14 34	20,000	pCi/L
B206789 Summary Statistics											
Metals											
Antimony	17 60	1/7	0	7	14	58	B	Y	18	300	µg/L
Arsenic	2 10	1/7	0	7	1	2 7	-	V	1	50	µg/L
Barium	9 200	4/7	0	7	16 1	22	B	Y	16	1 000	µg/L
Chromium	3 10	2/7	0	7	2	17	–	JA	4	50	µg/L
Copper	2 25	1/7	0	7	2	8	B	Y	4	1 300	µg/L
Lead	1 5	2/7	0	7	1	1 2	B	V	1	50	µg/L
Manganese	1 15	5/7	0	7	2 8	9 7	–	V	6 3	200	µg/L
Nickel	10 40	1/7	0	7	3	11 1	B	Y	5	100	µg/L
Selenium	0 5	7/7	7	7	488	815	+	JA	665	20	µg/L
Silver	4 10	1/7	0	7	2	10 9	N	JA	3	70	µg/L
Thallium	2 10	1/7	0	7	1	1	B	V	1	400	µg/L
Tin	18 200	1/7	0	7	10	19.2	B	V	12	8 000	µg/L
Vanadium	3 50	3/7	0	7	2 9	8 9	BE	JA	5	40	µg/L
Zinc	3 20	4/7	0	7	9 1	52 7	–	JA	19 3	2 000	µg/L
Radionuclides											
Americium-241	0 01	1/1	0	1	-0 433	0 433	J	-	-0 433	1 2	pCi/L
Plutonium 239/240	0 01	2/2	0	2	0 001103	0 004	–	A	0 003	1 2	pCi/L
Radium 226	0 06 0 5	2/2	0	2	0 35	0 52		A	0 44	4	pCi/L
Tritium	211 7 840	10/10	0	10	138	230	U	V	21	20,000	pCi/L

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Table 3-19
ARARs Comparison for Groundwater Downgradient of the Landfill

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Semivolatile Organic Compounds											
Bis(2-ethylhexyl)phthalate	10	1/2	0	2	3	3	J	A	4	10	µg/L
Volatile Organic Compounds											
Acetone	10	1/17	0	17	8	11	B	–	5	100	µg/L
Benzene	0 1 10	1/19	0	19	0 1	0.1	J	–	2	1	µg/L
Methylene chloride	0 1 10	1/19	0	19	0.1	3	J	–	2	4.7	µg/L
Indicator Parameters											
Fluoride	100 200	13/13	0	13	300	500	–	–	399.2	2,000	µg/L
Nitrate/nitrite	20 2,800	18/18	0	18	3,000	9,700	–	–	6,583	10,000	µg/L
Sulfate	2,000 100,000	13/13	13	13	580,000	900,000	–	V	643,600	250,000	µg/L
[illegible] Summary Statistics											
Radionuclides											
Tritium	266 660	9/9	0	9	164.48541	130.4	J	–	16	20,000	pCi/L
Uranium-233,-234	0	1/1	0	1	49.32	49.32	–	A	49.32	20	pCi/L
Uranium-235	0.07	1/1	0	1	2.82	2.82	–	A	2.82	24	pCi/L
Uranium-238	0 07 - 0 18	2/2	0	2	29.81	35.45	–	A	32.63	24	pCi/L
Volatile Organic Compounds											
Acetone	10 - 100	1/13	0	13	10	24	B	–	10	100	µg/L
Benzene	0.1 5	1/18	0	18	0.1	0.5	J	A	2	1	µg/L
Carbon tetrachloride	0.2 5	2/18	0	18	0.2	7 11	–	Y	3	1	µg/L
Ethylbenzene	0.2 5	1/18	0	18	0.2	0.3	J	A	2	680	µg/L
Methylene chloride	0 1 5	2/18	1	18	0.1	8	B	–	3	4.7	µg/L
Tetrachloroethene	0.1 - 5	1/18	0	18	0.1	0.769	–	Y	2	1	µg/L
Toluene	0.1 5	1/18	0	18	0.1	3	J	A	2	1,000	µg/L
Total xylenes	0 5 5	1/16	0	16	0.5	3	J	A	2	10,000	µg/L
Trichloroethene	0 1 5	1/18	0	18	0 1	1.49	–	Y	2	2 7	µg/L
Indicator Parameters											
Fluoride	100	2/2	0	2	450	500	–	V	475	2,000	µg/L
Nitrate/nitrite	20 200,000	11/11	11	11	82,000	290,000	–	JA	157,275	10,000	µg/L
Sulfate	2,000 250,000	2/2	2	2	1,420,000	1,600,000	–	V	1,510,000	250,000	µg/L
[illegible] Summary Statistics											
Radionuclides											
Tritium	236.92 420	5/5	0	5	-141	107 12	–	V	-17	20,000	pCi/L
Volatile Organic Compounds											
Methylene chloride	0 1 5	3/15	2	15	0.1	8	B	–	2	4 7	µg/L
Toluene	0 1 5	1/16	0	16	0 1	1	J	–	2	1,000	µg/L
Indicator Parameters											
Fluoride	100	1/1	0	1	230	230	–	V	230	2,000	µg/L
Nitrate/nitrite	20	5/5	5	5	36,000	72,000	–	V	49,600	10,000	µg/L
Sulfate	5,000	1/1	1	1	2,800,000	2,800,000	–	V	2,800,000	250,000	µg/L

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Table 3-19
ARARs Comparison for Groundwater Downgradient of the Landfill

Analyte	Detection Limit Range	Detection Frequency	Detections Exceeding ARARs	Number of Samples	Minimum Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	Mean	ARAR	Units
B207089 Summary Statistics											
Metals											
Antimony	60	1/6	0	6	8	66 8	-	JA	21	300	µg/L
Barium	200	5/6	0	6	27 5	42 9	B	V	32	1 000	µg/L
Cadmium	5	2/6	0	6	1	2 4	B	V	1	5	µg/L
Chromium	10	3/6	0	6	2 5	18	–	V	7	50	µg/L
Copper	25	1/6	0	6	3 5	6 2	B	JA	4	1 300	µg/L
Manganese	15	6/6	0	6	14 1	109	–	V	43	200	µg/L
Nickel	40	2/6	0	6	4	7 5	B	JA	6	100	µg/L
Selenium	5	1/6	0	6	1	1	B	JA	1	20	µg/L
Silver	10	1/5	0	5	2	2 2	B	V	2	70	µg/L
Tin	200	1/5	0	5	10	20 2	B	V	12	8 000	µg/L
Vanadium	50	3/5	0	5	5	11 5	B	JA	7	40	µg/L
Zinc	20	3/5	0	5	11 3	33 4	–	V	20 8	2 000	µg/L
Radionuclides											
Americium-241	0 0 03	17/17	0	17	0	0 012	–	A	0 005	1 2	pCi/L
Cesium 137	0 74 2 37	8/8	0	8	0 498	0 4298	J	A	0	120	pCi/L
Plutonium-239/240	0 0 087	19/19	0	19	0 000272	0 009	J	V	0 002	1 2	pCi/L
Radium 226	0 096	1/1	0	1	0 64	0 64	B	Y	0 64	4	pCi/L
Strontium-89,90	0 38 1 6	3/3	0	3	-0 14	0 31	–	A	0 06	8	pCi/L
Tritium	0 820	20/20	0	20	78 34	400	U	–	103	20,000	pCi/L
Uranium 233, 234	0 0 36	2/2	0	2	2 8	4 25	–	–	3 5	20	pCi/L
Uranium-235	0 0 25	2/2	0	2	0 082	0 351	–	–	0 217	24	pCi/L
Uranium-238	0 0 37	2/2	0	2	1 5	1 58	–	–	1 5	24	pCi/L
Volatile Organic Compounds											
Benzene	0 1 5	1/18	0	18	0 1	0 1	J	–	2	1	µg/L
Methylene chloride	0 1 5	4/19	2	19	0 1	12	B	–	3	4 7	µg/L
Toluene	0 1 5	1/19	0	19	0 1	0 2	J	–	2	1 000	µg/L
Indicator Parameters											
Cyanide	5 100	2/17	0	17	1	56 000	B	V	9	200	µg/L
Fluoride	0 100	18/18	0	18	300	750	–	Y	369 6	2 000	µg/L
Nitrate/nitrite	20 2 800	17/18	0	18	665	2 400	-	JA	1 101	10 000	µg/L
Sulfate	1 000 100 000	18/18	18	18	440 000	19 000 000	–		1 612 462	250 000	µg/L

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Table 3-19
ARARs Comparison for Groundwater Downgradient of the Landfill

Data Qualifiers

__	Data qualifier field in database is blank
+	Correlation coefficient for matrix spike analysis is less than 0.995 (estimated value)
B	For inorganics, reported value is < CRDL but > IDL (estimated value)
B	For organics, analyte is also detected in blank; for common lab contaminants include as detection if blank result > 10 times detection limit; for all other organics include if blank result > 5 times detection limit
B	For radionuclides, constituent also detected in associated blank whose concentration was greater than CRDL
E	For inorganics, value is an estimate due to interference (estimated value)
J	For inorganics, value > IDL but control sample analysis not within control limits (estimated value)
J	For organics, MS data indicate presence of compound but below detection limit (estimated value)
N	For inorganics, spiked sample recovery is not within control limits (estimated value)
U	Organics and inorganics, analyte analyzed but not detected at the quantitation limit

Data Validation Codes

__	Data qualifier field in database is blank
A	acceptable result
JA	acceptable result (For Estimated Value)
V	valid result
Y	analytical results in validation process

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Table 3-20
Potential Location-Specific ARARs

Law/Regulation	Citation	Description	ARAR Designation	Comments
Federal Laws				
Endangered Species Act	16 USC § 1538 50 CFR Part 17	Ensures that remedial/removal actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify their critical habitats	Applicable	Listed endangered species found around Rocky Flats include the bald eagle Category 2 species found at Rocky Flats include the ferruginous hawk and Preble s meadow jumping mouse The Rocky Flats area supports habitat for many other endangered and category 2 species but none have been found
Bald and Golden Eagle Protection Act	16 USC § 668a 50 CFR Part 22	Contains permitting requirements to take (kill or *destroy habitat*) possess or transport bald (American) and golden eagles their nests or their eggs anywhere in the United States	Applicable	General applicability Bald and golden eagles have been identified migrating through Rocky Flats Some habitat at Rocky Flats is suitable for nesting
Fish and Wildlife Coordination Act	16 USC § 661 *et seq*	Requires consultation by the federal department or agency proposing or authorizing any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources	Applicable	Applicable because possible remedial action (e g reducing the size of the pond as a result of the extent of the landfill cap) may affect wildlife that depend on the pond
Wetlands Assessment	Executive Order 11990 40 CFR Part 6 Appendix A	Federal agencies must prevent to the extent possible the adverse impacts of destroying or modifying wetlands and must prevent direct or indirect support of new construction in wetlands if there is a practicable alternative	Applicable	Applicable because riparian areas around the East Landfill Pond have been identified as wetland areas
Clean Water Act	33 CFR §§ 320 330 40 CFR Part 230	Action to dispose of dredge and fill material in waters of the United States is prohibited without a permit Under CERCLA § 121(e) no permitting is required for onsite actions however consultation with the U S Army Corps of Engineers remains important	Applicable	Action to drain the East Landfill Pond is a dredging operation within the parameters of the Clean Water Act
State Laws				
Colorado Nongame Endangered or Threatened Species Conservation Act	CRS Part 33-2 101 to 107	Establishes requirements for protection of wildlife	Applicable	Parallels the federal Endangered Species Act In addition to the species identified above Rocky Flats contains two species of concern in Colorado forktip three-awn and toothcup

Definitions

ARAR applicable or relevant and appropriate requirement
CERCLA Comprehensive Environmental Response Compensation and Liability Act
CFR Code of Federal Regulation
CRS Colorado Revised Statutes
USC United States Code

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Table 3-21
Potential Federal and State Action-Specific ARARs

Law/Regulation	Citation	Description	ARAR Determination	Comments
Federal Laws				
Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste	40 CFR Part 261	Defines those solid wastes that are subject to regulation as hazardous wastes	Applicable	Characterization of waste at the landfill may determine the selection of a remedy
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	Establishes the methodology for determining if a solid waste is a hazardous waste.	Applicable	Characterization of waste at the landfill may determine the selection of a remedy
Resource Conservation and Recovery Act	42 USC § 9621 et seq.			
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable possibility of adverse effect on health or the environment.	Relevant and appropriate	Not applicable because it applies to ongoing operations at solid waste disposal facilities (OU 7 is now regulated as an interim status facility under 40 CFR 265) Relevant and appropriate to identifying criteria that may pose a reasonable probability of adverse effect on human health or the environment.
Criteria for Municipal Solid Waste Landfills	40 CFR Part 258	Establishes minimum criteria for municipal solid waste landfills to ensure protection to human health and the environment. Subpart E Ground Water Monitoring and Corrective Action; Subpart F, Closure and Post-Closure Care; and Appendix 1 and 2 are all identified as potential ARARs.	Relevant and appropriate	Not applicable because OU 7 is not a municipal site. Relevant and appropriate because OU 7 contains wastes typical for a municipal landfill Identified sections relate to post-closure environmental issues.
Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	40 CFR Part 264	Establishes minimum national standards that define the acceptable management of hazardous waste for owners and operators of facilities that treat, store, and dispose of hazardous waste.	Relevant and appropriate	CDH directs that monitoring and post-closure care requirements are relevant and appropriate for detecting contaminant levels near the East Landfill Pond.
Interim Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 265	Establishes minimum national standards that define the acceptable management of hazardous waste during the period of interim status and until certification of final closure, or if the facility is subject to post-closure until responsibilities are fulfilled.	Applicable	Applicable because OU 7 is undergoing closure as an interim status RCRA facility pending closure
Land Disposal Restrictions	40 CFR Part 268	Establishes restrictions for the land disposal of hazardous wastes.	Relevant and appropriate	Not applicable because OU 7 remediation does not "place" hazardous wastes outside the area of contamination. It is relevant and appropriate because the type of place regulated is sufficiently similar
Clean Water Act	33 USC §§ 1251 1376			
Discharge of Stormwater	40 CFR § 122.21 and § 122.26	Controls point source discharges of stormwater associated with industrial activity including requirements for pollution prevention plans.	Relevant and appropriate	Relevant and appropriate because industrial activity includes landfills.

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Table 3-21
Potential Federal and State Action-Specific ARARs

Law/Regulation	Citation	Description	ARAR Designation	Comments
Criteria and Standards for the National Pollutant Discharge Elimination System	40 CFR Part 125 Subpart K	Requires that best management practices be maintained by the operator of a system that discharges pollutants directly into the environment and requires that point source discharges be monitored to ensure compliance with effluent discharge limits	Applicable	Applicable through the NPDES Federal Facility Compliance Agreement (FFCA CWA 90 1)
Atomic Energy Act	42 USC § 2011 *et seq*			
Standards for Protection Against Radiation	10 CFR Part 20	Establishes minimum standards for radioactive waste disposal	Relevant and appropriate	Not applicable because Rocky Flats is not an NRC licensed facility It is relevant and appropriate for its standards to protect the public from radiation exposure and radionuclide contamination of waters and soils
State Laws				
Colorado Solid Waste Disposal Sites and Facilities Act	CRS 30 20-100 5 *et seq*			
Colorado Solid Waste Disposal Sites and Facilities Regulations	6 CCR 1007 2	Establishes solid waste disposal criteria including the collection storage treatment utilization processing and final disposition of solid wastes	Relevant and appropriate	Not applicable because OU 7 is not regulated under state standards for solid waste disposal Closure monitoring and post closure maintenance requirements are relevant and appropriate to the Present Landfill because they apply to facilities that are sufficiently similar to OU 7
Soil Erosion Dust Blowing Act	CRS 35 72 101 *et seq*	*Creates an actionable duty to all real property* owners in the state to prevent soil from blowing to neighboring lands	*Applicable*	*Intended to apply to all lands in the state of Colorado*

Definitions

§ section
ARAR applicable or relevant and appropriate requirement
CCR Colorado Code of Regulation
CDH Colorado Department of Health
CFR Code of Federal Regulation
CRS Colorado Revised Statutes
CWA Clean Water Act
DOE U S Department of Energy
FFCA Federal Facility Compliance Agreement
NPDES National Pollutant Discharge Elimination System
NRC Nuclear Regulatory Commission
OU operable unit
RCRA Resource Conservation and Recovery Act
USC United States Code

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Table 3-22
Regulatory and Technical Guidance to be Considered

A Guide to Delisting of RCRA Wastes for Superfund Remedial Responses	OSWER 9347 3-09FS September 1990	Circumstances delisting wastes may be appropriate and the procedures for delisting a RCRA hazardous waste as part of a Superfund remedial response.	TBC	This guidance document lists maximum allowed concentrations (MACs) for various hazardous constituents, above which solids containing those wastes are not eligible for delisting. Although the guidance states that these levels are not to be used for setting cleanup levels, MACs may be relevant and appropriate for defining an outer boundary where soil contamination may not exceed that level.
Land Disposal Restrictions for Newly Identified and Listed Hazardous Wastes and Hazardous Soil	58 FR 48092 48097 (1993)	Proposed numerical treatment standards for organic and metal constituents in soil	TBC	As it is a proposed regulation, it is at most a TBC. Its use is relevant and appropriate for setting chemical-specific standards for soil. If promulgated, it will become an ARAR.
Air Emissions from Municipal Solid Waste Landfills	56 FR 24468 (1991)	Proposed threshold standards for NMOCs at municipal solid waste landfills	TBC	Relevant and appropriate for determining acceptable NMOC limits before triggering the need for additional treatment.
Presumptive Remedy for CERCLA Municipal Landfill Sites	EPA Directive No. 9355 0-49FS	Containment is the presumptive remedy for CERCLA municipal landfills	TBC	OU 7 is largely a landfill containing a combination of solid and hazardous wastes consistent with characterization as a municipal landfill
DOE Orders				
General Environmental Protection Program	DOE Order 5400 1	Specifies environmental protection standards applicable to DOE operations	TBC	Contains broad requirements for environmental monitoring.
Environment, Safety and Health Program for Department of Energy Operations	DOE Order 5480 1B	Specifies responsibility of DOE and conditions under which operations are to be curtailed due to risks.	TBC	Applicable as a potential ARAR because onsite remedial activities need to conform to its restrictions
Environmental Protection, Safety, and Health Protection Standards	DOE Order 5480 4	Specifies environment and safety requirements for facility construction, operation and decommissioning including requirements applicable to DOE and subcontractors.	TBC	Applicable as general standards under which remedial activities must be conducted.

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Table 3-22
Regulatory and Technical Guidance to be Considered

Guidance Source	Citation	Description	ARAR Designation	Comments
Radiation Protection of the Public and the Environment	DOE Order 5400 5	Specifies compliance of DOE and its contractors under Atomic Energy Act radiation protection requirements	TBC	Contains compliance guidelines for managing residual radioactive material Basic dose limits guidelines and authorized limits for allowable levels of residual radioactive material and control requirements for radioactive wastes and residues
Radioactive Waste Management	DOE Order 5480 2A	Specifies environmental protection requirements for management of low level waste	TBC	Includes general performance objectives and monitoring requirements

Definitions

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
EPA	U S Environmental Protection Agency
FR	Federal Register
MAC	maximum allowed concentration
NMOC	non methane organic compound
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
RCRA	Resource Conservation and Recovery Act
TBC	guidance or recommendation to be considered

Table 3-23
Comparison of PCOC Concentrations in Leachate at the Seep to MACs

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metals					
Antimony	60	µg/L	27.52	63	no
Barium	1,550	µg/L	742.52	6,300	no
Semivolatile Organic Compounds					
2 4-Dimethylphenol	3	µg/L	5 45	26.24	no
Bis(2-ethylhexyl)phthalate	2	µg/L	6.06	18.93	no
Diethyl phthalate	3	µg/L	4 05	189,000	no
Fluorene	3	µg/L	2.92	12.62	no
Naphthalene	22	µg/L	21.26	63,090	no
Phenanthrene	5	µg/L	4 92	12 62	no
Volatile Organic Compounds					
1 1-Dichloroethane	10	µg/L	7.20	2.524	yes
Acetone	220	µg/L	52.88	25,240	no
Benzene	2	µg/L	2.14	31.66	no
Carbon disulfide	6	µg/L	2.98	25,240	no
Ethylbenzene	18	µg/L	14 42	4,410	no
Tetrachloroethene	1	µg/L	2 53	31 55	no
Toluene	88	µg/L	47.55	12,020	no
Total xylenes	25	µg/L	16.8	63,090	no
Trichloroethene	4	µg/L	2.44	21 55	no
Vinyl chloride	11	µg/L	5.92	12.62	no

Note

All concentrations are for total analytes.

Definitions

PCOC potential contaminant of concern
MAC maximum allowable concentrations

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Table 3-24
Evaluation of Remedial Action Objectives for Developing Response Actions

Media Addressed by Remedial Action Objective (RAO)	Potential Exposure Pathways	Analytes Exceed PRGs	Risk Assessment Required?	Human Health Risk carcinogenic: HI > 1E-04 noncarcinogenic: HI > 1	Ecological Risk HI > 1	ARARs Exceedances	Response Action
Present Landfill/ IHSS 203/ Asbestos Disposal Areas	Eliminated under containment presumptive remedy	NA	no	NA	NA	Cover to be determined by closure ARARs	Presumptive remedy
Landfill Gas	Eliminated under containment presumptive remedy	NA	no	NA	NA	Gas emissions to be determined by air emission ARARs	Presumptive remedy
Landfill Leachate at the Seep	Eliminated under containment presumptive remedy	no	no	none	HI = 50 mallard HI = 3 raccoon HI = 3 coyote	Aluminum manganese zinc naphthalene 2 methynaphthalene benzene, vinyl chloride	Presumptive remedy
Surface Water in the East Landfill Pond	Inhalation ingestion dermal contact	no	yes	none	HI = 10 mallard	Manganese	No action required no risk to humans risk to wildlife overestimated
Sediments in the East Landfill Pond	Inhalation ingestion dermal contact	no	yes	none	HI > 1 100 aquatic life HI = 6 raccoon HI = 4 coyote HI = 3 mule deer HI = 3 Preble s meadow jumping mouse	No ARARs for soils	No action required no risk to humans risk to wildlife overestimated
Surface Soils in Spray Evaporation Area	Inhalation ingestion dermal contact, external irradiation	yes	yes	none	NA	No ARARs for soils	No action required no risk
Subsurface Geologic Materials Downgradient of the Landfill	Inhalation ingestion dermal contact, external irradiation	no	no	none	NA	No ARARs for soils	No action required no risk
Groundwater Downgradient of the Landfill in the Vicinity of East Landfill Pond	Inhalation ingestion dermal contact	yes	yes	none carcinogenic risk, HI = 3 noncarcinogenic risk	NA	Selenium	No action required pathway incomplete
Groundwater Downgradient of the Landfill Downgradient of Dam	Inhalation ingestion dermal contact	yes	yes	none	NA	Nitrate/nitrite sulfate	No action required pathway incomplete

Definitions

PRG preliminary remediation goal
HI hazard index
ARAR applicable or relevant and appropriate requirement
IHSS individual hazardous substance site
NA not applicable

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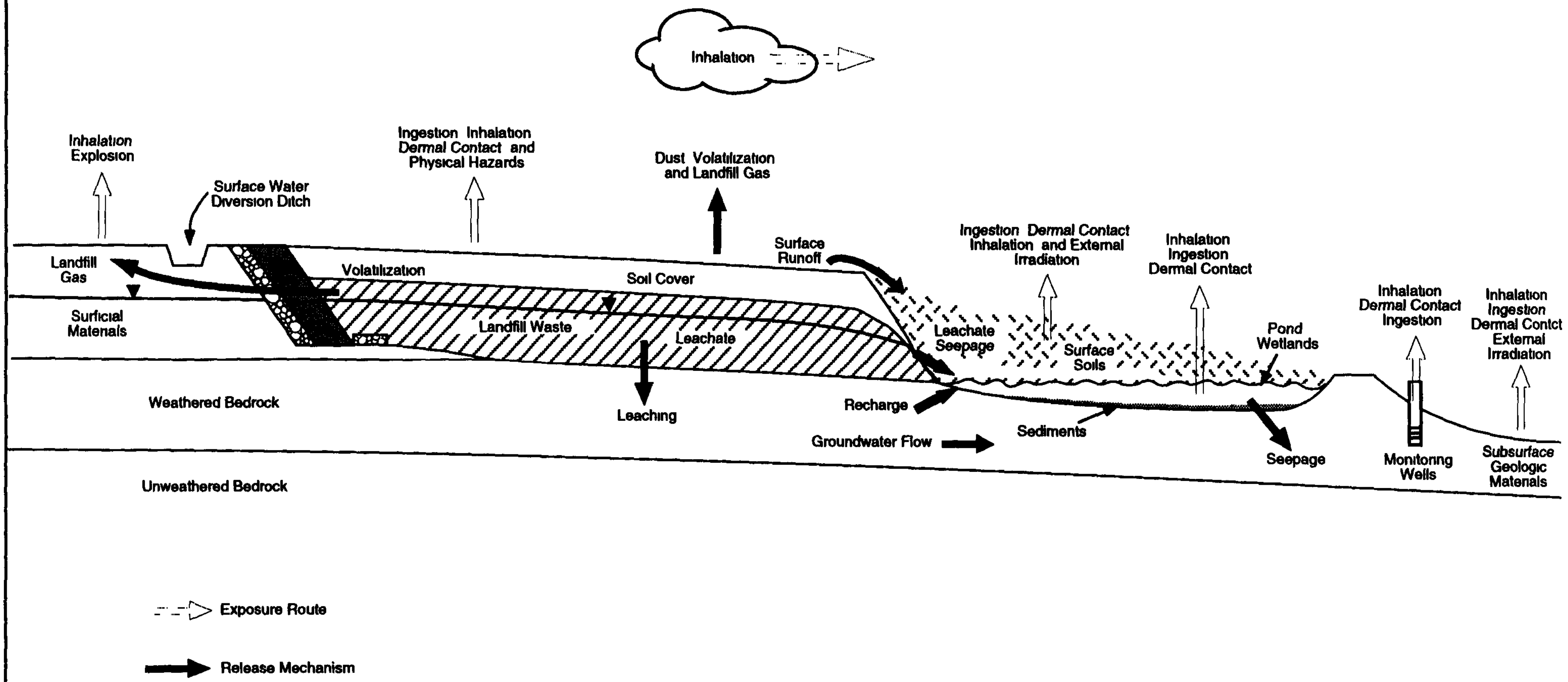

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Conceptual Site Model for Defining Risks at OU 7

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 3-1

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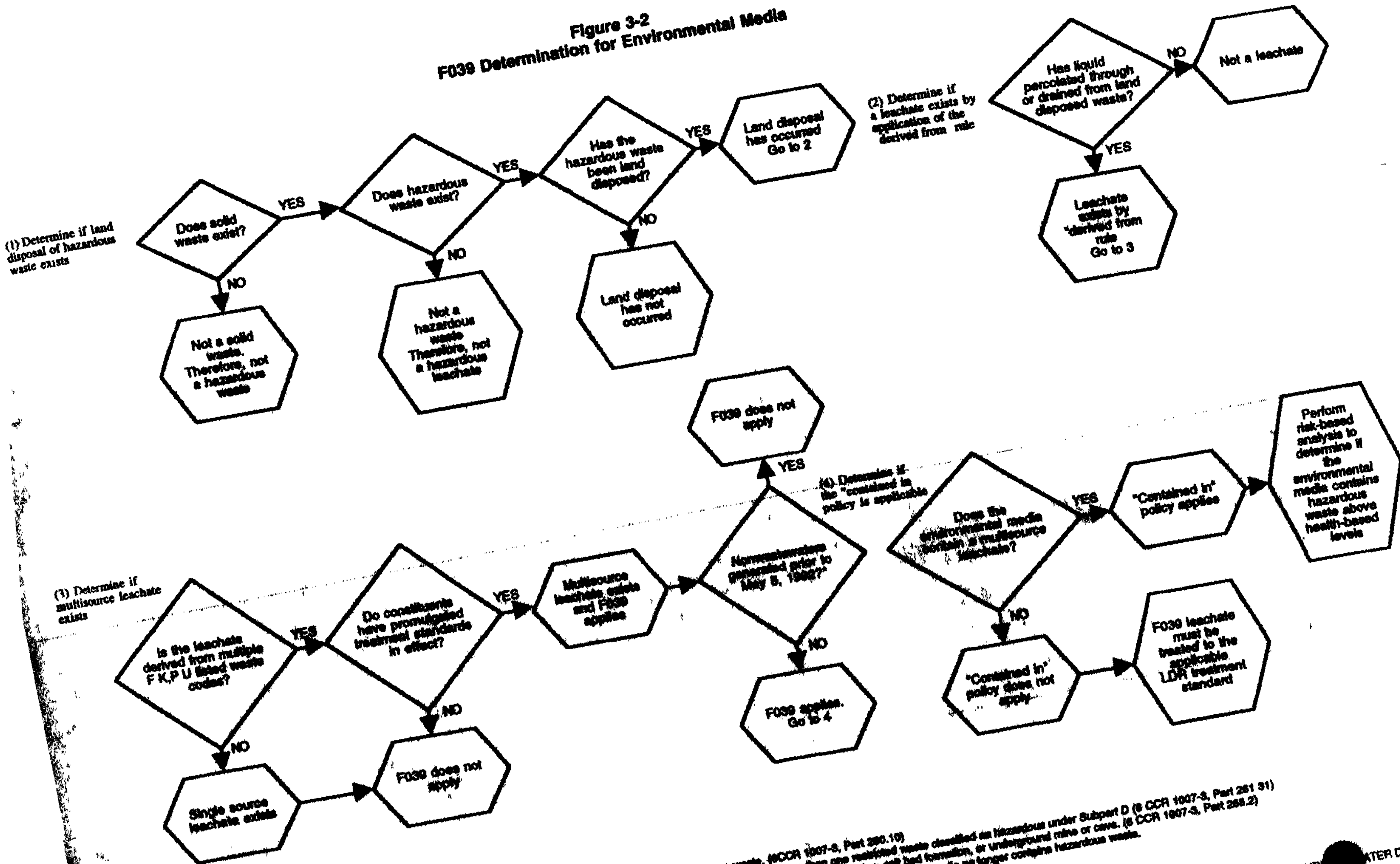
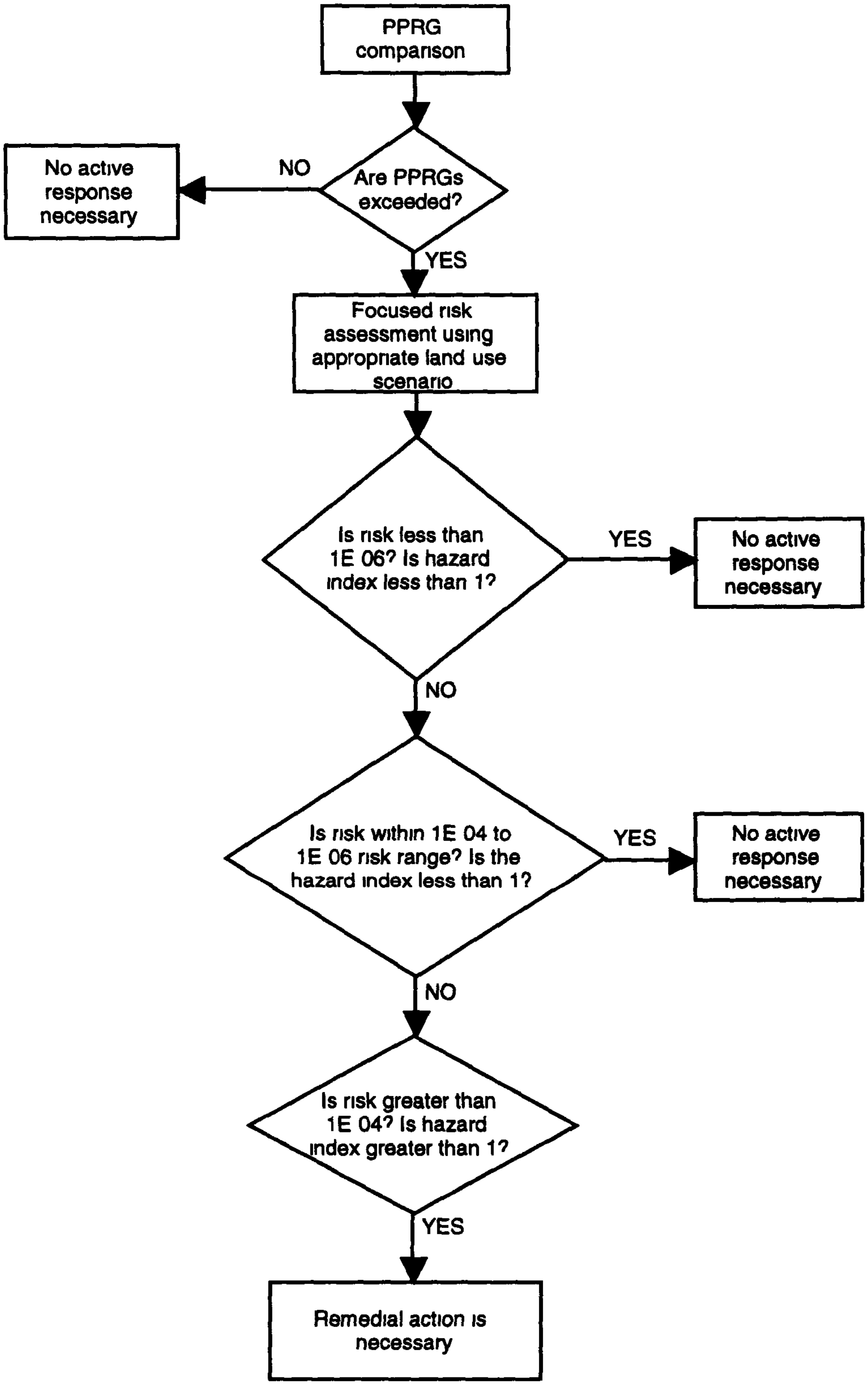
G95EBIMIRA DD OU 7\Conceptual model for risk cdw

Figure 3-2
F039 Determination for Environmental Media



Definitions
Leachate Any liquid, including any suspended components in the liquid, that has percolated or drained from hazardous waste. (6CCR 1007-3, Part 260.10)
F039 (multi-source leachate) Leachate (liquids that have percolated through land disposed wastes) resulting from the disposal of more than one restricted waste classified as hazardous under Subpart D (6 CCR 1007-3, Part 261 31)
Land disposal Placement of hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave. (6 CCR 1007-3, Part 268.2)
Contained in policy Any environmental media (e.g., groundwater, soil) contaminated with a hazardous waste must be managed as a hazardous waste until the media no longer contains hazardous waste.
A national capacity variance granted an extension until May 8, 1992 for the F039 nonwastewater
Modified from the Rocky Flats Field Office Guidance Brief — F039 Multi-Source Leachate (DOE 1990c).

G05\ES\MMRA DD OU7\OU7 SUR[illegible]TER DET 2510 FLW



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Remediation Determination for Environmental Media

Phase I IM/IRA DD	Operable Unit No 7
July 1995	Figure 3-3

g95ESIMIRA DD OU 7\OU7 Treatm't Det vertical CD

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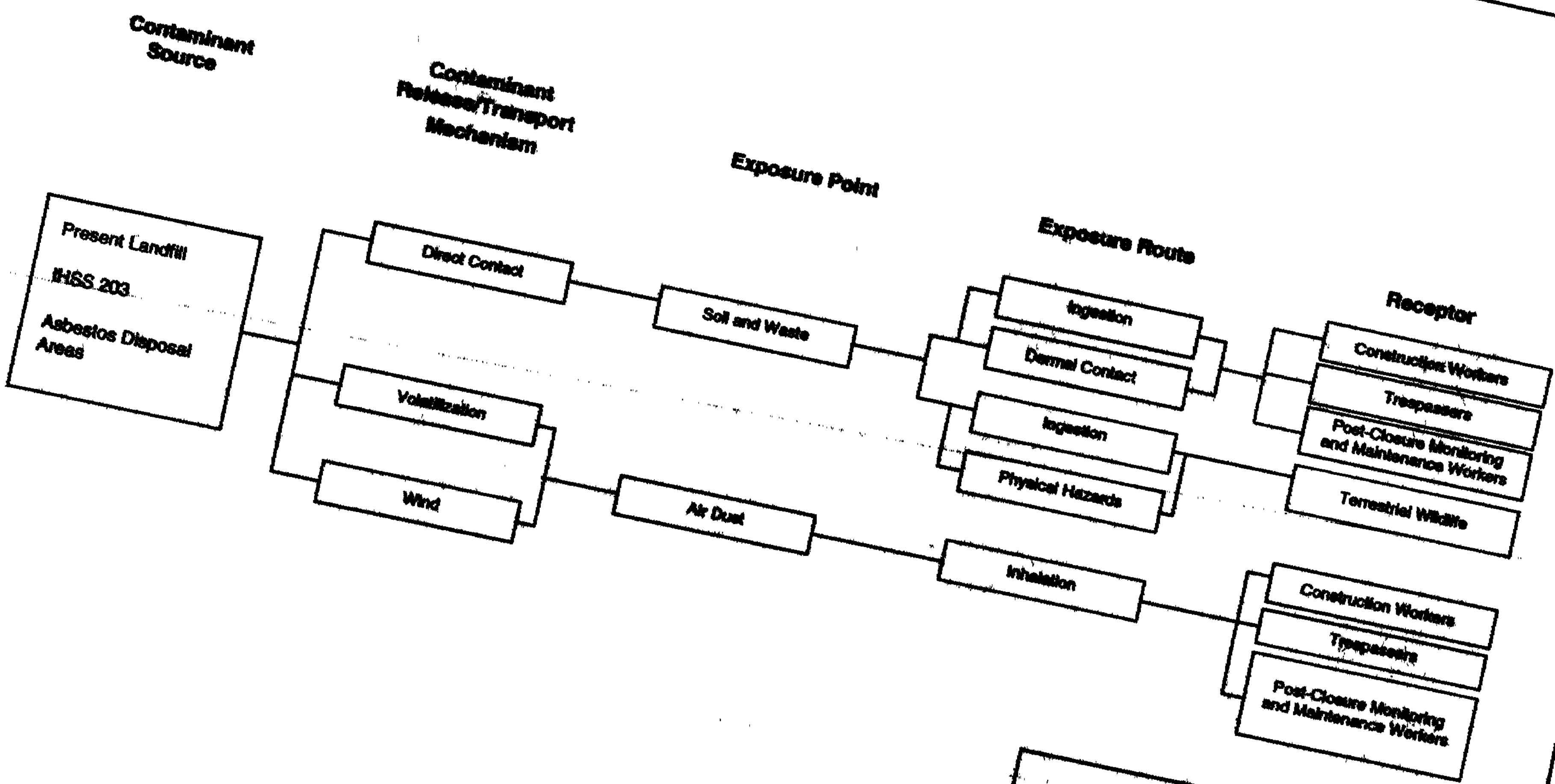

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Conceptual Site Model for the Source Area

Phase I IM/IRA DD

July 1995

Operable Unit No.

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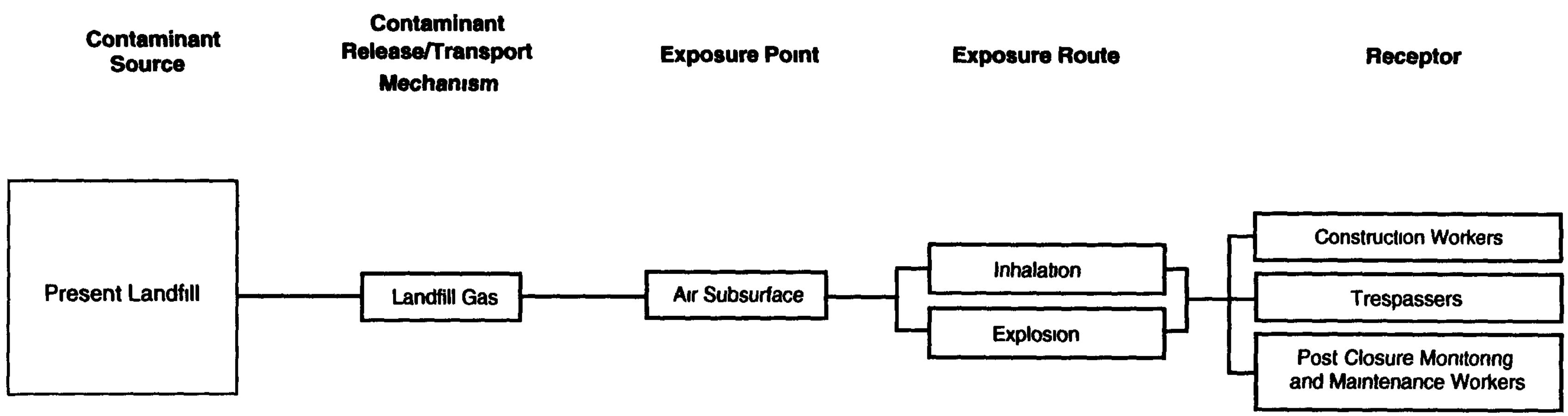

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Conceptual Site Model for Landfill Gas

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 3-5

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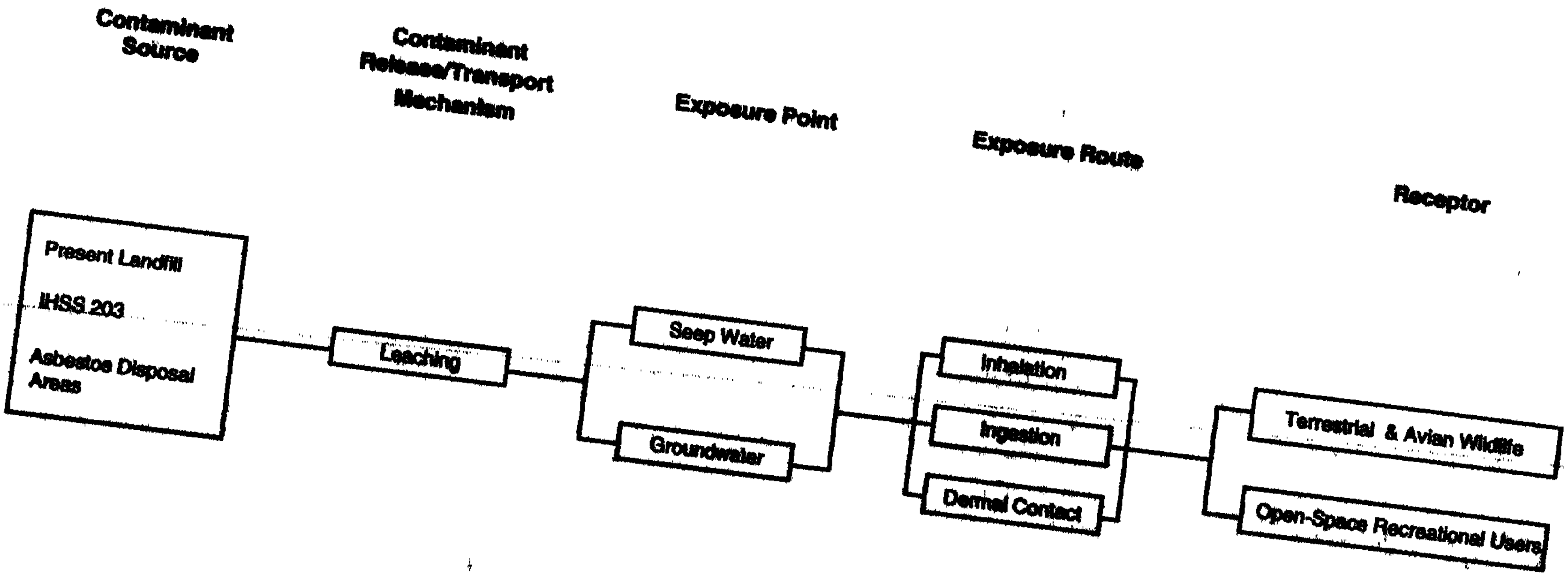
G95/ES/IM/IRA/DD OU 7/Conceptual Site Models mdw



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Conceptual Site Model for Landfill Leachate at the Seep

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 3-6

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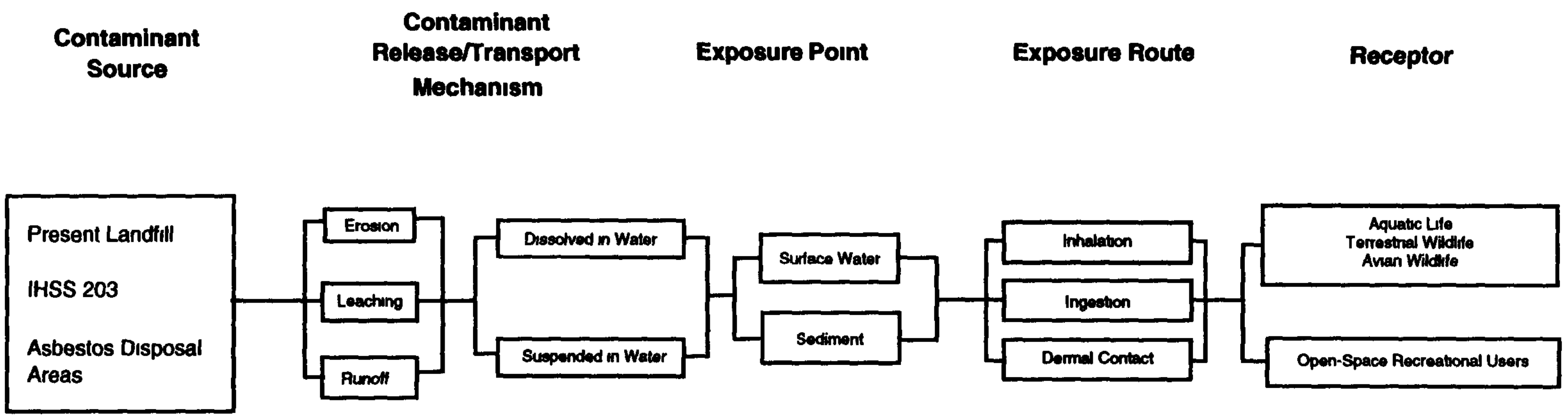

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Conceptual Site Model for the East Landfill Pond

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 3 7

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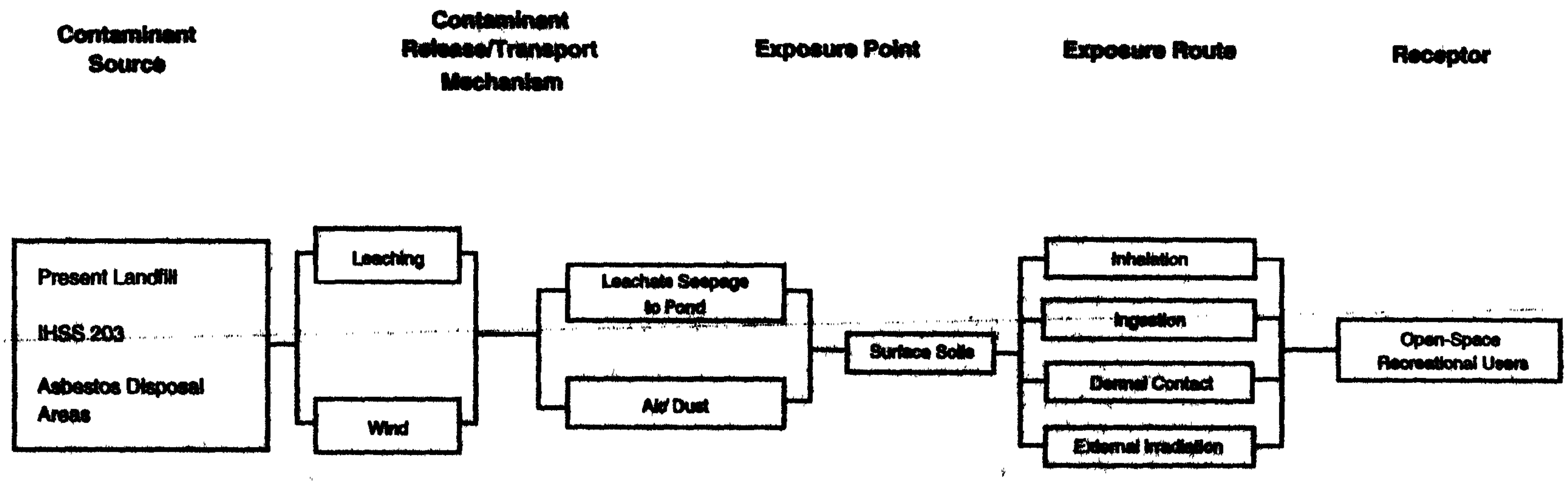
G95/ES/IM/IRA/DD OU 7/Conceptual Site Models mdw



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Golden Colorado

Conceptual Site Model for Surface Soils in Spray Evaporation Areas

Phase I IM/IRA DD	Operable Unit No 7
July 1995	Figure 3-8

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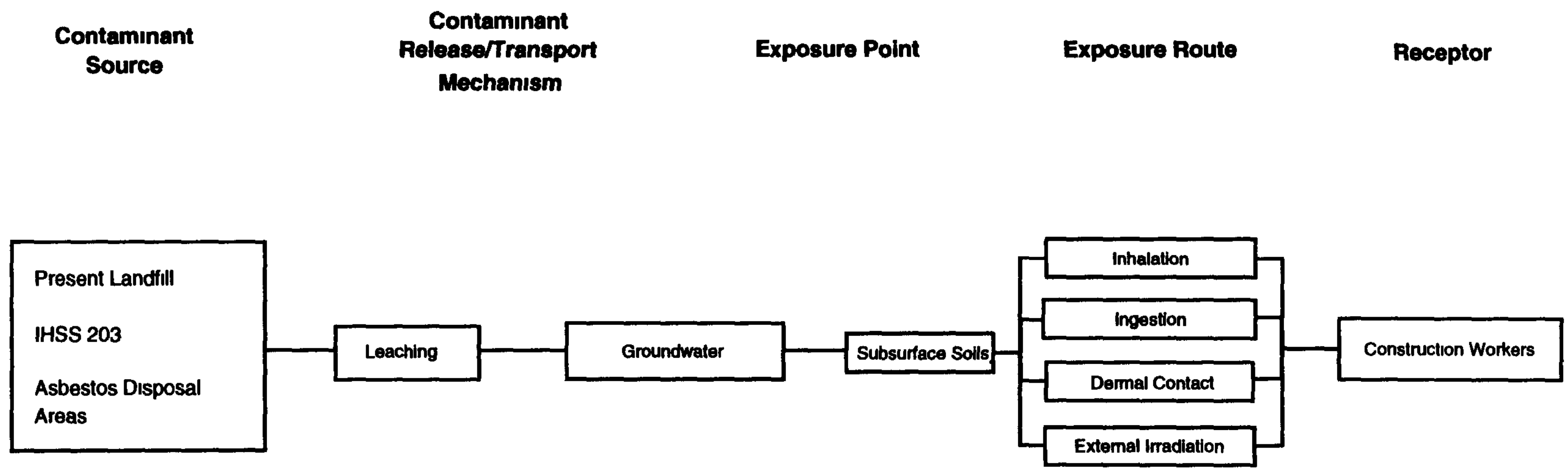

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Conceptual Site Model for Subsurface Geologic Materials Downgradient of the Landfill

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 3 9

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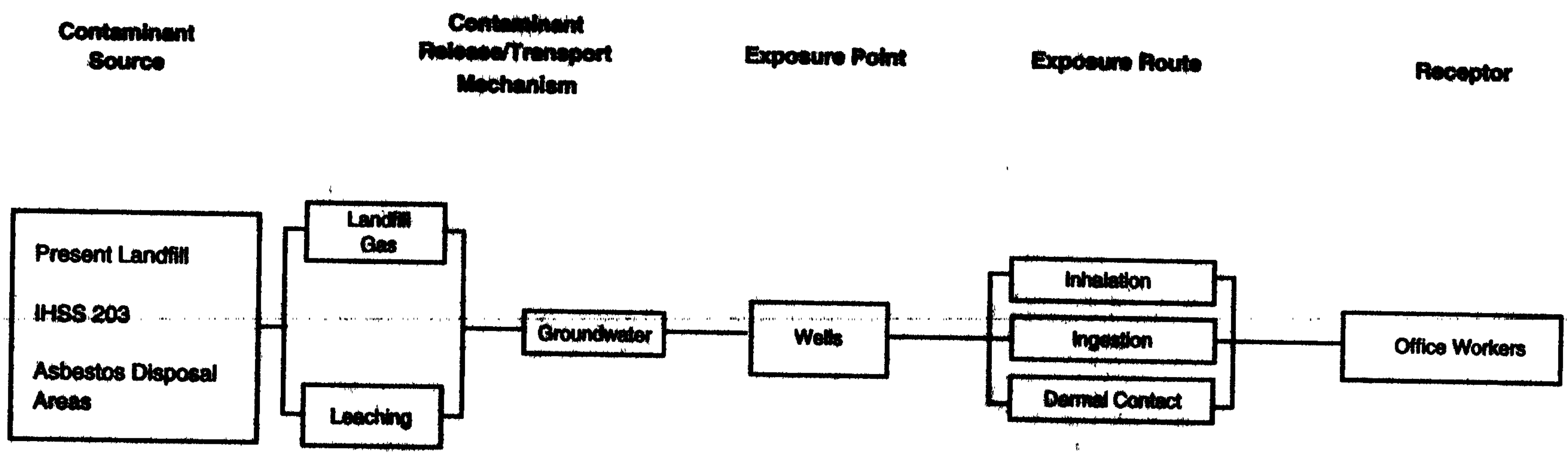
G95/ES/IM/IRA/DD OU 7/Conceptual Site Models.mdw



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Golden Colorado

Conceptual Site Model for Groundwater Downgradient of the Landfill

Phase I IM/IRA DD | Operable Unit No. 7

July 1995 | Figure 3-10

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G95/ES/IM/IRA/DD OU 7/Conceptual Site Models.mdw

4 Identification and Screening of Technologies

In this section technologies are identified and screened to develop a set of usable waste management options that will ensure protection of human health and the environment The primary purpose is to streamline the selection process to allow the most promising alternatives to be selected for further scrutiny in the detailed analysis (EG&G 1988)

In Section 3 RAOs were identified for various media Based on these RAOs, general response actions (GRAs) are developed for each medium from the available technologies The technologies that are considered for the screening are identified in the OU 7 Technology Literature Research Report, compiled in April 1994 to support the selection of an IM/IRA (EG&G 1994c) The initial screening of technologies is performed to eliminate those that are technically not feasible The remaining options, grouped by technology type, are then evaluated against each other based on effectiveness implementability and cost Technologies carried forward in the screening process will be used for the development and screening of alternatives presented in Section 5

4 1 General Response Actions

GRAs are general categories of activities that may satisfy the RAOs (EPA 1988) and include no action institutional controls containment, removal/collection, disposal, and treatment For each GRA, there are a number of potentially effective technologies for each medium

Under the presumptive remedy certain GRAs have been determined to be most effective for CERCLA landfills The two primary components of the presumptive remedy at OU 7 are containment of the landfill mass and collection and/or treatment of the landfill gas (EPA 1993a) Institutional controls are also recommended to supplement engineering technologies

4 2 Identification and Screening of Technologies

For each GRA identified under the presumptive remedy, there are a number of applicable technologies The technically feasible technologies identified in the OU 7 Technology Literature Research Report (EG&G 1994d) are evaluated relative to each other and screened to reduce the number of technologies used in preparation of the alternatives This section summarizes the screening process

4 2 1 Screening Process

In the screening process, technologies are evaluated in terms of effectiveness, implementability, and cost (Table 4-1) Comparisons during screening are made between technologies within each category of GRAs, not between categories of GRAs For example, in Table 4-2 the land-use restrictions, deed restrictions, and zoning ordinances are rated relative to each other but not in comparison to fencing and warning signs, which are access restrictions Effectiveness in protecting human health and the environment is given the greatest weight The cost criteria is used only to distinguish between two similarly rated technologies

The effectiveness criteria include the degree to which a technology meets RAOs and ARARs, reduces toxicity, mobility, or volume through treatment; affords long-term protection, and minimizes short-term impacts

The implementability evaluation criteria include a determination of the technical and administrative feasibility of implementing the technology Technical feasibility is used in the OU 7 Technology Literature Research Report (EG&G 1994c) as an initial screen of technology types to eliminate those that were clearly ineffective or unworkable at OU 7 Technical issues relating to implementation include availability of materials, ease of construction, and post-construction repairs Administrative feasibility addresses the ability to obtain approval from regulatory agencies The initial screening also emphasizes the institutional aspects of implementability, including the ability to obtain necessary permits and community acceptance and the availability of necessary equipment and skilled workers to implement the technology

Cost plays a limited role in the screening of technologies, it is used primarily to distinguish between two similarly rated technologies. At this stage, the cost analyses are based on engineering judgment of the relative direct and indirect capital and operation and maintenance (O&M) costs

4 2 2 No Action

Although no action is not identified in the presumptive remedy as a GRA, it is always used to establish a baseline for comparison Under no action, no preventive or corrective actions are taken

4 2 3 Institutional Controls

Institutional controls are methods by which federal, state, and local governments or private citizens can limit exposure to contamination Most institutional controls take the form of use or access restrictions These may include simple physical actions such as fencing and warning signs or more complex regulatory actions such as implementing zoning controls controlling water use and deed restrictions

Each of the four institutional control technologies evaluated in Table 4-2 land-use restrictions access restrictions water-use controls and public education are retained All of the technologies are effective and implementable and are included in the alternative development In addition all of the technologies are already in place to some extent

4 2 4 Containment

Containment actions restrict contact with and migration of contaminants Under the presumptive remedy a landfill cap is the preferred containment technology Table 4-3 identifies three types of capping technologies a native soil cover a single-barrier cap and a composite-barrier cap Although composite-barrier caps are ranked most effective each cap is considered fully effective for certain site conditions Therefore each of the three caps is modeled and evaluated in more detail in the alternative analysis

As discussed in Section 2 3, the groundwater in the source area is presently contained laterally by the existing groundwater-intercept system and proposed slurry wall (Section 1 3 2), and flow downgradient is significantly reduced by the East Landfill Pond dam This evaluation assumes that the proposed slurry wall is constructed prior to any response actions proposed in this report Containment of the groundwater will not be addressed further in this report

4 2 5 Landfill Gas Collection

Collection response actions partially or completely remove contaminants from their original location In landfills gas is generally collected to protect the integrity of the cap Landfill gas may also be collected prior to treatment (Section 4 2 6)

Table 4-4 shows the evaluation of various types of passive and active collection systems Both types of systems have been used in municipal landfills for gas collection and control However hazardous waste landfills have rarely used active systems because they normally do not produce much gas Although active gas-extraction wells have been used in municipal landfills they have had only limited success effectively collecting gas over a large area Due to the variability in the waste composition, the optimal design of a gas-extraction well is difficult

A passive gas-extraction system is applicable to sites where offsite migration is limited and gas will be forced to collect in a blanket collection system Conditions at the Present Landfill are conducive to this type of system The landfill is underlain by low-permeability weathered bedrock and the perimeter of the landfill is or will be surrounded by a low-permeability barrier (Section 1 3.2). This will prevent offsite migration of gas forcing the gas to be collected under the cover

Venting trenches are eliminated because they are considered the least effective and the most difficult type of gas-collection system to implement at OU 7

Both passive vents and permeable layers are carried forward to the development of alternatives in Section 5

4 2 6 Landfill Gas Treatment

Treatment response actions reduce the toxicity, mobility, and/or volume of contaminants through physical or chemical alteration Table 4-5 shows the evaluation of landfill gas-treatment systems

As discussed in Section 3 4, it is not anticipated that landfill gas will exceed ARARs However, maintenance actions (such as construction of a new slurry wall) and the proposed closure of the landfill may affect gas generation by limiting the migration of gas and decreasing the infiltration of surface water Due to the unknown impacts on the gas concentration and flow rates as a result of these actions, it is unknown at this time what, if any treatment will be required.

Based on these uncertainties, it is recommended that a gas-collection system be installed that would allow for post-closure monitoring of gas composition concentration and flow rate until treatment requirements can be determined The collection system should also be designed to be compatible with gas-treatment units should they be required

The passive gas-collection system will have vent pipes or gravel columns at various locations across the cover The vent pipes or gravel columns will extend through the cover and will be logical points for monitoring emissions from the landfill If required, the vent pipes could be routed directly to a treatment system to reduce emissions from the landfill

4 3 Results of Screening

Based on the screening presented in this section, the following technologies will be considered in alternatives development

Institutional Controls (included in all alternatives)

- Use restrictions
- Access restrictions

Table 4-1
Screening Criteria Summary

Criteria	Assessment Components
Effectiveness	Meet RAOs and ARARs Reduce toxicity mobility and volume through treatment Provide long term protection Minimize short term impacts
Implementability	Technical feasibility of implementing technology • Availability of materials • Ease of construction • Post construction repairs Administrative feasibility of implementing technology • Ability to obtain approvals from regulatory agencies
Cost	Comparative costs based on engineering judgment

Table 4-2
Evaluation of Remedial Technologies Institutional Controls

Response Action	Description	Effectiveness	Implementability	Cost	Comments
Institutional Controls					
• Land Use Restrictions	Legal restrictions on future use of the site				Some restrictions already in place
– Deed Restrictions	Restrictive covenants on deed to the landfill property May include limitations on excavation and basements in contaminated areas	Low	High	Low	
– Zoning Ordinances	Zoning change administrative consent order, or judicial order prohibiting certain land uses.	Moderate	Moderate	Moderate	
• Access Restrictions	Physical restrictions to limit access to site				Some restrictions already in place including a barbed-wire fence around Rocky Flats and a 4 foot high fence around the landfill
– Fencing	Restrict general public and large wildlife from onsite hazards	Moderate	Moderate	Moderate	
– Written Warnings	Place warning signs in area to warn public of hazards.	Low	High	Low	
• Water-Use Controls	Restrictions on use of water associated with site				
– Well Permit Regulation	Regulate drilling of new wells in potentially contaminated aquifer	Moderate	Moderate	Low	Alternate water sources exist.
– Inspect and Seal Existing Wells	Wells in contaminated areas	Low	High	Moderate	Unnecessary Wells will be plugged and abandoned under a separate action prior to closure
• Public Education	Increase public awareness of site conditions and remedies through written notices meetings, and news releases	Low	High	Low	The draft final Phase I IM/IRA DD will be available for public review and comment

Note
Ratings indicate performance relative to other technologies within the same bulleted category of response action

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Table 4-3
Evaluation of Remedial Technologies Containment

Response Action	Description	Effectiveness	Implementability	Cost	Comments
Containment Actions					
• **Capping**	Provides physical barrier between contaminants and the environment May include surface regrading and revegetation				
– Native Soil Cover	Reduces exposure to and migration of contaminated materials through use of a native soil cover	Low	High	Low	Allows some infiltration of precipitation
– Single Barrier Cap	Uses a cap constructed of a single layer of various media such as clay flexible membrane liner asphalt or concrete based material	Moderate	Moderate	Moderate	Limits infiltration of precipitation
– Composite Barrier Cap	Uses multiple barrier layer design Media include soil and synthetics	High	Low	High	Minimizes infiltration of precipitation Creates relatively high volume of clean run off Meets RCRA capping guidance

Note

Ratings indicate performance relative to other technologies within the same bulleted category of response action

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Table 4-4
Evaluation of Remedial Technologies Landfill Gas Collection

Response Action	Description	Effectiveness	Implementability	Cost	Comments
Collection/Removal Actions					
• Passive	Control migration of gases by altering the path of flow using high-permeability preferential pathway				
– Vents	Pipe vents or gravel columns are used for venting gas at points where it is collecting and building up pressure.	Moderate	High	Low	May be limited by impermeable layers Potential odor Low energy Low O&M
– Venting Trench	Gravel trenches form a path of least resistance for gases	Low	Moderate	Moderate	Small zone of influence
– Permeable Layer	High-permeability blanket layer provides preferential pathway for gases	High	Low	Moderate	Depth limited to 20 feet. Gases may migrate underneath Most applicable near sources of gases. May require cover and drainage layer to prevent freezing
• Active	Control gas migration by extraction/collection via vacuum blowers or compressors.				
– Extraction Wells	Gases drawn into a perforated pipe surrounded by permeable material by blower or compressor system	Moderate	High	Low	May be limited by impermeable layers. Not sensitive to freezing or saturation of surface or cover soils.
– Extraction Trench	Gases drawn into perforated pipe in gravel-filled trench by blower or compressor system.	Low	Moderate	Moderate	Good for deep landfills.
– Permeable Layer	Gases drawn into permeable layer by blower or compressor system	High	Low	High	Depth limited to 20 feet. Perched water table or impermeable geological layer limits technology.

Note
Ratings indicate performance relative to other technologies within the same bulleted category of response action.

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Table 4-5
Evaluation of Remedial Technologies Landfill Gas Treatment

Response Action	Description	Effectiveness	Implementability	Cost	Comments
Treatment Actions					
• **Thermal**	Use of heat to destroy contaminants				May require supplementary fuels for a continuous burn
– Open Flare	Gases combusted by exposure to open flame	Moderate	High	Low	Lower combustion efficiency than enclosed flame Open flame may cause public concern
– Enclosed Flare	Gases combusted by exposure to flame within a flame enclosure or stack	High	Moderate	Moderate	For destruction of vapors that are easily burned and have no harmful products of combustion

Note
R ti ig   dicate perf rm n e rel tive to the technol g es w th   the same bulleted category of response action

5 Development of Alternatives

Technologies retained after the initial screening presented in Section 4 are now used to form alternatives to address the OU 7 site as a whole The resulting alternatives can be individual technologies or a combination of technologies designed to meet RAOs such that human health and the environment are protected from exposure pathways to contaminated media As a result of the presumptive remedv approach the number of alternatives formed is limited and consists of various cap cross sections Institutional controls and potential gas treatment technologies are included in all options The propsed slurry wall scheduled for construction in fiscal year 1996 is assumed to be in place for all alternatives

The alternatives are further refined and screened based on the following three evaluation criteria effectiveness implementability and cost Alternatives must be compared at an equal level of analvsis with sufficient detail to be able to distinguish among the various alternatives (EG&G 1988)

5 1 Cover Design

The proposed action must meet the CHWA requirements for landfill closure [6 CCR 1007-3 Part 265 310] as follows

- Provide long-term minimization of migration of liquids through the closed landfill
- Function with minimum maintenance
- Promote drainage and minimize erosion or abrasion of the cover
- Accommodate settling and subsidence so that the integrity of the cover is maintained
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoil present

The alternatives consist primarily of different cap cross sections however, a number of design parameters are common to all capping alternatives These include (1) extent of the landfill cover (2) wetland and sensitive-habitat mitigation, (3) the grading plan (4) surface-water management and (5) basic cover components

5 1 1 Extent of the Landfill Cover

The proposed landfill cap covers the Present Landfill (IHSS 114) Inactive Hazardous Waste Storage Area (IHSS 203) and asbestos-disposal areas as shown on Figure 5-1 and encompasses approximately 20 acres The extent of waste material was determined using historical photographs of OU 7 and field tests performed during the Phase I RFI/RI (DOE 1994a)

Although there is no contamination of soils at IHSS 203 (DOE 1994a), it is located within the boundary of the Present Landfill and therefore will be capped along with the landfill mass

The asbestos-disposal areas have an existing soil cover that meets disposal requirements for asbestos (40 CFR Part 61) However, the asbestos areas also are located within the boundary of the Present Landfill and therefore will be capped

5 1 2 Wetland and Sensitive-Habitat Mitigation

Areas in and around the East Landfill Pond have been designated as wetlands by the U S Army Corps of Engineers (Figure 2-12), as discussed in Section 2 4 To provide slope stability along the east face of the landfill, the cover must extend over a portion of the designated wetlands A wetlands assessment is required under 40 CFR Part 6 (Section 3 4 2 1) and is included as part of the recommended IM/IRA in Section 7 The proposed mitigation plan for onsite wetlands impacted by the remedial action at OU 7 is to use acreage from the 8-acre wetland mitigation bank proposed for development adjacent to the Standley Lake Protection Project, pending final approval

OU 7 has been identified as potential habitat for Preble's meadow jumping mouse, a candidate for listing as a threatened or endangered species (Figure 2-12) The Preble's meadow jumping mouse is currently protected under the Colorado Non-game, Endangered or Threatened Species Conservation Act DOE will mitigate losses to the Preble s meadow jumping mouse habitat as a result of the remedial action as needed

5 1 3 Grading Plan

Given the extent of the landfill cover as described in Section 5 1 1, the primary variables in determining the grading plan are the maximum and minimum slopes for the cover Maximum slopes are generally based on stability and erosion concerns. Minimum slopes are based on providing adequate surface-water drainage for the entire cover area after settlement

The existing side slopes extending down into the East Landfill have a slope of approximately 33 percent The slopes on the north side of the East Landfill Pond have exhibited signs of instability in the past, including shallow slumping and seeps To stabilize these areas, the grading plan includes placement of fill to buttress the slopes For preliminary planning purposes, it is assumed the slopes are regraded to a slope of approximately 20 percent. This is considered to be a stable slope to prevent slumping and erosion A slope angle of less than 20 percent could be used if the slurry wall maintenance action is performed sooner, because the slurry wall will limit groundwater inflow and allow groundwater within the landfill to drain

Minimum slope angles are selected to provide adequate drainage after settlement Conservative settlement estimates were made and are based on a variety of landfill-settlement models as summarized in Appendix F The resulting grading plan for the top surface has a minimum 7 percent grade Final design analyses may indicate that slightly lower initial grades may be acceptable for the Present Landfill

Figures 5-2, 5-2a and 5-2b show the grading plan which is crowned in the center and slopes outward to the perimeter surface-water diversion ditch The grading plan addresses the 6 CCR 1007-3 Part 265 310 requirements to promote drainage and minimize erosion or abrasion of the cover and accommodate settling and subsidence so that the integrity of the cover is maintained Minimizing soil erosion and settlement of the waste will allow the cover to function with minimum maintenance

5 1 4 Surface-Water Management

The OU 7 cover, as designed, is mounded in the center and graded to drain to the perimeter as shown in Figure 5-2 Along the north south, and west sides of the landfill, surface water draining off the cover is collected in the existing perimeter surface-water drainage ditch and routed to the east around the landfill and past the East Landfill Pond dam The ditch will be rerouted along the south side of the landfill where the cap extends over the existing ditch The surface-water drainage ditch ultimately discharges into No Name Gulch Surface-water runoff from the landfill to the east flows directly into the East Landfill Pond In addition to receiving surface-water runoff from the landfill, the perimeter surface-water drainage ditch will also receive water from the lateral drainage layer in the cover section

5 1 5 Cover Components

Because some hazardous waste was disposed in the Present Landfill until 1986, a RCRA Subtitle C cover or equivalent is required Five layers are typically used in a RCRA Subtitle C cover vegetative cover lateral drainage, barrier, gas collection, and grading fill The purpose of each layer and the materials that may be used are discussed in the following sections Table 5-1 presents a summary of the cover components, including the objectives and materials considered for each component

5 1 5 1 Vegetative-Cover Layer

The vegetative-cover layer is intended to provide a suitable growth media for local vegetation after construction of the cover The vegetative-cover soil must provide suitable moisture retention characteristics to establish and sustain vegetation A secondary intent of this vegetative-soil cover is to provide an insulation or protective layer over the barrier layers to prevent freezing or drying This design criterion normally dictates the ultimate depth of the vegetative-cover soil Frost depth in the Rocky Flats area is approximately 3 feet

A 36-inch vegetative-soil layer is included in all cover alternatives The vegetative layer is made up of 2.5 feet of soil under 0 5 feet of topsoil The main plant species proposed for revegetation consist of tall-prairie grasses western wheatgrass, blue grama, green needlegrass, and little bluestem (SCS 1983)

5 1 5 2 Lateral-Drainage Layer

This layer intercepts and drains any water that infiltrates through the vegetative cover The lateral-drainage layer is continuous over the top of the cover and discharges collected water at the perimeter surface-water drainage ditch.

Materials considered for the lateral-drainage layer include granular soil, geotextiles, geonets, and geocomposites Each is described in more detail below

Granular Soil

Granular-soil drainage layers have been used successfully for many years in a variety of drainage-layer applications, however, there are some limitations to their use in cover applications Media may consist of coarse sands or fine gravels A geotextile filter fabric is required between the vegetative cover soil and the drainage layer soil to prevent migration of fines into the drainage layer The drainage-layer material must be reasonably well graded and not too coarse grained to prevent damage to the underlying geomembrane Alternatively, a geotextile cushion may be required between this geomembrane and the granular soil

Recently, soil-drainage layers in cover applications have been replaced or supplemented with geosynthetic-drainage layers, which have a higher transmissivity and will not damage underlying geomembranes

Geotextiles

Geotextiles are commonly used as filter layers between soil materials with differing grain-size distributions (i e , between drainage layers and barrier layers) The geotextile retains the fines and prevents them from migrating into other layers and causing a reduction in permeability

Geotextiles are also used as cushion layers between geomembranes and coarse-grained soils that could damage a geomembrane In some cases, very thick and very high-transmissivity geotextiles have been used for lateral-drainage layers However, they are generally used in conjunction with geonet drainage products

Geonets

Geonets have become the most common type of lateral-drainage layers used in landfill cover and liner designs Geonets are used for this type of application because of their high transmissivity low damage potential when used with geomembranes competitive cost compared to granular drainage layers, ease of installation, and compatibility with leachates of varying compositions

Geocomposites

Geocomposites are a combination of geonet and geotextile The geotextile is generally heat bonded to one or both sides of the geonet A geocomposite provides the high-transmissivity benefits of a geonet and the filtration characteristics of a geotextile but is installed in one step instead of two

A geocomposite has been selected for the lateral-drainage layer in all cover options for OU 7 due to the benefits of a geocomposite compared to a granular drainage layer or a geotextile or geonet alone

5 1 5 3 Barrier Layer

The barrier layer is included in the cover design to prevent water from infiltrating into the waste and to prevent uncontrolled venting of gases at the surface The three types of barrier layers considered for the OU 7 cover can be used alone or in combination and include flexible membrane covers (FMCs), geosynthetic clay liners (GCLs), and compacted clay covers

FMC

Geosynthetic FMC materials are available in a variety of compositions, thicknesses surface textures, colors and other physical properties FMC material laminated with geonets and geotextiles that serve dual functions as barrier and drainage layers are also available

The FMCs considered for the OU 7 cover include high-density polyethylene (HDPE) and PVC Both materials are considered to have permeabilities in the range of 1E-13 cm/sec Each has advantages and disadvantages in terms of durability, chemical compatibility, strength elasticity and ease of installation The selection of the type of FMC material to be used at OU 7 will be made during the final design

GCL

A GCL is composed of a commercial bentonite layer sandwiched between sheets of woven or non-woven geotextiles The bentonite in a GCL is supplied at a relatively low moisture content and can swell to many times the installed thickness if it is exposed to water The bentonite has a very low inherent permeability (approximately 1E-09 cm/sec) Because the material is supplied at a low initial moisture content, it is not susceptible to desiccation cracking Research on GCLs has indicated that they will exhibit low permeability even after repeated wetting and drying and/or freezing and thawing cycles (Corser *et al* 1992) GCLs have been in use for only seven years No data on their long-term effectiveness are available

Compacted Clay

Compacted clay covers may consist of any natural soil deposit that can be placed and compacted to achieve a permeability of 1E-07 cm/sec or less. These generally consist of fine-grained soils that exhibit plasticity Coarse-grained soils can be mixed with various percentages of bentonite to achieve the required permeability and plasticity characteristics However, admixed soil barrier layers are generally much more expensive than natural clay barrier layers

Compacted clay covers are generally placed at moisture contents above optimum and therefore are susceptible to desiccation cracking and freeze cracking After initial cracks are formed, compacted clays in general do not swell and heal like GCLs unless they are placed under very high normal loads High normal loads are not predicted for the OU 7 cover However, because they are placed in relatively thick layers (2 feet), they can accommodate minor settlement and some surface cracking or deterioration without complete failure

The cover alternatives considered for OU 7 utilize various combinations of these materials for the barrier layer

5 1 5 4 Gas-Collection Layer

The gas-collection layer collects migrating gases across the entire landfill surface and transmits them to selected discharge points Gases that collect in this layer flow to vent pipes and/or gravel columns where they vent through the cover

A geocomposite is used for the gas-collection layer in all alternatives As discussed under lateral drainage, a geocomposite is a geonet drainage layer with geotextile bonded to both sides to prevent infiltration of fine soils

All cover options incorporate monitoring the gas composition, concentration, and flow rate the during post-closure care period until treatment requirements can be determined The design incorporates provisions to facilitate gas treatment if needed

5 1 5 5 General Grading Fill Layer

To achieve adequate surface-water drainage off the landfill, general grading fill is required The intent of the grading fill is to achieve a crown in the center of the landfill to shed water off the slopes Fill is thickest in the center of the landfill and thinner toward the edges

The general fill material can consist of almost any natural soil material There are no specific restrictions on the composition of the soil as long as it can be compacted to a firm, unyielding subgrade Fill material is expected to come from both onsite and offsite sources (EG&G 1994d)

5 2 Description of Alternatives

Alternatives are developed to cover the range of remedial actions available under the presumptive remedy The capping options may include the following elements as described in Section 5 1

- Institutional controls
- 36-inch vegetative cover layer
- Geocomposite lateral-drainage layer
- Various combinations of barrier layers
- Geocomposite gas-collection layer and venting system
- Grading fill

5 2 1 Alternative 1 No Action

Under Alternative 1, no action is taken The no-action alternative required under the NCP provides a baseline for comparison of other alternatives (55 Federal Register 8704) The cover in the no-action alternative is the interim soil cover material, which is of variable thickness Under the existing conditions, the waste and fill material in the landfill has a permeability of approximately 1E-02 cm/sec This alternative is shown in Figure 5-3

5 2 2 Alternative 2 Institutional Controls

Alternative 2 is similar to the no-action alternative in that the existing interim soil cover material is the final cover, however, the alternative includes institutional controls for both the landfill and groundwater as described below Under existing conditions, the waste and fill material in the landfill have a permeability of approximately 1E-02 cm/sec The cover cross section for this alternative is the same as that for no action and is shown in Figure 5-3 Public education and statutory reviews by EPA are also included in this alternative

5 2 2 1 *Land Use and Access Restrictions*

A 6-foot chain-link fence and warning signs limit access to the landfill In addition, the Rocky Flats site is fenced. Workers and visitors may enter the Rocky Flats site through the east or west gates; however, access is limited and is enforced by a 24-hour security force

As part of landfill closure, DOE will record a notation on the property deed to identify it as a hazardous waste landfill and restrict future use. DOE may lease Rocky Flats property for up to 10 years, but because Rocky Flats is listed on the National Priorities List for CERCLA, DOE must obtain EPA approval EPA will determine if the terms and conditions of the lease agreement are consistent with the safety and protection of public health and the environment (DOE 1993c).

In addition, under the Community Environmental Response Facilitation Act (CERFA), an amendment to CERCLA, DOE is required to notify the state of any lease that will encumber property on which any hazardous substance was stored for one year or more, and on which it plans to terminate federal government operations (DOE 1993c)

5 2 2 2 *Groundwater Controls*

Under this alternative, the existing restrictions on use of groundwater at the site are maintained. There are no existing water supply wells at Rocky Flats The nearest supply wells downgradient of the landfill are 2 miles from OU 7 Institutional controls include monitoring of one upgradient and three downgradient wells as described in the OU 7 Post-Closure Plan in Section 8 2 3

The drilling of new wells is regulated by DOE and the state of Colorado Rocky Flats Environmental Management Department Operating Procedure No GWT 06, Revision 2 (EG&G 1992b) requires that a Well Installation Notification (WIN) form (GT 6A) be completed to ensure that new well administrative controls are met by the inclusion of requester information, installation methods, purpose, initial well-permit data, environmental-protection measures, and additional information The requester must also supply information necessary to prepare and file applicable well permits required by the state of Colorado

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5 2 2 3 Public Education

Community relations activities such as posting written notices of public meetings publishing fact sheets that summarize alternatives being evaluated, holding public meetings to discuss community concerns and explain alternatives, and publishing news releases will increase public awareness of site conditions and the alternatives considered for final closure of OU 7 The public can comment on remedy selection and provide input to the decision-making process during the public comment period for the Draft Final Phase I IM/IRA DD

5 2 2 4 EPA Reviews

In accordance with CERCLA, Section 121(c) and NCP Section 300 430 (f)(4)(ii) reviews are required of any remedial action that results in any hazardous substances, pollutants or contaminants remaining at the site ' These Statutory Reviews" are necessary for any site at which a post-Superfund Amendments and Reauthorization Act (SARA) remedy, upon attainment of the Record of Decision (ROD) cleanup levels, will not allow unlimited use and unrestricted exposure Reviews must occur at least every five years but may be terminated when hazardous substances, contaminants, and pollutant levels allow for unlimited use and unrestricted exposure

Reviews ensure that the response action remains protective of human health and the environment In most cases, a Level I review is adequate For Level I reviews a site visit, limited analysis of site conditions, and information gathered during routine operation and maintenance activities will suffice In the event of new or revised regulations or changes in site conditions, the level of review may be adjusted

5 2 3 Alternative 3 Native Soil Cover

Alternative 3 consists of a 36-inch native soil cover placed directly over the grading fill The native soil cover is expected to consist of Rocky Flats Alluvium or other free draining granular material Furthermore, it was assumed that the native soil cover would be placed in a single lift without compaction Based on these assumptions, the native soil cover was considered to have a permeability of approximately 1E-02 cm/sec The cap cross section is shown in Figure 5-3 Institutional controls are included as described in Section 5 2 2

5 2 4 Alternative 4 Single-Barrier Clay Cover

Alternative 4 consists of a single-barrier clay cover and institutional controls The cover section consists of the following layers (Figure 5-3)

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer

- 24-inch compacted clay barrier layer
- Geocomposite gas-collection layer and venting system
- Grading fill

The barrier layer is made up of compacted clay with a permeability of approximately 1E-07 cm/sec The gas-collection system has provisions for gas treatment if needed

5 2 5 Alternative 5 Single-Barrier FMC Cover

Alternative 5 consists of a single-barrier FMC cover and institutional controls The cover section consists of the following layers (Figure 5-3)

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer
- FMC barrier layer
- 6-inch bedding layer for the FMC
- Geocomposite gas-collection layer and venting system
- Grading fill

The FMC barrier layer has a permeability of approximately 1E-13 cm/sec It is placed on 6 inches of a bedding soil to cushion the FMC from the underlying geocomposite The soil has a permeability of approximately 1E-02 cm/sec and is not designed to act as a barrier layer The gas-collection system has provisions for gas treatment if needed.

5 2 6 Alternative 6 Single-Barrier GCL Cover

Alternative 6 consists of a single-barrier GCL cover and institutional controls The cover consists of the following layers (Figure 5-3)

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer
- GCL barrier layer
- Geocomposite gas-collection layer and venting system
- Grading fill

The barrier layer is a GCL with a permeability of approximately 3E-09 cm/sec Gas treatment will be added if needed

5 2 7 Alternative 7 Single-Barrier FMC with a Low-Permeability Soil Cover

Alternative 7 consists of institutional controls and a cover with an FMC barrier and a 12-inch layer of low-permeability soil The cover consists of the following layers (Figure 5-3)

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- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer
- FMC barrier layer
- 12 inches of a low-permeability soil barrier layer
- Geocomposite gas-collection layer and venting system
- Grading fill

The presence of the low-permeability soil (approximately 1E-05 cm/sec) gives the cover system some of the benefits of a composite cover without the rigorous installation requirements of a full compacted clay The barrier layer is an FMC with a permeability of approximately 1E-13 cm/sec The gas-collection system is designed to facilitate gas treatment if needed

5 2 8 Alternative 8 Composite-Barrier FMC and GCL Cover

Alternative 8 is a true composite barrier with both FMC and GCL Institutional controls are also included in this alternative The cover consists of the following layers (Figure 5-3)

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer
- FMC barrier layer
- GCL barrier layer
- Geocomposite gas-collection layer and venting system
- Grading fill

The barrier layers are an FMC with a permeability of approximately 1E-13 cm/sec and a GCL with a permeability of 3E-09 cm/sec The gas-collection system has provisions for gas treatment if needed

5 2 9 Alternative 9 Composite-Barrier FMC and Clay Cover

Alternative 9 is a composite barrier with both FMC and compacted clay as well as institutional controls The cover consists of the following layers (Figure 5-3)

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer
- FMC barrier layer
- 24 inches of a compacted clay barrier layer
- Geocomposite gas-collection layer and venting system
- Grading fill

This cover section follows EPA guidance documents for a RCRA Subtitle C facility (EPA 1989d EPA 1989e) The FMC has a permeability of approximately 1E-13

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cm/sec and overlies a compacted clay with a permeability less than or equal to 1E-07 cm/sec The gas-collection system has provisions for gas treatment if needed

5 3 Screening of Alternatives

This section documents screening of the nine alternatives presented above to provide sitewide protectiveness based on their effectiveness, implementability, and cost The screening of alternatives in this section examines each criteria in greater detail than was used in Section 4 This serves to limit the number of alternatives that will be considered and refined in the detailed analysis The criteria are outlined in Table 5-2 and described below

5 3 1 Screening Criteria

5 3 1 1 Effectiveness

The effectiveness criteria include the degree to which a technology meets RAOs and ARARs, reduces toxicity, mobility, or volume through treatment, affords long-term protection, and minimizes short-term impacts Alternatives that are not protective of human health and the environment are eliminated from further consideration

As described in Section 3 5, RAOs for OU 7 include the following.

- Prevent direct contact with landfill contents
- Minimize infiltration and resulting contaminant leaching to groundwater
- Control surface-water runoff and erosion
- Control landfill gas (treat as needed)
- Remediate wetlands (as needed)

The proposed cover must meet the requirements of 6 CCR 1007-3 Part 265 310 The most important requirement for the evaluation of alternatives is that the cover have a permeability less than the underlying bedrock. As described in Section 2 3, the weathered bedrock has a permeability of 1E-06 to 1E-07 cm/sec

Each of the alternatives is evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model (EPA 1994b) A description of the HELP model, inputs used for this evaluation, and output runs are presented in Appendix G Figure 5-4 shows leakage rates for the nine cover alternatives

5 3 1 2 Implementability

The implementability evaluation criteria include a determination of the technical and administrative feasibility of implementing the technology Alternatives that are not technically or administratively feasible are eliminated from further consideration

Technical issues relating to implementation include availability of materials to construct the cover, ease of construction, and post-construction repairs Availability of general fill geosynthetic layer, and vegetative layer materials are equivalent among the alternatives, whereas availability of barrier soil and barrier soil preparation requirements differ Ease of construction considers equipment labor and construction quality assurance (CQA) efforts required for subgrade preparation and cover installation Post-construction repair considers equipment, labor, and CQA effort required to repair damage to a small area of the cover

Administrative feasibility addresses the ability to obtain approvals from regulatory agencies and coordinate with other agencies

5 3 1 3 Cost

A preliminary cost estimate was developed for each alternative These are conceptual costs and should be used for comparison purposes only The estimates include direct and indirect capital and O&M costs Direct costs include site preparation, mobilization, demobilization, landfill cap components, gas monitoring, groundwater monitoring and fencing gates and signs Indirect costs include project and construction management, CQA health and safety, administrative costs, and a contingency The present worth cost is based on a discount rate of 3 percent over the 30-year post-closure period It is assumed that O&M costs are the same for all capping options Cost estimates and associated assumptions are provided in Appendix H

5 3 2 Alternative 1 No Action

5 3 2 1 Effectiveness

The no-action alternative does not meet any of the RAOs nor does it address the closure requirements The HELP model shows an average annual leakage rate of 1 4 inches/year

There is no treatment of waste or leachate in this alternative, therefore, there is no reduction in toxicity mobility or volume of waste or leachate through treatment However, the toxicity of contaminants in leachate may decrease due to natural attenuation There are no short-term impacts There is no monitoring, allowing long-term threats to human health and the environment to go undetected

5 3 2 2 Implementability

The no-action alternative involves no implementation but, because it does not address RAOs or closure requirements, it is unlikely to be approved by CDPHE or EPA

5 3 2 3 Cost

The conceptual cost estimate for Alternative 1, No Action, is

Total capital cost	$0
Annualized O&M cost	$0
Total present worth cost	$0

5 3 3 Alternative 2 Institutional Controls

5 3 3 1 Effectiveness

Direct contact with the landfill contents can be limited by access and use restrictions if properly enforced. However, the exposure pathway is not eliminated No attempt is made under this alternative to address infiltration and resulting contaminant leaching to groundwater, surface-water runoff and erosion, or landfill gas control The leakage rate for this alternative is the same as that for no action. However, groundwater monitoring would detect changes in contamination or migration.

Closure regulations are not met for this alternative. The final interim cover has a permeability of approximately 1E-02 cm/sec, which is greater than the permeability of the underlying bedrock.

As with the no-action alternative, there is no treatment so there is no reduction in the toxicity, mobility, or volume of waste or leachate through treatment. However, there may be some reduction in toxicity of leachate due to natural attenuation Apart from installing the fence, there is limited construction under this alternative and as a result, short-term impacts are minimal

5 3 3 2 Implementability

Construction is minimal, groundwater monitoring procedures are standard, and administrative requirements are straightforward This alternative involves limited implementation, but it is unlikely to be approved by CDPHE or EPA because it does not address RAOs or closure requirements

5 3 3 3 Cost

The conceptual cost estimate for Alternative 2, Institutional Controls, is

Total capital cost	$135,700
Annualized O&M cost	$41,700/year
Total present worth cost	$952,600

Cost estimates and associated assumptions are provided in Appendix H

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5 3 4 Alternative 3 Native Soil Cover

5 3 4 1 Effectiveness

The native soil cover provides a physical barrier to minimize the potential for human contact with the landfill contents Depending on the permeability characteristics of the native soil, this cover may reduce infiltration into the groundwater The HELP model shows an average annual leakage rate of 1 1 inches/year (Figure 5-4) The leakage rate for this alternative is slightly less than the leakage rate for the no-action alternative This alternative does not include treatment of waste or leachate, so there is no reduction in toxicity, mobility or volume through treatment The alternative reduces infiltration and will ultimately reduce leachate generation through time The cover is designed to control surface-water runoff and erosion but does not address landfill gas control

The permeability of the native soil cover is approximately 1E-02 cm/sec This does not meet the requirement under 6 CCR 1007-3 Part 265 310 that the cover must have a permeability less than the permeability of the underlying bedrock (1E-06 to 1E-07 cm/sec)

With proper maintenance, the cover has a design life of 30 years and therefore affords long-term protection Institutional controls to address access and use should be effective in preventing a breach of the cap The construction of the cover may have some short-term impacts due to dust generation and erosion during construction However, these are easily mitigated using standard construction techniques

5 3 4 2 Implementability

The native soil cover can consist of any mineral soil and can be obtained from either onsite or offsite sources (EG&G 1994d) Placement of the native soil cover is limited to placing and spreading the material in a single lift directly over the existing interim soil cover The material is end dumped from haul trucks and spread with a bulldozer to the desired depth The surface is graded to design lines and grades with motor graders and then revegetated

Based on the above description of the construction procedures, this implementation is straightforward Materials should be easily obtained, construction methods are standard, and CQA is minimal Post-construction repairs involving replacement of soil or vegetation would be relatively simple Administratively Alternative 3 is unlikely to be approved by the regulatory agencies because it does not meet closure requirements

5 3 4 3 Cost

The conceptual cost estimate for Alternative 3, Native Soil Cover, is.

Total capital cost	$5,408,400
Annualized O&M cost	$51,700/year
Total present worth cost	$6,421,400

Cost estimates and associated assumptions are provided in Appendix H.

5 3 5 Alternative 4 Single-Barrier Clay Cover

5 3 5 1 Effectiveness

The single-barrier clay cover meets all of the RAOs. The cover, in conjunction with institutional controls, prevents direct contact with landfill contents and minimizes infiltration of precipitation and resulting contaminant leaching to groundwater The cover is designed to control surface-water runoff, erosion, and landfill-gas migration

The clay barrier layer has a permeability of approximately 1E-07 cm/sec, which is equal to the permeability of the underlying bedrock and therefore meets the closure requirement

This alternative does not include treatment of waste or leachate, therefore, there is no reduction of toxicity, mobility, or volume through treatment However, the cover reduces the average annual leakage rate to 1 0 inch, which will decrease leachate production through time

The cover has a design life of 30 years and therefore affords long-term protection. Institutional controls to address access and use should be effective in preventing a breach of the cap However, because there is no FMC or vapor barrier above the clay, there is potential for desiccation Construction of the cover may have some short-term impacts due to dust generation and erosion during construction, however, these are readily mitigated using standard construction techniques

5 3 5 2 Implementability

Implementation of this cover option requires that a borrow source of fine-grained soil that meets the design specifications be identified. At this time, there are no known borrow sources at Rocky Flats that meet specifications (EG&G 1994d) Therefore, it is expected that an offsite borrow source will be required. Alternatively, alluvium from onsite could be used if it is screened and mixed with bentonite However, this may increase the cost for soil

After a source is located, the material is hauled to the site for processing and conditioning Processing consists of reducing the maximum particle size to 1 inch or less and moisture conditioning to the specified moisture-content range This generally requires the use of a mixing table where the material is spread in thin lifts (6 to 12 inches) to allow processing and conditioning Particle-size reduction is achieved with discs and/or soil mixers Water is generally added during processing to facilitate particle-size reduction and increase moisture content to the desired range

When the material meets particle-size and moisture-content requirements, it is hauled to the landfill and placed in controlled lifts Each lift is compacted and tested Prior to placing a new lift of clay, the underlying lift surface is scarified to facilitate bonding between lifts This process is repeated until the desired thickness of clay cover is obtained The surface of the completed clay cover is then graded to the design contours Equipment for preparation of the clay usually includes bulldozers water pulls pavement recyclers or soil mixers, and large-diameter earth-turning discs

CQA monitoring of the clay preparation is also required to ensure that the clay material meets specifications when it is placed The clay preparation process is sensitive to frost and heavy rains and special steps must be taken to control rainwater runoff at the prepared clay stockpiles

Two geocomposite layers, one for lateral drainage and one for gas collection are also required These materials are readily available and easy to install Geotextiles are unrolled and seams are either overlapped, heat bonded, or sewn together CQA involves material conformance testing and observation of the deployment and seaming operations to document conformance with plans and specifications

Because compacted clay covers are placed wet of optimum to achieve the minimum permeability, there is an increased potential for desiccation In this cover section, there is no FMC or other vapor barrier above the compacted clay cover Therefore it is expected that over time the clay will dry and crack (Corser *et al* 1992) Without substantial confining pressure, compacted clay covers that desiccate and crack will not re-heal even if subjected to free moisture

A stockpile of clay can be maintained on the site to ensure that a suitable source is available should repairs become necessary Alternatively, GCLs or other appropriate materials can be warehoused for the same purpose CQA testing of the clay material used for repair is the same as CQA testing during construction, therefore, mobilization of those resources is required If the area is large enough special designs of clay layer tie-ins to existing clay may be necessary

Based on the above description of the construction of a compacted clay cover, this alternative is technically feasible Equipment, labor, and materials required for construction are commonly available The single-barrier clay cover meets RAOs and closure requirements and therefore should be administratively feasible

5 3 5 3 Cost

The conceptual cost estimate for Alternative 4, Single-Barrier Clay Cover, is

Total capital cost	$10,179,400
Annualized O&M cost	$51,700/year
Total present worth cost	$11,192,400

Cost estimates and associated assumptions are provided in Appendix H.

5 3 6 Alternative 5 Single-Barrier FMC Cover

5 3 6 1 Effectiveness

The single-barrier FMC cover meets all RAOs. Institutional controls will prevent access and use of the area, which may result in breaching of the cap. The cover will prevent direct contact with landfill contents and minimize infiltration and resultant leaching of contaminants to groundwater The cover is designed to control surface-water runoff, erosion, and landfill-gas migration

The FMC barrier layer has a permeability of approximately 1E-13 cm/sec, which is less than the permeability of the underlying bedrock, meeting the closure requirements

This alternative does not include treatment and therefore does not reduce toxicity, mobility, or volume of waste or leachate through treatment, however, the cover reduces the average annual leakage rate to 0.021 inches, which reduces infiltration and ultimately reduces leachate generation The 30-year design life provides long-term protection Short-term impacts during construction, such as dust generation and erosion, are easily mitigated

5 3 6 2 Implementability

Although specialized, numerous sources exist for the purchase and installation of an FMC Thickness, composition, and type of FMC will be determined during design The geocomposite layers used for drainage and gas collection are also readily available and relatively easy to install as discussed under Alternative 4

Adequate quality control and quality assurance during fabrication, placement, and seaming of the FMC are essential Prior to the material arriving at the site, quality control certifications from the manufacturer are reviewed to confirm that the material meets the specifications After the material arrives onsite, quality assurance samples are obtained to confirm that specifications are met

After the FMC is laid out the panels are seamed together using fusion and/or extrusion welding methods A hot wedge or chemical is used to melt the panel surfaces in fusion seaming The panels then bond directly to each other In extrusion welding, molten polymer is extruded over the edge or between the panels, melting the surface of the sheets The panels and polymer then cool and bond together

All seaming methods require extensive CQA Destructive and nondestructive testing is generally performed In destructive tests, a piece of the seam is cut out and removed for onsite or laboratory testing The sample undergoes shear and peel testing to give an indication of the overall quality of the seaming Nondestructive testing attempts to validate the integrity of all seams Common methods include the air lance, pressurized dual seam, and vacuum chamber box Each method is applicable to certain seam configurations and types of FMC

To repair an FMC, special welding equipment and qualified personnel would have to be mobilized The FMC welding processes are sensitive to the presence of dust or moisture on the sheet and the ambient sheet temperature CQA must generally be performed during daylight hours to enable adequate visual inspection of the material Both nondestructive and destructive seam testing are required Thus, weather and work schedule can greatly influence the cost and quality of an FMC repair

Depending on the location of the repair geotextile seaming personnel also may be required Otherwise simply overlapping or heat bonding the material may be sufficient In either case, CQA personnel need to observe and document repair work

Based on the description of construction above, this alternative is technically feasible All equipment, materials, and labor required for construction are commonly available The single-barrier FMC cover alternative meets RAOs and closure requirements and therefore should be administratively feasible

5 3 6 3 Cost

The conceptual cost estimate for Alternative 5, Single-Barrier FMC, is

Total capital cost	$7 908,500
Annualized O&M cost	$51,700/year
Total present worth cost	$8,921,500

Cost estimates and associated assumptions are provided in Appendix H

5 3 7 Alternative 6 Single-Barrier GCL Cover

5 3 7 1 Effectiveness

The single-barrier GCL cover meets all RAOs The GCL barrier layer has a permeability of 3E-09 cm/sec, which is less than the permeability of the underlying bedrock and therefore meets the closure requirement

There is no treatment of waste or leachate, so this alternative does not reduce toxicity, mobility, or volume through treatment However, the cover reduces infiltration by reducing the average annual leakage rate to 0 035 inches and will ultimately reduce the volume of leachate through time. The cover is designed to last 30 years, however, GCLs have been in use only for about seven years, and the long-term protectiveness of this technology is not proven Short-term impacts during construction include dust generation and erosion, which can be mitigated using standard construction techniques.

5 3 7 2 Implementability

GCL materials are generally available as composites of geotextile or HDPE Geosynthetic drainage and gas collection materials are available as single layers of geonet or laminated combinations of geotextile and geonet. No soil material, other than the vegetative layer, is required

A gas-collection layer is placed directly above the waste or interim soil cover followed by placement of overlying GCL, lateral-drainage, and vegetative layers. Although the gas-collection layer also serves as a cushion layer for the GCL, it is necessary to prepare the general fill for geosynthetic placement. This surface is graded and rolled until it is smooth and firm without any protrusions or depressions

Due to the large absorptive capacity of GCLs, they must be stored to prevent exposure to snow or rain This generally requires that the material be stored in a covered container or enclosed building

Placement of the GCL as part of the cover construction is relatively simple GCL is unrolled over the surface of the landfill with an overlap of 6 to 12 inches The construction process must be sequenced to allow all of the GCL that is deployed in one day to be covered by the end of the day to ensure that the exposed GCL is not damaged by precipitation

CQA observation and testing associated with the placement of a GCL are limited to review of quality control testing of the material prior to shipment, conformance testing of the material delivered to the site, and observation of the deployment to confirm overlaps between rolls

Post-construction repairs to GCLs can be accomplished by removing the vegetative soil cover and drainage layer and overlapping a section of new GCL over the damaged area No seaming is required with a GCL The drainage layer and vegetative soil are then replaced Very minor defects in the GCL will be healed without specific repair measures by the swelling characteristics of the GCL when exposed to any free liquids

Based on the description of construction above this alternative is technically feasible All of the equipment, materials, and labor required for the construction are commonly available The single-barrier GCL cover meets RAOs and closure requirements and therefore is considered administratively feasible

5 3 7 3 Cost

The conceptual cost estimate for Alternative 6, Single-Barrier GCL, is

Total capital cost	$8,391,300
Annualized cost	$51,700/year
Total present worth cost	$9,404,300

Cost estimates and associated assumptions are provided in Appendix H

5 3 8 Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover

5 3 8 1 Effectiveness

The single-barrier FMC with low-permeability soil cover meets all RAOs The FMC barrier layer has a permeability of approximately 1E-13 cm/sec, which is less than the permeability of the underlying bedrock and therefore meets the closure requirements

This alternative does not include treatment and therefore does not reduce toxicity, mobility, or volume of waste or leachate through treatment However the cover reduces the average annual leakage rate to 0 00016 inches which reduces infiltration and ultimately reduces the volume of leachate This leakage rate is substantially less than any of the previous cover alternatives The reduction in leakage is primarily the result of the presence of the low-permeability soil below the FMC The low-permeability soil serves two functions to provide a good bedding layer for the FMC and to reduce the effect of a small leak in the geomembrane by containing the leak with a second barrier

The 30-year design life with institutional controls to protect the cover ensures long-term protection Short-term impacts during construction including dust generation and erosion are readily mitigated

5 3 8 2 Implementability

Geosynthetic FMC materials are available in a wide variety of compositions, thicknesses, surface textures, colors, and other physical properties FMC material laminated with geonets and geotextiles that serve dual functions as barrier and drainage layers are also available The type and weight of the FMC will be determined during design Placement and seaming of the FMC is similar to Alternative 5

The low-permeability soil required in this alternative should be available from nearby borrow sources (EG&G 1994d) Some screening to remove oversize particles or admixture of clay material may be required to meet the gradation and permeability requirements of 1E-05 cm/sec These requirements are significantly less than the clay-barrier layer in Alternative 9, which needs to meet a much more rigid specification for gradation, moisture content, and compaction in order to achieve its required 1E-07 cm/sec permeability The vegetative soil, drainage, and gas-collection layers are all readily available

Alternative 7 calls for a geocomposite gas-collection layer to be placed above the waste followed by, from bottom up, the low-permeability soil, FMC, drainage layer, and vegetative layer The gas-collection layer could also be placed on top of the low-permeability soil instead of directly on the waste surface, provided that the soil can readily transmit gas from the waste mass This eliminates the need to prepare the waste surface for geosynthetic deployment This option will be evaluated during final design.

Placement of geosynthetic materials for gas collection and drainage employs standard construction equipment, labor, and CQA techniques as described in Alternative 4

Based on the construction techniques, this alternative is technically feasible All of the equipment, materials, and labor required for construction are commonly available The single-barrier FMC and low-permeability soil cover meets RAOs and closure requirements and provides two layers of protection. Therefore, it is considered administratively feasible

5 3 8 3 Cost

The conceptual cost estimate for Alternative 7, Single-Barrier FMC Cover with Low-Permeability Soil Cover, is

Total capital cost	$8,623,700
Annualized O&M cost	$51,700/year
Total present worth cost	$9,636,700

Cost estimates and associated assumptions are provided in Appendix H

5 3 9 Alternative 8 Composite-Barrier FMC and GCL

5 3 9 1 Effectiveness

The composite-barrier FMC and GCL cover meets all RAOs The FMC barrier layer has a permeability of approximately 1E-13 cm/sec, and the GCL has a permeability of approximately 1E-09 cm/sec Both are less than the permeability of the underlying bedrock and therefore meet the closure requirement

This alternative does not reduce toxicity mobility or volume of landfill waste through treatment because there is no treatment of waste or leachate However, the cover reduces the average annual leakage rate to 0 00000002 inches, which reduces infiltration and ultimately reduces the volume of leachate Limited long-term experience with GCLs results in uncertainty regarding the long-term effectiveness of this technology Potential short-term impacts during construction include dust generation and erosion

5 3 9 2 Implementability

As mentioned earlier, geosynthetic materials can be readily obtained The 36-inch vegetative layer is the same as that used in the other alternatives No other soil or clay is required for this alternative, therefore soil availability is not a factor

This cover system could be constructed in two separate layers a GCL and an FMC The implementability criteria would be similar to those described for Alternative 5 (single FMC cover) and Alternative 6 (single GCL cover) Alternatively, some manufacturers are producing a single material that consists of a GCL bonded to an FMC This material can be deployed in one step As a minimum, the seams are overlapped However, this system has the potential for FMC components to be welded to each other in a fashion similar to Alternative 5

Post-construction repairs to this cover system would be made to each component individually as described in Alternatives 5 and 6 As a minimum, repairs to the combined materials would consist of placing a bonded GCL/FMC over the damaged area with sufficient overlap around the damage To further secure the patch, a single layer of FMC could be placed over the patch and welded to the surrounding FMC

Based on the above description of construction, this alternative is technically feasible All of the equipment, materials, and labor required for construction are commonly available The composite-barrier FMC and GCL cover fulfills RAOs and closure requirements and provides two barrier layers Thus, it is considered an administratively feasible alternative

5 3 9 3 Cost

The conceptual cost estimate for Alternative 8, Composite-Barrier FMC and GCL Cover, is

Total capital cost	$8,927,500
Annualized O&M cost	$51,700/year
Total present worth cost	$9,940,500

Cost estimates and associated assumptions are provided in Appendix H

5 3 10 Alternative 9: Composite-Barrier FMC and Clay Cover

5 3 10 1 Effectiveness

The composite-barrier FMC and clay cover meets all RAOs. It also follows EPA guidance on the recommended cover cross section for a RCRA Subtitle C cap (EPA 1989d, EPA 1989c) The FMC barrier layer has a permeability of approximately 1E-13 cm/sec, and the compacted clay has a permeability of approximately 1E-07 cm/sec Both are less than or equal to the permeability of the underlying bedrock and therefore meet the closure requirements

This alternative does not reduce toxicity, mobility, or volume of landfill waste through treatment because there is no treatment of waste or leachate However, the cover reduces the average annual leakage rate to 0 00001 inches, which reduces infiltration and ultimately reduces the volume of leachate generated. The 30-year design life with institutional controls to preserve the cover assures long-term protection. Potential short-term impacts during construction include dust generation and erosion

5 3 10 2 Implementability

The geotextile and FMC materials are readily available. The clay material used for the barrier layer may have to be developed by modifying a local borrow source material or importing it from offsite A recently constructed landfill at Rocky Flats used a shale material purchased from a local aggregate company as a low-permeability barrier in the landfill-liner system (EG&G 1994d). Alternatively, screening local borrow source material and adding bentonite admixture is also a possible source for low-permeability clay Inclusion of the FMC over the clay tends to inhibit desiccation when intimate contact between the clay and FMC is maintained. Installation methods for compacted clay liners are discussed under Alternative 4. Equipment, labor, and CQA requirements for installation are similar to those previously discussed for Alternatives 4 and 5

Post-construction repairs are complicated by having two barrier layers. Repair of the clay layer is discussed in Alternative 4, repair of the FMC is discussed in Alternative 5

Based on the construction process discussed above, this alternative is technically feasible All of the equipment, materials, and labor required for construction are commonly available The composite-barrier FMC and clay cover meet RAOs and closure requirements in addition to following EPA guidance on the recommended cover cross section It is considered likely to receive approval from CDPHE and EPA

5 3 10 3 Cost

The conceptual cost estimate for Alternative 9 Composite-Barrier FMC and Clay Cover, is

Total capital cost	$10 680,000
Annualized O&M cost	$51,700/year
Total present worth cost	$11,693,000

Cost estimates and associated assumptions are provided in Appendix H

5 4 Summary of Screening

The screening of alternatives is based on effectiveness implementability, and cost as described in Section 5 3 Table 5-3 summarizes the permeability and leakage rates for each of the alternatives These parameters, in addition to long-term permanence, are used to compare the effectiveness of each alternative Figure 5-4 shows leakage rates for each alternative graphically Table 5-4 summarizes the costs for each alternative Table 5-5 presents a summary of the comparative analysis of the alternatives

Institutional controls native soil cover, and the single-barrier clay cap are eliminated because they do not meet basic effectiveness and implementability criteria

Although GCLs have good permeability and low leakage rates, they have been in use for less than 10 years and as a result long-term effectiveness is unproven Because the panels are not seamed settlement or movement in the cap may cause leakage at these joints over the long term Therefore, those alternatives with GCLs were eliminated from further evaluation

Based on the alternative screening three alternatives are refined and evaluated in the detailed analysis

- Alternative 5 Single-Barrier FMC Cover
- Alternative 7 Single-Barrier FMC with a Low-Permeability Soil Cover
- Alternative 9 Composite-Barrier with FMC and Clay Cover

The no-action alternative is retained as a baseline for comparison

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Table 5-1
Summary of Landfill Cover Components

Cover Component	Objectives	Materials
Vegetation and Vegetation Cover Soil	Growth media for cover vegetation Insulation for barrier layer Limits erosion of cover	General fill Top soil at surface Tall prairie grasses
Lateral Drainage Layer	Allows drainage of water that infiltrates through vegetative cover Controls head build up on barrier layer Discharges water to perimeter drainage ditch	Granular soil (sand/gravel) Geotextile Geonet Geocomposite (geotextile/geonet/geotextile)
Barrier Layer	Prevents infiltration of surface water into waste Prevents uncontrolled releases of gas from waste	Flexible membrane cover (FMC) Geosynthetic clay liner (GCL) Compacted clay
Gas Collection Layer	Allows collection and controlled discharge of gases at selected locations from beneath cover	Geocomposite (geotextile/geonet/geotextile)
General Grading Fill	Fill to achieve design surface grades to promote runoff without erosion after settlement	Any locally available soil

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Table 5-2
Screening Criteria Summary

Criteria	Assessment Components	Discussion of Evaluation
Effectiveness	Meets RAOs and ARARs	
	RAOs	
	• Prevent contact with landfill contents	Engineering judgment
	• Minimize infiltration and resulting loading	HELP analysis
	• Control surface-water runoff and erosion	Erosion analysis
	• Control landfill gas (and treat if necessary)	Engineering judgment
	• Remediate wetlands (as needed)	
	ARARs	
	• Provide long term minimization of migration of liquids through closed landfill	Engineering judgment and HELP analysis
	• Function with minimum maintenance	Erosion and settlement analysis
	• Promote drainage and minimize erosion of cover	Erosion analysis
	• Accommodate settling and subsidence	Settlement analysis
	• Have permeability less than or equal to permeability of any bottom liner or natural subsoil	Analysis of cover sections
	Reduce toxicity mobility and volume through treatment	
	Provide long-term protection	
	Minimize short term impacts	
Implementability	Technical feasibility	
	• Availability of materials	All materials are considered available with exception of the clay barrier soil
	• Ease of construction	
	• Post-construction repairs	
	Administrative feasibility	
	• Ability to obtain approvals from regulatory agencies	
Cost	Comparative cost estimates	
	• Direct and indirect capital costs	Compare total present worth cost
	• Direct and indirect O&M costs	

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Table 5-3
Comparison of Effectiveness Factors

Alternative		Permeability (cm/sec)	Average Annual Leakage (in/year)
Alternative 1	No Action	1E 02	1 4
Alternative 2	Institutional Controls	1E 02	1 4
Alternative 3	Native Soil	1E 02	1 1
Alternative 4	Single Barrier Clay	1E 07	1 0
Alternative 5	Single Barrier FMC	1E 13	0 021
Alternative 6	Single Barrier GCL	3E 09	0 035
Alternative 7	Single Barrier FMC with Low Permeability Soil	1E 13	0 00016
Alternative 8	Composite Barrier FMC and GCL	1E 13	0 00000002
Alternative 9	Composite Barrier FMC and Clay	1E 13	0 00001

Definitions

m/sec   timete per se ond
n/year   ches per year
FMC   fl bl membrane er
GCL   geosynthet cl y l ne

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Table 5-4
Conceptual Cost Estimate Summary

Alternative	Annualized O&M Costs	O&M Present Worth Cost	Capital Cost	Total Present Worth Cost
1	$0	$0	$0	$0
2	$41,700	$816 900	$135,700	$952 600
3	$51,700	$1 013 000	$5,408,400	$6,421,400
4	$51,700	$1,013,000	$10,179,400	$11 192 400
5	$51,700	$1,013 000	$7,908,500	$8,921 500
6	$51,700	$1 013,000	$8,391,300	$9,404 300
7	$51,700	$1,013,000	$8,623,700	$9 636,700
8	$51,700	$1,013,000	$8,927,500	$9,940,500
9	$51,700	$1,013,000	$10,680,000	$11,693,000

Table 5-5
Summary of Comparative Analysis Alternatives Screening

Alternative		Effectiveness[1]	Implementability[2]	Subtotal[3]	Cost (millions)	Action
Alternative 1	No Action	—	—	0	$0	Retain
Alternative 2	Institutional Controls	—	—	0	$ 95	Eliminate
Alternative 3	Native Soil	—	—	0	$6 4	Eliminate
Alternative 4	Single Barrier Clay	1	2	3	$11 2	Eliminate
Alternative 5	Single Barrier FMC	2	2	4	$8 9	Retain
Alternative 6	Single Barrier GCL	2	1	3	$9 4	Eliminate
Alternative 7	Single Barrier FMC with Low Permeability Soil	3	2	5	$9 6	Retain
Alternative 8	Composite Barrier FMC and GCL	3	1	4	$9 9	Eliminate
Alternative 9	Composite Barrier FMC and Clay	3	3	6	$11 7	Retain

Notes

N[illegible] rating was g[illegible] alternat[illegible] th[illegible] did not meet basic effe[illegible] criteria F[illegible] alternat[illegible] that met bas[illegible] criteri[illegible] rating [illegible] was [illegible] Rating [illegible] below

1 Infiltration 1 inch/year or more
2 Infiltration between 1 and 1E 0[illegible] [illegible]h/year
3 I[illegible] between 1E 03 and 1E 08 inch/year

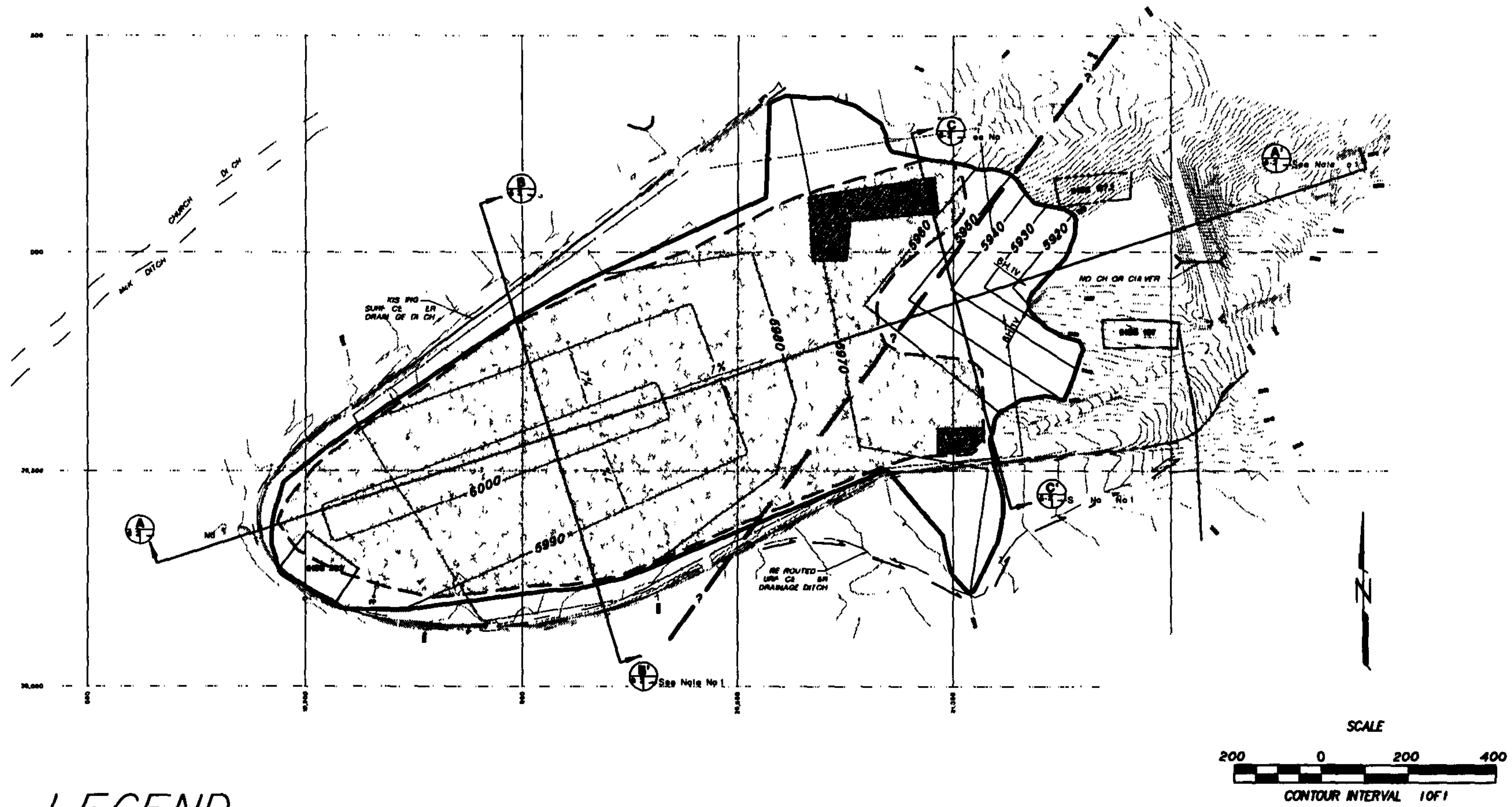
N[illegible] rating was g[illegible] to Alternat[illegible] that did not meet basic implementability criteri[illegible] A rating of 1 [illegible] 3 was [illegible] for altern[illegible] that met basic implementability crite[illegible] R[illegible] defined below

1 In[illegible] construction material
2 Includes components that are similar to those in EPA guidance
3 F[illegible] EPA guidan[illegible] documents

S[illegible] add[illegible] of ratings for effectiveness and implementability The higher the subtotal the better the alternative

Definitions

FMC flexible membrane co[illegible]e
GCL ge[illegible]synthetic clay liner



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA
- EDGE OF LANDFILL (AREA 110,332 FT²)
- ASBESTOS AREA
- COVER AREA (AREA 70 332 FT²)

NOTES

1) REFERENCED ON DRAWINGS 5 2A AND 5 2B
2) BASE TOPOGRAPHY AND FEATURES (DECEMBER 1994)

DETAIL/SECTION NUMBER — DRAWING No. WHERE DETAIL/SECTION IS REFERENCED — DRAWING No. WHERE DETAIL SECTION IS SHOWN

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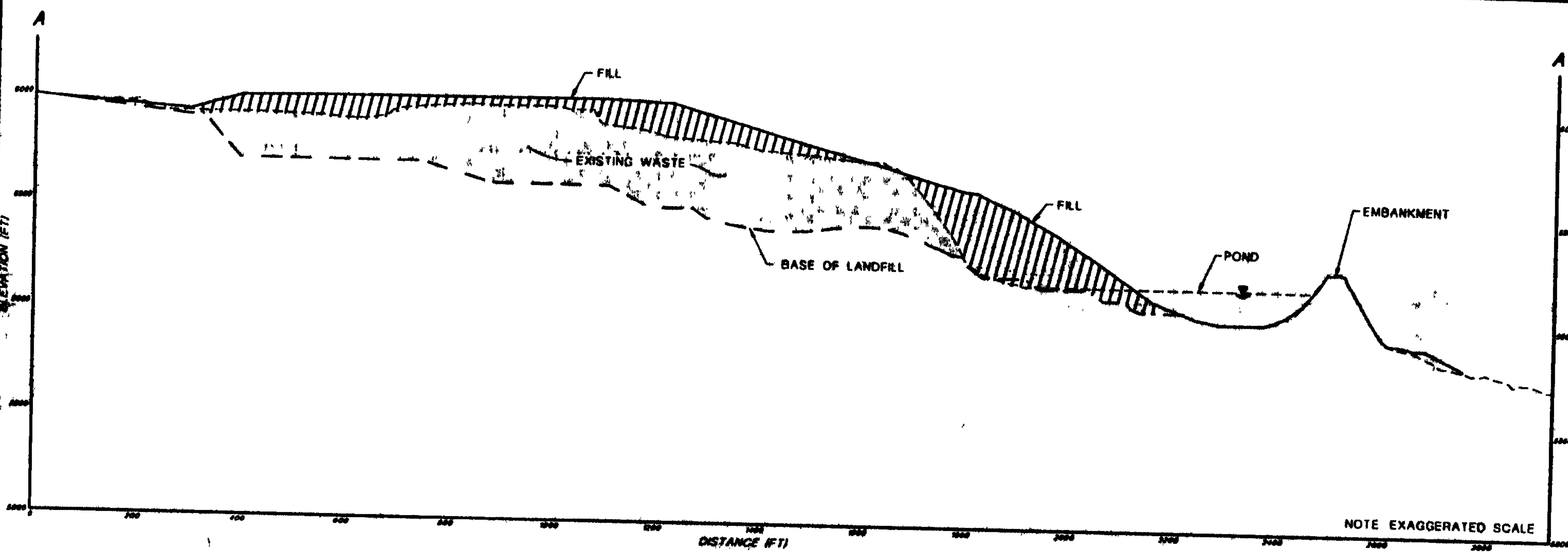
U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Proposed Conceptual Grading Plan, Extent of Cover, and Surface-Water Control Plan

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 5 2



See Note No 1 — CROSS-SECTION A-A'

HORIZONTAL SCALE 0 100' 200

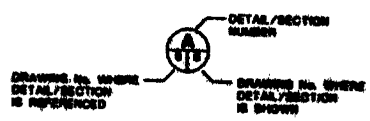
VERTICAL SCALE 0 25' 50'

LEGEND

- CURRENT SURFACE
- BASE OF LANDFILL SURFACE
- PROPOSED CONCEPTUAL GRADING PLAN
- FILL
- EXISTING LANDFILL

NOTE:

1.) REFERENCED ON DRAWING, 5-2



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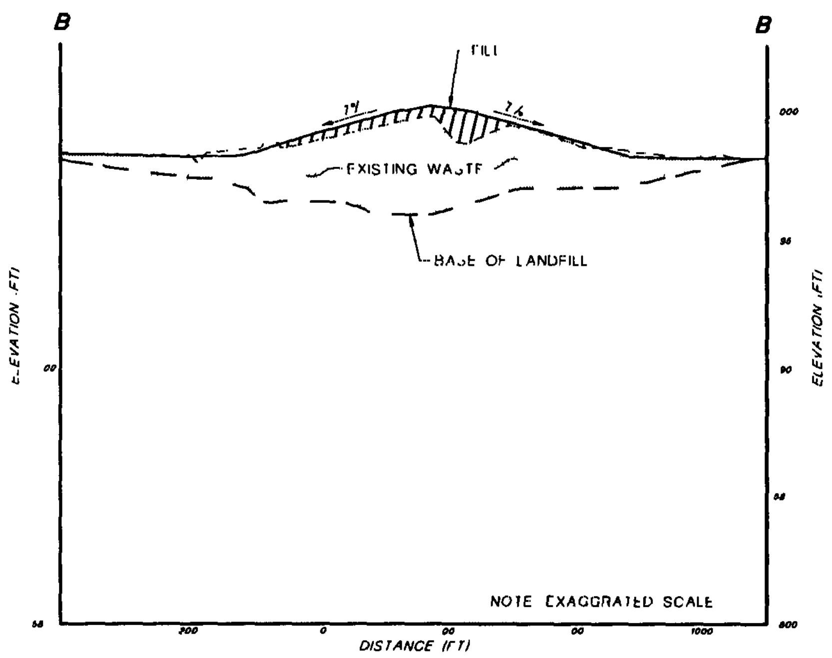
U.S. Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Landfill Cover Cross-Section A-A'

Phase I IM/IRA DD | Operable Unit No 7

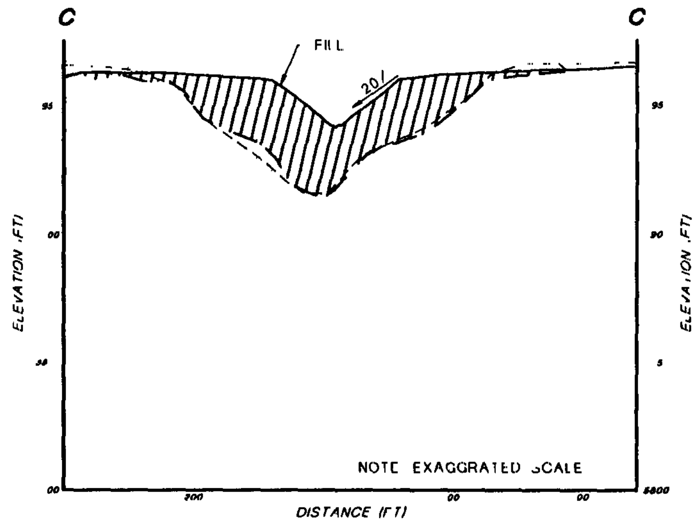
July 1995 | Figure 5 2A



CROSS SECTION B B

HORIZONTAL SCALE 0 100 200

VERTICAL SCALE 0 25 50



CROSS SECTION C-C

HORIZONTAL SCALE 0 100 200

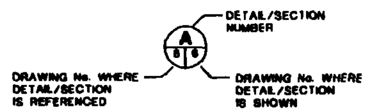
VERTICAL SCALE 0 25 50

LEGEND

- CURRENT SURFACE
- BASE OF LANDFILL SURFACE
- PROPOSED CONCEPTUAL GRADING PLAN
- FILL
- EXISTING LANDFILL

NOTE

1) REFERENCED ON DRAWING 5 2



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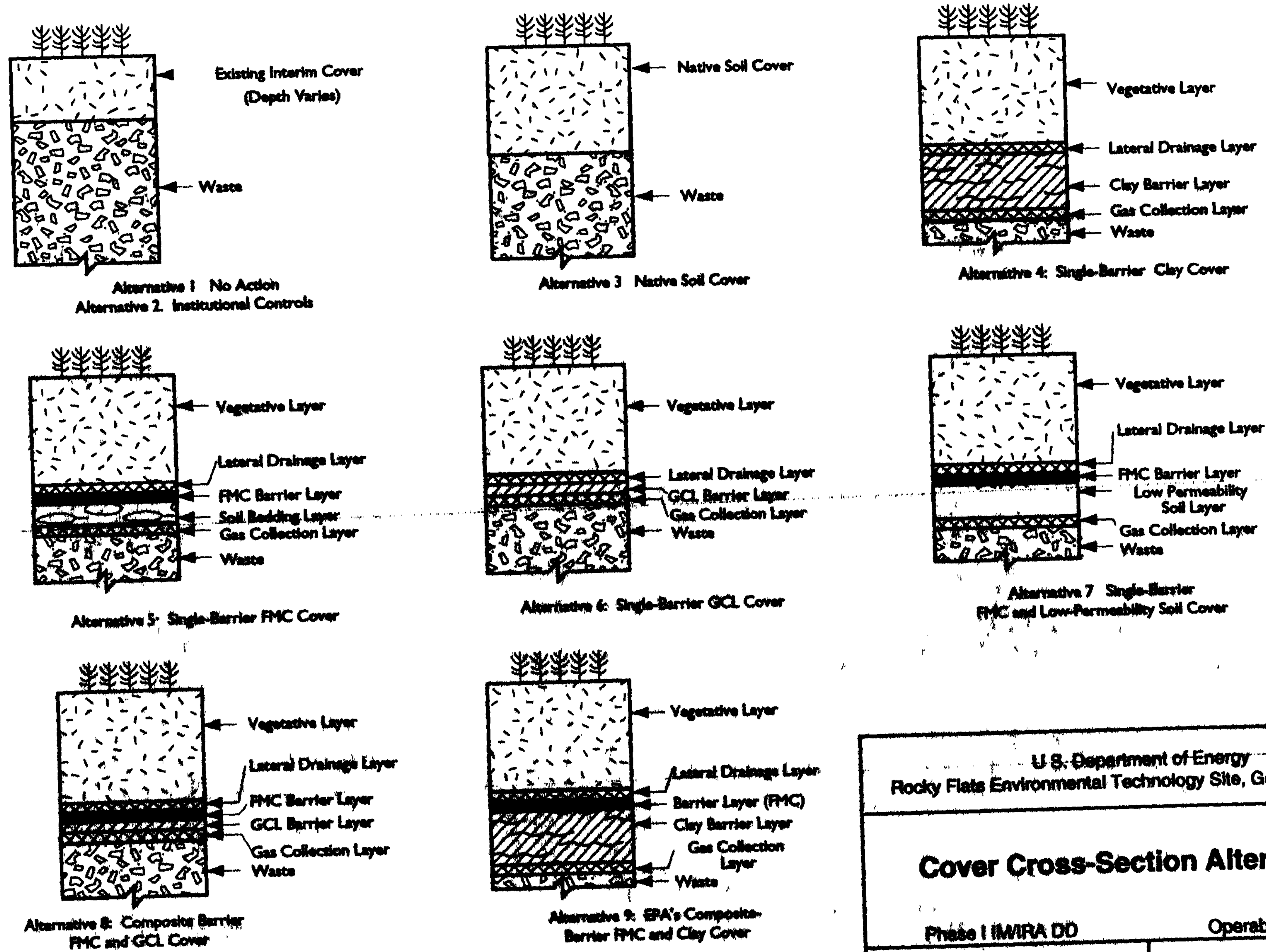
U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Landfill Cover Cross-Sections B-B' & C-C'

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 5 2B



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Cover Cross-Section Alternatives

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 5-3

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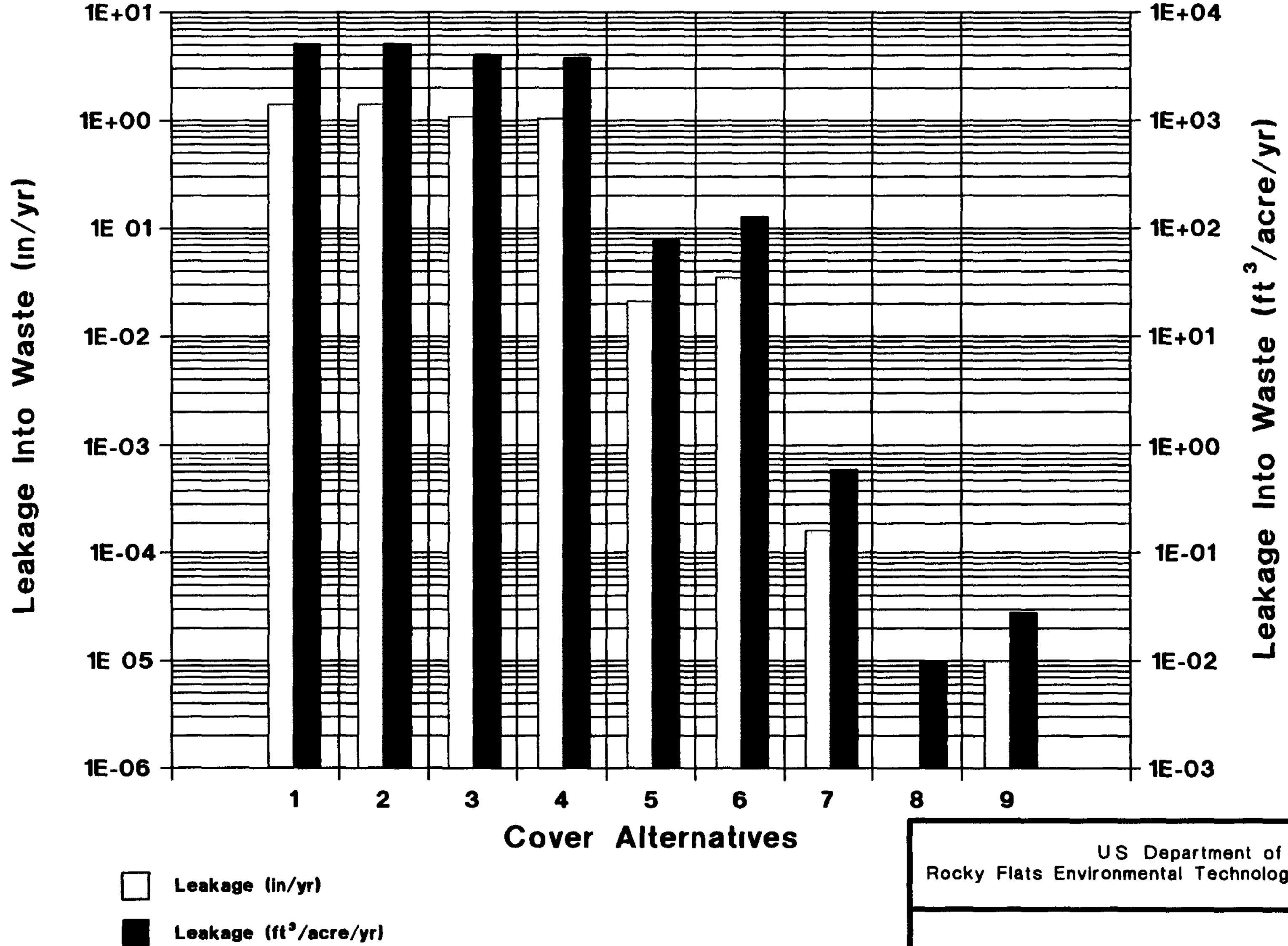

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Rocky Flats Environmental Technology Site Golden Colorado

Leakage Rates for Cover Alternatives

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 5 4

6 Detailed Analysis of Alternatives

The purpose of the detailed analysis of alternatives is to analyze existing data and provide decision makers with sufficient information to adequately compare alternatives select an appropriate remedy for OU 7 and demonstrate that CERCLA remedy selection requirements have been met (EPA 1988)

The detailed analysis process consists of describing each alternative in detail to evaluate the alternatives using the nine CERCLA criteria and performing a comparative analysis among the alternatives to assess the relative performance of each alternative with respect to the evaluation criteria (EPA 1988) The screening process presented here is more detailed than the effectiveness implementability and cost screening presented in Section 5

Three of the alternatives are carried forward through the screening process presented in Section 5 The no-action alternative is retained as a baseline for comparison The alternatives evaluated during the detailed analysis include the following

- Alternative 1 No Action
- Alternative 5 Single-Barrier FMC Cover
- Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover
- Alternative 9 Composite-Barrier FMC and Clay Cover

The proposed slurry wall scheduled for construction in fiscal year 1996 is assumed to be in place for all alternatives

6 1 Screening Process

The NCP identifies nine criteria to be used as evaluation criteria in the detailed analysis of alternatives EPA separates the criteria into three groups (EPA 1988) The first two criteria are considered threshold criteria that relate to statutory requirements and must be met The next five criteria are technical criteria used to compare the alternatives and balance the advantages and disadvantages The final two criteria are modifying criteria that will be evaluated by CDPHE and EPA after the public comment period and will be incorporated into the CAD/ROD The nine criteria are as follows

Threshold Criteria

1 Overall Protection of Human Health and the Environment
2 Compliance with ARARs

Primary Balancing Criteria

3 Long-Term Effectiveness and Permanence
4 Reduction of Toxicity Mobility and Volume through Treatment
5 Short-Term Effectiveness
6 Implementability
7 Cost

Modifying Criteria

8 Regulatory Agency Acceptance
9 Community Acceptance

Each of the criteria is divided into specific factors to facilitate consistent analysis of alternatives The factors are briefly described below and are presented in Table 6-1

Evaluation of overall protectiveness of human health and the environment draws on long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs This criterion provides a final check to assess whether each alternative provides adequate protection

Compliance with ARARs is evaluated for chemical-specific, location-specific, and action-specific ARARs identified in Section 3 4 The detailed analysis should summarize which requirements are applicable or relevant and appropriate to an alternative and describe how the requirements are met When an ARAR is not met, the analysis should include justification for an ARARs waiver under CERCLA if appropriate (EPA 1988)

Long-term effectiveness and permanence is used to assess risks remaining after treatment or risks due to untreated waste This criterion also focuses on the adequacy and reliability of controls used to manage treatment residuals or untreated waste It includes an assessment of the potential need to replace components of the proposed action over the 30-year post-closure care period

Reduction of toxicity, mobility, and volume through treatment addresses the statutory preference for treatment technologies that produce a significant, permanent reduction in hazardous waste Treatment is not part of the presumptive remedy Therefore, this criterion does not strictly apply to the screening process for cover sections at OU 7 The criterion is used in reference to reductions in volume of landfill leachate

Short-term effectiveness addresses the risks to human health and the environment during implementation of the remedial action. This criterion evaluates protection of the community construction workers, and the environment and includes an estimate of the time required to complete construction

Evaluation of implementability includes technical feasibility administrative feasibility and the availability of services and materials This criterion includes potential difficulties associated with construction and operation reliability of the technology ease of undertaking additional remedial actions if needed likelihood of obtaining agency approvals steps required to coordinate with agencies and availability of equipment specialists and technologies

Costs are evaluated using detailed estimates developed for each alternative A present worth analysis is used to discount all future costs to the current year to facilitate comparison among alternatives The present worth costs are based on a 3-percent discount rate over a 30-year post-closure period Detailed cost estimates are a refinement of the conceptual cost estimate presented in Section 5 Additional costs include wetlands mitigation, Preble s meadow jumping mouse habitat mitigation, surface-water diversion ditch rerouting equipment decontamination certification of final closure and a notation on the property deed

The regulatory agency acceptance criterion addresses the concerns of the Natural Resource Trustees including DOE CDPHE the U S Department of the Interior (DOI) the state of Colorado Attorney General and the state of Colorado Department of Natural Resources (CDNR) A Memorandum of Understanding (MOU) (DOE 1994f) has been signed between the trustees and EPA to provide broad guidance for natural resource trustee cooperation at Rocky Flats under Section 104 (b)(2) of CERCLA This cooperative relationship is intended to encourage an interchange of technical expertise and ensure protection and restoration of natural resources during planning and implementation of the IM/IRA for OU 7 Potential environmental impacts of the remedial action and mitigation measures are addressed in this document in accordance with the MOU and the NCP (40 CFR Part 300 430) Comments from the regulatory agencies and the Natural Resource Trustees on the Phase I IM/IRA DD and the Proposed Plan will be addressed in the CAD/ROD

The community acceptance criterion addresses concerns raised by the public during public meetings and the formal public comment period As with regulatory acceptance the community acceptance criterion is not addressed in this report Comments from the public will be incorporated into the CAD/ROD

6 2 Evaluation of Alternatives

Each of the four alternatives is evaluated using seven of the nine CERCLA criteria outlined above In accordance with EPA guidance, the modifying criteria (regulatory agency acceptance and community acceptance) are not used at this stage of the screening process (EPA 1988) The analysis of individual alternatives includes a description of the technology components and construction procedures and an assessment of how each of the evaluation criteria are addressed by the alternative

6 2 1 Alternative 1 No Action

6 2 1 1 Description

Under Alternative 1 no action is taken (Figure 6-1) The cover for the no-action alternative consists of existing interim soil cover material of variable thickness The no-action alternative is required under the NCP and provides a baseline for comparison of other alternatives

6 2 1 2 Evaluation

Overall Protection of Human Health and the Environment

None of the RAOs or closure requirements are met under the no-action alternative Potential risks to human health and the environment are not addressed and will not be monitored Because no action is taken, there are no short-term effects

Compliance with ARARs

The no-action alternative will not meet chemical-specific ARARs for surface water or groundwater Leachate at the seep exceeds Colorado Water Quality (CWQ) standards for aluminum, benzene, manganese, and zinc, Safe Drinking Water Act (SDWA) MCLs for vinyl chloride, and PQLs for 2-methylnaphthalene and naphthalene Surface water in the East Landfill Pond exceeds CWQ standards for manganese Groundwater downgradient of the landfill exceeds SDWA MCLs for nitrate/nitrite, CWQ standards for sulfate, and the PQL for selenium. Tables showing mean concentrations of contaminants and their respective chemical-specific ARAR are included in Section 3 An ARARs waiver under Section 121 of CERCLA is not justified for this alternative.

Location-specific ARARs that are generally applicable for OU 7 do not necessarily apply for the no-action alternative This alternative poses no threat to wetlands (40 CFR Part 6) or to threatened and endangered species habitat (CRS 33-2-101) Because the pond will be left undisturbed, permitting requirements for dredging under Section 404 of the CWA do not apply

Action-specific ARARs under the CHWA, including closure requirements (6 CCR 1007-3 Part 265 310) post-closure maintenance requirements (6 CCR 1007-3 Part 265 117), and post-closure groundwater-monitoring requirements (6 CCR 1007-3 Part 265 228) will not be met In addition, the existing interim soil cover will not meet requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101) No ARARs waiver is justified for any of these action-specific ARARs

Long-Term Effectiveness and Permanence

The no-action alternative does not reduce the risk at the site Existing interim cover and fencing will degrade and become ineffective over time The average annual leakage rate for the no-action alternative is 1 4 inches A description of leakage rates is included in Appendix G

Reduction of Toxicity, Mobility, and Volume through Treatment

The no-action alternative relies on natural biodegradation for any reductions in toxicity or mobility There is no expected reduction in volume of waste material or leachate

Short-Term Effectiveness

No construction or implementation is required therefore there are no short-term impacts to the community workers or the environment The RAOs will not be achieved during the 30-year life of the project

Implementability

The no-action alternative requires no technical implementation, however because it does not meet closure regulations administrative approval is unlikely

Cost

The costs for Alternative 1 No Action are

Total capital cost	$0
Annualized O&M cost	$0 /year
Total present worth cost	$0

6 2 2 Alternative 5 Single-Barrier FMC Cover

6 2 2 1 Description

Alternative 5 consists of a single-barrier FMC cover and institutional controls The existing dam is left in place to control groundwater migration Institutional controls including use and access restrictions are described in detail in Section 5 2 2 The barrier layer is made up of an FMC with a permeability of approximately 1E-13 cm/sec Approximately 885 240 ft^2 of landfill and surrounding area will be covered in this design option A cross section of this cover is shown in Figure 6-2

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Mobilization and Demobilization

Mobilization and demobilization of individual contractors takes place at different times during the construction project Peak labor loading also varies between contractors depending on the type of work being performed Geosynthetic contractors commonly have several mobilization and demobilization periods during a liner or closure project This enables earthwork contractors, whose mobilization and demobilization periods are more costly to perform their work in a continuous fashion

Site Preparation

Water levels in the East Landfill Pond must be lowered to provide access for cover construction and slope stabilization Water is pumped to the A-series ponds using the existing pumping system. The required water-level elevation for construction is based on final cover extent and slope buttress design and is determined during final design

Soil material is required to buttress unstable slopes It is placed by first establishing a bench of material on the lower toe of slope areas Additional material then is placed in uniform lifts gradually proceeding up slope until the design elevation is reached Trimming operations begin at the top of the slope and progress downward to remove excess material In seep areas, a blanket or French drain is constructed below the grading fill or cover section

A storage area is designated near the construction zone for geosynthetic material Geotextile material is shipped in plastic covers to protect the material from truck exhaust fumes road grit and solar degradation Deliveries are inspected and sampled for conformance testing Rolls of geosynthetic material are stacked on heavy wooden pallets above the ground surface to protect the material from dirt and mud The stacks are arranged to allow easy access for handling and sampling

Rerouting of the Surface-Water Drainage Ditch

The existing perimeter surface-water drainage ditch is incorporated into the cover design to collect surface-water run-off from the cover and to intercept surface-water run-on to the landfill The capacity of the existing ditch is compared to the expected design flows for the final design Select portions of the perimeter ditch are rerouted to accommodate the grading plan (Figure 5-2)

Landfill Cap

A summary of quantities of material for landfill cover construction is presented in Table 6-2 Individual cover layers are described below

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Fill Layer

Construction of the cover begins with placement of general fill Thickness varies from 3 to 15 feet depending on the grading plan The grading plan is designed to promote drainage off the cover to the perimeter drainage ditch In central areas of the cell where design elevations are greatest the fill is thickest In lower elevation areas near the perimeter of the cell fill is thinner

The grading of the fill layer is determined by two factors the upper bound for the slope is based on stability and erosion control and the lower bound is to provide adequate surface-water drainage after settlement as discussed in Section 5 1 3 Based on these conditions approximately 131 400 yd^3 of fill will be placed

The thickness of the general fill may also be affected by the final waste configuration It is assumed that additional waste placement at OU 7 will not occur after the new landfill is operational (early 1997)

It is likely that onsite alluvial materials are satisfactory borrow sources for fill material (EG&G 1994d) Special preparation of this material is generally not required except for the top 6 inches of the placed layer In this area the fill material should be free of rocks or particles larger than 1 inch to prevent puncture of the geosynthetic layer of the gas-collection system

Gas-Collection Layer

A composite made up of geonet with filter fabric on each side is rolled out over the general fill for gas collection The geonet is sandwiched between two layers of filter fabric to prevent fines from clogging the geonet The composite panels are overlapped heat bonded or tied together

Gas vents extend through the cover and vent at the surface at regular intervals The vents consist of PVC or HDPE pipe (depending on the FMC material selected) or gravel columns Gas monitoring will be conducted after closure in accordance with the post-closure plan

Soil Bedding Layer

Soil bedding is placed on top of the upper gas-collection filter fabric layer using low ground pressure bulldozers The surface of the soil layer is then trimmed with motor graders and compacted with a smooth drum vibratory roller to provide a smooth firm surface upon which to place the FMC

FMC Layer

The FMC geomembrane is rolled out and seamed using both fusion-welding and extrusion-welding techniques Long, straight seams are fusion seamed while extrusion welding is used in smaller, confined areas or where sharp turns in the weld are required Patches for destructive seam sample areas and fusion welder entry and exit holes are examples of extrusion weld applications

Destructive and nondestructive testing is performed on the geomembrane seams to document seam strength and seam integrity Samples of the seam are extracted and pulled apart in a tensiometer to test the weld strength Vacuum box tests and seam air-pressure tests are used to determine if the seam is airtight.

Drainage Layer

The drainage layer composite geonet and filter fabric is placed over the FMC The lower filter fabric provides a cushion so that the geonet does not damage the FMC Panels are overlapped heat bonded, or tied together

Vegetative and Top Soil Layers

Placement of soil material on geosynthetic layers can cause damage to the geosynthetic material if not done properly Typically, soil material is placed in thick lifts, generally 2 to 3 feet, and spread with low ground pressure equipment Care must be taken not to cause the geosynthetic material to wrinkle during soil placement and to maintain adequate lift thickness to reduce the chance of puncturing the material.

Top soil, fertilizer, and seeding complete the cover construction Top soil can be readily acquired from local offsite sources or, potentially, onsite sources could be amended with soil additives to create a suitable vegetative substrate (EG&G 1994d) Revegetation occurs in late fall Seeds are dormant through the winter and germinate the following spring

Decontamination

Decontamination activities for personnel and equipment are expected to be minimal because no waste excavation is planned Construction and other equipment used during landfill closure activities is decontaminated at the main decontamination facility at Rocky Flats as needed Air quality monitoring is conducted periodically by contractor and site personnel to ensure that workers are not exposed to potentially hazardous materials If monitoring indicates the presence of hazardous materials, appropriate personal protective equipment (PPE) is used and decontamination procedures are followed This may include the establishment of different contamination level zones and contamination reduction zones in the OU 7 work area

Certification of Final Closure

Construction activities are typically summarized in a final certification report which is prepared by the third-party CQA contractor All facets of the cover installation material testing and final as-built drawings etc are included in this report

6 2 2 2 Evaluation

Overall Protection of Human Health and the Environment

The single-barrier FMC cover alternative meets all RAOs The cap fence and institutional controls prevent direct contact with landfill contents The cap has a permeability of approximately 1E-13 cm/sec and therefore minimizes infiltration leaching, and resulting contaminant loading to groundwater The surface is graded and revegetated to control surface-water run-off and erosion A gas-collection system controls landfill gas Gas treatment may be added to the system if needed

Properly installed and maintained the FMC provides protection to human health and the environment over the 30-year post-closure care period Short-term impacts due to implementation are minimal and easily mitigated The alternative does not comply with EPA guidance for a RCRA Subtitle C cap (EPA 1989e), however the single-barrier FMC cover is equally protective of human health and the environment and meets state and federal regulations for closure

Compliance with ARARs

Alternative 5 meets all chemical-specific ARARs for surface water except one Surface water in the East Landfill Pond exceeds CWQ standards for manganese however manganese is a naturally occurring element common in the geologic materials surrounding the pond and in pond sediments Discharge of leachate into the pond may have resulted in mobilization of manganese from the pond sediments Because the cap reduces leachate generation mobilization of manganese is not expected to continue Alternative 5 does not meet chemical-specific ARARs for groundwater Groundwater downgradient of the landfill exceeds SDWA MCLs for nitrate/nitrite, CWQ standards for sulfate and PQLs for selenium However the exposure pathway for groundwater is incomplete Tables showing mean concentrations of contaminants and their respective chemical-specific ARAR are included in Section 3 Flow modeling, particle tracking and contaminant transport modeling performed for this report (Appendices C and E) indicate that the East Landfill Pond dam significantly reduces groundwater flow The clay in the dam core and in bedrock naturally attenuates contaminants As a result contaminant migration down No Name Gulch is expected to be minimal Concentrations of nitrate/nitrite, selenium, and sulfate are not expected to exceed ARARs at the compliance wells downgradient of the East Landfill Pond dam In addition, the exposure pathway is incomplete

Location-specific ARARs that are generally applicable for OU 7 are met The cap extends over areas designated as wetlands by the U S Army Corps of Engineers and areas identified as potential habitat for the Preble's meadow jumping mouse (Figure 2-12) A wetlands assessment, required under 40 CFR Part 6, is provided in Section 7 Injury to wetlands is mitigated using acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project, pending final approval Injury to Preble's meadow jumping mouse habitat is mitigated as needed Although the portion of the pond not covered by the landfill cap remains in place, dredge and fill requirements under Section 404 of the CWA are applicable. Alternative 5 meets substantive requirements of permitting under the CWA

Action-specific ARARs under the CHWA, including closure requirements (6 CCR 1007-3 Part 265 310), post-closure maintenance requirements (6 CCR 1007-3 Part 265 117) and post-closure groundwater-monitoring requirements (6 CCR 1007-3 Part 265 228) are met for Alternative 5

The single-barrier FMC cover meets the following requirements for landfill closure (6 CCR 1007-3 Part 265 310)

- Provides long-term minimization of migration of liquids through the closed landfill
- Functions with minimum maintenance
- Promotes drainage and minimizes erosion or abrasion of the cover
- Accommodates settling and subsidence to maintain the integrity of the cover
- Has a permeability less than or equal to the permeability of any bottom liner system or natural subsoil present

The natural subsoil under the landfill has a permeability of 1E-06 to 1E-07 cm/sec The single-barrier FMC cover has a permeability of approximately 1E-13 cm/sec Although the cover for Alternative 5 meets all regulatory requirements for closure, this cap does not follow EPA guidance for a RCRA Subtitle C cap (EPA 1989e) The guidance recommends a composite barrier with an FMC layer and a clay layer, similar to the cover of Alternative 9 Engineering analyses have shown that Alternative 5 is equally protective Construction procedures during installation of the landfill cap meet requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101) Alternative 5 meets MACs for delisting leachate under 40 CFR 260 20 Compliance with NPDES (40 CFR Part 125) occurs by meeting substantive requirements for a discharge permit for periodic surface-water discharge to decrease water levels in the East Landfill Pond

Long-Term Effectiveness and Permanence

The landfill which is the source of contamination, remains in place However risks due to direct contact with waste material and leaching of source contaminants into the groundwater are minimized by the cap and institutional controls

The single-barrier FMC cover is considered a proven technology and if properly installed and maintained is effective over the 30-year life of the project The cap is designed to prevent breaching from settling erosion, and freeze/thaw cycles The average annual leakage rate for this alternative is 0 021 inches A description of leakage rates is included in Appendix G

Maintenance of the cap is not difficult or labor intensive but inspections must be conducted on a periodic basis and if portions of the cap are damaged must be repaired immediately DOE is responsible for conducting routine semiannual inspections of the final cover surface-water drainage ditch surveyed benchmarks, security fence groundwater-monitoring system and gas-monitoring system Defects will be repaired

Long-term effectiveness will be monitored and additional measures will be taken as required The groundwater-monitoring system consists of one well upgradient of the landfill and three wells downgradient of the landfill DOE will monitor the wells semiannually as outlined in the OU 7 Closure Plan

The effectiveness of the remedial action will be evaluated every 5 years Mandated under Section 121(c) of CERCLA and Section 300 430 (f)(4)(ii) of the NCP reviews are required of any site where contaminants remain onsite after remediation Reviews are required minimally every 5 years or until contaminant levels allow for unlimited use and unrestricted exposure The purpose of the reviews is to assure that the remedial action remains protective of human health and the environment The level of the reviews will be at the discretion of CDPHE and EPA however it is expected that a Level 1 review consisting of a site visit review of operation and maintenance activities and a brief site inspection will be sufficient

Reduction of Toxicity, Mobility, and Volume through Treatment

Although there is no treatment with this option there may be some decrease in toxicity and mobility of the waste material over time due to natural attenuation processes The cap also decreases infiltration into the waste which then limits the generation and migration of leachate

Short-Term Effectiveness

The contaminants are currently under a 12- to 36-inch-thick soil cover No excavation into contaminated areas is required to implement this option Therefore, risks to the community and site workers are minimal The possibility exists that workers could be exposed to contamination accidentally during construction however this is unlikely and proper use of PPE limits such exposure

The remedial action would result in dust generation during excavation, transport, and placement of fill and vegetative soil The primary method of dust emissions control requires frequent periodic water spray of high traffic roadways, particularly dirt or gravel roads An alternate method is application of chemical polymer soil binders, but due to the short-term nature of this project, application of soil binders may not be justifiable from a cost standpoint

During construction, there is potential for increased erosion and therefore increased solids loading to the surface-water drainage ditch Erosion of the cover soil diminishes as vegetation proliferates on the surface Until that time, however, berms and hay bales are used to intercept surface-water run-off and prevent the offsite transport of solids Erosional features such as rills and gullies will need to be repaired This post-closure maintenance work will involve importation and placement of top-soil material Earthwork equipment and manpower to spread material in the required areas will also be necessary The extent of this repair work will be largely dependent on the severity of the weather

As described in the ARARs section, potential adverse environmental impacts to wetlands and Preble's meadow jumping mouse habitat may result from construction and implementation of this alternative (Figure 2-12) These impacts are mitigated as needed using acreage from the 8-acre wetlands mitigation bank proposed for devlopment adjacent to the Standley Lake Protection Project, pending final approval

Implementation, including design and construction, takes approximately one year

Implementability

Installing an FMC is a labor-intensive operation that includes extensive CQA However, industry standards are well developed and companies specializing in installation of geosynthetics are readily available

The long-term durability of FMCs has been evaluated through field testing of actual installations and through laboratory compatibility testing designed to simulate exposure to leachate for long periods of time Both PVC and HDPE have been proven reliable as barrier layers for at least 30 years In all of the cover options being considered, the

FMC component is covered with a 36-inch-thick vegetative soil The vegetative soil layer prevents exposure of the FMC to ultraviolet radiation and prevents punctures bv plant roots and burrowing animals

The FMC will be exposed to surface water that infiltrates through the vegetative soil and to landfill gas The rain water is expected to be nonhazardous and the gases are expected to contain onlv low concentrations of hazardous components

Because the cap is the presumptive remedy for the landfill it is unlikely that future actions would be required to address the waste itself It is more likely that containment collection or treatment systems would be added to modify or enhance the existing remedy In the event that additional remedial actions are required alternatives could be developed that do not breach the cap or if necessary an area of the cap could be excavated and replaced

The effectiveness of the remedy will be monitored by post-closure monitoring programs as described in Section 8

Cost

The costs for Alternative 5 Single-Barrier FMC Cover are

Total capital cost	$8 390 100
Annualized O&M cost	$55 000/year
Total present worth cost	$9 469,100

Detailed cost estimates are provided in Appendix H

6 2 3 Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover

6 2 3 1 Description

Alternative 7 consists of institutional controls and a single-barrier FMC with a 12-inch layer of low-permeability soil The presence of the low-permeability soil gives the cover system some of the benefits of a composite cover without the strict installation requirements of a full clay liner The existing dam is left in place to contain the groundwater The barrier layer is an FMC with a permeability of approximately 1E-13 cm/sec This cover section is illustrated in Figure 6-3

The construction procedures for this alternative are the same as those for Alternative 5 except that a low-permeability soil replaces the soil bedding layer under the FMC The low-permeability soil layer is placed in a single 1-foot lift using low ground pressure bulldozers Subsequently this surface is compacted using sheepsfoot or wedgefoot compactors The surface of the soil is then trimmed Material placed is tested for moisture content, compaction, and conformance with source material index tests

6 2 3 2 *Evaluation*

Overall Protection of Human Health and the Environment

Alternative 7 provides protection of human health and the environment by meeting all RAOs The cap prevents direct contact with the landfill contents Security measures limit access to Rocky Flats Fencing and other institutional controls limit access to the landfill at OU 7 The cap minimizes infiltration and, in conjunction with the proposed slurry wall, limits leaching and contaminant loading to groundwater The cover is designed to direct the majority of the surface-water run-off to the surface-water drainage ditch and the remainder to the East Landfill Pond. The cover is graded and revegetated to limit erosion to 2 tons/acre/year A landfill gas-collection layer and venting system is installed to protect the integrity of the cap The design accommodates future landfill gas treatment if needed.

The FMC is relatively easy to install and the low-permeability layer provides an additional barrier without the strict installation requirements of clay The cap provides protection to human health and the environment over the 30-year post-closure care period Short-term impacts to the community workers, and the environment are minimal because there is no excavation of waste The alternative does not comply with EPA guidance for a RCRA Subtitle C cap (EPA 1989e), however, the single-barrier FMC with low-permeability soil cover is equally protective of human health and the environment and meets state and federal regulations for closure.

Compliance with ARARs

As with Alternative 5, Alternative 7 meets all but one chemical-specific ARARs for surface water Surface water in the East Landfill Pond exceeds CWQ standards for manganese However, installation of the cap reduces leachate generation and migration, and therefore, mobilization of manganese from pond sediments is not expected to continue Alternative 7 does not meet chemical-specific ARARs for groundwater Groundwater downgradient of the landfill exceeds SDWA MCLs for nitrate/nitrite CWQ standards for sulfate, and the PQL for selenium Particle tracking and contaminant transport modeling indicate that concentrations of nitrate/nitrite, selenium, and sulfate are not expected to exceed ARARs at compliance wells downgradient of the East Landfill Pond dam In addition, the groundwater exposure pathway is incomplete.

Location-specific ARARs that are generally applicable for OU 7 are met The cap extends over areas designated as wetlands by the U S Army Corps of Engineers and areas identified as potential habitat for the Preble s meadow jumping mouse (Figure 2-12) Injurv to wetlands and to Preble s meadow jumping mouse habitat are mitigated as needed Although the portion of the pond not covered by the landfill cap will remain in place dredge and fill requirements under Section 404 of the CWA are applicable Alternative 7 meets substantive requirements of permitting under the CWA

Action-specific ARARs under the CHWA including closure requirements (6 CCR 1007-3 Part 265 310) post-closure maintenance requirements (6 CCR 1007-3 Part 265 117) and post-closure groundwater-monitoring requirements (6 CCR 1007-3 Part 265 228) are met for Alternative 7 The single-barrier FMC with low-permeability soil cover has a permeability of approximately 1E-13 cm/sec As with Alternative 5 the cover for Alternative 7 meets all of the regulatory requirements for closure but does not follow EPA guidance for a RCRA Subtitle C cap (EPA 1989e) Construction procedures during installation of the landfill cap meet requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101) As with the other alternatives Alternative 7 meets MACs for delisting leachate under 40 CFR 260 20 Compliance with NPDES (40 CFR Part 125) occurs by meeting substantive requirements for a discharge permit for periodic surface-water discharge to decrease water level in the East Landfill Pond

Long-Term Effectiveness and Permanence

The FMC barrier is considered a proven technology and if properlv installed and maintained is effective over the 30-year life of the project In addition this alternative has a second low-permeability laver to act as backup which increases the reliability of the technology The average annual leakage rate for Alternative 7 is 0 00016 inches A description of cap leakage rates is included in Appendix G

The maintenance and monitoring are the same as discussed under Alternative 5

As directed under the presumptive remedy the source of contamination remains However risks associated with the direct contact and leaching of source contaminants into the groundwater are minimized by the cap and institutional controls As with Alternative 5 CDPHE and EPA will evaluate the effectiveness of the remedial action every 5 years

Reduction of Toxicity, Mobility, and Volume through Treatment

There is no active treatment with this option However there may be some decrease in toxicity and mobility over time due to natural attenuation processes Leachate generation and migration will be reduced as a result of the cap

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Short-Term Effectiveness

No excavation into contaminated areas is required to implement this alternative The contaminants are currently under a 12- to 36-inch-thick interim soil cover Therefore risks to the community and site workers are minimal The possibility exists that workers could be exposed to contamination accidentally, however proper use of PPE would limit potential exposure

Dust is generated during excavation, transport, and placement of fill, the low-permeability soil layer, and the vegetative layer The dust emissions are controlled by water spraying or possibly soil binders Erosion during construction is controlled by berms and hay bales

As described in the ARARs section, construction and implementation of this alternative may result in potential adverse environmental impacts to wetlands and Preble's meadow jumping mouse habitat (Figure 2-12) These impacts are mitigated as needed using acreage from the 8-acre wetlands mitigation bank proposed for development adjacent the Standley Lake Protection Project, pending final approval

Cap construction would be complete within one year

Implementability

The addition of the low-permeability soil does not add significantly to the installation of this cap in comparison with the FMC barrier as discussed under Alternative 5 The low-permeability soil is placed on top of the gas-collection layer and spread in a single 1-foot lift The surface of the 1-foot lift is compacted and rolled to form a smooth low-permeability surface for placement of the FMC Some minor grading of the low-permeability soil may be required to maintain surface grades and prevent ponding Addition of the low-permeability soil increases the reliability of the technology because the low-permeability soil acts as a backup barrier for the FMC layer

Cost

The costs for Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover are

Total capital cost	$9,070,000
Annualized O&M cost	$55,000/year
Total present worth cost	$10,149 000

Detailed cost estimates are provided in Appendix H

6 2 4 Alternative 9 Composite-Barrier FMC and Clay Cover

6 2 4 1 Description

Alternative 9 is a composite barrier with both FMC and 24 inches of compacted clay As with all of the alternatives the existing dam remains in place to control groundwater migration away from the source Use and access restrictions are described in Section 5 2 2 The design follows EPA guidance for a RCRA Subtitle C facility This cover section is shown in Figure 6-4

This cover differs from Alternative 5 in that a clay barrier layer with a permeability of approximately 1E-07 cm/sec replaces the low-permeability soil Clay must be transported, processed and conditioned as described in Section 5 3 5 2 Prepared clay material is placed on top of the filter fabric of the upper gas-collection layer in a 1 foot or thicker lift using low ground pressure bulldozers Subsequent lifts are placed in 6- to 9-inch-thick loose lifts and compacted using sheepsfoot or wedgefoot compactors The surface of the clay layer is tested and scarified to increase bonding between lifts

During placement care must be taken to protect the clay from moisture loss during dry periods or over moisturizing during rainy periods After the clay is placed and before it is covered with the geomembrane similar steps must be taken to prevent desiccation over moisturizing or erosion

6 2 4 2 Evaluation

Overall Protection of Human Health and the Environment

The composite-barrier FMC and clay cover alternative meets all RAOs The cap fence and institutional controls prevent direct contact with landfill contents The cap has a permeability of approximately 1E-13 cm/sec and therefore minimizes infiltration leaching and resulting contaminant loading to groundwater The surface is graded and revegetated to control surface-water run-off and erosion A gas-collection system is designed to control landfill gas Treatment may be added to the system if needed

The compacted clay liner provides a secondary barrier however the clay requires intensive effort for proper installation The cap provides protection over the 30-year life of the project Because there is no planned excavation into landfill waste short-term impacts are minimal

Compliance with ARARs

As with Alternatives 5 and 7 Alternative 9 meets all chemical-specific ARARs for surface water except one Surface water in the East Landfill Pond exceeds CWQ standards for manganese Manganese is a naturally occurring element that is likely

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mobilized from pond sediment by leachate Containment of the leachate is expected to reduce manganese mobilization Alternative 9 does not meet chemical-specific ARARs for groundwater. Groundwater downgradient of the landfill exceeds SDWA MCLs for nitrate/nitrite, CWQ standards for sulfate, and PQLs for selenium Particle tracking and contaminant transport modeling indicate that concentrations of nitrate/nitrite selenium, and sulfate are not expected to exceed ARARs at the compliance wells downgradient of the East Landfill Pond dam. In addition, the exposure pathway for groundwater is incomplete

Location-specific ARARs that are generally applicable for OU 7 are met The cap extends over areas designated as wetlands by the U S Army Corps of Engineers and areas identified as potential habitat for the Preble's meadow jumping mouse (Figure 2-12) Injury to wetlands and Preble's meadow jumping mouse habitat is mitigated as needed Although the portion of the pond not covered by the landfill cap remains in place, dredge and fill requirements under Section 404 of the CWA are applicable Alternative 9 meets substantive requirements of permitting under the CWA

Action-specific ARARs under the CHWA, including closure requirements and post-closure maintenance and groundwater-monitoring requirements are met for Alternative 9 The composite-barrier FMC and clay cover has a permeability of approximately 1E-13 cm/sec The cover for Alternative 9 meets all of the regulatory requirements for closure and follows EPA guidance for a RCRA Subtitle C cap (EPA 1989e), which recommends a composite barrier with an FMC layer and a clay layer Construction procedures during installation of the landfill cap meet requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101) As with the other alternatives, Alternative 9 meets MACs for delisting leachate under 40 CFR 260 20 Compliance with NPDES (40 CFR Part 125) occurs by meeting substantive requirements for a discharge permit for periodic surface-water discharge to decrease water levels in the East Landfill Pond

Long-Term Effectiveness and Permanence

Both the FMC and clay barriers are considered proven technologies. If properly installed and maintained, they are effective over the 30-year life of the project However the compacted clay layer is subject to desiccation cracking The 5-year average annual leakage rate for Alternative 9 is 0 00001 inches A description of cap leakage rates is included in Appendix G

The schedule for maintenance and monitoring is the same for all capping alternatives and is described under Alternative 5

Landfill waste material, which is the source of contamination, remains at OU 7 However, the cap and institutional controls minimize risks that result from direct contact with waste material and leaching of source contaminants into the groundwater

Every 5 years CDPHE and EPA will evaluate the effectiveness of the action as mandated under Section 121(c) of CERCLA and Section 300 430 (f)(4)(ii) of the NCP The level of the reviews will be at the discretion of CDPHE and EPA however it is expected that a Level 1 review will be sufficient

Reduction of Toxicity, Mobility, and Volume through Treatment

This alternative does not include active treatment However as with the other alternatives there may be some decrease in toxicity and mobility over time due to natural attenuation processes In addition the cap minimizes infiltration into the waste thus decreasing generation and migration of leachate

Short-Term Effectiveness

As with the other alternatives, no excavation into contaminated areas is required to implement this alternative Therefore risks to the community and site workers are minimal Workers could be exposed to contamination accidentally during construction however proper use of PPE limits exposure

This remedial action results in dust generation during excavation transport and placement of fill clay and vegetative layers The dust emissions are readily mitigated using standard dust suppression techniques Erosion during construction is addressed by using hay bales and berms

Potential adverse environmental impacts to wetlands and Preble s meadow jumping mouse habitat may result from implementation of this alternative (Figure 2-12) These impacts are mitigated as needed using acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project pending final approval

Cap construction could be complete within one year

Implementability

Installation of the clay barrier layer requires a significant level of effort The clay material must be mined sized moisture conditioned and allowed to cure before it can be placed Implementation of other elements of this alternative are the same as those for Alternative 5

Cost

The costs for Alternative 9 Composite-Barrier FMC and Clay Cover are

Total capital cost	$11,024,600
Annualized O&M cost	$55 000/year
Total present worth cost	$12,103,600

Detailed cost estimates are provided in Appendix H

6.3 Comparative Analysis

In the previous sections, each of the alternatives is evaluated individually against the seven CERCLA criteria This section provides a relative comparison of their performance based on the same criteria The purpose of this analysis is to identify the strengths and weaknesses of the alternatives relative to each other

With the exception of the no-action alternative, all the alternatives meet the threshold criteria of overall protection of human health and the environment and compliance with ARARs Reduction of toxicity, mobility, and volume through treatment (a primary balancing criterion) is the same for all alternatives None of the remedial actions include treatment although decreasing leakage rates will decrease the volume of leachate in the landfill

All of the alternatives are compared based on the remaining primary balancing criteria. long-term effectiveness and permanence, short-term effectiveness, implementability, and cost The focus is on the soil layer beneath the geomembrane, which is the only difference among the three alternatives

6 3 1 Long-Term Effectiveness and Permanence

For long-term effectiveness, the focus is on the two main functions of the soil layer beneath the geomembrane

- Ability of the soil to support and enhance the function of the geomembrane
- Long-term permeability of the soil barrier itself

Alternatives 7 and 9 have similar degrees of long-term effectiveness The soil bedding layer of Alternative 5 serves to support the FMC as do the low-permeability soil layer of Alternative 7 and the clay-barrier layer of Alternative 9, however, if a breach in the membrane occurs, the soil bedding layer would not impede the movement of liquids as well as either the low-permeability soil or the clay barrier layer On this basis, Alternative 5 presents a higher long-term risk than the other two alternatives

Alternatives 7 and 9 have leakage rates approaching zero The leakage rate for Alternative 5 is the highest of the three alternatives at 0 021 cm/sec

During the life of the project the kev difference between the low-permeability soil and clay barrier is resistance to desiccation Studies indicate that covers constructed with clay materials at high moisture contents may be subject to greater desiccation than covers constructed of soil materials at lower moisture contents (Corser *et al* 1992) The desiccation cracking provides pathways for liquids to travel through the clay barrier layer thus increasing its permeability and reducing its long-term effectiveness The low-permeability soil layer which is placed at lower moisture contents may have a higher initial permeability when placed but in the long term may be less permeable than the clay barrier layer due to its resistance to desiccation Alternative 7 affords the highest degree of long-term effectiveness and permanence

6 3 2 Short-Term Effectiveness

None of the alternatives present a significant danger to the community construction workers or the environment during construction Alternatives 5 7 and 9 may be differentiated in terms of dust generation and potential for erosion due to the varving quantities of soil Alternative 5 has the greatest short-term effectiveness because it has only 6 inches or 16,393 vd^3 of bedding soil Alternative 7 has 12 inches or 32 787 yd^3 of low-permeability soil Alternative 9 has 24 inches or 65 573 yd^3 of compacted clay In addition to having the greatest quantity of soil, the compacted clay in Alternative 9 requires the most labor during construction and therefore has the potential for the most dust generation of the three alternatives

6 3 3 Implementability

The three alternatives are compared in terms of technical feasibility administrative feasibility and availability of services and materials

6 3 3 1 Technical Feasibility

Ability to Construct and Operate

Alternative 5 would be simplest to construct Repairs are most easily made to Alternatives 5 and 7 because clay materials do not have to be prepared or maintained onsite If in the future, new clay borrow sources are selected to repair the clay layer in Alternative 9 it may be necessary to complete a new test fill and chemical compatibility tests for that clay material

The clay barrier in Alternative 9 is more difficult to construct than the low-permeability soil layer or the bedding soil layer due to required moisture conditioning and maintenance of exposed clay during construction The clay typically is moisture conditioned and allowed to cure on stockpiles in advance of scheduled placement in the cell Care must be taken to protect the clay from moisture loss during dry periods or over moisturizing during rainy periods After the clay is placed and before it is covered with the geomembrane, similar steps must be taken to prevent desiccation, over moisturizing or erosion

Reliability of Technology

All three alternatives have an FMC barrier layer that has proven reliable in field and laboratory testing. Alternative 7 includes a low-permeability soil layer and would be most reliable Alternative 9 provides a second barrier for added reliability but the clay is subject to desiccation The 2-foot-thick clay barrier in Alternative 9 may tolerate more differential settlement than the other alternatives However, due to the volume of general fill to be placed over the waste as part of the grading plan, the potential for localized differential settlement is limited

Ease of Additional Remediation

In the event that additional action is required, it is unlikely that the cap will interfere However if action must be taken below the cap, Alternative 5 is simplest to repair and Alternative 9 the most difficult to repair

Monitoring

Monitoring the condition of the cover will be the same for Alternatives 5 7 and 9 Details of inspections and maintenance are presented in the OU 7 Post-Closure Plan (Section 8 2 2)

6 3 3 2 *Administrative Feasibility*

All alternatives meet RAOs. However, proposed design alternatives that differ from suggested EPA guidance may undergo more scrutiny during technical review (EPA 1989c, EPA 1989d) Alternative 9, which most closely follows prescribed EPA guidance (EPA 1989e), would likely garner the most support Alternative 7, which includes an FMC-barrier layer with a low-permeability soil, is equally protective and is significantly less expensive

6 3 3 3 *Availability of Services and Materials*

Alternatives 5 7, and 9 employ standard industry materials, equipment, and skilled labor types Onsite clay borrow sources have not been located, however clay materials are available from a local offsite supplier (EG&G 1994d).

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6 3 4 Cost

Table 6-3 summarizes the detailed cost estimate The total present worth costs for the alternatives are as follows

Alternative 1	No Action	$0
Alternative 5	Single-Barrier FMC Cover	$9 469 100
Alternative 7	Single-Barrier FMC with Low-Permeability Soil Cover	$10 149 000
Alternative 9	Composite-Barrier FMC and Clay Cover	$12 103 600

The O&M costs are the same for all alternatives because inspection maintenance and monitoring of the cover are the same for all capping alternatives Periodic inspections will minimize repairs to the barrier layer Capital costs are different for each alternative lowest for Alternative 5 and highest for Alternative 9 As a result of the difference in capital costs total present worth costs are different for each alternative The total present worth cost for Alternative 7 is 7 percent higher than the cost for Alternative 5 The total present worth cost for Alternative 9 is 22 percent higher than the cost for Alternative 5 and 16 percent higher than the cost for Alternative 7

6 4 Summary of Comparative Analysis

Table 6-4 summarizes the detailed analysis of alternatives Each of the seven CERCLA criteria is weighted from 0 to 20 based on its relative importance at OU 7 Overall protection of human health and the environment is the most important criterion Compliance with ARARs long-term effectiveness and permanence reduction in toxicity mobility and volume and cost are next and are equally important criteria They are followed by implementability and short-term effectiveness Short-term effectiveness is the least important of the balancing criteria because OU 7 is located within a large buffer zone and implementation of the remedial action will cause few adverse impacts to the community or the environment Each of the three alternatives is then ranked based on performance for each criteria Weighting factors are multiplied by the rating to reach a weighted score The weighted scores are summed for each alternative Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover has the highest total score and is proposed as the preferred IM/IRA for OU 7

Table 6-1
Evaluation Criteria for the Detailed Analysis of Alternatives

Nine CERCLA Criteria	Assessment Components	Discussion of Evaluation
Threshold Criteria		
Overall Protection of Human Health and the Environment	Long term effectiveness and permanence short term effectiveness and compliance with ARARs	Focused risk evaluation ARARs engineering judgment
Compliance with ARARs	Chemical Specific ARARs	Federal and state standards
	Location Specific ARARs	CWA 40 CFR 6 3 02[a] (wetlands) Endangered Species Act
	Action Specific ARARs	RCRA and CHWA closure air emission delisting discharge and groundwater monitoring requirements
	Compliance with other criteria advisories and guidance	EPA guidance on RCRA Subtitle C caps
Primary Balancing Criteria		
Long Term Effectiveness and Permanence	Magnitude of residual risk	Engineering judgment HELP analysis erosion analysis settlement analysis
	Adequacy and reliability of controls	
Reduction of Toxicity Mobility and Volume through Treatment	Treatment process used and materials treated	Treatment of landfill waste leachate and groundwater are not part of the presumptive remedy and therefore this criterion does not apply criterion is used in reference to reduction in volume of landfill leachate
	Amount of hazardous materials destroyed or treated	
	Degree of expected reduction in toxicity mobility, and volume	
	Degree to which treatment is irreversible	
	Type and quantity of residuals remaining after treatment	
Short Term Effectiveness	Protection of community during implementation of remedial actions	Engineering judgment air-quality modeling gas emission modeling
	Protection of workers during implementation of remedial actions	
	Environmental impacts during implementation of remedial actions	
	Time until remedial action objectives are achieved	
Implementability	Technical feasibility	Construction and operation reliability monitoring effectiveness and ease of additional remedial action
	Administrative feasibility	Regulatory approval and coordination with other agencies
	Availability of services and materials	Offsite treatment storage and disposal capacity equipment and specialists and prospective technologies
Cost	Capital costs (direct and indirect)	Detailed cost estimates
	Annual O&M costs	
	Total present worth costs	

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Table 6-1
Evaluation Criteria for the Detailed Analysis of Alternatives

Modifying Criteria		
Regulatory Agency Acceptance	CPHE, EPA, and Natural Resource Trustee Approval	Engineering judgment, risk management, and political issues
Community Acceptance	Public approval	Personal issues and concerns

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Table 6-2
Quantities of Material for Landfill Cover Construction

Landfill Cover Material	Volume (yd^3)	Area (ft^2)
Fill	131,400	
Vegetative	82,000	
Top Soil	16,400	
Soil Bedding	16,400	
Low Permeability	32,800	
Clay	65,600	
GCL		885,240
FMC		885,240
GCL/FMC		885,240
Geocomposite		
Drainage Layer		885,240
Gas Collection		885,240

Definitions

ft^2 square feet
yd^3 cubic yards
GCL geosynthetic clay liner
FMC flexible membrane cover

Table 6-3
Detailed Cost Estimate Summary

1	$0	$0	$0	$0
5	$55,000	$1,079,000	$8,390,100	$9,469,100
7	$55,000	$1,079,000	$9,070,000	$10,149,000
9	$55,000	$1,079,000	$11,024,600	$12,103,600

Definitions

O&M Operation and Maintenance

Table 6-4
Summary of Comparative Analysis

	Weighting Factor	Alternative 5 Single-Barrier FMC		Alternative 7 Single-Barrier FMC with Low-Permeability Soil		Alternate 9 Composite-Barrier FMC and Clay	
		Rating*	Weighted Score	Rating*	Weighted Score	Rating*	Weighted Score
Threshold Criteria							
Overall Protectiveness	20	2	40	3	60	3	60
Compliance with ARARs	15	2	30	2	30	3	45
Balancing Criteria							
Long Term Effectiveness and Permanence	15	1	15	3	45	2	30
Reduction in Toxicity, Mobility, and Volume	15	1	15	2	30	3	45
Short Term Effectiveness	5	3	15	2	10	1	5
Implementability	10	3	30	2	20	1	15
Cost	15	3	45	2	30	1	15
Total			190		225		215

Rating

1 Poor
2 Moderate
3 Good

Definitions

FMC flexible membrane cover
ARAR applicable or relevant and appropriate requirements

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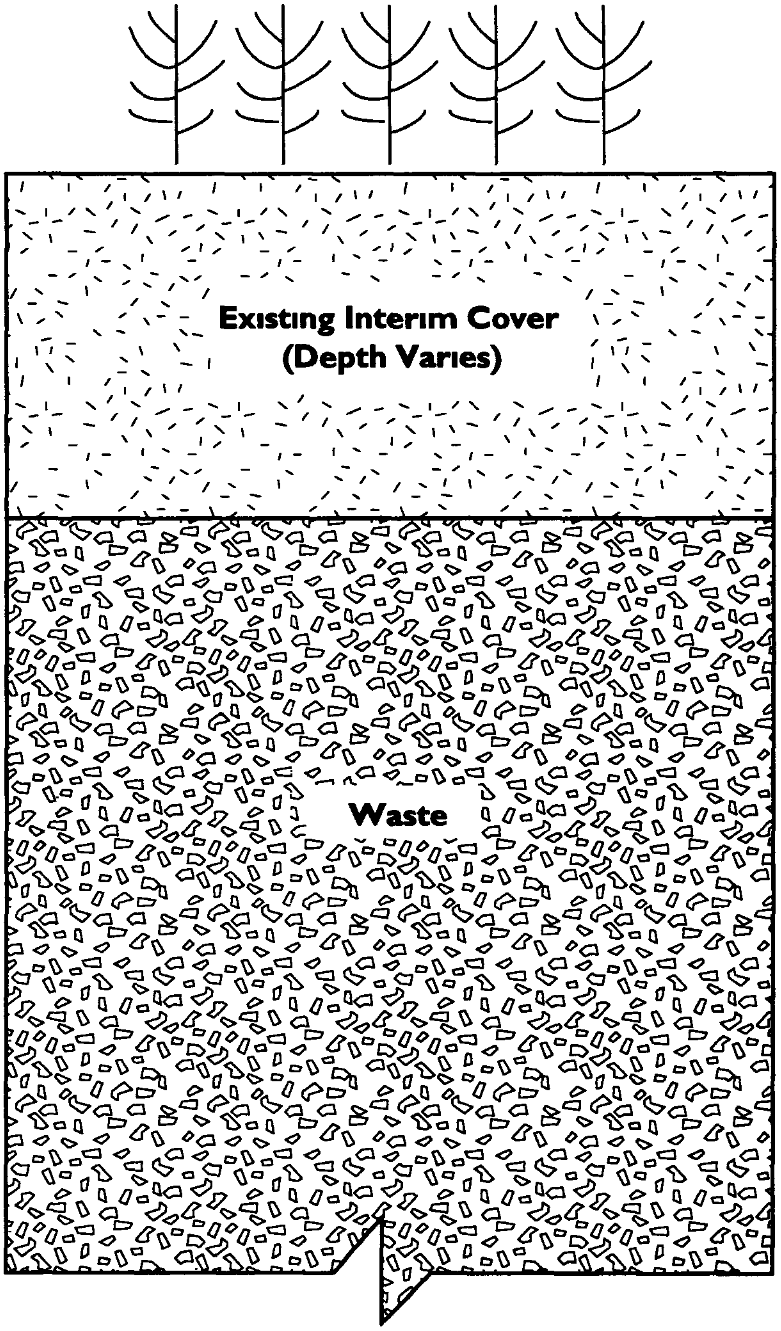

U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Alternative 1 No Action

Phase I IM/IRA DD

Operable Unit No 7

July 1995

Figure 6 1

G95ESIM/IRA DD OU7/Cover Alt No Action 2510 ill

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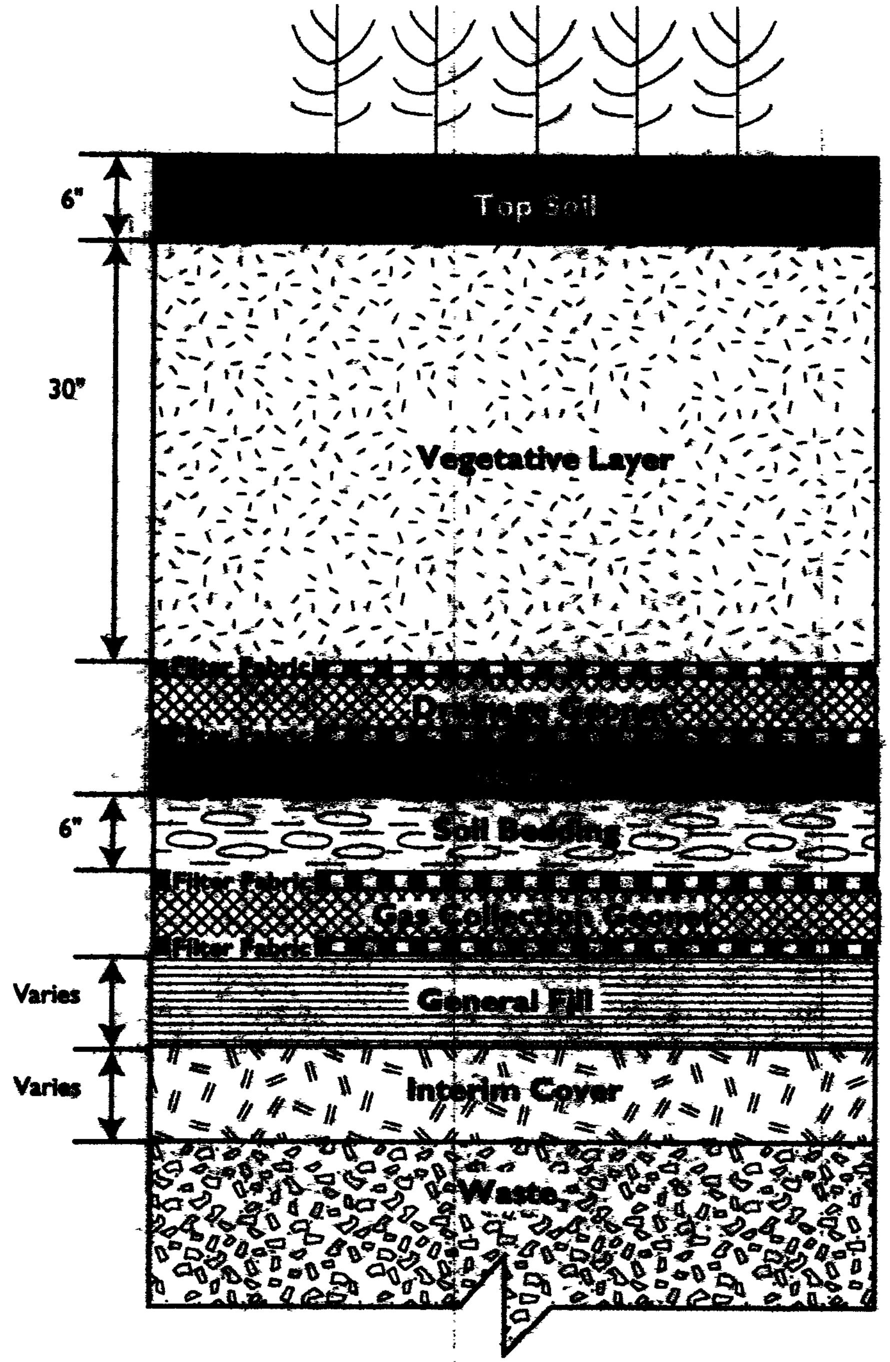

U.S Department of Energy
Rocky Flats Environmental Technology Site, Golden, Colorado

Alternative 5: Single-Barrier FMC Cover Cross Section

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 6-2

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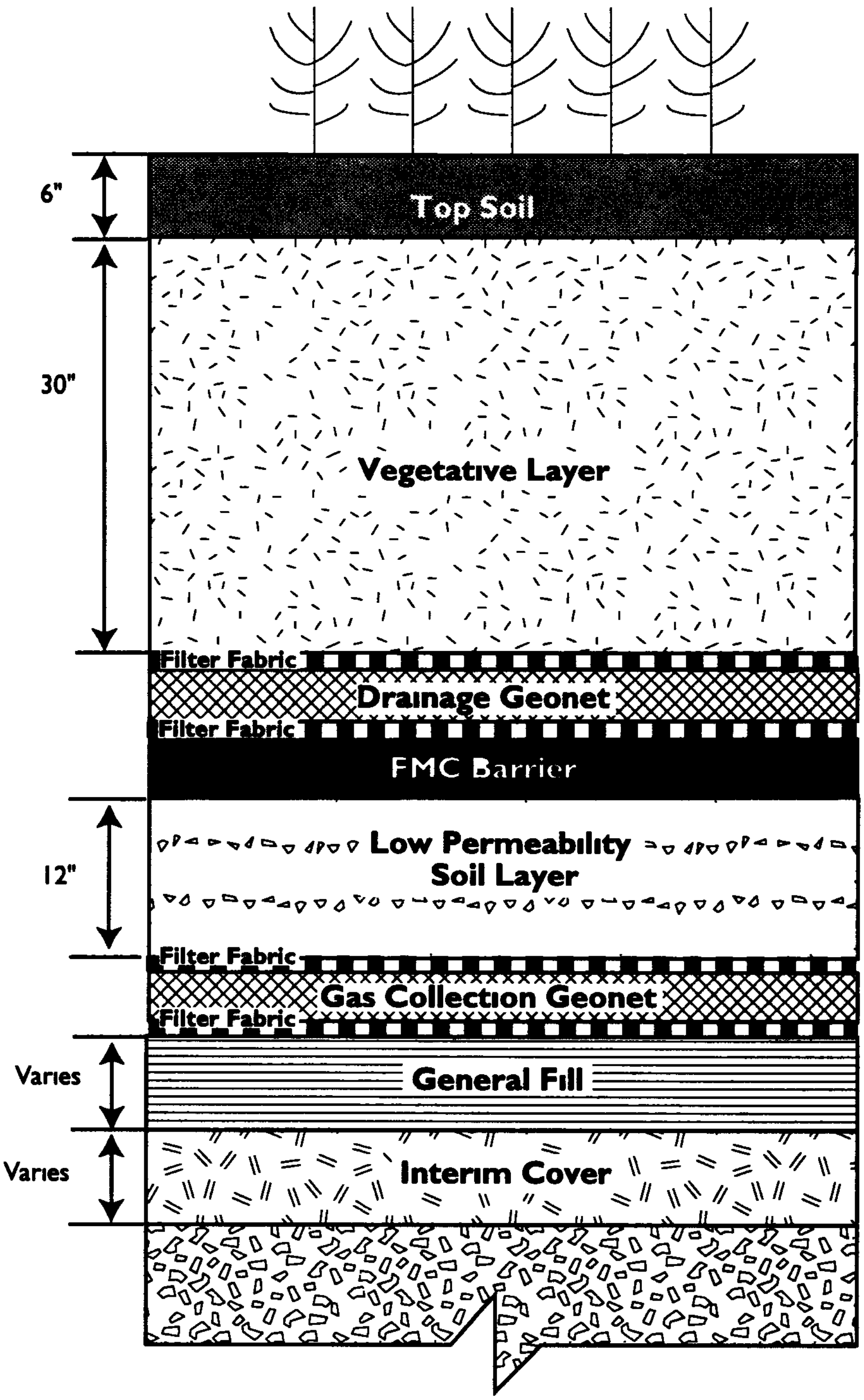

U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Alternative 7 Single-Barrier FMC & Low-Permeability Soil Cover Cross Section

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 6-3

G95\ESIM/IRA DD OU7/Cov Alt #7 2510.ill

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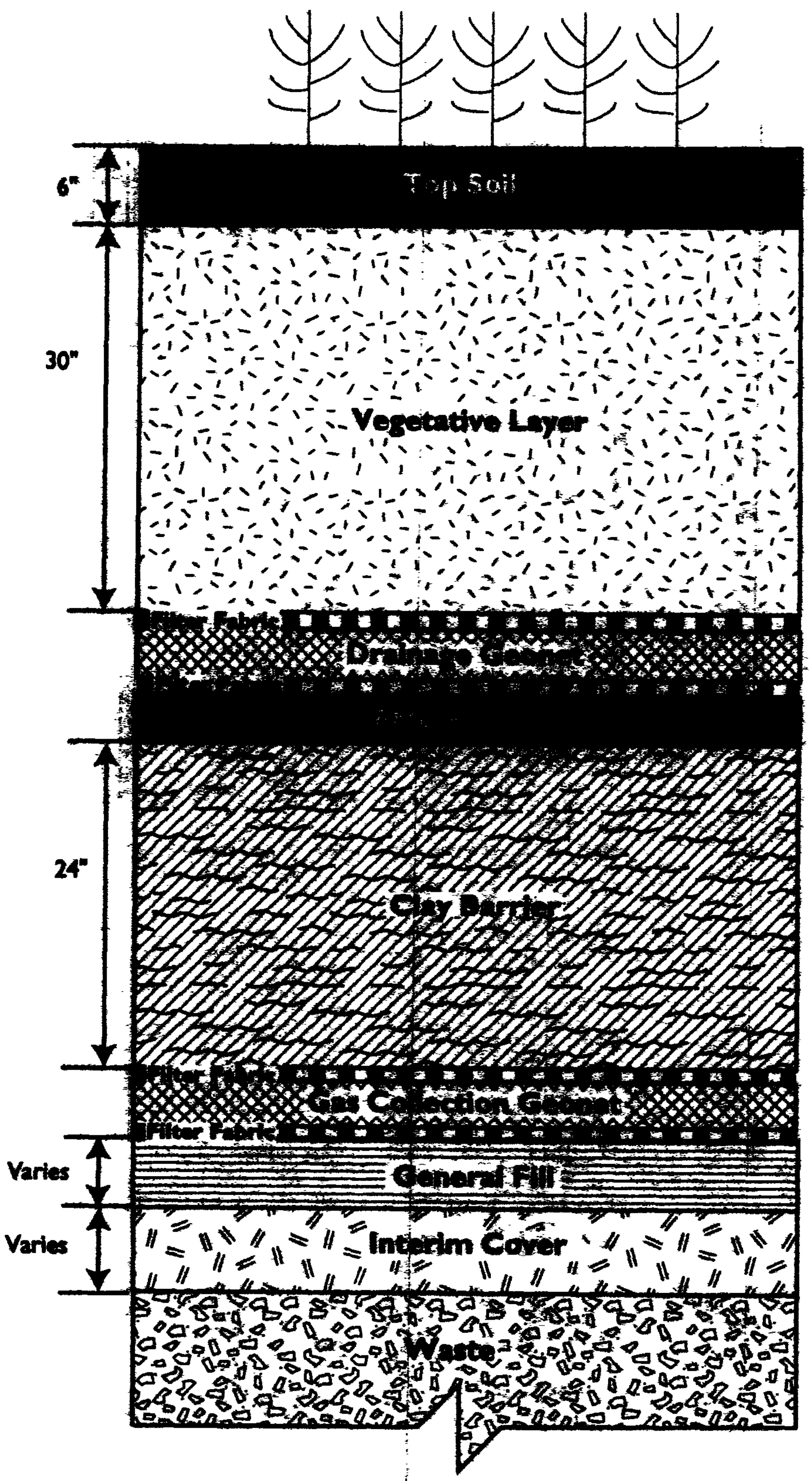

U.S. Department of Energy
Rocky Flats Environmental Technology Site Golden, Colorado

Alternative 9: Composite-Barrier FMC and Clay Cover Cross Section

Phase I IM/IRA DD	Operable Unit No 7
July 1995	Figure 6-4

G95ES\M\IRA DD OU 7/Cover Alt #9-2510.ill

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7 Recommended Alternative

The detailed analysis of alternatives and the comparative analysis presented in Section 6 highlight the relative advantages and disadvantages of each alternative to identify key tradeoffs Tradeoffs coupled with risk management decisions serve as the basis for selection of the preferred alternative The recommended alternative is Alternative 7 a single-barrier cap with FMC and low-permeability soil

A draft Proposed Plan has been developed around selection of the recommended alternative and is presented as an attachment to this report The Phase I IM/IRA DD along with the Proposed Plan will be submitted for public review and comment in December 1995 Results of the detailed analysis support the final selection of a remedial action and the foundation for the CAD/ROD for OU 7

The objective of this section is to describe the components of the recommended action in detail and to document how the final RAOs ARARs and other regulatory criteria are met Design analyses have been completed to support the selection of the major design components that are described in this section Additional design analyses will be completed as part of the Title II design

7 1 Description

The recommended alternative for OU 7 consists of a single-barrier cover over the Present Landfill (IHSS 114) Inactive Hazardous Waste Storage Area (IHSS 203) and asbestos-disposal areas and institutional controls to prevent unauthorized access It is assumed that the slurry wall maintenance action (Section 1 3 2), scheduled for construction in fiscal year 1996 is complete The slurry wall is essential to reducing groundwater inflow and leachate generation

The cover consists of the following layers

- 36-inch vegetative-soil layer
- Geocomposite lateral-drainage layer (geonet and filter fabric)
- FMC barrier layer
- 12-inch low-permeability soil layer
- Geocomposite gas-collection layer and venting system (geonet and filter fabric)
- Grading fill

This cover section is shown in Figure 7-1 The presence of the low-permeability soil gives the cover system some of the benefits of a composite cover without the rigorous installation requirements costs and potential for desiccation of a full clay layer

The conceptual site model for the source area shown in Figure 3-4 indicates that the exposure points are soil, waste, and dust. The containment presumptive remedy eliminates these exposure points The cap covers an area of approximately 20 acres most of which encompasses the landfill One-third of the East Landfill Pond and adjacent wetlands area is also covered by the cap as a result of the general fill needed to achieve design grades

Based on Figure 3-6 there are two potential exposure points for leachate seep water and groundwater Before closure, leachate is intercepted at the seep and treated using a passive system as a separate accelerated action for OU 7 Potential exposure to leachate after closure is addressed by the presumptive remedy for source containment The landfill cap covers the seep and thus eliminates exposure to the seep A gravel blanket or French drain beneath the general fill prevents leachate from building up and creating a seep in the new cap The groundwater pathway is already incomplete

Based on the screening-level risk evaluation and the comparison to MACs for delisting presented in Section 3, the leachate is nonhazardous, does not pose a threat to human health, and therefore should be delisted After the leachate is delisted, it is no longer subject to CHWA and RCRA Subtitle C hazardous waste regulations

The landfill cap eliminates infiltration of approximately 99 999 percent of the precipitation, which reduces leachate generation and migration and contaminant loading to groundwater In addition, the proposed slurry wall eliminates 93 percent of the groundwater inflow as discussed in Section 2 3 Leachate control for the landfill exceeds regulatory requirements Under 40 CFR Parts 265 118 and 265 310(b)(2) existing units at interim status landfills are not required to have leachate collection and removal systems and are not required to manage leachate during the post-closure period (EPA 1987a)

Surface water in the East Landfill Pond does not require remediation because it does not pose a risk to human or ecological receptors The pond and the dam currently act as barriers to groundwater flow and contaminant migration and they remain in place and continue to impede flow after landfill closure

Groundwater downgradient of the landfill does not require remediation Potential exposure pathways associated with UHSU groundwater (Figure 3-10) are incomplete because there are no plans for future development of groundwater for any use at OU 7 One-third of the pond area is covered by the landfill cap, which reduces the amount of recharge to groundwater in this area The pond and the dam impede the flow of groundwater to the east in No Name Gulch

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7 2 Design Requirements

Design of the landfill cover must consider all RAOs ARARs and requirements set forth by 6 CCR 1007-3 Part 265 310 The regulatory requirements are broadly based and allow for individually tailored designs to meet site-specific conditions such as climate topography and waste characteristics This section describes how the RAOs ARARs and guidance requirements are met for the recommended alternative

7 2 1 Compliance with RAOs

In order to meet the overall objective of protecting human health and the environment RAOs developed in Section 3 must be met All of the RAOs except one (remediate wetland areas) are for presumptive remedy components of OU 7 and are specified in EPA guidance (EPA 1993a) Media-specific RAOs for other components were developed using exposure pathways, risk and compliance with ARARs With the exception of remediating wetland areas media-specific RAOs were eliminated from the final response action because (1) there is no risk to the potential receptor (2) analytes do not exceed ARARs or (3) the exposure pathway is incomplete The final RAOs for OU 7 are as follows

- Prevent direct contact with landfill contents
- Minimize infiltration and resulting contaminant leaching to groundwater
- Control surface-water run-off and erosion
- Control landfill gas (treat as needed)
- Remediate wetland areas (as needed)

The single-barrier cover with FMC and low-permeability soil addresses each RAO

Direct contact with soil or waste material in the Present Landfill Inactive Hazardous Waste Storage Area and asbestos-disposal areas is prevented by the landfill cover Because the continued effectiveness of the containment remedy depends on the integrity of the containment system, institutional controls are necessary to prevent access to the site A deed notation under CHWA limits future development of the landfill area

The cover minimizes infiltration and resulting contaminant leaching Contaminant leaching is decreased by reducing infiltration of precipitation through the landfill cover and controlling surface-water flow by diverting it around the landfill In addition the proposed slurry wall maintenance action reduces contaminant leaching by controlling groundwater inflow into the landfill area

Grading of the landfill surface requires minimum slopes to provide adequate surface-water drainage after settlement Promoting drainage minimizes erosion or abrasion of

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the cover The vegetative-cover layer provides suitable media for the growth of vegetation and reduces erosion Grading of the landfill surface forces surface water to drain to the perimeter of the landfill, where it is collected in the perimeter surface-water drainage ditch and is routed around the landfill and past the East Landfill Pond dam

Exposure to landfill gas is controlled by a gas-collection system The gas-collection layer collects migrating gases across the landfill surface and transmits them to selected discharge points Gas collected in this layer flows to vent pipes or gravel columns and vents to the surface through the cover The system has the capability for adding gas treatment as needed

Lateral migration of landfill gas away form the source is prevented by the existing impermeable barrier and the proposed slurry wall

Acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project is used to mitigate the loss of wetland areas that fall under the landfill cover and injury to surrounding wetland areas, pending final approval Injury to Preble's meadow jumping mouse habitat is mitigated as needed

7 2 2 Compliance with ARARs

In order to meet the overall objective of protecting human health and the environment pursuant to the IAG (DOE 1991b), the recommended alternative for OU 7 must address all ARARs developed in Section 3 Compliance with applicable chemical-specific location-specific, and action-specific ARARs is addressed in the following sections

7 2 2 1 Chemical-Specific ARARs

The recommended alternative meets all but one chemical-specific ARAR for surface water and all but three chemical-specific ARARs for groundwater (Section 3 4 1)

Surface water in the East Landfill Pond exceeds CWQ standards for manganese However, manganese is a naturally occurring element common in the geologic materials surrounding the pond and in pond sediment Discharge of leachate into the pond may have resulted in mobilization of manganese from the pond sediments It is expected that concentrations of manganese and other PCOCs will decrease in response to reductions in leachate generation and migration resulting from the landfill cap Based on the results of the focused risk assessment, there is no associated risk to human or ecological receptors from pond water

Groundwater downgradient of the landfill exceeds SDWA MCLs for nitrate/nitrite, CWQ standards for sulfate, and the PQL for selenium. Flow modeling indicates that the East Landfill Pond dam significantly reduces groundwater flow and attenuates contaminants As a result contaminant migration down No Name Gulch is expected to be minimal Particle tracking and contaminant transport modeling indicate that concentrations of nitrate/nitrite selenium and sulfate are not expected to exceed ARARs at the compliance wells downgradient of the East Landfill Pond dam On the basis of the focused risk assessment carcinogenic risk from ingestion of UHSU groundwater is within the acceptable risk range (1E-05 in groundwater in the vicinity of the pond and below 1E-06 in groundwater downgradient of the dam) however the noncarcinogenic risk is above the acceptable risk or HI of 1 (HI = 3) in groundwater in the vicinity of the pond The primary contributor to noncarcinogenic risk is selenium UHSU groundwater in wells 4287 52894 and 53194 meets ARARs

7 2 2 2 *Location-Specific ARARs*

Location-specific ARARs are met Construction of the recommended alternative is conducted in a manner that minimizes destruction loss or degradation of wetlands (40 CFR 6 302[a]) and Preble s meadow jumping mouse habitat (CRS 33-2-101) A wetlands assessment is included in this section of the report in accordance with 40 CFR Part 6 and with wetlands/floodplains environmental review requirements under 10 CFR Part 1022 Draining water from the pond to dry out the area before construction is considered dredging and triggers substantive requirements for a permit under Section 404 of the CWA

<u>Wetlands Assessment</u>

Wetlands Effects

Placement of fill to achieve design grades covers approximately 1 1 acres of wetlands including submerged and emergent species It was assumed that another 10 percent or 0 1 acre may be injured during placement of the various cover layers at the east end of the landfill Because two-thirds of the East Landfill Pond and wetland areas remain in place after closure the proposed activities have only negligible positive or negative direct or indirect short-term or long-term effects on the survival, quality, or natural and beneficial values of the wetlands

Alternatives

Three other alternatives were evaluated in the detailed analysis of alternatives Two of the alternatives Alternative 5 and Alternative 9 would have adverse impacts to wetland areas very similar to those of the recommended alternative The other alternative Alternative 1 No Action, would result in no adverse impacts to wetlands areas However the no-action alternative would not meet applicable state and federal water-quality standards nor would it meet closure requirements (6 CCR 1007-3 Part

310) and post-closure maintenance and monitoring requirements (6 CCR 1007-3 Part 265 117 and Part 265.228).

Mitigation of Wetland Impacts

Acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project is used to mitigate loss or injury to wetland areas, pending final approval of the project. Wetlands mitigation is based on a 3 1 mitigation to injury ratio As a result, 3 6 acres of wetlands are mitigated for closure of OU 7

Preble's Meadow Jumping Mouse Habitat Mitigation

It was assumed that 7 26 acres of Preble's meadow jumping mouse habitat are injured during placement of fill, grading and placement of the cover layers. Preble's meadow jumping mouse habitat mitigation is based on a 1 1 mitigation to injury ratio An estimated 7 26 acres of Preble's meadow jumping mouse habitat may require mitigation

7 2 2 3 *Action-Specific ARARs*

Action-specific ARARs include requirements for closure, air emissions, groundwater monitoring, and delisting leachate.

Closure Requirements

Because hazardous waste was disposed in the landfill after 1980, the cover is designed to meet RCRA Subtitle C design requirements The proposed action must meet the following requirements for landfill closure under CHWA (6 CCR 1007-3 Part 265 310)

- Provide long-term minimization of migration of liquids through the closed landfill
- Function with minimum maintenance
- Promote drainage and minimize erosion or abrasion of the cover
- Accommodate settling and subsidence to maintain the integrity of the cover
- Have a permeability less than or equal to the permeability of any bottom-liner system or natural subsoil present

The cap is designed with a multi-layer system that minimizes migration of liquids through the landfill over the long term The vegetative layer promotes evaporation and transpiration, the drainage layer provides pathways to divert water off the cover, and the barrier layer limits infiltration to the waste HELP modeling indicates that 99 999 percent of the precipitation on the landfill is diverted as discussed in Section 7 3 3

Future maintenance is minimized by designing for post-settlement slopes of 3 to 5 percent to minimize damage to the cover from surface water Settlement issues are described further in Section 7 3 1 1 Institutional controls are used to limit access and control use to protect the integrity of the cap The vegetative cover is planted with native species that require low maintenance

Final slopes are selected to promote drainage and minimize erosion of the cover As described in Section 7 3 1 2 the maximum erosion rate does not exceed guidance requirements (EPA 1989d EPA 1989e) The existing surface-water drainage ditch is modified as necessary to accommodate a 100-year 24-hour storm (Section 7 3 2)

The grading plan accommodates settling and subsidence to safeguard cover integrity As described in Section 7 3 1 settlement has been analyzed and design slopes of 7 percent ensure post-settlement slopes that meet guidance requirements (Table 7-1) Unstable areas have been identified along the west end of the pond These areas are buttressed and subsurface drainage is incorporated into the design

The permeability of the FMC barrier layer is 1E-13 cm/sec which is less than the permeability of natural subsoils at the landfill (1E-06 to 1E-07 cm/sec)

EPA has issued various guidance documents on the design and construction of cover systems for hazardous waste facilities These documents, along with state and federal regulations for closure are as follows

- CWHA Hazardous Waste Regulation 6 CCR 1007-3 Colorado Department of Health, August 1992
- Title 40 - Code of Federal Regulations (40 CFR) Part 265
- U S Environmental Protection Agency Technical Guidance Document Covers for Uncontrolled Hazardous Waste Sites EPA/540/2-85-002 September (EPA 1985)
- U S Environmental Protection Agency Draft Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments - Design Construction and Operations EPA/530-SW-85-014 April (EPA 1987b)
- U S Environmental Protection Agency Technical Guidance Document Final Covers on Hazardous Waste and Surface Impoundments EPA/530-SW-89-047 July (EPA 1989d)

- U S Environmental Protection Agency Technical Guidance Document Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182, September (EPA 1993c)

Table 7-1 provides a summary of EPA guidance criteria for design of landfill cover systems, which addresses the vegetative cover, drainage layer, and barrier layers Table 7-2 describes how individual design components of the recommended alternative address closure requirements and EPA guidance Because the landfill waste remains in place, the post-closure requirements of 6 CCR 1007-3 Parts 265 117 through 265 120 apply Details of the 30-year post-closure care period are presented in the OU 7 Post-Closure Plan in Section 8

Air Emission Requirements

Closure of the landfill at OU 7 requires an APEN, a construction permit, development of a fugitive emission control plan, and implementation of standard dust-control procedures during construction The existing Plan for Prevention of Contaminant Dispersion for Rocky Flats (DOE 1992c) addresses the requirement for development of a fugitive emission control plan Periodic watering during construction addresses the requirement for implementation of standard dust-control procedures and can reduce dust emissions by up to 50 percent Specific controls for gas emissions from the landfill are not expected to be required based on estimated emission rates of NMOCs (Appendix I) Due to potential future changes in gas emissions resulting from construction of the proposed slurry wall maintenance action and the final cover, it is proposed that the landfill gas be monitored and technology for treatment added if needed Post-closure gas monitoring is described in the OU 7 Post-Closure Plan (Section 8 2)

Groundwater Monitoring Requirements

6 CCR 1007-3 Subpart F states that groundwater monitoring is required for all landfills At minimum, one hydraulically upgradient well and three downgradient wells are required. Well 70393, located due west of the landfill near the headwaters of the former drainage is proposed as the upgradient well to provide background data Three wells, 4287, 52894, and 53194, located downgradient of the landfill in the No Name Gulch drainage beyond the area where groundwater flow in surficial materials is impeded by the dam, are proposed as the downgradient monitoring wells These locations will ensure that potential contaminants are detected if they migrate away from the landfill and provide information regarding improvement or degradation of groundwater quality

Groundwater monitoring continues during closure under the existing sitewide groundwater-monitoring program A streamlined groundwater-monitoring program is

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proposed for the 30-year post-closure care period Two categories of sampling and analysis are required Contamination parameters which include pH specific conductance TOC and TOX are required semiannually whereas groundwater quality parameters which include chloride iron manganese phenols sodium and sulfate are at a minimum required annually

Delisting Requirements

Alternative 7 meets MACs for delisting leachate under 40 CFR 260 20 Under the presumptive remedy it is proposed that the leachate, which is considered F039 RCRA-listed waste contained in groundwater be delisted Based on the screening-level risk evaluation and the comparison to MACs for delisting presented in Section 3 the leachate is nonhazardous does not pose a threat to human health and therefore should be delisted After the leachate is delisted it is no longer subject to CHWA and RCRA Subtitle C hazardous waste regulations

7 3 Conceptual Design

The landfill cover extends over the limits of the Present Landfill (IHSS 114), Inactive Hazardous Waste Storage Area (IHSS 203) and the north and south asbestos-disposal areas The existing topography and surface features are shown on Figure 7-2 The limits of the cover are shown on Figure 7-3 To construct the cover over these areas and maintain minimum slopes the general fill extends beyond the limits of the cover in some locations

The conceptual design incorporates the proposed grading plan, settlement soil erosion buttressing requirements general fill surface-water control cover section seepage control, gas control ancillary facilities and costs It is assumed that the slurry wall maintenance action (Section 1 3 2) is completed prior to construction of the cover

7 3 1 Proposed Grading Plan

The existing landfill operations plan for OU 7 envisions mounding waste to 6-percent slopes in the center of the landfill to provide surface-water drainage to the perimeter of the waste before closure However, given the current and projected waste inflow rates the waste does not reach these design grades before closure of the facility in early 1997 Therefore a large volume of general fill is required to achieve grades that drain surface water off of the facility and meet regulatory requirements

Figure 7-3 shows the conceptual grading plan for OU 7 Figures 7-4 and 7-5 are cross sections through the landfill that show the extent of the general fill The grading plan incorporates a 7-percent surface grade across the majority of the landfill that drains to the perimeter Along the east slope of the landfill the grade increases to approximately

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20 percent Based on this plan, a total of approximately 131,400 yd^3 of fill material is required to achieve the design grades

7 3 1 1 Settlement

The 7-percent surface grade is established based on the EPA guidance criteria of 3- to 5-percent minimum post-closure surface grades and the expected amount of surface settlement from placement of the general fill and decomposition of the waste

Settlements at representative points on the landfill surface were estimated using a simple percent of thickness assessment, Sowers method, Gibson and Lo method, and power creep law Details of the settlement analysis calculations are presented in Appendix F These methods yielded maximum settlements ranging from 2 9 to 5 5 feet in areas where the waste fill is thickest The change in surface elevations resulting from these settlements was computed, and the resulting surface slopes remained within the recommended 3- to 5-percent range

7 3 1 2 Soil Erosion

Grasses and topsoil indigenous to Rocky Flats are used for the vegetative cover Grasses include prairie grass, wheat grass, and green needle grass It is expected that topsoil from onsite sources of the Flatirons soil formation can be amended with fertilizers to form a suitable substrate to establish cover vegetation

Erosion analyses using the Flatirons as a base, typical Rocky Flats site climatic information, and the design topography indicate that the 20-percent slopes surrounding the East Landfill Pond yield soil erosion rates of 1.8 tons per acre per year The 7-percent slopes yield soil erosion rates of 0 5 tons per acre per year after vegetation is established These soil erosion rates are less than the maximum allowable value of 2 tons per acre per year recommended by EPA guidance (EPA 1989d) Assumptions, methodologies, and erosion calculations for annual soil loss are presented in Appendix J These erosion rates are not expected to cause higher than normal sedimentation in the pond or perimeter drainage ditches It should be noted that this erosion analysis considered only average vegetation conditions and that a well established vegetative cover reduces the erosion yields significantly

7 3 1 3 Buttress East Side

As previously mentioned (Sections 2 2 and 2.3), the northeast slope of the landfill that extends down to the East Landfill Pond exhibits signs of slumping. Seeps have been observed in this area. Due to the presence of these features, the grading plan has incorporated a large buttress fill in this area. The buttress fill results in 20 to 25 feet of material at the base of the slumps and is sloped at approximately 20 percent In addition, a blanket drain or system of French drains is planned in and around the seep areas to allow drainage if the seep flow continues after closure This system will be designed as part of Title II design It is expected that seep flow will decrease significantly due to the combined effects of the proposed slurry wall and cap Preliminary stability analyses indicate that the effect of placing buttress fill reducing the slope from 33 percent to approximately 20 percent and installation of the subsurface drains results in long-term stability

7 3 1 4 General Fill

The requirements for the general fill material used to achieve design grades are minimal The purpose of the fill is to achieve design grades while minimizing the potential for future settlement Therefore the type of material used does not greatly impact the performance of the cover system The only requirements for the general fill are that it is placed and compacted to form an unyielding subgrade for construction of the cover system and that it is sufficiently permeable to allow vertical migration of gases generated in the waste Based on these requirements almost any type of granular soil is used A low-plasticity soil could also be used provided that some gravel columns are incorporated into the fill to allow gas to migrate to the gas-collection system within the cover section

Based on the performance requirements and to control costs, limited requirements for placing, spreading and compacting this material will be included in the specifications The fill is obtained from nearby borrow sources Several onsite and offsite borrow sources have been evaluated for use at OU 7 in terms of material type, estimated costs and other environmental technical and institutional factors (EG&G 1994d)

7 3 2 Surface-Water Control

The majority of the surface-water run-off is controlled by grading the surface to shed water to the landfill perimeter drainage ditches Surface water in these ditches discharges into No Name Gulch below the East Landfill Pond dam The eastern slope of the landfill cover drains into the pond The central portion of the landfill is mounded and slopes toward the perimeter Slopes are approximately 7 percent Existing surface-water drainage ditches on the north and south side of the landfill are rerouted to accommodate regrading of surface contours in these areas (Figure 7-3) These ditches handle surface-water run-off from the cover as well as intercept the run-on to the landfill from the surrounding area

During final design the volume of run-off from the landfill and run-on to the landfill will be determined to size the drainage ditches around the perimeter of the landfill The design analyses will be conducted to determine the amount of run-off and run-on for a

100-year, 24-hour storm as required by state regulations for hazardous waste landfills (6 CCR 1007-3). The existing ditches are upgraded as required prior to closure

7 3 3 Cover Section

As previously described in Sections 5 and 6, the recommended alternative, Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover, best meets the evaluation criteria considered in the IM/IRA screening process In addition to meeting CERCLA criteria, Alternative 7 is compatible with the cover elements and functions described in previous sections For example, if settlement occurs in the central portion of the landfill, the cover becomes compressed The physical flexibility properties of the soil and geosynthetic material components allow the cover to sustain minor displacements without rupturing Similarly, the geosynthetic materials are flexible when thermal expansion or contraction takes place The local soils and vegetation used in the vegetative layer, which serve to resist erosion and promote evaporation of precipitation, are visually compatible with the surrounding landscape. The cover materials are also adaptable to the penetrations made for the gas-collection system piping Geosynthetic boots designed to restrict infiltration around the pipe penetration are commonly used in landfill cover construction

The individual layers of the recommended alternative, Alternative 7 Single-Barrier FMC with Low-Permeability Soil Cover, are illustrated in Figure 7-1 The components from top down are the vegetative layer, a drainage layer, the FMC barrier, a low-permeability soil layer, the gas-collection layer, and a general fill layer that lies directly on the interim soil cover overlying the waste Each of these components plays an important role in the overall hydrologic performance of this cover system as described in Section 5 1

Groundwater modeling has shown that 60 percent of the leachate is from inflow through the groundwater-intercept system and 40 percent from infiltration The proposed slurry wall addresses the subsurface inflow and the landfill cap addresses infiltration The top soil component and underlying vegetative layer provide a substrate for vegetation development and evapotranspiration of precipitation Water leaving the system in this manner does not contribute to leachate generation HELP analyses indicate that 61 7 percent of the precipitation that falls onto the surface of the cover is removed from the system through evapotranspiration and 0 2 percent through direct run-off

Most of the remainder percolates through the soil and geotextile filter fabric into the geonet drainage layer that lies directly on the FMC Another 38 1 percent of the percolating water is removed from the system via the drainage geonet

Of the surface water that originally entered the system this leaves 0 001 percent which is either stored in the interim cover or waste layer or flows out of the landfill as leachate With the proposed slurry wall diverting upgradient groundwater around the landfill flow and the cover diverting surface water away from the landfill water levels inside the landfill are expected to decrease Eventually the leachate outflow and groundwater baseflow will be reduced substantially

7 3 4 Seepage Control

Previous field investigations at OU 7 have documented seeps at the toe of the eastern slope of the landfill The proposed slurry wall along the north side of the landfill is expected to reduce the amount of groundwater entering the landfill, and therefore may reduce the flow or even stop the flow at the seep A gravel blanket or French drain prevents seep water from building up and creating a seep in the new cap

7 3 5 Gas Control

Gas generation and discharge from the landfill has been well documented (DOE 1994a) The final cover is designed to collect and discharge the gas in a safe and controlled manner The cover section includes a gas-collection layer at the base of the cover section directly on top of the general fill layer Gas is routed to a series of collection pipes or gravel columns that penetrate through the cover at select locations to vent gas to the surface

Lateral migration of landfill gas is prevented by the existing impermeable barrier and the proposed slurry wall

Based on the gas monitoring that has been completed to date an assessment of the requirements for permitting the gas discharge was made and is presented in Appendix I This analysis indicates that gas treatment is not required Due to potential future changes in gas emissions resulting from construction of the proposed slurry wall and final cover, landfill gas will be monitored during the post-closure care period and gas will be treated if needed

7 3 6 Surface-Water Controls

Recharge to the East Landfill Pond is greatly decreased as a result of the proposed slurry wall and landfill cap Water levels in the pond are monitored and water is pumped down as necessary The water is presently pumped to the A-ponds for treatment and discharge under the existing surface-water management plan Over the 30-year post-closure care period other alternatives may be considered

7 3 7 Institutional Controls

A 6-foot-high chain-link fence that entirely surrounds the landfill prohibits access by unauthorized personnel. The fence is located outside the limits of the cover and its construction does not impact the cover. Gates allow access to the cover for maintenance and inspections In addition, the area is identified with signs indicating the nature of the facility and warning the public about the dangers of excavation in the area and a notation is made on the deed No groundwater wells are anticipated at OU 7

7 3 8 Cost Estimate

Detailed written cost estimation must be provided for closure and O&M post-closure care as mandated by 6 CCR 1007-3 Parts 265 142 and 265 144, respectively The cost estimate is based on expenses when hiring a third party and does not include salvage value Cost estimates were developed using the Guidance Manual Cost Estimates for Closure and Post-Closure Plans (Subparts G and H) (EPA 1987a) and the Rocky Flats Plant Cost Estimating Handbook (DOE 1994g) to identify applicable activities to be costed Vendors and site operators were contacted to provide accurate unit costs for each activity Other resources used include the Means Cost Handbook (Means 1994) and previous closure activities Quantities are site specific, developed using engineering judgment and design considerations.

The total present worth for the recommended IM/IRA design is $10,149,000 The cost is higher than average for capping a landfill because a large volume of general fill is needed to achieve design grade Normally, waste material would be accepted until the landfill reached capacity, which would require much less general fill to achieve grade Detailed cost estimates and assumptions are provided in Appendix H

7 4 Title II Design

The Title II design attempts to meet environmental, safety, security, and quality assurance requirements following good engineering and construction practices and simultaneously minimizes project costs The Title II design should include the following information further development of the Conceptual/Title I design, a detailed cost estimate and construction schedule, analysis of health, safety, and environmental impacts, identification of relevant quality verification test plan and permits, a procurement plan, any necessary utility services, and determination of job/work task assessments and training required. The Title II Design Document, which will be submitted for review, will contain a summary of the Title II design, final technical specifications and drawings, design calculations, a construction cost estimate and a CQA plan

Initiation of Title II design will begin with approval of the Phase I IM/IRA DD by CDPHE and EPA A preliminary list of Title II design drawings is provided in Table 7-3 A preliminary list of technical specifications is presented in Table 7-4

7 5 Justification for Recommended Alternative

The recommended alternative for OU 7 consists of a single-barrier cover over the Present Landfill, Inactive Hazardous Waste Storage Area and asbestos-disposal areas and institutional controls to prevent unauthorized access It is assumed that the slurry wall maintenance action is complete

The single-barrier FMC with low-permeability soil cover meets RAOs and location-specific and action-specific ARARs The recommended alternative meets all but one chemical-specific ARAR for surface water and all but three chemical-specific ARARs for groundwater However there is no associated risk to human or ecological receptors from surface water in the East Landfill Pond and potential exposure pathways associated with UHSU groundwater are incomplete UHSU groundwater in downgradient compliance wells 4287 52894 and 53194 meets ARARs

The single-barrier FMC with low-permeability soil cover best meets the evaluation criteria considered in the IM/IRA screening process Alternative 7 is the best alternative for long-term effectiveness and permanence The presence of the low-permeability soil gives the cover system some of the benefits of a composite cover without the rigorous installation requirements costs and potential for desiccation of a full clay liner The physical flexibility properties of the soil and geosynthetic material components allow the cover to sustain minor displacements without rupturing Similarly the geosynthetic materials are flexible when thermal expansion or contraction takes place The FMC barrier has proven reliable in field and laboratory testing The combination of the FMC and the low-permeability soil layer in the recommended alternative is the most reliable technology of all alternatives evaluated

The recommended alternative in conjunction with the proposed slurry wall eliminates 93 percent of the water flowing into the landfill Forty percent of the total water flowing into the landfill is from surface water such as precipitation The cap eliminates 99 999 percent of this flow The remaining 60 percent is subsurface flow and is addressed by the proposed slurry wall

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Table 7-1
Summary of EPA Guidance Criteria for Design of Cover Systems

Component	Design Criteria
Vegetative Cover	Thickness greater than or equal to 2 feet
	Minimal erosion and/or maintenance
	Vegetative root growth not to extend below 2 feet
	Final top slope between 3 to 5 percent after settlement or subsidence Slopes greater than 5 percent not to exceed 2 0 tons/acre erosion (USDA Universal Soil Loss Equation)
	Surface-water drainage system capable of conducting run-off across cover without rills and gullies
Drainage Layer	Thickness greater than or equal to 1 foot
	Saturated hydraulic conductivity greater than or equal to 1E 03 cm/sec
	Bottom slope greater than or equal to 2 percent (after settlement)
	Overlain by graded granular filter or synthetic filter to prevent clogging
	Allow lateral flow and discharge of liquids
Barrier Layer FMC Component	Thickness greater than or equal to 20 mil
	Final upper slope greater than or equal to 2 percent (after settlement)
	Located wholly below the average depth of frost penetration in the area
Barrier Layer Soil Component	Thickness greater than or equal to 2 feet
	Saturate hydraulic conductivity less than or equal to 1E 07 cm/sec
	Installed in 6 inch lifts

Note

The above design components are only recommendations by EPA Alternative designs can be suggested provided that they result in comparable performance of the cover system

Sources

EPA 1989d EPA 1991a

Definitions

USDA U S Department of Agriculture
cm/sec centimeters per second
FMC flexible membrane cover

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Table 7-2
Design Components that Meet Closure ARARs

Regulatory Criteria	[illegible]
6 CCR 1007-3 (Colorado Department of Public Health and Environment) CHWA Hazardous Waste Regulation	
Minimize fluid migration through the closed landfill	Based on HELP modeling, the cover system only allows 0.001 percent of rainfall to infiltrate the waste
Function with minimum maintenance	The grading plan meets minimum recommended surface grades after settlement of the waste, therefore, grading maintenance should be minimized.
Promote drainage and minimize erosion or abrasion of the cover	The grading plan directs surface water off the cover to the perimeter of the landfill. Estimates of erosion off the cover indicate that they are less than EPA recommended levels of 2 tons/acre/year (EPA 1989d).
Accommodate settling so that the integrity of the cover is maintained	The grading plan allows for settlement of the waste. The settlements are expected to put the cover in compression rather than tension, which will protect the cover integrity
Have permeability less than or equal to the permeability of any bottom liner system or material subsoils present	The permeability of the FMC in the cover is 1E-13 cm/sec, which is less than the permeability of the subsoils (1E-06 to 1E-07 cm/sec).
EPA Guidance Documents	
Vegetative Cover Thickness greater than or equal to 2 feet Minimize erosion and/or maintenance Vegetative root depth not to extend below 2 foot depth Final top surface slope between 3 to 5 percent after settlement or subsidence. Slopes greater than 5 percent not to exceed 2 tons/acre/year Surface water drainage system capable of conducting run-off across cover without rills and gullies	The vegetative cover soil is a total of 36-inches thick to provide adequate protection against frost penetration. The vegetation prevents excessive erosion, which minimizes maintenance. The grading plan has been prepared and allows settlement to take place and result in cover slopes that are in the range of 3 to 5 percent. Erosion estimates for the steep slopes on the cover indicate that the erosion is less than 2 tons/acre/year
Drainage Layer Thickness greater than or equal to 1 foot Saturated hydraulic conductivity greater than or equal to 1E-03 cm/sec Bottom slope greater than or equal to 2 percent after settlement Overlain by graded granular filter or synthetic filter to prevent clogging Allow lateral flow and discharge of liquids	The drainage layer consists of a geocomposite drainage layer, which is composed of a geonet sandwiched between two geotextiles. The drainage capacity of the geocomposite exceeds that of a 1-foot granular soil material. The upper geotextile provides a filter for the overlying vegetative soil cover. The lateral drainage layer drains to the perimeter surface-water drainage ditch.

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Table 7-2
Design Components that Meet Closure ARARs

Regulatory Criteria	Design Components that Address Regulatory Criteria
Barrier Layer FMC Component Thickness greater than or equal to 20 mil Final upper slope greater than or equal to 2 percent (after settlement) Located wholly below the average depth of frost	The FMC component has a minimum thickness of 30 mils The final slope of the barrier layer is the same as the surface slope and is expected to be in the range of 3 to 5 percent The FMC is located under the 36 inch vegetative soil layer which is the average depth of frost in the area
Barrier Layer Soil Component Thickness greater than or equal to 2 feet Saturated hydraulic conductivity less than or equal to 1E 07 cm/sec Installed in 6 inch lifts	The barrier soil layer in the proposed cover section is 1 foot thick and consists of a very low plasticity to non plastic soil with a permeability of 1E 05 cm/sec or less The low permeability soil layer is placed directly over the gas collection geocomposite In order to protect the gas collection layer from being damaged the low permeability soil layer is placed in one single lift and compacted The barrier soil layer is the only component in the cover system that deviates from the EPA guidance documents However based on HELP modeling and experience with desiccation cracking of compacted clay covers the proposed low permeability layer is expected to have comparable or better performance than EPA guidance recommendations

Table 7-3
Preliminary List of Drawings for the Title II Design

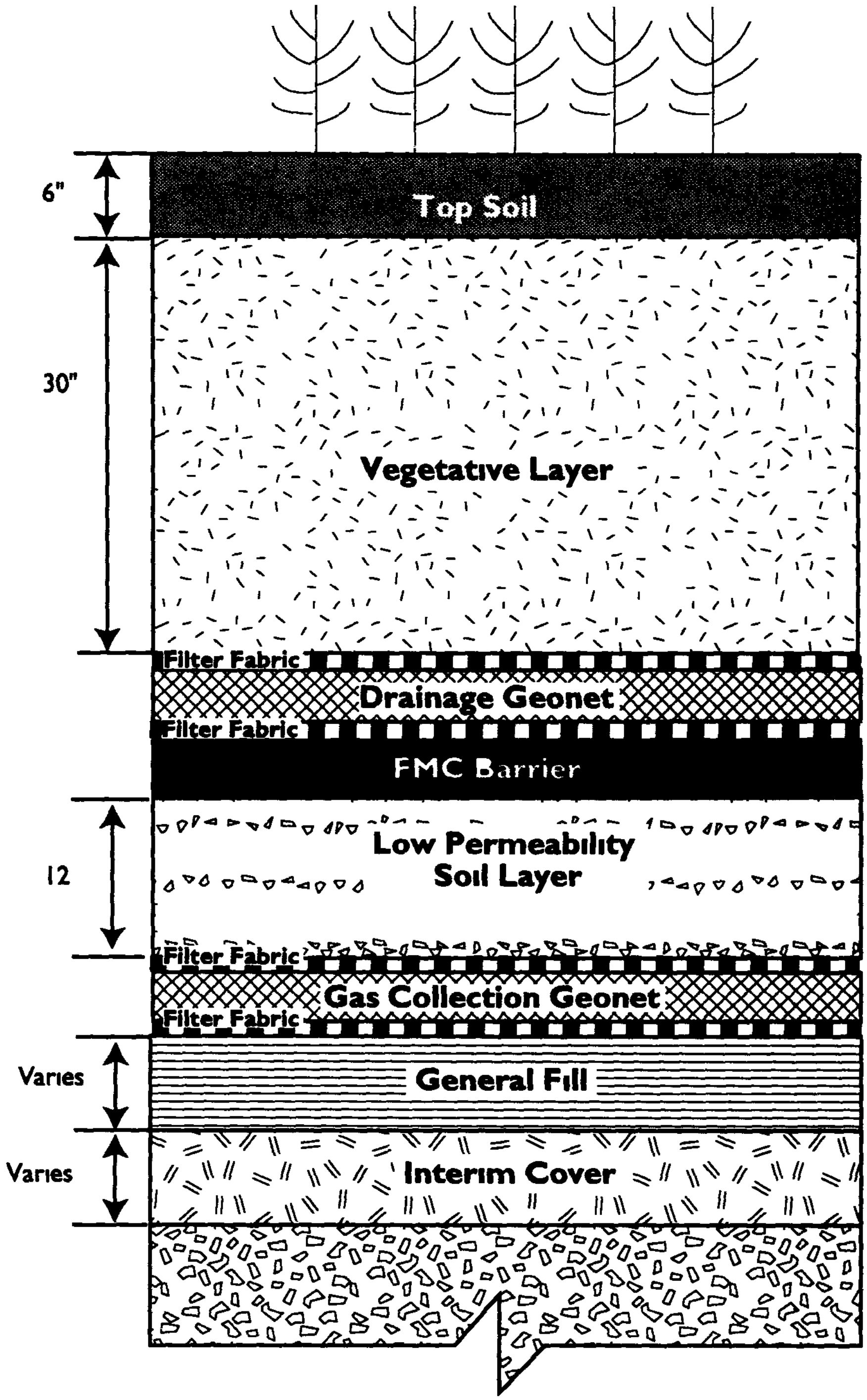
1	Cover Sheet
2	Existing Topography
3	Existing Topography Grid Point Locations
4	Landfill Cover General Arrangement
5	Cover Cross Sections and Details (2 sheets)
6	Cover Section
7	Proposed Filling Plan
8	Top of Vegetative Layer Contours
9	Top of Vegetative Layer Grid Point Locations and Staking Plan
10	Top of Top-Soil Layer Contours
11	Top of Top-Soil Layer Grid Point Locations and Staking Plan
12	Top of Low-Permeability Soil Contours
13	Top of Low-Permeability Soil Grid Point Locations and Staking Plan
14	North Slope Buttress Plan and Details (2 sheets)
15	Surface-Water Drainage Plan and Details (2 sheets)
16	Gas Monitoring and Collection System Plan and Details (2 sheets)
17	Access Road Details
18	Fence and Security System Details
19	Lighting and Electrical Plan

Table 7-4
Preliminary List of Technical Specifications for Landfill Closure

Division I	**General Requirements**
01100	Special Subcontract Requirements
01300	Submittals
01400	Quality Control/Quality Assurance
01500	Temporary Facilities, Controls, and Special Project Requirements
01600	Material and Equipment
Division 2	**Site Work**
02080	Gas Management System (included for information only, not for construction)
02102	Clearing and Grubbing
02200	Earthwork
02210	Test Fill
02220	Excavation, Trenching, Backfill, and Compaction
02231	Aggregate Base Course
02271	Geomembranes
02272	Geotextile
02273	Geonet
02278	Geocomposite Clay Layer
02667	Site Water Lines
02781	Site Grounding
02800	Signage
02830	Chain Link Fencing
02900	Topsoil and Revegetation
02930	Erosion Control Measures
Division 10	**Specialties**
10800	Toilet and Bath Accessories
10820	Emergency Eyewash and Body Spray Equipment
Division 11	**Equipment**
11600	Gas Monitoring Instrumentation
11700	Alternative Daily Cover System

Table 7-4
Preliminary List of Technical Specifications for Landfill Closure

Division 13	**Special Construction**
13200	Liquid Storage Tanks
13210	Pumping Equipment
13215	Piping
13410	Instrumentation
13420	Control Panels
Division 15	**Mechanical**
15050	Basic Mechanical Materials and Methods
Division 16	**Electrical**
16050	Basic Electrical Materials and Methods



U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Recommended Alternative Single-Barrier FMC & Low-Permeability Soil Cover Cross Section

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 7 1

G95\ES\IM\IRA DD OU7\Cove Alt #7 5 2510 ill

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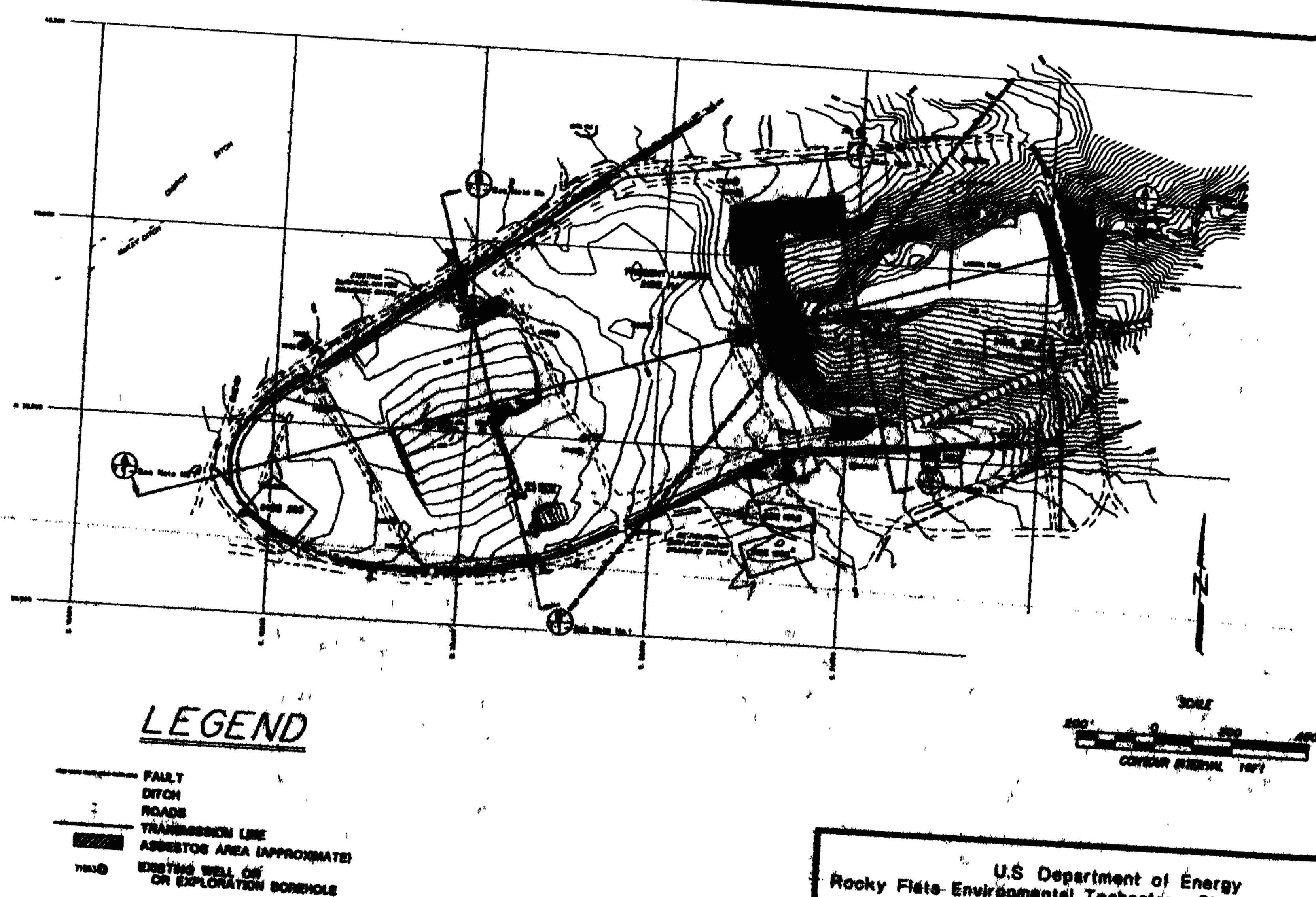

NOTES

1) REFERENCED ON DRAWINGS 7 3 AND 7 4
2) BASE TOPOGRAPHY AND FEATURES (DECEMBER 1994)

U.S Department of Energy
Rocky Flats Environmental Technology Site, Golden Colorado

Existing Topography and Surface Features

Phase I IM/IRA DD

Operable Unit No 7

July 1995

Figure 7 2

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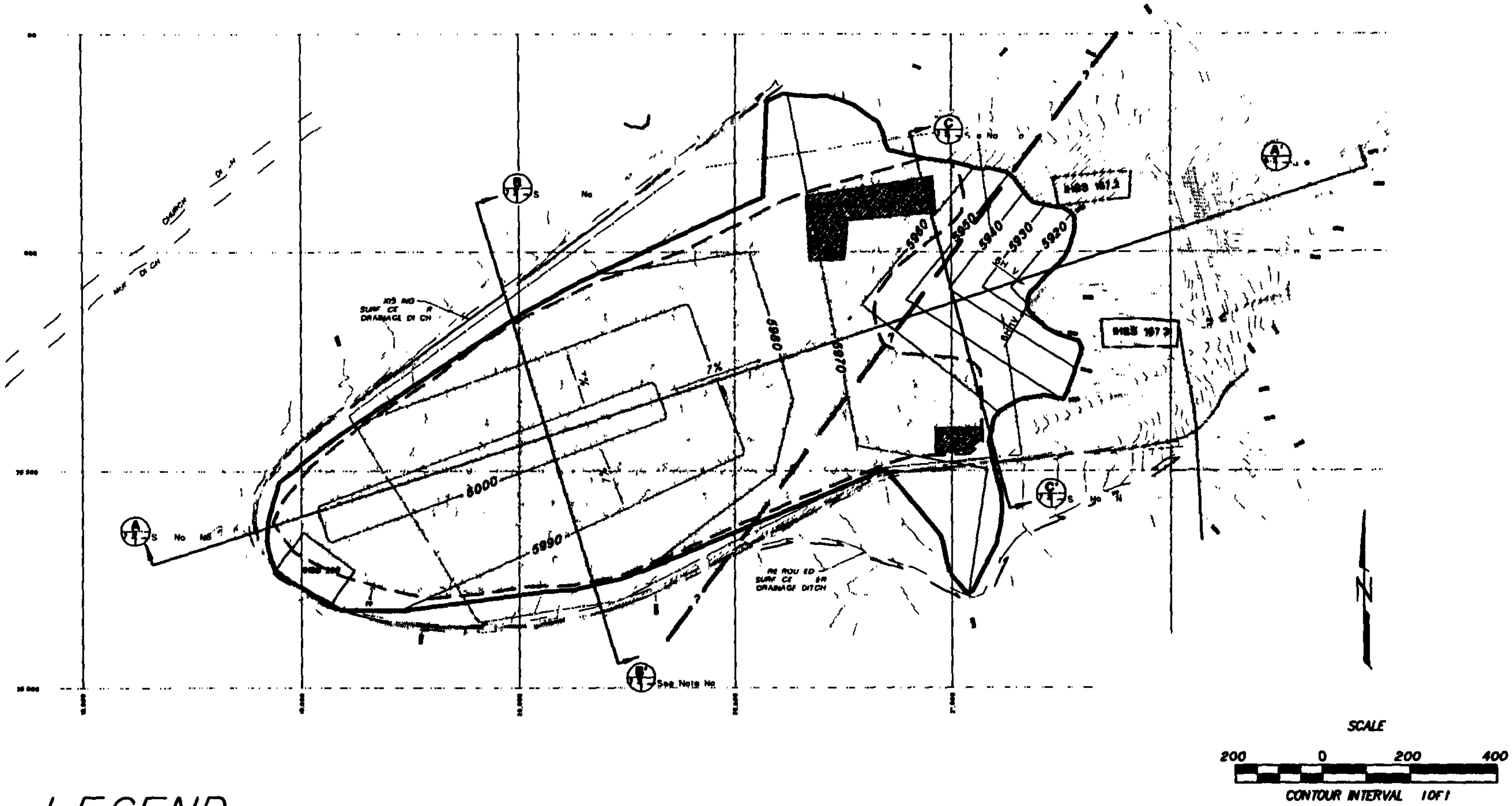

LEGEND

- ? FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA
- EDGE OF LANDFILL
- ASBESTOS AREA
- COVER AREA

NOTES

1) REFERENCED ON DRAWINGS 7 3 AND 7 4
2) BASE TOPOGRAPHY AND FEATURES (DECEMBER 1994)

DETAIL SECTION NUMBER
DRAWING No WHERE DETAIL/SECTION IS REFERENCED
DRAWING No WHERE DETAIL/SECTION IS SHOWN

U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Proposed Conceptual Grading Plan, Extent of Cover, and Surface-Water Control Plan

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 7 3

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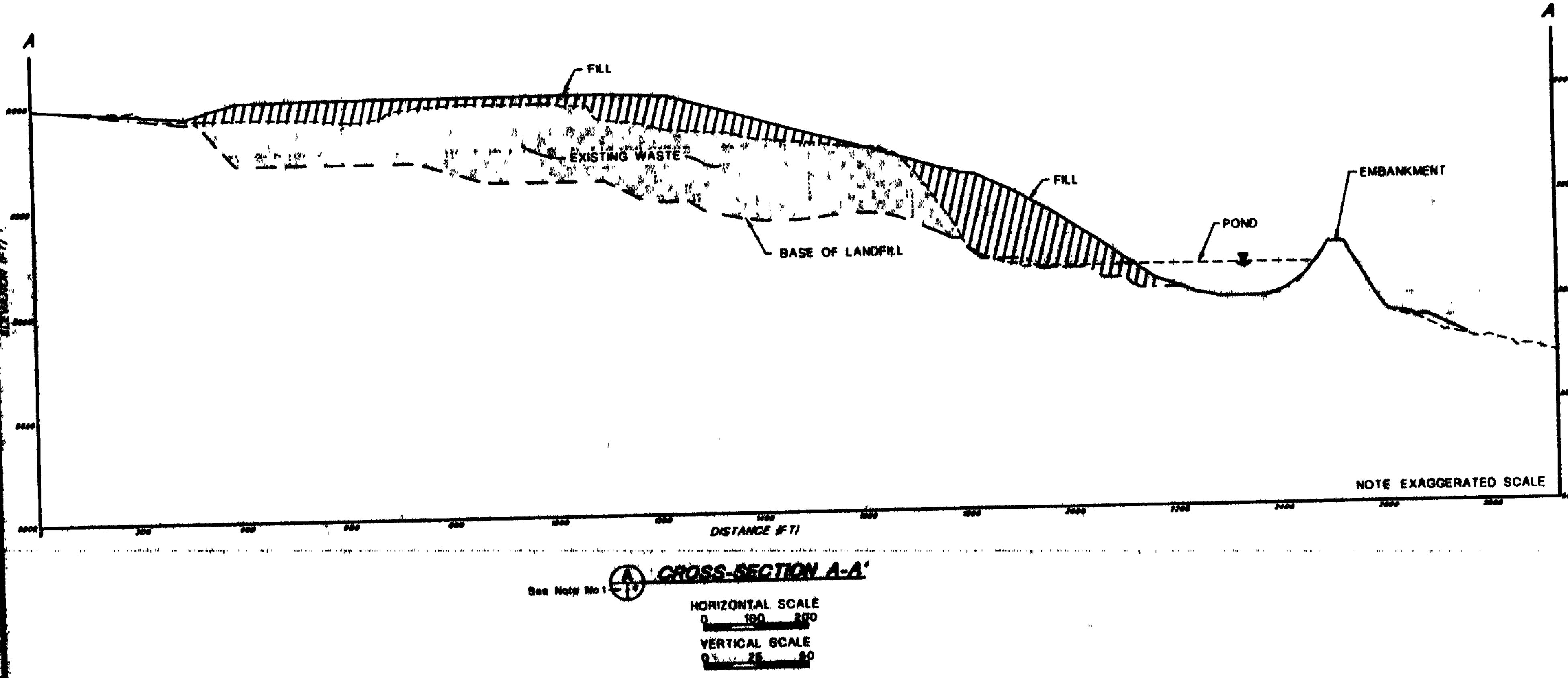
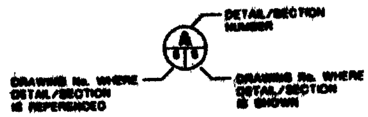


LEGEND

- CURRENT SURFACE
- BASE OF LANDFILL SURFACE
- PROPOSED CONCEPTUAL GRADING PLAN
- FILL
- EXISTING LANDFILL

NOTE:

1.) REFERENCED ON DRAWING, 7 1 AND 7 2



US Department of Energy
Rocky Flats Environmental Technology Site, Golden, Colorado

Landfill Cover Cross-Section A-A'

Phase I IM/IRA DD | Operable Unit No. 7

July 1995 | Figure 7-4

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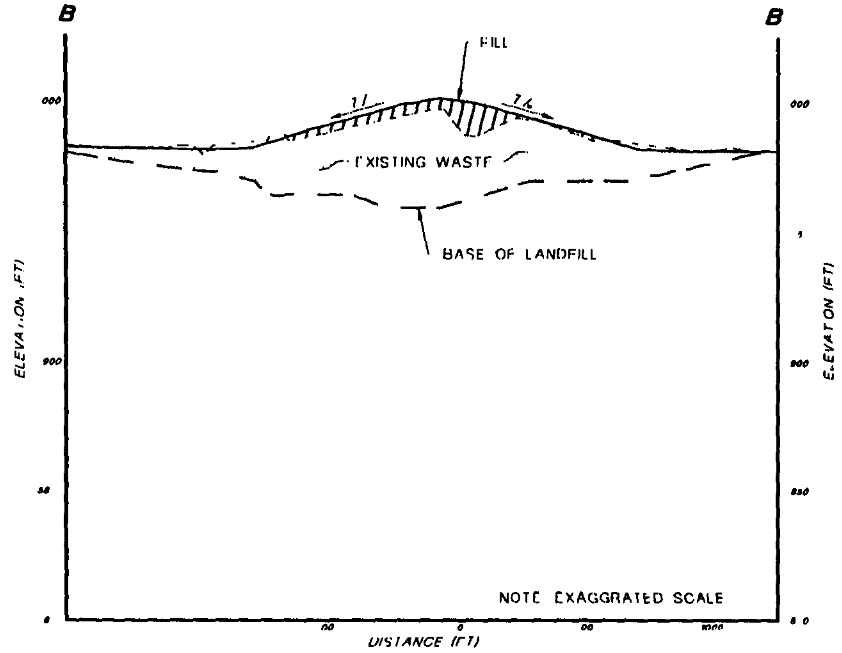
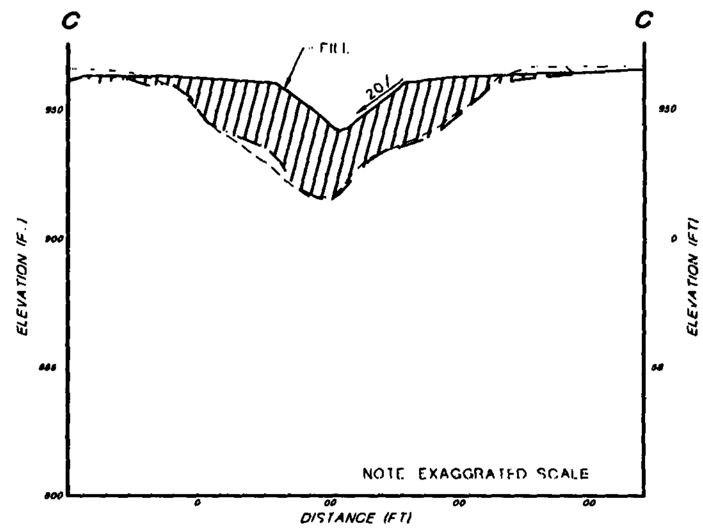


CROSS-SECTION B B

HORIZONTAL SCALE 0 100 200

VERTICAL SCALE 0 25 50



CROSS-SECTION C C

HORIZONTAL SCALE 0 100 200

VERTICAL SCALE 0 25 50

LEGEND

- CURRENT SURFACE
- BASE OF LANDFILL SURFACE
- PROPOSED CONCEPTUAL GRADING PLAN
- FILL
- EXISTING LANDFILL

NOTE

1) REFERENCED ON DRAWING 7 1 AND 7 2

U S Department of Energy
Rocky Flats Environmental Technology Site Golden Colorado

Landfill Cover Cross-Sections B-B' & C-C'

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Figure 7 5

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8 Closure and Post-Closure Plans

Closure of OU 7 is being implemented under CHWA regulations for hazardous waste landfills (6 CCR 1007-3) The Phase I IM/IRA DD and the Phase I RFI/RI Report constitute the OU 7 Closure Plan (CDPHE 1992) General closure requirements for interim status units are contained in Part 265, Subpart G Specific closure requirements for interim status units are contained in Part 265, Subparts I through Q

The CHWA/RCRA closure process includes the following steps

- Identification of a treatment, storage or disposal unit that needs to be closed from a hazardous waste management perspective
- Development of a closure plan
- Implementation of the closure plan
- Certification of closure
- Performance of a post-closure residual risk assessment if needed
- Development of a post-closure plan
- Implementation of the post-closure plan through the CAD/ROD
- Certification of completion of post-closure activities

OU 7 was identified as an interim status unit undergoing closure in the IAG In accordance with the Rocky Flats Cleanup Agreement in the IAG, DOE agrees to 'clean close' any unit for which clean closure performance standards are reasonably achievable using decontamination, treatment, and/or removal actions (DOE 1991b) Because of the size of the landfill clean closure is not possible and the post-closure requirements of 6 CCR 1007-3 Parts 265 117-265 120 apply

This section presents the closure plan for OU 7 which addresses the necessary CHWA requirements for interim status closures and can be used for implementation Because a focused risk assessment was performed for this Phase I IM/IRA DD, a post-closure residual risk assessment is not needed The evaluation of risks presented in Section 3 3 shows that the risk to human health is within the acceptable risk range for carcinogens (1E-04 to 1E-06) and below the HI of 1 for noncarcinogens for surface water and sediment in the East Landfill Pond surface soils in spray evaporation areas, and subsurface geologic materials downgradient of the landfill Exposure pathways are incomplete for leachate at the seep and groundwater downgradient of the landfill

Risks to ecological receptors are above the HI of 1, but risks were conservatively overestimated because it was assumed that ecological receptors spend 100 percent of their time at the East Landfill Pond This section also presents the post-closure plan for OU 7, which addresses CHWA requirements for the 30-year post-closure care period

8 1 Closure Plan

Closure of the landfill at OU 7 meets CHWA requirements, which state that closure will minimize the need for further maintenance and control, minimize or eliminate, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere (6 CCR 1007-3 Part 265 111). The final action complies with closure requirements of Subpart G and 6 CCR 1007-3 Subpart N Part 265.310, which are ARARs for OU 7

This closure plan describes the facility, extent of operations and management of maximum inventory, notification of closure, final cover, decontamination procedures, groundwater monitoring, ancillary closure activities, emergency response, closure certification, survey plat, record of wastes, and deed notation A closure schedule is included in accordance with the regulation.

8 1 1 Facility Description

The Present Landfill encompasses approximately 20 acres and has been used for disposal of hazardous and nonhazardous wastes from 1968 to 1986 Since 1986, only nonhazardous wastes have been disposed Asbestos was disposed in discrete pits near the eastern limit of the landfill. The Inactive Hazardous Waste Storage Area is located at the southwest corner of the Present Landfill It encompasses approximately one-half acre but is included within the acreage of the Present Landfill The area was used to store drummed liquids and solids between 1986 and 1987 All drums were removed in May 1987 The East Landfill Pond is located east of the landfill and was constructed to control leachate from the landfill The Pond Area Spray Field and South Area Spray Field are adjacent to the pond. Spray evaporation areas each encompass approximately 1 acre Water from the East Landfill Pond was periodically sprayed in these areas to prevent the pond from exceeding capacity by evaporating the water Spray evaporation activities ceased in September 1994

Groundwater in the UHSU at OU 7 generally flows to the east, however, localized flow follows topographic slopes toward the pond or toward the drainage below the dam The depth to groundwater in the UHSU is approximately 5 feet in No Name Gulch east of the landfill Groundwater flows to the east within the valley-fill alluvium, however, flow is intermittent. Certain UHSU groundwater-monitoring wells east of the East

Landfill Pond dam are often dry Groundwater is diverted around the landfill by an existing groundwater-intercept system and slurry walls Some of the groundwater flows under the groundwater-intercept system on the north side of the landfill The depth to groundwater within the landfill is approximately 20 feet Leachate and groundwater discharge from the landfill at a seep located at the base of the east face of the landfill Seep water flows into the East Landfill Pond

Under the presumptive remedy, it is proposed that the leachate, which is considered F039 RCRA-listed waste contained in groundwater be delisted and thus no longer be subject to CHWA and RCRA Subtitle C hazardous waste regulations Section 3 4 3 3 has shown that the leachate is nonhazardous and does not pose a threat to human health or the environment

Criteria and standards for NPDES (40 CFR Part 125) under the CWA and CWQA are applicable Because OU 7 is an onsite CERCLA action only substantive provisions of these acts must be met A NPDES permit is not required for discharges from the East Landfill Pond to No Name Gulch However discharge requirements will be negotiated with CDPHE and EPA

8 1 2 Extent of Operations and Management of Maximum Inventory

Operation of the Present Landfill began in August 1968 and will end in early 1997 The active portion of the landfill and the known extent of the waste are shown on Figure 5-1 All wastes will remain within the landfill, including soils in IHSS 203 and asbestos in the disposal areas, and will be covered during closure

Given the current and projected waste generation rates (DOE 1994a), the landfill will not reach capacity before closure in 1997 For this reason, a large volume of general fill will be required to achieve grades that will drain surface water and allow for landfill settlement The volume of fill material required to achieve grade was determined by subtracting the total volume from the total capacity

8 1 3 Notification of Closure

DOE will notify CDPHE of the impending closure of the landfill in February 1997 at least 60 days before closure is to begin (6 CCR 1007-3 Part 265 112[e]) No specific form is required for notification of closure Closure must begin no later than 30 days after receipt of the final volume of waste material Disposal of the final volume of waste is assumed to be in April 1997 Completion of closure activities must occur within 180 days of receipt of the final volume of waste, which is October 1997 Closure requirements are described below

8 1 4 Final Cover

The construction specifications for each material will be presented in the OU 7 Title II Design Document Placement of the individual components of the cover system is governed by technical specifications provided in the OU 7 Title II Design Document The contractor performing construction of the final cover system will be held in strict conformance to the Title II construction design drawings and specifications.

Quality control (QC) and quality assurance (QA) inspection and testing will be performed during construction of the final engineered cover system. The Title II Design Document will include a CQA plan that outlines specific inspection and testing requirements for all materials and construction performance, necessary documentation, procedures for correcting nonconforming items, and the party responsible for each portion of the CQA. All materials and placement of materials for the cover system construction will be subject to inspection and testing to assure conformance to the specifications Documentation of the inspection and testing will be presented in the final closure certification to be submitted upon completion.

8 1 5 Decontamination Procedures

Construction and other equipment used during landfill closure activities will be decontaminated at the main decontamination facility at Rocky Flats, as needed The waste is covered by a 12- to 36-inch interim soil cover, and no excavation into the waste is anticipated Decontamination will be conducted in accordance with EMD Operating Procedure 5-21000-OPS, Field Operations, FO.04, Decontamination of Equipment at Decontamination Facilities (EG&G 1995c), and FO.12, Decontamination Facility Operations (EG&G 1994e)

8 1 6 Groundwater Monitoring

Groundwater monitoring during the closure period is consistent with the quarterly monitoring conducted at the landfill during its operation Twenty-six of the monitoring wells at OU 7 that fall under the footprint of the landfill cap have been abandoned as a separate maintenance action The 28 remaining groundwater-monitoring wells are sampled during closure (Figure 8-1) The sitewide groundwater-monitoring program is outlined in the Groundwater Protection and Monitoring Program Plan (EG&G 1993d) Routine sampling and analysis is performed quarterly in accordance with EMD Operating Procedure 5-21000-OPS, GW.6, Groundwater Sampling (EG&G 1992b) Samples are collected for analysis in the following sequence radiation screening, VOCs, SVOCs, indicator parameters, gross alpha, gross beta, uranium, dissolved and total metals, other radionuclides, cyanide, and orthophosphate

Water-level measurements are collected quarterly as part of the groundwater-monitoring program Water levels are measured in accordance with EMD Operating Procedure 5-21000-OPS GW 1, Water Level Measurements in Wells and Piezometers (EG&G 1992c) Well maintenance activities, including routine assessment of sediment buildup in well sumps sediment removal and redevelopment well pad repair, and an overall assessment of well condition are also performed during routine monitoring

The monitoring program for OU 7 will be streamlined after landfill closure The post-closure groundwater-monitoring program is described in Section 8 2 3

8 1 7 Ancillary Closure Activities

Activities performed concurrently with the closure operation include wetlands mitigation Preble's meadow jumping mouse habitat mitigation surface-water management and site security Leachate management will be performed as a continuation of the accelerated action until the seep is covered Gas monitoring will not be performed until after closure

Acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project is used to mitigate the loss of wetland areas that fall under the landfill cover and injury to surrounding wetland areas pending final approval Approximately 1 1 acres of wetlands are mitigated Injury to Preble's meadow jumping mouse habitat is mitigated as needed Approximately 7 26 acres of habitat is mitigated

Surface-water run-on and run-off will be controlled by grading the surface of the landfill Surface water will drain to the perimeter drainage ditches and be routed to No Name Gulch The Title II design for the drainage ditches will be based on run-off and run-on for a 100-year 24-hour storm as required by CHWA (6 CCR 1007-3) The water level in the East Landfill Pond will be lowered to allow better access for construction activities during closure by transferring water to the A-series ponds

Site security will be maintained during construction activities for closure A chain-link fence surrounds the landfill and prohibits access by unauthorized personnel Gates will be installed for construction access Signs will be posted warning the public of the potential dangers at the landfill

8 1 8 Emergency Response

Hazardous waste facilities are required under 40 CFR 265 50 Subpart D to provide contingency plans and emergency procedures The purpose of the emergency response plan is to minimize danger to human health and the environment in the event of a fire explosion or release of hazardous waste The plan outlines the actions facility

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personnel, describes agreements made with local hospitals, state and local response teams, and police and fire departments, specifies the emergency coordinator, provides updated lists of emergency equipment and their physical locations and descriptions, and includes an evacuation plan The Rocky Flats Environmental Technology Site Emergency Plan (EG&G 1994f) contains the necessary information to satisfy these requirements

8 1 9 Closure Certification

DOE will submit a certification that closure has been conducted in accordance with the approved OU 7 Closure Plan to CDPHE in December 1997 The certification must be signed by an independent registered professional engineer and DOE and submitted no later than 60 days after closure Supporting documentation will include inspection reports made by the professional engineer and results of sampling and analyses

8 1 10 Survey Plat

DOE will submit a survey plat to the Jefferson County Clerk and CDPHE in December 1997, no later than submission of the certification of closure. The plat will be prepared and certified by a professional land surveyor licensed in the state of Colorado The plat will include a note that states the obligation of the owner or operator to restrict disturbance of the hazardous waste disposal unit in accordance with 6 CCR 1007-3 Subpart G The survey plat will indicate the location and dimensions of the landfill with respect to surveyed benchmarks Locations of temporary benchmarks in the vicinity of OU 7 are shown on Figure 8-2

8 1 11 Record of Wastes

DOE will submit a record of wastes to the Jefferson County Clerk and CDPHE in February 1998, no later than 60 days after certification of closure The record of wastes will document the type, location, and quantity of hazardous wastes in the landfill

8 1 12 Deed Notation

Within 60 days of certification of closure (February 1998), DOE must record a notation on the property deed that states that hazardous wastes have been disposed on the property and that use is restricted under 6 CCR 1007-3 Part 265 119(b)(1) Current holders of easements may be notified to ensure that they are aware of the restriction on the property The deed notation should include the owner's name and address, the address and legal description of the property, a reference to the use of the property as a hazardous waste disposal facility, the date the landfill began to receive hazardous waste, a reference to Subpart G land-use restrictions, a statement informing future purchasers and lessees of the regulations and the types and locations of wastes on the

the owner or operator In addition, DOE must submit a signed certification to CDPHE stating that the deed notation has been recorded A copy of the document in which the notation has been placed should be included with the certification

8 1 13 Final Closure Schedule

The schedule for final closure was developed in accordance with the RCRA Guidance Manual for Subpart G Closure and Post-Closure Care Standards (EPA 1987a) It was assumed that the Present Landfill would receive the final volume of waste for disposal and the new landfill would be operational in April 1997 The closure timeline is presented in Table 8-1

8 2 Post-Closure Plan

This OU 7 Post-Closure Plan addresses the requirements for post-closure care outlined in 6 CCR 1007-3 Part 265 117-120 and describes the monitoring and maintenance activities that will be performed during the 30-year post-closure care period

8 2 1 Post-Closure Permit

A post-closure permit is required for all landfills under 40 CFR 270 1(c) to detail the requirements of post-closure care The landfill closure action must comply only with the substantive aspects of this requirement Post-closure permits generally include a copy of the post-closure inspection schedule, the post-closure plan and a notation to the property deed Floodplain information, applicable groundwater and landfill gas monitoring data, and information demonstrating compliance or corrective action are also included Permits also describe IHSSs, provide information on corrective actions for releases from those IHSSs and information on the potential for the public to be exposed to hazardous wastes released from the site

The Draft Proposed Plan and Draft Modification of the Colorado Hazardous Waste Permit for the Rocky Flats Environmental Technology Site is included as an attachment to this report The Draft Permit Modification is used to incorporate remedial action decisions at Rocky Flats into the site's RCRA permit CDPHE issues the Final Hazardous Waste Permit Modification after the remedial decision process is complete

8 2 2 Post-Closure Inspection and Maintenance

Post-closure inspection and maintenance activities include routine facility inspections and repairs, repair of the vegetative cover due to erosion damage, maintenance of surveyed waste management area boundary markers, and inspection and maintenance of monitoring systems The proposed frequency of inspection and maintenance activities that will be performed by DOE is provided in Table 8-2 Routine facility inspections will be performed semiannually Components of the facility that will be inspected include the final cover, East Landfill Pond and dam, surface-water drainage ditches, surveyed benchmarks, groundwater-monitoring system, gas-monitoring system, and security system.

The integrity and effectiveness of the final cover will be maintained by fertilizing, reseeding, and mulching bald spots and eroded areas, replacing soil lost to erosion, and controlling rodents. Wind dispersion of particulates will also be controlled Severe erosion or frost damage will require spreading a new layer of topsoil and revegetating the area. These activities may be needed more frequently early in the 30-year post-closure care period before the vegetation becomes established.

Inspections of the East Landfill Pond and dam will be performed semiannually Water levels in the pond will be controlled in accordance with the sitewide surface-water management plan Water will be discharged if the pond becomes too full Perimeter surface-water drainage ditches will be cleaned and repaired as necessary. Silt deposits and organic material will be removed from the channel. Ditches will be regraded or revegetated to prevent erosion

The gas-monitoring system and groundwater-monitoring system will be inspected annually Maintenance may include replacing or redrilling monitoring wells, repairing well pads, removing sediment from the sump, redeveloping wells as needed, replacing piping or caps, and other routine equipment maintenance Most of these activities will be needed at irregular intervals during the post-closure care period

The security system will be inspected and maintained annually Fencing, gates, posts, and warning signs may be periodically replaced Fencing should last for 30 years but sections of the fence may need to be replaced due to normal wear, weather conditions, or vandalism. Standard signs last about 7 years. Warning signs posted around the landfill will be periodically replaced

8 2 3 Post-Closure Monitoring

Post-closure monitoring consists of gas monitoring to determine if gas treatment is needed and groundwater monitoring to detect future releases from the landfill Existing units at interim status landfills are not required to have leachate collection and removal systems and are not required to manage leachate during the post-closure period (40 CFR 264.118 and 264 310[b][2]) Leachate at the seep is routed to the edge of the cover system and discharges to the East Landfill Pond.

8 2 3 1 Gas Monitoring Program

Landfill gas monitoring will be performed quarterly using the system of passive gas vents installed within the engineered cover The objective of the gas-monitoring program is to monitor emissions to determine if gas treatment is needed Gas monitoring is performed in accordance with the requirements of 40 CFR Part 258 23

Gas monitoring will be performed manually at each gas vent location using a portable combustible gas indicator (CGI) and a photoionization detector (PID) or equivalent The CGI detects and measures the concentration of combustible gases and oxygen levels to quantify the explosive potential and levels of asphyxiant gases and vapors The PID will be used to detect and measure volatile organic constituents

An instrument, such as a hot wire anemometer or equivalent, will be used to obtain gas-flow measurements Generally, these field measurements can be accomplished by one person equipped with a portable combustible gas meter and velocity/temperature measuring instrumentation Precise field flow measurements of landfill gas are difficult to achieve However, these measurements can be improved by conversion charts that relate the cooling effect of for example methane versus typical ambient air Conversions can also be made to relate recorded readings to actual flow readings using standard conditions

Quarterly gas-monitoring data will be used to evaluate the effectiveness of the passive gas-collection system at the landfill and to assess compliance with air emission requirements under CAQCC Regulation No 3

8 2 3 2 Point of Compliance

Post-closure groundwater-monitoring requirements are relevant and appropriate to interim status facilities such as the Present Landfill and require implementation of a groundwater-monitoring program capable of determining the impact of the landfill on groundwater quality in the UHSU (6 CCR 1007-3 Part 265 90[a]) The requirement does not address the point of compliance for remediation activities Because interim status units and regulated units are addressed in a similar manner, the point-of-compliance provision that applies to regulated units is relevant and appropriate to the remediation of interim status units (6 CCR 1007-3 Part 264 92)

The point of compliance is defined as the vertical surface that extends down into the UHSU at the downgradient limit of the waste-management area Remediation levels should generally be attained "at and beyond the edge of the waste-management area when waste is left in place" (55 Federal Register 8753) Although the downgradient limit of the waste-management area is currently at the toe of the landfill face, the cap extends out toward the middle of the East Landfill Pond to achieve design grade required for closure As a result, the downgradient limit of the waste-management area shifts to the east Rather than installing monitoring wells in the middle of the pond, monitoring wells located downgradient of the dam are proposed as compliance wells Wells immediately downgradient of the dam are currently used as compliance wells for the annual RCRA groundwater-monitoring report, but these wells rarely yield enough groundwater for sampling Wells farther downgradient are proposed as compliance monitoring wells

Well 53194, which is located east of the dam and routinely yields enough groundwater for sampling, is proposed as the compliance well The point of compliance is the hydrologically downgradient limit of the area in which contamination exists The compliance well ensures that hazardous constituents detected in groundwater do not exceed concentration limits in the uppermost "aquifer" (or UHSU) underlying the waste-management area beyond the point of compliance (6 CCR 1007-3 Parts 264 93 and 264 94) The regulations also provide that the owners or operators conduct a corrective-action program to remove or treat any hazardous constituents that exceed ARARs between the compliance point and the downgradient property boundary (6 CCR 1007-3 Part 264 95) Wells 4287 and 52894 are proposed as monitoring wells for the detection-monitoring program at OU 7 to detect releases before groundwater reaches the point of compliance

There is no potential for exposure to contaminated groundwater at OU 7 Future land use for the buffer zone, which includes the area downgradient of the landfill, is open space (DOE 1995d) Groundwater will not be used as a source of drinking water In addition, No Name Gulch is a losing stream, which means that vertical gradients are downward and surface water recharges the groundwater in the UHSU. Groundwater is not discharged to surface water in No Name Gulch.

The NCP states that attaining ARARs at the proposed point of compliance will ensure protection of human health and the environment at all points of potential exposure (55 Federal Register 8753) DOE proposes a point of compliance for OU 7 downgradient of the dam, which is protective of human health and the environment There is no potential exposure because there are no plans for future development of groundwater for any use at OU 7 Chemical-specific ARARs can be met at this point

8 2 3 3 *Groundwater-Monitoring Program*

This section describes the proposed groundwater-monitoring program that will serve as the detection-monitoring program for post-closure activities The primary objective of the groundwater-monitoring program is to detect potential future releases that migrate beyond the boundary of OU 7

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One upgradient and three downgradient monitoring wells are required for post-closure groundwater monitoring (6 CCR 1007-3 Part 265 90[a]) The proposed upgradient monitoring well is 70393 which is due west of the landfill near the headwaters of the former drainage (Figure 8-2) This location will provide information on groundwater quality upgradient of the landfill The proposed downgradient monitoring wells for UHSU groundwater are 4287, 52894, and 53194 These wells are downgradient of the landfill in the No Name Gulch drainage (Figure 8-2) These locations will ensure that contaminants are detected if they migrate away from the source and provide information regarding improvement or degradation of groundwater quality All proposed wells are alluvial wells

The four downgradient weathered bedrock wells (B206789 B206889, B206989, and 52994) (Figure 8-1) were considered for post-closure monitoring but were rejected for several reasons Location B206789 falls under the proposed footprint of the landfill cap Well B206989 does not exhibit a strong connection with the surficial materials The difference in potentiometric surfaces between surficial materials and weathered bedrock exceeds 20 feet at well cluster 4087/B206989 Both wells B206889 and B206989 consistently exhibit water levels 12 to 15 feet below the top of bedrock elevation indicating only partial saturation of weathered bedrock and a 'perched' water table condition for surficial materials Neither well produces enough water for a full suite of chemical analyses For most historical sampling events, the wells yielded only enough groundwater for a VOC sample (40 milliliters) Well 52994 is dry Downgradient weathered bedrock wells were rejected for post-closure monitoring because they were beneath the cap, not hydraulically connected to alluvial wells at well clusters, partially saturated or dry

Groundwater sampling will be performed at the proposed compliance wells in accordance with EMD Operating Procedure 5-21000-OPS, GW 6, Groundwater Sampling (EG&G 1992b) Water-level measurements will be collected as part of the groundwater-monitoring program Water levels are measured in accordance with EMD Operating Procedure 5-21000-OPS, GW 1 Water Level Measurements in Wells and Piezometers (EG&G 1992c) Groundwater monitoring will be limited to the background (upgradient) well and the three compliance/detection (downgradient) wells Table 8-3 provides a list of parameters that will be used for sampling and analysis in accordance with 6 CCR 1007-3 Part 265 92 Groundwater samples will be collected annually for indicator parameters and semiannually for contamination parameters

The semiannual groundwater-monitoring data will be reviewed and analyzed to evaluate groundwater quality at OU 7 New groundwater data will be compared to historical data to detect trends in potential groundwater contamination Statistical methods of analysis will be used to determine if significant changes in contaminant concentrations occur within individual wells, within well groups, and within the monitoring system.

8 2 4 5-Year Review

Under CERCLA, Section 121(c) and the NCP (Section 300 430[f][4][ii]), statutory reviews are required at least every 5 years to assure that the remedial action remains protective of human health and the environment The level of the reviews will be at the discretion of CDPHE and EPA; however, it is expected that a Level I review, consisting of a site visit, review of operation and maintenance activities, and a brief site inspection, will be sufficient

8 2 5 Post-Closure Certification

DOE will submit a certification that post-closure care has been completed in accordance with the approved OU 7 Post-Closure Plan to CDPHE no later than 60 days after completion of the 30-year post-closure care period. The post-closure certification must be signed by an independent registered professional engineer and DOE Supporting documentation will include inspection reports made by the professional engineer and results of sampling and analyses

8 2 6 Financial Assurance and Cost Estimates

State and federal governments are exempt from the financial assurance requirements of 40 CFR 265 140(c) Subpart H

The estimated capital cost for closure of the landfill is $9,070,000 The annualized O&M cost for post-closure is $55,000 per year over the 30-year post-closure period. The total present worth cost is $10,149,000. The detailed cost estimate is provided in Appendix H

Table 8-1
Closure Timeline

Activity	Date
Notification of Closure	February 1997
Receipt of Final Volume	April 1997
Completion of Closure Activities	October 1997
Submittal of Survey Plat	December 1997
Submittal of Certification of Closure	December 1997
Submittal of Record of Wastes	February 1998
Submittal of Deed Notation	December 1998

Note

Assumes final volume of waste received in April 1997

Table 8-2
Post-Closure Inspection, Maintenance, and Monitoring Schedule

Item	Frequency
Inspection and Maintenance	
Routine facility inspection	semiannually
Final cover survey	annually
East Landfill Pond	semiannually
Drainage ditch cleanout	annually
Fence inspection	annually
Gas-monitoring system	annually
Groundwater-monitoring system	annually
Monitoring	
Gas monitoring	quarterly
Groundwater monitoring	
Indicator parameters	annually
Contamination parameters	semiannually

Table 8-3
Groundwater-Monitoring Parameters

	Parameter	Frequency	Reference
Groundwater Quality List	Chlonde	annually	6 CCR 10077 3 265 91(2)
	Iron	annually	
	Manganese	annually	
	Phenols	annually	
	Sodium	annually	
	Sulfate	annually	
Groundwater Contamination List	pH	semiannually	6 CCR 1007 3 265 91(3)
	Specific conductance	semiannually	
	Total organic carbon	semiannually	
	Total organic halogens	semiannually	

9 Environmental Assessment

The proposed IM/IRA for landfill closure is the final action for OU 7 Implementation of the remedy has some potential impacts to OU 7 and the surrounding area when compared to the impacts expected from the no-action alternative This section presents potential environmental and human health effects resulting from the proposed IM/IRA activities and is the functional equivalent of an environmental impact statement (EIS) Human health exposures during construction of the final remedy, and during post-closure maintenance and monitoring activities, and exposures resulting from possible accidents are analyzed for risks to workers involved with IM/IRA activities, other workers at Rocky Flats, and the public Environmental impacts to ecology, and air, surface-water, and groundwater are also evaluated The commitment of personnel and material resources and potential impacts to transportation and other short-term, long-term, and cumulative impacts are also evaluated

Proposed construction activities for the recommended alternative include placement of general fill and regrading to achieve adequate surface drainage, placement of the engineered cover system, placement of the final vegetative cover, and upgrading the run-off/run-on drainage-ditch system A post-closure inspection, maintenance, and monitoring program will be performed for 30 years after landfill closure The post-closure inspection and maintenance program will include routine facility inspections and repairs repair of the vegetative cover due to erosion damage, maintenance of surveyed waste management area boundary markers, and inspection and maintenance of monitoring systems Post-closure monitoring consists of gas monitoring and groundwater monitoring

9 1 Screening-Level Human Health Risk Assessment

The purpose of this screening-level risk assessment is to identify and qualitatively examine the potential risks to human receptors associated with the installation and maintenance of the engineered cover under the IM/IRA at the Present Landfill This assessment includes

- Identification of potential contaminants of concern or activities of concern
- Characterization of potential exposure
- Estimation of potential magnitude of risk
- Identification of uncertainties associated with the assessment

Assessment of potential risks associated with IM/IRA activities will allow risk managers to ensure that measures are taken to mitigate any significant risks that are identified This screening-level risk assessment does not examine risks associated with leaving landfill contents in place, nor does it examine the individual risks to receptors following interim measures Only risks associated with the process of implementing interim measures are evaluated

9 1 1 Identification of Potential Contaminants of Concern or Activities of Concern

Construction activities anticipated for the IM/IRA and included in this screening-level risk assessment are as follows

- Construction of an unpaved haul road between an offsite borrow source and the Present Landfill
- Transportation of the fill and cover material on the haul road
- Placement of the fill and engineered cover at the landfill

Post-construction activities will include inspection and maintenance of the cover. The landfill contents are covered daily with interim soil, therefore, the waste is not exposed when IM/IRA construction activities begin No construction activities are anticipated that require intrusion into the landfill contents or asbestos-disposal areas or contact with landfill leachate, adjacent surface water or pond sediments, or groundwater downgradient from the landfill In the event that intrusion or contact becomes likely, worker safety and any necessary precautions will be addressed by the site-specific health and safety plan Long-term risks evaluated as part of the presumptive remedy process are described in Section 3.3

Methane and carbon dioxide gases are generated by biodegradation of the landfill contents, however, as they are emitted from the landfill, these simple asphyxiants are expected to be greatly diluted and dispersed by the wind. Because they are not expected to displace the oxygen present in the air, they pose negligible risk at the low concentrations anticipated in the breathing zone Therefore, the identification of PCOCs focuses on the material used for the fill and engineered cover

The material used to construct the haul road is expected to be road-base aggregate, and materials for the fill and engineered cover include general fill and topsoil vegetative cover During earth moving activities, there is a potential to generate dust Because the earthen materials used are uncontaminated materials, the potential concern is the nuisance associated with dust emissions

An occupational activity of concern is the operation of heavy equipment when transporting the road-base aggregate and fill and cover material. However, these activities are addressed under routine occupational standards designed to reduce risks and are typically incorporated into the health and safety plan.

In summary, construction activities do not involve intrusion into the landfill contents, and the fill and cover materials used are uncontaminated Therefore, the only PCOC identified for the OU 7 IM/IRA is nuisance dust

9 1 2 Characterization of Exposure

The objective of characterizing exposure is to estimate the type and potential magnitude of exposures to the PCOCs that are present at the site or that may migrate from the site The results of the exposure assessment are combined with guidelines for nuisance dust to characterize potential risks

The exposure assessment consists of the following components

- Characterize potentially exposed human populations (i e , receptors)
- Identify exposure pathways
- Qualitatively determine the extent of exposure

9 1 2 1 Potentially Exposed Populations and Exposure Pathways

Potential scenarios and exposure pathways are identified onsite and offsite Activities planned for OU 7 include capping, inspecting, and maintaining the engineered cover of the closed landfill, and post-closure monitoring These activities involve construction workers for capping and maintenance and field technicians for monitoring activities Because the potential for dust generation is higher during the earth-moving activities the exposure to dust is greater for construction workers at OU 7 than for technicians

Offsite land uses are considered according to current and future uses, which are identified through county zoning maps and observation or projections based on growth patterns and community development plans Current land uses around Rocky Flats include open space limited agricultural, commercial or industrial, and residential Although there is currently no residential use adjacent to Rocky Flats, a hypothetical residential receptor is conservatively assumed for this screening-level analysis

Two potentially exposed human receptors are selected for pathway analysis in this screening-level human health risk assessment onsite worker and offsite resident

9 1 2 2 Exposure Pathway Analysis

An exposure pathway describes a specific environmental pathway by which a receptor can be exposed to PCOCs that are present at or migrating from the site Five elements

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comprise an exposure pathway. These elements, identified to determine potential exposure pathways at OU 7, are as follows:

- Source
- Mechanism of release to the environment
- Environmental transport medium for the released constituent (e.g., air, groundwater)
- Point of contact between the contaminated medium and the receptor (i.e., the exposure point)
- Exposure route (e.g., inhalation of dust) at the exposure point

All five of these elements must be present for an exposure pathway to be potentially complete.

An exposure route is the pathway through which a contaminant enters or impacts an organism. There are four basic human exposure routes:

- Inhalation
- Ingestion
- Dermal absorption
- External irradiation, if radionuclides are present

Potential exposure pathways during implementation of the IM/IRA at OU 7 include inhalation of airborne particulates, soil ingestion, and dermal contact with soil. Because no chemicals are present in the earthen fill and cover materials, no impacts are expected from inadvertent ingestion of soil or from absorption through the skin. Inhalation of nuisance dust is generally unpleasant but is not expected to have any impact except to individuals who may have severe pre-existing respiratory problems. Therefore, the pathway that is qualitatively evaluated for the onsite worker and hypothetical offsite receptor is inhalation of nuisance dust.

9.1.3 Potential Magnitude of Exposure and Risk

The potential magnitude of exposure and risk to nuisance dust is dependent on the emission rates and airborne concentrations, which are evaluated in Section 9.3, Impact to Air Quality.

No adverse health impacts are anticipated for offsite residents or construction workers. As presented in Section 9.3.2, it is unlikely that air-quality standards for respirable dust will be exceeded at the Rocky Flats property boundary. The total sampled particulate concentration in the work area is controlled through the application of water by a truck such that the occupational limit will not be exceeded A typical occupational exposure limit for nuisance dust is 10 milligrams per cubic meter (mg/m^3), a level under which it is believed that nearly all workers can be repeatedly exposed day after day without adverse health effects

Occupational risks associated with operation of heavy equipment and transportation of the road-base aggregate and fill and cover material are expected to be low and are controlled through occupational regulations or standards Furthermore, transportation associated with OU 7 will occur on private roads and at lower speeds than are associated with most vehicle accident data Therefore, these risks are not addressed quantitatively

9 1 4 Identification of Uncertainty

The uncertainty analysis characterizes the uncertainty associated with each step of the process of assessing risk These uncertainties are driven by uncertainty in assumptions of work activities, identification of PCOCs, estimation of emission rates, the screening-level transport model used to estimate concentrations at receptor locations, and assumed receptor locations Uncertainties associated with this risk assessment are summarized in Table 9-1

Of the uncertainties identified, a key assumption is that there is no intrusion into the landfill contents or asbestos-disposal areas, as part of the IM/IRA It is also assumed that there is no direct contact with leachate, adjacent surface water or pond sediments, or groundwater downgradient from the landfill In the event that intrusion or contact becomes likely, worker safety and any necessary precautions will be addressed by the site-specific health and safety plan The health and safety plan describes potential hazards and locations, entry and exit requirements for controlled areas, use of monitoring equipment, and use of PPE such as protective clothing and respirators Emergency response is addressed by the Rocky Flats Environmental Technology Site Emergency Plan (EG&G 1994e) Occupational risk is expected to be maintained well within standards under these controls

9 2 Ecological Risk

Construction of the proposed IM/IRA requires soil materials obtained from offsite commercial operations The excavation of borrow materials may have potential impacts to wildlife and vegetation habitats and nearby wetlands and floodplains These potential impacts are considered in operational permits issued for these facilities by the state of Colorado and local county governments

The following subsections describe potential ecological impacts at OU 7 as a result of construction activities associated with the proposed IM/IRA.

9 2 1 Wildlife and Vegetation

9 2 1 1 Short-Term (Construction Period) Impacts

Some IM/IRA construction activities would have impacts to wildlife habitats within the proposed landfill resurfacing area and surrounding areas. Potential habitat for the Preble's meadow jumping mouse and wetland areas in and around the East Landfill Pond will be significantly affected by construction activities for the eastern end of the cap, which extends across part of the existing pond

Temporary loss of mid-grass prairie wildlife habitat is expected because of the surface disturbance (stripping of vegetation) and construction activities (equipment traffic, human activities, etc). The total area of disturbed vegetation would be approximately 39 acres, including the area of the landfill resurfacing (28 acres), borrow material haul roads (9 acres), and miscellaneous construction activities (2 acres). It should be noted that the numbers used in this estimate are preliminary More recent numbers indicate that the area of disturbed vegetation is closer to 35 acres. The existing minimal vegetation on the surface of the landfill is considered a minor wildlife habitat and would be significantly enhanced by the revegetation plan proposed for the Phase I IM/IRA Temporary loss of mid-grass prairie wildlife habitat would be expected at the offsite material borrow source. In addition, noxious weeds could be introduced during revegetation and would be controlled until adequate native vegetation is established.

Temporary loss of habitat may cause direct mortality to small and less mobile animals such as rodents and reptiles resident in the area. Indirect mortality may occur due to displacement and loss of habitat of larger or more mobile animals such as birds and mule deer and may occur from loss of habitat effectiveness in undisturbed areas next to the construction activities.

Increased equipment and human activities associated with construction inevitably result in increased noise levels and vehicle traffic These activities probably have the least disturbance to wildlife because surrounding areas are already in industrial use and wildlife is habituated. Habitat loss is expected to be temporary and would continue only until adequate revegetation is established. With the use of straw mulch, adequately spaced silt fences, and other appropriate measures, the final vegetative cover would be established within two to three years.

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9 2 1 2 *Long-Term Impacts*

Construction of the East Landfill Pond to control landfill leachate has created persistent wetlands and aquatic habitats that are small but important components of a drv environment such as the environment at Rockv Flats As a result species drawn to the aquatic resources around the East Landfill Pond are potentially exposed to contaminants from landfill leachate Contaminant migration from the landfill is minimized after the engineered cover is in place A screening-level ecological risk assessment performed for OU 7 provides baseline information on the potential ecotoxicity and ecological risk of PCOCs in leachate at the seep and in surface water and sediments in the East Landfill Pond (Appendix D Screening-Level Ecological Risk Assessment) Leaving approximately two-thirds of the East Landfill Pond in place results in minimal risk to aquatic life and wildlife

Risks to aquatic life in the pond appear to be minimal Results of the literature-based toxicity screen and laboratorv toxicity testing indicate that surface water in the pond represents negligible risk to aquatic life Results of site-specific surface water and sediment toxicity tests indicate no toxicity

Low potential toxicity to mammalian and avian wildlife is also observed, seep water is the main contributor to overall risk for mallards raccoons and coyotes (Appendix D) However the seep is eliminated as an exposure point during implementation of the proposed remedy Pond sediments may pose a risk to raccoons coyotes and Preble s meadow jumping mice (Appendix D) The primary risks are from naturally occurring metals such as aluminum vanadium and arsenic but the relatively low HI values (HI = 3 to 6) for exposure to the metals suggest low potential toxicity Risks are conservatively overestimated because it was assumed that receptors spend all of their time at the East Landfill Pond

Risks to wildlife from surface water in the pond appear to be limited to exposure of mallards and other waterfowl to bis(2-ethylhexyl)phthalate and di-n-butylphthalate Risks to mallards are conservatively overestimated because it was assumed that they spend all of their time at the East Landfill Pond (Appendix D)

9 2 1 3 *Sensitive Habitats and Endangered Species*

The shoreline of the East Landfill Pond and the No Name Gulch drainage is potential habitat for the Preble s meadow jumping mouse Construction of the engineered cover reduces Preble s meadow jumping mouse habitat near the west end of the pond Habitat mitigation is proposed as needed

9 2 2 Wetlands/Floodplains

Approximately two-thirds of the wetlands area located on the east edge of the landfill boundary in and along the East Landfill Pond remain in place after the landfill closure activities are completed. One-third of the pond and wetlands fall under the proposed engineered landfill cover A wetlands assessment which describes the recommended alternative, is included in Section 7 The proposed mitigation plan is to use acreage from the 8-acre wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project, pending final approval

The closest 100-year floodplain to the proposed IM/IRA activities is along Woman Creek (approximately 1 mile to the south) (DOE 1992d). The proposed action does not alter or impact the 100-year floodplain configuration

9 2 2 1 Short-Term (Construction Period) Impacts

Potential impacts to the wetlands can occur from sediment loading from stormwater run-off and surface disturbance during construction activities Surface-water control measures are used to minimize surface water from contacting potentially contaminated soil or groundwater and minimize erosional effects during the construction activities Most of the precipitation falling on areas where construction is in progress is diverted to existing drainage ditches along the north and south boundaries of the OU 7 Other shallow ditches and silt fences may be constructed to prevent significant sediment from flowing into the landfill pond. Newly constructed soil surfaces are properly protected using methods described in Section 9 5 to minimize soil erosion until the required vegetation is established

9 2 2 2 Long-Term Impacts

The East Landfill Pond includes approximately 3 percent of the open water habitat and 6 percent of the available shoreline habitat at Rocky Flats, the adjacent wetlands represent approximately 1 6 percent of the total (COE 1994). Because the East Landfill Pond was constructed only about 20 years ago, it is probably not a historically important component of the local ecosystem.

The importance of the East Landfill Pond to aquatic life at Rocky Flats and the Big Dry Creek basin appears to be minimal (Appendix D) The pond apparently does not contain fish or crayfish populations, if it does, the populations are very small Without a complex aquatic food web that includes upper-level aquatic consumers, the pond is a limited resource for aquatic-feeding wildlife and potential transfer of contaminants via food web interactions is limited Because the pond lacks predaceous fish such as bass, it may be a resource for breeding amphibians such as tiger salamanders, chorus frogs, and bullfrogs

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The East Landfill Pond does not empty directly into a stream under normal flow conditions however, large rainstorms could cause the pond to overflow into No Name Gulch Because this has not occurred, sensitive fish such as common shiners and stonerollers are not at risk from release of contaminants into streams

9 3 Impact to Air Quality

The purpose of this section is to assess the potential impacts to air quality associated with the proposed installation and maintenance of the engineered cover and the potential off-gases from the OU 7 landfill This assessment includes

- Estimation of potential fugitive-dust emissions
- Estimation of downwind airborne particulate concentrations at the Rocky Flats property boundary using an EPA screening-level model
- Comparison to EPA air-quality standards
- Estimation of potential methane emissions

9 3 1 Estimation of Potential Fugitive-Dust Emissions

Fugitive-dust emissions arising from construction activities are estimated by identifying the type of equipment and capacities expected to be used volume of earthen materials travel distances, and climate conditions Construction involved with the IM/IRA includes three representative tasks

- Construction of a haul road between an offsite borrow source and the landfill
- Transport of fill and cover material to the landfill
- Installation of the engineered cover over the landfill

Post-construction activities include inspection and maintenance of the cover and post-closure monitoring The landfill contents are covered daily with interim soil as waste is placed therefore, the landfill contents are covered before IM/IRA construction activities begin Materials used for the fill and engineered cover include general fill, low-permeability soil topsoil and a vegetative cover after construction is complete

The construction tasks require the use of bulldozers compactors water trucks and haul trucks Because of the transport distances, the use of scrapers is probably not economically feasible EPA has developed empirical equations for estimating dust emissions from typical construction equipment (EPA 1995b) The equations used to represent emission rates from anticipated OU 7 construction activities include operation of haul trucks on unpaved roads dumping of haul truck contents and operation of bulldozers and compactors

$$\text{Bulldozer EF} = 1.0(s)^{1.5}(M)^{-1.4}$$

where

EF	=	Emission factor (lb/hr)
s	=	Silt content of soil (assumed 10 percent)
M	=	Moisture content of soil (assumed 10 percent)

Two bulldozers and two compactors are assumed. A 25-percent reduction was applied to estimate respirable particulate matter (PM-10) emissions (EPA 1995b). A 50-percent reduction is applied to account for dust control from periodic watering using watering trucks

$$\text{Dumping EF} = K(0.0032)\left(\frac{U}{5}\right)^{1.3}\left(\frac{M}{2}\right)^{1.4}$$

where

EF	=	Emission factor (lb dust per ton dumped [lb/ton])
K	=	Particle size multiplier = 0.35 (PM-10) (EPA 1995b)
U	=	Mean wind speed, miles per hour (mph) (assumed 8 mph)
M	=	Moisture content of soil (assumed 10 percent)

Approximately 25 to 30 haul trucks are used. The silt content of soil is assumed to be 10 percent A 50-percent reduction is applied to account for dust control from watering

$$\text{Transportation EF} = K(5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right)$$

where

EF	=	Emission factor (lb per vehicle mile traveled [lb/VMT])
K	=	Particle size multiplier = 0.36 (PM-10) (EPA 1995b)
s	=	Silt content of onsite soil (assumed 10 percent)
S	=	Mean vehicle speed (assumed 15 mph)
W	=	Mean vehicle weight (assumed 25 tons)
w	=	Mean number of wheels (assumed 18)
p	=	Number of days per year with precipitation greater than or equal to 0.01 inches = 87 (EPA 1995b)

Approximately 25 to 30 haul trucks are used A 99-percent reduction is applied to account for dust control from periodic watering using contractor watering trucks, e.g., near 100-percent effectiveness has been obtained with applications of 0.125 gallons per square yard every 20 minutes (DOE 1992c)

Each of the three representative construction tasks involves different assumptions regarding distances, material volumes, and equipment usage which result in different estimated emission rates These emission rates are then used as input to the conservative EPA screening model Screen2, which is a module of TSCREEN (EPA 1994c) Screen2 was used assuming worst-case downwind dispersion conditions to calculate airborne particulate concentrations at the Rocky Flats property boundary The emission rate for dumping truck contents assumes a higher wind speed (8 mph) than that assumed in the air-dispersion model (2 2 mph) These are reasonable worst-case assumptions because greater emissions result during higher wind speeds, but the least amount of dispersion occurs during low wind speeds The assumptions, estimated emissions and dispersion modeling results are presented in the following sections for each of the three representative construction tasks

9 3 1 1 *Haul Road Construction*

The construction haul road is built between a nearby borrow and the landfill The distance required is assumed to be 2 5 miles With an approximate width of 30 feet, the total area is approximately 9 acres The road is built with approximately 8 000 yd^3 of aggregate road base, with an assumed silt content of 10 percent At 15 yd^3 per truck, 533 round trips (loads or number of dumps) are required to build the road Trucks need to travel only short distances as the road is started and travel the entire length of the road as it is finished Using half the length to represent the average round trip distance, 1 333 vehicle miles are required Construction of the road requires approximately 10 working days using two bulldozers and two compactors

These estimations of vehicle miles traveled and durations of activities are used as input to the equations for estimating fugitive-dust emissions The emissions from constructing the haul road, which are displayed in the second column of Table 9-2, indicate that haul truck transportation is expected to contribute the majority of emissions for this task

For use as input to the air model, the emissions are input as grams per second (g/s), and the area of the road as 9 acres (36,400 square meters [m^2]) Because the trucks traveling back and forth along the road and the distance to the west (closest) property boundary changes continuously, the average emissions location is assumed to be the midpoint between the borrow pit and the landfill The distance to the fence line at this point is approximately 1,300 meters (m) The estimated airborne particulate concentrations are summarized in Section 9 3 2

9 3 1 2 *Transport of Fill and Cover Material to the Landfill*

An estimated 243 480 yd^3 of general fill low-permeability soil, vegetative soil and topsoil are needed as fill and cover material At 15 yd^3 per truck and a round trip distance of 5 miles, 81,160 vehicle miles are required during an estimated duration of 500 work-hours. Because the transport and installation of the cover are overlapping activities, and the dumping of the haul truck loads occurs at the landfill, dumping is considered part of the cover installation (Section 9.3 1 3) The estimation of vehicle miles traveled is used as input to the equations for estimating emissions, along with standard default values The emissions from transporting the fill and cover material are displayed in the third column of Table 9-3 Note that more recent estimates indicate a volume of only 229,800 yd^3 of fill and cover material, which is less conservative

Similar to the discussion in Section 9 3 1 1, the transport emissions are input as g/s, the area of emissions is assumed to be 36,400 m^2, and the average distance to the fence line is assumed to be approximately 1,300 m. The estimated airborne particulate concentrations are summarized in Section 9 3 2

9 3 1 3 Installation of Engineered Cover over the Landfill

Installation of the fill and cover material at the landfill includes dumping of the haul truck loads, spreading with two bulldozers, and compaction with two compactors. It is estimated that 500 work-hours are needed to install the material. This duration is input to the equations for dumping haul truck loads and operating bulldozers, along with standard default assumptions The results for installation of fill and cover material, which are presented in the fourth column of Table 9-3, indicate that bulldozer and compactor operations are expected to contribute the majority of emissions for this task.

These estimated emissions are input to the Screen2 air model as g/s; the area of emissions is assumed to be slightly larger than the area of the landfill, 28 acres or 113,300 m^2, and the distance to the fence line is assumed to be approximately 2,550 m The estimated airborne particulate concentrations are summarized in Section 9 3 2.

Emissions of fugitive dust from the cover surface are not addressed quantitatively due to the extensive watering by the contractor The earthen materials of the cover layers are installed in many sub-layers as the work progresses Each sub-layer is watered to ensure proper moisture content and compaction. The exposed cover must be kept moist during workdays, nights, and weekends to prevent drying and cracking (loss of the cover integrity) Keeping the cover moist is typically accomplished through the application of water by watering trucks or by covering the completed sub-layer with a loose lift of moist clay clumps. The clay clumps tend to dry over weekends but have low potential as a source of respirable particulates

9 3 2 Comparison to EPA Air Quality Standards

The state and federal 24-hour PM-10 standards and annual standards are 150 micrograms per cubic meter ($\mu g/m^3$) and 50 $\mu g/m^3$, respectively Table 9-3 presents the modeled and cumulative PM-10 concentrations for the reasonable worst-case scenario

As presented in Table 9-3, under reasonable worst-case conditions, respirable dust concentrations are not expected to exceed the 24-hour standard of 150 $\mu g/m^3$ at the property boundary during the construction activities Similarly, emissions are also expected to be well below the annual standard

9 3 3 Estimation of Potential Methane Emissions

Methane emissions from the OU 7 landfill may be estimated from the volume of the waste contents The approximate volume of waste is expected to be approximately 404,000 yd^3 in 1997, with 124,000 yd^3 of daily soil cover (DOE 1994a) The methane and carbon dioxide content of the soil gas is 60 percent and 40 percent, respectively, indicating anaerobic conditions (DOE 1994a) Concentrations of these gases are highest in the younger, eastern portions of the landfill

Measurements of other landfills with similar conditions support an average emissions factor for landfill gas of 0 1 cubic feet per pound (ft^3/lb) refuse per year (DOE 1994a) This value is typical of landfills in drier climates, as compared to values 10 or more times greater in moist climates (Tchobanoglous *et al* 1992) To use this empirical approach to estimate landfill gas emissions, it is necessary to calculate the weight of landfill contents The density of the individual items in the landfill varies, but the average density of contents is assumed to be approximately 1,000 pounds per cubic yard (lb/yd^3) (DOE 1994a) Multiplying 404,000 yd^3 times 1,000 lb/yd^3 provides a total weight of landfill contents of 4 04E+08 lb

The emission rate of landfill gas is calculated by multiplying the average emissions factor, 0 1 ft^3/lb refuse/yr, by the total weight of the landfill contents 4 04E+08 lb The calculated result, 4 04E+07 lb landfill gas per year, is multiplied times the percent methane content, 60 percent, to determine methane emission rates The resulting average annual emission rate of methane is 2 42E+07 cubic feet per year (ft^3/yr) and is characteristic of the low generation rates of medium size landfills in drier climates (Tchobanoglous *et al* 1992) The result is a conservative overestimate because it assumes the older wastes are producing methane at the same rate as younger wastes The generation rate is also similar to that expected from the new Rocky Flats landfill (DOE 1994h)

9 4 Impact to Surface-Water Quality

9 4 1 Short-Term (Construction Period) Impacts

Construction activities associated with installation of the engineered cover would result in surface disturbance from the clearing of vegetation, excavation, and salvage of topsoil material, blading and leveling of land preceding construction, and the potential for accidental uncovering of contaminated media. Potential impacts to surface water during the construction phase include increased erosion, contamination from inadvertent water contact with uncovered wastes, and subsequent sediment loading to drainage ditches and to the East Landfill Pond during storm events. The absence of vegetative cover and the steepening of slopes result in increased potential for both sheet and channelized run-off and wind and water erosion, resulting in increased sedimentation of ditches and the East Landfill Pond.

The proposed action is limited to constructing an engineered cover system for containment of the landfill waste Construction requires soil obtained from offsite commercial operations Excavation of these borrow materials has impacts similar to those identified above, which are addressed in permits issued for the offsite facilities The proposed construction activities are not expected to have any physical contact with contaminated soils or waste material In the event that equipment and personnel come in contact with potentially contaminated materials during construction, decontamination is performed at the Rocky Flats main decontamination facility to reduce potential impacts to surface water Given the expected conditions, no significant surface-water impacts are expected.

The total area of disturbed soils is approximately 39 acres, including the area of the landfill to be resurfaced (28 acres), haul roads to the offsite borrow areas (9 acres), and miscellaneous construction activities (2 acres). (As previously noted these numbers are preliminary, more recent estimates show a total of 35 acres will be disturbed.) Surface-water control measures are used to minimize surface-water contact with potentially contaminated soils or groundwater and minimize erosional effects during the construction activities Precipitation falling on areas where construction is in progress is diverted to existing surface-water drainage ditches along the north and south boundaries of OU 7 Other shallow ditches are temporarily constructed as needed to prevent sediment-laden stormwater from flowing directly into the East Landfill Pond.

Newly constructed soil surfaces are properly protected using soil terracing, hydromulch, straw-mulch, silt fencing, etc , to minimize soil erosion and surface-water degradation until the required vegetation is established. Average potential loss of soils from newly constructed surfaces due to water erosion is estimated at 6 tons/acre/year for the first two years during and after construction activities This loss is estimated using the Universal Soil Loss Equation (USLE) (SCS 1983 SCS 1984) The use of straw-mulch, adequately spaced silt fences, and other appropriate measures minimizes soil loss and allows the final vegetative cover to be established within 2 to 3 years Potential soil loss from surfaces with established vegetation similar to surrounding areas is estimated at 0 5 tons/acre/year as presented in Appendix J

9 4 2 Long-Term Impacts

Long-term protection is maximized because the proposed IM/IRA engineered cover minimizes infiltration of precipitation and subsequent contact with contaminants and incorporates surface drainage features to prevent run-on/run-off and to provide erosion control The proposed action ultimately results in a decrease in the risk of contaminants reaching surface water by eliminating the possibility of precipitation contacting contaminated soils or waste material Precipitation falling within the boundary of the landfill is drained off the cover and diverted away from the landfill Surface-water drainage from areas outside the landfill boundary would be prevented from flowing onto the landfill and diverted around the boundary Using appropriate surface-reclamation measures adequate vegetation cover should be established on the final surface of the landfill in 2 to 3 years The establishment of vegetative cover on stabilized slopes contours of the landfill and the surrounding disturbed surfaces greatly reduces erosional hazards to levels similar to surrounding areas

Post-closure monitoring activities would include inspections of the landfill surface and associated drainage ditch conditions and will continue for 30 years on a semiannual basis Observations of the vegetative cover and evidence of soil erosion and loss would be included in the routine inspection and maintenance efforts Further erosion-control measures regrading and revegetation would be implemented if maintenance inspections indicate that the landfill surface reclamation is not effective as planned

9 5 Impact to Groundwater Quality

Sources of groundwater recharge to the UHSU include infiltration of precipitation snowmelt storm run-off and downward seepage from the East Landfill Pond The level of groundwater rises annually in response to spring and summer recharge and declines during the remainder of the year Groundwater generally flows to the east however, localized flow follows topographic slopes toward the pond or toward the drainage below the dam Groundwater intermittently flows to the east within the saturated valley-fill alluvium The average depth to groundwater in the landfill mass is approximately 20 feet, the average saturated thickness is 11 feet

9 5 1 Short-Term (Construction Period) Impacts

Local impacts to hydraulic gradient are expected because the engineered cover reduces surface-water infiltration, however, enhanced groundwater quality results from reducing water flow through waste The proposed slurry wall installed as part of the landfill maintenance program is expected to greatly reduce the volume of upgradient groundwater flowing through the landfill mass and the groundwater-flow direction in the vicinity of the landfill The engineered cover system also minimizes outflow to surface water

An estimate of potential infiltration and percolation through the proposed engineered cover system was performed using the HELP Version 3 computer model (EPA 1994b) A summary of the HELP modeling and model runs is presented in Appendix G The results of the HELP model computations for the proposed engineered cover design indicate that the potential average annual leakage through the engineered cover is approximately 0 00016 inches/year The leakage rate of the existing interim soil cover is estimated to be 1 4 inches/year This indicates that the engineered cover would reduce the amount of infiltration that would potentially flow through the landfill waste by 99 99 percent The HELP model does not account for capillary flow in the variably saturated components, and as a consequence, provides a conservative estimate of percolation through the engineered cover

As described in Section 2 3, a water balance was performed for the landfill mass using the MODFLOW (McDonald and Harbough 1991) computer model with site-specific data for the no-action alternative The water balance calculations indicate that approximately 60 percent of the inflow to the landfill is upgradient groundwater from the alluvium and 40 percent is recharge by infiltration of precipitation. Most of the groundwater inflow (87 percent) occurs on the north side of the landfill. Contributions from the west side (6 percent) and the south side (7 percent) are relatively insignificant. The water balance shows that both the proposed engineered cover system and proposed slurry wall on the north side of the landfill would minimize additional water inflow and leachate generation Water balance calculations are presented in Appendix C.

The surface-water drainage ditch would divert stormwater run-off around the landfill, resulting in further reduction of surface infiltration and groundwater recharge through waste material

9 5 2 Long-Term Impacts

The eventual effects of constructing the low-permeability cover would be a 99 99-percent reduction in precipitation reaching the waste This would cause a significant reduction in saturated thickness of the waste material In conjunction with the proposed slurry wall diverting upgradient groundwater around the landfill mass and the reduction of surface-water infiltration a 96-percent reduction of water flow through the waste mass is expected A significant reduction of saturated waste would result in reduced leachate generation and migration which would ultimately reduce contaminant loading to groundwater

The overall impact to groundwater from the proposed IM/IRA would be enhanced groundwater quality at the site No significant negative impact to groundwater qualitv is expected from the proposed action

9 6 Commitment of Irreversible and Irretrievable Resources

The proposed IM/IRA results in some permanent commitments of resources but is not expected to result in a substantial loss of valuable resources Most of the resources used for construction of the engineered cover are permanently committed to the implementation of the remedial action Irreversible and irretrievable resources are defined as resources that are either consumed committed or lost For OU 7 irreversible and irretrievable resources include the following

- Consumptive use of geological resources (e g , quarried rock clay sand, and gravel for road construction) is required for construction activities Supplies of these materials are provided by the construction contractor The preferred alternative requires a permanent commitment of 243,480 yd^3 of fill topsoil, and vegetative cover from offsite sources to construct the final landfill cover However adequate supplies are available without affecting local demand for these products

- Fuel consumed in construction equipment and vehicles for the construction of the landfill cover will not be recovered

- Soil at OU 7 is disturbed by construction activities Many impacts are temporary pending completion of remedial activities and associated restoration programs

- Resources that underlie the landfill are lost However there appear to be no commercially exploitable mineral resources at Rocky Flats (DOE 1980)

- Commitment of up to 28 acres of land as a landfill permanently commits and constrains the area to limited land-use options

- Wetlands and associated natural resources are reduced at OU 7 but will be mitigated offsite Long-term direct impacts to the floodplain resulting in changes of flood elevations do not occur

- Long-term commitment of personnel and funds to perform post-closure inspection maintenance and monitoring activities

- Maintenance activities are performed as necessary Long-term negative environmental impacts are not expected to occur from the OU 7 selected remedy Monitoring and periodic site inspections would be performed to ensure long-term protection of human health and the environment.

As a result of the constructed engineered cover and the network of monitoring wells to remain in-place, commercial, industrial, and residential land use are permanently prohibited within the landfill boundaries Appropriate landfill surface reclamation results in an acceptable appearance of the remediated site, and the ecological succession of the closed landfill and adjacent land are improved by surface revegetation Vegetation and habitat eventually become similar to surrounding areas

Incidental resources that are consumed, committed, or lost on a temporary and/or partial basis during construction include construction personnel and equipment, the construction water source, and the construction materials used for equipment haul roads During construction of the proposed IM/IRA, it is expected that 20 to 35 personnel are required for the duration of the construction activities (less than 1 year) The raw water supply available at Rocky Flats is used to conserve water that is treated by the onsite water treatment plant The compacted soil portion of the engineered cover system would require 8 to 10 million gallons of water during construction activities Approximately 7,000 to 8,000 yd^3 of material are temporarily used for construction of haul roads This material is salvaged and available for reuse

9 7 Impact to Transportation

The proposed IM/IRA is expected to cause minimal direct and indirect impacts to the transportation systems in and around Rocky Flats Most materials necessary for the construction of the engineered cover system are transported using tandem semi-trucks from a nearby offsite borrow source (EG&G 1994d). A construction haul road (approximately 2 5 miles long) is constructed from the offsite borrow pit to the site The construction haul road is paved with aggregate road base only The new haul road results in no impact to State Highway 93 west of Rocky Flats Transport of other construction materials and supplies, as well as construction mobilization equipment and construction personnel, use existing transportation systems The traffic impact from these activities are expected to be minor

9 8 Impact to Cultural, Historical, and Archaeological Resources

No known significant cultural, historical, or archaeological resources are expected to be impacted by the proposed IM/IRA activities (CHS 1992)

9 9 Cumulative Impacts

Cumulative impacts may result from the combination of incremental impacts from past present and reasonably foreseeable future actions Cumulative impacts could have the potential of being more significant than the individual impacts due to synergism between types and areas of impact or the individual impacts collectively resulting in significant effects to the environment

There are no other activities scheduled for the OU 7 area that are expected to cause significant impacts Ongoing maintenance and groundwater and landfill gas monitoring are limited to short-period events Construction activities at other OUs at Rocky Flats will also continue in the future but these activities are not likely to overlap due to the lengthy process of design approval and implementation Therefore expected short-term future cumulative effects are substantial Long-term cumulative impacts (i e IM/IRA activities in conjunction with other Rocky Flats restoration activities) facilitate future beneficial use of Rocky Flats land and fulfill mandated cleanup objectives

The following types of cumulative impacts may occur

- Additional construction personnel have an additive effect on existing workload for site operations This effect is short-term however maintenance and monitoring activities would continue during the post-closure period The anticipated workload of these personnel would be significantly less than what is currently required

- Potential waste generated by this proposed action is very limited and may include small amounts of soil from construction activities potentially contaminated water from decontamination operations and water generated from sampling activities during groundwater monitoring The small amounts of waste generated are insignificant and any impacts are negligible

- Wetlands mitigation is necessary to replace the portion of the East Landfill Pond that is covered by implementation of the engineered cover system Potential cumulative impacts such as mitigation of other onsite wetland areas, can be expected because the mitigation plan is to use acreage from the offsite wetlands mitigation bank proposed for development adjacent to the Standley Lake Protection Project pending final approval of the project

9 10 Comparison of the Preferred IM/IRA to the No-Action Alternative

The potential adverse and beneficial impacts of the Preferred Alternative and No Action are expected to be significantly different in the magnitude to which they affect the quality of the environment Implementation of the proposed IM/IRA is not expected to have any substantial adverse impacts to human health or the environment

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and is consistent with long-term remediation goals for Rocky Flats Where potential impacts may occur, effects are expected to be small, temporary and appropriate mitigation measures implemented

The no-action alternative could have potentially adverse impacts to both human health and the environment by allowing landfill waste to remain uncovered, resulting in continued leachate generation and migration, and potentially resulting in exposure to human and ecological receptors Therefore, the no-action alternative potentially allows for direct or indirect receptor intake A comparison of how the two alternatives could impact human health and the environment is presented in Table 9-4

Table 9-1
Uncertainties Associated with Assessing Risk

Issue	Remarks	Potential Impact on Exposure
Assumptions regarding duration of work activities	Actual durations of activities at OU 7 may differ from planning assumptions	Slightly overestimate or underestimate exposure
Assumptions regarding construction materials	The potential for particulate emissions from actual construction materials used at OU 7 may differ from planning assumptions	Slightly overestimate or underestimate exposure
Assumption that construction activities will not involve intrusion into landfill contents	Intrusion into landfill contents is not anticipated However if this became necessary or occurred accidentally worker protection would be addressed by health and safety precautions	Slightly underestimate exposure
Estimation of emission rates	Emission rates are estimated for construction activities using empirically derived EPA algorithms	Moderately overestimate or underestimate exposure
Use of a screening level transport model (gaussian dispersion in air)	Screening level models are based on conservative bounding assumptions and algorithms	Moderately overestimate exposure
Assumptions about receptor locations	Worker exposure may vary depending on the proximity to the dust emission sources Dust concentrations were modeled at the Rocky Flats boundary but current residential receptors are located more than 1 mile away from this point	Moderately overestimate exposure
Occupational exposure limit for nuisance dust	Limits are based on observation of human exposure and are reasonable upper bound values	Moderately overestimate exposure
Heavy equipment and vehicle accident risk	These are addressed by occupational regulations Transportation will be on private roads at low speeds	Slightly underestimate or overestimate exposure

Table 9-2
Fugitive-Dust Emissions from IM/IRA Construction

[illegible]	[illegible]	[illegible]	[illegible]
Haul Truck	0 132	0.721	NA
Dumping Load	0 001	NA	0.010
Bulldozer	0.238	NA	0.238
Total	0.37	0.72	0.25

Table 9-3
Modeled and Cumulative PM-10 Concentrations for IM/IRA Construction

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Haul Road Construction	24-hour	0.37	26.1	47	73
	Annual		2.1	15	17
Transport of Fill and Cover Material	24-hour	0.72	52.1	47	99
	Annual		8.9	15	24
Installation of Engineered Cover	24-hour	0.25	6.6	47	54
	Annual		1.1	15	16

Notes

Rocky Flats Plant Site Environmental Report (DOE 1993c).

[2] Cumulative concentrations are estimated by adding the modeled concentrations to the measured PM-10 background concentrations.

Definitions

N/A not applicable
g/s grams per second
μg/m[3] micrograms per cubic meter

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Table 9-4
Summary of Potential Impacts
Preferred IM/IRA versus No Action

Impact	Preferred IM/IRA	No-Action
Human Health	Reduce or eliminate existing risks to long term exposure to potentially contaminated soil Short term risks of exposure to construction workers Rocky Flats workers and public from construction activities (e g increased fugitive dust increased traffic) Potential short term risks to personnel as a result of inadvertently disturbing landfill waste areas with high levels of contamination Risk to personnel as a result of contacting contaminants during groundwater monitoring and sampling	Risks to onsite and offsite persons as a result of long term exposure to potential contaminated soil airborne contaminants contaminated surface water and groundwater No risks of exposure to construction workers Potential risks to personnel as a result of inadvertently disturbing landfill waste areas with high levels of contamination Potential risks of contaminating groundwater and surface water downgradient of the landfill
Environment	Short term disturbance of the site and immediate area during construction activities less than 39 acres will be disturbed by construction activities Short term disturbance of the borrow site where soil materials will be obtained for construction of the cover Increases in local traffic fugitive dust combusted fuels due to construction activities potential erosion due to surface disturbances during construction and topographical changes of the landfill and the borrow area A portion of the East Landfill Pond wetlands area is covered by the engineered cover system Wetlands mitigation involve an exchange from an offsite wetlands mitigation bank No floodplains are affected Potential habitat of the Preble s meadow jumping mouse is covered by the placement of the engineered cover	Contaminated media remains in place with potential for exposure to humans and environment Uncontrolled contaminants and waste could negatively affect vegetation and wildlife and impact receiving surface water and groundwater The East Landfill Pond wetlands area is potentially affected by leachate and/or groundwater contamination No floodplain critical habitats or threatened and endangered species are affected
Air Quality	Landfill off gases could potentially impact the air quality at and near OU 7 The proposed engineered cover system includes a gas collection layer that provides control of landfill off gases as well as the option for future treatment if necessary The construction of the haul road used to transport fill material affects air quality during construction activities However control measures are implemented to minimize the effects The material hauling and construction of the engineered cover would affect air quality during construction activities However control measures are implemented to minimize the effects	Landfill off gases could potentially impact the air quality at and near OU 7 and continue to be uncontrolled No increase in dust emissions

Table 9-4
Summary of Potential Impacts·
Preferred IM/IRA versus No Action

Impact	Preferred IM/IRA	No Action
Groundwater Quality	The eventual effect of constructing the low-permeability cover is a significant reduction of the saturated waste, leachate generation, migration of contaminants and contaminant loading. Potential effects on local hydrogeologic characteristics by reducing groundwater inflow and changing topography in a groundwater recharge area.	Downward migration of water through the waste continues resulting in leachate generation. Potential for contaminant migration to downgradient groundwater
Surface-Water Quality	Coverage of waste under engineered cover minimizes or eliminates potential for contaminated surface-water run-off Construction activities disturb surfaces and erosion from storm run-off would impact surface-water quality until vegetation is established.	Potential for surface-water run-off to contact waste and transport contamination into surface-water bodies.
Cultural, Historical and Archaeological Resources	No resources present.	No resources present.
Transportation	Minor increase in traffic volume and patterns during construction activities negligible impact on surrounding transportation infrastructure.	No increase in traffic volume
Short-Term vs. Long-Term Uses	Implementation of the proposed IM/IRA is not expected to have substantial adverse short-term or long-term impacts to human health or the environment. The IM/IRA is consistent with long-term remediation goals for Rocky Flats	The no-action alternative has no significant short-term impacts, with the exception of land use Wetlands and wildlife habitat would remain undamaged. The no-action alternative has potentially adverse long-term impacts to both human health and the environment because contaminated media remaining in place may result in potential exposure.
Irreversible and Irretrievable Resource Commitments	Clean fill from offsite borrow areas, construction materials, and very limited land use or resources beneath the site. Resources to implement the proposed IM/IRA are lost or consumed (i.e., capital, fuel, manhours, construction, water, etc.)	Very limited land use and resources beneath the site.
Cumulative Impacts	Implementation of the IM/IRA is consistent with the long-term mission of remediating Rocky Flats Implementation may interfere slightly with other activities in progress at Rocky Flats Short-term increases in personnel at the site would result from the implementation of the IM/IRA. Wetlands mitigation is necessary.	Implementation of the no-action alternative impedes or delays long-term sitewide remediation goals. The no-action alternative has potentially adverse impacts to both human health and the environment because contaminated media are contained and not removed such that the exposure to humans and environment exist.

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Table 9-4
Summary of Potential Impacts
Preferred IM/IRA versus No Action

Impact	Preferred IM/IRA	No-Action
Mitigation Measures	Because a portion of the existing wetlands at the East Landfill Pond will be under the engineered cover it is necessary to mitigate lost or injured wetlands Potential mitigation of surface run off and erosion from the construction area may be necessary Potential mitigation of Preble s meadow jumping mouse habitat if needed	Future mitigation of leachate may be necessary

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10 References

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DRAFT PROPOSED PLAN AND DRAFT MODIFICATION OF COLORADO HAZARDOUS WASTE PERMIT FOR ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE OPERABLE UNIT 7 PRESENT LANDFILL

United States Department of Energy (DOE) | Jefferson County Colorado | August 24 1995

DOE Announces Preferred Alternative for OU 7 Present Landfill

The responsibility for the cleanup of the Rocky Flats Environmental Technology Site (Rocky Flats) (formerly known as the Rocky Flats Plant) has been assigned to the United States Department of Energy (DOE) The site is located north of Golden Colorado in Jefferson County

Cleanup at Rocky Flats is being administered under both the ***Comprehensive Environmental Response Compensation and Liability Act (CERCLA)***[1] and the ***Resource Conservation and Recovery Act (RCRA)*** The specific requirements and responsibilities for Rocky Flats cleanup are outlined in the ***Interagency Agreement (IAG)*** among DOE the United States Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE) CDPHE is the lead regulatory agency for this action

The subject of this document which is a combination ***Corrective and Remedial Action Proposed Plan (PP)*** and Draft Hazardous Waste Permit Modification is Rocky Flats ***Operable Unit*** (OU) 7 the Present Landfill OU 7 consists of four ***individual hazardous substance sites (IHSSs)*** including and associated with the Present Landfill This PP applies only to OU 7

The purpose of the PP is to announce DOE s ***preferred alternative*** for OU 7 The PP serves as the basis for the ***Corrective Action Decision/ Record of Decision (CAD/ROD)*** for OU 7 The Draft Permit Modification is used to incorporate remedial action decisions at Rocky Flats into the site s RCRA permit CDPHE issues the Final Hazardous Waste Permit Modification after the remedial decision process is complete Closure requirements for OU 7 under RCRA and the Colorado Hazardous Waste Act (CHWA) can be achieved through two actions an accelerated action for passive leachate collection and treatment and an interim/final action of landfill containment Landfill containment is the preferred remedy for CERCLA municipal landfills and can thus be pursued as a presumptive remedy The accelerated action for passive leachate collection and treatment was approved by EPA and CDPHE in June 1995 Passive leachate collection will be completed by December 1995 This PP addresses the presumptive remedy for containment of the landfill source area and also addresses pathways and potentially contaminated media outside the source area resulting in a comprehensive plan for closure of OU 7

MARK YOUR CALENDAR OPPORTUNITIES FOR PUBLIC INVOLVEMENT

Public Comment Period December 15 1995 February 16 1996

Public Hearing December ___ 1995
Time 7 00 8 00 PM
Location Arvada Center 6901 Wadsworth Blvd Arvada

Send Comments to
DOE s External Affairs Office
P O Box 928 Golden CO 80402 0928

W Carl Spreng Geologist
Colorado Department of Public Health and Environment HMWMD HWC B2
4300 Cherry Creek Drive South
Denver CO 80222 1530
Phone (303) 692 3358

Information Repositories

Rocky Flats Public Reading Room
Front Range Community College
Level B
3645 W 112th Avenue
Westminster CO 80030

Colorado Department of Public Health and Environment
Hazardous Materials and Waste Management Division
4300 Cherry Creek Drive South
Denver CO 80222 1530

Rocky Flats Citizens Advisory Board
9035 Wadsworth Parkway
Suite 2250
Westminster CO 80021

Standley Lake Library
8485 Kipling
Arvada, CO 80005

U S Environmental Protection Agency
Superfund Records Center
999 18th Street 5th floor
Denver CO 80202 2466

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[1] Words shown in italics on the first mention are defined in the glossary at the end of this Proposed Plan

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The preferred alternative for landfill containment proposed in this plan is Alternative 7 Single-Barrier Flexible Membrane Cover (FMC) with Low Permeability Soil. This alternative is one of nine originally identified and represents the best solution relative to the CERCLA evaluation criteria. The nine (remedial) alternatives were screened based on effectiveness, implementability and cost. Four of the nine alternatives were carried through the EPA detailed analysis of alternatives process using seven of the nine CERCLA evaluation criteria. The final two criteria, regulatory and community acceptance will be addressed in the CAD/ROD The three alternatives considered in detail in addition to Alternative 7 include Alternative 1 No Action Alternative 5 Single Barrier FMC Cover and Alternative 9 Composite-Barrier FMC with Clay Cover

The alternative presented here is DOE s recommended alternative for OU 7 DOE CDPHE, and EPA will make the final remedy selection after considering comments from the public A summary of responses to comments will be prepared and included in the ***Responsiveness Summary*** section of the CAD/ROD The CAD/ROD will be prepared and published by DOE following the public comment period

PUBLIC INVOLVEMENT PROCESS

Community acceptance is one of the criteria that DOE and the regulatory agencies must evaluate during the process of selecting a final remedy Evaluation of community acceptance can be accomplished through a formal public involvement program. DOE s program consists of (1) continuing dialogue with citizens on issues of concern such as the OU 7 Draft Phase I ***Interim Measure/Interim Remedial Action*** (IM/IRA) Decision Document (DD) and Closure Plan (2) seeking citizen participation in the selection of the final remedy at the site This PP is issued for public input in support of both components of DOE's process. Public interaction is critical to the successful implementation of the RCRA/CERCLA programs

Although this plan identifies a single-barrier FMC cap with a low permeability soil layer as the preferred alternative for OU 7 the public is encouraged to review and comment on all the alternatives The final alternative may be different from the preferred alternative depending on new information or arguments that the agencies consider as a result of public comments. Details on the individual alternatives can be found in the OU 7 Draft Phase I IM/IRA DD located in the information repositories listed on page 1 of this plan

A public comment period will be held for the PP and Draft Permit Modification The public comment period will be from December 15 1995 to February 16 1996 A public hearing will be held on December __ 1995 Comments on the PP Draft Permit Modification, and OU 7 Draft Phase I IM/IRA DD may be submitted orally or in writing at the public hearing. Alternatively written comments, postmarked no later than February 12 1996 can be sent to the addresses listed on page 1 of this plan.

Upon timely request, the comment period may be extended Such a request must be submitted in writing to DOE, postmarked no later than February 12 1996 FAILURE TO RAISE AN ISSUE OR PROVIDE INFORMATION DURING THE PUBLIC COMMENT PERIOD MAY PREVENT THE PUBLIC FROM RAISING THAT ISSUE OR SUBMITTING SUCH INFORMATION IN AN APPEAL OF THE AGENCIES FINAL DECISION

SITE BACKGROUND

Rocky Flats is located in northern Jefferson County Colorado (see Figure 1) Rocky Flats occupies approximately 6,550 acres of federal land and is a government-owned contractor-operated facility in the nationwide nuclear weapons production complex. DOE's former mission at Rocky Flats was to produce components for nuclear weapons from plutonium, uranium, and non-radioactive materials. The current mission is to manage wastes and materials and to cleanup and convert the Rocky Flats site to beneficial use in a manner that is safe, environmentally and socially responsible, physically secure, and cost-effective

Most plant buildings are located within the Rocky Flats industrial area, which occupies approximately 400 acres This area is surrounded by a buffer zone of approximately 6,150 acres. OU 7, the Present Landfill, is located in the Rocky Flats buffer zone north of the industrial area.

OU 7 began receiving hazardous and nonhazardous plant waste in 1968 Since 1986, only nonhazardous plant waste such as office trash construction debris, scrap metal dried sanitary sewage sludge and miscellaneous containers has been disposed in the landfill Landfill operations will continue until the new landfill opens in 1997 As is common practice at municipal landfills, waste delivered to the landfill is spread across the work area, compacted, and covered with soil

OU 7 includes four areas previously identified as IHSSs where past operational practices may have resulted in environmental impacts (Figure 2) Brief descriptions of the OU 7 IHSSs are presented below

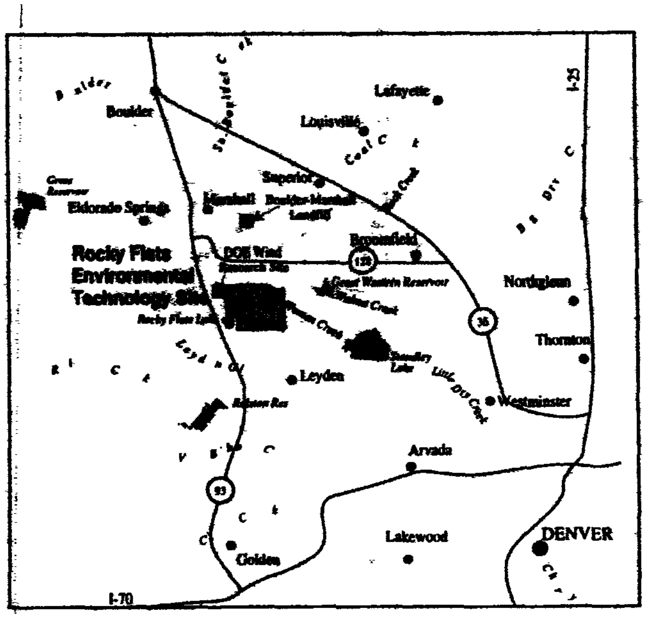

Figure 1

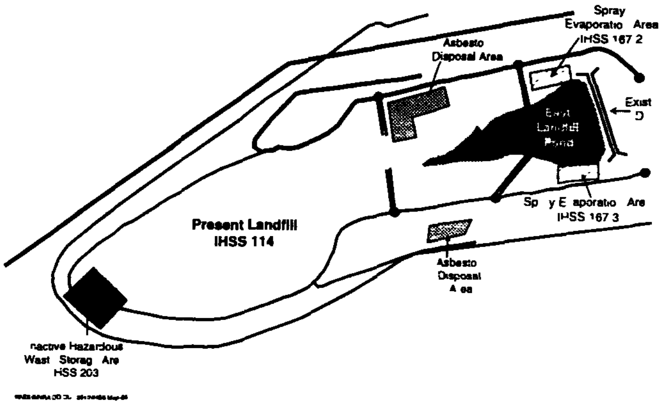

Figure 2

- **IHSS 114, Present Landfill** The Present Landfill is located north of the industrial area on the western end of No Name Gulch It encompasses approximately 20 acres Initially soils were hauled in from an onsite borrow area and deposited in the natural drainage to provide a 5 foot thick base to start landfilling Rocky Flats hazardous waste was disposed at the landfill between 1968 and 1986 nonhazardous wastes have been disposed at the landfill since 1968 Asbestos was disposed in pits near the eastern edge of the landfill

- **IHSS 203 Inactive Hazardous Waste Storage Area.** The Inactive Hazardous Waste Storage Area is located at the southwest corner of the Present Landfill The area was actively used between 1986 and 1987 as a hazardous waste storage area for both drummed liquids and solids Cargo containers on the ground contained drums with liquid waste solid waste in drums was stored outside the cargo containers All drums and cargo containers were removed in May 1987

- **IHSSs 167 2 and 167.3 Spray Evaporation Areas** These IHSSs are two discrete areas adjacent to the landfill that received spray waters from the East Landfill Pond between 1975 and 1994 Waters collected in the East Landfill Pond were periodically sprayed at the two locations to maintain the pond water level at 75 percent capacity

Several interim response actions have been implemented at OU 7 since 1973 to control landfill leachate They include construction of a surface water diversion ditch two detention ponds east of the landfill a subsurface groundwater intercept system and a subsurface leachate collection trench A slurry wall will be constructed on the north side of the landfill in fiscal year 1996 to address failure of the existing system

SUMMARY OF SITE RISKS

The ***risks*** to human health and the environment associated with OU 7 were characterized through two phases of field investigations and are summarized in the OU 7 Draft Phase I IM/IRA DD Under the presumptive remedy approach a quantitative ***baseline risk assessment*** is not necessary if the containment remedy addresses pathways and contaminants of concern associated with the source Rather all potential exposure pathways can be identified using a conceptual site model and compared to the pathways addressed by a presumptive remedy These comparisons are provided in the OU 7 Draft Phase I IM/IRA DD

The risks present in potential exposure pathways at OU 7 that will not be addressed by the presumptive remedy were quantified using a focused risk assessment approach to determine if a response action is necessary The focused risk assessment process consists of comparing the maximum concentration of each PCOC occurring at OU 7 against the sitewide preliminary remediation goal (PRG) established for Rocky Flats PCOCs occurring at concentrations exceeding the PRG are then subjected to the focused quantitative risk assessment analysis including quantification of exposure and toxicities This process is undertaken for both human and ecological receptors No significant environmental risks (outside of the acceptable range) were identified beyond the proposed landfill containment Average concentrations of PCOCs were also compared to ***applicable or relevant and appropriate requirements (ARARs)*** Final ***Remedial Action Objectives (RAOs)*** were developed by eliminating preliminary RAOs for which there is no risk to the potential receptor analytes do not exceed ARARs or the exposure pathway is incomplete Post closure monitoring for 30 years is included as part of the PP in accordance with CHWA requirements to confirm that risk remains in the acceptable range

The following ***RAOs*** have been set in accordance with EPA guidance for protection of human health and environmental receptors from potential adverse effects associated with the landfill

1 prevent direct contact with landfill contents
2 minimize infiltration and resulting contaminant leaching to groundwater
3 control surface water run off and erosion
4 control landfill gas (treat as needed)
5 remediate wetland areas (as needed)

These RAOs were used to formulate appropriate remedial action alternatives for OU 7

SUMMARY OF REMEDIAL ACTION ALTERNATIVES

The following remedial action alternatives were subjected to a detailed analysis to identify a preferred remedy for OU 7

- **Alternative 1 No Action.** This alternative as required under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provides a baseline for comparison of other alternatives Under this alternative the landfill remains as is and the existing interim soil cover serves as the final cover

- **Alternative 5 Single-Barrier FMC Cover** This alternative consists of a single-barrier FMC cover and institutional controls The membrane cover has a permeability of 1×10^{13} cm/sec and is underlain by a 6-inch soil bedding layer and a geocomposite gas-collection layer. This soil has a permeability of 1×10^{-2} cm/sec The cover is overlain by a geocomposite lateral drainage layer and a 3 foot vegetative layer

- **Alternative 7 Single-Barrier FMC with a Low Permeability Soil Cover** This alternative parallels Alternative 5 in every feature except for the soil layer immediately underlying the membrane cover Alternative 7 proposes a 12 inch layer of soil with a permeability of 1×10^{5} cm/sec reducing the overall potential for migration through the cover

- **Alternative 9· Composite-Barrier FMC and Clay Cover** This alternative includes a membrane cover underlain by 24 inches of compacted clay with a permeability of 1×10^{-7} cm/sec and a geocomposite gas-collection layer The membrane is overlain with a geocomposite lateral drainage layer and a 3 foot vegetative layer The alternative also includes institutional controls. This composite cover follows EPA guidance for a RCRA Subtitle C cover

All alternatives are based on the assumption that the slurry wall maintenance action is complete

SUMMARY OF DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives conducted as part of the IM/IRA decision process evaluated each of the alternatives with respect to nine criteria identified by the NCP Figure 3 graphically summarizes comparisons of the alternatives Each of the criteria is discussed briefly below

1 **OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT** All of the alternatives, with the exception of the no-action alternative, meet the criteria for overall protection of human health and the environment

2 **COMPLIANCE WITH ARARS** Each of the alternatives for containment achieve the same level of compliance with ARARs The surface water ARAR for manganese is not addressed by any of the alternatives However manganese is naturally occurring in sediments in the East Landfill Pond Discharge of leachate into the pond may have resulted in mobilization of manganese from the sediments Containment of leachate under the cap is expected to reduce concentrations of manganese In addition, results of the focused risk assessments have shown that there is no associated risk to human or ecological receptors from pond water Groundwater ARARs for nitrate/nitrite sulfate, and selenium are not addressed by any of the alternatives However the cap will reduce recharge to groundwater and as a result, contaminant migration away from the landfill is expected to be minimal Potential exposure pathways associated with groundwater are incomplete because there are no plans for future development of groundwater at OU 7

3 **REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT** Because there is no treatment in any of the alternatives this criteria does not apply However, there may be some decrease in toxicity and mobility over time due to natural attenuation In addition the cap minimizes infiltration into the waste thus decreasing generation and migration of leachate.

4 **LONG-TERM EFFECTIVENESS AND PERMANENCE.** Long term effectiveness and permanence is very similar between the three cover alternatives. Alternative 7, with the low permeability soil affords the highest degree of long-term protection due to its increased resistance to eventual desiccation

5 **SHORT-TERM EFFECTIVENESS.** Short term effectiveness is not variable between the cover alternatives. Alternative 5 is deemed slightly better because it involves the least soil quantities and therefore poses the lesser risk to construction workers from dust generation

6 **IMPLEMENTABILITY** Implementability is comparable among the three cover alternatives Alternative 7 is the most reliable and Alternative 9 is the most difficult to construct and maintain.

7 **COST** Cost is a significant distinguishing factor among the three containment alternatives. The total present worth costs are

Alternative 1	$0
Alternative 5	$9 469 100
Alternative 7	$10,149,000
Alternative 9	$12,103,600

8 **REGULATORY AGENCY ACCEPTANCE.** This criterion is evaluated after the public involvement process, before the final decisions regarding the PP

9 **COMMUNITY ACCEPTANCE.** This criterion is evaluated after the public involvement process before the final decisions regarding the PP

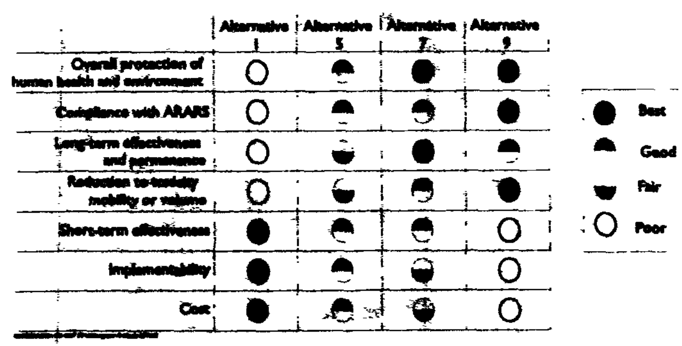

Figure 3

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SUMMARY OF PREFERRED ALTERNATIVE

The OU 7 detailed analysis of alternatives concludes that Alternative 7 the Single Barrier FMC with Low Permeability Soil Cover best meets the RAOs of the IM/IRA Major factors including the long term and short term effectiveness and implementability coupled with the technical performance made this the preferred alternative In addition to the cover and the institutional controls the IM/IRA document proposes a 30 year post closure maintenance and monitoring plan to be implemented once the cover is installed This plan includes semiannual upgradient and downgradient groundwater monitoring quarterly gas monitoring and annual cover surveys and facility inspections The OU 7 Closure and Post Closure Plans are included in the OU 7 Draft Phase I IM/IRA DD located in the information repositories listed on page 1 of this plan

GLOSSARY

Applicable or Relevant and Appropriate Requirements (ARARs) ARARs are criteria standards or limitations promulgated under state or federal law that may be selected to establish cleanup levels a remedial action is to obtain

Baseline Risk Assessment (BRA) An assessment of the risks to human health and the environment at a site The methodology employed in risk assessment uses contaminant concentrations and potential exposure routes to quantify risks associated with present and future site conditions

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) A law passed in 1980 and amended in 1986 to establish a program to identify abandoned hazardous waste sites ensure that they are cleaned up and evaluate damages to natural resources

Corrective Action Decision/Record of Decision (CAD/ROD) A public document that explains which cleanup alternative(s) are selected at a RCRA/CERCLA site The CAD/ROD is based on information obtained from the RFI/RI the CMS/FS and community participation

Corrective and Remedial Action Proposed Plan (PP) The public document that first introduces the lead agency s preferred alternative for site remediation The PP is produced through the cooperation of the lead and regulatory agencies and is reviewed by the public

Individual Hazardous Substance Site (IHSS) An area that may be contaminated as a result of previous operations and disposal practices

Interagency Agreement (IAG) The January 22 1991 document prepared by representatives from DOE EPA and CDPHE It presents the objectives and general protocols for addressing the cleanup or evaluation of each of the operable units at Rocky Flats

Interim Measure/Interim Remedial Action (IM/IRA) An early action taken to control a release or threatened release of hazardous substances

Operable Unit (OU) A term defined by CERCLA used to describe a certain portion of a CERCLA site An operable unit may be established based on a particular type of contamination contaminated media (e g soils water) source of contamination and/or geographical location

Preferred Alternative The preliminary recommendation that is judged to best address the CERCLA criteria of overall protection of human health and environment compliance with ARARs long and short term effectiveness implementability cost and the reduction of contaminant toxicity mobility or volume through treatment

Remedial Action Objectives (RAOs) RAOs are medium specific goals for protecting human health and the environment

Resource Conservation and Recovery Act (RCRA) A law passed in 1976 by the U S Congress to require the cradle to grave management of hazardous wastes CDPHE through the Hazardous Materials and Waste Management Division implements RCRA in Colorado

Responsiveness Summary The part of the CAD/ROD that summarizes public and agency comments and provides responses to those comments

Risk The likelihood of an adverse effect on the health of a human or ecological population as a result of exposure to chemical and/or radiological constituents

Phase I IM/IRA Decision Document for Operable Unit 7 Present Landfill

Draft Report

Appendices

August 24, 1995

U S Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

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Table of Contents

SOIL TYPES

Major Divisions			Letter	Symbol	Description
Coarse Grained Soils	Gravel and Gravelly Soils	Clean Gravels	GW		Well graded gravels or gravel sand mixtures little or no fines Uc >4 (lab only)
		(<5% fines)	GP		Poorly graded gravels or gravel sand mixtures little or no fines
		Gravel with Fines	GM		Silty gravels gravel-sand-silt mixtures
	More than 50% of coarse fraction retained on no 4 sieve	(>12% fines)	GC		Clayey gravels gravel-sand-clay mixtures.
	Sand and Sandy Soils	Clean Sand	SW		Well graded sands or gravelly sands little or no fines. Uc >6 (lab only)
		(<5% fines)	SP		Poorly-graded sands or gravelly sands little or no fines
More than 50% of material is larger than no 200 sieve size		Sands with Fines	SM		Silty sands sand-silt mixtures
	More than 50% of coarse fraction passed no 4 sieve	(>12% fines)	SC		Clayey sands sand-clay mixtures.
Fine Grained Soils	Silts and Clays	Low Plasticity	ML		Inorganic silts and very fine sands rock flour silty or clayey fine sands or clayey silts with slight plasticity
			CL		Inorganic clays of low to medium plasticity gravelly clays sandy clays silty clays lean clays
			OL		Organic silts and organic silty clays of low plasticity
		High Plasticity	MH		Inorganic silts, micaceous or diatomaceous fine sand or silty soils.
More than 50% of material is smaller than no 200 sieve size			CH		Inorganic clays of high plasticity fat clays
			OH		Organic clays of medium to high plasticity organic silts
Highly Organic Soils			PT		Peat, humus swamp soils with high organic contents

After Unified Soil Classification System

ROCK TYPES

Division	Lithology Symbol	Name
CLAYSTONE		Claystone
		Silty Claystone
		Sandy Claystone
SILTSTONE		Siltstone
		Clayey Siltstone
		Sandy Siltstone
SANDSTONE		Sandstone
		Silty Sandstone
		Clayey Sandstone
		Coal
		Ironstone
		Caliche

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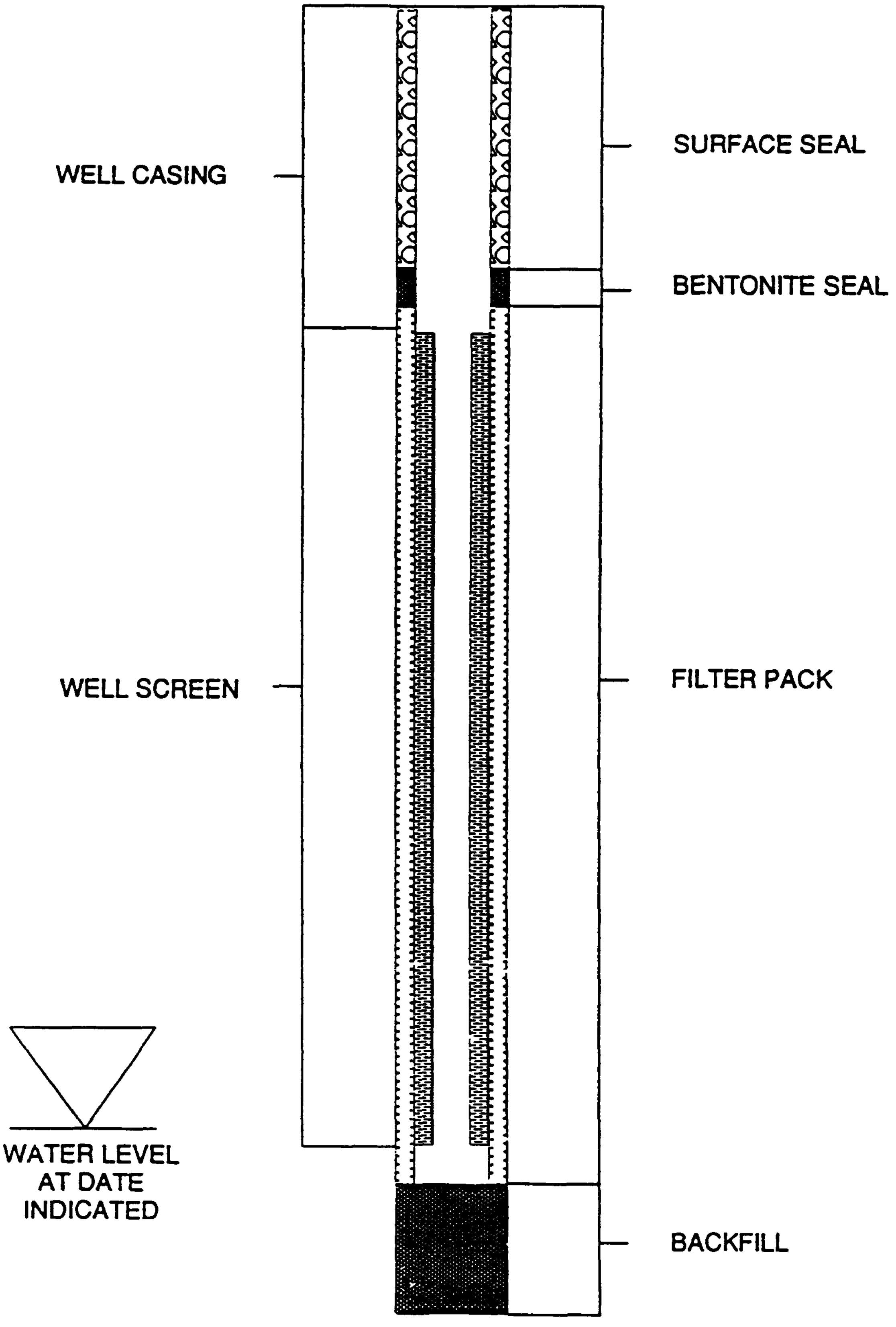
WELL OR PIEZOMETER CONSTRUCTION



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STATE PLANE COORDINATE — NORTH 753013 — EAST 2085106

TOTAL DEPTH (FT) 10 00 — AREA 007 PRESENT LANDFILL — LOCATOR NUMBER 0

GROUND ELEVATION (FT) 5897 90 — CASING DIAMETER (IN) — BOREHOLE DIAMETER (IN) 7 00

PROJECT NUMBER 007-RFI/RI — GEOLOGIST D L RIGOR — DATE DRILLED 10/12/94

LOG OF BORING NUMBER

52694

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 10 0 TOP OF BEDROCK 4 0 TOP OF UN WEATHERED BEDROCK 7 0

CORE LOGGER J A HIGGINS DRILLED WITH HOLLOW STEM AUGER NO SAMPLES TAKEN

CHEMICAL SAMPLE DEPTH — GRADATIONAL DEPTH — SAMPLE NUMBER — SAMPLE GRAIN SIZE (0% 50% 100%) — PERCENT RECOVERY (0% 100%) — RECOVERY/INTERVAL — DATUM (FT) — DEPTH (FT) — WELL OR PIEZOMETER CONSTRUCTION — LITHOLOGY

Depth (ft)	Recovery/Interval	Datum	Unified Soils Classification or Rock Type	Description
0–2	0 75 /2 00	5897, 5896	CL	Silty clay with some sand and a trace of gravel Olive brown (2 5Y4/4) Gravel fine, medium, coarse (clasts to 2" diameter max), sand fine, medium, coarse (predominately fine), gravel sub-rounded, sand subangular High plasticity Gravel is weathered metamorphic rock fragments, sand mainly quartz Bedding not apparent Abundant organics, roots grass, etc Dry Medium stiffness 53% clay, 26% silt, 18% sand, 3% gravel
2–4	2 00 /2 00	5895, 5894	CL	Silty clay with a trace of sand and gravel Light olive brown (2 5 Y 5 4) Gravel fine to medium, sand fine, medium, coarse (predominately fine), gravel rounded, sand subangular, high plasticity, gravel made up of metamorphic rock fragments sand mainly quartz Bedding not clear, may have thin laminations, highly weathered Roots and organics present Dry Medium stiffness 75% Clay, 18% silt, 5% sand, 2% gravel
4–7	2 00 /2 00	5893, 5892, 5891	SILTY CLAYSTONE	Top of bedrock 4 0' Silty claystone with some sand Grayish brown (10 YR 5/2) to light olive brown (2 5 Y 5/3) Silt and sand very fine to fine, sub-angular, mainly quartz Moderately sorted Porosity 20% - 30%, cement none (clay?) Highly friable Bedding structures not apparent No fractures in intact core majority of core is disturbed Frequent Fe-oxide staining along fracture Trace of carbonaceous material Trace of caliche Dry 80% clay, 11% silt, 9 % sand
7–10	2 00 /2 00, 2 00 /2 00	5890, 5889, 5888	SILTY CLAYSTONE	Top unweathered bedrock 7 0' Silty claystone with some sand Dark gray (7 5 YR 4/1) to gray (10 YR 5/1) to grayish brown (10 YR 5/2) Sand and silt very fine to fine, sub-angular, mainly quartz Moderately sorted Porosity 10% - 20% Moderately to highly friable Laminar horizontal thin bedding marked by color change Few micro-fine horizontal fractures in intact core Most of core is distubed Unweathered bedrock begins at 7 0 marked by loss of Fe-oxide stains Few Fe-oxide stains along fractures Trace of carbonaceous material Dry 75% clay 18% silt 7% sand

Total Depth Drilled 10 00

3538

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 20.00	GROUND ELEVATION (FT)	5940.70	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	752589	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D L HIGOR	52794
EAST	2084578	LOCATION NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/13/94	

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH - 20.0' TOP OF BEDROCK 2.0' TOP OF UNIT ENTERED BEDROCK 14.0
GEOTECHNICAL SAMPLES ONLY CORE LOGGER: J.A. HIGGINS

Column headings: CHEMICAL SAMPLE DEPTH / GRADATIONAL SAMPLE DEPTH; SAMPLE NUMBER; SAMPLE GRAIN SIZE (0% 50% 100%); PERCENT RECOVERY (0% 100%); RECOVERY/INTERVAL; DATUM (FT) / DEPTH (FT); WELL OR PIEZOMETER CONSTRUCTION; LITHOLOGY; UNIFIED SOILS CLASSIFICATION OR ROCK TYPE; DESCRIPTION

Sample number: BH70-0051 (at approx. 5 ft)

Depth (FT)	Datum (FT)	Recovery/Interval
0	5940	1.25/2.00
2	5938	2.00/2.00
4	5936	2.00/2.00
6	5934	2.00/2.00
8	5932	2.00/2.00
10	5931	

Depth	Classification	Description
0–2.0	MH	Sandy Silt with some gravel and a trace of clay. Very dark brown (10 YR 2/2). Gravel rounded, sand subangular. Medium plasticity. Gravel made up of granite fragments and quartzite; sand is mainly quartz and mafic mineral fragments. No bedding. Dry. Top soil with abundant organics. 44% Silt, 24% sand, 20% gravel, 12% clay. No recovery (1.25'-2.0')
2.0–4.0	SANDY CLAYSTONE	Top of bedrock 2.0'. Sandy Claystone with abundant silt. Olv ylw (2.5 Y 6/6) to lt ylw brn (2.5 Y 6/4) to gryish brn (2.5 Y 5/2). Sand f to m, subangular, composed of qtz and mafic minerals. Prly sorted. Porosity - 30%. CaCO3 cement. Highly friable. No bedding apparent. Micro-fractures are at 45 degrees from hztal in intact core. Abundant calcium carbonate nodules throughout core. Some Fe-oxide staining and carbonaceous material. Highly weathered and disturbed, some core intact. Slightly moist. 35% Clay, 32% silt, 33% sand
4.0–6.5	SANDY CLAYSTONE	Sandy Claystone with some silt. Light brownish gray (2.5 Y 6/2) to olive yellow (2.5 Y 6/6). Sand fine grained. Sand and silt subangular, mainly quartz. Moderately sorted. Porosity - 20%. Not cemented (Clay?). Soft, very slighty friable. Bedding not apparent. Calcium carbonate and carbonaceous deposits present in spotty appearance and along fractures. Highly weathered. Fe-oxide stains throughout section (more strongly stained below 5.0'). Core is intact. Moist. 70% Clay, 20% sand, 10% silt
6.5–	SILTY CLAYSTONE	Silty Claystone with some sand. Olive yellow (2.5 Y 6/6) to light yellowish brown (2.5 Y 6/3). Sand is very fine to fine. Sand and silt subangular, mainly quartz. Moderate to poorly sorted. Porosity 25%-30%. Not cemented. Highly friable. No bedding structures apparent. Some fractures are apparent. Core is highly disturbed. Highly weathered. Abundant Fe-oxide staining. Some carbonaceous fragments. Iron stains give motteled appearance. Trace caliche from 6.5'-7.0'. 53% Clay, 35% silt, 12% sand

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STATE PLANE COORDINATE	TOTAL DEPTH (FT) 20 00	GROUND ELEVATION (FT) 5940 70	PROJECT NUMBER 007-RFI/RI	LOG OF BORING NUMBER	
NORTH 752589	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	GEOLOGIST D L RIGOR	52794	
EAST 2084678	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7 00	DATE DRILLED 10/13/94		

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 20 0 TOP OF BEDROCK 2 0 TOP OF UNWEATHERED BEDROCK 14 0 GEOTECHNICAL SAMPLES ONLY CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION

0% 50% 100% 0% 100%

Depth (ft)	Datum (ft)	Recovery/Interval	Sample number
10	5930	2 00 /2 00	
11	5929		
12	5928	1 75 /2 00	
13	5927		
14	5926	1 00 /2 00	BH70-08ST
15	5925		
16	5924	2 00 /2 00	
17	5923		
18	5922	2 00 /2 00	
19	5921		
20			

CLAYEY SILTSTONE Clayey Siltstone with some sand Lt olv brn (2 5 Y 5/6) to gryish brn (2 5 Y 5/2) Sand f to vf Silt and sand made-up of subangular grains of quartz Poorly sorted Porosity 30% Very friable Thinly laminated Fractures at 45 degree angles, micro-fine, no apparent weathering on fractures (may not be natural) Highly Fe-oxide stained along laminae Core disturbed (by drill action?) in sections, and intact in others Dry 46% Silt, 44% clay, 10% sand
No recovery (13 75' 14 0')

SILTY CLAYSTONE Top of unweathered bedrock 14 0' Silty Claystone with sm sand Gry (2 5 Y 6/1) to drk gry (2 5 Y 4/1) Sand f, silt f to vf Both sbanglr, qrtz Mod sorted Porosity 15% 20% No cement (clay?) Mod friable Laminar to thnly bedded Hrzntl and angular micro-frctrs occur on intact core Slt tr of vert Fe-oxide stains along frctrs Most of core sec is intact Tr of crbncs material Slt friable in last foot of core Dry Top of unweathered bedrock is at 14 0 65% Clay 28% silt 7% sand
No recovery (15 0' 16 0')

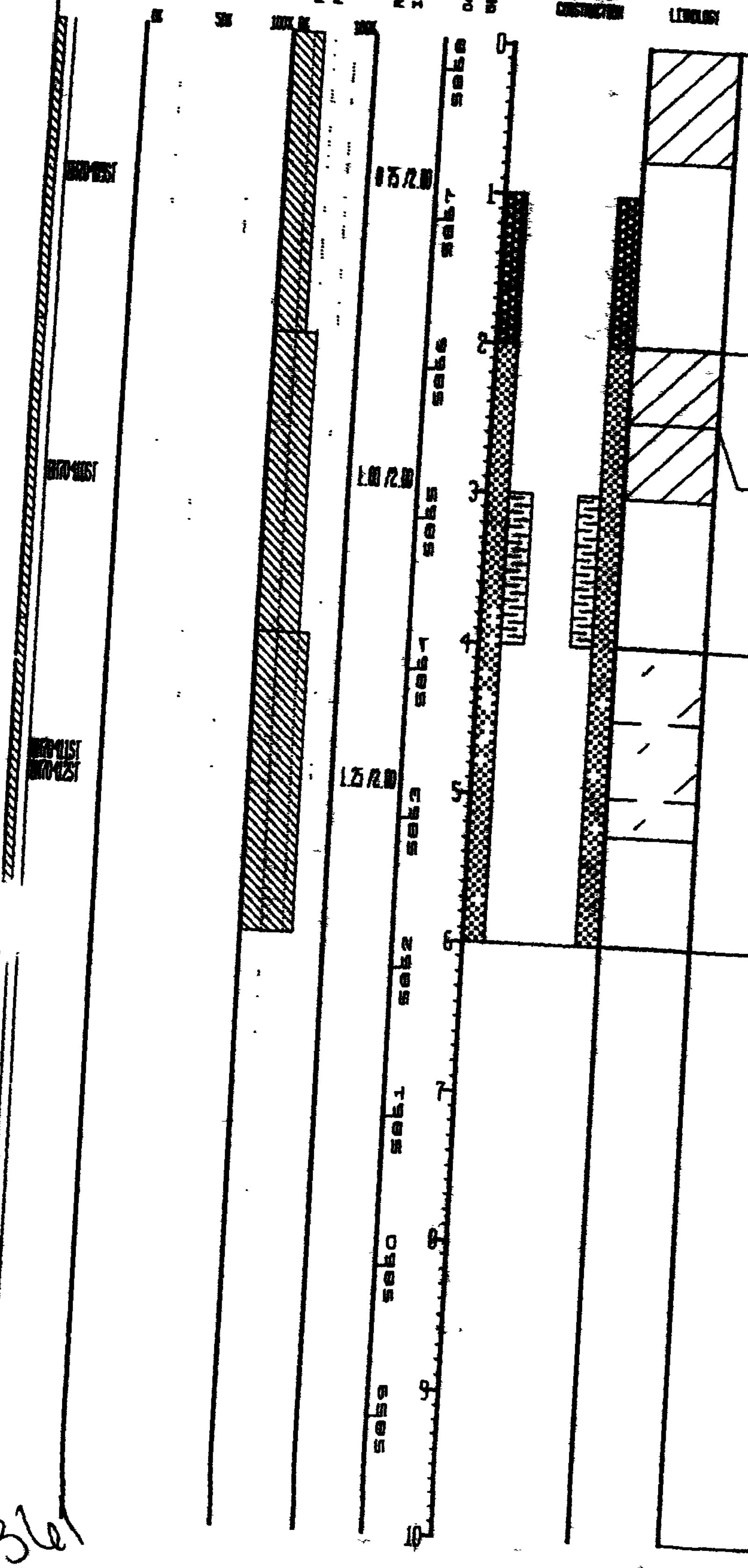
Total Depth Drilled 20 00

360

LOG OF BORING NUMBER 52894

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 6.00	GROUND ELEVATION (FT)	5868.20	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH 753222	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	2.00	GEOLOGIST	8 L HIGOR	52894
EAST 2085099	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/25/94	

REMARKS: ALLUVIAL WELL INSTALLED. TOTAL DEPTH 6.0' NO GROUT SEAL DUE TO SHALLOWNESS OF WELL. TOP OF BEDROCK 4.0' CORE LOGGER: J.A HIGGIN.



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
CL	All core used for samples. Field description follows: "Clayey Silt with trace of gravel. Brown (organics, grass roots etc., in top 0.25')." Gravel at base, clasts to 3", subangular, but angular where broken during drilling. Increasing clay content near base. Dry to slightly moist. No recovery (0.75'-2.0')
CL	All core used for samples. Field description follows: Clayey Silt with some gravel. Light brown. Gravel subangular (clasts to 2"). Dry
CL	All core used for samples. Field description follows: Silty Clay with some gravel. Dark brown. Gravel fine, no gravel in top of core. Trace of caliche. Dry. No recovery (3.0'-4.0')
CLAYEY SILTSTONE	Top of bedrock 4.0'. All core used for samples. Field description follows: Clayey Siltstone. Light grayish brown. Trace of carbonaceous material and caliche. Trace of Fe-oxide at base of interval. Dry. No recovery (5.25'-6.0').

Total Depth Drilled 6.00
Bottom of Filter Pack 6.00
Total Depth Casing 6.00

369

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 18 00	GROUND ELEVATION (FT)	5871 40	PROJECT NUMBER	OU7-RFI/RI	LOG OF BORING NUMBER
NORTH	753196	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	2 00	GEOLOGIST	D L HIGOR	52994
EAST	2085085	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/25/94	

REMARKS BEDROCK WELL INSTALLED TOTAL DEPTH 18 0 TOP OF BEDROCK 5 0 TOP OF UNWEATHERED BEDRPCL 16 0 CORE LOGGER J A HIGGINS

SAMPLE NUMBER	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
	1 75 /2 00	5871–5869	0–2	OL	Sandy Silt with trace of gravel Dark grayish brown (2 5 Y 4/2) Sand fine grained, subangular to angular Sand mainly quartz Some organic material top 0 25 feet Trace of Fe at the very base of interval Gravel at 1 75' (clasts to 2 0") Dry to slightly moist 53% Silt, 46% sand, 1% gravel No recovery (1 75' 2 0')
	1 00 /2 00 / 0 00 /1 00	5869–5866	2–5	SM	Gravelly sand with some silt and a trace of clay Dark olive brown (2 5 Y 3/3) Gravel subangular, sand subangular to subrounded Gravel to 2 0", sand coarse to fine grained Gravel composed of quartzite, sand composed of quartz Slightly moist Well sorted 65% Sand, 18% gravel, 14% silt, 3% clay No recovery (3 0'-5 0')
	1 00 /1 00 / 0 00 /2 00	5866–5863	5–8	SANDY CLAYSTONE	Top of weathered bedrock 5 0 Sandy Claystone with some silt Olive brown (2 5 Y 4/3) Fine grained sand, subrounded 10% Porosity Non-friable Sand mainly quartz Some caliche, trace of carbonaceous material throughout Fe-staining at 6 0 Slightly moist 56% Clay, 30% sand, 14% silt No recovery (6 0 -8 0')
	1 00 /2 00	5863–5861	8–10	SILTY CLAYSTONE	Silty Claystone with some sand Light brownish gray (2 5 Y 6/2) Sand very fine grained, subangular 30% Porosity Moderately friable Sand mainly quartz Thin laminar bedding (sandy layers) Trace of Fe-staining Dry 43% Clay, 30% silt 27% sand No recovery (9 0 -12 0')

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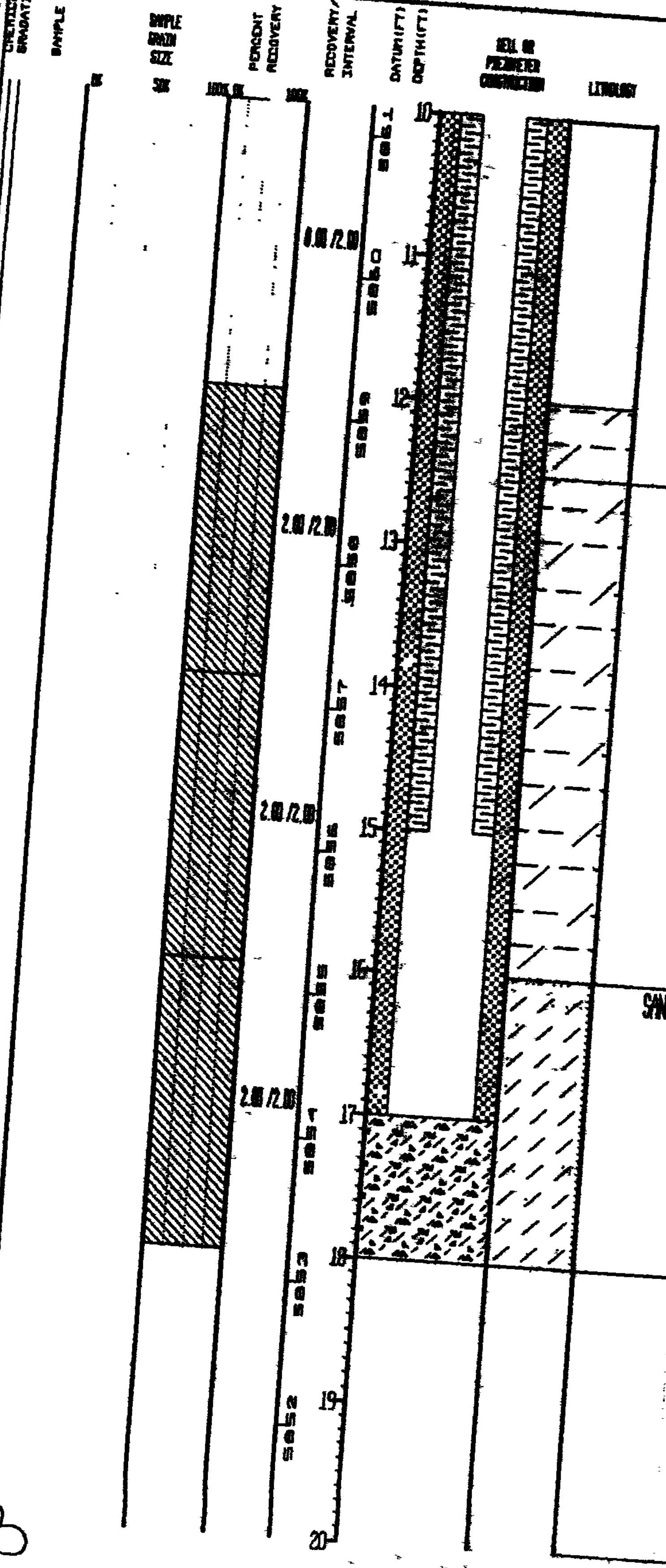
STATE PLANE COORDINATE		TOTAL DEPTH (FT) 18.00	GROUND ELEVATION (FT)	5871.20	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753196	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN)	2.00	GEOLOGIST	D. L. RIGAR	52994
EAST	2085085	LOCATION NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/25/94	

REMARKS: BEDROCK WELL INSTALLED. TOTAL DEPTH 18.0' TOP OF BEDROCK 5.0' TOP OF UNWEATHERED BEDROCK 16.0' CORE LOGGER: J.A. HIGGINS



SILTY CLAYSTONE: Top of unweathered bedrock 16.0' Silty Claystone with some sand. Same as above with color change to grayish brown (2.5 Y 5/2) and increase in clay content. Friable, weathered, trace of fractures with limonite staining from 12.0'-14.0'. 55% Clay, 24% silt, 21% sand

SANDY SILTSTONE: Sandy Siltstone with some clay. Very dark grayish brown (2.5 Y 3/2). Fine sand, subangular. 20% Porosity. Sand mainly quartz. Laminar bedding where core not broken-up. Trace of carbonaceous material. Dry. Moderately friable, moderately weathered. Trace of FeO2 and MnO2.

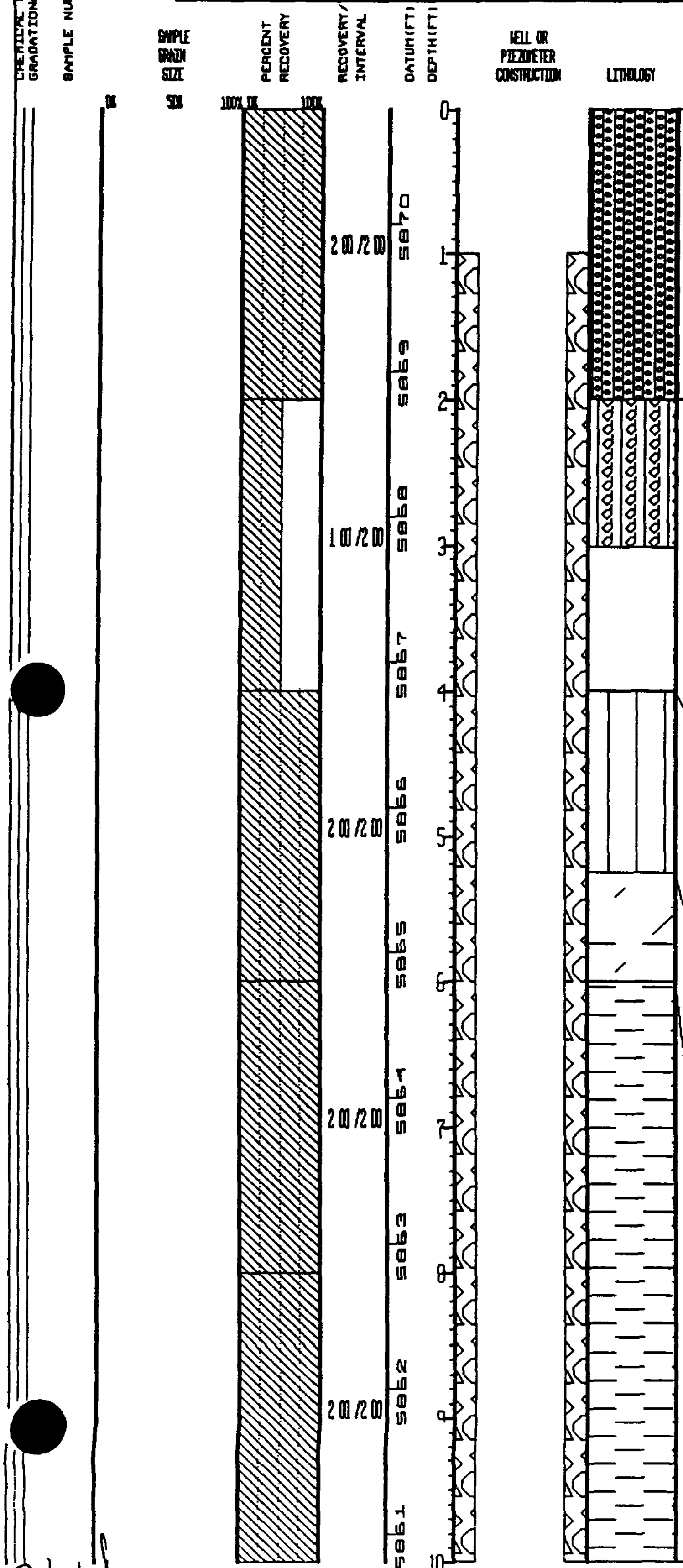
Total Depth Drilled 18.00 Total Depth Casing 17.00
Bottom of Filter Pack 17.00

363

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 90 00	GROUND ELEVATION (FT)	5870 80	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753198	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	2 00	GEOLOGIST	D L HIGOR	53094
EAST	2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90 0 TOP OF BEDROCK 5 25 TOP OF UNWEATHERED BEDROCK 19 0 NO SAMPLES

CORE LOGGER J A HIGGINS



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
OL	Clayey Silt with some sand and a trace of gravel Olive brown (2 5 Y 4/4) to very dark gray (2 5 Y 3/1) Gravel is f, sand is fmc (mainly f) Gravel subrounded, sand subangular Moderate to low plasticity Gravel consists of ironstone nodules and quartzite Sand is mainly quartz, some ironstone and mafic minerals Abundant organic material (roots and grass) Bedding not apparent Moderately stiff Slightly moist 56% Silt, 24% clay, 19% sand, 1% gravel
SM	Gravelly Sand with some silt and a trace of clay Olive brown (2 5 Y 4/4) Gravel subangular, sand angular to subrounded Low plasticity, loose gravel in sandy matrix Gravel f to c (up to 1 5" diameter) Sand fmc (mainly f) Gravel is prominantly quartzite, with metamorphic rock fragments Sand is mainly quartz and mafic mineral fragments Bedding not apparent Dry 2 8' 3 0' Very hard gravelly clay clasts with a trace of caliche Trace of cobbles 52% Sand, 29% gravel 14% silt, 5% clay No recovery (3 0 -4 0)
ML	Clayey Silt with abundant sand and trace of gravel Grayish brown (2 5 Y 5/2) Gravel is f, sand is fmc (mainly f) Well graded Gravel subangular, sand subangular to subrounded Moderate to low plasticity Stiff, but core broken-up Gravel mainly quartzite sand mainly quartz with other mafic minerals Bedding not apparent Dry Transition to bedrock 39% Silt, 32% clay, 26% sand, 3% gravel
CLAYEY SILTSTONE	Top of bedrock 5 25 Clayey Siltstone with some sand Olive brown (2 5 Y 4/3) Sand and silt m-f, subangular, quartz, ironstone, and mafic minerals Moderate to poorly sorted Porosity 25%-30% Moderately friable No apparent bedding Dry Trace of caliche, Fe and carbonaceous material 52% Silt 27% clay, 21% sand
SANDY CLAYSTONE	Sandy Claystone with some silt Overall color is olive brown (2 5 Y 4/4) From 7 0' 8 0' dark gray (2 5 Y 4/1), from 8 5 -10 0' light olive brown (2 5 Y 5/6) Sand m-f, silt f, subangular, quartz and mafic minerals Poorly sorted Porosity 20% Moderately friable Thinly laminated in intact sections Micro-fine fresh horizontal, vertical, and angular fractures in intact core Generally Fe-stained throughout Moderately stiff 42% Clay, 30% sand, 28% silt 7 0 -8 0 Abundant carbonaceous deposits section is intact 8 5 -10 0 Abundant Fe-staining throughout interval Interval has banding of Sandy Claystone/Silty Claystone section intact Remainder of interval is disturbed

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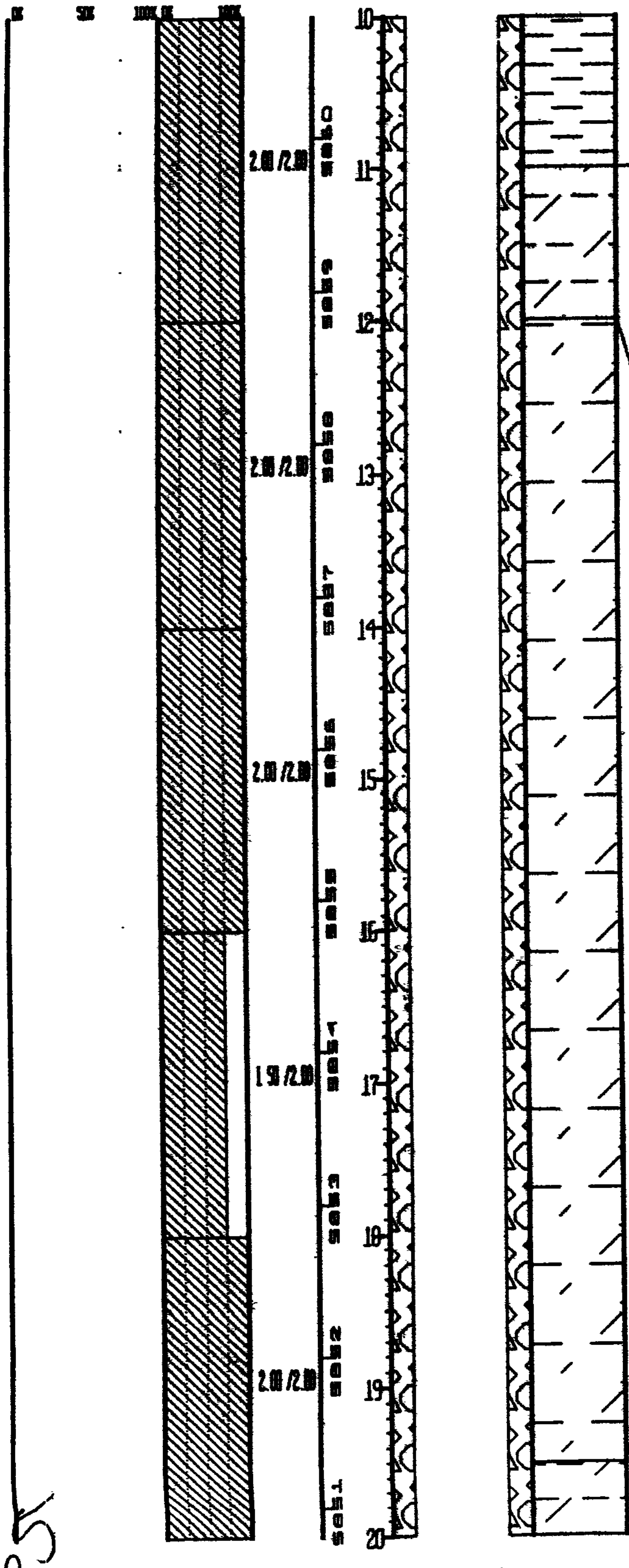
STATE PLANE COORDINATE		TOTAL DEPTH (FT) 90.00	GROUND ELEVATION (FT)	5680.80	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753198	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	2.00	GEOLOGIST	D. L. RIGOR	53094
EAST	2085095	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67.0' TOTAL DEPTH DRILLED 90.0' TOP OF BEDROCK 5.25' TOP OF UNWEATHERED BEDROCK 19.0' NO SAMPLES

CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION



SILTY CLAYSTONE Silty Claystone with some sand. Yellowish brown (10YR 5/8). Sand f, sand and silt subrounded, quartz and mafic minerals. Moderately sorted. Porosity=15%. Slightly friable. Laminar bedding marked by color change. Micro-fractured (fresh). Becomes less silty at 11.5'. Dry. Fe-stained. Stiff and dense. 53% Clay, 35% silt, 12% sand

CLAYEY SILTSTONE Clayey Siltstone with some sand. Dark brown (10 YR 3/3). Sand f. Sand and silt subangular, quartz and mafic minerals. Moderately to poorly sorted. Porosity=20%, moderately friable. Laminar color band bedded. Micro-fractures fresh. Abundant carbonaceous. Strongly Fe-stained above 14.0', below much less Fe-staining from 14.0'-18.0'. Most of core is intact. 41% Silt, 40% clay, 19% sand
Some Mn-oxide from 14.0'-18.0'
Highly disturbed from 16.0'-18.0'
Limonite (Fe-oxide) in vertical and horizontal fractures

SILTY CLAYSTONE Silty Claystone with some sand. Strong brown (7.5 Y 4/6). Sand and silt vf, subangular, quartz, and mafic minerals. Poorly to moderately sorted. Porosity 15% Slightly friable, laminar bedding marked by color bands. Few micro-fractures. Dry. Fe-oxide stained. 57% Clay 25% silt, 18% sand

365

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 90 00	GROUND ELEVATION (FT)	5870 80	PROJECT NUMBER	OU7-RFI/RI	LOG OF BORING NUMBER
NORTH	753198	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	2 00	GEOLOGIST	D L RIGOR	53094
EAST	2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90 0 TOP OF BEDROCK 5 25 TOP OF UNWEATHERED BEDROCK 19 0 NO SAMPLES

CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE (0% 50% 100%) | PERCENT RECOVERY (0% 100%) | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION

Recovery/Interval	Datum (ft)
1 25/2 00	5850, 5849
2 00/2 00	5848, 5847
2 00/2 00	5846, 5845
2 00/2 00	5844, 5843
2 00/2 00	5842, 5841

Depth (ft): 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

CLAYEY SILTSTONE Top of unweathered bedrock 19 0' Clayey Siltstone with some sand Light olive brown (2 5 Y 5/4) Slough with trace of gravel Sand m-f silt and sand subrounded mainly quartz Poorly sorted Porosity-35% very soft - crumbled by drilling Highly disturbed Dry 52% Silt, 35% clay, 12% sand, 1% gravel
No recovery (21 25' 22 0')

SILTY CLAYSTONE Silty Claystone with some sand Olive brown (2 5 Y 4/4) Sand mf Sand and silt subrounded, mainly quartz Poorly sorted Porosity=20%, moderately to slightly friable (more friable where more strongly disturbed by drilling) Bedding not apparent Few micro-fractures Hard Most of section is intact Slightly moist 42% Clay, 38% silt, 20% sand

CLAYEY SILTSTONE Interlayered Clayey Siltstone and Silty Claystone with some sand Light olive brown (2 5 Y 5/3) to grayish brown (2 5 Y 5/2) Sand mf Sand and silt subangular, mainly quartz and mica Poorly sorted Porosity-20% 25% Highly friable, soft Bedding not apparent Core mostly broken-up Chunks of claystone is mixed with layers of siltstone Fe-oxide stained along vertical fractures Dry 43% Silt 43% clay, 14% sand

SILTY CLAYSTONE Silty Claystone with some sand Light yellowish brown (2 5 Y 6/3) to gray (2 5 Y 6/1) Sand f Sand and silt mainly quartz, subangular Moderate to poorly sorted Porosity-20% Moderately friable Laminar bedding Very stiff Dry 63% Clay 27% silt 10% sand

SILTY CLAYSTONE Silty Claystone with some sand Light yellowish brown (2 5 Y 6/3) to grayish brown (2 5 Y 5/2) Sand f Sand and silt subangular, mainly quartz Moderate to poorly sorted Porosity-20% Highly friable to moderately friable 'Laminar bedding where core is intact Dry Most of core is highly disturbed Generally soft Some Fe-oxide staining 28 0'-29 0' along fractures 60% Clay, 32% silt, 8% sand

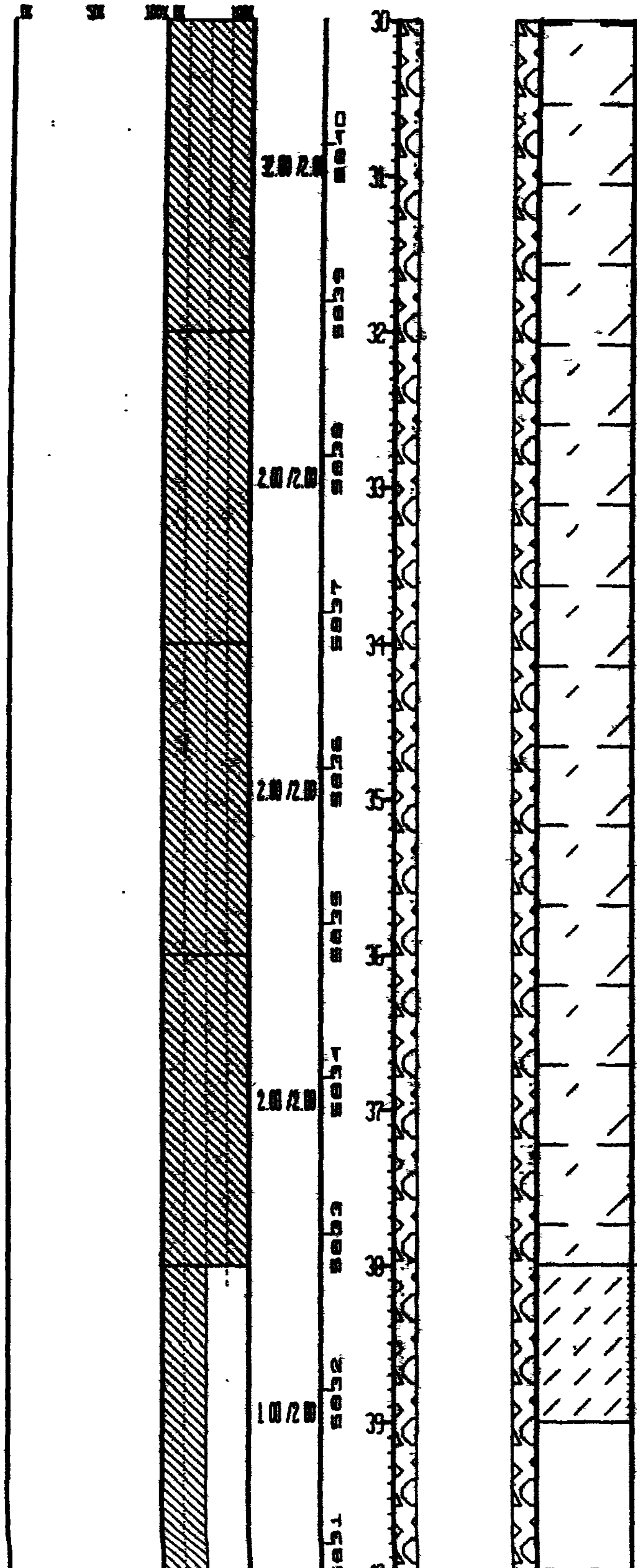
3666

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 90 00	GROUND ELEVATION (FT)	5870.80	PROJECT NUMBER	OU7-RFI/RI	LOG OF BORING NUMBER	
NORTH	753198	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	2.00	GEOLOGIST	D. L. RIGOR	53094	
EAST	2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/19/94		

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90.0 TOP OF BEDROCK 5.25 TOP OF UNWEATHERED BEDROCK 19.0' NO SAMPLES

CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL SAMPLE DEPTH / SAMPLE NUMBER / SAMPLE GRAIN SIZE / PERCENT RECOVERY / RECOVERY/INTERVAL / DATUM(FT) / DEPTH(FT) / WELL OR PIEZOMETER CONSTRUCTION / LITHOLOGY / UNIFIED SOILS CLASSIFICATION OR ROCK TYPE / DESCRIPTION



CLAYEY SILTSTONE Clayey Siltstone with some sand Very dark grayish brown (2 5 Y 3/2) to very dark gray (2 5 Y 3/1) Sand vf, subrounded, mainly quartz. Silt subrounded to subangular, quartz and carbonaceous deposits Poorly sorted Porosity=20% Very stiff, moderately friable but variable throughout section depending on degree of weathering and degree of disturbance. Thin laminar bedded in core that is intact Micro-fractures in the horizontal, vertical, and angular directions. Dry Entire section has abundant carbonaceous deposits Most of core is fairly well intact
48% Silt, 32% clay, 20% sand
Fe-stains along fractures 29 0'-31.0' 30 degrees from horizontal at 30 5'
Carbonaceous deposits, coal, more abundant 36 5'-38 0'
29 0'-30 0' Color is strongly brown and has slightly higher clay content
37 0'-37 5' Abundant thin lignite laminae

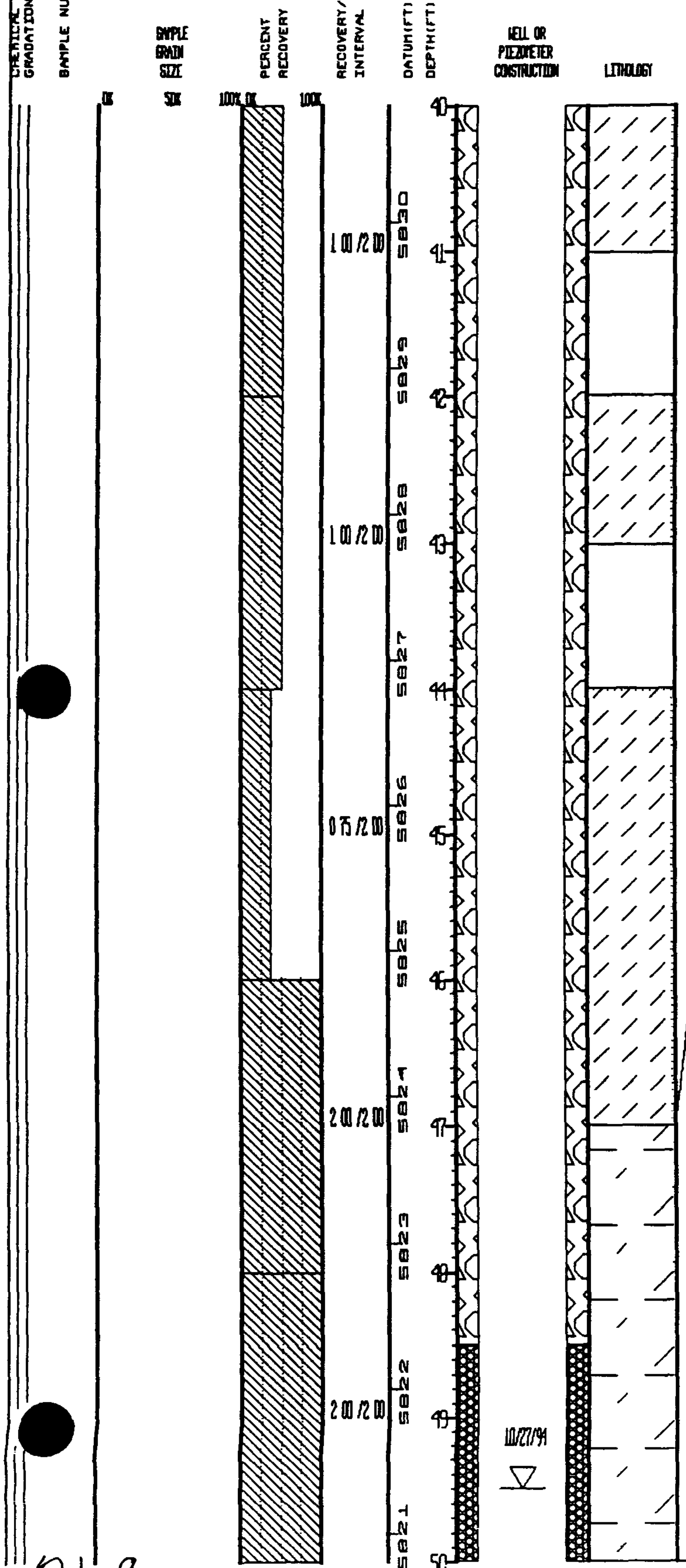
SANDY SILTSTONE Sandy Siltstone with some clay Dark gray (2 5 Y 4/1) Sand vf Sand and silt subrounded, mainly composed of quartz with carbonaceous sand fragments Poorly sorted Porosity=20% Highly friable, very soft with chunks of stiff clayey siltstone Highly disturbed core from drilling Dry 45% Silt, 30% sand 25% clay
No recovery (39 0'-40 0'), (41 0'-42 0), (43 0-44 0')
44 0'-46 0' Clay chuncks become soft

367

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 90 00	GROUND ELEVATION (FT)	5870 80	PROJECT NUMBER	OU7-RFI/RI	LOG OF BORING NUMBER
NORTH	753198	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	2 00	GEOLOGIST	D L RIGOR	53094
EAST	2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90 0 TOP OF BEDROCK 5 25 TOP OF UNWEATHERED BEDROCK 19 0 NO SAMPLES

CORE LOGGER J A HIGGINS



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION

CLAYEY SILTSTONE Clayey Siltstone with some sand Color varies from gray (2 5 Y 5/1) to dark gray (2 5 Y 4/1) to very dark gray (2 5 Y 2 3/1) to black (2 5 Y 2 5/1) sand mf Sand and silt subangular to subrounded, composed of quartz, and carbonaceous fragments Poorly sorted Highly friable in some sections and moderate to slightly friable in other sections Bedding appears thin and laminar in core that is intact Micro-fractures, mainly horizontal, some vertical, few angular Abundant carbonaceous deposits (Areas where core is broken-up may have slightly higher silt content) Dry 63% Silt, 27% clay, 10% sand

47 0'-50 0' Core intact and stiff
50 0'-50 2' Core broken-up and soft
50 2 -51 8' Core intact and stiff, core feels waxy, may have higher clay content, some slickensides noted
51 8 -52 4' Core broken-up very soft
52 4 -53 0 Core intact soft
53 0 -53 5' Core broken-up and soft
53 5 -54 0' Core intact and semi-stiff
54 0 -54 2 Core broken-up and soft

368

LOG OF BORING NUMBER

53094

STATE PLANE COORDINATE
NORTH 753198
EAST 2080095

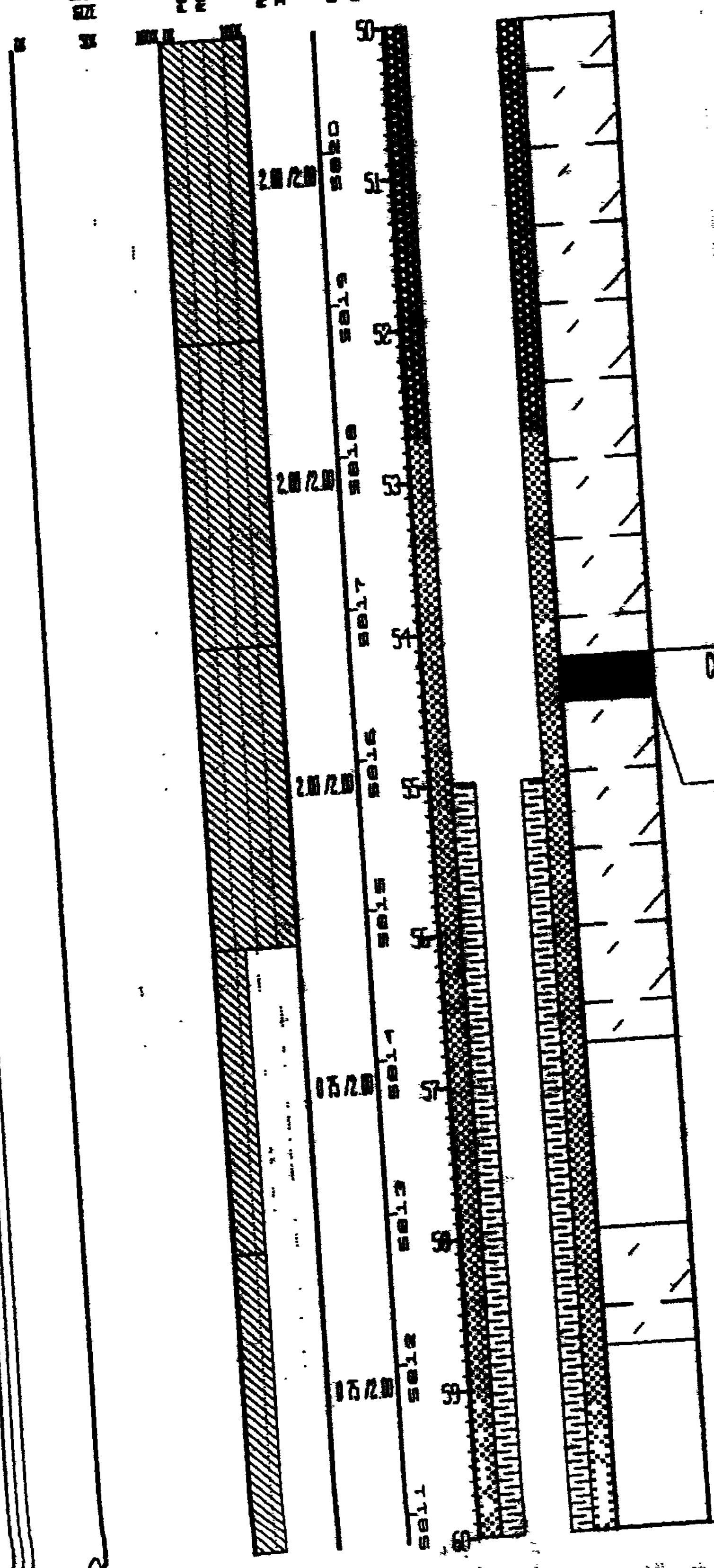
TOTAL DEPTH (FT) 90.00
AREA: 807 PRESENT LANDFILL
LOCATOR NUMBER: 0

GROUND ELEVATION (FT) 5870.80
CASING DIAMETER (IN) 2.00
BOREHOLE DIAMETER (IN) 7.00

PROJECT NUMBER 807-RFI/RI
GEOLOGIST D L ALGAR
DATE DRILLED 10/19/94

REMARKS: BEDROCK WELL INSTALLED TO 62.0', TOTAL DEPTH DRILLED 90.0' TOP OF BEDROCK 5.25', TOP OF UNWEATHERED BEDROCK 19.0' - NO SAMPLES.
CORE LOGGER J A HIGGINS

SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY / INTERVAL	DATUM (FT) / DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
						COAL	Lignite (Coal) with some sand, silt and a trace of clay Black (2.5 Y 2.5/1) Sand f. Sand and silt subangular, composed of carbonaceous fragments and quartz. Very friable Dry. 80% silt, 15% sand, 5% clay
						CLAYEY SILTSTONE	Clayey siltstone with some sand. Dark gray (2.5 Y 4/1). Sand f. Sand and silt subangular to subrounded, composed of quartz and carbonaceous material. Moderately to highly friable. Bedding not apparent. Dry. 62% Silt, 22% clay, 16% sand 54.5'-56.0' Core intact, stiff and moderately friable 56.0'-60.0' Core broken up, soft and highly friable No recovery (56.75'-58.0'), (58.75'-60.0')



STATE PLANE COORDINATE — NORTH 53198 — EAST 2085095

TOTAL DEPTH (FT) 90 00 — AREA 007 PRESENT LANDFILL — LOCATOR NUMBER 0

GROUND ELEVATION (FT) 5870 80 — CASING DIAMETER (IN) 2 00 — BOREHOLE DIAMETER (IN) 7 00

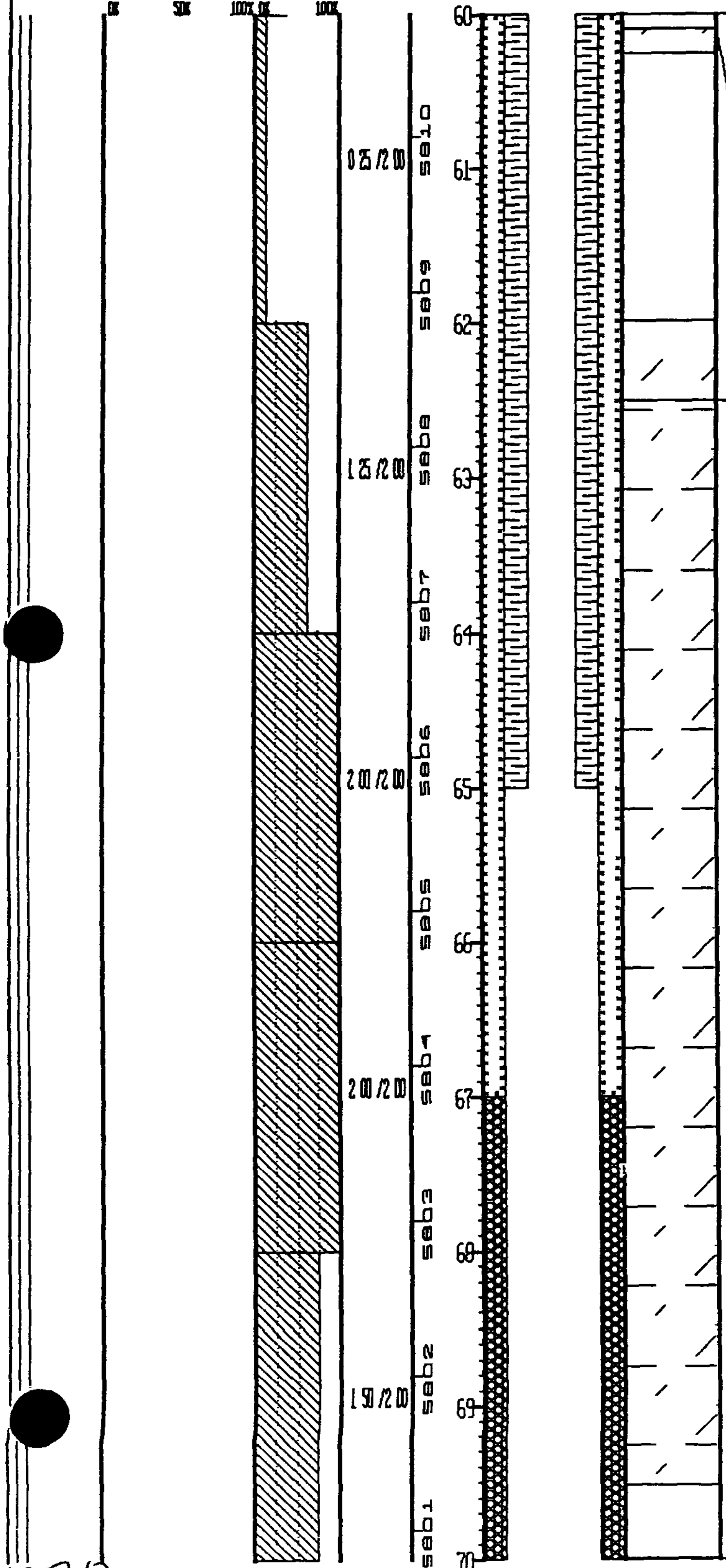
PROJECT NUMBER 007-RFI/RI — GEOLOGIST D L RIGOR — DATE DRILLED 10/19/94

LOG OF BORING NUMBER **53094**

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90 0 TOP OF BEDROCK 5 25 TOP OF UNWEATHERED BEDROCK 19 0 NO SAMPLES

CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE / GRADATIONAL DEPTH	SAMPLE NUMBER	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/ INTERVAL	DATUM(FT) DEPTH(FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION



SILTY SANDSTONE — Silty Sandstone with some clay Dark gray (2 5 Y 4/1) Silt and sand mf mainly composed of quartz, subangular Poorly sorted Not friable, soft and moleable No bedding apparent Wet 53% Sand, 33% silt, 14% clay

SILTY SANDSTONE — Silty Sandstone Gray (5 Y 5/1) Sand mf Sand and silt mainly quartz, subrounded Moderately sorted Cemented with argillaceous cement Not friable, hard but is easily broken Bedding is thinly laminated and marked by color banding Core is disturbed Dry 68% Sand, 32% silt
No recovery (60 25'-62 0)

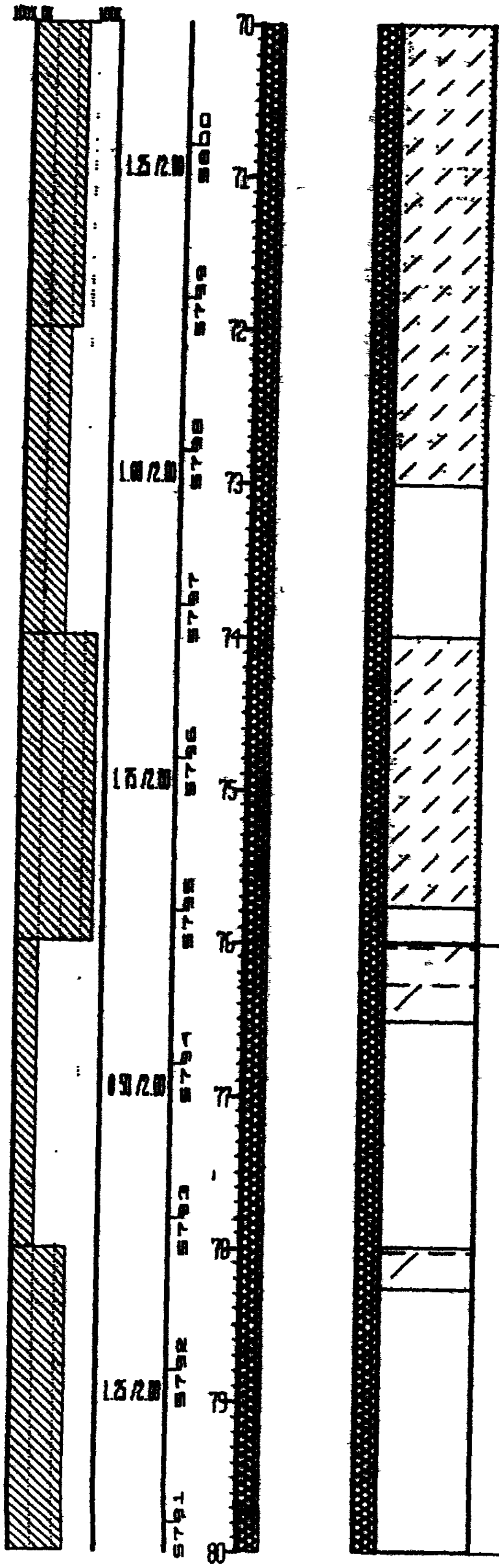
CLAYEY SILTSTONE — Clayey Siltstone with some sand Very dark gray (10 YR 3/1) to dark gray (10 YR 4/1) Sand f Sand and silt subrounded, mainly composed of quartz with abundant carbonaceous material to 65 0' Moderate to poorly sorted Bedding appears to be thinly laminated Moderate to non-friable Hard Core mainly highly disturbed and broken-up Intact from 62 5 63 25' Trace of carbonaceous deposits throughout interval Dry 64% Silt, 26% clay, 10% sand
No recovery (69 5' 70 0')

370

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 98 00	GROUND ELEVATION (FT)	5870 80	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753198	AREA 4U7 PRESENT LANDFILL	CASING DIAMETER (IN)	2 00	GEOLOGIST	D. L. HIGOR	53094
EAST	2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67 0', TOTAL DEPTH DRILLED 90 0' TOP OF BEDROCK 5.25' TOP OF UNWEATHERED BEDROCK 19 0' NO SAMPLES
CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRADATION SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION



SANDY SILTSTONE Sandy Siltstone with some clay Olive gray (5 Y 5/2) to gray (5 Y 5/1) Sand of Sand and silt subangular to subrounded, mainly quartz and carbonaceous fragments Moderately sorted. Non-friable, hard, very hard Clay cement Core is highly disturbed from drilling and broken into large chunks Bedding not apparent Dry Carbonaceous deposits present 70% Silt, 20% Sand, 10% clay
No recovery (73 0'-74 0'), (75 75'-76 0')

SILTY CLAYSTONE Silty Claystone with a trace of sand. Dark grayish brown (2.5 YR 4/2) Sand of mainly subrounded, composed of quartz Silt subrounded composed of quartz and trace carbonaceous flakes Moderately sorted Very hard Non-friable Bit of core is broken up Moist
No recovery (76 5'-78 0'), (78 25'-80 0') (80 0'-90 0')

377

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 90 00	GROUND ELEVATION (FT) 5870 80	PROJECT NUMBER 007-RFI/RI	LOG OF BORING NUMBER
NORTH 753198	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN) 2 00	GEOLOGIST D L HIGOR	53094
EAST 2085095	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7 00	DATE DRILLED 10/19/94	

REMARKS BEDROCK WELL INSTALLED TO 67 0' TOTAL DEPTH DRILLED 90 0 TOP OF BEDROCK 5 25 TOP OF UNWEATHERED BEDROCK 19 0 NO SAMPLES
CORE LOGGER J A HIGGINS

DEPTH (FT)	DATUM (FT)	RECOVERY/INTERVAL	DESCRIPTION
80	5790		SILTY CLAYSTONE No recovery (80 0'-90 0')
81	5789	0 00 /2 00	
82	5788		
83	5787	0 00 /2 00	
84	5786		
85	5785	0 00 /2 00	10/24/94 ▽ (water level)
86	5784		
87	5783	0 00 /2 00	
88	5782		
89	5781	0 00 /2 00	
90			

Column headings: CHEMICAL SAMPLE DEPTH, GRADATIONAL DEPTH, SAMPLE NUMBER, SAMPLE GRAIN SIZE (0% 50%), PERCENT RECOVERY (100% 0% 100%), RECOVERY/INTERVAL, DATUM (FT), DEPTH (FT), WELL OR PIEZOMETER CONSTRUCTION, LITHOLOGY, UNIFIED SOILS CLASSIFICATION OR ROCK TYPE, DESCRIPTION

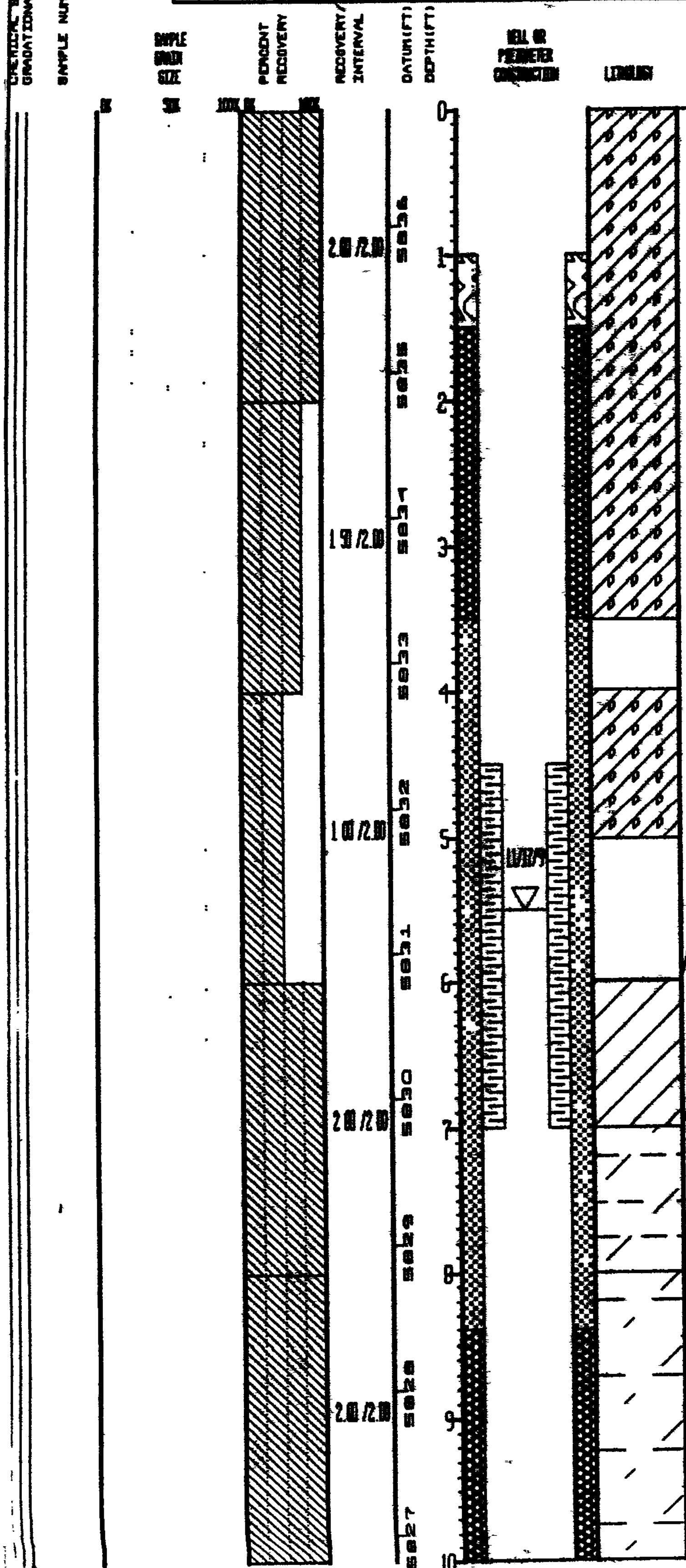
Total Depth Drilled 90 00 Total Depth Casing 67 00
Bottom of Filter Pack 67 00

372

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 10.00	GROUND ELEVATION (FT)	5836.80	PROJECT NUMBER	007-RFI/RI
NORTH 753434	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	2.00	GEOLOGIST	D L RIGOR
EAST 2086037	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/14/94

LOG OF BORING NUMBER **53194**

REMARKS: ALLUVIAL WELL INSTALLED TOTAL DEPTH 10.0' TOP OF BEDROCK 7.0' NO SAMPLES COLLECTED CORE LOGGED J.A. HIGGINS



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
SC	Gravelly Clayey Sand with some silt. Brown (10 YR 5/3). Gravel fac: mainly f with clasts to 2" maximum diameter. Sand fac: mainly medium. Gravel subangular to rounded, sand subangular to subrounded. Medium to low plasticity. Gravel is mainly quartzite fragments of metamorphic rock. Sand is made-up of mainly quartz and other mafic mineral fragments from metamorphic rocks. Dry, dense. Bedding not apparent. Caliche deposits present. 65% Sand, 17% gravel, 11% clay, 7% silt. 3.4"-3.5' lense of hard sand with clay and less gravel. No recovery (3.5'-4.0'). 4.5'-4.8' lense of hard sand with clay and less gravel. No recovery (5.0'-6.0')
CL	Silty Sandy Clay with a trace of gravel. Olive yellow (2.5 Y 6/8) to olive brown (2.5 Y 4/3). Sand and gravel subangular, made-up of quartz and mafic mineral fragments, mainly fine. High plasticity. Bedding not apparent. Moist. 66% Clay, 16% silt, 16% sand, 2% gravel. Transition into bedrock.
SILTY CLAYSTONE	Top of bedrock 7.0'. Silty Claystone with some sand. Olive yellow (2.5 Y 6/6), light olive brown (2.5 Y 5/3) to olive brown (2.5 Y 4/3). Sand and silt fine, subangular, quartz. Porosity=20%. Soft to moderately friable. Banded coloring may be indicative of bedding. Abundant Fe-staining, some carbonaceous deposits. Weathered, no fractures. Moist. 64% Clay, 27% silt, 9% sand.
CLAYEY SILTSTONE	Clayey Siltstone with some sand. Light olive brown (2.5 Y 5/6) to olive brown (2.5 Y 4/4). Sand f-m, silt f. Sand and silt subangular to subrounded, mainly quartz. Moderately sorted. Porosity=25%-30%. Moderately friable. Thinly laminated. Some Fe-oxide staining. Slightly moist. 65% Silt, 27% clay, 8% sand.

Total Depth Drilled 10.00 Total Depth Casing 9.40
Bottom of Filter Pack 8.40

373

STATE PLANE COORDINATE NORTH 7F3291 EAST 2083637

TOTAL DEPTH (FT) 30 00
AREA OU7 PRESENT LANDFILL
LOCATOR NUMBER 0

GROUND ELEVATION (FT) 5971 90
CASING DIAMETER (IN)
BOREHOLE DIAMETER (IN) 7 00

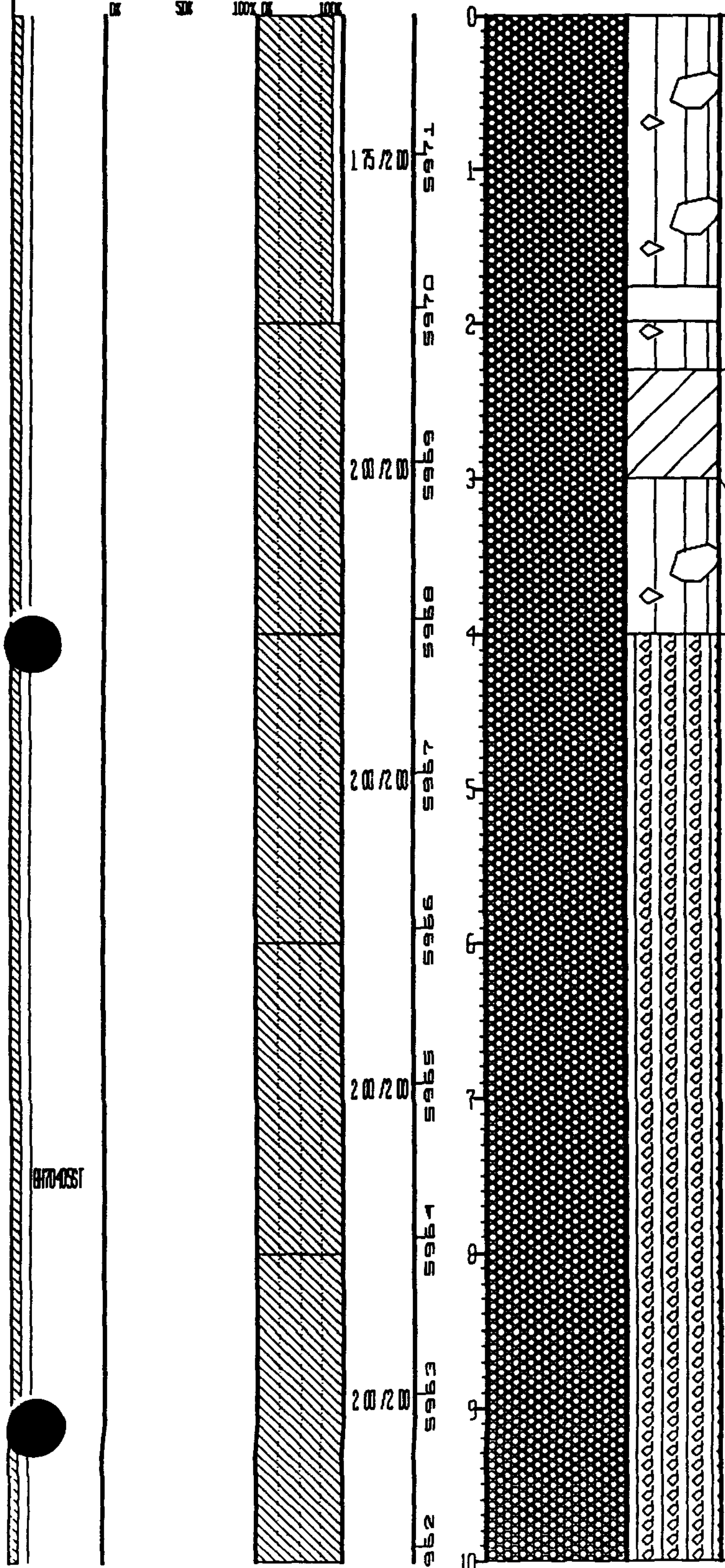
PROJECT NUMBER OU7-RFI/RI
GEOLOGIST D L RIGOR
DATE DRILLED 10/10/94

LOG OF BORING NUMBER

53494

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 30 0 TOP OF BEDROCK 12 6 TOP OF UN WEATHERED BEDROCK 27 0'
GEOTECHNICAL SAMPLES ONLY CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL DEPTH	SAMPLE NUMBER	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM(FT)	DEPTH(FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION



GW/gc — Sandy Gravel with some silt and clay Matrix is yellowish red (5 YR 4/6) Gravel and sand f-c, angular to subrounded Gravel is made-up of metamorphic rock fragments (quartz, schist, gneiss), sand is mainly quartz Moderate plasticity in matrix Trace of CaCO3 No bedding apparent (Coarse gravel up to 2" maximum diameter) Clay matrix lense at 1 75' Dry 44% Gravel, 26% sand, 20% silt, 10% clay
No recovery (1 75' 2 0')

CL — Silty Clay with some sand and a trace of gravel Yellowish red (5 YR 4/6) Sand c-f, quartz, subangular Gravel f, quartzite, angular Moderate plasticity No bedding Dry 57% Clay, 25% silt, 15% sand, 3% gravel

GW/gc — Sandy Gravel with some silt and clay
Same as 0 0'-2 3' See description above
44% Gravel 26% sand, 20% silt 10% clay

SW/sc — Gravelly sand with some silt and clay Color varies from Olive Yellow (5 Y 6/6), yellow (2 Y 7/6), strong brown (7 5 YR 5/8), strong brown (7 5 YR 4/6 to brown (7 5 YR 5/4) Well sorted Gravel m-f Sand f-c Gravel and sand rounded to subrounded Gravel mainly metamorphic rock fragments, sand mainly quartz No bedding apparent Slightly moist to very moist becomming more wet with depth Sand becomes more fine with depth 63% Sand, 25% gravel, 6% silt, 6% clay
4 0'-7 0' appears to be composed of weathered schist, gneiss, and granite Mottled color
7 0'-12 6' Finer sand and gravel with less mottling Becomes wet to saturated at 12 0'
11 5'-12 6' Less gravel fraction, increase in fine fraction (53% Sand, 18% gravel, 15% clay, 14% silt)

374

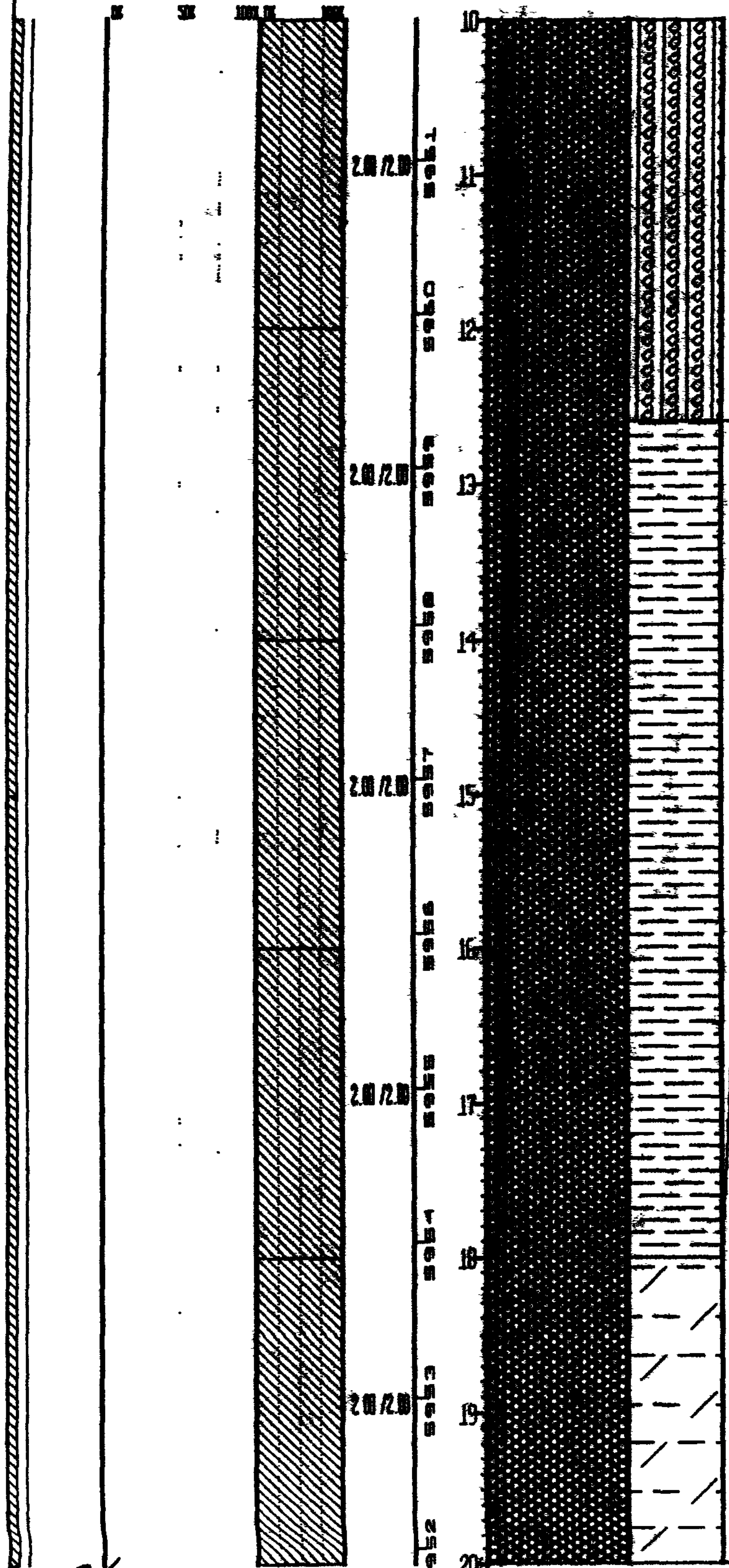
STATE PLANE COORDINATE		TOTAL DEPTH (FT) 30 00		GROUND ELEVATION (FT)	5971 90	PROJECT NUMBER	007-RFI/RI
NORTH	753291	AREA 007 PRESENT LANDFILL		CASING DIAMETER (IN)		GEOLOGIST	D. L. HIGOR
EAST	2083637	LOCATOR NUMBER 0		BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/10/94

LOG OF BORING NUMBER

53494

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING. TOTAL DEPTH = 30.0' TOP OF BEDROCK 12.6' TOP OF UN WEATHERED BEDROCK 27 0'
GEOTECHNICAL SAMPLES ONLY CORE LOGGER J.A. HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM(FT) | DEPTH(FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION



CLAYSTONE — Top of bedrock 12.6' Claystone with a trace of silt and sand Light yellowish brown (2.5 Y 6/3) to light brownish gray (2.5 Y 6/2). Fine grained sand Sand and silt angular to subangular mainly composed of quartz, poorly sorted, porosity 20%-30%, not cemented (clay?) Very slightly friable, plastic No apparent bedding Micro-fine horizontal and vertical fractures, Some Fe-oxide staining gives mottled appearance Trace of carbonaceous material Trace caliche nodules, weathered Moist 97% Clay, 2% silt, 1% sand.

SILTY CLAYSTONE — Top of unweathered bedrock 27 0' Silty Claystone with a trace of sand Color varies greatly with degree of weathering From light brownish gray (2.5 Y 6/2), grayish brown (2.5 Y 5/2) olive yellow (2.5 Y 6/8), brown (7.5 YR 5/2), to gray (10 YR 5/1). Poorly sorted sand and silt Fine grained sand, angular to subangular, mainly quartz Porosity ranges from 10% to 20%. No cement Very to moderately friable. Moderately soft and plastic thinly laminated with Fe-oxide stains and trace of carbonaceous laminae Micro-fractures occur on core that is intact, vertical and horizontal fracturing not apparent on disturbed sections of core 18.0' Slightly moist, 22'-30' saturated. 80% Clay, 17% silt, 3% sand.

18 0'-19.5' Core is highly disturbed Lightly Fe-oxide stained and carbonaceous material spotty

19 5'-26.0' Core mainly intact Fe-oxide heavily stains this section

26.0'-27 0' Soft plastic

27 0'-29.0' Unweathered bedrock. Same composition as above with darker coloring, lack of Fe-stains, and abundant carbonaceous material

29 0'-30 0' Heavily FeO2 stained core marks thin fine sand and silt laminae as well as spotty carbonaceous material Slightly weathered

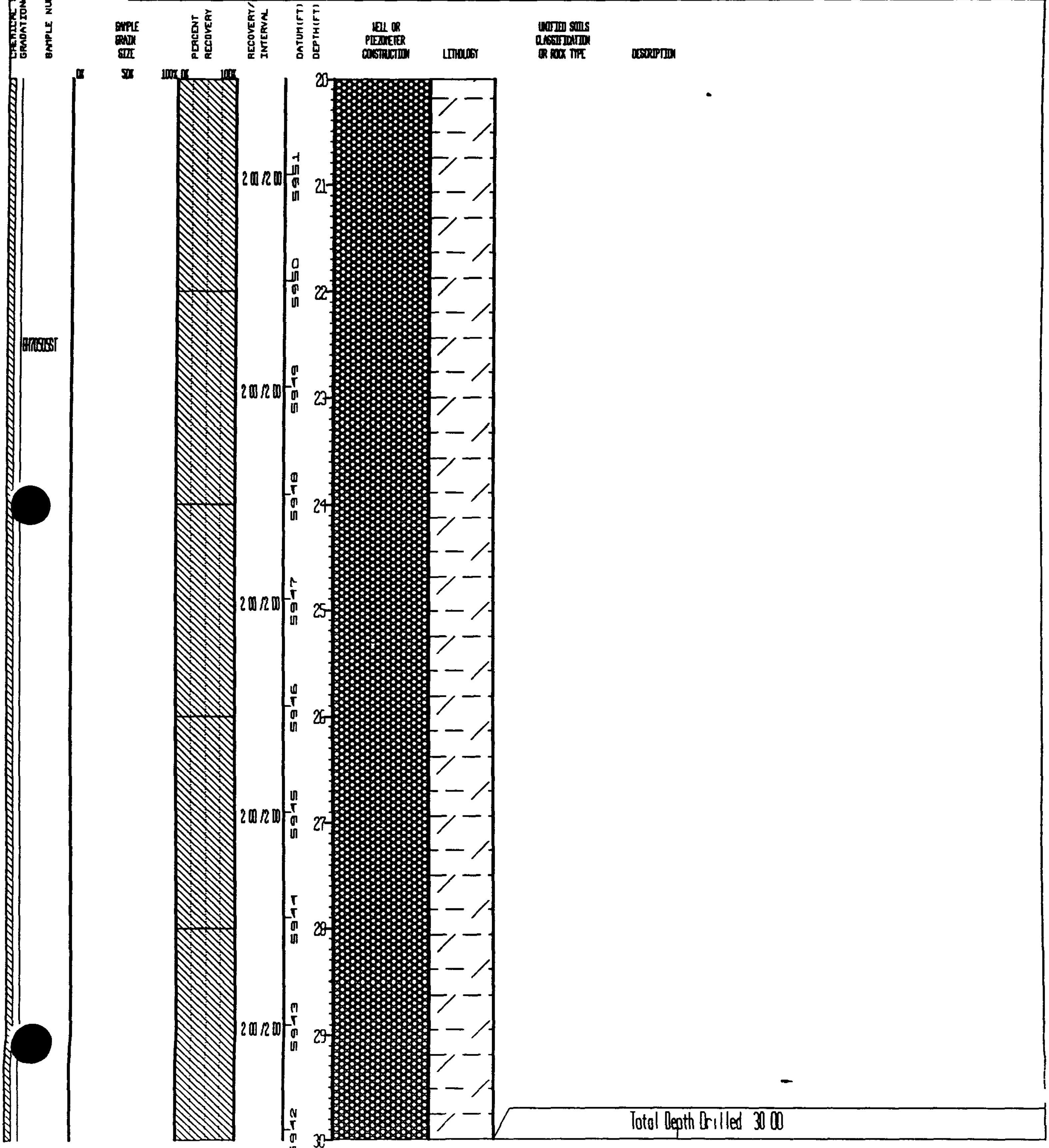
375

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 30.00	GROUND ELEVATION (FT) 5971.90	PROJECT NUMBER OU7-RFI/RI
NORTH 753291	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)	GEOLOGIST D L RIGOR
EAST 2083637	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7.00	DATE DRILLED 10/10/94

LOG OF BORING NUMBER

53494

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 30.0 TOP OF BEDROCK 12.6 TOP OF UN WEATHERED BEDROCK 27.0' GEOTECHNICAL SAMPLES ONLY CORE LOGGER J A HIGGINS



Total Depth Drilled 30.00

376

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 30 00	GROUND ELEVATION (FT)	5561.20	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753360	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D L HIGOR	53594
EAST	2084089	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/10/94	

REMARKS: WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 30 0' TOP OF BEDROCK 16.2' TOP OF UNWEATHERED BEDROCK 28 1'
GEOTECHNICAL SAMPLES ONLY CORE LOGGER: J.A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE (0% – 50%) | PERCENT RECOVERY (100% 0% – 100%) | RECOVERY/INTERVAL | DATUM (FT) / DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION

Recovery/Interval
0.50 /2.00
1.75 /2.00
1.75 /2.00
2.00 /2.00
2.00 /2.00

Depth (ft)	USCS	Description
0	SW	Gravelly Sand with some silt and a trace of clay Matrix is brown (10 YR 5/3) Gravel fmc (mainly medium with clasts up to 2.0"), sand fmc (mainly medium) Well graded Gravel and sand angular to subangular Gravel mainly quartzite with other metamorphic rock types. Sand predominantly quartz with hornblend, feldspar, and other metamorphic rock types Dry No apparent bedding CaCO3 present in top 4 inches (in spotty pockets) 53% Sand, 40% gravel, 6% silt, and 1% clay No recovery (0 5'-2 0'), (3 75'-4 0')
4	SM	Silty Sand with trace of clay and gravel Light yellowish brown (10 YR 6/4) Gravel f, sand fmc (predominantly f) Poorly graded Sand is subangular to rounded made up of quartz and feldspar No apparent bedding Moist to wet Loose 90% Sand, 7% silt, 2% clay, 1% gravel No recovery (4 75'-6 0')
6	SM	Gravelly Sand with some silt and clay Yellowish brown (10 YR 5/8) Gravel mf, sand fmc (predominantly f) Gravel subrounded, sand subangular to subrounded Well graded Gravel is quartzite and other metamorphic rock fragments Sand quartz, feldspar, hornblend Very moist Loose 78% Sand, 10% gravel, 6% silt, and 6% clay
7	SC	Clayey Sand interlayered with Sandy Clay with some silt and a trace of gravel Mottled yellowish brown (10YR 5/8) and Light olive gray (5 Y 6/2) Gravel f Sand fmc (predominantly f) Gravel rounded to subangular, sand angular to subrounded Gravel is quartzite and ironstone nodules Sand is mainly quartz and feldspar No apparent bedding Moist 69% Sand, 23% clay, 6% silt, 2% gravel

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 30 00	GROUND ELEVATION (FT) 5951 20	PROJECT NUMBER 007-RFI/RI	LOG OF BORING NUMBER	
NORTH 753060	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	GEOLOGIST D L HIGOR	**53594**	
EAST 2084089	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7 00	DATE DRILLED 10/10/94		

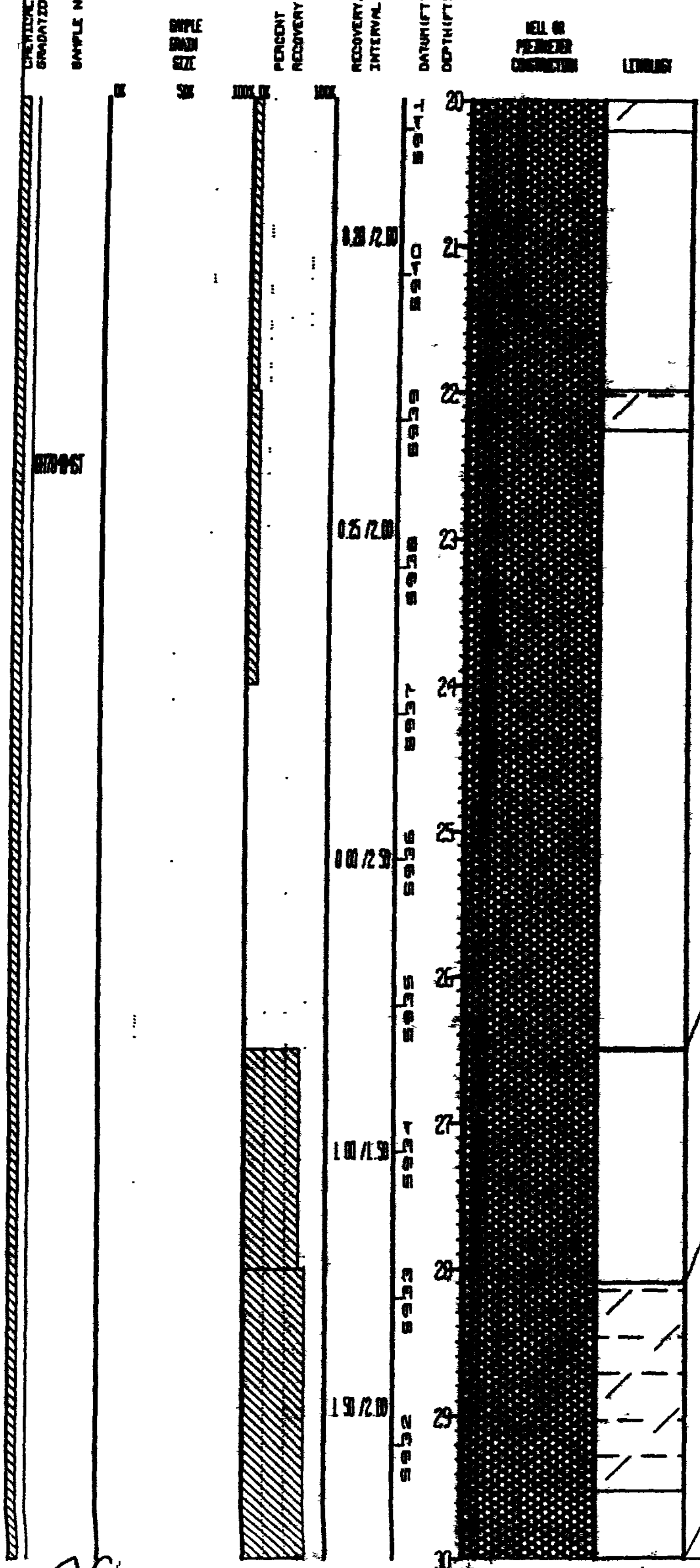
REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 30 0 TOP OF BEDROCK 16 3 TOP OF UNWEATHERED BEDROCK 28 1
GEOTECHNICAL SAMPLES ONLY CORE LOGGER J A HIGGINS

CHEMICAL SAMPLE DEPTH / GRADATIONAL DEPTH / SAMPLE NUMBER / SAMPLE GRAIN SIZE (0% 50% 100%) / PERCENT RECOVERY (0% 100%) / RECOVERY/INTERVAL / DATUM (FT) / DEPTH (FT) / WELL OR PIEZOMETER CONSTRUCTION / LITHOLOGY / UNIFIED SOILS CLASSIFICATION OR ROCK TYPE / DESCRIPTION

RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
2 00/2 00	5951, 5950	10–12	SM	Gravelly Sand with some silt and clay interlayered with Gravelly Sandy Clay with some silt Yellowish brown (10 YR 5/8) Gravel f Sand f&c Gravel rounded to subangular, sand angular to rounded Gravel dominantly ironstone, sand mainly quartz with feldspar No apparent bedding Wet 11 0'-12 0' Ironstone nodules heavily concentrated and carbonaceous deposits present 61% Sand, 19% gravel, 10% clay, 10% silt
0 25/2 00	5949, 5948	12–14	SM	Gravelly Sand with some silt and trace of clay Dark yellowish brown (10 Y 3/6) Gravel f-m Sand c&f Gravel and sand dominantly angular Gravel and sand both completely composed of ironstone fragments No apparent bedding Saturated (Probably weathered ironstone) 46% Sand, 38% gravel, 14% silt, 2% clay Top of bedrock 16 3' No recovery (12 25' 16 0')
0 00/2 00	5947, 5946	14–16		
1 00/2 00	5945, 5944	16–18	SILTY CLAYSTONE	Silty Claystone with a trace of sand Light yellowish brown (2 5 Y 6/3) to gray (2 5 Y 5/1) Sand is f angular, quartz Well sorted Porosity 5%-10% Not cemented (clay?) Very slightly friable Bedding not apparent Fractures at 16 5' micro-fine in the horizontal and vertical directions Slight iron staining throughout section (16 3' 18 0', 20 0'-22 0', 22 0' 24 0') Moist 90% Clay, 6% silt, 4% sand 20 0'- 20 2' Dry No recovery (20 2' 22 0'), (22 25' 26 50')
0 00/2 00	5943, 5942	18–20		

STATE PLANE COORDINATE		TOTAL DEPTH (FT) 30 00	GROUND ELEVATION (FT)	5961 20	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER	
NORTH	753060	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D. L. HIGAR	53594	
EAST	2084089	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7.00	DATE DRILLED	10/10/94		

REMARKS: WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 30 0' TOP OF BEDROCK 16 3' TOP OF UNWEATHERED BEDROCK 28 1' GEOTECHNICAL SAMPLES ONLY CORE LOGGER- J.A HIGGINS



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
SANDY CLAYSTONE	Sandy Claystone with some silt Light olive brown (2 5 Y 5/3) Moderately sorted Sand angular, fine, mainly quartz Porosity=15%-20% highly friable. No bedding apparent Core is highly disturbed, brecciated or caused by drilling unknown. Abundant iron-oxide staining lessening with depth Dry Slightly to moderately weathered No recovery (26 5'-28 1')
SILTY CLAYSTONE	Top of unweathered bedrock 28 1' Silty Claystone with trace of sand Very dark grayish brown (2 5 Y 3/2) Sand f, angular, quartz Well sorted Porosity=20% not cemented highly friable No bedding apparent in broken-up core Core is broken-up, appears brecciated Lacks Fe-oxide stains, has few carbonaceous deposits thinly laminated where preserved Dry 85% Clay, 10% silt, 5% sand Top of unweathered bedrock 28 1' No recovery (29 5-30 0')
	Total Depth Drilled 30.00

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STATE PLANE COORDINATE		TOTAL DEPTH (FT) 34 00	GROUND ELEVATION (FT)	5939 00	PROJECT NUMBER	OU7-RFI/RI	LOG OF BORING NUMBER
NORTH	753403	AREA OU7 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D L RIGOR	53694
EAST	2084561	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/05/94	

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 34 0 TOP OF BEDROCK 2 0 TOP OF UNWEATHERED BEDROCK 13 8
CORE LOGGER J A HIGGINS GEOTECHNICAL SAMPLES ONLY

CHEMICAL BREAK DEPTH / GRADATIONAL BREAK DEPTH	SAMPLE NUMBER	SAMPLE GRAIN SIZE (0% – 50% – 100%)	PERCENT RECOVERY (0% – 100%)	RECOVERY/ INTERVAL	DATUM(FT)	DEPTH(FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
	BH70401ST			1 50 /2 00	5939 – 5938	0–2			CH	Silty Clay with some sand and a trace of gravel Light brownish gray (2 5 Y 6/2) Gravel and sand fine Gravel and sand subangular Highly plastic Gravel and sand made up of quartz No apparent bedding Top of bedrock at 2 0' Dry CaCO3 present in small nodules Weathered bedrock mixed into soil zone Dry 44% Clay, 30% silt, 21% sand, 5% gravel No recovery (1 5'-2 0')
	BH70402ST			2 00 /2 00	5937 – 5936	2–3.5			SILTY CLAYSTONE	Top of bedrock 2 0' Silty Claystone with a trace of silt Light yellowish brown (2 5 Y 6/3) Sand content quartz, vf Very well sorted Porosity-10% Not cemented Slightly friable Bedrock broken-up by drilling action Bedding not apparent Highly disturbed Dry 74% Clay, 18% silt, 8% clay
				1 75 /2 00	5935 – 5934 – 5933	4–6				
				2 00 /2 00	5932 – 5931	7–8				
				2 00 /2 00	5930	8–10			SANDY CLAYSTONE	Sandy Claystone with a trace of silt Light yellowish brown (2 5 Y 6/4) to pale olive (5 Y 6/4) Abundant iron-oxide staining gives a mottled appearance Sand predominantly fine Well sorted, angular to subangular Slightly to moderately friable Porosity-15% Not cemented Sand grains dominantly quartz Bedding is laminar v thin and horizontal Micro-fractures exist at 45 degree angles and horizontal Dry 86% Clay 13% sand, 1% silt No recovery (5 75 6 0)

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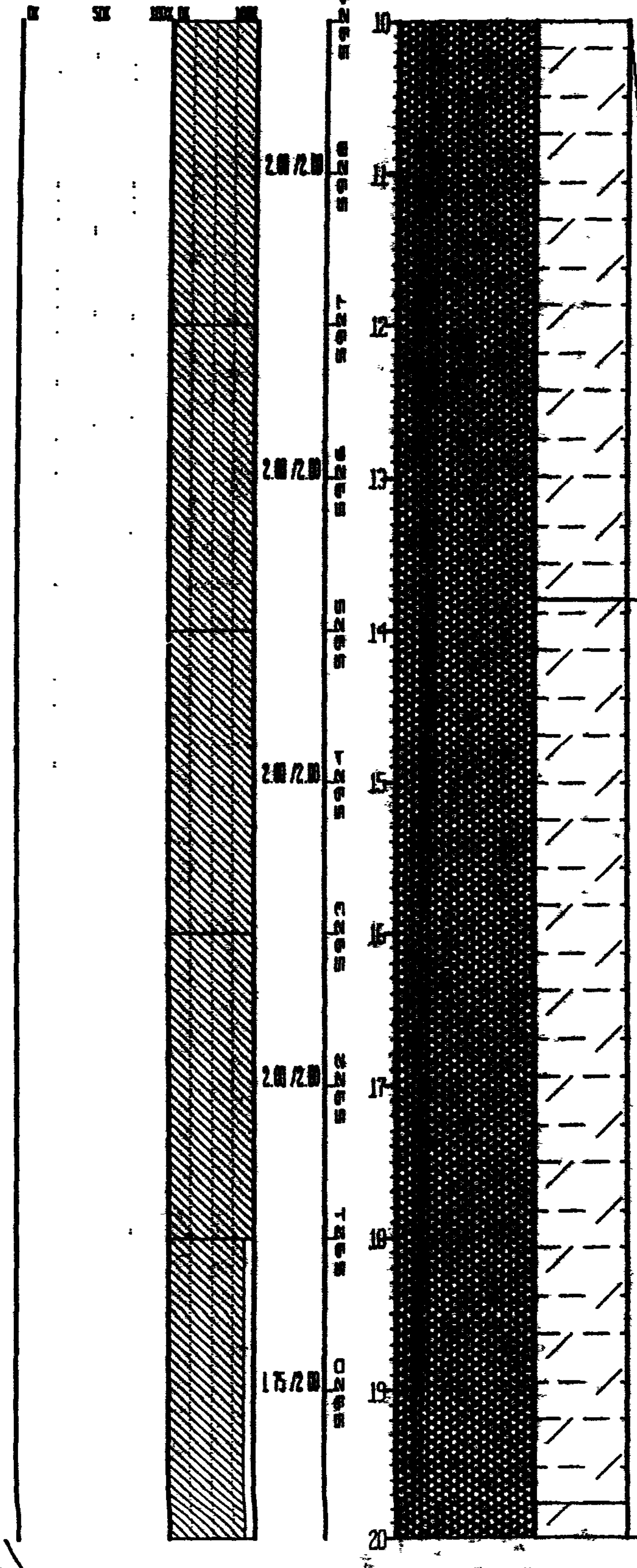
STATE PLANE COORDINATE	TOTAL DEPTH (FT) 34 00	GROUND ELEVATION (FT)	5939 00	PROJECT NUMBER	OU7-RFI/RI
NORTH 753403	AREA 4U7 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D L HIGAR
EAST 2084561	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/05/94

LOG OF BORING NUMBER

53694

REMARKS: WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 34 0' TOP OF BEDROCK 2.0' TOP OF UNWEATHERED BEDROCK 13 8'
CORE LOGGER J A HIGGINS. GEOTECHNICAL SAMPLES ONLY

CHEMICAL SAMPLE DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION



SILTY CLAYSTONE Silty Claystone (Silt and sand content each no more than 5%) with a trace of sand Mottled, dominantly olive yellow (2.5 Y 6/6) and light brownish gray (2.5 Y 6/2) Sand grains are fine, mainly quartz, angular Well sorted Porosity=5%-10% Not cemented. Moderately friable Bedding appears laminated, very thin and horizontal Multiple very fine horizontal fractures (caused by drilling?). Abundant iron-stains and some carbonaceous pockets present Core is highly disturbed from 10.0'-10 5' Dry to slightly moist 91% Clay, 5% silt, 4% sand.
10.0'-11 0' Highly weathered with iron-stains and fractures

SILTY CLAYSTONE Top of unweathered bedrock 13.8' Silty Claystone with some sand Very dark grayish brown (2 5 Y 4/2) to dark gray (2 5 Y 4/1) Sand is F angular to subangular, made-up mainly of quartz Moderately to poorly sorted. Porosity=1% No cement Very to slightly friable Bedding is thinly laminated some horizontal few vertical fractures (micro-fine) Dry Abundant coal nodules, few iron-stains 49% Clay, 37% silt, 14 % sand
Decreasing sand content with depth and increasing clay content, increasing silt content and becoming more weathered at 18.0'. Bedrock is very disturbed from 18 0'-20 0' Trace of vertical fractures with limonite (FeO2) staining
16 0'-18 0' 50% Clay, 42% silt, 8% sand
18.0'-19 75' 80% Clay, 15% silt, 5% sand
13 8'-22 0' Becomes moderately weathered with a trace of FeO2 along fractures
No recovery (19 75-20 0)

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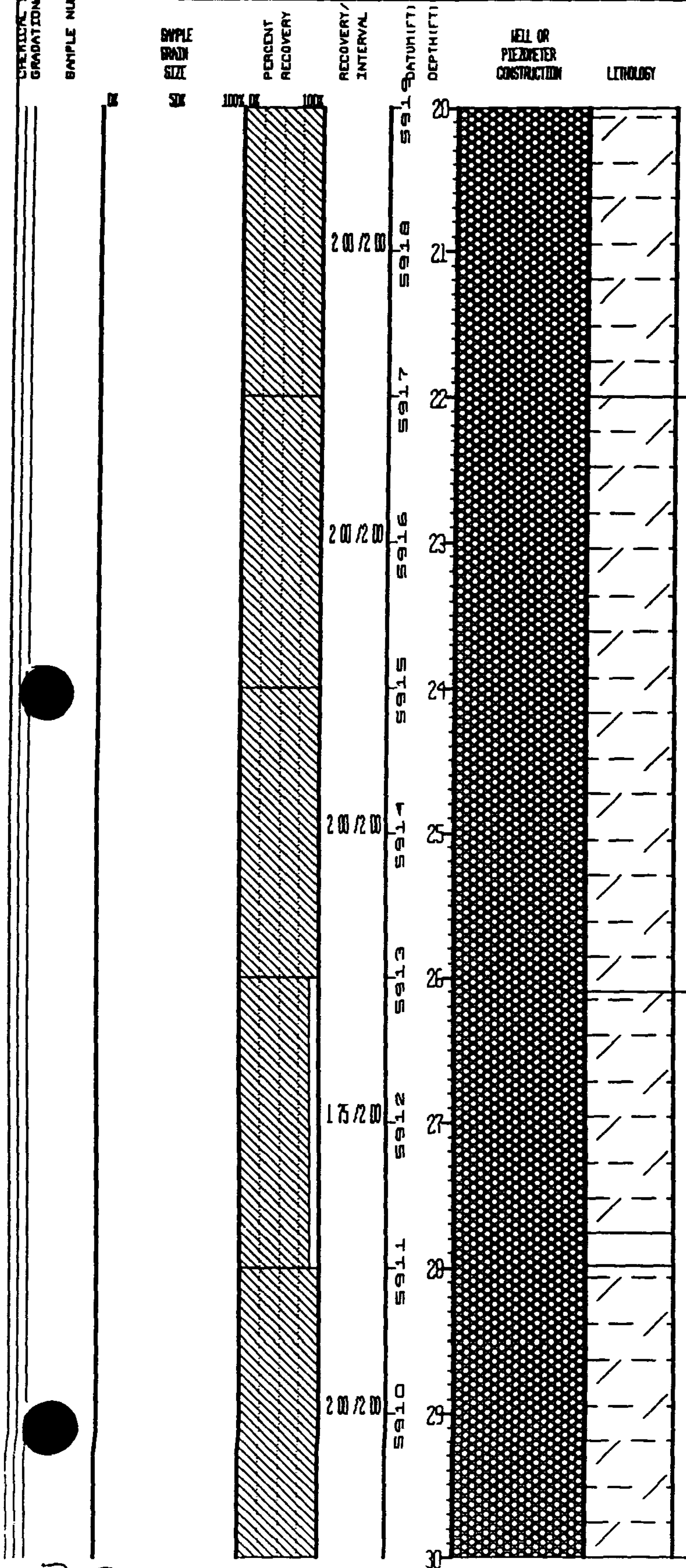
STATE PLANE COORDINATE		TOTAL DEPTH (FT) 34 00	GROUND ELEVATION (FT)	5939 00	PROJECT NUMBER	007-RFI/RI	LOG OF BORING NUMBER
NORTH	753403	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)		GEOLOGIST	D L RIGOR	53694
EAST	2084561	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN)	7 00	DATE DRILLED	10/05/94	

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOTAL DEPTH 34 0 TOP OF BEDROCK 2 0 TOP OF UNWEATHERED BEDROCK 13 8

CORE LOGGER J A HIGGINS GEOTECHNICAL SAMPLES ONLY



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
SILTY CLAYSTONE	Silty Claystone with some sand light yellowish brown (2 5 Y 6/4) to grayish brown (2 5 Y 5/2) Sand fm, angular, quartz Moderately sorted Porosity 20%-30% Not cemented Very friable Thinly laminated, thin and horizontal Micro-fractures horizontal, vertical, and at 45 degree angles Few iron-stone nodules and little iron-staining Carbonaceous deposits in few spots Core is 'blocky' and in some spots very disturbed (24 0'-24 4') Layers alternate between more silty and less silty Dry 50% Clay, 35% silt, 15% sand
SILTY CLAYSTONE	Silty Claystone with some sand Dominantly olive yellow (2 5 Y 6/6) to dark olive brown (2 5 Y 3/3) to grayish brown (2 5 Y 5/2) to olive brown (2 5 Y 4/3) Sand mf, angular, quartz Moderately sorted Porosity 30%-50% Not cemented Highly friable Moderately weathered No apparent bedding Core is very disturbed Natural or caused by drilling actions unknown Appearance seems brecciated Alternates between more silty and less silty layers, color alternates with silt content With more silt, more brown, less silt more gray Abundant iron-stains occur in more silty layers 26 1'-28 0 Higher silt content 29 5'-30 3 Higher silt content, ironstone nodules 33 0 -34 0 Higher silt content No recovery (27 75-28 0')

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LOG OF BORING NUMBER

53694

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 34.00	GROUND ELEVATION (FT) 5939.00	PROJECT NUMBER 007-RF3/RE
NORTH 753403	AREA 007 PRESENT LANDFILL	CASING DIAMETER (IN)	GEOLOGIST D. L. HIGOR
EAST 2084561	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7.00	DATE DRILLED 10/05/94

REMARKS: WELL NOT INSTALLED. BOREHOLE ABANDONED AFTER DRILLING. TOTAL DEPTH 34.0'. TOP OF BEDROCK 2.0'. TOP OF UNWEATHERED BEDROCK 33.0'.
CORE LOGGER: J. A. HIGGINS. GEOTECHNICAL SAMPLES ONLY.

CHEMICAL ANALYSIS SAMPLE DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE | PERCENT RECOVERY | RECOVERY/INTERVAL | DATUM (FT) | DEPTH (FT) | WELL OR PIEZOMETER CONSTRUCTION | LITHOLOGY | UNIFIED SOILS CLASSIFICATION OR ROCK TYPE | DESCRIPTION

0% 50% 100% 0% 100%

Recovery/Interval: 2.00 /2.00 (at 31); 2.00 /2.00 (at 33)

Datum (ft): 5909, 5908, 5907, 5906, 5905, 5904, 5903, 5902, 5901, 5900

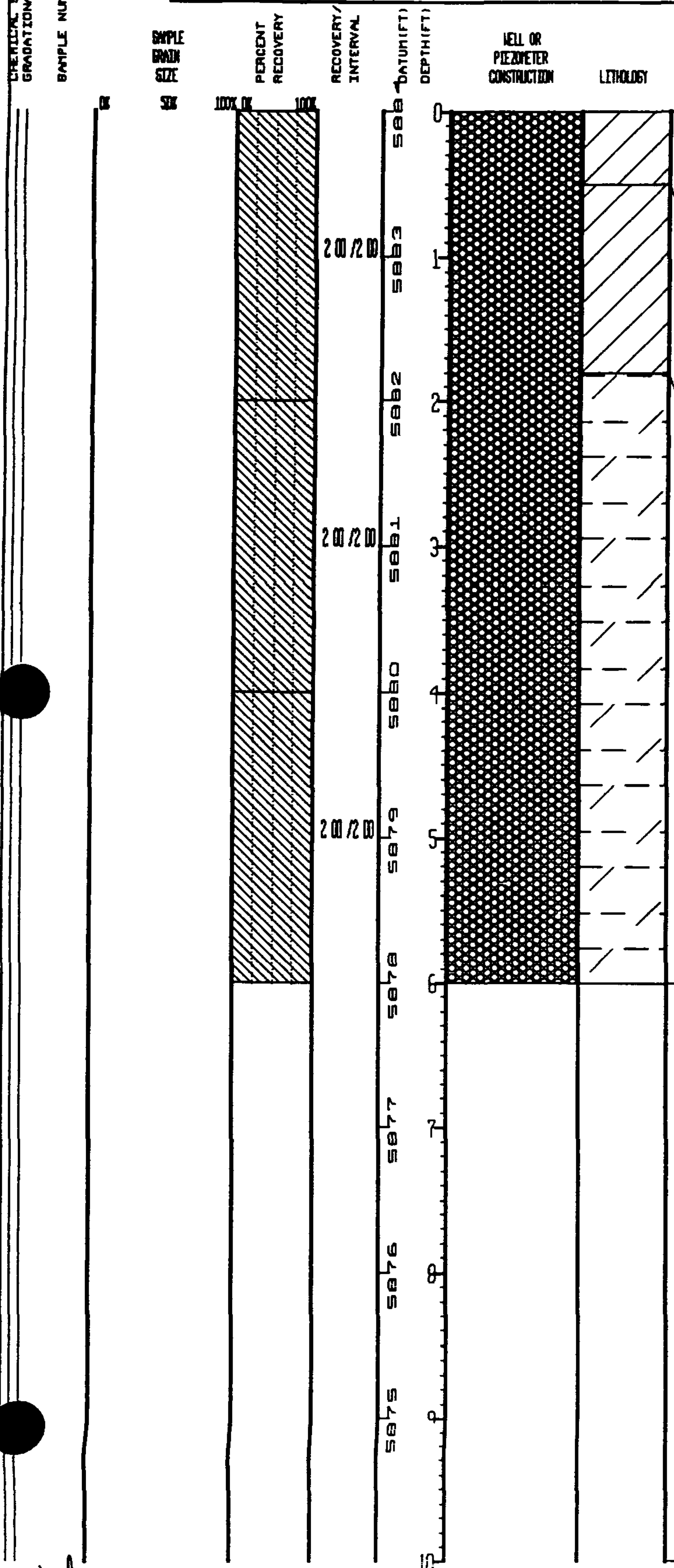
Depth (ft): 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

Total Depth Drilled 34.00

LOG OF BORING NUMBER 53794

STATE PLANE COORDINATE	TOTAL DEPTH (FT) 6 00	GROUND ELEVATION (FT) 5884 00	PROJECT NUMBER 0U7-RFI/RI
NORTH 753304	AREA 0U7 PRESENT LANDFILL	CASING DIAMETER (IN)	GEOLOGIST D L RIGOR
EAST 2085068	LOCATOR NUMBER 0	BOREHOLE DIAMETER (IN) 7 00	DATE DRILLED 10/11/94

REMARKS WELL NOT INSTALLED BOREHOLE ABANDONED AFTER DRILLING TOP OF BEDROCK 1 8 TOTAL DEPTH 6 0 CORE LOGGER J A HIGGINS
NO SAMPLES COLLECTED



UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
CL	Silty Clay with some sand and trace of gravel Olive brown (2 5 Y 4/3) Sand and gravel fine, subrounded, quartzite and quartz High plasticity No bedding Abundant roots and other organics Dry 55% Clay 37% silt, 7% sand, 1% gravel
CL	Silty Clay with some sand and a trace of gravel Light olive brown (2 5 Y 5/4) Gravel and sand f, rounded angular, quartz and ironstone nodules High plasticity No bedding apparent Stiff Dry CaCO3 and carbonaceous deposits present 77% Clay, 20% silt 2% sand, 1% gravel
SILTY CLAYSTONE	Top of bedrock 1 8' Silty Claystone with a trace of sand Light yellowish brown (2 5 Y 6/4) to grayish brown (2 5 Y 5/2) Sand medium to fine, rounded to subangular, quartz Porosity 20% 35% Moderate to highly friable No apparent bedding Stiff Fractures not apparent, core too broken up Dry 80% Clay, 14% silt, 5% sand 1 8'-3 5' abundant Fe-oxide staining, core basically intact 3 5'-4 0' core intact, lacks Fe-oxide staining (Top of unweathered bedrock) 4 0'-6 0' core very broken up by drilling Same composition but highly disturbed Lacks Fe-stains
	Total Depth Drilled 6 00

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B 1 Drawdown Recovery Test Data and Analytical Solutions

The data for the hydraulic conductivities are compiled from two sources Tables B-1 through B-5 present the hydraulic conductivities established in the OU 7 Final Work Plan (DOE 1994) In Figures B-1 through B-3, the results of the tests performed in the additional Phase I field investigation are shown The data from additional Phase I field investigation are not included in Tables B-1 through B-5 because these tests were performed after the information was compiled for the numerical flow model However, these values fall well within the range of the data found in the OU 7 Final Work Plan A description of the methodologies for the drawdown-recovery and slug tests performed is located in the OU 7 Final Work Plan

The hydraulic conductivity ranges for the various geological formations are as follows the values ranged from 9 62 E-06 to 6 70 E-04 for the artificial fill, the values ranged from 5 90 E-06 cm/sec to 1 30 E-03 cm/sec for the alluvial materials, the values ranged from 1 48 E-07 cm/sec to 1 29 E-06 cm/sec for the weathered bedrock hydraulic conductivity, and finally, the values ranged from 4 70 E-07 cm/sec to 1 05 E-06 cm/sec for the unweathered bedrock

Completion information for wells downgradient of the landfill is provided in Table B-6

B 2 References

DOE 1994 Final Work Plan Technical Memorandum for Operable Unit No 7—Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203) U S Department of Energy Rocky Flats Site, Golden Colorado September

Table B-1
Geometric Mean of Hydraulic Conductivity for OU 7 Surficial Materials (Alluvial and Artificial Fill)

Location	Type of Test	Hydraulic Conductivity K	Natural Log K	K, ft/day
6087	s	1 30E-03	6 65E+00	3 68
6187	s	9 90E 04	-6 92E+00	2 81
70093	d	4 05E 04	7 81E+00	1 15
5987	d	1 60E-05	1 10E+01	0 05
70393	d	2 99E 05	1 04E+01	0 08
70693	d	3 37E 04	8 00E+00	0 96
7893	d	6 20E 05	9 69E+00	0 18
71193	d	5 90E 06	1 20E+01	0 02
71493	d	9 62E 06	1 16E+01	0 03
6287	s	6 20E 04	7 39E+00	1 76
6387	s	6 70E 04	7 31E+00	1 90
72393	d	1 35E-04	8 91E+00	0 38
72093	d	2 32E-05	1 07E+01	0 07
6587	s	4 60E 04	7 68E+00	1 30
6687	s	1 80E 04	8 62E+00	0 51
72293	d	6 48E 05	9 64E+00	0 18
6787	s	6 40E-05	9 66E+00	0 18
7187	s	6 60E 04	7 32E+00	1 87
Averages		**3 35E-04**	**-8 96E+01**	
Exponent Average Nat Log			**1 28E-04**	
Conversion (cm/sec to ft/day)			**2833 92**	
K ft/day			**0 36**	

Definitions

d drawdown recovery test
lug te t

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Table B-2
Geometric Mean of Hydraulic Conductivity for OU 7 Artificial Fill

Location	Type of Test	Hydraulic Conductivity K	Natural Log K	K, ft/day
71493	d	9.62E-06	-1.16E+01	0.03
6387	s	6.70E-04	7.31E+00	1.90
72393	d	1.35E-04	-8.91E+00	0.38
72093	d	2.32E-05	-1.07E+01	0.07
72293	d	6.48E-05	-9.64E+00	0.18
Averages		1.81E-04	-9.62E+00	
Exponent Average Nat Log			6.7E-05	
Conversion (cm/sec to ft/day)			2833.92	
K, ft/day			0.19	

Definitions

d drawdown-recovery test
s slug test

Table B-3
Geometric Mean of Hydraulic Conductivity for OU 7 Alluvial Materials

Location	Type of Test	Hydraulic Conductivity K	Natural Log K	K, ft/day
6087	s	1 30E 03	6 65E+00	3 68
6187	s	9 90E 04	-6 92E+00	2 81
70093	d	4 05E 04	7 81E+00	1 15
5987	d	1 60E 05	1 10E+01	0 05
70393	d	2 99E 05	1 04E+01	0 08
70693	d	3 37E 04	8 00E+00	0 96
7893	d	6 20E-05	9 69E+00	0 18
71193	d	5 90E 06	1 20E+01	0 02
6287	s	6 20E 04	7 39E+00	1 76
6587	s	4 60E 04	7 68E+00	1 30
6687	s	1 80E 04	8 62E+00	0 51
6787	s	6 40E 05	9 66E+00	0 18
7187	s	6 60E 04	7 32E+00	1 87
Averages		**3 95E-04**	**-8 71E+00**	
Exponent Average Nat Log			**1 65E-04**	
Conversion (cm/sec to ft/day)			**2833 92**	
K ft/day			**0 47**	

Definitions

d drawdown recovery test
s slug test

Table B-4
Geometric Mean of Hydraulic Conductivity for OU 7 Weathered Bedrock

Location	Type of Test	Hydraulic Conductivity K	Natural Log K	K, ft/day
70193	d	1 29E-06	1.36E+01	0 0037
70493	d	1 48E-07	1 57E+01	0 0004
B206489	s	5 80E-07	1.44E+01	0.0016
B207089	s	2 30E-07	-1.53E+01	0 0007
Averages		**5 62E-07**	**-1.47E+01**	
Exponent of Average Nat Log			**4.0E-07**	
Conversion (cm/sec to ft/day)			**2833.92**	
K, ft/day			**0.0011**	

Definitions

d drawdown-recovery test
s slug test

Table B-5
Geometric Mean of Hydraulic Conductivity for OU 7 Unweathered Bedrock

Location	Type of Test	Hydraulic Conductivity K	Natural Log K	K, ft/day
70293		4 70E-07	-1 46E+01	0 0013
70595		5 60E-07	1 44E+01	0 0016
70893		5.90E-07	1 43E+01	0.0017
53094		1 05E-06	1 38E+01	0 0030
Averages		**5.40E-07**	**-1.43E+01**	
Exponent of Average Nat Log			**6.35E-07**	
Conversion (cm/sec to ft/day)			**2833.92**	
K, ft/day			**0.0018**	

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Table B-6
Completion Information for Wells Downgradient of the Landfill

Location	Formation Completed	Screen Interval (feet bgs)	Hydrostratigraphic Unit	Date Completed
Wells in the Vicinity of the East Landfill Pond				
0786	Qc	3 00 5 74	UHSU	1986
0886	KaKlss(u)	59 08 63 79	LHSU	1986
B206789	KaKl(w)	9 80-19 28	UHSU	1989
B206889	KaKl(w)	8 00-17 45	UHSU	1989
Wells Downgradient of the Dam				
4087	Qvf	3 50 6 46	UHSU	1987
4187	KaKlss(u)	81 21 93 79	LHSU	1987
4287	Qvf	3 00 6 36	UHSU	1987
B206989	KaKl(w)	11 80-21 30	UHSU	1989
B207089	KaKlss(u)	31 32 57 98	LHSU	1989
52894	Qvf	3 00-4 00	UHSU	1994
52994	KaKl(w)	7 50 15 00	UHSU	1994
53094	KaKlss(u)	55 00 65 00	LHSU	1994
53194	Qvf	4 50-7 00	UHSU	1994

Definitions

KaKl(w) weathered undifferentiated Cretaceous Arapahoe and Laram e Formation
KaKlss(u) unweathered undifferentiated Cretaceous Arapahoe and Laramie Formation
Qc Quaternary colluvium
Qvf Quaternary valley fill alluvium
bgs below ground surface
UHSU upper hydrostratigraphic unit
LHSU lowe hydrostratigraph c un t

Figure B-1
AQTESOLV Solution for Well 53094x

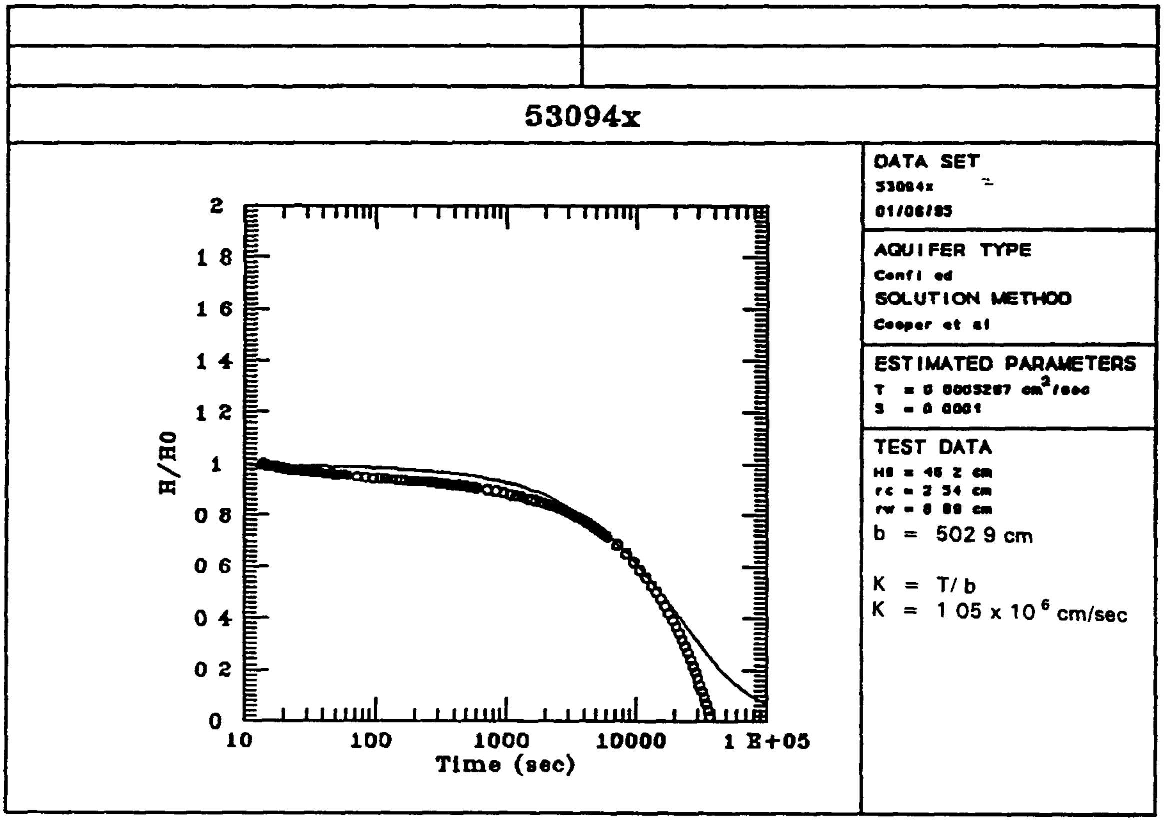

Figure B-2
AQTESOLV Solution for Well 53194

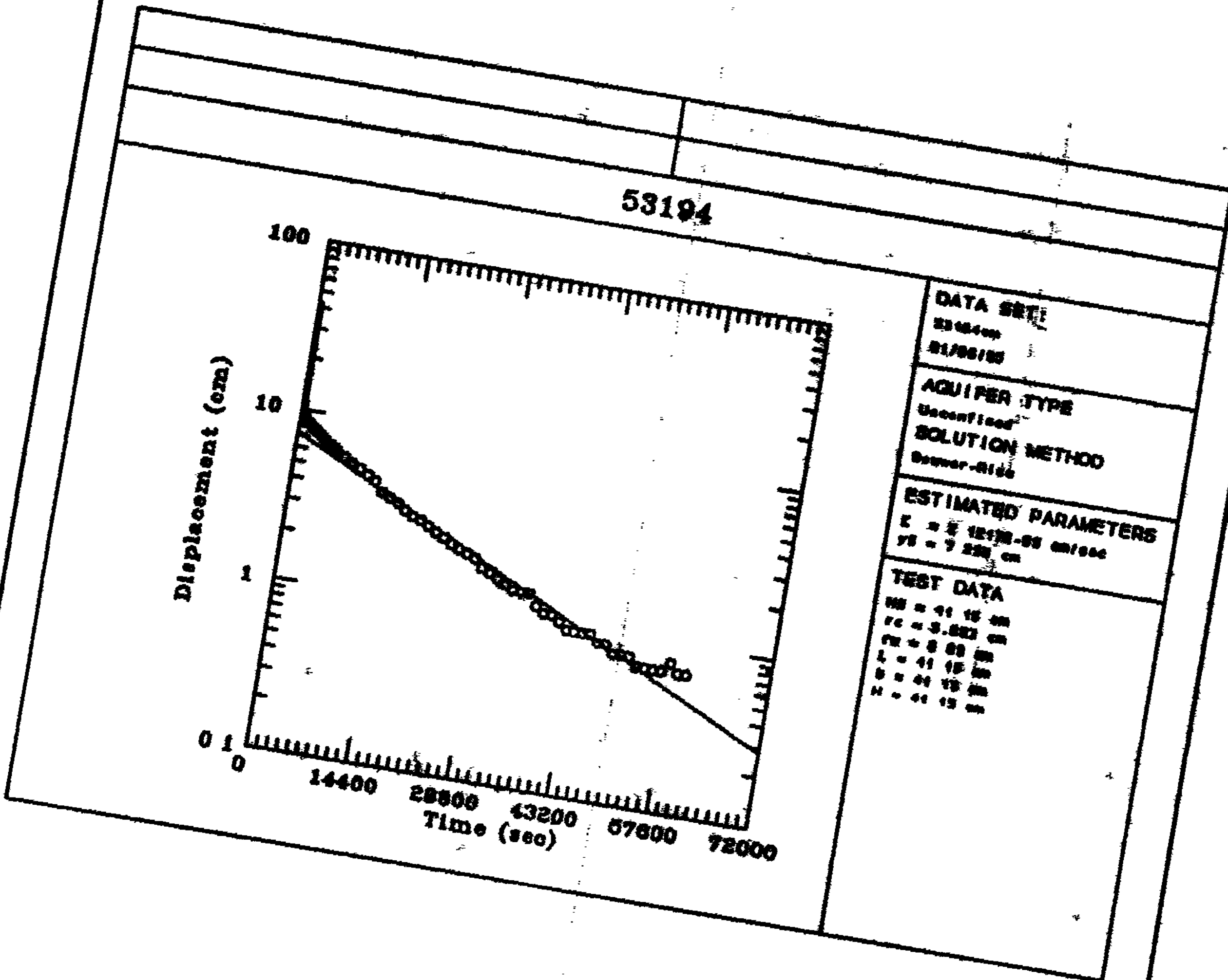

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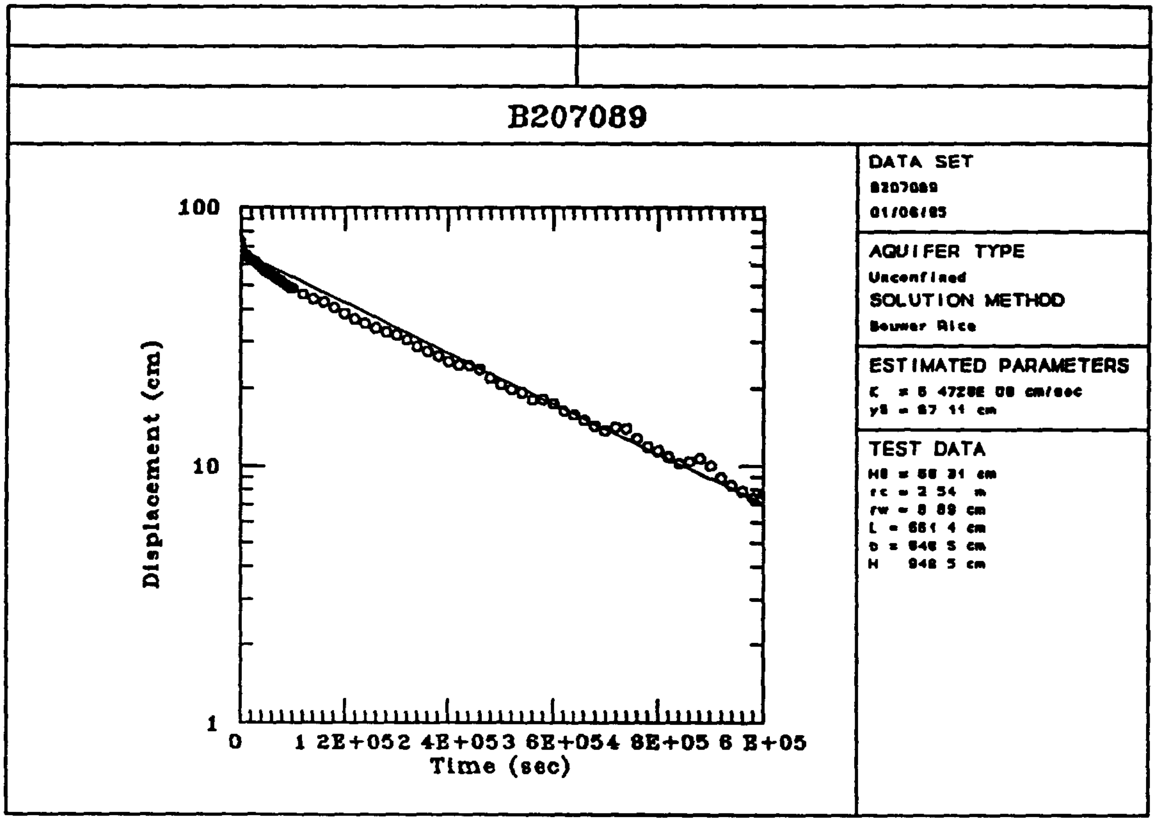
Figure B-3
AQTESOLV Solution for Well B207089



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C 1 Introduction

Groundwater flow modeling and particle tracking were performed in support of the Phase I Interim Measure/Interim Remedial Action (IM/IRA) Decision Document for Operable Unit (OU) 7 The flow modeling and particle tracking increased understanding of the hydrogeologic system and provided information regarding the effectiveness of various closure scenarios for the landfill Water balances were performed for various closure scenarios using the numerical model The purpose of the water balances is to assess the contributions of the various potential sources of inflow to the landfill that contribute to leachate generation These sources include infiltration of precipitation or recharge, inflow under or through the groundwater-intercept system inflow under or through the north and south slurry walls and inflow from the weathered bedrock below the landfill

C 2 Objectives

The objectives of the groundwater modeling for OU 7 are as follows

- Support the Phase I IM/IRA Decision Document
- Develop an enhanced conceptual model of the flow system at OU 7
- Estimate flow volumes into the landfill through groundwater flow and infiltration
- Establish the relative importance of surficial materials and weathered bedrock in the transport of contaminated groundwater
- Provide estimates of flow into and out of the landfill mass at various locations around the landfill perimeter
- Determine pathways for contaminants and develop strategies to intercept or interrupt these pathways
- Provide a relative comparison of various remedial action alternatives designed to intercept or interrupt contaminant pathways

C 3 Conceptual Model

The conceptual model is described in Section 2 3 1 of this report Important components of the groundwater system in and near the landfill include infiltration flow in surficial materials flow in weathered bedrock flow captured by the groundwater-intercept system flow that escapes the groundwater-intercept system, flow to the seep at SW097, pond interactions with groundwater, and seepage between the surficial materials and weathered bedrock Flow in the unweathered bedrock and seepage between weathered bedrock and unweathered bedrock were assessed as negligible in the conceptual model and were not included in the numerical model

C.4. Model Selection

The numerical modeling code chosen to simulate the groundwater system was MODFLOW PATH3D was chosen as a particle tracking software to simulate the flow of contaminated water. MODELCAD386 was used as preprocessor for MODFLOW and PATH3D Postprocessing was performed using CALSTATS, SURFER, and POSTMOD The reasons for the selection of MODFLOW and PATH3D include the following

- The ability to simulate two layers, alluvium and weathered bedrock, was an important requirement for the model
- MODFLOW and PATH3D are well documented, widely used, and well validated
- The sitewide groundwater modeling effort at Rocky Flats uses MODFLOW Use of MODFLOW at OU 7 enhances the possibility of integration of the modeling efforts
- PATH3D was chosen to help identify contaminant pathways and estimate travel times for conservative contaminants such as chloride The effectiveness of interrupting contaminant pathways can be evaluated using PATH3D

The MODFLOW and PATH3D modeling consisted of the following steps (1) model construction, including selection of grid extent and model boundaries, selection of grid cell size, and importing of existing topographic data and aquifer data, (2) calibration using one set of well head measurements, (3) verification using an alternate set of well head measurements, (4) sensitivity analysis on various parameters, and (5) predictive simulations of flow and particle behavior under various scenarios

C.5. Model Construction

Construction of the MODFLOW model involved the selection of grid extent and model boundaries, selection of grid cell size, and importing of existing topographic data and aquifer data

C.5 1 Selection of Grid Extent and Model Boundaries

A model grid of 5,000 feet by 1,500 feet was selected The selected area extends approximately 500 feet upgradient of the landfill mass to the west, 2,000 feet downgradient of the East Landfill Pond to the east 200 feet south of the landfill to a groundwater divide and 500 feet north of the landfill The long axis of the model grid is oriented approximately 16 degrees north of magnetic east This orientation puts the long axis of the model grid parallel to the main direction of flow Surficial materials are modeled as the upper layer weathered bedrock is simulated as the second layer, and unweathered bedrock is modeled as a no-flow boundary This grid size and orientation focuses on the landfill mass and surrounding area This area has approximately 30 monitoring wells in surficial materials and 10 monitoring wells in weathered bedrock The area has been well studied by previous investigations (DOE 1994)

The south boundary of the model is coincident with a groundwater divide and is simulated as a no-flow boundary The west and east boundaries are simulated as constant head boundaries The north boundary is simulated as a general head boundary which allows adjustment of the flux of water in the model The stream below the dam was simulated using general head boundary cells Drain cells with low conductivity cells directly downgradient were used to simulate the existing groundwater-intercept system The East Landfill Pond is modeled as a constant head boundary Two different boundary conditions were used to simulate the leachate seep a constant head boundary cell and a drain cell No major differences were observed between the use of the two different types of boundaries The final calibrated model used a constant head cell to simulate the seep Existing slurry walls and the East Landfill Pond dam are simulated by low hydraulic conductivity cells Layer 1 model grid and model boundaries are presented in Figure C-1 and Table C-1 Layer 2 model grid and model boundaries are presented in Figure C-2 and Table C-2

C 5 2 Selection of Grid Cell Size

A grid cell size of 50 feet by 50 feet is used throughout the model This size was chosen because of the need to simulate a variety of saturated zone features such as slurry walls, drains, capture wells and low conductivity areas (i e landfill dam), that are relatively close together

C 5 3 Topographic and Hydraulic Parameter Data

The bottom of alluvium and bottom of weathered bedrock elevations were obtained from available sitewide geographic information system (GIS) information These values were refined in the center of the landfill area using information in the OU 7 Final Work Plan (DOE 1994) Bottom elevations for layers 1 and 2 are presented in Figure C-3 and Figure C-4, respectively The number inside each cell represents a model zone number' for elevation The elevations corresponding to each elevation zone number are presented in Table C-3

The geometric means of previous hydraulic conductivity measurements were used as initial values for hydraulic conductivity for the two layers The range of measured

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hydraulic conductivity values determined the allowable hydraulic conductivities in the two layers Individual hydraulic conductivity measurements are presented in Figure 2-10 and in Appendix B of this report.

Other parameters include recharge, specific storage, specific yield, and porosity Parameters, acceptable ranges, and information sources are presented in Table C-4

C.6. Calibration and Verification

The model was calibrated using one set of well head measurements and verified using another set of well head measurements

C.6 1 Calibration Using March 1993 Head Measurements

The flow model was steady-state calibrated to well head measurements taken in March 1993 These flows are representative of moderate flow conditions approximately midway between the low water levels in winter and the highs that are usually recorded in April (see well hydrographs in EG&G 1995) Five variables were altered to achieve calibration (1) recharge, (2) heads of the constant head and general head boundaries, (3) conductances of the general head boundaries and the drain cells, (4) hydraulic conductivities of individual cells, and (5) ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity The model was run using a transient state for 10,000 days with a time step of 5 days This 10,000-day time period with no excitations simulated a steady-state condition. At the end of the simulation the heads were saved These saved heads were used as the starting heads for future simulations

Calibration was assessed by comparison to point measurements (well water elevations) and by comparison to interpolated potentiometric surface contours. The goals of calibration are as follows

- Achieve the general configuration of potentiometric surfaces and hydraulic gradients
- Simulate observation wells within plus or minus 3 feet in 90 percent of the locations.
- Achieve the above goals with reasonable parameter values

To assist in calibration, the computer program CALSTATS was used This program calculates the residual at each well, residual mean, residual standard deviation, residual sum of squares, and absolute residual mean For surficial materials, 16 target locations and heads were used For weathered bedrock, nine target locations and heads were used The CALSTATS results for the no-action scenario are presented in Table C-5

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The current model calibration uses a recharge value of 0 0002 feet/day or 0 88 inches/year This value is approximately 5 5 percent of the average annual precipitation at Rocky Flats This value was selected through a trial and error process with hydraulic conductivity values set at the values discussed below The conductances of general head boundaries and drain cells were varied to modulate flows into and out of these cells Unfortunately, no data exist regarding flows in the groundwater-intercept system Similarly there are no monitoring wells or piezometers at or near the selected model boundaries Any errors at the boundaries should be relatively unimportant within the area of concern (the landfill mass and surrounding area)

The hydraulic conductivities were changed within the range of conductivities that had been exhibited for the layer in question Hydraulic conductivity values for Layer 1 range from 0 072 to 7 2 feet/day with 0 72 feet/day assigned to most cells Most cells in Layer 2 are assigned a hydraulic conductivity value of 0 0022 feet/day, with certain cells assigned a value of 0 022 feet/day Hydraulic conductivity values for layers 1 and 2 are presented in Figure C-5 and Figure C-6, respectively The number inside each cell represents a model zone number for hydraulic conductivity Note that each cell is assigned a zone number for bottom elevation and a different zone number for hydraulic conductivity The hydraulic conductivities corresponding to each hydraulic conductivity zone number are presented in Table C-6

The model was not particularly sensitive to the ratio of horizontal to vertical hydraulic conductivities Ratios between 1 and 10 were evaluated The ratio of 10 was selected for the final calibration because this value resulted in a slightly reduced residual sum of squares value

To confirm the assumptions used within the MODFLOW model and the water balance, the evidence and conclusions presented in the OU 7 Final Work Plan (DOE 1994) were examined The Final Work Plan concluded that the groundwater-intercept system is effective on the south side of the landfill and is not effective on the north side of the landfill This conclusion is supported by Figure C-7, Potentiometric Map of Surficial Material and by Figure C-8 Saturated Thickness of Surficial Material Figure C-7 shows the 5 970-foot potentiometric surface line bulging into the landfill mass, and Figure C-8 shows that saturated thicknesses on the north side of the landfill range from 10 to 20 feet The potentiometric surface is depressed on the south side of the landfill The wells on the south side of the landfill (wells 71693 and 6487) in the area where the intercept system is potentially not keyed into weathered bedrock are either dry or nearly dry Based on the information presented in these figures, the assertion that the groundwater-intercept system is failing on the north side and working on the south side appears justified

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The groundwater flow model is relatively successful in simulating the potentiometric surface of the surficial materials The calibration goals above are met with one exception Only 81 percent of the wells are simulated within plus or minus 3 feet Three of 16 wells exceed this target Of these, one is on the north side of the landfill near the groundwater-intercept system, the second is north of the landfill and out of the area of concern, and the third is below the dam The well below the dam has a simulated head higher than the actual head, making flow estimates at this point conservative Figure C-9 presents the simulated potentiometric surface for surficial materials (Layer 1 in the model) The calibration with respect to individual water levels in wells is also shown A negative number indicates that the modeled head is greater than the actual head. A positive number indicates that the modeled head is less than the actual head

The groundwater flow model is less successful in simulating the potentiometric surface of the weathered bedrock. The calibration goals were not met. The weathered bedrock heads tended to mirror the heads in surficial materials While this is fairly accurate for some well clusters in many locations the weathered bedrock is unsaturated and a "perched" water table condition exists in surficial materials MODFLOW is not capable of modeling this type of perched condition The model shows more water in the weathered bedrock layer than actually exists Therefore, the model should generate conservative flow estimates for the weathered bedrock However, flows and potential transport in fractures are not modeled

C 6.2 Verification Using April 1992 Well Head Measurements

An alternate set of well head measurements from April 1992 was used to verify the final model configuration and final hydraulic conductivity assignments These head measurements were selected because they were significantly greater than any other available well head measurements The heads were simulated by altering the recharge and the heads of the constant head and general head boundaries The verification was fairly successful However, the residual sum of squares for Layer 1 was larger than the residual sum of squares for the no-action scenario and the percentage of wells not meeting the calibration criteria increased The goal of the alternate calibration was to determine if the hydraulic conductivity values used in the initial calibration are "reasonable" If the hydraulic conductivity values are not "reasonable," a large variation in model response in different areas would be expected. This variation was not observed The CALSTATS results for the April 1992 well head measurements are presented in Table C-7

C.7. Sensitivity Analysis

Sensitivity analysis was performed on the following parameters recharge hydraulic conductivity, the heads of the constant head and general head boundaries and the

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conductances of the general head boundaries and the drain cells The measures used to assess quality of fit were the parameters calculated by the CALSTATS program CALSTATS calculates the residual mean the residual standard deviation, the residual sum of squares, the absolute residual mean, the minimum residual the maximum residual the observed range in head and the residual standard deviation/range for the entire model and for each of the layers separately The model showed itself to be somewhat insensitive to the heads of the constant head and general head boundaries on the perimeter of the model A set of estimated head values for the model boundary were established from an existing sitewide potentiometric surface map (EG&G 1995) Changing values within a reasonable range (plus/minus three feet) did not drastically affect the calibration The model was more sensitive with respect to the heads and conductances of the general head boundaries representing the streams and the drain cells representing the existing groundwater-intercept system Hydraulic conductivities and recharge are heavily interdependent For any given set of hydraulic conductivities the model was sensitive with respect to recharge The hydraulic conductivities used are grouped around a value two times the geometric mean of measured values The model also calibrated well (residual sum of squares for Layer 1 less than 150) using values grouped around the geometric mean The model did not calibrate well using greater hydraulic conductivities (residual sum of squares increased and number of wells not meeting calibration target increased) The calibration using two times the geometric mean as the base' hydraulic conductivity was chosen because of quality of fit and reasonableness of simulated flows at the leachate seep

C 8 Predictive Simulations

As stated above the initial model was run using a transient state for 10 000 days with a time step of 5 days This 10 000-day time period with no stresses simulated a steady-state condition The steady state heads were used as the initial heads for predictive simulations No attempt was made to model seasonal conditions Rather, average conditions over time were modeled

C 8 1 Water Balance Calculations for Various Scenarios

Using the calibrated flow model multiple scenarios using different configurations of slurry walls, caps, and drains were modeled A water balance for the landfill mass was performed using the MODFLOW model cell-by-cell flow outputs for three alternatives A summary of the flows for the three scenarios is presented in Table C-8 For each scenario, outflow equals inflow The model shows that approximately three-fourths of the outflow is in the vicinity of the seep The remaining one-fourth flows into the pond as groundwater baseflow The scenarios and resultant flows are as follows

1 **No-Action Scenario** This scenario assumes that the groundwater flow system remains unchanged Total flow into the landfill is 1 9 gallons per minute (gpm)

Recharge or infiltration contributes approximately 0 8 gpm of that amount. Groundwater inflow contributes approximately 1 1 gpm. Outflow equals inflow

2 **North Slurry Wall Scenario** This scenario assumes that the groundwater flow is altered by the addition of a 1 x 10^{7} cm/sec hydraulic conductivity slurry wall on the north side of the landfill No cap is assumed Total flow into the landfill is 1 3 gpm Recharge or infiltration contributes approximately 0 8 gpm of that amount Groundwater inflow contributes approximately 0 5 gpm. Outflow equals inflow

3 **North Slurry Wall and Cap Scenario** This scenario assumes that the groundwater flow is altered by the addition of a 1 x 10^{7} cm/sec hydraulic conductivity slurry wall on the north side of the landfill and a single-barrier cap Total flow into the landfill is 0 4 gpm. Recharge or infiltration contributes approximately 0 01 gpm of that amount. Groundwater inflow contributes approximately 0 4 gpm. Outflow equals inflow

Each water balance was performed on Layer 1 in the model, which includes alluvial material and artificial fill and excludes weathered bedrock and unweathered bedrock. The water balance includes flow in and out of the surficial materials from the weathered bedrock. The following steps were performed

1 A horizontal boundary plane was defined using the right-hand and front faces of individual cells in Layer 1 These cells were just inside the drain cells used to simulate the existing groundwater-intercept system. The location of the horizontal boundary plane is presented in Figure C-10 As used by MODFLOW, horizontal inflow is groundwater flow between cells within a single model layer (flow through the right face or front face of a single model cell). Figure C-11 presents the MODFLOW terminology for the flows out of an individual cell

2 Cell-by-cell flows recorded at the final modeled time step were used in tabulating the flows through the defined horizontal boundary plane Cell-by-cell flows out of the right face and out of the front face are recorded as positive numbers. A multiplier of -1 was used where flows into the landfill are from right to left or from bottom to top (plan view) Cells on the north, west, and south are tabulated together because these are the expected inflow cells to the landfill Cells on the east side are tabulated separately because they are the expected outflow cells to the landfill (Table C-9) The flows across each segment of the boundary plane are tabulated in Table C-9 and presented in Figure C-10. The flow rates presented in Figure C-10 represent the results of the water balance for the no-action scenario

3 Vertical flow is tabulated in Table C-10 for all cells within the horizontal boundary planes For the MODFLOW model, vertical inflow is groundwater flow between cells in different model layers (flow through the lower face of individual cells) (Figure C-11)

4 The landfill area receiving recharge from precipitation (infiltration) is calculated A check was performed to locate any dry cells that will not receive recharge The

flow rate of recharge is calculated using the recharge area and the recharge flux rate (Table C-11)

5 A water balance is performed using the horizontal inflow, vertical inflow recharge and horizontal outflow (Table C-12)

6 Tables C-13 to C-16 provide detailed information on the water balance for the north slurry wall alternative Tables C-17 to C-20 provide detailed information on the water balance for the north slurry wall and cap alternative

C 8 2 Particle Tracking

The basic calibrated flow model combined with particle tracking using PATH3D was used to establish flow paths in and near the landfill mass Particle tracking for surficial materials and weathered bedrock is presented in Figures C-12 and C-13 respectively The particle tracking is for 10,000 days for both figures PATH3D uses effective porosity combined with specific discharge to calculate seepage velocity Retardation is incorporated in PATH3D by multiplying the effective porosity by the retardation factor decreasing the seepage velocity

For these particle tracking runs, effective porosity is assumed to be 0 30 and retardation is set to 1 0 The particle tracking is extremely sensitive to the input values for effective porosity and retardation The porosity value of 0 30 is a reasonable value for overall porosity Multiple sources report that effective porosity is approximately equal to overall porosity (Freeze and Cherry 1989, Fetter 1988) However other studies at Rocky Flats have used an effective porosity value of 0 10 which is closer to the specific yield than to the overall porosity (Belcher 1995) This smaller value of effective porosity would increase the speed of contaminant movement The speed that particles travel is highly dependent on the effective porosity used However the value of 0 30 used in these simulations is adequate for the following reasons

- One of the major purposes of the particle tracking is to show flow paths Flow paths are the same regardless of the effective porosity used

- Most contaminants exhibit a retardation factor significantly greater than one If the effective porosity is actually 0 10, the value used for porosity is equivalent to an effective porosity of 0 10 and a retardation factor of 3 This is a reasonable retardation factor for many contaminants

- One use of the particle tracking is to estimate the time required to receive a pore volume change of water For most types of soils, a value closer to the overall porosity should give a better estimate than a value close to the specific yield

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The particle tracking illustrates the following points

- Flows from the east end of the landfill are concentrated in the vicinity of the leachate seep (SW097)
- A potential flow path exists from the vicinity of IHSSs 166 1, 166 2, and 166 3 around the south side of the dam
- Contaminant movement in the weathered bedrock matrix is expected to be very slow Particles in Layer 2 of the model move very little which implies that contaminant transport in the weathered bedrock matrix will be dominated by diffusion MODFLOW and PATH3D are not capable of modeling potential flow and contaminant transport in fractures

Although not shown in these particular figures, particles initially placed in the dam are released very slowly, which illustrates the effectiveness of the dam in retarding the transport of contaminants in surficial materials

An examination of particle tracking at different times suggests that particles from the center of the landfill reach the seep in approximately 5,000 days (over 13 years) This suggests that this portion of the landfill receives a pore volume change of water during this time period. The eastern portion of the landfill receives a pore volume change more slowly (in approximately 10,000 days or over 27 years)

C 8.3 Estimation of Flow to Seep Area

The output from the basic calibrated flow model was examined to estimate the concentration of flow at the leachate seep (SW097) This was accomplished by examination of the cell-by-cell flows to the drain cell simulating the seep and the constant head cells at the pond The total simulated flow into the seep and pond is 414 ft^3/day, or 2 15 gpm The flows into the one drain cell and the two constant head cells directly east of the drain cell total 284 ft^3/day, or 1 47 gpm The drain cell could not lower the potentiometric surface down to the seep elevation (approximately 5,923 feet) Based on observations at the seep and at well 0786, it is likely that in the physical system most if not all of the simulated flow to the drain and the first two constant head cells exits at the seep The fraction of simulated flow in the immediate vicinity of the seep is 68 percent of the total flow to the pond and seep

C 8 4 Estimation of Time Required to Dewater Landfill Mass

A simulation was run using low hydraulic conductivity cells to simulate the proposed north slurry wall and recharge was set to 2E-06 feet/day (reduced by two orders of magnitude) over the landfill mass to simulate the proposed cap Flows out of the landfill mass over the 10,000-day period are presented in Table C-21 Flows out of the landfill mass decreased from 1 81 gpm at zero days to 0 88 gpm at 2,000 days to 0 39 gpm at 9 000 days The flow rate remained steady after 9,000 days This implies that equilibrium has been reached with the inflow to the landfill equaling the outflow The potentiometric surfaces for Layer 1 for every 1 000 days of simulated time are presented in Figures C-14 through C-24 Areas of dewatering are shown by multiple potentiometric lines converging around an area Figure C-14 shows four areas of dewatering east of the dam at time zero in the simulation Although no wells exist in the dewatered areas this is consistent with the observation that wells below the dam are often dry At 1 000 days (Figure C-15), a small area of dewatering is observed west of the pond By 3,000 days (Figure C-17) significant areas of dewatering have developed in the eastern portion of the landfill mass Additional dewatering has occurred by 6 000 days (Figure C-20)

Full dewatering of the landfill does not occur in the simulation Two factors prevent full dewatering (1) a small amount of infiltration still occurs and (2) a weathered bedrock ridge exists near the center of the landfill, effectively trapping some water in surficial materials west of this ridge Based on this simulation, a decrease in potentiometric surfaces, saturated thickness in landfill mass, and outflow from the landfill is expected in 5 to 10 years from the date of implementation of the cap and north slurry wall

C 9 Summary and Conclusions

A MODFLOW model simulating OU 7 groundwater flow system was constructed calibrated and verified Predictive simulations included water balance calculations for various scenarios particle tracking using PATH3D to identify contaminant pathways, estimation of flow to the seep area and estimation of the time required to dewater the landfill mass The model objectives listed in Section C 2 were met

C 10 References

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C.11. Software

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Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
Constant Head Cells				
2	100	1	5905	NA
3	100	1	5905	NA
4	100	1	5905	NA
5	100	1	5905	NA
6	100	1	5903	NA
7	100	1	5901	NA
8	100	1	5893	NA
9	100	1	5884	NA
10	100	1	5871	NA
11	100	1	5861	NA
12	100	1	5853	NA
13	100	1	5845	NA
14	100	1	5837	NA
15	100	1	5831	NA
25	100	1	5869	NA
26	100	1	5877	NA
27	100	1	5883	NA
28	100	1	5891	NA
29	100	1	5895	NA
20	100	1	5831	NA
21	100	1	5837	NA
22	100	1	5845	NA
23	100	1	5853	NA
24	100	1	5861	NA
16	100	1	5827	NA
17	100	1	5825	NA
18	100	1	5825	NA
19	100	1	5825	NA
13	1	1	5990	NA
14	1	1	5990	NA
15	1	1	5990	NA
16	1	1	5990	NA
17	1	1	5990	NA
18	1	1	5990	NA
19	1	1	5990	NA
20	1	1	5990	NA
21	1	1	5990	NA
22	1	1	5990	NA
23	1	1	5990	NA
24	1	1	5990	NA
25	1	1	5990	NA
26	1	1	5990	NA
27	1	1	5990	NA
28	1	1	5990	NA
29	1	1	5990	NA

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
		Drain Cells		
17	17	1	5970	1.00E-03
18	17	1	5973	1.00E-03
16	17	1	5970	1.00E-03
16	18	1	5970	1.00E-03
15	18	1	5970	1.00E-03
15	19	1	5970	1.00E-03
15	20	1	5970	1.00E-03
14	20	1	5970	1.00E-03
14	21	1	5970	1.00E-03
12	30	1	5962	1.00E-03
12	31	1	5960	1.00E-03
12	32	1	5960	1.00E-03
12	33	1	5960	1.00E-03
12	34	1	5960	1.00E-03
19	18	1	5971	8.40E-01
18	18	1	5971	1.00E-03
20	18	1	5966	8.40E-01
20	19	1	5964	1.68E+00
20	20	1	5964	1.68E+00
21	20	1	5964	1.68E+00
21	21	1	5964	1.68E+00
21	22	1	5964	1.68E+00
22	22	1	5964	1.68E+00
22	23	1	5964	1.68E+00
22	24	1	5964	1.68E+00
23	24	1	5964	1.68E+00
23	25	1	5962	1.68E+00
23	26	1	5962	1.68E+00
23	27	1	5962	1.68E+00
23	28	1	5962	1.68E+00
23	29	1	5962	1.68E+00
23	30	1	5964	1.68E+00
23	31	1	5962	1.68E+00
23	32	1	5962	1.68E+00
23	33	1	5962	1.68E+00
23	34	1	5960	1.68E+00
23	35	1	5960	1.68E+00
23	36	1	5960	1.68E+00
14	22	1	5970	1.00E-03
14	71	1	5880	2.00E+00
15	71	1	5874	2.00E+00
16	71	1	5874	2.00E+00
17	71	1	5874	2.00E+00
18	71	1	5890	2.00E+00
14	59	1	5906	2.00E+00
15	59	1	5896	2.00E+00

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Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
16	59	1	5894	2 00E+00
17	59	1	5892	2 00E+00
18	59	1	5900	2 00E+00
13	71	1	5880	2 00E+00
19	71	1	5896	2 00E+00
General Head Boundary Cells				
1	41	1	5965	1 00E+00
1	42	1	5964	1 00E+00
1	43	1	5963	1 00E+00
1	44	1	5963	1 00E+00
1	45	1	5962	1 00E+00
1	46	1	5962	1 00E+00
1	47	1	5961	1 00E+00
1	48	1	5960	1 00E+00
1	49	1	5960	1 00E+00
1	50	1	5959	1 00E+00
1	51	1	5959	1 00E-01
1	52	1	5958	1 00E-01
1	53	1	5955	1 00E-01
1	54	1	5951	1 00E-01
1	55	1	5942	1 00E-01
1	56	1	5938	1 00E-01
1	57	1	5940	1 00E-01
1	58	1	5950	1 00E-01
1	59	1	5949	1 00E-01
1	60	1	5944	1 00E-01
1	61	1	5944	1 00E-01
1	62	1	5943	1 00E-01
1	63	1	5942	1 00E-01
1	64	1	5942	1 00E-01
1	65	1	5941	1 00E-01
1	66	1	5940	1 00E-01
1	67	1	5939	1 00E-01
1	68	1	5938	1 00E-01
1	69	1	5937	1 00E-01
1	70	1	5936	1 00E-01
1	71	1	5936	1 00E-01
1	72	1	5936	1 00E-01
1	73	1	5935	1 00E-01
1	74	1	5935	1 00E-01
1	75	1	5934	1 00E-01
1	76	1	5934	1 00E-01
1	77	1	5933	1 00E-01
1	78	1	5933	1 00E-01
1	79	1	5932	1 00E-01
1	80	1	5932	1 00E-01

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
1	81	1	5932	1.00E-01
1	82	1	5931	1.00E-01
1	83	1	5930	1.00E-01
1	84	1	5928	1.00E-01
1	85	1	5927	1.00E-01
1	86	1	5926	1.00E-01
1	87	1	5925	1.00E-01
1	88	1	5924	1.00E-01
1	89	1	5923	1.00E-01
1	90	1	5922	1.00E-01
1	91	1	5922	1.00E-01
1	92	1	5921	1.00E-01
1	93	1	5919	1.00E-01
1	94	1	5918	1.00E-01
1	95	1	5917	1.00E-01
1	96	1	5916	1.00E-01
1	97	1	5915	1.00E-01
1	98	1	5914	1.00E-01
1	99	1	5913	1.00E-01
1	100	1	5912	1.00E-01
16	73	1	5874	1.05E+00
16	74	1	5870	1.05E+00
16	75	1	5866	1.05E+00
16	76	1	5863	1.05E+00
16	77	1	5863	1.05E+00
16	78	1	5863	1.05E+00
16	79	1	5863	1.05E+00
16	80	1	5862	1.05E+00
16	81	1	5862	1.05E+00
16	82	1	5862	1.05E+00
16	83	1	5861	1.05E+00
16	84	1	5859	1.05E+00
16	85	1	5856	1.05E+00
16	86	1	5853	1.05E+00
16	87	1	5850	1.05E+00
16	88	1	5847	1.05E+00
16	89	1	5845	1.05E+00
16	90	1	5843	1.05E+00
16	91	1	5842	1.05E+00
16	92	1	5841	1.05E+00
16	93	1	5840	1.05E+00
16	94	1	5839	1.05E+00
16	95	1	5838	1.05E+00
16	96	1	5837	1.05E+00
16	97	1	5835	1.05E+00
16	98	1	5834	1.05E+00
16	99	1	5833	1.05E+00

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Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
1	27	1	5978	1 05E+00
2	24	1	5979	1 05E+00
2	25	1	5979	1 05E+00
2	26	1	5978	1 05E+00
2	27	1	5978	1 05E+00
3	22	1	5980	1 05E+00
3	23	1	5980	1 05E+00
3	24	1	5979	1 05E+00
4	19	1	5978	1 05E+00
4	20	1	5978	1 05E+00
4	21	1	5977	1 05E+00
4	22	1	5977	1 05E+00
5	17	1	5979	1 05E+00
5	18	1	5979	1 05E+00
5	19	1	5978	1 05E+00
6	14	1	5980	1 05E+00
6	15	1	5980	1 05E+00
6	16	1	5979	1 05E+00
6	17	1	5979	1 05E+00
7	12	1	5986	1 05E+00
7	13	1	5985	1 05E+00
7	14	1	5985	1 05E+00
8	10	1	5987	1 05E+00
8	11	1	5986	1 05E+00
8	12	1	5986	1 05E+00
9	7	1	5988	1 05E+00
9	8	1	5987	1 05E+00
9	9	1	5987	1 05E+00
9	10	1	5987	1 05E+00
10	5	1	5988	1 05E+00
10	6	1	5988	1 05E+00
10	7	1	5988	1 05E+00
11	2	1	5989	1 05E+00
11	3	1	5989	1 05E+00
11	4	1	5989	1 05E+00
11	5	1	5989	1 05E+00
12	1	1	5990	1 05E+00
12	2	1	5990	1 05E+00
1	28	1	5978	1 05E+00
1	29	1	5977	1 05E+00
1	30	1	5976	1 05E+00
1	31	1	5976	1 05E+00
1	32	1	5975	1 05E+00
1	33	1	5974	1 05E+00
1	34	1	5973	1 05E+00
1	35	1	5971	1 05E+00
1	36	1	5970	1 05E+00

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Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
1	37	1	5969	1.05E+00
1	38	1	5968	1.05E+00
1	39	1	5967	1.05E+00
1	40	1	5966	1.05E+00
2	57	1	5925	1.05E+00
3	58	1	5915	1.05E+00
3	59	1	5915	1.05E+00
4	60	1	5915	1.05E+00
4	61	1	5913	1.05E+00
4	62	1	5909	1.05E+00
4	63	1	5905	1.05E+00
5	64	1	5895	1.05E+00
5	65	1	5895	1.05E+00
6	66	1	5895	1.05E+00
7	67	1	5887	1.05E+00
8	68	1	5885	1.05E+00
9	69	1	5883	1.05E+00
9	70	1	5883	1.05E+00
10	71	1	5881	1.05E+00
11	72	1	5881	1.05E+00
12	72	1	5881	1.05E+00
13	73	1	5877	1.05E+00
14	74	1	5875	1.05E+00
15	74	1	5871	1.05E+00

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Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
Constant Head Cells				
2	100	2	5903	NA
3	100	2	5903	NA
4	100	2	5903	NA
5	100	2	5903	NA
6	100	2	5901	NA
7	100	2	5896	NA
8	100	2	5888	NA
9	100	2	5880	NA
10	100	2	5868	NA
11	100	2	5858	NA
12	100	2	5850	NA
13	100	2	5842	NA
14	100	2	5834	NA
15	100	2	5828	NA
16	100	2	5824	NA
17	100	2	5822	NA
18	100	2	5822	NA
19	100	2	5822	NA
20	100	2	5828	NA
21	100	2	5833	NA
22	100	2	5841	NA
23	100	2	5850	NA
24	100	2	5859	NA
25	100	2	5865	NA
26	100	2	5874	NA
27	100	2	5878	NA
28	100	2	5888	NA
29	100	2	5892	NA
12	1	2	5986	NA
13	1	2	5986	NA
14	1	2	5986	NA
15	1	2	5986	NA
16	1	2	5986	NA
17	1	2	5986	NA
18	1	2	5986	NA
19	1	2	5986	NA
20	1	2	5986	NA
21	1	2	5986	NA
22	1	2	5986	NA
23	1	2	5986	NA
24	1	2	5986	NA
25	1	2	5986	NA
26	1	2	5986	NA
27	1	2	5986	NA
28	1	2	5986	NA
29	1	2	5986	NA

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Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
Drain Cells				
14	71	2	5858	2.00E+00
15	71	2	5858	2.00E+00
16	71	2	5858	2.00E+00
17	71	2	5862	2.00E+00
18	71	2	5868	2.00E+00
13	71	2	5858	2.00E+00
19	71	2	5876	2.00E+00
General Head Boundary Cells				
16	73	2	5854	1.67E-02
16	74	2	5853	1.67E-02
16	75	2	5853	1.67E-02
16	76	2	5851	1.67E-02
16	77	2	5849	1.67E-02
16	78	2	5848	1.67E-02
16	79	2	5846	1.67E-02
16	80	2	5844	1.67E-02
16	81	2	5842	1.67E-02
16	82	2	5840	1.67E-02
16	83	2	5838	1.67E-02
16	84	2	5836	1.67E-02
16	85	2	5836	1.67E-02
16	86	2	5835	1.67E-02
16	87	2	5833	1.67E-02
16	88	2	5832	1.67E-02
16	89	2	5830	1.67E-02
16	90	2	5828	1.67E-02
16	91	2	5827	1.67E-02
16	92	2	5825	1.67E-02
16	93	2	5823	1.67E-02
16	94	2	5822	1.67E-02
16	95	2	5822	1.67E-02
16	96	2	5821	1.67E-02
16	97	2	5819	1.67E-02
16	98	2	5818	1.67E-02
16	99	2	5816	1.67E-02
2	57	2	5918	1.67E-02
3	58	2	5908	1.67E-02
3	59	2	5908	1.67E-02
4	60	2	5908	1.67E-02
4	61	2	5906	1.67E-02
4	62	2	5902	1.67E-02
4	63	2	5898	1.67E-02
5	64	2	5988	1.67E-02
6	65	2	5988	1.67E-02
6	66	2	5988	1.67E-02

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
7	67	2	5880	1 67E-02
8	68	2	5878	1 67E-02
9	69	2	5876	1 67E-02
9	70	2	5876	1 67E-02
10	71	2	5874	1 67E-02
11	72	2	5874	1 67E-02
12	72	2	5874	1 67E-02
13	73	2	5870	1 67E-02
14	74	2	5868	1 67E-02
15	74	2	5864	1 67E-02
1	26	2	5975	1 00E-01
1	27	2	5974	1 00E-01
2	23	2	5976	1 00E-01
2	24	2	5976	1 00E-01
2	25	2	5975	1 00E-01
2	26	2	5975	1 00E-01
3	20	2	5977	1 00E-01
3	21	2	5977	1 00E-01
3	22	2	5976	1 00E-01
3	23	2	5976	1 00E-01
4	18	2	5978	1 00E-01
4	19	2	5978	1 00E-01
4	20	2	5977	1 00E-01
5	15	2	5979	1 00E-01
5	16	2	5979	1 00E-01
5	17	2	5979	1 00E-01
5	18	2	5978	1 00E-01
6	12	2	5981	1 00E-01
6	13	2	5980	1 00E-01
6	14	2	5980	1 00E-01
6	15	2	5980	1 00E-01
7	10	2	5982	1 00E-01
7	11	2	5981	1 00E-01
7	12	2	5981	1 00E-01
8	7	2	5983	1 00E-01
8	8	2	5983	1 00E-01
8	9	2	5982	1 00E-01
8	10	2	5982	1 00E-01
9	5	2	5984	1 00E-01
9	6	2	5984	1 00E-01
9	7	2	5983	1 00E-01
10	2	2	5985	1 00E-01
10	3	2	5985	1 00E-01
10	4	2	5985	1 00E-01
10	5	2	5984	1 00E-01
11	1	2	5986	1 00E-01
11	2	2	5986	1 00E-01

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
1	28	2	5974	1.00E-01
1	29	2	5973	1.00E-01
1	30	2	5972	1.00E-01
1	31	2	5971	1.00E-01
1	32	2	5970	1.00E-01
1	33	2	5969	1.00E-01
1	34	2	5968	1.00E-01
1	35	2	5967	1.00E-01
1	36	2	5966	1.00E-01
1	37	2	5965	1.00E-01
1	38	2	5964	1.00E-01
1	39	2	5963	1.00E-01
1	40	2	5962	1.00E-01
1	41	2	5962	1.00E-01
1	42	2	5961	1.00E-01
1	43	2	5960	1.00E-01
1	44	2	5960	1.00E-01
1	45	2	5959	1.00E-01
1	46	2	5958	1.00E-01
1	47	2	5957	1.00E-01
1	48	2	5956	1.00E-01
1	49	2	5956	1.00E-01
1	50	2	5955	1.00E-01
1	51	2	5955	1.00E-01
1	52	2	5954	1.00E-01
1	53	2	5952	1.00E-01
1	54	2	5950	1.00E-01
1	55	2	5949	1.00E-01
1	56	2	5947	1.00E-01
1	57	2	5945	1.00E-01
1	58	2	5944	1.00E-01
1	59	2	5942	1.00E-01
1	60	2	5941	1.00E-01
1	61	2	5940	1.00E-01
1	62	2	5940	1.00E-01
1	63	2	5939	1.00E-01
1	64	2	5938	1.00E-01
1	65	2	5937	1.00E-01
1	66	2	5936	1.00E-01
1	67	2	5935	1.00E-01
1	68	2	5934	1.00E-01
1	69	2	5933	1.00E-01
1	70	2	5932	1.00E-01
1	71	2	5932	1.00E-01
1	72	2	5932	1.00E-01
1	73	2	5931	1.00E-01
1	74	2	5931	1.00E-01

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
1	75	2	5930	1 00E-01
1	76	2	5930	1 00E-01
1	77	2	5930	1 00E-01
1	78	2	5929	1 00E-01
1	79	2	5929	1 00E-01
1	80	2	5928	1 00E-01
1	81	2	5928	1 00E-01
1	82	2	5927	1 00E-01
1	83	2	5926	1 00E-01
1	84	2	5925	1 00E-01
1	85	2	5924	1 00E-01
1	86	2	5923	1 00E-01
1	87	2	5921	1 00E-01
1	88	2	5920	1 00E-01
1	89	2	5919	1 00E-01
1	90	2	5918	1 00E-01
1	91	2	5918	1 00E-01
1	92	2	5917	1 00E-01
1	93	2	5916	1 00E-01
1	94	2	5915	1 00E-01
1	95	2	5914	1 00E-01
1	96	2	5912	1 00E-01
1	97	2	5911	1 00E-01
1	98	2	5910	1 00E-01
1	99	2	5909	1 00E-01
1	100	2	5908	1 00E-01

Table C-3
Elevations Corresponding to Elevation Zone Numbers

Bottom Zone	Bottom Elevation (feet)
1	5800
2	5802
3	5804
4	5806
5	5808
6	5810
7	5812
8	5814
9	5816
10	5818
11	5820
12	5822
13	5824
14	5826
15	5828
16	5830
17	5832
18	5834
19	5836
20	5838
21	5840
22	5842
23	5844
24	5846
25	5848
26	5850
27	5852
28	5854
29	5856
30	5858
31	5860
32	5862
33	5864
34	5866
35	5868
36	5870
37	5872
38	5874
39	5876
40	5878
41	5880
42	5882
43	5884
44	5886
45	5888
46	5890
47	5892

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Table C-3
Elevations Corresponding to Elevation Zone Numbers

Bottom Zone	Bottom Elevation (feet)
48	5894
49	5896
50	5898
51	5900
52	5902
53	5904
54	5906
55	5908
56	5910
57	5912
58	5914
59	5916
60	5918
61	5920
62	5922
63	5924
64	5926
65	5928
66	5930
67	5932
68	5934
69	5936
70	5938
71	5940
72	5942
73	5944
74	5946
75	5948
76	5950
77	5952
78	5954
79	5956
80	5958
81	5960
82	5962
83	5964
84	5966
85	5968
86	5970
87	5972
88	5974
89	5976
90	5978
91	5980
92	5982
93	5984
94	5986

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Table C-3
Elevations Corresponding to Elevation Zone Numbers

Bottom Zone	Bottom Elevation (feet)
95	5988
96	5990
97	5992
98	5994
99	5996

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Table C-4
Model Parameters

Parameter	Acceptable Range	Information Sources
Hydraulic Conductivity	Layer 1 0 02–3 68 ft/day Layer 2 0 0004–0 004 ft/day	Measured hydraulic conductivities (Figure 2 10 and Appendix B)
Recharge	No cap 0 8–1 6 inches/year (5–10% of precipitation) With cap approximately 0 01 inches/year	Telephone interview Barry Roberts EG&G Rocky Flats August 18 1994 HELP modeling runs
Specific Storage	0 005 or less (used 0 001)	Fetter 1988
Specific Yield	0 10 to 0 12	Telephone interview Barry Roberts EG&G Rocky Flats August 18 1994
Porosity	Sand 25–40% gravel 25–50% Silt 35–50% Clay 40–70% (used 30% value should be effective porosity which is the porosity available for fluid flow)	Freeze and Cherry 1989

Table C-5
CALSTATS Results for No-Action Scenario

Well Name	Target Head	Model Head	Residual
Layer 1			
1086	5984.28	5983.42	0.86
4087	5879 71	5885 92	-6.21
5887	5983.10	5982 01	1.09
6187	5972.48	5971 77	0.71
6487	5966.21	5967 61	-1 40
6687	5969 71	5968.47	1.24
6887	5960.25	5958.08	2.17
7187	5958 36	5953.74	4.62
70093	5978.48	5979.35	-0 87
70393	5986 17	5984.86	1.31
70693	5972.53	5974 74	2.21
71893	5970.36	5970.31	0.05
72293	5943 41	5943 75	-0.34
B206489	5965.20	5964 42	0.78
70193	5978 15	5979 35	1.20
71493	5970 14	5975 79	-5 65
72393	5971 03	5969.06	1 97

Summary Statistics for Entire Model

Residual Mean = 3 647242

Residual Standard Dev = 7 088455

Residual Sum of Squares = 1588.714301

Absolute Residual Mean = 4.830528

Minimum Residual = 25.920410

Maximum Residual = 4 619766

Observed Range in Head = 126.170000

Res. Std. Dev./Range = 0.056182

Well Name	Target Head	Model Head	Residual
Layer 2			
70493	5965.66	5984 85	19 19
B206189	5965.23	5966.57	1 34
B206289	5953.07	5965.25	12 18
B206589	5960.64	5961 71	1 07
B206689	5941.46	5948.64	7 18
B206789	5916.65	5925.75	-9 10
B206889	5900.12	5912.24	-12 12
B206989	5860.00	5885.92	-25.92

Statistics for Layer 1

Number of Targets = 16

Residual Mean = -0 117091

Residual Standard Dev = 2.671101

Residual Sum of Squares = 114.375860

Absolute Residual Mean = 1.965975

Minimum Residual = -6.208945

Maximum Residual = 4.619766

Observed Range in Head = 106.460000

Res. Std. Dev./Range = 0.025090

Statistics for Layer 2

Res. Std. Dev./Range = 0.068430

Residual Mean = -9.923066

Residual Standard Dev. = 8.083819

Residual Sum of Squares = 1474.338441

Absolute Residual Mean = 9.923066

Minimum Residual = -25.920410

Maximum Residual = 1.072891

Observed Range in Head = 118.150000

Number of Targets = 9

Table C-6
Hydraulic Conductivity Values Corresponding to Hydraulic Conductivity Zones

Zone	K_x (ft/day)	K_y (ft/day)	K_z (ft/day)
1	7 20E-01	7 20E-01	7 20E-02
3	7 20E-01	7 20E-01	7 20E-02
4	7 20E-02	7 20E-02	7 20E-03
5	3 60E+00	3 60E+00	3 60E+00
6	7 20E-03	7 20E-03	7 20E-04
8	1 44E+00	1 44E+00	1 44E-01
10	7 20E-02	7 20E-02	7 20E-03
11	7 20E+00	7 20E+00	7 20E-01
12	4 70E-03	4 70E-03	4 70E-03

Table C-7
CALSTATS Results for April 1992 Well Head Measurements

Well Name	Target Head	Model Head	Residual
Layer 1			
1086	5984.28	5983.42	1.87
4087	5879 71	5885 92	-9.84
5887	5983 10	5982.01	3.94
6187	5972.48	5971.77	-0.56
6487	5966.21	5967.61	-2.97
6687	5969 71	5968 47	-0.35
6887	5960.25	5958 08	-0.02
7187	5958.36	5953.74	1 14
B206489	5965.20	5964 42	-3 87

Well Name	Target Head	Model Head	Residual
Layer 2			
B206189	5966.23	5966.57	-9 14
B206289	5953 07	5965.25	-19.76
B206589	5960.64	5961.71	-0 18
B206689	5941.46	5948.84	-5 60
B206789	5916.65	5925.75	15 06
B206889	5900 12	5912.24	-15.36
B206989	5860.00	5886.92	-30.25

Summary Statistics for Entire Model

Residual Mean = -6.78324

Residual Standard Dev = 8.94270

Residual Sum of Squares = 2024.437190

Absolute Residual Mean = 7 494327

Minimum Residual = 30.247988

Maximum Residual = 3.937949

Observed Range in Head = 134 100000

Res. Std. Dev./Range = 0 066997

Statistics for Layer 1

Number of Targets = 9

Residual Mean = 1.437548

Residual Standard Dev = 3.691674

Residual Sum of Squares = 141.255019

Absolute Residual Mean = 2.728220

Minimum Residual = -9.8351117

Maximum Residual = 3.937949

Observed Range in Head = 113.630000

Res. Std. Dev./Range = 0.032489

Statistics for Layer 2

Number of Targets = 7

Residual Mean = 13.6221179

Residual Standard Dev = 9 135768

Residual Sum of Squares = 1883 1821711

Absolute Residual Mean = 13.622179

Minimum Residual = -30.247988

Maximum Residual = -0 181602

Observed Range in Head = 103.02000

Res. Std. Dev./Range = 0.088680

433

Table C-8
Summary of Flows for Three Scenarios

Scenario	No Action		North Slurry Wall		North Slurry Wall and Cap	
Component of Inflow and Recharge	Subtotals for Horizontal Inflow (gpm)	Flow Rate (gpm)	Subtotals for Horizontal Inflow (gpm)	Flow Rate (gpm)	Subtotals for Horizontal Inflow (gpm)	Flow Rate (gpm)
Recharge		0 77		0 77		0 01
Horizontal Inflow (Individual segments directly below)		1 12		0 48		0 35
Inflow through or under North Slurry Wall	0 375		0 140		0 070	
Inflow through or under North Groundwater Intercept	0 601		0 232		0 100	
Inflow through or under West Groundwater Intercept	0 068		0 034		0 035	
Inflow through or under South Groundwater Intercept	-0 002		0 0002		0 073	
Inflow through or under South Slurry Wall	0 075		0 074		0 071	
Vertical Inflow		0 02		0 02		0 02
Summary of Flows		**1 9**		**1 3**		**0 4**

Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Cells on North, West, and South, from Northeast Corner going Counterclockwise

North Slurry Wall

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
1	9	48				1 8	1	1.8		
1	9	47				2 5	1	2.5		
1	9	46				3.0	1	3 0		
1	9	45				3.4	1	3.4		
1	9	44				4.0	1	4 0		
1	9	43				4.1	1	4 1		
1	9	42	-0 4	-1	0.4					
1	8	42				2.6	1	2.6		
1	8	41				5.2	1	5.2		
1	8	40				5.5	1	5.5		
1	8	39				5.9	1	5.9		
1	8	38				6.3	1	6.3		
1	8	37				7 3	1	7.3		
1	8	36				3.3	1	3.3		
1	9	36	3.7	1	3.7					
1	10	35	7.2	1	7.2					
1	11	35	5.8	1	5.8					
Summary (positive is into landfill) for north slurry wall					17 1			55 0	72 1	0 4

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Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
North Groundwater Intercept										
1	12	35	5 4	1	5 4					
1	13	35	21 4	1	21 4					
1	14	35	23 2	1	23 2	2 9	1	2 9		
1	14	34				4 8	1	4 8		
1	14	33				5 2	1	5 2		
1	14	32				4 9	1	4 9		
1	14	31				4 4	1	4 4		
1	14	30				3 9	1	3 9		
1	14	29				4 1	1	4 1		
1	14	28				3 9	1	3 9		
1	14	27				4 3	1	4 3		
1	14	26				4 3	1	4 3		
1	14	25				5 1	1	5 1		
1	15	24	5 5	1	5 5	4 2	1	4 2		
1	15	23				1 6	1	1 6		
1	15	22				2 7	1	2 7		
1	15	21				3 8	1	3 8		
Summary (positive is into landfill) for north intercept					55 5			60 1	115 6	0 6

436

Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
West Groundwater Intercept										
1	16	20	3.2	1	3.2	3 0	1	3.0		
1	17	19	3.7	1	3.7					
1	18	19	2.4	1	2.4					
1	19	19	0 8	1	0 8					
1	19	20				3.6	-1	-3.6		
1	19	21				1 6	-1	-1.6		
1	20	21	5 2	1	5.2					
								-2.3	13.0	0.1
Summary (positive is into landfill) for west intercept					15 3					

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Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
South Groundwater Intercept										
1	20	22				2 9	-1	-2 9		
1	20	23				1 4	-1	-1 4		
1	21	23	8 8	1	8 8					
1	21	24			0 0	2 4	-1	-2 4		
1	21	25				1 1	-1	-1 1		
1	22	25	7 0	1	7 0					
1	22	26				1 9	-1	-1 9		
1	22	27				2 0	-1	-2 0		
1	22	28				1 9	-1	-1 9		
1	22	29				1 7	-1	-1 7		
1	22	30				0 7	-1	-0 7		
1	22	31				1 1	-1	-1 1		
1	22	32				0 7	-1	-0 7		
1	22	33				0 4	-1	-0 4		
1	22	34				0 1	-1	-0 1		
1	22	35				-0 6	-1	0 6		
1	22	36				-1 7	-1	1 7		
1	23	36	0 0	1	0 0					
Summary (positive is into landfill) for south intercept					15 8			-16 1	-0 3	0 0

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Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
South Slurry Wall										
1	23	37				-1 4	-1	1 4		
1	23	38				-1.5	-1	1.5		
1	23	39				-1 7	-1	1 7		
1	23	40				-1 6	-1	1.6		
1	23	41				-0 9	-1	0.9		
1	23	42				-0 8	-1	0.8		
1	23	43				-0 7	-1	0 7		
1	23	44				-1 1	-1	1.1		
1	23	45				-0.9	-1	0 9		
1		46				-1.3	-1	1.3		
1	23	47				-1.4	-1	1.4		
1	23	48				-1 2	-1	1 2		
Summary (positive is into landfill) for south slurry wall					0 0			14 3	14.3	0 1
Total Flow into Landfill from North, West, South									214.8	1 1

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Table C-9
Cell-by-Cell Flows for the No-Action Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
Cells on East Landfill Boundary										
1	10	48	-0 5	-1	0 5					
1	11	48	-0 1	-1	0 1					
1	12	48	0 0	-1	0 0					
1	13	48	0 7	-1	-0 7					
1	14	48	1 1	-1	-1 1					
1	15	48	75 5	-1	-75 5					
1	16	48	145 0	-1	-145 0					
1	17	48	100 6	-1	-100 6					
1	18	48	18 3	-1	-18 3					
1	19	48	6 2	-1	-6 2					
1	20	48	0 6	-1	-0 6					
1	21	48	0 1	-1	-0 1					
	22	48	0 2	-1	-0 2					
1	23	48	0 6	-1	-0 6					
Summary (negative is flow out of landfill)					-348 3			0 0	-348 3	-1 8

shaded cells define the boundary plane for the landfill mass

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Table C-10
Vertical Flows for the No-Action Scenario

All Landfill Cells, Lower Face, Flow Down into Layer 2			
Layer	Rows	Column	Lower Face Flow
1	17-19	20	-0.15
1	16-19	21	-0 08
1	16-20	22	0 00
1	16-20	23	0 05
1	16-21	24	0.08
1	15-21	25	0.16
1	15-22	26	0 10
1	15-22	27	0.06
1	15-22	28	0 01
1	15-22	29	-0 03
1	15-22	30	0.00
1	15-22	31	-0 01
1	15-22	32	0 02
1	15-22	33	0 02
1	15-22	34	-0.01
1	15-22	35	-0 02
1	9-22	36	-0.57
1	9-23	37	-0.24
1	9-23	38	-0 19
1	9-23	39	-0 28
1	9-23	40	-0 35
1	9-23	41	-0 24
1	9-23	42	-0 20
1	10-23	43	-0 23
1	10-23	44	-0.37
1	10-23	45	-0 30
1	10-23	46	-0 43
1	10-23	47	-0 39
1	10-23	48	0.39
Summary (positive is flow out of landfill) (ft^3/day)			-3.22
Summary (positive is flow out of landfill) (gpm)			-0.02

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Table C-11
Recharge for the No-Action Scenario

Layer	Row	Columns From	Columns To	No of Cells	No of Dry Cells	No of Cells with Recharge
1	9	36	42	7	0	7
1	10	36	48	13	0	13
1	11	36	48	13	0	13
1	12	36	48	13	0	13
1	13	36	48	13	0	13
1	14	36	48	13	0	13
1	15	25	48	24	0	24
1	16	21	48	28	0	28
1	17	20	48	29	0	29
1	18	20	48	29	0	29
1	19	20	48	29	0	29
1	20	22	48	27	0	27
1	21	24	48	25	0	25
1	22	26	48	23	0	23
1	23	37	48	12	0	12
Total No of Cells Receiving Recharge						298
Area per Cell (ft^2)						2 500
Total Area (ft^2)						745 000
Recharge Flux (ft/day) (value used in best-fit calibration)						2 00E-04
Recharge (ft^3/day)						**149**
Recharge (gpm)						**0 77**

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Table C-12
Water Balance for the No-Action Scenario

Horizontal Flow In				
Total Flow into Landfill from North, West, South	214.8	ft^3/day	1 12	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	3.2	ft^3/day	0 02	gpm
Recharge into Landfill	149	ft^3/day	0 77	gpm
Flow In + Recharge	367.0	ft^3/day	1 91	gpm
Recharge as Percent of (Flow In + Recharge)	40.6%			
Horizontal Flow In as Percent of (Flow In + Recharge)	58.5%			
Vertical Flow In as Percent of (Flow In + Recharge)	0.9%			
Summary of Flows In (percent)	100 0%			
Water Balance Compare Inflow and Outflow				
Flow In + Recharge	367 0	ft^3/day	1 91	gpm
Horizontal Flow Out of Landfill at East Boundary	-348 3	ft^3/day	-1 81	gpm
Percent Error	5 1%		5 1%	

Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
Cells on North, West, and South, from Northeast Corner going Counterclockwise										
North Slurry Wall										
1	9	48				1 1	1	1 1		
1	9	47				1 1	1	1 1		
1	9	46				1 2	1	1 2		
1	9	45				1 2	1	1 2		
1	9	44				1 3	1	1 3		
1	9	43				1 2	1	1 2		
1	9	42	0 0	-1 0	0 0					
1	8	42				1 2	1	1 2		
1	8	41				2 0	1	2 0		
1	8	40				1 8	1	1 8		
1	8	39				1 9	1	1 9		
1	8	38				2 0	1	2 0		
1	8	37				2 6	1	2 6		
1	8	36				1 2	1	1 2		
1	9	35	1 6	1 0	1 6					
1	10	35	3 1	1 0	3 1					
1	11	35	2 5	1 0	2 5					
Summary (positive is into landfill) for north slurry wall					7 2			19 8	27 0	0 1

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Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
North Groundwater Intercept										
1	12	35	2.7	1 0	2.7					
1	13	35	11.9	1.0	11 9					
1	14	35	14.7	1.0	14 7	0.2	1	0 2		
1	14	34				1 3	1	1 3		
1	14	33				1 4	1	1.4		
1	14	32				1.2	1	1.2		
1	14	31				0.7	1	0.7		
1	14	30				0.3	1	0.3		
1	14	29				0.5	1	0.5		
1	14	28				0.5	1	0.5		
1	14	27				0.7	1	0.7		
1	14	26				0.6	1	0.6		
1	14	25				0 8	1	0.8		
1	15	24	3.8	1 0	3 8	-0 1	1	-0.1		
1	15	23				0.5	1	0 5		
1	15	22				1.3	1	1 3		
1	15	21				1.7	1	1 7		
Summary (positive is into landfill) for north intercept					33 2			11 4	44 6	0 2

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Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
West Groundwater Intercept										
1	16	20	1 8	1 0	1 8	1 4	1	1 4		
1	17	19	2 4	1 0	2 4					
1	18	19	1 8	1 0	1 8					
1	19	19	0 6	1 0	0 6					
1	19	20				1 4	-1	-1 4		
1	19	21				0 4	-1	-0 4		
1	20	21	0 3	1 0	0 3					
Summary (positive is into landfill) for west intercept					6 8			-0 4	6 5	0 03

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Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
South Groundwater Intercept										
1	20	22				1.0	-1	-1.0		
1	20	23				0.3	-1	-0.3		
1	21	23	0.3	1.0	0.3					
1	21	24			0.0	0.7	-1	-0.7		
1	21	25				0.2	-1	-0.2		
1	22	25	0.3	1.0	0.3					
1	22	26				0.7	-1	-0.7		
1	22	27				0.7	-1	-0.7		
1	22	28				0.7	-1	-0.7		
1	22	29				0.6	-1	-0.6		
1	22	30				0.2	-1	-0.2		
1	22	31				0.3	-1	-0.3		
1	22	32				0.0	-1	0.0		
1	22	33				-0.3	-1	0.3		
1	22	34				-0.6	-1	0.6		
1	22	35				-1.3	-1	1.3		
1	22	36				-2.4	-1	2.4		
1	23	36	0.1	1.0	0.1					
Summary (positive is into landfill) for south intercept					0.7			-0.6	0.04	0.0

447

Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
South Slurry Wall										
1	23	37				-1 5	-1	1 5		
1	23	38				-1 5	-1	1 5		
1	23	39				-1 6	-1	1 6		
1	23	40				-1 6	-1	1 6		
1	23	41				-0 9	-1	0 9		
1	23	42				-0 8	-1	0 8		
1	23	43				-0 7	-1	0 7		
1	23	44				-1 1	-1	1 1		
1	23	45				-0 9	-1	0 9		
1	23	46				-1 2	-1	1 2		
1	23	47				-1 4	-1	1 4		
1	23	48				-1 2	-1	1 2		
Summary (positive is into landfill) for south slurry wall					0 0			14 3	14 3	0 1
Total Flow into Landfill from North, West, South (ft^3/day)									92 4	0 5

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Table C-13
Cell-by-Cell Flows for the North Slurry Wall Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
Cells on East Landfill Boundary										
1	10	48	-1.2	-1.0	1.2					
1	11	48	-0.2	-1.0	0.2					
1	12	48	0.0	-1.0	0.0					
1	13	48	0.9	-1.0	-0.9					
1	14	48	0.4	-1.0	-0.4					
1	15	48	43.5	-1.0	-43.5					
1	16	48	118.8	-1.0	-118.8					
1	17	48	70.4	-1.0	-70.4					
1	18	48	10.5	-1.0	-10.5					
1	19	48	3.4	-1.0	-3.4					
1	20	48	0.6	-1.0	-0.6					
1	21	48	0.1	-1.0	-0.1					
1	22	48	0.2	-1.0	-0.2					
1	23	48	0.6	-1.0	-0.6					
Summary (negative is flow out of landfill)					-248.1			0.0	-248.1	-1.3

shaded cells define the boundary plane for the landfill mass

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Table C-14
Vertical Flows for the North Slurry Wall Scenario

All Landfill Cells, Lower Face, Flow Down into Layer 2			
Layer	**Rows**	**Column**	**Lower Face Flow**
1	17-19	20	-0 27
1	16-19	21	-0 09
1	16-20	22	-0 03
1	16-20	23	0 04
1	16-21	24	0 05
1	15-21	25	0 11
1	15-22	26	0 06
1	15-22	27	0 03
1	15-22	28	-0 02
1	15-22	29	-0 05
1	15-22	30	-0 01
1	15-22	31	-0 02
1	15-22	32	0 02
1	15-22	33	0 01
1	15-22	34	-0 03
1	15-22	35	-0 04
1	9-22	36	-0 45
1	9-23	37	-0 21
1	9-23	38	-0 20
1	9-23	39	-0 28
1	9-23	40	-0 35
1	9-23	41	-0 23
1	9-23	42	-0 08
1	10-23	43	-0 33
1	10-23	44	-0 64
1	10-23	45	-0 08
1	10-23	46	-0 38
1	10-23	47	-0 39
1	10-23	48	0 77
Summary (positive is flow out of landfill) (ft^3/day)			**-3 1**
Summary (positive is flow out of landfill) (gpm)			**-0 016**

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Table C-15
Recharge for the North Slurry Wall Scenario

Layer	Row	Columns From	Columns To	No of Cells	No. of Dry Cells	No. of Cells with Recharge
1	9	36	42	7	0	7
1	10	36	48	13	0	13
1	11	36	48	13	0	13
1	12	36	48	13	0	13
1	13	36	48	13	0	13
1	14	36	48	13	0	13
1	15	25	48	24	0	24
1	16	21	48	28	0	28
1	17	20	48	29	0	29
1	18	20	48	29	0	29
1	19	20	48	29	0	29
1	20	22	48	27	0	27
1	21	24	48	25	0	25
1	22	26	48	23	0	23
1	23	37	48	12	0	12

Total No of Cells Receiving Recharge	298
Area per Cell (ft^2)	2,500
Total Area (ft^2)	745,000
Recharge Flux (ft/day) (value used in best-fit calibration)	2.00E-04
Recharge (ft^3/day)	**149**
Recharge (gpm)	**0.77**

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Table C-16
Water Balance for the North Slurry Wall Scenario

Horizontal Flow In				
Total Flow into Landfill from North West South	92 4	ft^3/day	0 48	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	3 1	ft^3/day	0 02	gpm
Recharge into Landfill	149	ft^3/day	0 77	gpm
Flow In + Recharge	244 4	ft^3/day	1 27	gpm
Recharge as Percent of (Flow In + Recharge)	61 0%			
Horizontal Flow In as Percent of (Flow In + Recharge)	37 8%			
Vertical Flow In as Percent of (Flow In + Recharge)	1 3%			
Summary of Flows In (percent)	100 0%			
Water Balance Compare Inflow and Outflow				
Flow In + Recharge	244 4	ft^3/day	1 27	gpm
Horizontal Flow Out of Landfill at East Boundary	-248 1	ft^3/day	-1 29	gpm
Percent Error	1 5%		1 5%	

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Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
Cells on North, West, and South, from Northeast Corner going Counterclockwise										
North Slurry Wall										
1	9	48								
1	9	47				0.7	1	0 7		
1	9	46				0 6	1	0 6		
1	9	45				0 5	1	0.5		
1	9	44				0.5	1	0 5		
1	9	43				0.6	1	0 6		
1	9	42	0.1	-1	-0 1	0 6	1	0.6		
1	8	42								
1	8	41				0.7	1	0.7		
1	8	40				1.0	1	1.0		
1	8	39				0.9	1	0.9		
1	8	38				1.0	1	1.0		
1	8	37				1.1	1	1.1		
1	8	36				1.6	1	1.6		
1	9	35	1.0	1	1.0	0.8	1	0.8		
1	10	35	1.3	1	1.3					
1	11	35	0.7	1	0 7					
Summary (positive is into landfill) for north slurry wall					2 9			10.6	13 5	0 1

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Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
North Groundwater Intercept										
1	12	35	0 7	1	0 7					
1	13	35	2 5	1	2 5					
1	14	35	5 5	1	5 5	0 4	1	0 4		
1	14	34				0 9	1	0 9		
1	14	33				1 2	1	1 2		
1	14	32				0 8	1	0 8		
1	14	31				0 6	1	0 6		
1	14	30				0 2	1	0 2		
1	14	29				0 5	1	0 5		
1	14	28				0 5	1	0 5		
1	14	27				0 7	1	0 7		
1	14	26				0 5	1	0 5		
1	14	25				0 5	1	0 5		
1	15	24	1 9	1	1 9	-0 2	1	-0 2		
1	15	23				0 2	1	0 2		
1	15	22				0 8	1	0 8		
1	15	21				1 0	1	1 0		
Summary (positive is into landfill) for north intercept					10 5			8 7	19 2	0 1

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Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
West Groundwater Intercept										
1	16	20	1.0	1	1.0	0.7	1	0.7		
1	17	19	1.4	1	1.4					
1	18	19	1.3	1	1.3					
1	19	19	0.8	1	0.8	-0.4	-1	0.4		
1	19	20				-0.5	-1	0.5		
1	19	21	0.7	1	0.7					
1	20	21								
Summary (positive is into landfill) for west intercept					5 1			1.6	6.7	0 03

Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
South Groundwater Intercept										
1	20	22				-0 8	-1	0 8		
1	20	23				-0 6	-1	0 6		
1	21	23	0 6	1	0 6					
1	21	24			0 0	-0 9	-1	0 9		
1	21	25				-0 6	-1	0 6		
1	22	25	0 5	1	0 5					
1	22	26				-0 7	-1	0 7		
1	22	27				-0 6	-1	0 6		
1	22	28				-0 6	-1	0 6		
1	22	29				-0 5	-1	0 5		
1	22	30				0 0	-1	0 0		
1	22	31				-0 4	-1	0 4		
1	22	32				-0 4	-1	0 4		
1	22	33				-0 8	-1	0 8		
1	22	34				-1 1	-1	1 1		
1	22	35				-1 7	-1	1 7		
1	22	36				-2 8	-1	2 8		
1	23	36	0 3	1	0 3					
Summary (positive is into landfill) for south intercept					1 4			12 6	14 0	0 1

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Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft³/day)	Sum of Right Face and Front Face (gpm)
South Slurry Wall										
1	23	37				-1.7	-1	1.7		
1	23	38				-1.4	-1	1.4		
1	23	39				-1.5	-1	1.5		
1	23	40				-1.5	-1	1.5		
1	23	41				-0.8	-1	0.8		
1	23	42				-0.8	-1	0.8		
1	23	43				-0.5	-1	0.5		
1	23	44				-1.1	-1	1.1		
1	23	45				-0.7	-1	0.7		
1	23	46				-1.1	-1	1.1		
1	23	47				-1.3	-1	1.3		
1	23	48				-1.2	-1	1.2		
Summary (positive is into landfill) for south slurry wall					0.0			13.7	13.7	0.1
Total Flow into Landfill from North, West, South (ft³/day)									67.2	0.3

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Table C-17
Cell-by-Cell Flows for the North Slurry Wall and Cap Scenario

Layer	Row	Column	Right Face Flow	Multiplier	Adjusted Right Face Flow	Front Face Flow	Multiplier	Adjusted Front Face Flow	Sum of Right Face and Front Face (ft^3/day)	Sum of Right Face and Front Face (gpm)
Cells on East Landfill Boundary										
1	10	48	-1 5	-1	1 5					
1	11	48	-0 3	-1	0 3					
1	12	48	0 0	-1	0 0					
1	13	48	1 8	-1	-1 8					
1	14	48		-1	0 0					
1	15	48	2 8	-1	-2 8					
1	16	48	58 1	-1	-58 1					
1	17	48	11 3	-1	-11 3					
1	18	48	0 9	-1	-0 9					
1	19	48	1 6	-1	-1 6					
1	20	48	0 3	-1	-0 3					
1	21	48	-0 1	-1	0 1					
1	22	48	0 0	-1	0 0					
1	23	48	0 7	-1	-0 7					
Summary (negative is flow out of landfill)					-75 5			0 0	-75 5	-0 4

shaded cells define the boundary plane for the landfill mass

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Table C-18
Vertical Flows for the North Slurry Wall and Cap Scenario

All Landfill Cells, Lower Face, Flow Down into Layer 2			
Layer	Rows	Column	Lower Face Flow
1	17-19	20	-0.26
1	16-19	21	-0.20
1	16-20	22	-0 14
1	16-20	23	-0.04
1	16-21	24	0.00
1	15-21	25	0 04
1	15-22	26	-0 01
1	15-22	27	-0 03
1	15-22	28	-0 11
1	15-22	29	-0 14
1	15-22	30	-0 11
1	15-22	31	-0 06
1	15-22	32	-0 02
1	15-22	33	0.06
1	15-22	34	-0.13
1	15-22	35	-0 13
1	9-22	36	-0 40
1	9-23	37	-0.16
1	9-23	38	-0.29
1	9-23	39	-0 44
1	9-23	40	-0 57
1	9-23	41	-0 26
1	9-23	42	-0 04
1	10-23	43	-0.09
1	10-23	44	-0.03
1	10-23	45	-0 31
1	10-23	46	-0 69
1	10-23	47	-0 17
1	10-23	48	0 07
Summary (positive is flow out of landfill) (ft^3/day)			-4.6
Summary (positive is flow out of landfill) (gpm)			-0 024

Table C-19
Recharge for the North Slurry Wall and Cap Scenario

Layer	Row	Columns From	Columns To	No of Cells	No of Dry Cells	No of Cells with Recharge
1	9	36	42	7	0	7
1	10	36	48	13	0	13
1	11	36	48	13	1	12
1	12	36	48	13	0	13
1	13	36	48	13	2	11
1	14	36	48	13	2	11
1	15	25	48	24	0	24
1	16	21	48	28	0	28
1	17	20	48	29	1	28
1	18	20	48	29	2	27
1	19	20	48	29	4	25
1	20	22	48	27	1	26
1	21	24	48	25	0	25
1	22	26	48	23	0	23
1	23	37	48	12	0	12
Total No of Cells Receiving Recharge						285
Area per Cell (ft^2)						2 500
Total Area (ft^2)						712 500
Recharge Flux (ft/day) (value used in best-fit calibration)						2 00E-06
Recharge (ft^3/day)						**1 425**
Recharge (gpm)						**0 007**

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Table C-20
Water Balance for the North Slurry Wall and Cap Scenario

Horizontal Flow In				
Total Flow into Landfill from North, West, South	67 2	ft^3/day	0 35	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	4 6	ft^3/day	0.02	gpm
Recharge into Landfill	1.425	ft^3/day	0 01	gpm
Flow In + Recharge	73.2	ft^3/day	0 38	gpm
Recharge as Percent of (Flow In + Recharge)	1 9%			
Horizontal Flow In as Percent of (Flow In + Recharge)	91 7%			
Vertical Flow In as Percent of (Flow In + Recharge)	6.3%			
Summary of Flows In (percent)	100 0%			
Water Balance Compare Inflow and Outflow				
Flow In + Recharge	73.2	ft^3/day	0 38	gpm
Horizontal Flow Out of Landfill at East Boundary	-75 5	ft^3/day	-0.39	gpm
Percent Error	3.1%		3.1%	

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Table C-21
Flows Out of Landfill Mass for the North Slurry Wall and Cap Scenario

Days	Flow (ft^3/day)	Flow (gpm)
0	348 3	1 81
1 000	227 9	1 18
2 000	170 0	0 88
3 000	132 6	0 69
4 000	107 9	0 56
5 000	94 0	0 49
6 000	85 5	0 44
7 000	80 5	0 42
8 000	77 7	0 40
9 000	75 6	0 39
10 000	75 5	0 39

Flow in surficial materials out of landfill mass estimated by flows out of right face for layer 1 column 43 rows 10 through 23 inclusive

Appendix C
Figures

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Figure C-1
Layer 1 Boundary Conditions

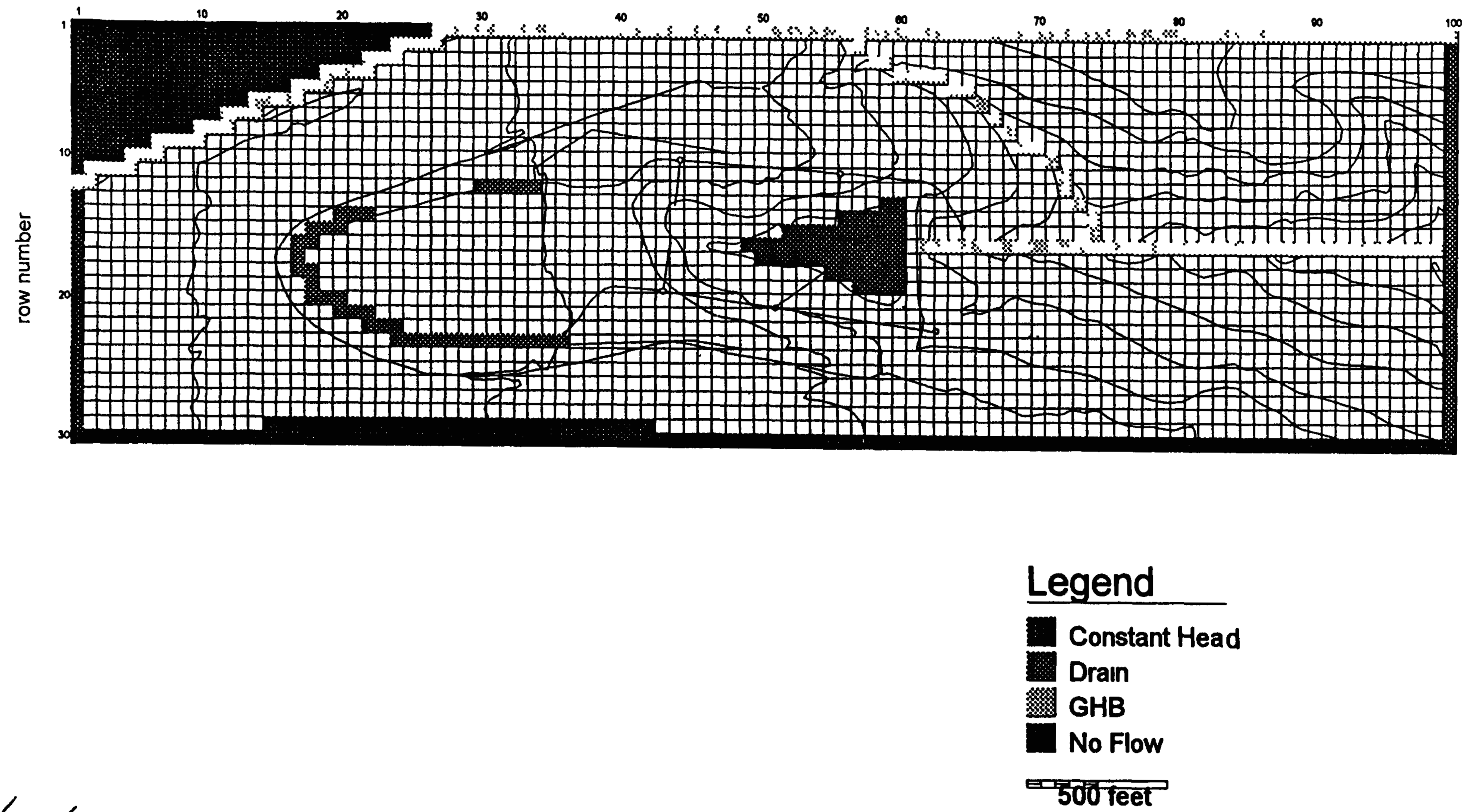

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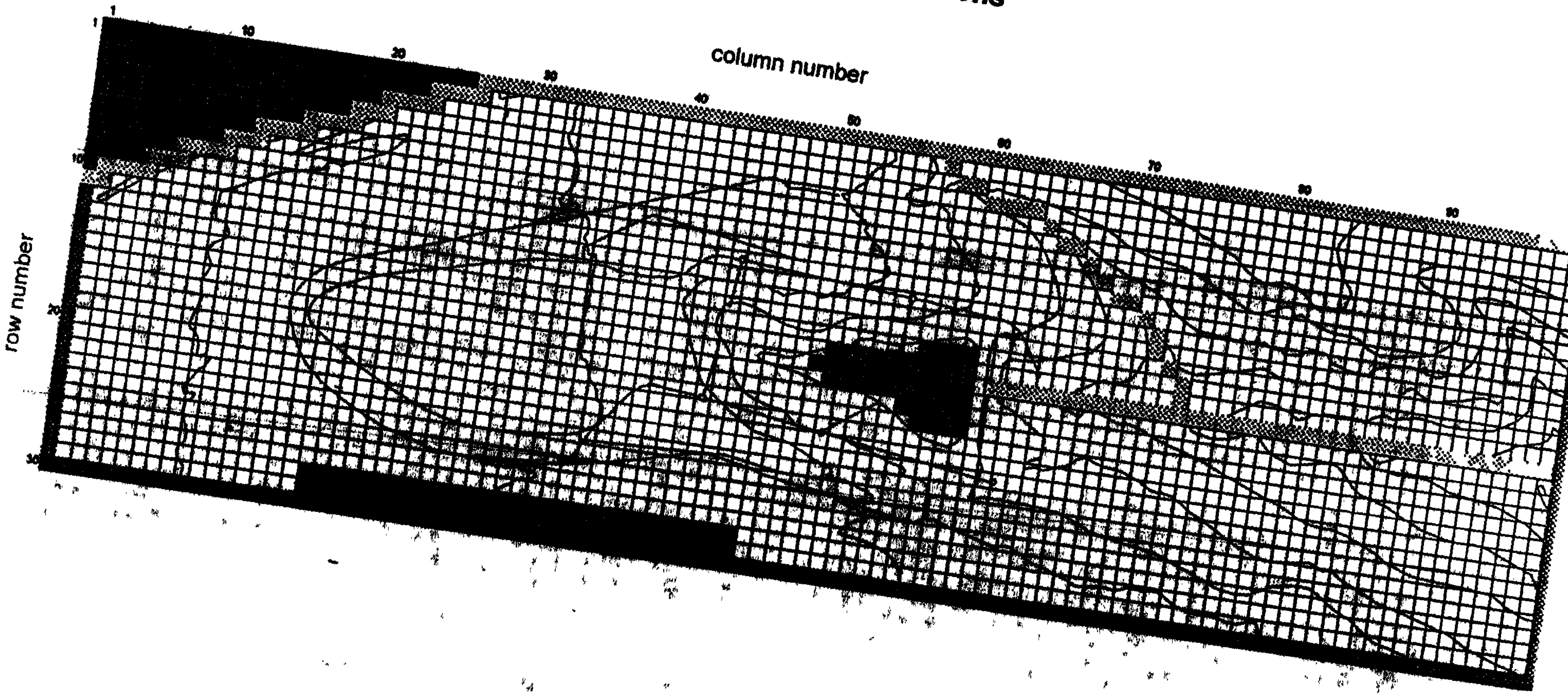
Figure C-2
Layer 2 Boundary Conditions



Legend

- Constant Head
- GHB
- No Flow

500 feet

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Figure C-3
Bottom Elevation of Layer 1

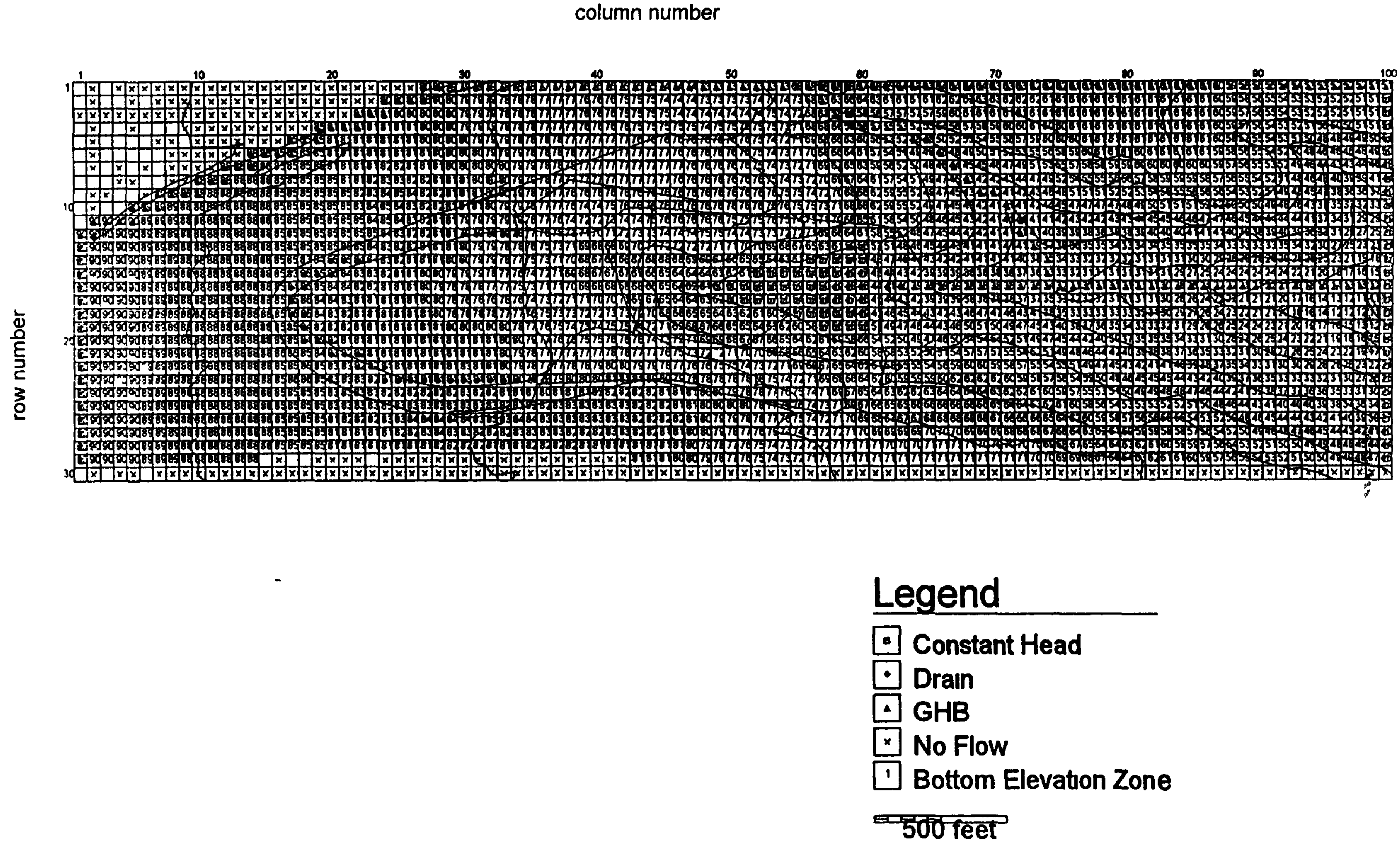

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Figure C-4
Bottom Elevation of Layer 2

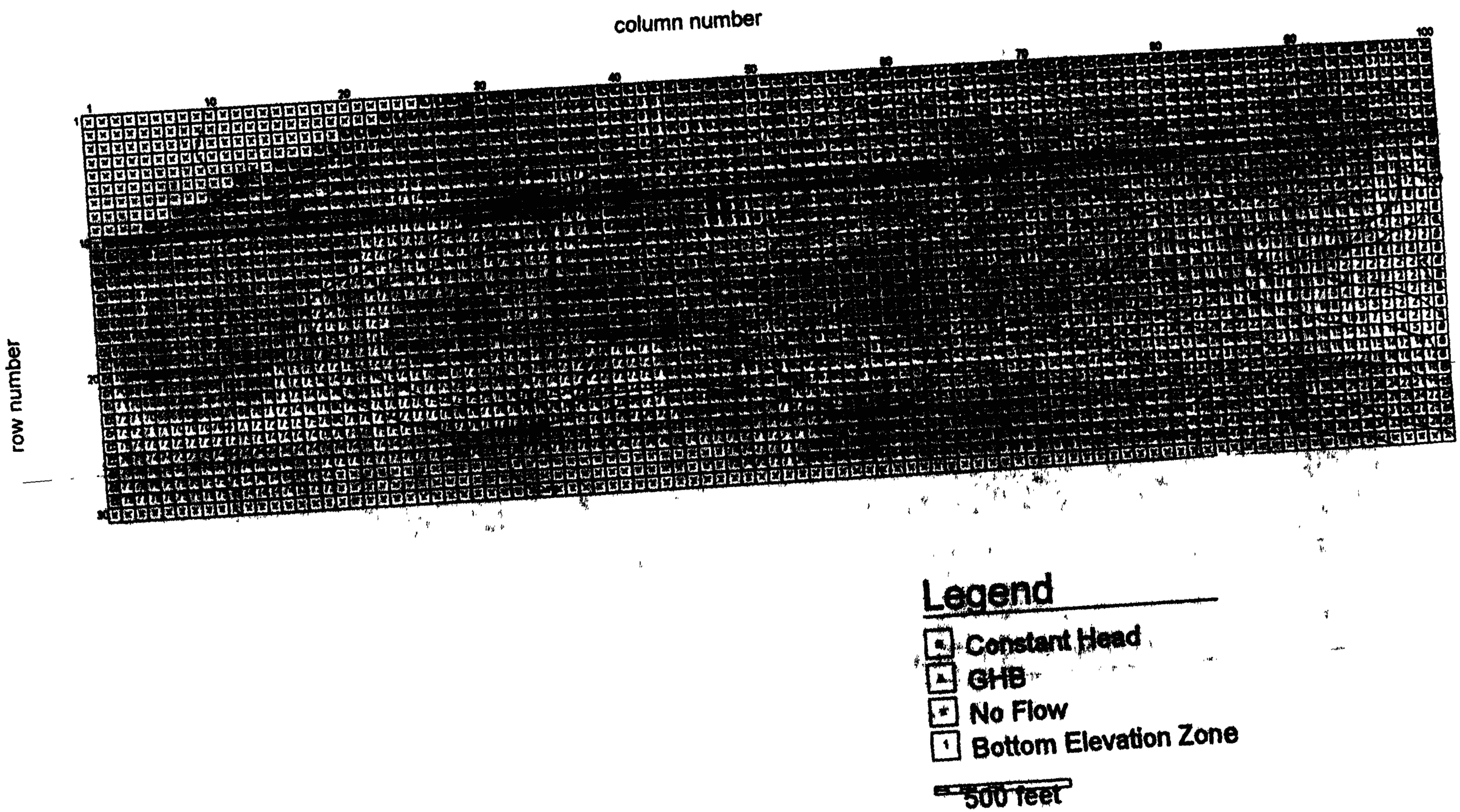

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Figure C-5
Layer 1 Hydraulic Conductivity Distribution

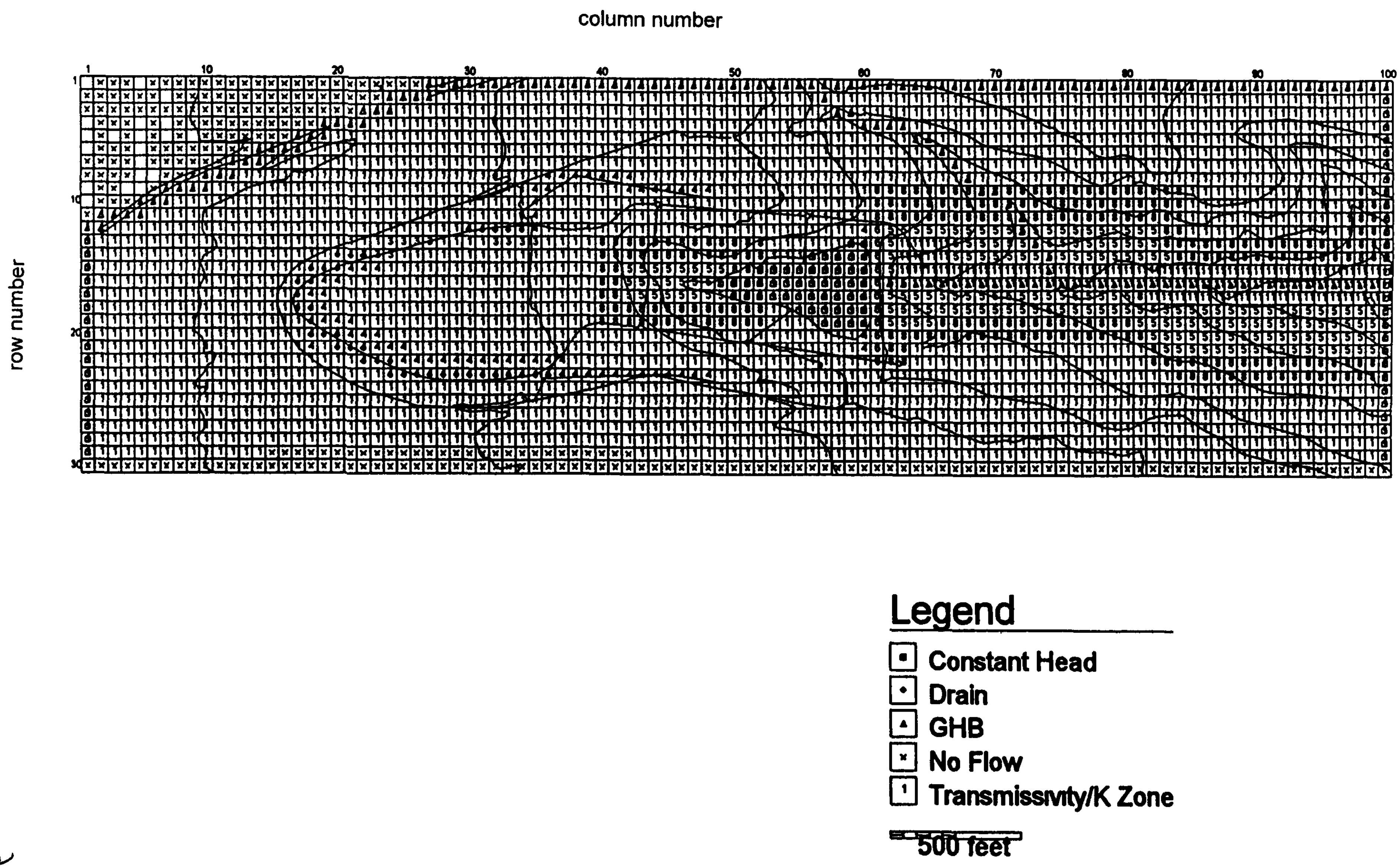

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Figure C-6
Layer 2 Hydraulic Conductivity Distribution

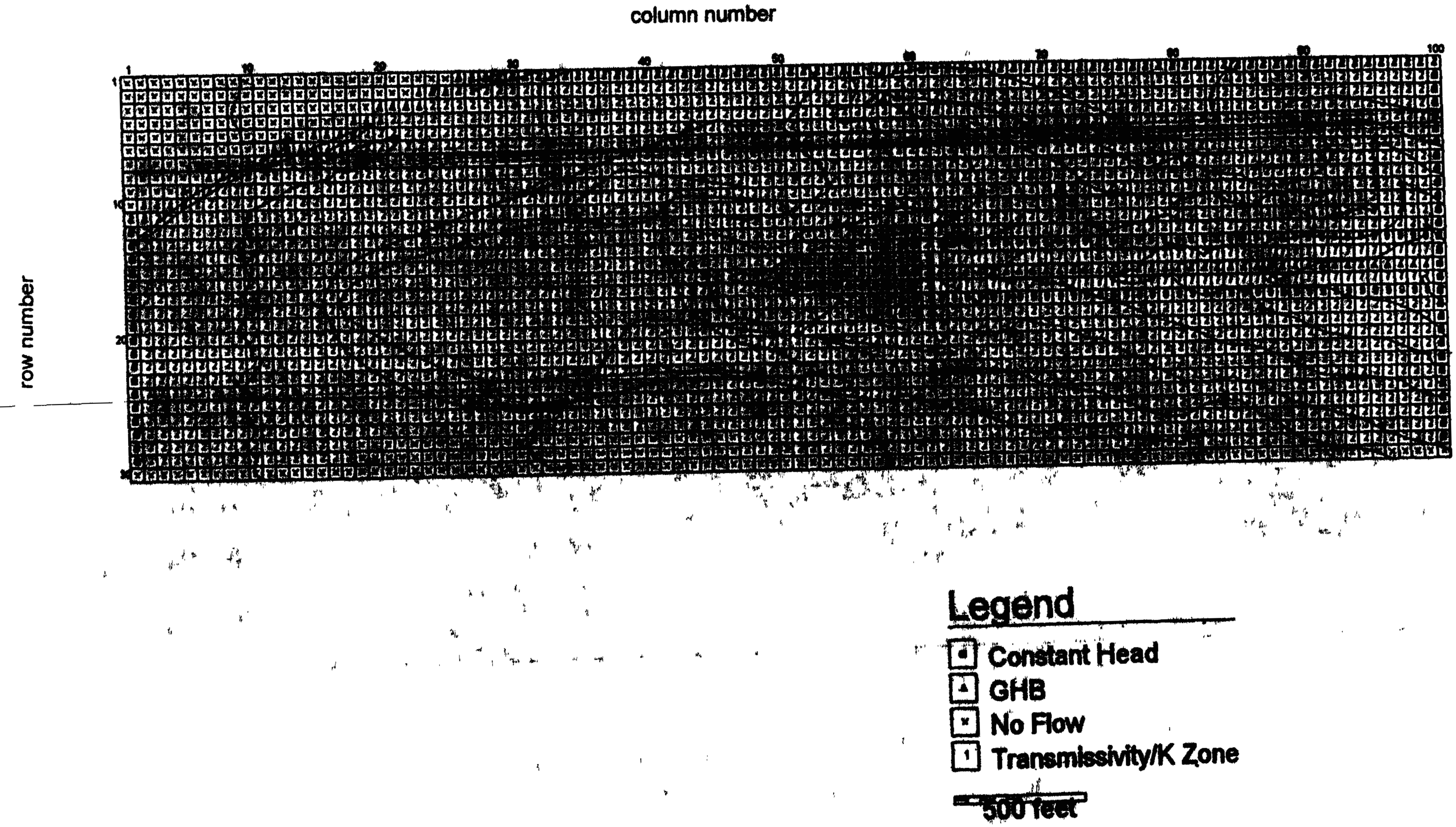

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Figure C-9
Simulated Potentiometric Surface for the No-Action Scenario

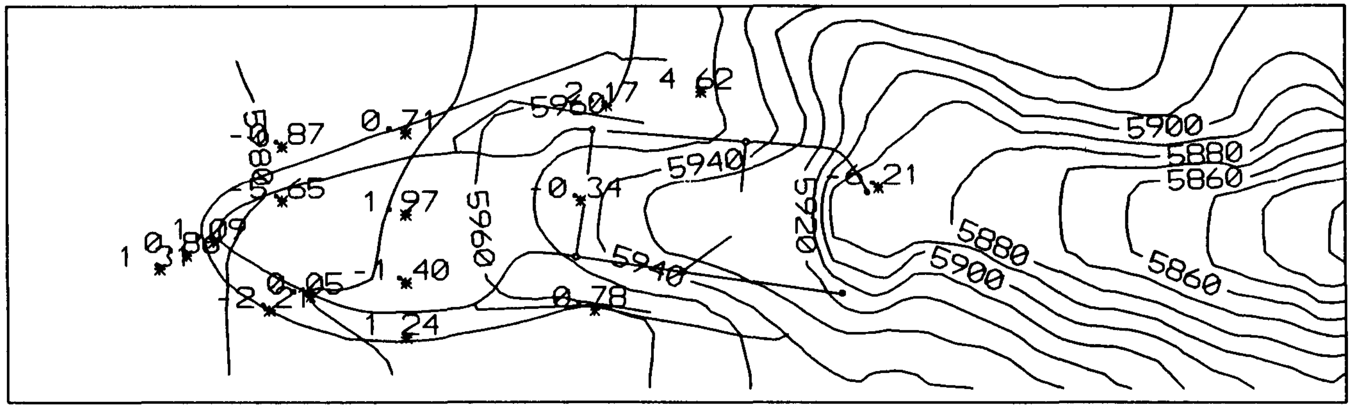

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Figure C-11. MODFLOW Terminology for Flows Out of a Single Model Cell

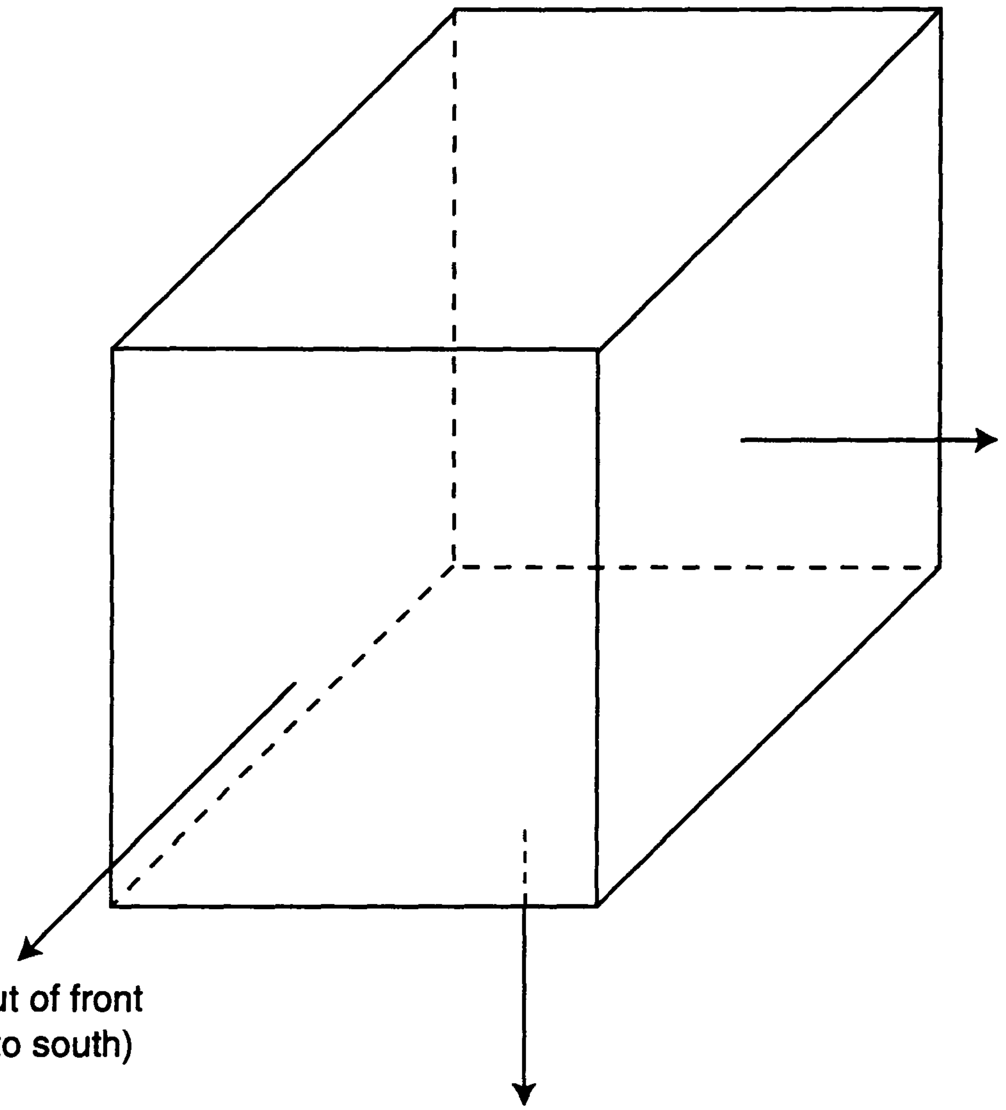

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Figure C-12
Particle Tracking in Layer 1 for the No-Action Scenario

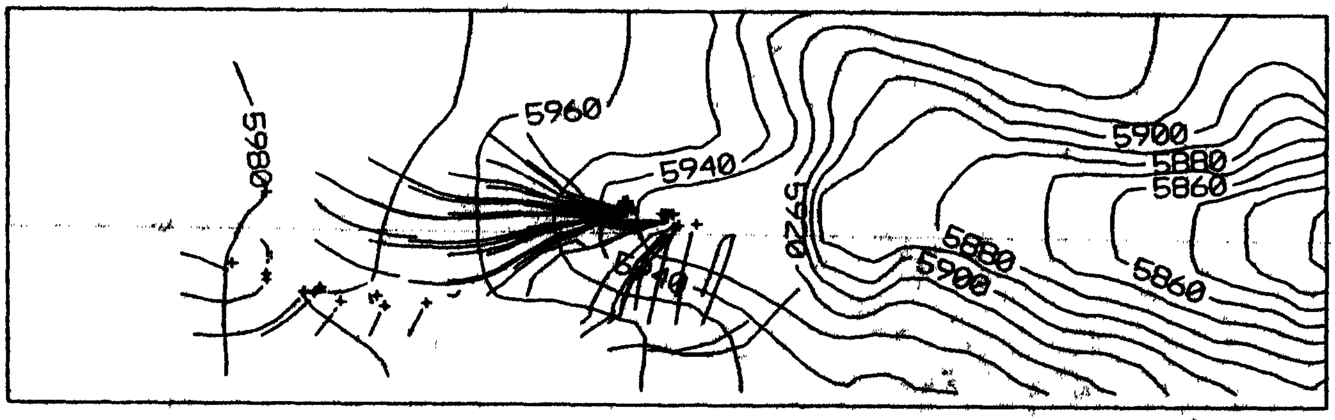

Figure C-13
Particle Tracking in Layer 2 for the No-Action Scenario

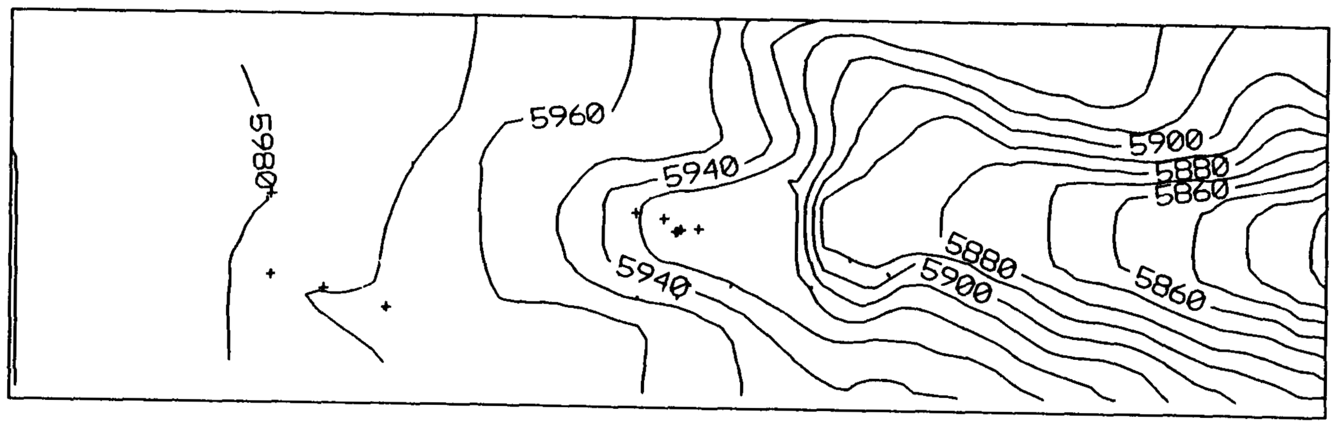

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Figure C-14
Potentiometric Surface in Layer 1 at 0 Days for the North Slurry Wall and Cap Scenario

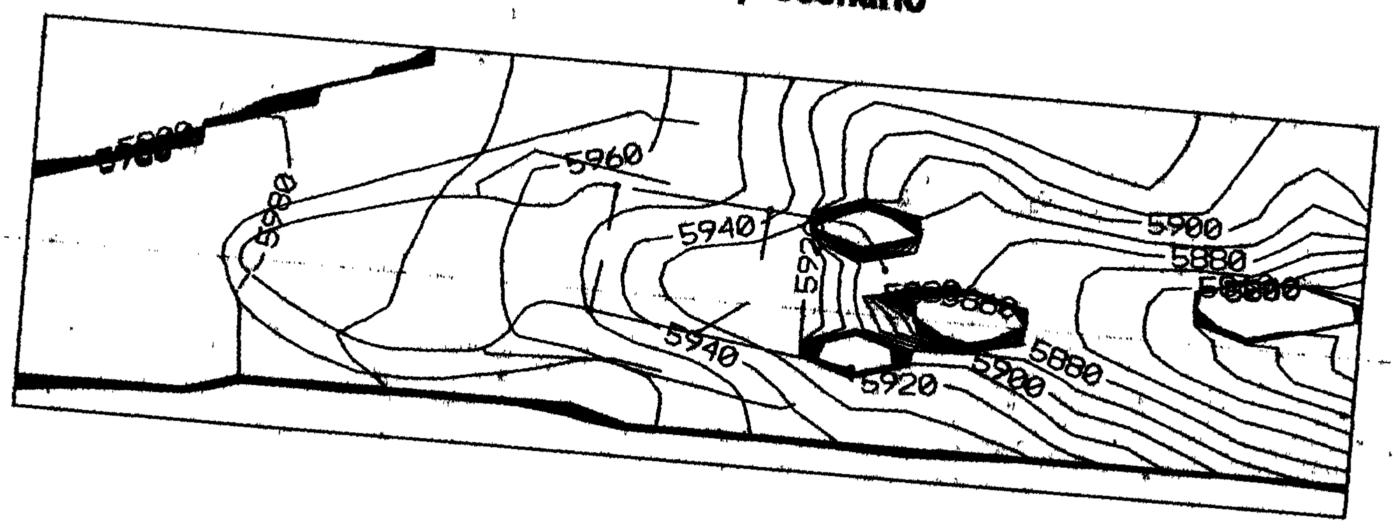

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Figure C-15
Potentiometric Surface in Layer 1 at 1,000 Days for the North Slurry Wall and Cap Scenario

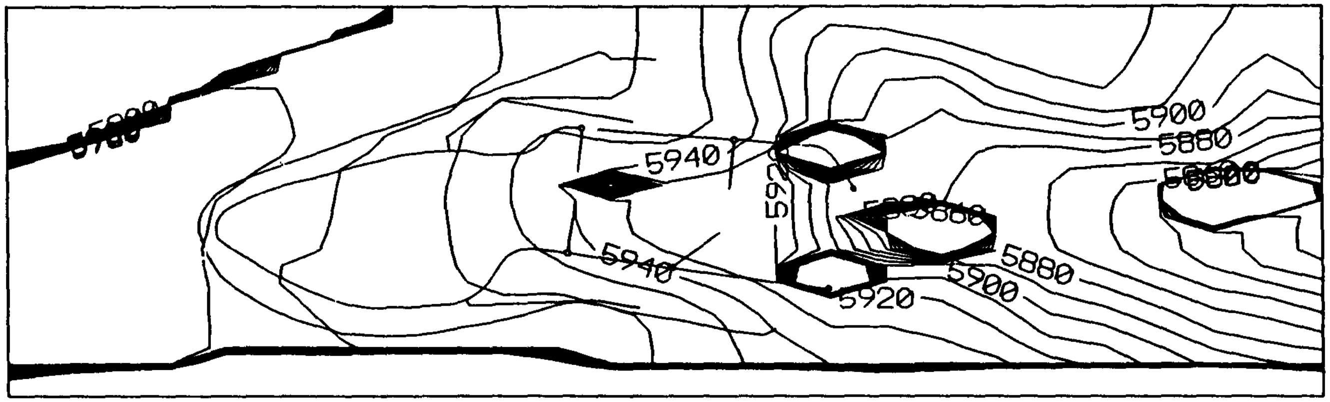

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Figure C-16
Potentiometric Surface in Layer 1 at 2,000 Days for the North Slurry Wall and Cap Scenario

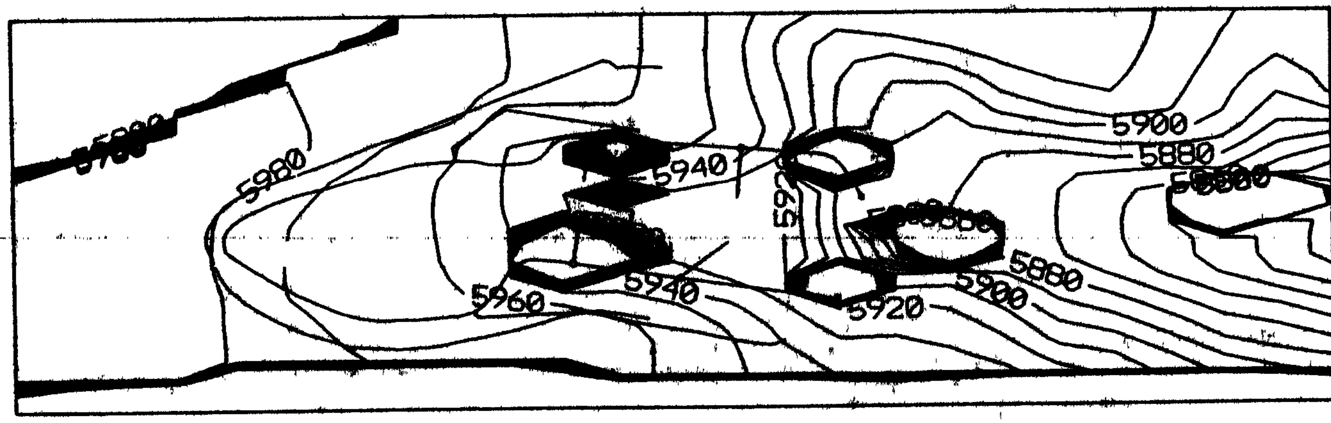

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Figure C-17
Potentiometric Surface in Layer 1 at 3,000 Days for the North Slurry Wall and Cap Scenario

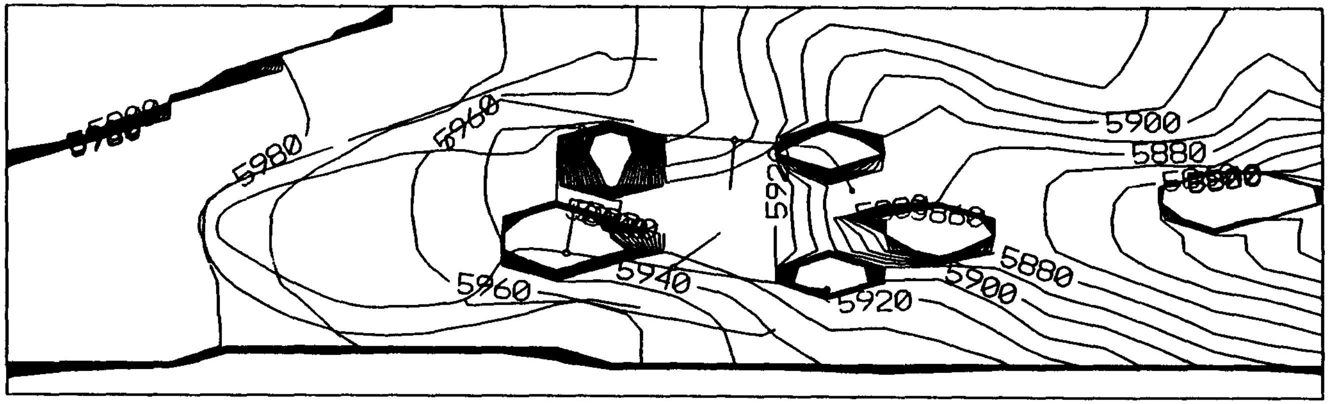

Figure C-18
Potentiometric Surface in Layer 1 at 4,000 Days for the North Slurry Wall and Cap Scenario

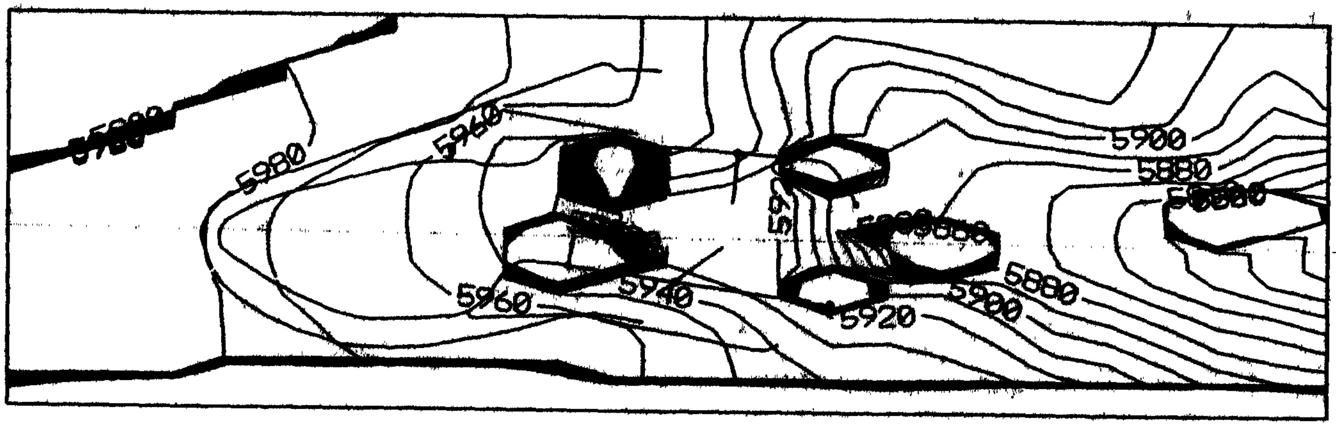

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Figure C-19
Potentiometric Surface in Layer 1 at 5,000 Days for the North Slurry Wall and Cap Scenario

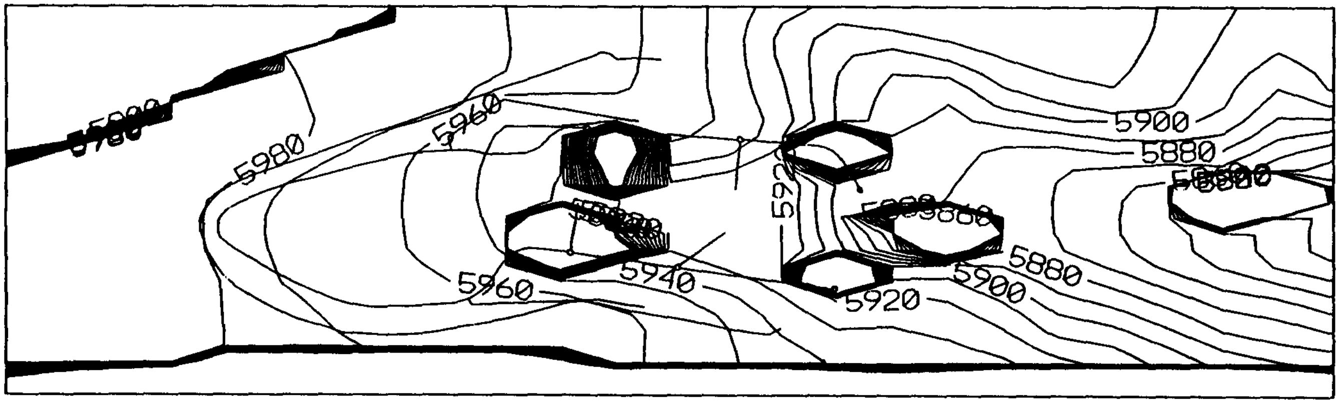

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Figure C-20
Potentiometric Surface in Layer 1 at 6,000 Days for the North Slurry Wall and Cap Scenario

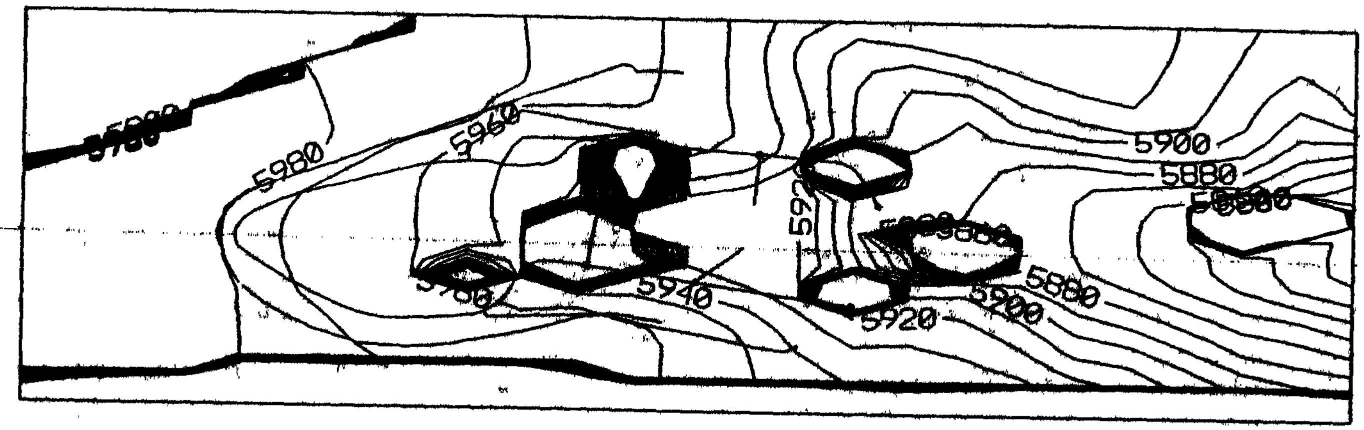

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Figure C-21
Potentiometric Surface in Layer 1 at 7,000 Days for the North Slurry Wall and Cap Scenario

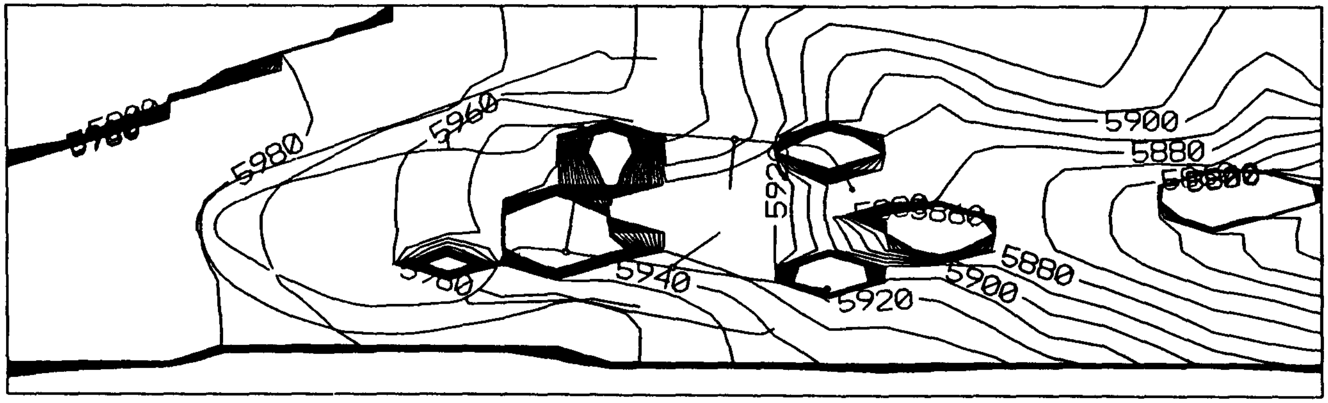

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Figure C-22
Potentiometric Surface in Layer 1 at 8,000 Days for the North Slurry Wall and Cap Scenario

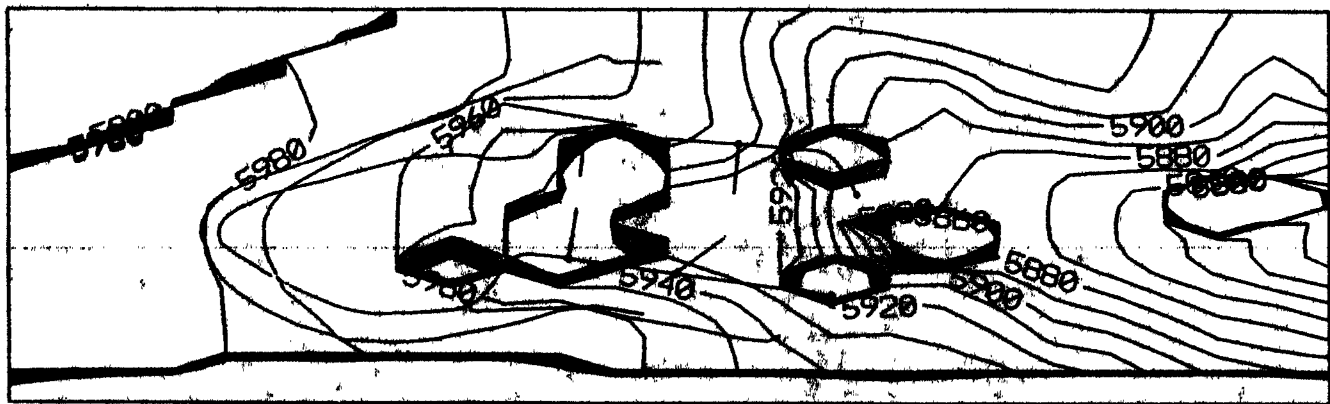

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Figure C-23
Potentiometric Surface in Layer 1 at 9,000 Days for the North Slurry Wall and Cap Scenario

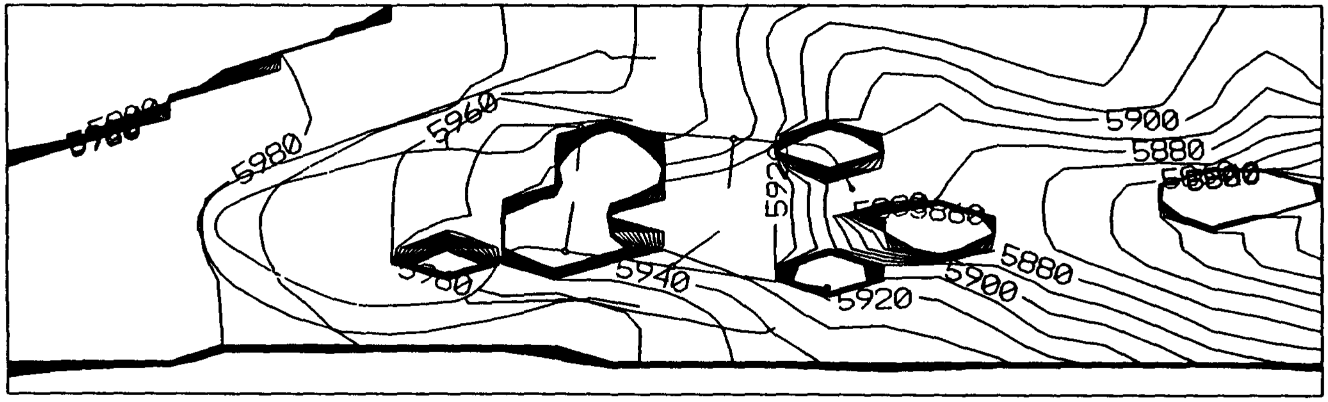
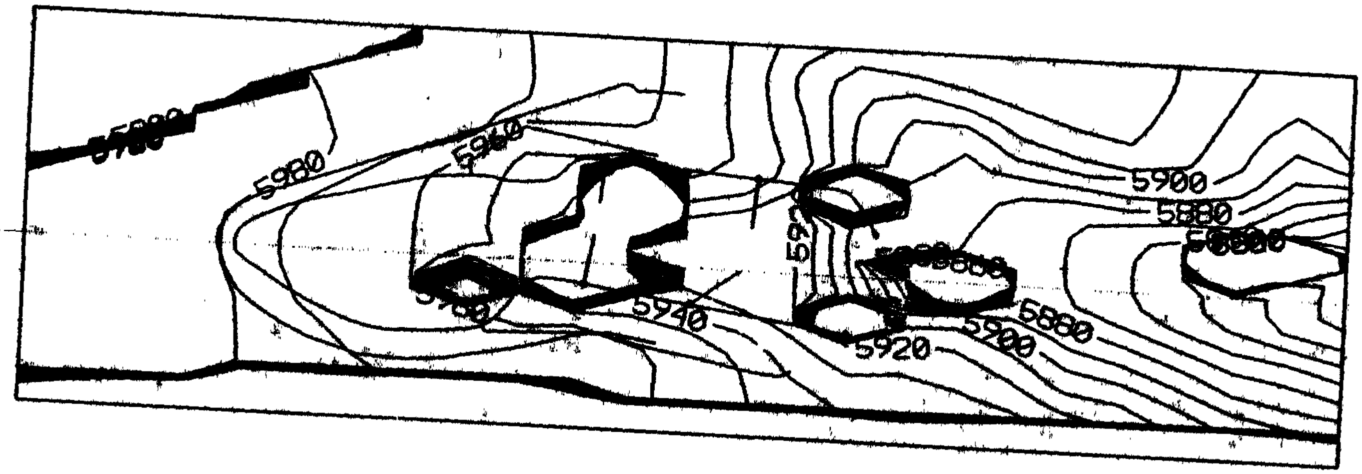


Figure C-24
Potentiometric Surface in Layer 1 at 10,000 Days for the North Slurry Wall and Cap Scenario



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D.1 Introduction

D.1.1 Background

The OU 7 Draft Phase I Interim Measure/Interim Remedial Action (IM/IRA) Decision Document describes the nature and extent of contamination associated with the landfill. This information is used to quantify the risk to human health and the environment present at OU 7. Because OU 7 is being closed under a presumptive remedy approach, a comprehensive baseline risk assessment was not necessary. The presumptive remedy allows a comparison of all exposure pathways that will be addressed by the presumptive remedy. The Phase I IM/IRA Decision Document concludes that the presumptive remedy, containment, will address all potential pathways with the exception of surface water and sediment from the East Landfill Pond. The pathways not addressed by the presumptive remedy were subjected to a focused risk assessment process for both human and ecological receptors. This appendix presents the focused risk assessment for ecological receptors.

The ecological risk assessment (ERA) contained in this appendix is a screening-level evaluation of the potential ecotoxicity of surface water and sediments in the East Landfill Pond. Protection of environmental (ecological) receptors is mandated in Sections 104 and 105 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which requires assessment of risks and impacts in accordance with the National Oil and Hazardous Substances Contingency Plan (NCP) (40 CFR Part 300.430 [e][2][i][G]). Protection of ecological receptors is also stipulated in the Interagency Agreement (IAG) between DOE, U.S. Environmental Protection Agency (EPA) and Colorado Department of Public Health and Environment (CDPHE).

OU 7 is located in the Walnut Creek drainage. DOE is currently conducting an ERA to evaluate the overall ecological risk resulting from all sources associated with the operable units in the Walnut Creek watershed. However, results of the watershed ERA will not be available in time to support current activities at OU 7. Therefore, in order to facilitate closure of OU 7, a screening-level risk assessment is documented here in advance of the watershed ERA.

Most of OU 7 has been subjected to extensive physical disturbance due to landfill operations and will probably be covered with a cap. The cap is expected to attenuate exposure of ecological receptors to chemicals in the landfill sections of OU 7 and is therefore not assessed in this document. The analyses in this document are restricted to evaluation of the potential ecotoxicity of OU 7 contaminants in surface water and sediment in the East Landfill Pond area.

D 1.2 Relationship to Rocky Flats Sitewide Ecological Risk Assessment Methodology and EPA Guidance

An ecological risk assessment methodology (ERAM) has been developed to support risk management decisions at Rocky Flats. The ERAM is documented in a series of Technical Memoranda (TMs) that are subject to the review and approval by EPA and CDPHE The methodology focuses primarily on evaluating the effects of potential chemicals of concern (PCOCs) and includes a process for conducting a screening-level exposure analysis and risk characterization for site-specific receptors. Assumptions about life history and exposure parameters for ecological receptors are described in Technical Memorandum No 2—Sitewide Conceptual Model (TM2) (DOE 1995a), methodology for screening chemicals for ecotoxicity is taken from Technical Memorandum No 3—Ecological Chemicals of Concern (ECOCs) Screening Methodology (TM3) (DOE 1995b)

The initial phases of the ERAM correspond to elements of EPA's eight-step (draft) guidance on conducting ERAs at Superfund sites (EPA 1994) The first two steps of EPA's process, Preliminary Problem Formulation and Ecological Effects Characterization (Step 1) and Preliminary Exposure Estimate and Risk Calculation (Step 2), are intended to allow risk assessors and managers to rapidly determine whether a site poses an ecological risk Subsequent steps of the EPA methodology are performed if potential risks are identified These steps are more detailed and are aimed at refinement of risk estimates and determining site-specific cleanup goals

The activities included in this OU 7 screening-level ERA correspond, in part, to Step 1 and Step 2 of the EPA guidance (EPA 1994) and employ methods and assumptions presented in TM2 and TM3 The extent of the evaluation and the use of results differ somewhat from the EPA guidance Results of the ecotoxicity screen are intended to support decisions regarding risk management and remedial actions for the East Landfill Pond Thus, the results will not be restricted to determining the need for further risk assessment, although results may be used to identify unacceptable data gaps

D 1.3 Objectives and Scope

Results of the toxicity screen will be used to help determine the feasibility of allowing the East Landfill Pond to remain in place after remediation Leaving the East Landfill Pond in place would reduce costs associated with landfill cap construction However, aquatic life, vegetation, and wildlife could be exposed to PCOCs in pond water and sediments in the East Landfill Pond The ERA was needed to help determine whether East Landfill Pond water and/or sediments should be remediated to mitigate ecotoxicological risks The primary objective of this evaluation is to provide data and analyses to help determine whether PCOCs in seep water, pond water, and sediment

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present an unacceptable toxicological risk to aquatic life, vegetation, and wildlife that may use the East Landfill Pond area Information needed to make these determinations are as follows

1 Estimates of exposure and toxicity of PCOCs in sediments and pond water to aquatic life are needed to determine whether conditions in the pond are adequate to support a functional aquatic habitat This objective will be addressed by comparing PCOC concentrations in pond water and sediments to state water-quality standards or risk-based sediment quality benchmarks (Section D 3 1 2 for description of ecotoxicological benchmarks and criteria)

2 Estimates of potential toxicity to vegetation are needed to evaluate risks from exposure to PCOCs in sediments in the East Landfill Pond This objective will be addressed by comparing PCOC concentrations in sediments to risk-based vegetation benchmarks

3 Estimates of potential toxicity to aquatic-feeding avian and mammalian wildlife species are needed to evaluate risks from exposure to PCOCs in pond water seep water and sediments in the East Landfill Pond Mallards and raccoons were identified as representative receptors for this assessment Data needed to address this objective are concentrations of PCOCs in each abiotic medium data on food and water ingestion rates, feeding habits, and home range size of the receptors and ecotoxicological benchmarks for determining the potential toxicity of estimated exposures

4 Estimates of potential toxicity to non-aquatic wildlife species are needed to evaluate risks from exposure to PCOCs in pond water seep water and sediments in the East Landfill Pond Mule deer coyotes and Preble's meadow jumping mouse were identified as representative receptors for this assessment The types of data needed to address this objective are the same as for aquatic-feeding species

Exposures and ecotoxicity are estimated for chemicals previously identified as PCOCs based on the evaluation of nature and extent of contamination (Section 2 5) Exposures and risk estimations are based on the same data used to characterize nature and extent of contamination and potential human health risks Results of water and sediment toxicity testing and aquatic community characterization are also used

D 2 Preliminary Problem Formulation and Ecological Effects Evaluation

D 2 1 Environmental Setting

Brief descriptions of the East Landfill Pond area and OU 7 are provided here More detailed descriptions of OU 7 site history and the nature and extent of contamination are presented in Section 2 of the main report and in DOE (1994) Ecological resources at OU 7 and the rest of the Walnut Creek watershed are described in detail in TM2 (DOE 1995a)

The East Landfill Pond was constructed in 1974 to help control leachate generated from the landfill The East Landfill Pond lies in the upper reaches of No Name Gulch (Figure D-1) and covers approximately 2 5 acres Sources of water in the pond include surface-water runoff from the landfill and the area surrounding the pond, leachate from the landfill, and subsurface recharge from groundwater No outflow occurs via surface water from the East Landfill Pond to No Name Gulch Until 1994, pond water levels were controlled by spray evaporation Since 1994, pond water levels are controlled by engineered water transfers to the A-series ponds

Historically constant water levels in the East Landfill Pond have resulted in a well-established, vegetated littoral zone at the north, south, and west pond margins Cattails (*Typha* sp) are the dominant emergent vegetation in these areas, and the area is used by common wetland wildlife species The U.S Army Corps of Engineers has designated the pond and pond margins as wetlands (COE 1994) Adjacent terrestrial areas are mostly grassland habitat and the disturbed portions of the active landfill Riparian areas downgradient are poorly developed and lack extensive woody vegetation Relatively well-developed riparian areas of North Walnut Creek lie approximately one-half mile to the south

The East Landfill Pond composes approximately 3 percent of the open water habitat and 6 percent of the available shoreline habitat at Rocky Flats The wetland around the East Landfill Pond composes approximately 1 6 percent of the total wetlands at Rocky Flats (COE 1994)

Riparian areas along No Name Gulch and North Walnut Creek have been identified as potential habitat for Preble's meadow jumping mouse (*Zapus hudsonius preblei*), a subspecies that has been petitioned for listing as threatened or endangered pursuant to the Endangered Species Act This mouse is protected under the Colorado Non-Game, Endangered, or Threatened Species Conservation Act The areas adjacent to the East Landfill Pond are included as potential habitat for this species

Vegetation and wildlife surveys conducted in 1992 indicate that no other state or federally protected species is likely to reside in the immediate vicinity of the East Landfill Pond but may use the area occasionally (See TM2 [DOE 1995a] for a summary of state and federally protected species at Rocky Flats) Migratory waterfowl and other migratory species that may occasionally use the East Landfill Pond come under protection of the Migratory Bird Treaty Act.

Based on aquatic surveys conducted in 1992 it appears that neither fish nor crayfish occur in the East Landfill Pond Baited minnow traps left in the pond for several days on two occasions resulted in no captures East Landfill Pond is not hydrologically connected with other surface water bodies that may support aquatic life Therefore, it is unclear whether the absence of fish and crayfish is a result of toxicity or lack of colonization Because the pond lacks predaceous fish such as bass, it may be a resource for breeding amphibians such as tiger salamanders, chorus frogs and bullfrogs Benthic samples from the pond included large numbers of chironomid (midge) larvae, some odonate (dragonflies and damselflies) larvae, and low numbers of several other taxa

D 2 2 Potential Chemicals of Concern

PCOCs identified for pond water and seep water are identified in Tables D-1 and D-2, those for sediments are listed in Table D-3 PCOCs were identified using a standard set of statistical and professional judgment criteria established for use at Rocky Flats Chemicals identified as PCOCs include organic compounds, metals, and radionuclides The objective of the screening-level risk assessment is to determine whether PCOCs may have toxic effects on organisms that contact surface water or sediments associated with the East Landfill Pond

D 2 3 Conceptual Exposure Model

A conceptual exposure model for ecological receptors was developed based on distribution of PCOCs in surface water and sediment and ecological information from the OU 7 area A conceptual model describes the source of chemical contaminants, mechanisms for release and transport, environmental media and locations at which receptors may contact contaminants and exposure routes by which receptors take up the contaminants (EPA 1989) The conceptual exposure model forms the basis for identifying the ecological receptors that may be exposed to site contaminants, the types of direct and indirect effects that may result, and the species to be used in preliminary risk calculations

The primary source of contaminants at the East Landfill Pond is leachate generated in the landfill, which is transported downgradient to the East Landfill Pond via the seep and groundwater The East Landfill Pond also receives runoff from the adjacent slopes Animal receptors that feed or water at the East Landfill Pond may contact contaminated surface water and sediment through ingestion or dermal absorption across external body surfaces (Figure D-2)

Under the current remedial strategy for OU 7 the seep at SW097 will be covered by the landfill cap thus eliminating it as a potential exposure point for wildlife Although risks from exposure to seep water are evaluated in this document, they will not contribute to overall risk remaining after remediation

Preliminary exposure and risk calculations were performed for species that were selected to represent receptors subject to the exposure pathways identified in Figure D-2 The species chosen were identified from TM2 (DOE 1995a) as representative or key receptors for use in ERAs at Rocky Flats Each taxon has the potential to contact contaminants in surface water or sediments in the East Landfill Pond, either by direct contact with these media or indirect contact through food-web interactions

The mallard (*Anas platyrhynchos*) and raccoon (*Procyon lotor*) were selected to represent semi-aquatic omnivores that feed on aquatic organisms. The aquatic food of both species consists of invertebrates and plant species The raccoon diet also includes small reptiles and amphibians Both species were included because birds and mammals differ in their capacity to metabolize organic contaminants Birds are generally more sensitive to organic contaminants because they have lower levels of oxidative enzymes than mammals (Hansen and Shane 1994). Evaluation of risk to mallards is representative of potential risk to other waterfowl, evaluation of risk to raccoons is representative of potential risk to other aquatic-feeding mammals (e.g , muskrats) Piscivorous predators were not included in the assessment because fish do not occur in the East Landfill Pond

The mule deer (*Odocoileus hemionus*) and coyote (*Canis latrans*) were included to represent wildlife species that do not eat substantial amounts of aquatic food but may utilize the East Landfill Pond as a drinking water source Both are wide-ranging species that may use the East Landfill Pond area occasionally Preble's meadow jumping mouse was included because of its potential occurrence in mesic grassy areas next to the pond Individuals have been captured in vegetation along pond margins in the South Walnut Creek drainage (DOE 1995a). Evaluation of risk to Preble's meadow jumping mouse is representative of potential risk to other small mammals (e.g , deer mice)

Evaluation of risk to vegetation was included to protect the plant community at the East Landfill Pond margin, therefore, no individual species were selected. Rather, risk-based vegetation criteria were compared to sediment concentrations to determine whether absorption of contaminants from sediments exceed acceptable levels

Evaluation of risk to aquatic life is based on state or federal water-quality standards and criteria developed to protect sensitive aquatic species, including fish and invertebrates Therefore, no individual species were selected Rather, the risk-based criteria have been used to determine whether contaminant concentrations exceed acceptable levels

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D 3 Screening-Level Exposure Estimates and Preliminary Risk Characterization

This section describes the screening-level exposure and risk estimates used to help determine whether contaminant concentrations in surface water and sediments at the East Landfill Pond represent a hazard to ecological receptors The procedures used correspond to the methods described for the Tier 3 ECOC screen described in TM3 (DOE 1995b) Exposures and toxicity are estimated using conservative assumptions to minimize the chance of underestimating the risk of contamination to the receptors that are evaluated For example, initial risk calculations assume that wildlife species spend all of their time at the East Landfill Pond The methods and assumptions used in the risk calculations are described in Section D 3 1 results are presented in Section D 3 2 Exposure point and benchmark formats used in preliminary risk calculations are presented in Table D-4

D 3 1 Methods

D 3 1 1 Exposure Point Concentrations

Summary statistics for pond water, seep water, and sediment PCOCs are listed in Tables D-1, D-2, and D-3 Data used in exposure assessments were collected during the OU 7 Phase I RFI/RI (DOE 1994) As noted previously, attempts to collect fish and crayfish for tissue analyses were unsuccessful Therefore, data on PCOC concentrations in biological tissues were not available However concentrations of PCOCs in surface water provide estimates of bioconcentration of contaminants in aquatic plants and animals that may be eaten by consumers

Exposure point concentrations for seep water and pond water were estimated from the mean and the upper confidence limit of the mean (95 percent) (UCL_{95}) Risk evaluations for exposure of aquatic life to pond water are based on the dissolved (filtered) component of chemical content The total (unfiltered) component was used to estimate chemical intakes by aquatic life

Concentration estimates for PCOCs in sediments were based on three samples collected from the East Landfill Pond (Table D-3) Detection frequency was 100 percent for most metals, but some organic compounds were detected in only one of the three samples Because of the low number of samples available, the exposure estimates of sediment-borne PCOCs were based on the maximum detected concentration Sediments in the East Landfill Pond were relatively shallow, the maximum sediment depth was approximately 10 inches (DOE 1994) The entire depth was considered to be relevant to exposure estimations, and samples from each location were composited over the entire depth interval from the surface to bedrock

D 3 1 2 Ecotoxicological Benchmarks

D 3 1 2 1 Aquatic Life

Risks to aquatic life were assessed for exposure to pond water and pond sediments Ecotoxicological benchmarks for pond water were based on Colorado surface water quality standards for protection of aquatic life (5 CCR 1002-8), EPA Ambient Water Quality Criteria (AWQC), or risk-based values derived from other sources such as the Environmental Restoration program at Oak Ridge National Laboratory (ORNL) (Suter and Mabrey 1994) Benchmark values used for radionuclides are risk-based concentrations developed by Los Alamos National Laboratory (LANL) and Oregon State University (Higley and Kuperman 1995)

Statewide standards have been promulgated for some metals and indicator parameters but not for most organic compounds or radionuclides (5 CCR 1002-8, September 1993) The Colorado Water Quality Control Commission (CWQCC) has classified segments of Woman Creek and Walnut Creek at Rocky Flats as Class 2 Aquatic Life Class 2 streams are not capable of sustaining a wide variety of aquatic fauna due to lack of physical habitat, insufficient flow, or uncorrectable water-quality conditions (5 CCR 1002-8, April 1993) Aquatic standards for Class 2 stream segments are set on a site-specific basis The CWQCC published site-specific standards for some organics and radionuclides for segments 4 and 5 of the Big Dry Creek basin, which includes parts of Rocky Flats (5 CCR 1002-8, April 1993)

Sediment benchmarks were derived from EPA guidance on estimating sediment quality criteria (EPA 1992) and risk-based sediment benchmarks developed for other freshwater sites in the United States and Canada (Hull and Suter 1994) Benchmarks for most non-ionic organic compounds were based on the equilibrium partitioning approach recommended by EPA (1992) This approach is based on the assumption that sediment toxicity is primarily dependent upon contaminant concentration in the interstitial water Information on the aqueous solubility of the contaminant and the total organic carbon content of the sediment is used to estimate a concentration in bulk sediment that would result in interstitial water concentrations equal to the water-quality benchmark Benchmarks for metals in sediments were taken primarily from risk-based values developed for freshwater habitats at other sites (Hull and Suter 1994) Sediment benchmarks for radionuclides were developed specifically for Rocky Flats (Higley and Kuperman 1995)

D 3 1 2 2 Vegetation

Risks to vegetation were assessed for exposure to pond sediments Vegetation benchmarks for metal and organics were based on soil benchmarks from Opresko *et al.* (1994) Vegetation benchmarks for radionuclides were not available, however, small

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mammal benchmarks for radionuclides developed specifically for Rocky Flats are presented in lieu of vegetation benchmarks because they are considered protective of all ecological receptors (Higley and Kuperman 1995)

D 3 1 2 3 Wildlife

State and federal water-quality standards for various environmental contaminants may be considered 'standards' for regulating exposures of wildlife to anthropogenic contaminants However risk evaluations and remediation decisions are based on risk-based criteria developed in site-specific ERAs A process for developing ecotoxicological benchmarks and a database for some chemicals and receptor types were developed at ORNL (Opresko *et al* 1994) The benchmarks were derived to approximate no-observed-adverse-effects levels (NOAELs), which represent the greatest exposures at which no adverse effects are observed NOAELs (and benchmarks) may be expressed as a dose (e g , milligrams contaminant ingested/kilogram body weight [bw]/day) or ecological effects concentrations (EECs) (e g milligrams contaminant/liter water) In some cases, data were available for the wildlife species of concern However, in most cases benchmarks were derived from data on the toxicity to laboratory test animals and extrapolated to wildlife species by scaling to body size and applying uncertainty factors to account for variability among species and data types (Opresko *et al* 1994) The ORNL database includes information for 17 species of birds and mammals that are common in the eastern United States but may not be common at Rocky Flats Where appropriate, these benchmarks were adapted for use in ERAs at Rocky Flats using methods described in TM3 (DOE 1995b)

Benchmarks for surface water (seep water and pond water) are expressed as concentrations This approach was used because data on contaminant content of biological tissues were not available Surface water toxicity benchmarks used in these comparisons take into account the potential for bioaccumulation of contaminants in aquatic prey or forage (Opresko *et al* 1994) The methods used to estimate bioconcentration are based primarily on the chemical-specific octanol-water partition coefficient (K_{OW}) of organic chemicals Metabolism and elimination (depuration) rates are not explicitly considered

In some cases, intakes of PCOCs estimated from concentrations in soils, surface water, or sediments from background (non-impacted) areas of Rocky Flats exceeded literature-based ecotoxicological benchmarks In these cases it was assumed that the literature-based values were too sensitive to accurately judge conditions at Rocky Flats, and the background values were used as benchmarks This approach was proposed in TM3 (DOE 1995b) and has been approved by EPA for use in ERAs at Rocky Flats Estimation of PCOC intakes from background areas is presented in Attachment D1

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Benchmarks were established to approximate the NOAEL and are based on sublethal, chronic endpoints. It is important to note that the NOAEL is not equivalent to the threshold exposure above which adverse effects may be expected The threshold is commonly referred to as the lowest-observed-adverse-effects level (LOAEL) Thus, exceeding the NOAEL does not necessarily imply the onset of adverse effects The relationship between NOAELs and LOAELs varies with chemicals, species, and other biological factors. Thus, exceeding the NOAEL should be considered a threshold for concern and not necessarily an indicator of unacceptable ecological risks

D 3 1 3 Exposure Estimates

D 3 1 3 1 Aquatic Organisms

Exposure of aquatic organisms to contaminants was estimated directly from the PCOC concentrations in surface water and sediments State standards and federal criteria are applied to measurements of dissolved (filtered) metal concentrations and total (unfiltered) concentrations of organic compounds Exposure estimates for sediments are based on measurements of PCOC concentrations in bulk sediments.

D 3 1 3 2 Vegetation

Vegetation may be exposed through absorption from sediments. Exposure of vegetation to contaminants was estimated directly from the PCOC concentrations in sediments Because the distribution of concentrations in sediments at the pond margin is not known, exposure estimates are based on measurements of PCOC concentrations in bulk sediments These sediment concentrations were compared to vegetation benchmark concentrations that would result in the NOAEL (Opresko *et al.* 1994)

D 3 1 3 3 Mallards and Raccoons

Mallards and raccoons may be exposed through direct ingestion of surface water and sediments or through ingestion of aquatic food items Risks from ingestion of surface water and aquatic food were evaluated using benchmarks that account for potential bioaccumulation in forage and prey species and are expressed as a concentration term (Section D 3 1 2 and Opresko *et al* 1994) Contaminant intakes due to ingestion of sediments were estimated using EPA estimates of incidental soil/sediment ingestion rates (EPA 1993, DOE 1995a) and data on PCOC concentrations in sediments from the East Landfill Pond. Preliminary exposure estimates were made assuming that individual animals spend all of their time at the East Landfill Pond.

D 3 1 3 4 Mule Deer and Coyotes

Risks to mule deer and coyotes were estimated for ingestion of surface water and sediments Surface water concentrations were compared to benchmark concentrations that would result in the NOAEL (Opresko *et al* 1994) Contaminant intakes due to ingestion of sediment were estimated as for mallards and raccoons Exposure estimates assumed that individual animals spend all of their time at the East Landfill Pond

D 3 1 3 5 Preble s Meadow Jumping Mouse

Risks to the Preble's meadow jumping mouse were estimated for ingestion of surface water and sediments Surface water concentrations were compared to benchmark concentrations that would result in the NOAEL (Opresko *et al* 1994) Contaminant intakes due to ingestion of sediments were estimated as for all other wildlife species Exposure estimates assumed that each individual animal spends all of its time at the East Landfill Pond

D 3 1 4 Risk Calculations

Potential ecotoxicity of contaminants is evaluated by comparing site-specific exposures to ecotoxicological benchmarks The comparison is expressed as a hazard quotient (HQ), the ratio of a site-specific exposure estimate to the benchmark (EPA 1994, DOE 1995b)

$$HQ = \frac{\textit{Exposure Estimate}}{\textit{Benchmark Exposure}}$$

Benchmarks are usually selected so that significant ecological effects are not expected when exposures are lower than the benchmarks (HQ < 1) Concentrations or exposures exceeding benchmarks (HQ > 1) do not necessarily indicate significant risk but do indicate that potential effects of the contaminant may require further evaluation

Cumulative risk of exposure to multiple contaminants is evaluated using the hazard index (HI) approach (EPA 1994) The HI assumes that the effects of exposure to multiple chemicals is an additive function of the effects of individual chemicals The HI is calculated as the sum of HQs for individual chemicals within a medium Thus, an HI less than 1 0 is consistent with negligible, or *de minimis*, risk (Suter 1993) An HI greater than 1 0 indicates potentially significant risk even if no single HQ is greater than 1 0 Cumulative or total risk from all media is summarized as the total HI (HI_{total}), which is the sum of the HIs from each exposure point (e g , surface water, seep water, and sediments)

Estimated HQs and HIs are based on the risk of effects to individual organisms This level of risk estimation is adequate for threatened/endangered or other sensitive species for which protection of individual organisms is desired However, protection of populations is more appropriate for species that are not protected or rare (Barnthouse 1993) In these cases extrapolation to population-level effects should be considered in risk management decisions. Qualitative discussion of population-level effects are included in the results for each species

D 3 2 Results

Exposure and risk estimates for aquatic life, vegetation, and wildlife are discussed separately Risks to aquatic life are discussed in Section D 3.2 1 and risks to vegetation are discussed in Section D 3 2.2. In Section 3 2.3, risks to wildlife are discussed separately for each wildlife receptor species Each section includes a discussion of the factors contributing to the uncertainty of exposure and risk estimates.

D 3 2 1 Aquatic Life

D 3 2 1 1 Surface Water (East Landfill Pond Water)

None of the surface-water PCOCs exceeded state water quality standards or risk-based benchmarks (Table D-5, Figure D-3) The cumulative risk, expressed as the HI, also did not exceed 1 0 These data are consistent with whole effluent toxicity (WET) tests conducted using water from two sites in the East Landfill Pond (Table D-6) Tests were conducted in accordance with standard EPA methods (APHA 1985, Peltier and Weber 1985) Fathead minnows and *Ceriodaphnia dubia* were exposed to East Landfill Pond water for 48 and 24 hours, respectively Fathead minnow survivorship was 75 percent in one sample and 100 percent in the other Survivorship of *C dubia* was 100 percent for samples from both locations (Table D-6) Results of the toxicity test and the preliminary risk calculation indicate that pond water represents negligible risk to aquatic life

D 3 2 1 2 Sediment

The HI for exposure of aquatic life to sediments was greater than 1,100 (Table D-7), indicating the potential for toxic conditions PCOCs contributing most to risk estimates were the polyaromatic hydrocarbons (PAHs) fluorene, anthracene, chrysene, and benzo(b)fluoranthene, which were associated with HQs well over 10 (Figure D-4, Table D-7) Barium was the only inorganic PCOC present at concentrations that greatly exceeded benchmarks (HQ = 10 75) (Table D-7)

Results of toxicity tests conducted with East Landfill Pond sediments are not consistent with the high toxicities predicted from HQs (Table D-6) The toxicity tests indicate that there is no toxicity in sediment for the following reasons

- Sediment samples used in toxicity tests were collected from the same locations (SED70093 and SED700293) as samples collected for chemical analyses Laboratory toxicity tests were conducted using the amphipod *Hyallela azteca* and standard testing procedures (ASTM method E1383-90, Nelson *et al* 1990)

Survivorship and growth were higher for East Landfill Pond samples than for controls (clean sand) (Table D-6)

- Similar tests using larval chironomids were planned but were not implemented due to inadequate laboratory cultures Larvae of several chironomid species were present in sediment samples from the East Landfill Pond indicating conditions adequate to support natural populations (Table D-8)

Sediment quality benchmarks for the above PAHs were calculated using the EPA equilibrium partitioning (EqP) approach (EPA 1992 Hull and Suter 1994) The EqP approach applies only to relatively hydrophobic organic chemicals and is based on the assumption that sediment toxicity is primarily due to contaminants dissolved in interstitial waters The approach uses K_{OW} and site-specific total organic carbon content in sediments to estimate the contaminant concentration in bulk sediments that would result in interstitial water concentrations equal to water-quality benchmarks The EqP may have overestimated PCOC concentrations in interstitial water leading to inconsistencies between the predicted and measured toxicity In addition water-quality benchmarks for PAHs were based on Colorado regulations for the Woman Creek and Walnut Creek segments of Big Dry Creek and may be based on risk to human health Use of these values may be too conservative for aquatic life

D 3 2 2 Vegetation

The HI for exposure of vegetation to sediments was 12 (Table D-11), indicating the potential for toxic conditions PCOCs contributing most to risk estimates were the metals zinc, aluminum vanadium chromium and selenium However, the HQs for these metals were relatively low—1 1 to 2 6—(Table D-11 Figure D-21) suggesting low potential toxicity In addition, although these metal concentrations in sediments in the East Landfill Pond exceed the site-specific benchmarks, the sediment concentrations represent concentrations within the range of background metals concentrations for Rocky Flats and can be considered to be naturally occurring

D 3 2 3 Wildlife

Preliminary risk calculations for wildlife species are summarized in the following sections Exposure point estimates and risk calculations for surface water seep water and sediments are presented in Tables D-9 D-10, and D-11 Cumulative risks to representative species from all three abiotic media are summarized in Figure D-5 The contribution of each PCOC and exposure point to total risk is characterized separately for each species in the following figures

Species	Surface Water	Seep Water	Sediments
Mallard	Figure D-6	Figure D-7	Figure D-8
Raccoon	Figure D-9	Figure D-10	Figure D-11
Mule deer	Figure D-12	Figure D-13	Figure D-14
Coyote	Figure D-15	Figure D-16	Figure D-17
Preble's meadow jumping mouse	Figure D-18	Figure D-19	Figure D-20

Based on preliminary risk calculations, mallards are subject to the greatest risk at the East Landfill Pond, followed by mule deer, raccoons, coyotes, and Preble's meadow jumping mice (Figure D-5). The HI_{total} for all of the species was greater than 1.0, suggesting that risk is not negligible. However, conservative assumptions were used in estimating exposure and may tend to overestimate risk. The effects of these assumptions on the risk estimates are summarized for each species. Unless otherwise indicated, exposure point concentrations, HQs, and HIs refer to estimates calculated using the UCL_{95}

Seep water appears to represent a significant risk for mallards, raccoons, and coyotes (Figure D-5). However, under the current remedial strategy for OU 7, the seep (SW097) will be covered when the cap is installed thus eliminating the seep as a potential exposure point

D.3.2.3.1 Mallard

Based on the initial estimates, seep water represents approximately 81 percent and surface water approximately 17 percent of the total risk to mallards at the East Landfill Pond (Figure D-5). The HIs exceeded 1.0 for both pond water (11.3, Figure D-6) and seep water (53, Figure D-7), and the HI_{total} was greater than 60. Sediments appear to represent negligible risk because the HI is less than 1.0 (0.8, Figure D-8) and they contribute less than 2 percent of the total risk (Figure D-5)

As noted in Section D.3.2.2, the seep at SW097 will be covered during remediation, eliminating the primary source of risk to mallards. Remaining risks are mainly due to bis(2-ethylhexyl)phthalate and di-n-butyl phthalate in pond water (Figure D-6). Risks from these chemicals are due primarily to their potential to bioconcentrate in aquatic prey species (Opresko *et al* 1994)

Risk estimates were made assuming that mallards feed exclusively in the East Landfill Pond. Although this scenario is unlikely, it is difficult to accurately predict the level to which mallards use the East Landfill Pond. In order to assess potential risk under different scenarios, HIs were estimated for intensities of site use ranging from zero (never used) to 1.0 (used exclusively) (Figure D-6). Based on these estimates, the HI for mallards would exceed 1 0 for individuals that use the East Landfill Pond greater than approximately 10 percent of the time

Preliminary risk calculations should be viewed as conservative estimates of risk Potential uncertainties that may affect evaluation of risk in making decisions regarding risk management and remedial actions include the following

- Although 10-percent site use is a relatively plausible exposure scenario for individual ducks it may be less likely that all of the mallard population at Rocky Flats would use the East Landfill Pond to that extent The East Landfill Pond represents approximately 3 percent of the total open water habitat on Rocky Flats Thus while some individuals may be at risk of exceeding the benchmark exposures it is not clear that effects to these individuals would be manifested at the population level

- Both phthalate compounds were detected in only one of eight (12 percent) samples from SW098 (Table D-1 Figure D-1) (DOE 1994) Bis(2-ethylhexyl)phthalate was detected at only SED70093 the sampling locations nearest to the landfill (Figure D-1) (DOE 1994) The occurrence of phthalates in surface water is related to seep flow, and these and other semivolatile organic compounds are probably deposited in sediments near the seep Exposure estimates assumed that PCOC concentrations remain constant However, these data suggest that concentrations fluctuate and exposure of mallards and other waterfowl to phthalates may be far less frequent In addition the seep at SW097 will be eliminated as a source of contaminants Phthalates remaining in pond sediments did not appear to represent a risk to mallards (Table D-11)

- The ecotoxicological benchmarks for the two phthalate compounds were based primarily on their capacity for bioconcentration in aquatic forage and prey Because concentrations in aquatic biota were not available, C_W values were based on maximum estimates of bioconcentration (Opresko *et al* 1994) Both of these compounds are metabolized rapidly limiting movement through food chains

- The toxicological study used to establish the benchmarks for phthalates was based on eggshell thinning and water permeability of eggs laid by dosed birds (Peakall 1974 cited in Opresko *et al* 1994) The study included only one dose level 1 11 mg/kg/day for both compounds Di-n-butyl phthalate had no effect on eggshells at this dose rate Therefore, the confidence that the benchmark is at or below the NOAEL is high Bis(2-ethylhexyl)phthalate did affect eggs at the administered dose rate Consequently the nominal dose rate was considered to be the LOAEL and divided by a factor of 10 to estimate the NOAEL (Opresko *et al* 1994) The confidence that the nominal dose rate was equal to the LOAEL is not high, but the ten-fold uncertainty factor applied to the LOAEL to estimate the NOAEL is higher than the typical LOAEL/NOAEL ratio for organic compounds (Lewis *et al* 1990)

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Therefore, the benchmark for bis(2-ethylhexyl)phthalate is a reasonable estimate of the NOAEL

- The HQs and HIs are estimated for risks associated with NOAELs for individual compounds Risk is lower for exceeding LOAELs, the exposure thresholds for adverse effects

D 3 2 3 2 Raccoon

The HI_{total} for raccoons at the East Landfill Pond was 9 2, with risk of toxicity resulting primarily from seep water and sediments (Figure D-5) As noted in Section D 3 2.2, the seep at SW097 will be covered during remediation, thus eliminating it as a source of exposure to raccoons Risk from surface water in the East Landfill Pond appears to be negligible based on HQ estimates for individual PCOCs and the HI for pond water (Figure D-9) Remaining risks are mainly due to incidental ingestion of aluminum, vanadium, and arsenic in sediments (Figure D-11) Total risk from sediments was moderate with an HI of 6 4

The risks due to aluminum are based on comparison to background The estimated intake of aluminum from background soils and sediments at Rocky Flats was higher than the ecotoxicological benchmark derived from literature values (Table D-11) Therefore, the site-specific benchmark for raccoons at Rocky Flats was set equal to the intake expected under natural conditions Risk estimates for vanadium and arsenic are based on benchmarks derived from toxicity studies.

Preliminary risk calculations should be viewed as conservative estimates of risk Potential uncertainties that may affect evaluation of risk in making decisions regarding risk management and remedial actions include the following

- Sediment samples were collected from locations away from the East Landfill Pond shoreline in open water areas that are probably inaccessible to raccoons The effect on the accuracy of the exposure point estimate is unclear This may overestimate exposure to sediment-borne PCOCs because the contaminants are transported primarily to the pond in water from the seep Thus, contaminants may be concentrated in the areas of the pond that are continually fed by seep water Data for sediments along the East Landfill Pond margins are not available Aluminum concentrations in surface soils adjacent to the East Landfill Pond area did not exceed background concentrations (Attachment D1). Concentrations of arsenic and vanadium marginally exceeded background soil concentrations (Attachment D1)

- The exposure estimate assumes that raccoons use the East Landfill Pond 100 percent of the time This is unlikely because the pond apparently lacks crayfish and fish and therefore may be of limited value as a foraging resource Based on exposure estimates made for a range of site use factors, individual raccoons using the East Landfill Pond 15 percent of the time or more would exceed an HI of 1 0 (Figure D-11) It is also unlikely that a significant proportion of the raccoon population at Rocky Flats uses the East Landfill Pond to that extent because this pond contains only 6 percent of the pond shoreline habitat on Rocky Flats

- The metals that contribute most of the overall risk from sediments are present in natural soils and sediments of Rocky Flats For aluminum, the HQ of 2 4 (Figure D-11) indicates that concentrations of this metal are approximately twice that of background sediments This estimate may be conservative if background samples were collected from areas that contain a lower percentage of fine clays than sediments at the East Landfill Pond The clays have a high aluminosilicate content Therefore, soils or sediments that have a higher content of fine clays may be expected to have a higher aluminum content than coarser materials

- The exposure estimates assume that 100 percent of the chemical content of soils and sediments is bioavailable This may be a reasonable assumption for most organic compounds but probably overestimates the bioavailable fraction of metals Benchmarks for metals are based on studies in which experimental animals are dosed with highly soluble and bioavailable forms of the metals (Opresko *et al* 1994) The prevalent forms of heavy metals in soils and sediments are usually far less soluble Toxicity estimates were based on comparison of experimentally derived values to site data without adjustment for lower bioavailability of soils and sediments This approach was taken because no standard approach is available for estimating bioavailability without site-specific measurements Thus the exposure estimates may overestimate risk

D 3 2 3 3 Mule Deer

The total risk (HI_{total}) to mule deer was the lowest among the wildlife receptors (Figure D-5) Nearly 100 percent of the risk to mule deer was due to ingestion of PCOCs in sediments (Figure D-5) HQs and HIs associated with ingestion of pond water and seep water were all below 1 0, indicating negligible risk associated with these media (Figures D-12 and D-13)

Aluminum in sediments contributed the greatest proportion of the total risk with an HQ of 2 39, none of the other PCOCs were associated with HQs greater than 0 28 (Figure D-14) Other naturally occurring metals such as vanadium and arsenic contributed approximately 17 percent of the total risk (Figure D-14) Organic contaminants such as benzo(a)pyrene contributed less than 1 percent of the total use Factors that may affect risk estimates include the following

- As with the other wildlife receptors, mule deer were assumed to spend 100 percent of their time around the landfill pond This probably is a gross overestimate for this wide-ranging species The East Landfill Pond includes 6 percent of the shoreline habitat at Rocky Flats and much higher quality habitats are available at other ponds However, given the HI estimated for sediments, individual deer would need to spend approximately 40 percent of their time at the landfill pond in order to exceed an HI of 1.0 (Figure D-14) As with mallards and raccoons, it is unclear what proportion of the mule deer population is exposed to East Landfill Pond sediments, but it is unlikely that a significant proportion would be affected.

- As noted in Section D 3 1 1, the maximum detected concentration of PCOCs in sediments was used as the exposure estimate and samples were collected from areas that are inaccessible to deer Benzo(a)pyrene and the other PAHs were detected in samples from only one (SED70093) of the three sampling locations (Table D-3) Thus, the effective area of exposure to organic contaminants may be restricted to the western edge of the East Landfill Pond and much smaller than was assumed in exposure calculations.

- As with raccoons, the literature-based benchmark for aluminum was less than the estimated intake from background sediments at Rocky Flats Therefore, in order to estimate risks from aluminum, intake from ELP sediments was compared to the estimated background intake. The results indicate that deer spending all of their time at the East Landfill Pond might ingest approximately 2 5 times more aluminum than if they were exposed only to background levels. Factors that may affect the risk estimate associated with this intake are the same as those discussed for raccoons (Section 3.2 2.2)

D 3 2 3 4 Coyote

The HI_{total} for coyotes was less than 10, with most of the risk resulting from exposure to seep water and sediments (Figure D-5). Surface water in the East Landfill Pond represents negligible risk, with all HQs and HIs less than 1 0 (Figure D-15) As noted earlier, the seep at SW097 will be eliminated by the proposed remediation Thus, residual risk for coyotes results from incidental ingestion of pond sediments As with raccoons, risk from sediments results primarily from ingestion of aluminum, vanadium, and arsenic Of these metals, only aluminum was associated with an HQ greater than 1 0 (Figure D-17) As noted in Section D 3 2.2.2, all three of these metals occur naturally in soils and sediments at Rocky Flats

Coyotes are a wide-ranging species that use nearly all parts of Rocky Flats Based on the preliminary risk calculations, coyotes would have to use the East Landfill Pond more than 30 percent of the time to experience exposures associated with an HI greater than 1 0 (Figure D-17)

D 3 2 3 5 Preble's Meadow Jumping Mouse

Risks to Preble's meadow jumping mouse were similar to those of raccoons, mule deer, and coyotes Risks from pond water (Figure D-18) and seep water (Figure D-19) were negligible Remaining risks were due primarily to aluminum in sediments (Figure

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D-20) The discussion of factors affecting the risk estimation for raccoons (Section D 3 2 2 2) is also applicable to Preble's meadow jumping mouse

Although the area around the East Landfill Pond has been identified as possible suitable habitat for Preble's meadow jumping mouse no individuals have been identified there However, individuals were caught on pond margins in the B-series detention ponds to the south The B-ponds are associated with a much more extensive riparian zone the preferred habitat of Preble's meadow jumping mouse

D 4 Summary and Conclusions

The purpose of the OU 7 screening-level ERA was to provide baseline information on the potential ecotoxicity and ecological risk of PCOCs in seep water associated with SW097 and pond water and sediments in the East Landfill Pond The information was needed to help determine the feasibility of leaving the East Landfill Pond in place as part of the OU 7 site remediation strategy Leaving the East Landfill Pond in place would reduce costs associated with landfill cap construction However, aquatic life, vegetation and wildlife could be exposed to PCOCs in pond water and sediments in the East Landfill Pond The ERA was needed to help determine whether East Landfill Pond water and/or sediments should be remediated to mitigate ecotoxicological risks

Risks were characterized by comparing chemical concentrations in abiotic media to literature-based benchmarks to determine whether PCOCs were present at concentrations that could be toxic Conservative assumptions were adopted in developing benchmarks and estimating exposures to minimize the chance of underestimating risk

Risks to aquatic life in the East Landfill Pond appear to be minimal Results of the literature-based toxicity screen and laboratory toxicity testing indicate that pond water represents negligible risk to aquatic life For sediments, preliminary risk calculations based on exposure estimations appear to overestimate risks to aquatic life Based on these calculations risk of toxicity to sediment-associated organisms appears to be high (Figure D-4) but results of site-specific surface water and sediment toxicity tests indicate no toxicity (Table D-6) In addition, many of the species present in sediment samples are moderately tolerant of polluted sediments, suggesting that conditions in the pond are not as toxic as indicated by the HQs (Table D-8)

Risks to vegetation were primarily due to exposure to naturally occurring metals in sediments These concentrations of zinc, aluminum, vanadium chromium, and selenium in sediments exceed site-specific benchmarks however, these sediment metals concentrations represent concentrations within the range of background metals concentrations for Rocky Flats In addition, HQ values for expose to these metals were relatively low—1.1 to 2.6—suggesting low potential toxicity (Table D-11)

Potential toxicity to mammalian and avian wildlife was also assessed. Baseline risk estimates were based on the conservative assumption that receptors spend all of their time at East Landfill Pond Under these conditions, HI_{total} was greater than 1.0 for each of the species evaluated. Seep water was a main contributor to overall risk for mallards and raccoons, however, the seep at SW097 will be eliminated as an exposure point if the proposed remedial strategy is implemented

Risks to raccoons, coyotes, Preble's meadow jumping mice, and mule deer were primarily due to exposure to naturally occurring metals in sediments Aluminum, vanadium, and arsenic were present in sediments at levels that exceed concentrations in background sediments. However, potential toxicity may be overestimated because site use and bioavailability of PCOCs were assumed to be 100 percent. In addition, HQ values for exposure to these metals were relatively low—approximately 1 5 to 2 5—suggesting low potential toxicity even using conservative assumptions

Pond water risks to wildlife appear to be limited for exposure of mallards and other waterfowl to bis(2-ethylhexyl)phthalate and di-n-butyl phthalate HQs suggest moderate risk of exceeding NOAELs for individual birds if they spend all of their time at the East Landfill Pond and if phthalate concentrations are constant (Figure D-6). Risk estimates were based on potential effects on shell thickness and weight of offspring of female birds that ingest phthalates during gestation (Peakall 1974) Hatching success and offspring survivorship were not affected at the dosage tested. It is not known whether mallards or other aquatic-feeding birds use the East Landfill Pond area during breeding, but areas at the pond margins appear to support suitable nesting habitat for a limited number of breeding pairs. However, the area around the East Landfill Pond represents a small part of the overall wetland and riparian habitat at Rocky Flats Therefore, it is not clear that mallard or other bird populations would be affected even if birds nesting at the East Landfill Pond were exposed to these contaminants

The major sources of uncertainty in this ERA are the actual bioavailability of PCOCs, the spatial and temporal distribution of contaminants, assumptions about frequency and duration of exposures, and the general importance of the East Landfill Pond as a local ecological resource Risk estimates incorporated conservative assumptions regarding bioavailability and exposure frequency and duration Important effects of these assumptions on exposure estimates are discussed for each receptor group However, the most important aspect of accurately estimating risk—the importance of the East Landfill Pond as a local ecological resource—is also the most difficult to assess

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The East Landfill Pond was constructed to control potential release of contaminants by retaining leachate and controlling sediment transport from the landfill during operation This is common practice in the construction and operation of any solid waste landfill As a result, a water body was created that contains surface water and sediments contaminated with chemicals that have leached from the waste areas However, construction of the pond also created persistent wetland and aquatic habitats that are small but important components of dry ecosystems such as Rocky Flats The current biological and abiotic conditions in the pond reflect its effectiveness as an artificially managed catchment for the landfill leachate and runoff The East Landfill Pond does not empty directly to a stream Therefore, sensitive stream fauna such as common shiners and stonerollers are not risk from contaminant release The area around the East Landfill Pond is a potential attractive nuisance because species drawn to the aquatic resources are also exposed to contaminants emanating from the landfill Preliminary risk calculations suggest that the resulting exposures present some, albeit limited, risk to wildlife

The aquatic community in the pond may be limited, in part, due to the semivolatile organic contaminants in sediments The pond apparently does not contain fish or crayfish populations or if it does, the populations are very small and difficult to detect or quantify Because the pond lacks predaceous fish such as bass, it may be a resource for breeding amphibians such as tiger salamanders, chorus frogs, and bullfrogs The lack of a complex aquatic food web with upper-level aquatic organisms makes the pond a limited resource for aquatic-feeding wildlife and attenuates the transfer of contaminants via food-web interactions (Rasmussen *et al* 1990)

The East Landfill Pond has been in existence for only 20 years, and therefore, is not an historically important component of the local ecosystem The current importance of the East Landfill Pond as aquatic habitat at Rocky Flats and in the Big Dry Creek basin also appear to be minimal The East Landfill Pond comprises approximately 3 percent of the open water habitat and 6 percent of the available shoreline habitat on Rocky Flats The wetland in and around the East Landfill Pond comprises approximately 1 6 percent of the total wetlands at Rocky Flats (COE 1994) The pond area has been identified as potential habitat for one federal candidate species, Preble's meadow jumping mouse (DOE 1995a) but their occurrence there has not been confirmed It is possible that other state or federally protected species may occasionally use the pond area (DOE 1995a), but the resources at the East Landfill Pond are not critical to any of the them

As noted in Section 1, the East Landfill Pond could be left intact after remediation, possibly resulting in a permanent aquatic habitat at Rocky Flats If this option were selected the source of contamination in the pond, the seep SW097, would be eliminated The pond sediments could represent a continuing source of exposure to wildlife and aquatic receptors after remediation However the exposure would be

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attenuated over time as organic contaminants in the sediments are degraded by chemical and biological processes and contaminated sediment would be covered with clean sediments washed into the pond by erosion Attenuation of these exposures over time would reduce the already limited ecological risk from the pond

D.5. References

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Table D-1
PCOCs in Pond Water (SW098)[1]

Analyte	Detection Frequency	Sample Mean	UCL$_{95}$	Maximum Detected Concentration	Sample Concentration Range	Detection Limit Range	Units[2]
Total Analytes							
Metals							
Arsenic	11/24	2	2 5	2 2	0 9 10	0 7 10	µg/L
Calcium	25/25	39 745	43 940	55 000	3 180 55 000	14 3 5 000	µg/L
Lithium	23/24	81	87	109	7 7 109	2 100	µg/L
Magnesium	25/25	39 640	42 400	48 300	4 270 48 300	0 1 5 000	µg/L
Manganese	24/25	101	142	430	2 5 430	1 15	µg/L
Molybdenum	4/24	38	56	13 1	3 100	5 7 500	µg/L
Nickel	17/25	11	12	22	6 3 40	0 02 40	µg/L
Potassium	25/25	8 816	9 430	10 900	1 360 10 900	10 5 000	µg/L
Sodium	25/25	161 245	173 950	196 000	19 900 196 000	10 5 000	µg/L
Strontium	24/24	476	518	598	44 9 598	2 3 200	µg/L
Thallium	3/24	3	3 4	7 4	0 9 10	0 1 10	µg/L
Tin	8/24	58	98	44 3	10 100	10 1 000	µg/L
Radionuclides							
Americium-241	18/18	0 011	0 0109	0 031	0 0005655 0 075	0 0 19	pCi/L
Gross Alpha	13/13	2	2 66	5	-0 67 5	2 8 68	pCi/L
Gross Beta	13/13	12	12 6	16	7 9 16	2 57535 7 6	pCi/L
Strontium 89 90	5/5	1 4	1 86	1 924	0 6635 1 924	0 23 1	pCi/L
Tritium	26/26	143	166 11	257 8	10 257 8	160 460	pCi/L
Uranium-235	10/10	0 1	0 163	0 3	-0 01 0 3	0 0 281	pCi/L
Uranium-238	10/10	1 1	1 36	1 964	0 6996 1 964	0 08 0 263	pCi/L
Volatile Organic Compounds							
Acetone	1/21	5	5 9	12	6 58	10 10	µg/L
Chlorinated Hydrocarbons							µg/L
Methylene Chloride	3/21	3	4	8	4 8	5 5	µg/L
Vinyl Acetate	1/20	9	15	80	10 80	10 10	µg/L
Semivolatile Organic Compounds							
Bis(2-ethylhexyl)phthalate	1/8	5	5 6	11	1 11	9 11	µg/L
Di-n Butyl Phthalate	1/8	5	5 6	1	2 11	9 11	µg/L
Dissolved Analytes							
Metals							
Antimony	8/23	23		35 3	8 60	0 05 60	µg/L
Arsenic	8/20	2	2 99	3	0 7 10	0 7 10	µg/L
Barium	24/24	167		204	135 204	0 02 50 000	µg/L
Calcium	24/24	41 182	44 181	55 900	26 100 55 900	14 3 100 000	µg/L
Lithium	22/23	86	89 14	110	62 9 110	2 2 000	µg/L
Magnesium	24/24	41 914	42 675	48 200	36 600 48 200	0 1 200 000	µg/L
Manganese	21/24	63	97 16	250	1 250	1 10 000	µg/L
Molybdenum	8/22	23	31 8	15 6	2 5 100	5 7 200	µg/L
Nickel	8/23	10	11 92	24 6	4 40	0 02 40	µg/L
Potassium	24/24	9 308	9 521	10 900	7 470 10 900	10 200 000	µg/L
Sodium	24/24	170 594	174 814	197 000	142 000 197 000	10 50 000	µg/L
Strontium	23/23	497	517 7	596	366 596	2 3 10 000	µg/L
Tin	7/21	41	2 79	86 1	10 4 100	10 200	µg/L
Vanadium	8/23	9	52 1	9 2	2 50	2 50	µg/L

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Table D-1
PCOCs in Pond Water (SW098)[1]

Analyte	Detection Frequency	Sample Mean	UCL_{95}	Maximum Detected Concentration	Sample Concentration Range	Detection Limit Range	Units[2]
Radionuclides							
Gross Alpha	7/7	1.9		4.2	-0.294 - 4.2	2 30914 - 10.2	pCi/L
Gross Beta	13/13	12		22	4.206 - 22	2 72271 - 7 7	pCi/L
Strontium-89 90	10/10	1	1.3	1.613	0.4 - 1.613	0.5 - 1	pCi/L
Uranium-238	15/15	2	3 89	15	0.3 - 15	0 - 0 6	pCi/L

[1] PCOCs are defined in the OU 7 Final Work Plan Technical Memorandum, 1994

[2] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter

Definition

PCOCs - Potential chemicals of concern

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Table D-2
PCOCs in Seep Water (SW097)[1]

Analyte	Detection Frequency	Sample Mean	UCL_{95}	Maximum Detected Concentration	Sample Concentration Range	Detection Limit Range	Units[2]
Total Analytes							
Metals							
Antimony	4/20	22	27 5	60 4	14 60 4	0 05 60	µg/L
Barium	21/21	640	743	1 550	297 1550	0 02 50 000	µg/L
Calcium	21/21	151 000	161 000	212 000	126 000 212 000	14 5 100 000	µg/L
Iron	21/21	80 510	90 000	155 000	61 300 155 000	4 7 30 000	µg/L
Lithium	17/21	48	55	107	34 107	2 2 000	µg/L
Magnesium	21/21	34 719	37 100	49 000	29 300 49 000	0 1 200 000	µg/L
Manganese	21/21	1 611	1 730	2 490	1 320 2 490	1 10 000	µg/L
Potassium	20/21	6 436	7 240	11 700	5 000 11 700	10 200 000	µg/L
Silicon	14/14	13 508	12 560	44 000	7 060 44 000	7 3 2 000	µg/L
Sodium	21/21	71 367	76 740	110 000	57 700 110 000	10 5 000	µg/L
Strontium	19/21	919	1 010	1 370	814 1 370	3 5 10 000	µg/L
Zinc	21/21	2 945	4 250	16 000	857 16 000	1 8 10 000	µg/L
Radionuclides							
Gross Beta	10/10	11	13 2	17	3 753 17	1 69 11 5	pCi/L
Strontium 89 90	10/10	1 3	2 01	4 06	0 66 4 06	0 21 1	pCi/L
Tritium	22/22	349	506 15	1 500	110 1 500	155 450	pCi/L
Water-Quality Parameters							
Nitrite	6/9	30 33	41 7	63	20 63	20 20	µg/L
Volatile Organic Compounds							
1 1 Dichloroethane	17/20	6	7 2	14	2 10	5 5	µg/L
2 Butanone	6/19	12	19	76	6 76	10 10	µg/L
2 Hexanone	1/20	5	5 7	10	1 10	10 10	µg/L
4 Methyl 2 pentanone	5/20	11	18 5	87	10 87	10 10	µg/L
Acetone	11/21	33	52 9	220	10 220	10 10	µg/L
Benzene	11/20	2	2 1	2	1 5	5 5	µg/L
Carbon Disulfide	1/20	3	3	6	5 6	5 5	µg/L
Chloroethane	15/20	22	27 1	57	10 57	10 10	µg/L
Chloromethane	2/20	5	5 3	7	4 10	10 10	µg/L
Ethylbenzene	19/20	13	14 4	18	1 18	5 5	µg/L
Methylene Chloride	10/20	14	29	190	3 190	5 5	µg/L
o-Xylene	3/4	6	8 5	8	5 8	5 5	µg/L
Tetrachloroethene	2/20	2	2 5	1	1 5	5 5	µg/L
Toluene	19/20	38	47 6	88	5 88	5 5	µg/L
Total Xylenes	19/20	14	16 8	25	1 25	5 5	µg/L
Trichloroethene	11/20	2	2 4	4	1 5	5 5	µg/L
Vinyl acetate	1/19	7	11 3	49	10 49	10 10	µg/L
Vinyl Chloride	5/20	5	5 9	11	3 11	10 10	µg/L
Semivolatile Organic Compounds							
2 4 Dimethylphenol	1/4	5	5 5	3	3 10	10 10	µg/L
2 Methylnaphthalene	4/4	16	19 9	23	12 23	10 10	µg/L
4 Methylphenol	3/4	4	5	4	2 10	10 10	µg/L
Acenaphthene	4/4	3	3 2	3	2 3	10 10	µg/L
Bis(2-ethylhexyl)phthalate	1/4	5	6 1	2	2 12	10 12	µg/L
Dibenzofuran	4/4	1	1 9	2	1 2	10 10	µg/L
Diethyl Phthalate	4/4	3	4 1	3	1 10	10 10	µg/L
Fluorene	4/4	2	2 9	3	2 3	10 10	µg/L
Naphthalene	4/4	18	21 3	22	14 22	10 10	µg/L
Phenanthrene	4/4	4	4 9	5	4 5	10 10	µg/L

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Table D-2
PCOCs in Seep Water (SW097)[1]

Analyte	Detection Frequency	Sample Mean	UCL_{95}	Maximum Detected Concentration	Sample Concentration Range	Detection Limit Range	Units[2]
Dissolved Analytes							
Metals							
Barium	20/20	567	590.1	673	447 - 673	0 02 50 000	µg/L
Calcium	20/20	149 580	156 129 9	207,000	123 000 - 207 000	14.5 - 100 000	µg/L
Iron	20/20	71 050	75 923 5	95 800	51,100 - 95,800	4 7 - 30 000	µg/L
Lithium	16/20	47	55.3	111	34 - 111	2 - 2,000	µg/L
Magnesium	20/20	34 690	37,002 6	47,500	28,700 - 47 500	0 1 - 200 000	µg/L
Manganese	20/20	1,581	1,664	2,040	1,300 - 2 040	1 - 10,000	µg/L
Potassium	19/20	5,912	6 588 5	8,790	3,500 8,790	10 - 200 000	µg/L
Sodium	20/20	71 720	78,068 5	116,000	55,100 - 116 000	10 - 50 000	µg/L
Strontium	19/20	939	1,011 5	1,350	778 - 1 350	3.5 - 10 000	µg/L
Tin	10/19	67	95.5	306	14.8 - 306	10 - 200	µg/L
Zinc	20/20	1 530	1 779	3,430	240 - 3,430	1 6 10,000	µg/L
Radionuclides							
Gross Beta	13/13	8	9 1	11	0.5469 11	2.8 - 4 3	pCi/L
Strontium-89 90	9/9	1 16	1 5	1 933	0.6806 - 1 933	0.32 1	pCi/L
Uranium-235	12/12	0 1	0.22	0 7	-0.0094 - 0.7	0 - 0 6	pCi/L

[1] PCOCs are defined in the OU 7 Final Work Plan Technical Memorandum, 1994

[2] All concentrations reported in micrograms per liter except radionuclide concentrations, which are reported in picocuries per liter

Definition

PCOCs - Potential chemicals of concern

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Table D-3
PCOCs in Sediments[1]

Analyte	Detection Frequency	Sample Mean	Maximum Detected Concentration	Sample Concentration Range[2]	Detection Limit Range	Units[3]
Metals						
Aluminum	2/2	14 450	16 600	12 300 16 600	7 7 12	mg/kg
Arsenic	3/3	4	5	2 7 5	0 32 0 42	mg/kg
Barium	3/3	198	215	174 215	1 6 2 5	mg/kg
Beryllium	3/3	1 2	1 5	0 81 1 5	0 22 0 34	mg/kg
Calcium	2/2	7 070	7 850	6 290 7 850	7 5 11 7	mg/kg
Chromium	3/3	14 7	17 5	12 3 17 5	0 64 0 99	mg/kg
Copper	3/3	16 0	18 6	11 2 18 6	0 71 1 1	mg/kg
Iron	2/2	13 500	15 400	11 600 15 400	1 8 2 8	mg/kg
Lead	3/3	29 7	33 7	21 6 33 7	2 5 3 8	mg/kg
Magnesium	2/2	2 710	3 250	2 170 3 250	9 5 14 8	mg/kg
Nickel	3/3	12 7	15 3	9 3 15 3	2 7 4 2	mg/kg
Potassium	2/2	1 995	2 640	1 350 2 640	190 295	mg/kg
Selenium	3/3	0 8	1 1	0 41 1 1	0 3 0 5	mg/kg
Sodium	2/2	367	447	286 447	15 23 4	mg/kg
Strontium	2/2	52 5	61 5	43 5 61 5	1 3 2 1	mg/kg
Vanadium	3/3	34	41	28 8 41	0 78 1 2	mg/kg
Zinc	3/3	106	187	49 2 187	0 59 0 91	mg/kg
Radionuclides						
Cesium 137	3/3	0 458	0 732	0 286 0 732	0 0	pCi/L
Volatile Organic Compounds						
2 Butanone	1/3	17	35	13 35	13 24	µg/kg
Toluene	3/3	307	440	180 440	10 33	µg/kg
Semivolatile Organic Compounds						
Acenaphthene[4]	1/3	220	100	100 670	450 790	µg/kg
Acetone	2/3	68	130	63 180	13 24	µg/kg
Anthracene[4]	1/3	240	160	160 670	450 790	µg/kg
Benzo(a)anthracene	1/3	300	340	340 670	450 790	µg/kg
Benzo(a)pyrene	1/3	293	320	320 670	450 790	µg/kg
Benzo(b)fluoranthene	1/3	343	470	450 670	450 790	µg/kg
Benzo(ghi)perylene	1/3	253	200	200 670	450 790	µg/kg
Benzo(k)fluoranthene	1/3	230	130	130 670	450 790	µg/kg
Benzoic acid[4]	3/3	537	870	260 870	2 200 3 900	µg/kg
Bis(2 chloroisopropyl)ether[4]	1/3	259	47	47 790	450 790	µg/kg
Bis(2-ethylhexyl)phthalate	1/3	213	80	80 670	450 790	µg/kg
Chrysene	1/3	290	310	310 670	450 790	µg/kg
Fluoranthene[4]	2/3	415	830	79 830	450 790	µg/kg
Fluorene	1/3	217	92	92 670	450 790	µg/kg
Indeno(1 2 3-cd)pyrene	1/3	247	180	180 670	450 790	µg/kg
Phenanthrene	2/3	346	630	73 670	450 790	µg/kg
Pyrene	2/3	386	750	74 750	450 790	µg/kg

[1] PCOCs are defined in the OU 7 Final Work Plan Technical Memorandum 1994

[2] Includes detection limits

[3] Metal concentrations are reported in milligram per kilogram radionuclide concentrations are reported in picocuries per liter volatile and semivolatile organic compounds are reported in micrograms per kilogram

[4] Indicates PCOCs for which the maximum detection limit (MDL) is greater than the maximum detected concentration (MDC)

Definitions

PCOCs Potential chemicals of concern

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Table D-4

Exposure Point and Benchmark Formats Used in Preliminary Risk Calculations

Receptor	Exposure Point	Exposure Point Estimate Format	Benchmark Format
Aquatic Life	surface water	dissolved fraction for metals radionuclides, total fraction for organics	**Dissolved concentration in water** Colorado state water-quality standards or federal Ambient Water Quality Criteria
Sediment-associated aquatic life	sediment interstitial water	PCOC concentration in bulk sediments	**Total concentration in bulk sediments** Organics - calculated from TOC and K_{ow} (EPA 1992) metals - sediment benchmarks in freshwater habitats (Hull and Suter 1994); radionuclides - calculated for RFETS (Higley and Kuperman 1995)
Vegetation	sediments	PCOC concentration in bulk sediments	**Total concentration in bulk sediments/soil** Organics and metals from Opresko *et al* (1994), radionuclides from Higley and Kuperman (1995)
Mallards Raccoons	surface water seep water	total fraction of PCOC concentration in water	**Total concentration in surface water** Based on ingestion of surface water and aquatic prey or forage includes bioconcentration (organics and metals from Opresko *et al* [1994]; radionuclides from Higley and Kuperman [1995])
	sediments	rate of incidental ingestion of PCOCs from ELP sediments	**Daily ingestion rate for each PCOC that results in a dose equal to the NOAEL**
Mule Deer, Coyotes, Preble's Meadow Jumping Mouse	surface water seep water	total fraction of PCOC concentration in water	**Total concentration in surface water:** Based on ingestion of PCOCs during drinking (organics and metals from Opresko *et al* [1994], radionuclides from Higley and Kuperman [1995])
	sediments	rate of incidental ingestion of PCOCs from ELP sediments, assumes ingestion of sediments is same as ingestion of soils	**Daily ingestion rate for each PCOC that results in a dose equal to the NOAEL**

TOC = total organic carbon

K_{ow} = octanol-water partition coefficient

PCOC = potential chemical of concern

ELP = East Landfill Pond

NOAEL = no-observed-adverse-effects level

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EXPOSTB[illegible]/14/95

Table D-5

Tier 3 Exposure Screening for Surface Water Quality[a] at the OU 7 East Landfill Pond

PCOC (Total Analytes)	UCL_{95} of Mean	Units	Water-Quality Standard (Chronic)	Hazard Quotient
METALS				
Arsenic[b]	2 99	ug/l	150	1 99E 02
Calcium	44181	ug/l	EN	EN
Lithium[c]	89 14	ug/l	2 500	3 57E 02
Magnesium	42675	ug/l	EN	EN
Manganese	97 16	ug/l	560	1 73E 01
Molybdenum[d]	31 80	ug/l	NA	NA
Nickel[e]	11 92	ug/l	149 4	7 98E-02
Potassium	9521	ug/l	EN	EN
Sodium	174814	ug/l	EN	EN
Strontium[d]	517 70	ug/l	620	8 35E 01
Thallium	2 79	ug/l	15	1 86E-01
Tin[d]	52 10	ug/l	74	7 07E 01
RADIONUCLIDES				
Americium-241[f]	0 13	pCi/l	13 000	9 78E 06
Strontium-89 90[f]	1 30	pCi/l	270 000	4 82E 06
Tritium[f h]	166	pCi/l	190 000 000	8 74E 07
Uranium-235[f]	0 22	pCi/l	4 300	5 12E 05
Uranium-238[f]	3 89	pCi/l	4 400	8 85E 04
VOLATILE ORGANIC COMPOUNDS				
Acetone[d h]	5 90	ug/l	11 200	5 27E 04
Methylene chloride[d h]	3 62	ug/l	2 240	1 62E 03
Vinyl acetate[d h]	15 23	ug/l	21	7 32E 01
SEMIVOLATILE ORGANIC COMPOUNDS				
Bis(2-ethylhexyl)phthalate[d h]	5 55	ug/l	32	1 72E 01
Di n butyl phthalate[g]	5 55	ug/l	2 700	2 06E 03
Hazard Index				**2 95**

EN = Essential Nutrient

Based on dissolved analyte chronic exposure

[b] CWQS Colorado Water Quality Standards

Colorado G-Water Std for RFETS (5 CCR 1002 8 3 12 7)

[d] Oak Ridge Tier II in EPA *Proposed Water Quality Guidance for the Great Lakes System* 1993 as cited in Suter and Mabrey 1994

[e] Based on hardness value of 180 mg/L

[f] Higley and Kuperman 1995

[g] Criteria for Human Health

[h] Based on "total recoverable analysis

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Table D-6
Results of Water and Sediment Toxicity Testing at the OU 7 East Landfill Pond

Whole Effluent Toxicity Tests					
		Fathead Minnows Survivorship		*Ceriodaphia* Survivorship	
Sampling Location	Sample I D	100 % ELP water	0 % ELP water (control)	100 % ELP water	0 % ELP water (control)
SED 70093	SW70041ST	15/20 (75%)	20/20 (100%)	20/20 (100%)	20/20 (100%)
SED 70293	SW70042ST	20/20 (100%)	20/20 (100%)	20/20 (100%)	19/20 (95%)

Sediment Toxicity Tests			
		Hyallela azteca	
Sampling Location	Sample I D	Survivorship (%)	Mean Weight (mg)
SED 70093	SD70000ST	97	0 24
SED 70293	SD70001ST	97	0.29
Sand Control	n/a	87	0 13

Table D 7
Comparison of OU 7 East Landfill Pond Maximum Sediment Concentrations to Sediment Quality Benchmarks

Chemical Species	log K_{oc}	Colorado Water Quality Standard[1] (ug/L)	Interim Sediment Quality Criterion[2] (mg/kg carbon)	Sediment Quality Benchmark[3] (mg/kg)	Maximum Detected Concentration	Maximum Concentration	Detection Frequency	Units
METALS								
Aluminum	NA	NA	not available	—	16600	16600	2/2	mg/kg
Arsenic[4]	NA	NA	not available	8 2	5	5	3/3	mg/kg
Barium[4]	NA	NA	not available	20	215	215	3/3	mg/kg
Beryllium	NA	NA	not available	—	1 5	1 5	3/3	mg/kg
Calcium	NA	NA	not available	EN	7850	7850	2/2	mg/kg
Chromium[4]	NA	NA	not available	81	17 5	17 5	3/3	mg/kg
Copper[4]	NA	NA	not available	34	18 6	18 6	3/3	mg/kg
Iron[4]	NA	NA	not available	30000	15400	15400	2/2	mg/kg
Lead[4]	NA	NA	not available	46 7	33 7	33 7	3/3	mg/kg
Magnesium	NA	NA	not available	—	3250	3250	2/2	mg/kg
Nickel[4]	NA	NA	not available	21	15 3	15 3	3/3	mg/kg
Potassium	NA	NA	not available	EN	2640	2640	2/2	mg/kg
Selenium	NA	NA	not available	—	1 1	1 1	3/3	mg/kg
Sodium	NA	NA	not available	EN	447	447	2/2	mg/kg
Strontium	NA	NA	not available	—	61 5	61 5	2/2	mg/kg
Vanadium	NA	NA	not available	—	41	41	3/3	mg/kg
Zinc[4]	NA	NA	not available	150	187	187	3/3	mg/kg
RADIONUCLIDES								
Cesium 137	NA	NA	not available	—	0 732	0 732	3/3	pCi/g
POLYCYCLIC AROMATIC HYDROCARBONS								
Acenaphthene[5,6]	3 76	520	140	1 18	0 1	0 67	1/3	mg/kg
Anthracene[5]	4 42	0 0028	not available	0 0006	0 16	0 67	1/3	mg/kg
Benzo(a)anthracene[5]	5 6	0 0028	1317	11 06	0 34	0 67	1/3	mg/kg
Benzo(a)pyrene[5]	6	0 0028	1063	8 93	0 32	0 67	1/3	mg/kg
Benzo(b)fluoranthene[7]	5 74	0 0028	not available	0 0129	0 47	0 67	1/3	mg/kg
Benzo(ghi)perylene[7]	6 89	0 0028	not available	0 1826	0 2	0 67	1/3	mg/kg
Benzo(k)fluoranthene[7]	6 64	0 0028	not available	0 1027	0 13	0 67	1/3	mg/kg
Chrysene[7]	5 39	0 0028	not available	0 0058	0 31	0 67	1/3	mg/kg
Fluoranthene[5]	5	42	1020	8 57	0 83	0 83	2/3	mg/kg
Fluorene[7]	3 7	0 0028	not available	0 0001	0 092	0 67	1/3	mg/kg

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Table D-7
Comparison of OU 7 East Landfill Pond Maximum Sediment Concentrations to Sediment Quality Benchmarks

Chemical Species	log K_{oc}	Colorado Water Quality Standard[1] (ug/L)	Interim Sediment Quality Criteron[2] (mg/kg carbon)	Sediment Quality Benchmark[3] (mg/kg)	Maximum Detected Concentration	Maximum Concentration	Detection Frequency	Units
Indeno(1,2 3-cd)pyrene[7]	7 49	0 0028	not available	0 7268	0 18	0 67	1/3	mg/kg
Phenanthrene[5]	4.46	0 0028	123	1 03	0 63	0 67	2/3	mg/kg
Pyrene[7]	4 81	0 0028	1311	10.97	0 75	0.75	2/3	mg/kg
SEMIVOLATILE ORGANIC COMPOUNDS								
Benzoic acid[7]	2.26	NA	not available	—	0.87	0.87	3/3	mg/kg
Bis(2-chloroisopropyl)ether[7]	1 79	not available	not available	—	0.047	0 79	1/3	mg/kg
Bis(2-ethylhexyl)phthalate[5,6]	9 44	32.2	not available	744964	0 08	0 67	1/3	mg/kg
VOLATILE ORGANIC COMPOUNDS								
2-Butanone[7]	0 09	not available	not available	—	0.035	0 035	1/3	mg/kg
Acetone[5,6]	-0.24	11200	not available	0 054	0 13	0 13	2/3	mg/kg
Toluene[5,6]	2 65	176	not available	0 66	0.44	0.44	3/3	mg/kg

[1] Colorado Water Quality Standard based on consumption of water and fish by humans Standard is applied to Big Dry Creek segments 4 and 5 (5 CCR 1002-8 April 1993)

[2] EPA 1988, 1991 Where available, these supercede equilibrium aproach to calculating Sediment Quality Benchmarks

[3] Sediment Quality Benchmarks are calculated for nonionic organic chemicals using the fraction organic carbon Koc, and water-quality standard
Sediment Quality Benchmarks for inorganics are from Hull and Suter (1994)

[4] Benchmark values from Hull and Suter (1994)

[5] Log K_{oc} values are from Hull and Suter (1994)

[6] Water-quality criteria are from Hull and Suter (1994).

[7] Log K_{oc} values are from Knox Sabatini, and Canter (1993).

Calculated an average of 0 84% organic carbon in sediments based on OU 7 data

Definitions

K_{oc} = Organic carbon-water partition coefficient

NA = Not applicable

— Insufficient information to calculate this SQB and Hazard Quotient

EN = Essential nutrient

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Table D-8
Summary of Benthic Macroinvertebrate Sampling from the OU 7 East Landfill Pond

Species	Family	Order	Individuals per m^2 (mean ± sd)[1]			Percent of Total Individuals	Pollution Hardiness Values[2]
Procladius sp	Tanypodinae	Diptera	1520	±	2252	23%	9
Culicoides sp	Ceratopogoninae	Diptera	1040	±	2259	16%	8
unknown	Tubificidae	Oligochaeta	760	±	1369	12%	10
Sphaerium sp	Sphaeriidae	Pelecypoda	424	±	594	6%	8
Hyallela azteca	Gammaridae	Amphipoda	344	±	367	5%	8
unknown	Tubificidae	Oligochaeta	328	±	292	5%	10
Psectrocladius sp	Orthocladiinae	Diptera	320	±	427	5%	8
Dicrotendipes sp	Chironominae	Diptera	304	±	341	5%	8
Limnodrilus hoffmeisteri	Limnodrilidae	Oligochaeta	304	±	636	5%	5
Ablabesmyia sp	Tanypodinae	Diptera	208	±	209	3%	na
Paratanytarsus sp	Chironomidae	Diptera	176	±	236	3%	6
Chironomus sp	Chironomidae	Diptera	96	±	104	≤1%	10
Limnochares sp	Limnocharidae	Hydracarina	96	±	171	≤1%	na
Caenis sp	Caenidae	Ephemeroptera	88	±	91	≤1%	7
Glypotendipes sp	Chironomidae	Diptera	80	±	179	≤1%	6
Parametriocnemus	Chironomidae	Diptera	64	±	104	≤1%	5
Ilyodrilus templetoni	Tubificidae	Oligochaeta	56	±	67	≤1%	10
Chaoborus sp	Chaoboridae	Diptera	48	±	52	≤1%	na
unknown pupa	Chironomidae	Diptera	48	±	87	≤1%	6
unknown	Glossophonidae	Rhynchobdellida	40	±	89	≤1%	8
unknown	Tabanidae	Diptera	40	±	40	≤1%	8
Ceratopogon sp	Ceratopogoninae	Diptera	32	±	72	≤1%	6
Enallagma sp	Coenagrionidae	Odonata	32	±	52	≤1%	9
Erpobdella punctata	Erpobdellidae	Pharyngobdellida	32	±	44	≤1%	8
unknown	Hydracarina	Hydracarina	32	±	52	≤1%	na
unknown	Orthocladiinae	Diptera	32	±	72	≤1%	6
Bezzia sp	Ceratopogoninae	Diptera	16	±	36	≤1%	6
Eukiefferiella sp	Orthocladiinae	Diptera	16	±	36	≤1%	8
Hydroporos sp	Dytiscidae	Coleoptera	8	±	18	≤1%	5
Peltodytes	Haliplidae	Coleoptera	8	±	18	≤1%	7
Physella sp	Physidae	Limnophila	8	±	18	≤1%	8
		MeanTotal Individials =	**6600**				

[1] mean ± standard deviation of 5 samples data extrapolated to number per square meter from counts in individual samples

[2] pollution hardiness values from IDEQ (1993) ranked on scale of 1 to 10 1 is most sensitive 11 is unknown

Definition

na = not available

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Table D-9

Tier 3 Exposure Screening for PCOCs in Surface Water at the OU 7 East Landfill Pond

PCOC	Exposure Point Concentration: UCL_{95} of Mean[a]	Exposure Point Concentration: Units	Raccoon: C_w[b]	Raccoon: Hazard Quotient	Mallard: C_w[b]	Mallard: Hazard Quotient	Mule Deer: C_w[c]	Mule Deer: Hazard Quotient	Coyote: C_w[c]	Coyote: Hazard Quotient	Preble's Meadow Jumping Mouse: C_w[c]	Preble's Meadow Jumping Mouse: Hazard Quotient
METALS												
Arsenic	0.0025	mg/L	0.40	6.25E-03	5.1	4.90E-04	0.40	6.25E-03	0.40	6.25E-03	0.93	2.69E-03
Calcium	43.94	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Lithium	0.067	mg/L	NA	NA	NA	NA	37	2.35E-03	37	2.35E-03	156	8.60E-04
Magnesium	42.4	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Manganese	0.142	mg/L	411	3.45E-04	877	1.62E-04	348	4.08E-04	348	4.10E-04	1458	9.74E-05
Molybdenum	0.058	mg/L	3.49	1.60E-02	3.49	1.60E-02	253	2.21E-04	3.49	1.60E-02	3.49	1.60E-02
Nickel	0.012	mg/L	10	1.20E-03	11	1.09E-03	158	7.59E-05	157	7.64E-05	663	1.81E-05
Potassium	9.43	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Sodium	173.95	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Strontium	0.518	mg/L	1227	4.22E-04	117	4.43E-03	1040	4.98E-04	1035	5.00E-04	4358	1.19E-04
Thallium	0.0034	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tin	0.098	mg/L	115.79	8.46E-04	NA	NA	97.33	1.01E-03	97.64	1.00E-03	418	2.34E-04
RADIONUCLIDES					Same as Raccoon							
Americium-241	0.0109	pCi/l	1300	8.38E-06								
Strontium-89,90	1.86	pCi/l	7.00E+05	2.66E-06								
Tritium	166.11	pCi/l	1.90E+08	8.74E-07								
Uranium-235	0.163	pCi/l	4300	3.79E-06								
Uranium-238	1.36	pCi/l	4400	3.09E-04								
VOLATILE ORGANIC COMPOUNDS												
Acetone	0.0059	mg/L	44	1.34E-04	1094	5.39E-06	40	1.48E-04	40	1.48E-04	166	3.55E-05
Methylene chloride	0.004	mg/L	15	2.67E-04	2	2.09E-03	23	1.74E-04	23	1.74E-04	97	4.12E-05
Vinyl acetate	0.015	mg/L	463.18	3.24E-05	NA	NA	369.32	3.85E-05	390.55	3.84E-05	1671	8.98E-06
SEMIVOLATILE ORGANIC COMPOUNDS												
Bis(2-ethylhexyl)phthalate	0.0056	mg/L	0.02	2.80E-01	0.00091	6.15E+00	32	1.75E-04	32	1.75E-04	135	4.15E-05
Di-n-butyl phthalate	0.0056	mg/L	8	7.00E-04	0.0011	5.06E+00	988	5.80E-06	982	5.82E-06	2069	2.68E-06
Hazard Index				8.31		11.27		0.012		0.03		0.02

[a] Concentration based on analysis of total recoverable chemical concentration

[b] C_w includes assumption of bioconcentration of contaminants in aquatic food items

[c] C_w based on ingestion of surface water only

Definitions:

EN = Essential Nutrient

NA = Data Not Available

Shading indicates that the background intake is greater than the NOAEL. In these cases, the background intake is used as the benchmark.

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Table D-10
Tier 3 Exposure Screening for PCOCs in Seep Water at the OU 7 East Landfill Pond

			Receptor									
			Raccoon		Mallard		Mule Deer		Coyote		Preble s Meadow Jumping Mouse	
PCOC	UCL_{95} of Mean	Units	C_w[a]	Hazard Quotient	C_w[a]	Hazard Quotient	C_w[b]	Hazard Quotient	C_w[b]	Hazard Quotient	C_w[b]	Hazard Quotient
METALS												
Antimony	0 0275	mg/L	6 42	4 28E-03	NA	NA	6 42	4 28E-03	6 42	4 28E 03	6 42	4 28E-03
Barium	0 743	mg/L	25 4	2 93E 02	175	4 25E-03	21 5	3 46E-02	21 4	3 47E-02	90	8 26E 03
Calcium	161	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Iron	90	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Lithium	0 055	mg/L	43 8	1 26E 03	NA	NA	37	1 49E-03	37	1 49E-03	156	3 53E-04
Magnesium	37 1	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Manganese	1 73	mg/L	410 73	4 21E 03	877 27	1 97E 03	347 87	4 97E 03	346 33	5 00E 03	1458	1 19E-03
Potassium	7 24	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Silicon	12 56	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	76 74	mg/L	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Strontium	1 01	mg/L	1227 5	8 23E-04	117 35	8 61E 03	1039 7	9 71E-04	1035	9 76E 04	4358	2 32E-04
Zinc	4 25	mg/L	746 79	5 69E 03	53 45	7 95E-02	632 5	6 72E 03	629 69	6 75E-03	2652	1 60E-03
RADIONUCLIDES												
Strontium 89 90	2 01	pCi/L	7 00E+05	2 87E 06	Same as Raccoon							
Tritium	506 15	pCi/L	1 90E+08	2 66E 06								
WATER QUALITY PARAMETERS												
Nitrite	0 0417	mg/L	4 87	8 56E 03	0 939	4 44E 02	2 251	1 85E 02	3 969	1 05E-02	1084	3 85E-05
VOLATILE ORGANIC COMPOUNDS												
1 1 Dichloroethane	0 0072	mg/L	463 1780015	1 55E-05	19 29	3 73E-04	389 317867	1 85E-05	390 546758	1 84E-05	1671	4 31E-06
1 2 Dichloroethene	0 00495	mg/L	19 94	2 48E 04	NA	NA	29 21	1 69E-04	29 3	1 69E 04	125 4	3 95E 05
2 Butanone	0 019	mg/L	7120 94	2 67E-06	NA	NA	6894 82	2 76E-06	6916 58	2 75E-06	29594	6 42E-07
2 Hexanone[d]	0 0057	mg/L	7120 94	8 00E-07	NA	NA	6894 82	8 27E-07	6916 58	8 24E-07	29594	1 93E-07
4-Methyl 2 pentanone	0 0185	mg/L	66 04	2 80E 04	NA	NA	98 83	1 87E-04	98 39	1 88E 04	414	4 47E-05
Acetone	0 0529	mg/L	43 89	1 21E 03	1093 73	4 84E 05	39 53	1 34E-03	39 35	1 34E-03	166	3 19E-04
Benzene	0 0021	mg/L	10 99	1 91E-04	5 84	3 60E-04	46 32	4 53E-05	46 12	4 55E-05	194	1 08E-05
Carbon disulfide	0 003	mg/L	NA	NA	NA	NA	42 82	7 01E-05	42 96	6 98E 05	184	1 63E-05
Chloroethane	0 0271	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloromethane	0 0053	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	0 0144	mg/L	NA	NA	NA	NA	529 47	2 72E-05	531 14	2 71E-05	2273	6 34E-06
Methylene chloride	0 029	mg/L	14 73	1 97E-03	2 29	1 27E-02	23 13	1 25E-03	23 02	1 26E-03	97	2 99E-04
Tetrachloroethene	0 0025	mg/L	0 76	3 29E-03	0 12	2 08E-02	24 05	1 04E-04	24 13	1 04E-04	103	2 43E-05
Toluene	0 0476	mg/L	4 36	1 09E-02	1 1	4 33E-02	45 65	1 04E-03	45 45	1 05E-03	192	2 48E-04
Total Xylenes	0 0168	mg/L	0 16	1 05E-01	12 8	1 31E-03	3 62	4 64E-03	3 6	4 67E-03	15 2	1 11E-03
Trichloroethene	0 0024	mg/L	39 47	6 08E-05	0 53	4 53E-03	252 38	9 51E-06	253 18	9 48E-06	1083	2 22E-06
Vinyl acetate	0 0113	mg/L	463 18	2 44E-05	1671 02	6 76E-06	389 32	2 90E-05	390 55	2 89E-05	1671	6 76E-06
Vinyl chloride	0 0059	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table D-10

Tier 3 Exposure Screening for PCOCs in Seep Water at the OU 7 East Landfill Pond

PCOC	UCL95 of Mean	Units	Raccoon C_w [1]	Raccoon Hazard Quotient	Mallard C_w [1]	Mallard Hazard Quotient	Mule Deer C_w [2]	Mule Deer Hazard Quotient	Coyote C_w [2]	Coyote Hazard Quotient	Preble s Meadow Jumping Mouse C_w [2]	Preble s Meadow Jumping Mouse Hazard Quotient
SEMIVOLATILE ORGANIC COMPOUNDS												
2 4-Dimethylphenol	0 0055	mg/L	102 19	5.38E-05	368 69	1 49E-05	85 9	6 40E-05	88 17	6 38E-05	389	1 49E-05
2-Methylnaphthalene	0 0199	mg/L	0.02	9 95E-01	0 001	1 99E+01	1756.47	1 13E-05	0 016	1 24E+00	7368	2 70E-06
4-Methylphenol	0 005	mg/L	255 8	1 95E-05	NA	NA	881.39	8.80E-06	884 1	5 79E-06	3897	1.35E-06
Acenaphthene	0.0032	mg/L	17.58	1.82E-04	5 41	5.91E-04	300.64	1.06E-05	301 59	1.06E-05	1290	2.48E-06
Bis (2-ethylhexyl)phthalate	0 0061	mg/L	0.021	2.90E-01	0 000908	6.72E+00	32 21	1.[illegible]E-04	32 07	1 90E-04	135	4 52E-05
Dibenzofuran	0 0019	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl phthalate	0.0041	mg/L	1157 99	3 54E-06	22 93	1 79E-04	8083 76	5 09E-07	8017 98	5 11E-07	2598	1 58E-06
Fluorene	0.0029	mg/L	4.97	5 84E-04	0 021	1.38E-01	214 74	1 36E-05	215.42	1 35E-05	922	3 15E-06
Naphthalene	0.0213	mg/L	0 02	1.07E+00	0 001	2.13E+01	1756.47	1.21E-05	0 016	1 33E+00	7368	2.89E-06
Phenanthrene	0.0049	mg/L	21 83	2.27E-04	0 0011	4.45E+00	1756.47	2.79E-06	0 016	3.08E-01	7368	6.85E-07
Hazard Index				2.53		62.73		0 08		2.96		0 02

Based on PCOC List of Total Analytes

[a] C_w includes assumption of bioconcentration of contaminants in aquatic food items

[b] C_w based on ingestion of surface water only

[c] 1 2 Dichloroethane C_w values used for mallard

[d] 2-Butanone C_w values used

Definitions:

EN = Essential Nutrient

NA = Data Not Available

Shading indicates that the benchmark C_w is background intake not NOAEL based

Table D 11

Tier 3 Exposure Screening for PCOCs in Sediment at the OU 7 East Landfill Pond

	Exposure Point Concentration		Receptor									
			Vegetation		Raccoon				Mallard			
PCOC	Maximum Detected Conc	Units	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient
METALS												
Aluminum	16600	mg/kg	6 96E+03	2 39E+00	0 0045	7 47E+01	3 13E+01	2 39E+00	0 0014	2 32E+01	5 74E+01	4 05E 01
Arsenic	5	mg/kg	1 00E+01	5 00E-01	0 0045	2 25E-02	2 10E-02	1 07E+00	0 0014	7 00E-03	5 13E+00	1 36E-03
Barium	215	mg/kg	5 00E+02	4 30E 01	0 0045	9 68E-01	2 03E+00	4 77E 01	0 0014	3 01E-01	9 90E+00	3 04E-02
Beryllium	1 5	mg/kg	1 00E+01	1 50E-01	0 0045	6 75E-03	2 50E 01	2 70E-02	0 0014	2 10E 03	NA	NA
Calcium	7850	mg/kg	EN	EN	0 0045	3 53E+01	EN	EN	0 0014	1 10E+01	EN	EN
Chromium	17 5	mg/kg	9 75E+00	1 79E+00	0 0045	7 88E-02	1 02E+03	7 71E-05	0 0014	2 45E-02	1 03E+00	2 38E 02
Copper	18 6	mg/kg	1 00E+02	1 86E-01	0 0045	8 37E-02	6 18E+00	1 35E-02	0 0014	2 60E 02	1 58E+01	1 65E-03
Iron	15400	mg/kg	EN	EN	0 0045	6 93E+01	EN	EN	0 0014	2 16E+01	EN	EN
Lead	33 7	mg/kg	5 00E+01	6 74E-01	0 0045	1 52E-01	2 99E+00	5 07E-02	0 0014	4 72E-02	1 80E+00	2 62E 02
Magnesium	3250	mg/kg	EN	EN	0 0045	1 46E+01	EN	EN	0 0014	4 55E+00	EN	EN
Nickel	15 3	mg/kg	3 00E+01	5 10E 01	0 0045	6 89E-02	1 50E+01	4 59E-03	0 0014	2 14E-02	6 84E+01	3 13E-04
Potassium	2640	mg/kg	EN	EN	0 0045	1 19E+01	EN	EN	0 0014	3 70E+00	EN	EN
Selenium	1 1	mg/kg	1 00E+00	1 10E+00	0 0045	4 95E-03	1 20E 02	4 13E-01	0 0014	1 54E-03	3 80E-01	4 05E-03
Sodium	447	mg/kg	EN	EN	0 0045	2 01E+00	EN	EN	0 0014	6 26E-01	EN	EN
Strontium	61 5	mg/kg	NA	NA	0 0045	2 77E-01	9 80E+01	2 82E-03	0 0014	8 61E 02	6 62E+00	1 30E-02
Vanadium	41	mg/kg	2 16E+01	1 90E+00	0 0045	1 85E-01	9 72E-02	1 90E+00	0 0014	5 74E-02	2 90E 01	1 98E-01
Zinc	187	mg/kg	7 19E+01	2 60E+00	0 0045	8 42E-01	5 97E+01	1 41E-02	0 0014	2 62E 01	3 02E+00	8 67E-02
RADIONUCLIDES												
Cesium-137[2]	0 732	pCi/g	8 40E+01	NA	0 0045	3 29E-03	8 40E+01	3 92E-05	0 0014	1 02E-03	8 40E+01	1 22E-05
VOLATILE ORGANIC COMPOUNDS												
2 Butanone	0 035	mg/kg	NA	NA	0 0045	1 58E-04	6 56E+02	2 40E-07	0 0014	4 90E 05	NA	NA
Toluene	0 44	mg/kg	2 00E+05	2 20E-06	0 0045	1 98E-03	4 31E+00	4 59E-04	0 0014	6 16E-04	4 39E+00	1 40E-04
SEMIVOLATILE ORGANIC COMPOUNDS												
Acenaphthene	0 10	mg/kg	5 00E+03	2 00E-05	0 0045	4 50E-04	2 86E+01	1 57E-05	0 0014	1 40E-04	3 63E+01	3 85E 06
Acetone	0 13	mg/kg	NA	NA	0 0045	5 85E-04	NA	NA	0 0014	1 82E 04	NA	NA
Anthracene	0 16	mg/kg	1 00E+01	1 60E 02	0 0045	7 20E-04	1 64E+02	4 40E-06	0 0014	2 24E-04	3 40E-01	6 59E-04
Benzo(a)anthracene	0 34	mg/kg	NA	NA	0 0045	1 53E-03	1 66E+00	9 22E-04	0 0014	4 76E-04	3 60E-01	1 32E 03
Benzo(a)pyrene	0 32	mg/kg	NA	NA	0 0045	1 44E-03	1 70E-01	8 47E-03	0 0014	4 48E-04	3 40E 01	1 32E-03
Benzo(b)fluoranthene	0 47	mg/kg	NA	NA	0 0045	2 12E-03	1 66E+00	1 27E-03	0 0014	6 58E-04	3 60E-01	1 83E 03
Benzo(k)fluoranthene	0 20	mg/kg	NA	NA	0 0045	9 00E-04	1 66E+00	5 42E-04	0 0014	2 80E 04	0 04	7 00E 03
Benzo(ghi)perylene	0 13	mg/kg	NA	NA	0 0045	5 85E-04	1 66E+01	3 53E-05	0 0014	1 82E 04	3 60E-01	5 06E 04
Benzoic acid	0 87	mg/kg	NA	NA	0 0045	3 92E-03	NA	NA	0 0014	1 22E 03	NA	NA
Bis(2-chloroisopropyl)ether	0 05	mg/kg	NA	NA	0 0045	2 12E-04	1 03E+01	2 05E-05	0 0014	6 58E-05	NA	NA
Bis(2-ethylhexyl)phthalate	0 08	mg/kg	2 00E+05	4 00E-07	0 0045	3 60E-04	3 04E+00	1 18E-04	0 0014	1 12E-04	5 70E-01	1 96E-04
Chrysene	0 31	mg/kg	NA	NA	0 0045	1 40E-03	1 66E+01	8 42E-05	0 0014	4 34E 04	3 60E 01	1 21E-03
Fluoranthene	0 83	mg/kg	NA	NA	0 0045	3 74E-03	2 04E+01	1 83E-04	0 0014	1 16E-03	3 60E-01	3 23E 03
Fluorene	0 09	mg/kg	NA	NA	0 0045	4 14E-04	2 04E+01	2 03E-05	0 0014	1 29E-04	3 60E-01	3 58E-04
Indeno(1 2 3-cd)pyrene	0 18	mg/kg	NA	NA	0 0045	8 10E-04	1 66E+00	4 88E 04	0 0014	2 52E-04	9 00E 02	2 80E-03
Phenanthrene	0 63	mg/kg	NA	NA	0 0045	2 84E-03	1 66E+02	1 71E 05	0 0014	8 82E-04	4 00E-02	2 21E-02
Pyrene	0 75	mg/kg	NA	NA	0 0045	3 38E-03	1 23E+01	2 75E-04	0 0014	1 05E-03	3 60E-01	2 92E-03
Hazard Index				**12.24**				**6.37**				**0.84**

Definitions
IR = Ingestion Rate
EN = Essential Nutrient
NA = Data Not Available

[1] NOAEL (No Observable Adverse Effects Level) used for benchmark unless UCL_{95} of mean background intake is greater than NOAEL value Background intake values are shaded
[2] Hazard quotient for vegetation was not calculated because no vegetation benchmark is available The sitewide benchmark is for small mammals and is protective of all ecological receptors

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Table D 11
Tier 3 Exposure Screening for PCOCs in Sediment at the OU 7 East Landfill Pond

	Exposure Point Concentration		Receptor											
			Mule Deer				Coyote				Preble's Meadow Jumping Mouse			
PCOC	Maximum Detected Conc.	Units	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	Benchmark[1] (mg/kg bw/dy)	Hazard Quotient
METALS														
Aluminum	16600	mg/kg	0.00023	3.82E+00	1.60E+00	2.39E+00	0.0013	2.16E+01	9.04E+00	2.39E+00	0.00406	6.77E+01	2.84E+01	2.38E+00
Arsenic	5	mg/kg	0.00023	1.15E-03	9.00E-03	1.28E-01	0.0013	6.50E-03	1.70E-02	3.82E-01	0.00406	2.04E-02	1.50E-01	1.36E-01
Barium	215	mg/kg	0.00023	4.95E-02	9.50E-01	5.21E-02	0.0013	2.80E-01	1.66E+00	1.69E-01	0.00406	8.77E-01	1.42E+01	6.17E-02
Beryllium	1.5	mg/kg	0.00023	3.45E-04	1.10E-01	3.14E-03	0.0013	1.95E-03	2.00E-01	9.75E-03	0.00406	6.12E-03	1.73E+00	3.54E-03
Calcium	7850	mg/kg	0.00023	1.81E+00	EN	EN	0.0013	1.02E+01	EN	EN	0.00406	3.20E+01	EN	EN
Chromium	17.5	mg/kg	0.00023	4.03E-03	4.76E+02	8.46E-06	0.0013	2.28E-02	8.33E+02	2.73E-05	0.00406	7.14E-02	7.16E+03	9.97E-06
Copper	18.6	mg/kg	0.00023	4.28E-03	2.88E+00	1.49E-03	0.0013	2.42E-02	5.00E+00	4.84E-03	0.00406	7.55E-02	4.32E+01	1.75E-03
Iron	15400	mg/kg	0.00023	3.54E+00	EN	EN	0.0013	2.00E+01	EN	EN	0.00406	6.25E+01	EN	EN
Lead	33.7	mg/kg	0.00023	7.75E-03	1.39E+00	5.58E-03	0.0013	4.38E-02	2.43E+00	1.80E-02	0.00406	1.37E-01	2.10E+01	6.55E-03
Magnesium	3250	mg/kg	0.00023	7.48E-01	EN	EN	0.0013	4.23E+00	EN	EN	0.00406	1.33E+01	EN	EN
Nickel	15.3	mg/kg	0.00023	3.52E-03	6.96E+00	5.06E-04	0.0013	1.99E-02	1.22E+01	1.63E-03	0.00406	6.24E-02	1.05E+02	5.95E-04
Potassium	2640	mg/kg	0.00023	6.07E-01	EN	EN	0.0013	3.43E+00	EN	EN	0.00406	1.08E+01	EN	EN
Selenium	1.1	mg/kg	0.00023	2.53E-04	6.00E-03	4.22E-02	0.0013	1.43E-03	1.00E-02	1.43E-01	0.00406	4.49E-03	9.00E-02	4.99E-02
Sodium	447	mg/kg	0.00023	1.03E-01	EN	EN	0.0013	5.81E-01	EN	EN	0.00406	1.82E+00	EN	EN
Strontium	61.5	mg/kg	0.00023	1.41E-02	4.57E+01	3.09E-04	0.0013	8.00E-02	8.00E+01	9.99E-04	0.00406	2.51E-01	6.88E+02	3.65E-04
Vanadium	41	mg/kg	0.00023	9.43E-03	3.40E-02	2.77E-01	0.0013	5.33E-02	6.20E-02	8.60E-01	0.00406	1.67E-01	5.00E-01	3.35E-01
Zinc	187	mg/kg	0.00023	4.30E-02	2.78E+01	1.55E-03	0.0013	2.43E-01	4.87E+01	4.99E-03	0.00406	7.63E-01	4.19E+02	1.82E-03
RADIONUCLIDES														
Cesium-137[2]	0.732	pCi/g	0.00023	1.68E-04	8.40E+01	2.00E-06	0.0013	9.52E-04	8.40E+01	1.13E-05	0.00406	2.99E-03	8.40E+01	3.56E-05
VOLATILE ORGANIC COMPOUNDS														
2-Butanone	0.035	mg/kg	0.00023	8.05E-06	3.03E+02	2.65E-08	0.0013	4.55E-05	5.35E+02	8.51E-08	0.00406	1.43E-04	4.67E+03	3.06E-08
Toluene	0.44	mg/kg	0.00023	1.01E-04	2.01E+00	5.03E-05	0.0013	5.72E-04	3.51E+00	1.63E-04	0.00406	1.80E-03	3.02E+02	5.94E-06
SEMIVOLATILE ORGANIC COMPOUNDS														
Acenaphthene	0.10	mg/kg	0.00023	2.30E-05	1.32E+01	1.74E-06	0.0013	1.30E-04	2.32E+01	5.57E-06	0.00406	4.06E-04	2.04E+02	2.00E-06
Acetone	0.13	mg/kg	0.00023	2.99E-05	NA	NA	0.0013	1.69E-04	NA	NA	0.00406	5.30E-04	2.80E+01	NA
Anthracene	0.16	mg/kg	0.00023	3.68E-05	7.56E+01	4.87E-07	0.0013	2.08E-04	1.33E+02	1.56E-06	0.00406	6.53E-04	1.16E+03	5.61E-07
Benzo(a)anthracene	0.34	mg/kg	0.00023	7.82E-05	7.70E-01	1.02E-04	0.0013	4.42E-04	1.35E+00	3.27E-04	0.00406	1.39E-03	1.20E+01	1.16E-04
Benzo(a)pyrene	0.32	mg/kg	0.00023	7.36E-05	8.00E-02	9.20E-04	0.0013	4.16E-04	1.40E-01	2.97E-03	0.00406	1.31E-03	1.20E+00	1.09E-03
Benzo(b)fluoranthene	0.47	mg/kg	0.00023	1.08E-04	7.70E-01	1.40E-04	0.0013	6.11E-04	1.35E+00	4.53E-04	0.00406	1.92E-03	1.20E+01	1.60E-04
Benzo(k)fluoranthene	0.20	mg/kg	0.00023	4.60E-05	7.70E-01	5.97E-05	0.0013	2.60E-04	1.35E+00	1.93E-04	0.00406	8.16E-04	1.20E+01	6.80E-05
Benzo(ghi)perylene	0.13	mg/kg	0.00023	2.99E-05	7.73E+00	3.87E-06	0.0013	1.69E-04	1.35E+01	1.25E-05	0.00406	5.30E-04	1.16E+02	4.57E-06
Benzoic acid	0.87	mg/kg	0.00023	2.00E-04	NA	NA	0.0013	1.13E-03	NA	NA	0.00406	3.55E-03	NA	NA
Bis(2-chloroisopropyl)ether	0.05	mg/kg	0.00023	1.08E-05	6.15E+01	1.76E-07	0.0013	6.11E-05	8.17E+01	5.60E-07	0.00406	1.92E-04	4.20E+01	4.57E-06
Bis(2-ethylhexyl)phthalate	0.08	mg/kg	0.00023	1.84E-05	1.42E+00	1.30E-05	0.0013	1.04E-04	2.48E+00	4.19E-05	0.00406	3.26E-04	2.13E+01	1.53E-05
Chrysene	0.31	mg/kg	0.00023	7.13E-05	7.73E+00	9.22E-06	0.0013	4.03E-04	1.35E+01	2.99E-05	0.00406	1.26E-03	1.16E+02	1.09E-05
Fluoranthene	0.83	mg/kg	0.00023	1.91E-04	9.45E+00	2.02E-05	0.0013	1.08E-03	1.67E+01	6.46E-05	0.00406	3.39E-03	1.46E+02	2.32E-05
Fluorene	0.09	mg/kg	0.00023	2.12E-05	9.45E+00	2.24E-06	0.0013	1.20E-04	1.67E+01	7.18E-06	0.00406	3.75E-04	1.46E+02	2.57E-06
Indeno(1,2,3-cd)pyrene	0.18	mg/kg	0.00023	4.14E-05	7.70E-01	5.38E-05	0.0013	2.34E-04	1.35E+00	1.73E-04	0.00406	7.34E-04	1.20E+01	6.12E-05
Phenanthrene	0.63	mg/kg	0.00023	1.45E-04	7.73E+01	1.88E-06	0.0013	8.19E-04	1.35E+02	6.07E-06	0.00406	2.57E-03	1.16E+03	2.21E-06
Pyrene	0.75	mg/kg	0.00023	1.73E-04	5.67E+00	3.04E-05	0.0013	9.75E-04	1.00E+01	9.75E-05	0.00406	3.06E-03	8.70E+01	3.52E-05
Hazard Index						2.96				3.99				2.96

Definitions
IR = Ingestion Rate
EN = Essenti[illegible]trient
NA = Data [illegible]ilable

[1] NOAEL (No Observable Adverse Effects Level) used for benchmark, unless UCL_{95} of mean background intake is greater than NOAEL value. Background intake values are shaded.
[2] Hazard quotient for vegetation was not calculated becau[illegible] vegetation benchmark is available. The sitewide benchmark is for small mammals and is p[illegible] of all ecological receptors

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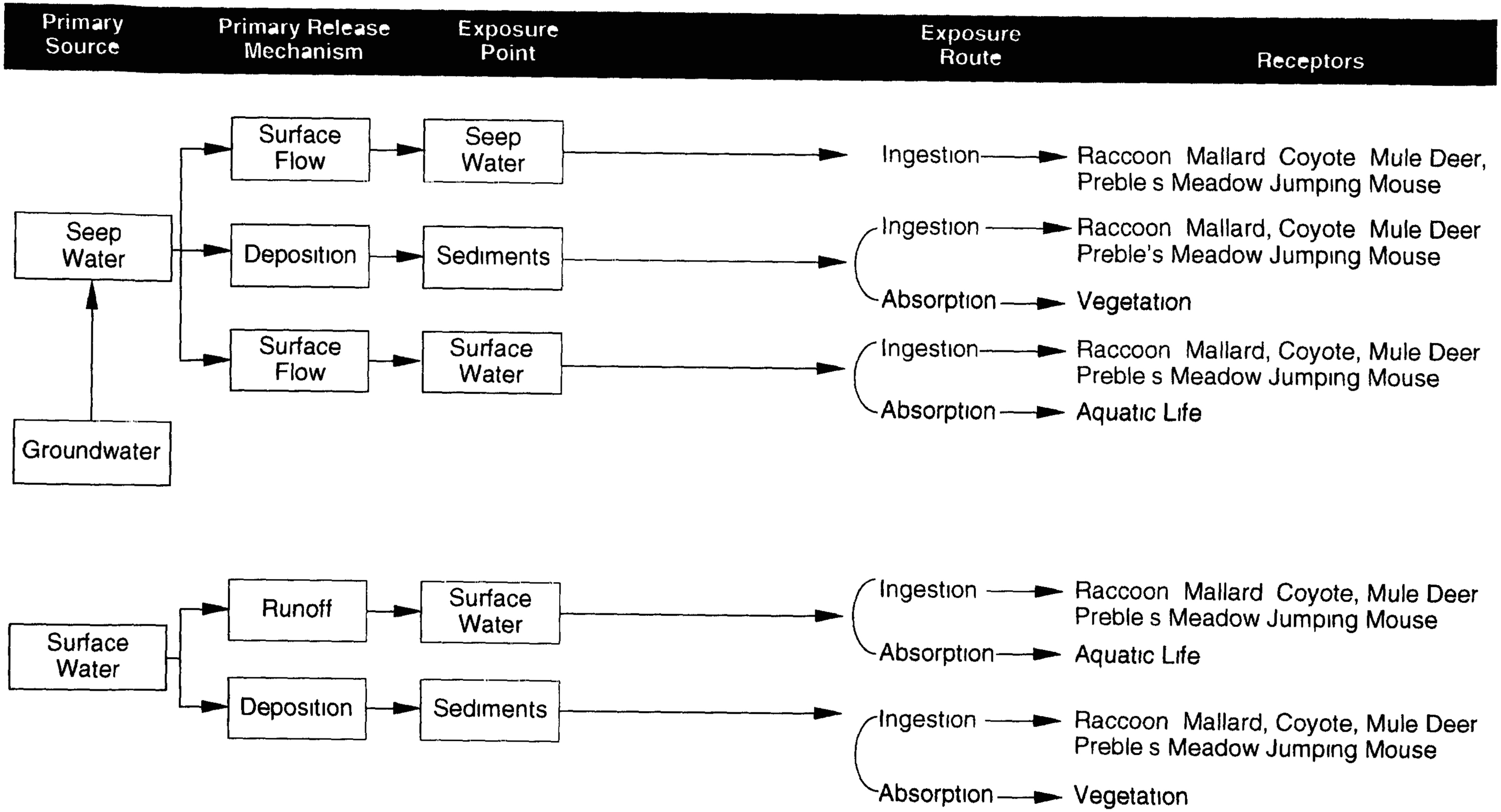

U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden Colorado

OU7 ELP Screening Level Ecological Risk Assessment

Conceptual Exposure Model for
Surface Water and Sediments

July 1995	Figure D-2

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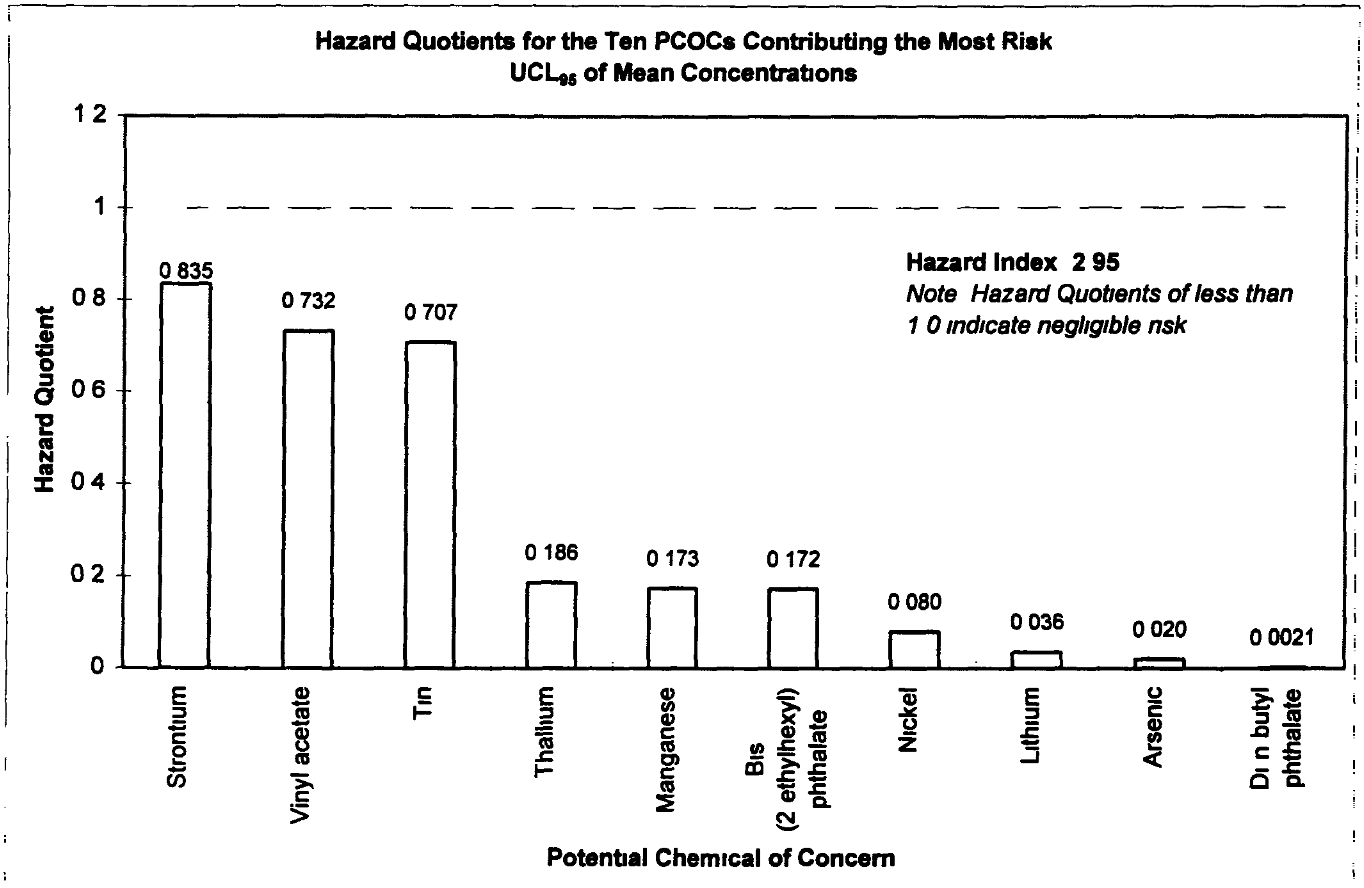
Figure D-3
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Potential Toxicity of Pond Water to Aquatic Life



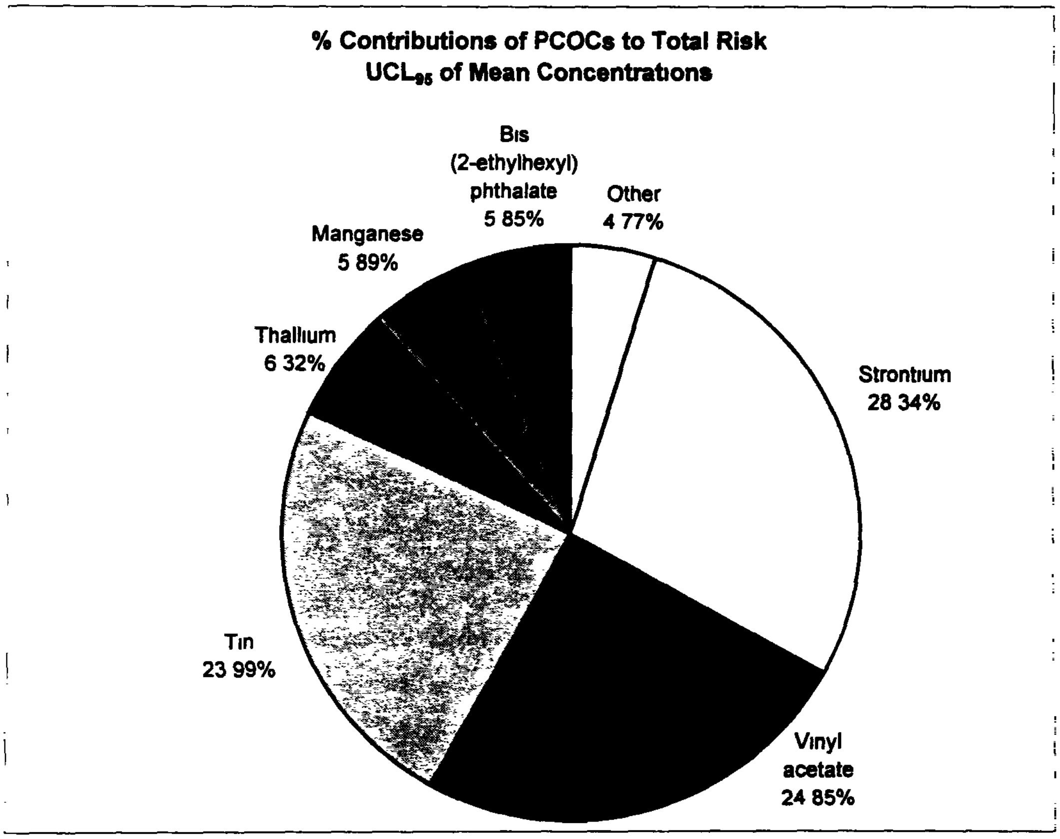


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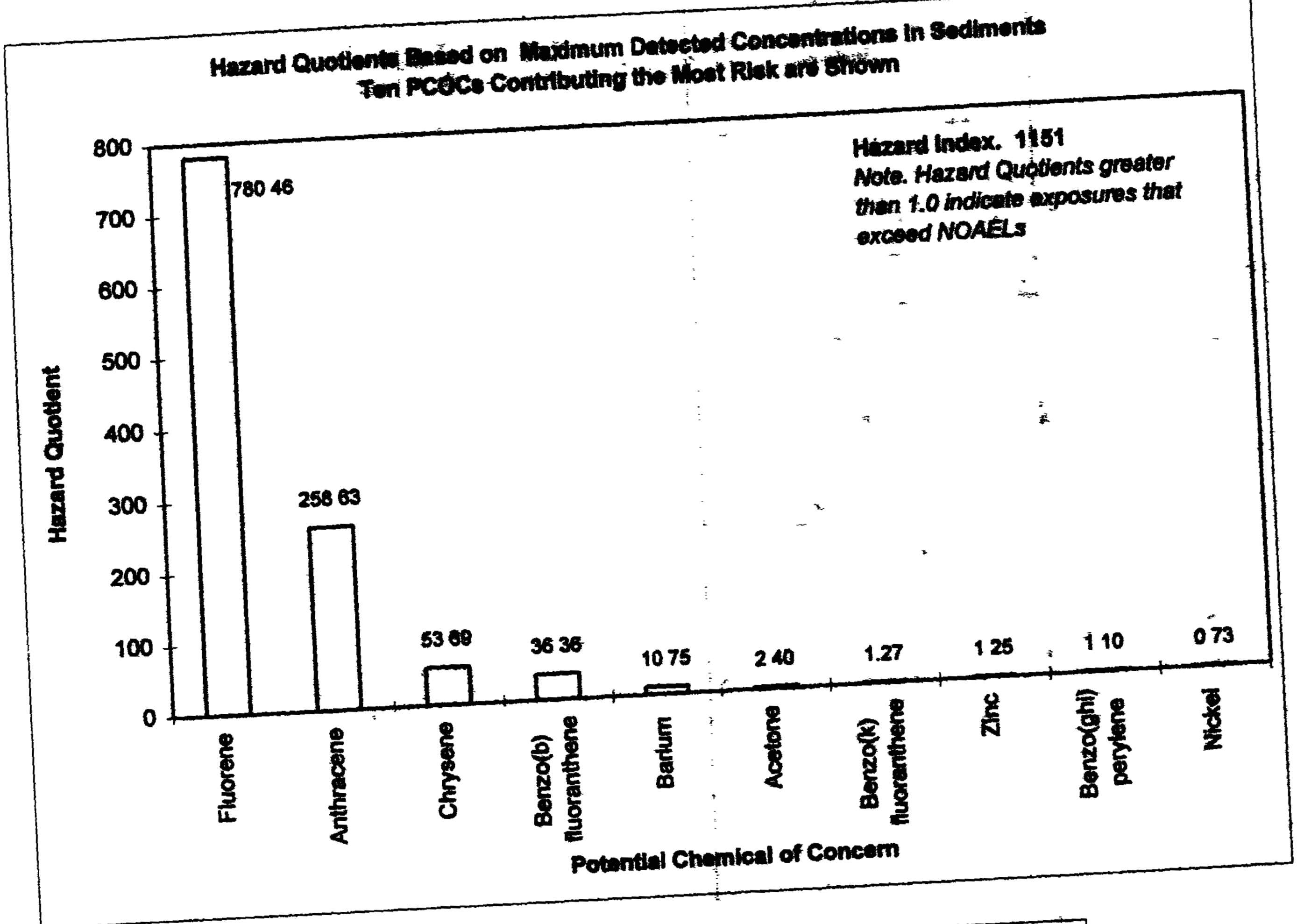
Figure D-4
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Potential Toxicity of Sediments to Aquatic Life



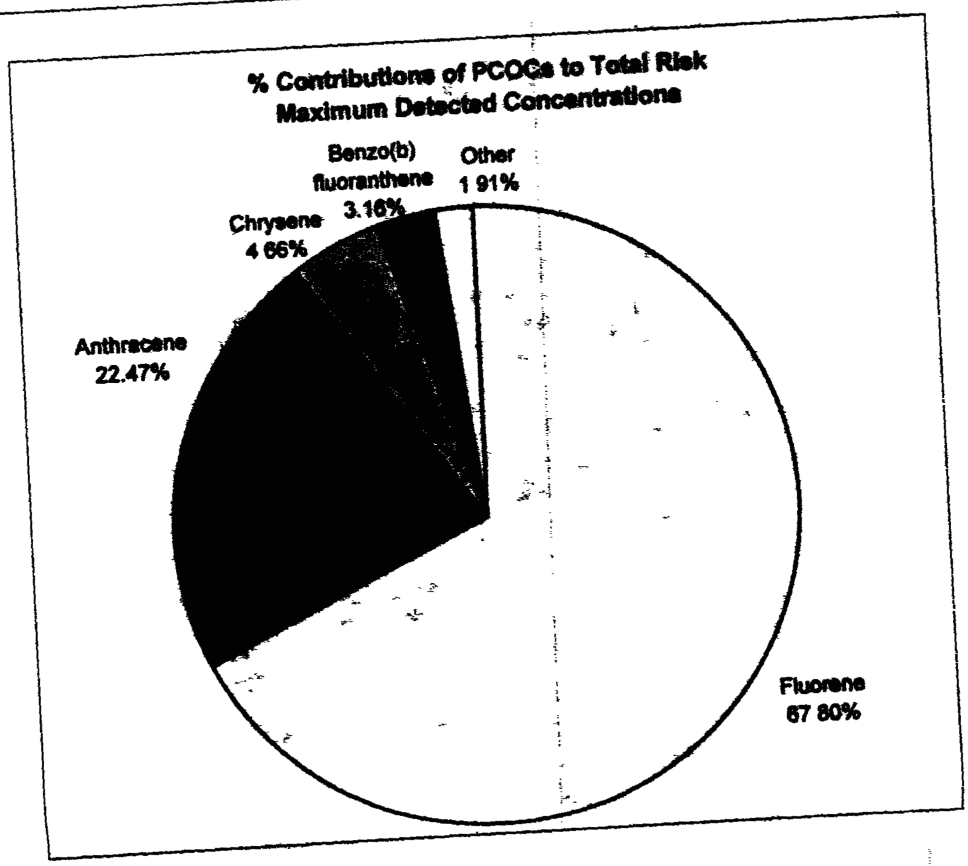


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Figure D-5
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Summary of Risk to Wildlife

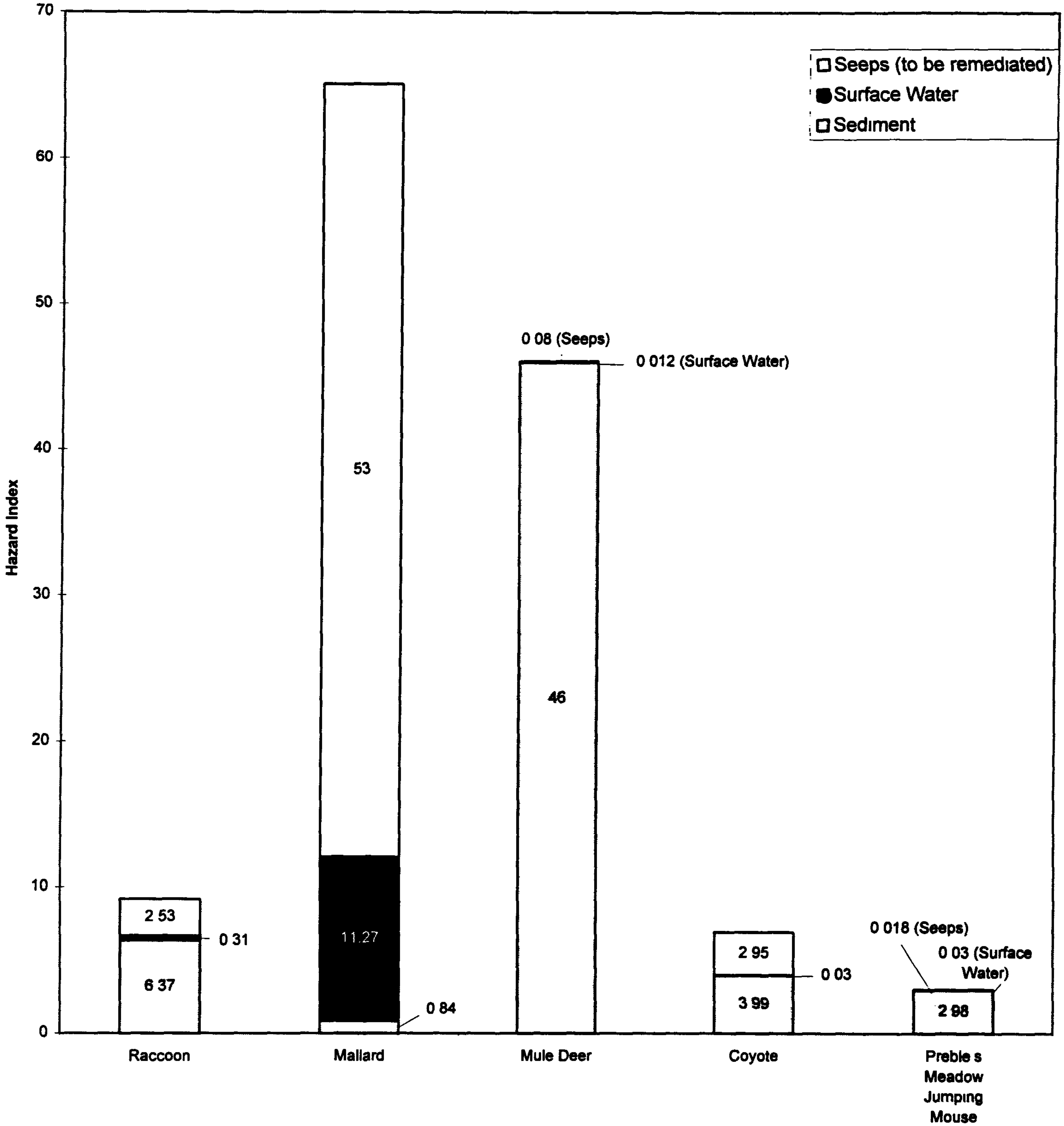

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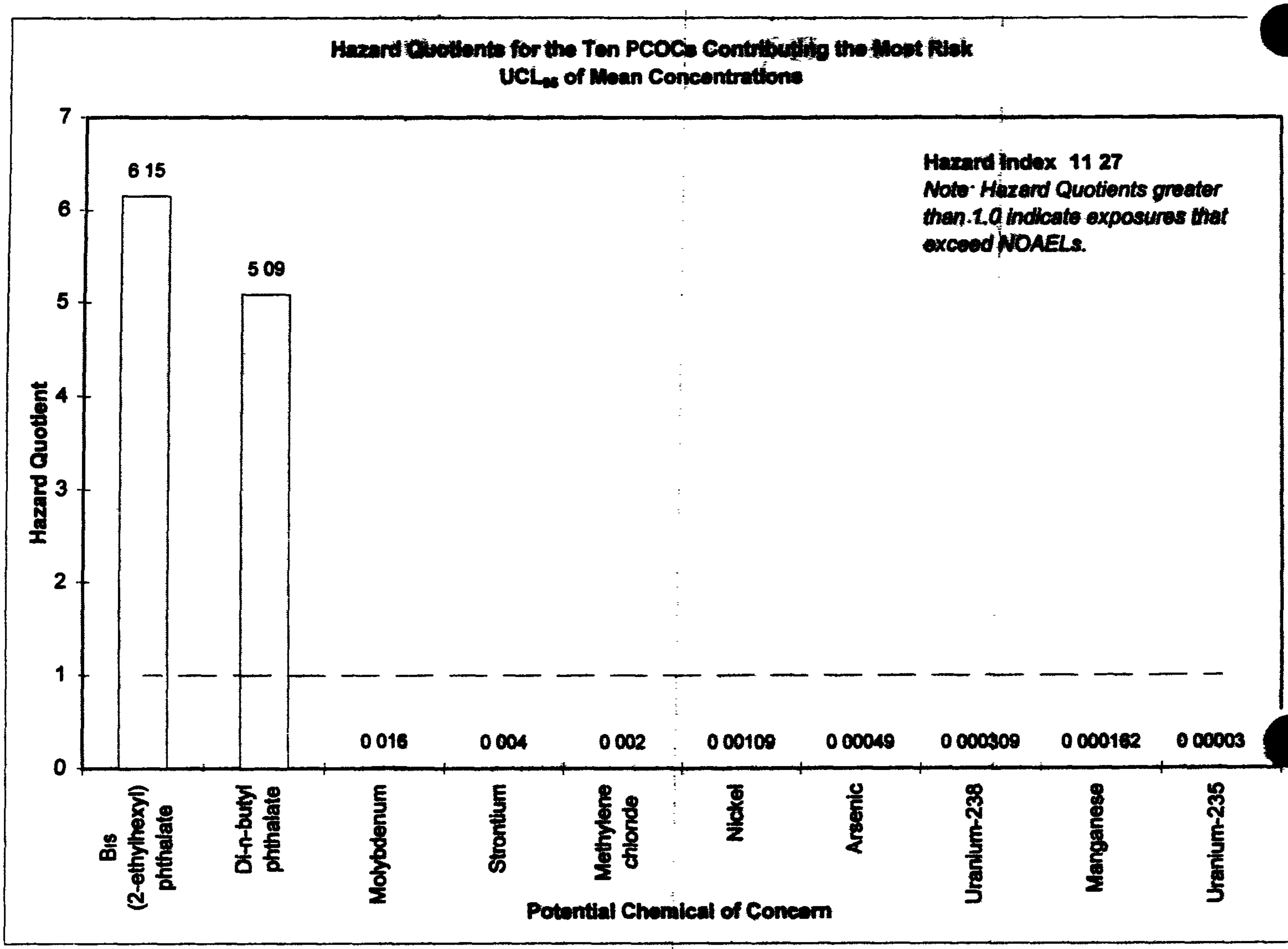
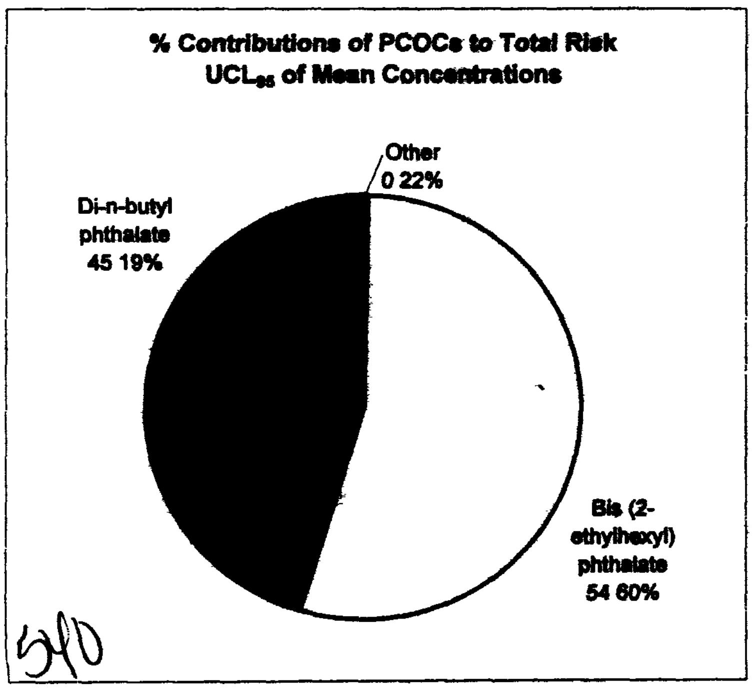
Figure D-6
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mallards - Surface Water





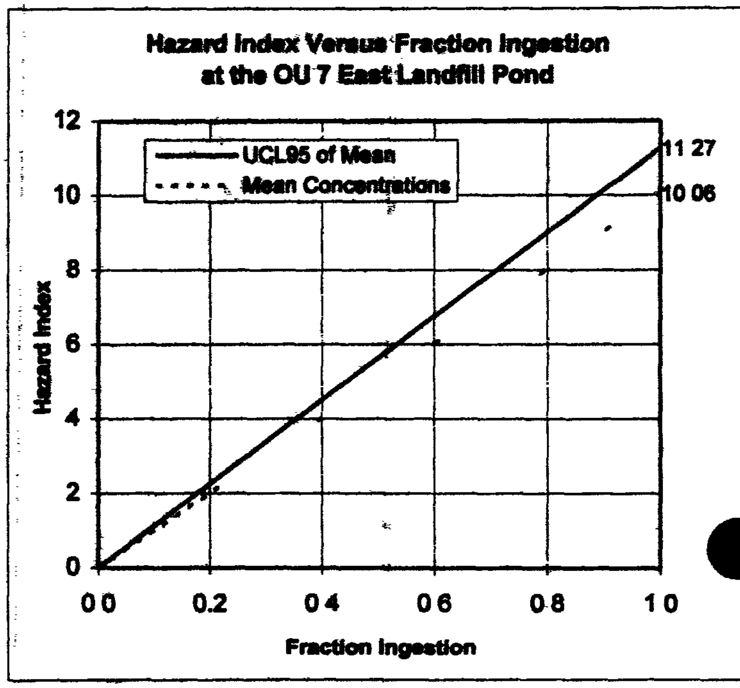


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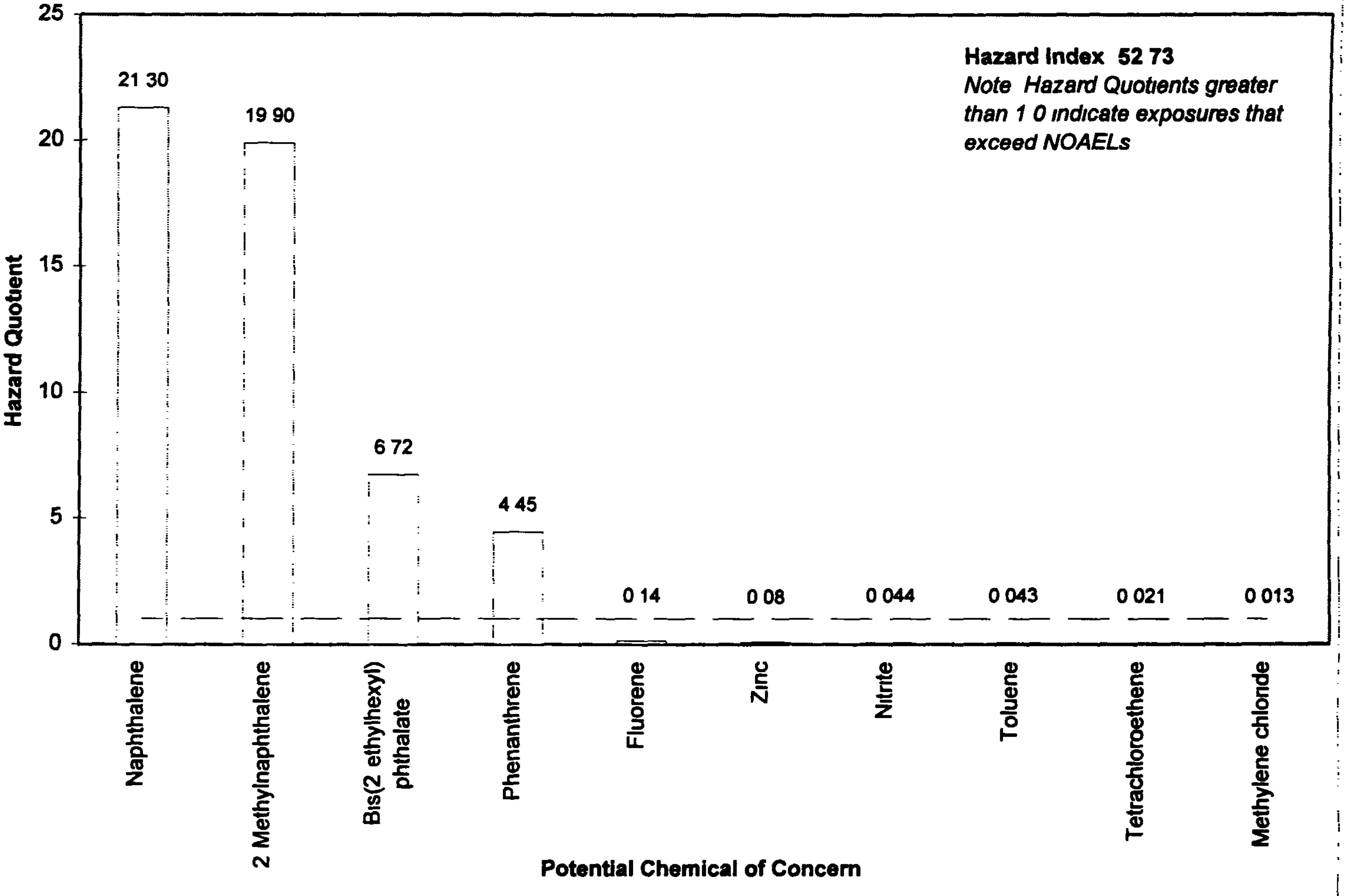
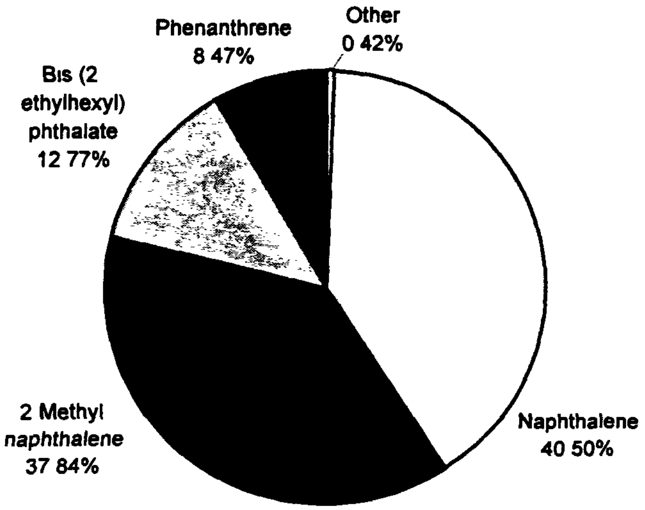
Figure D-7
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mallards - Seep Water

Hazard Quotients for the Ten PCOCs Contributing the Most Risk
UCL$_{95}$ of Mean Concentrations



% Contributions of PCOCs to Total Risk
UCL$_{95}$ of Mean Concentrations



Hazard Index Versus Fraction Ingestion
at the OU 7 East Landfill Pond

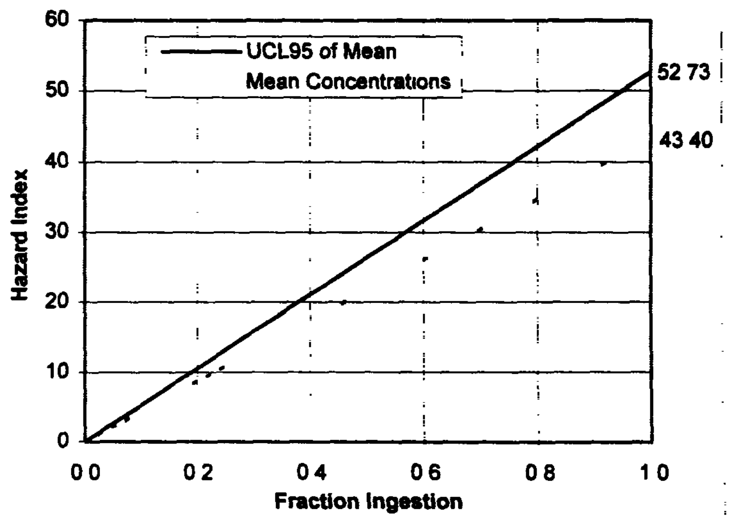


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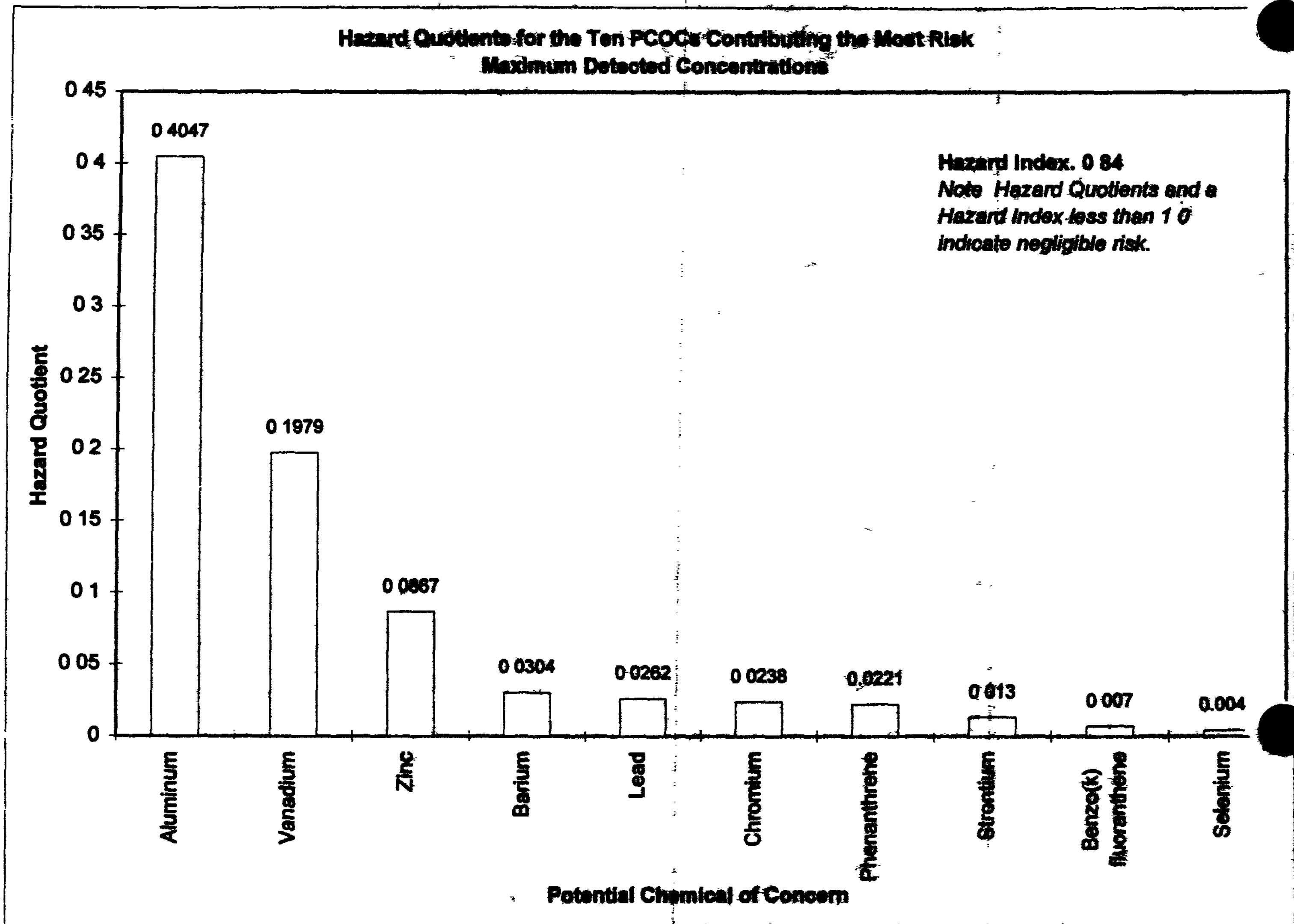
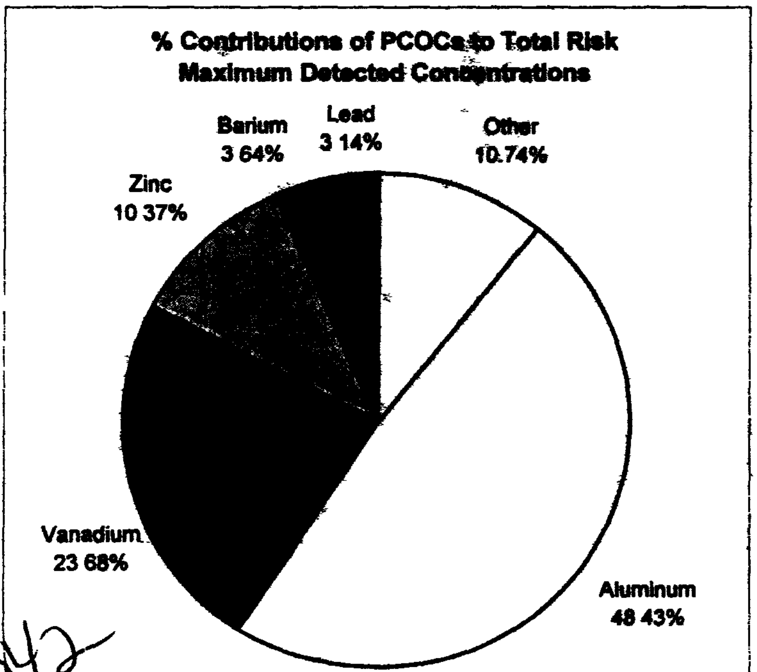
Figure D-8
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mallards - Sediment





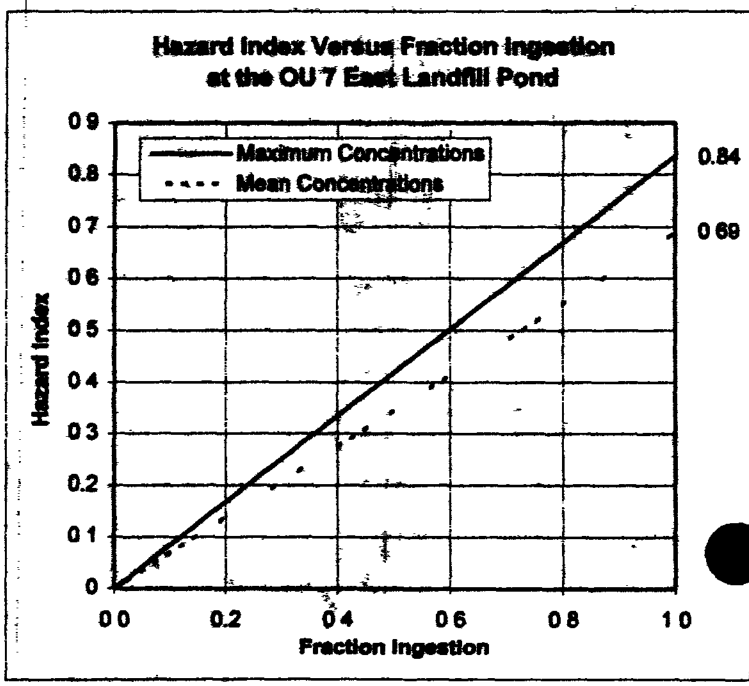


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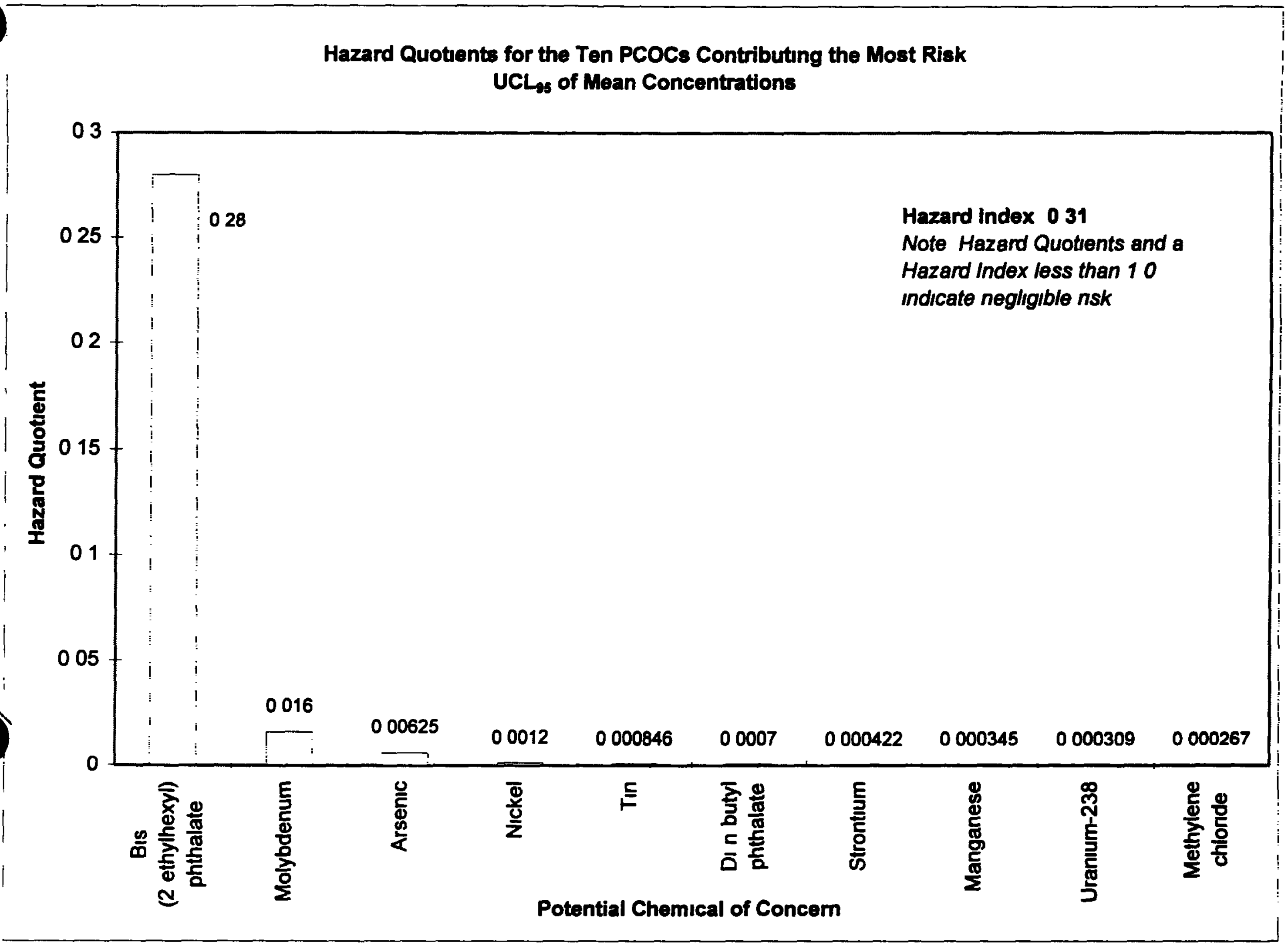
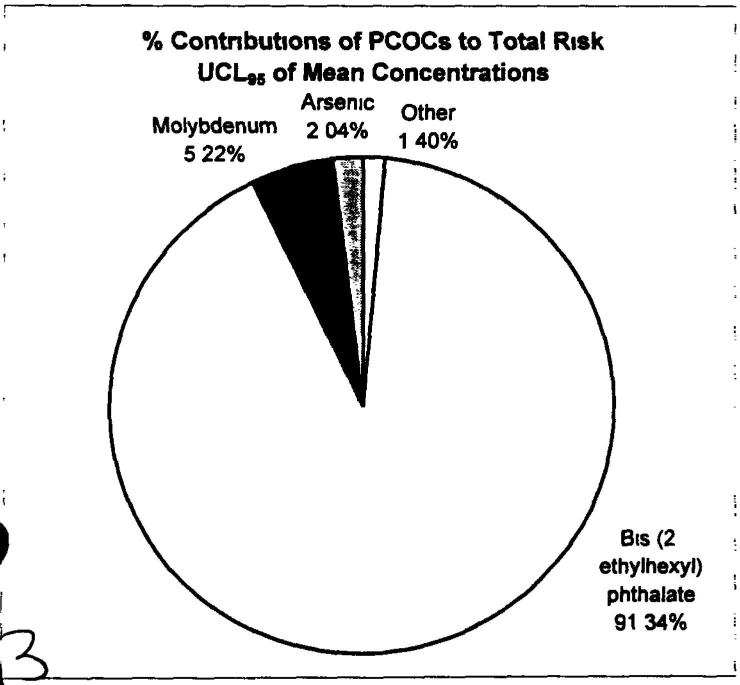
Figure D-9
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Raccoons - Surface Water





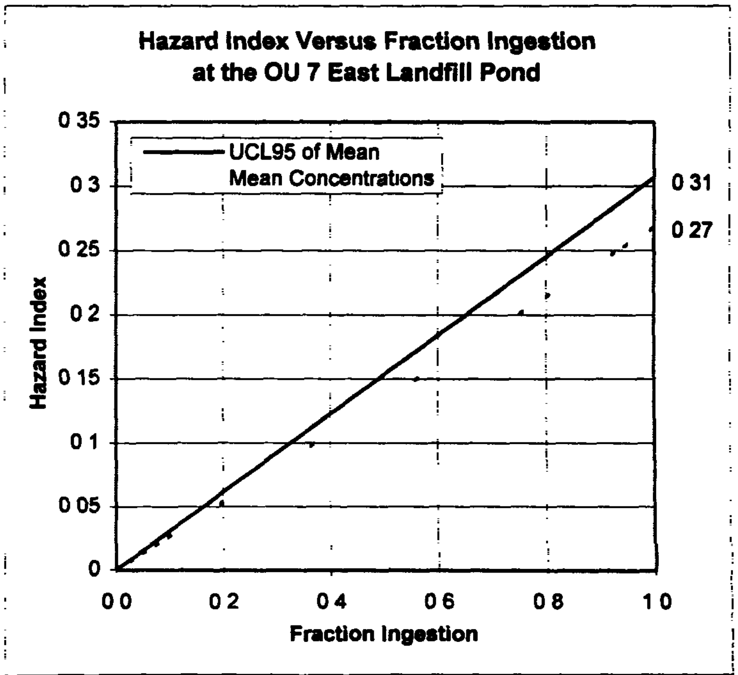


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Figure D-10
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Raccoons - Seep Water

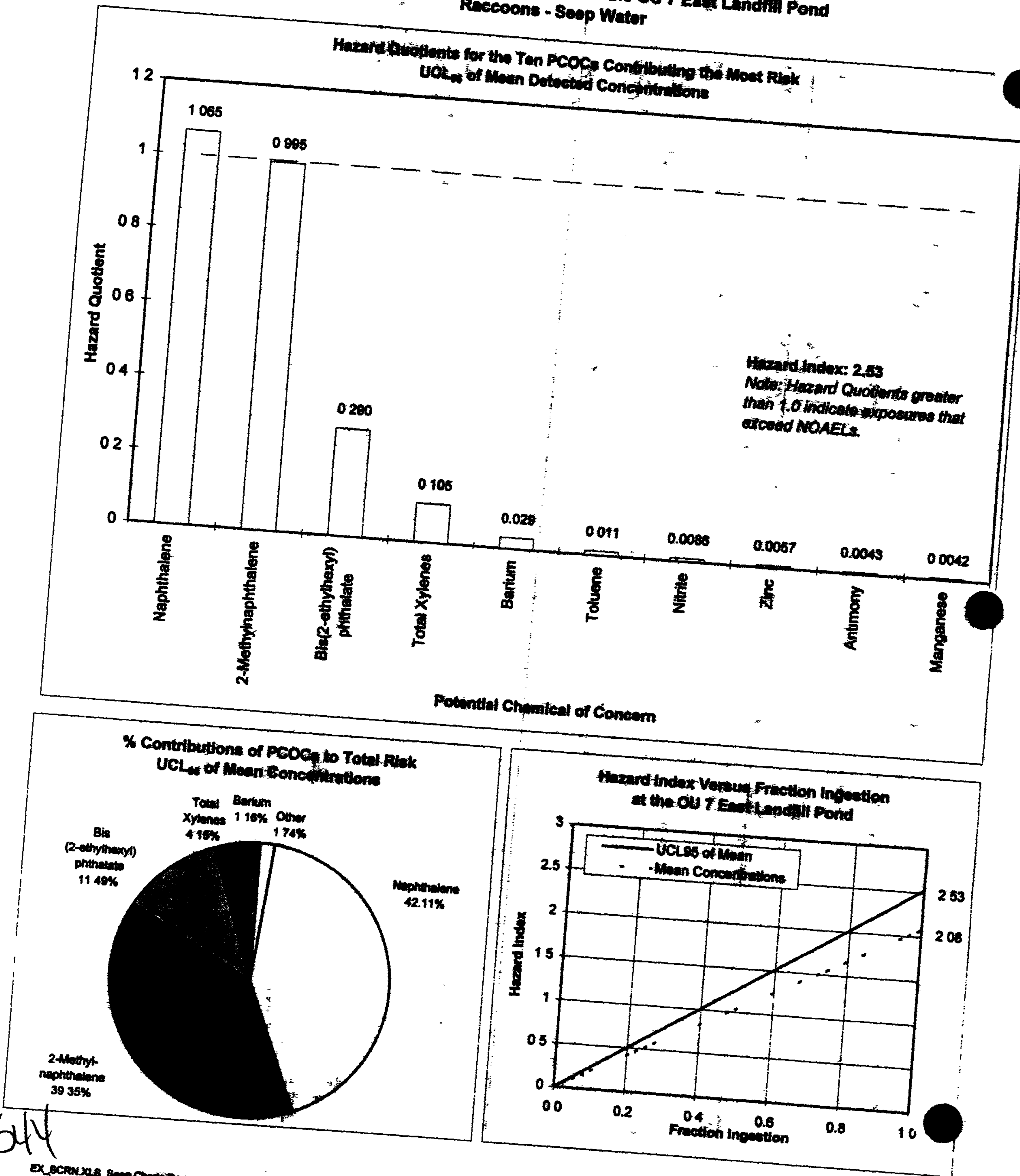

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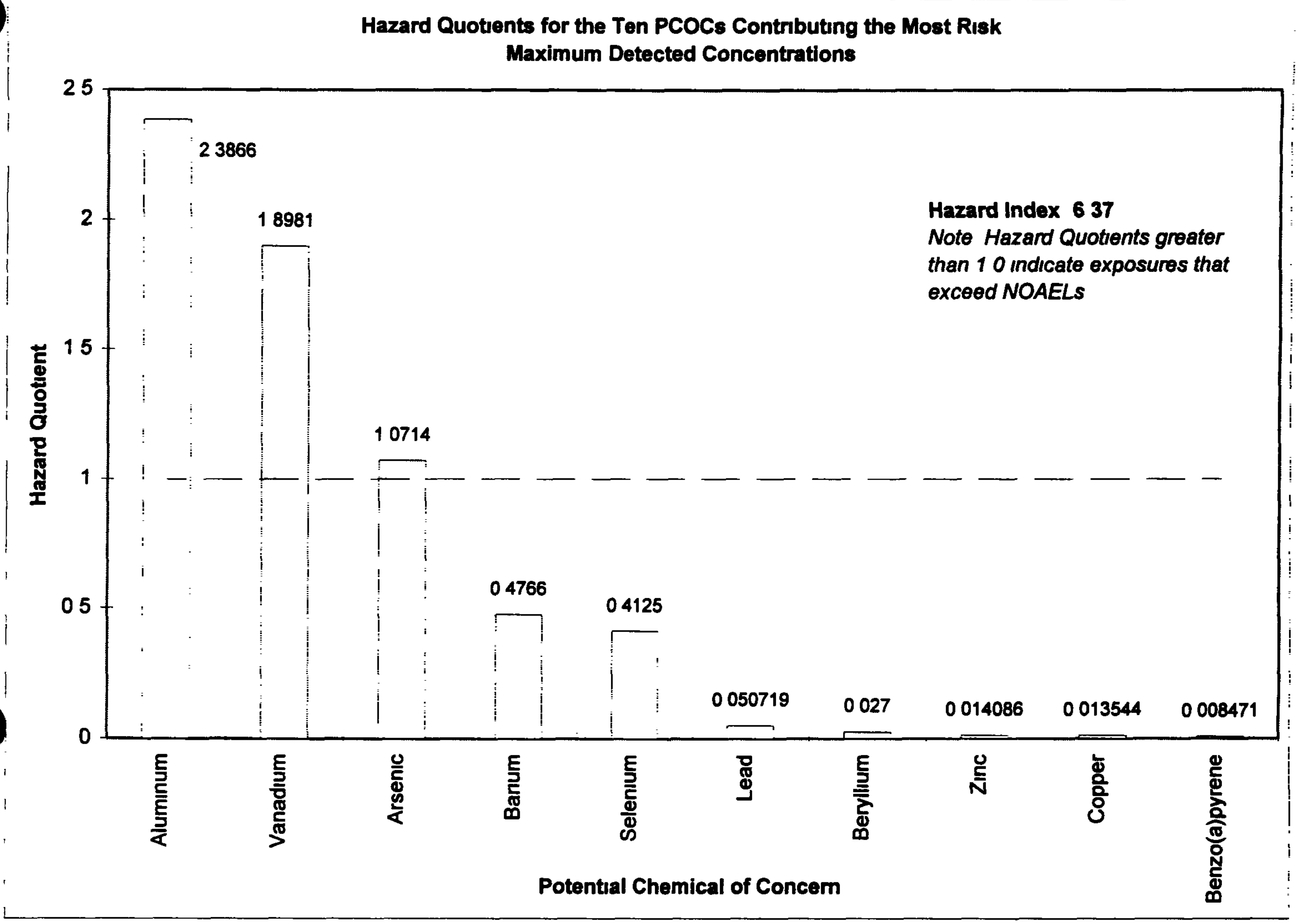
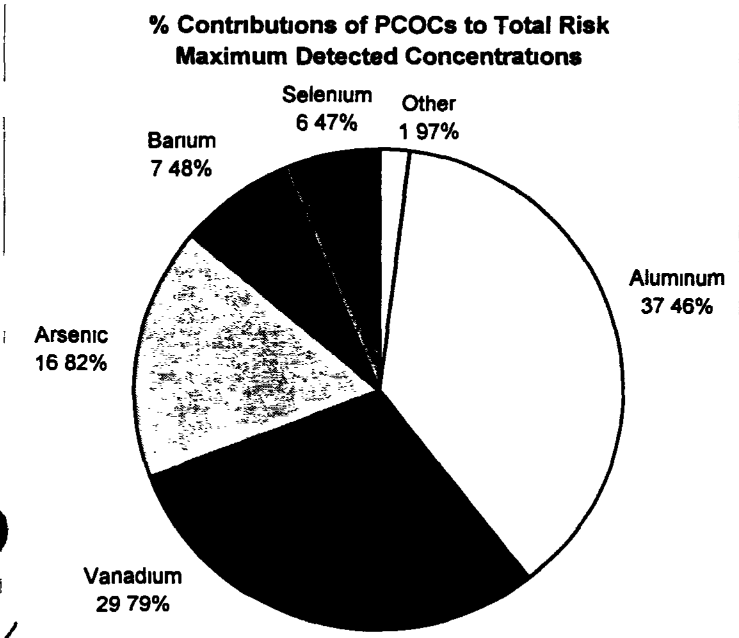
Figure D-11
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Raccoons - Sediment





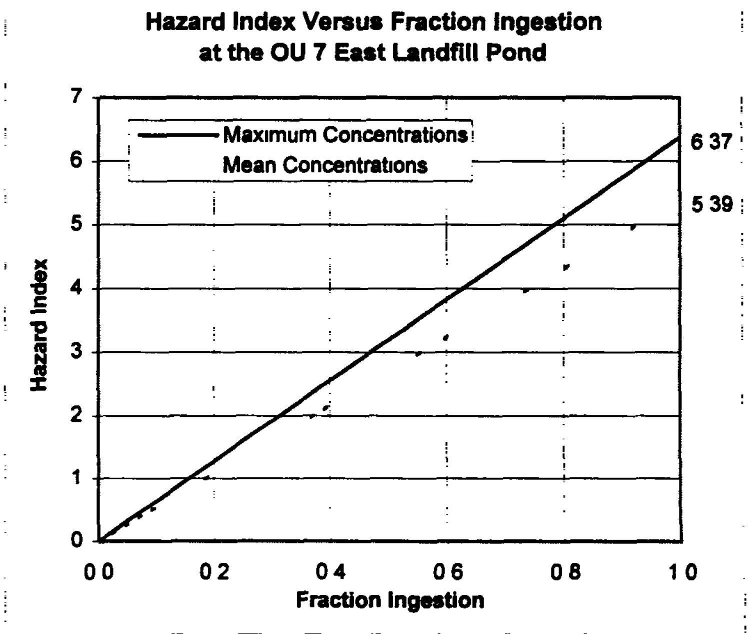


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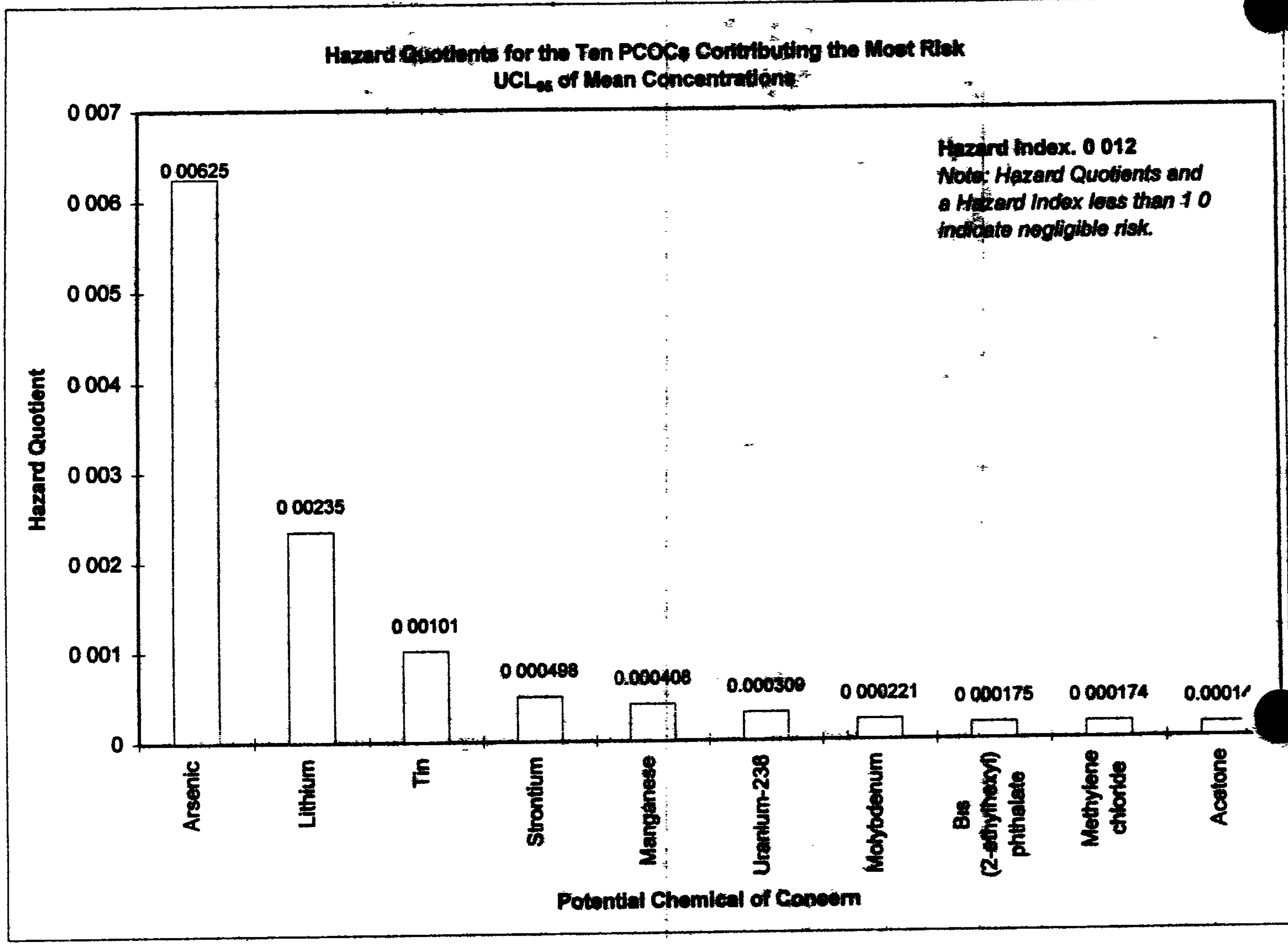
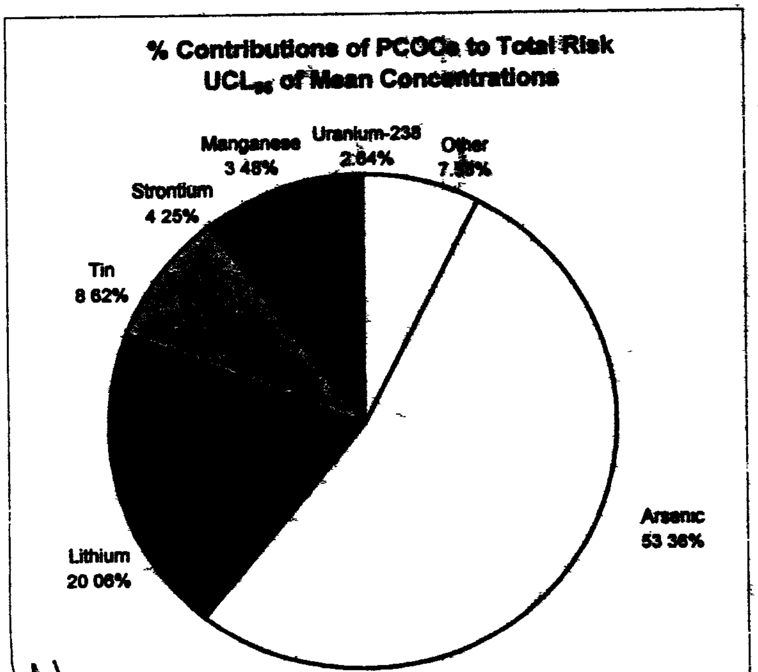
Figure D-12
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mule Deer - Surface Water





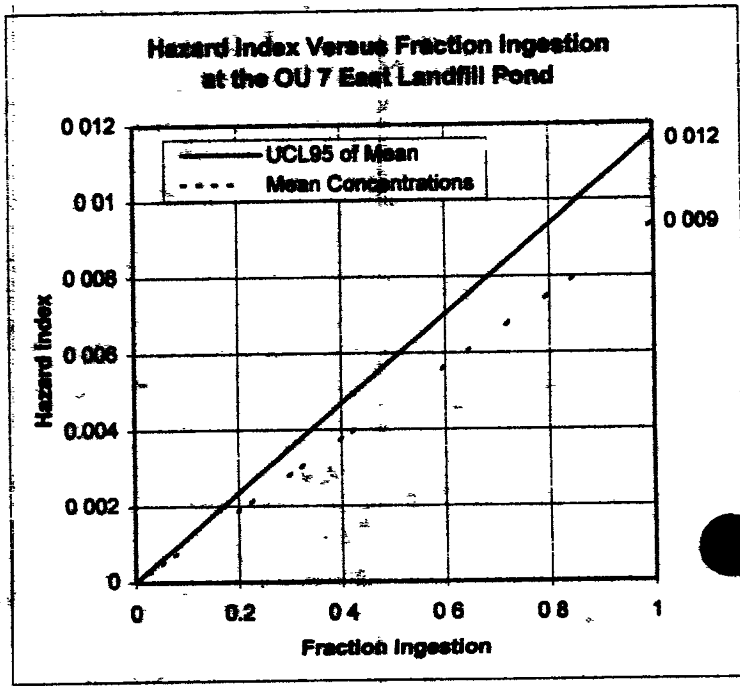


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Figure D-13
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mule Deer - Seep Water

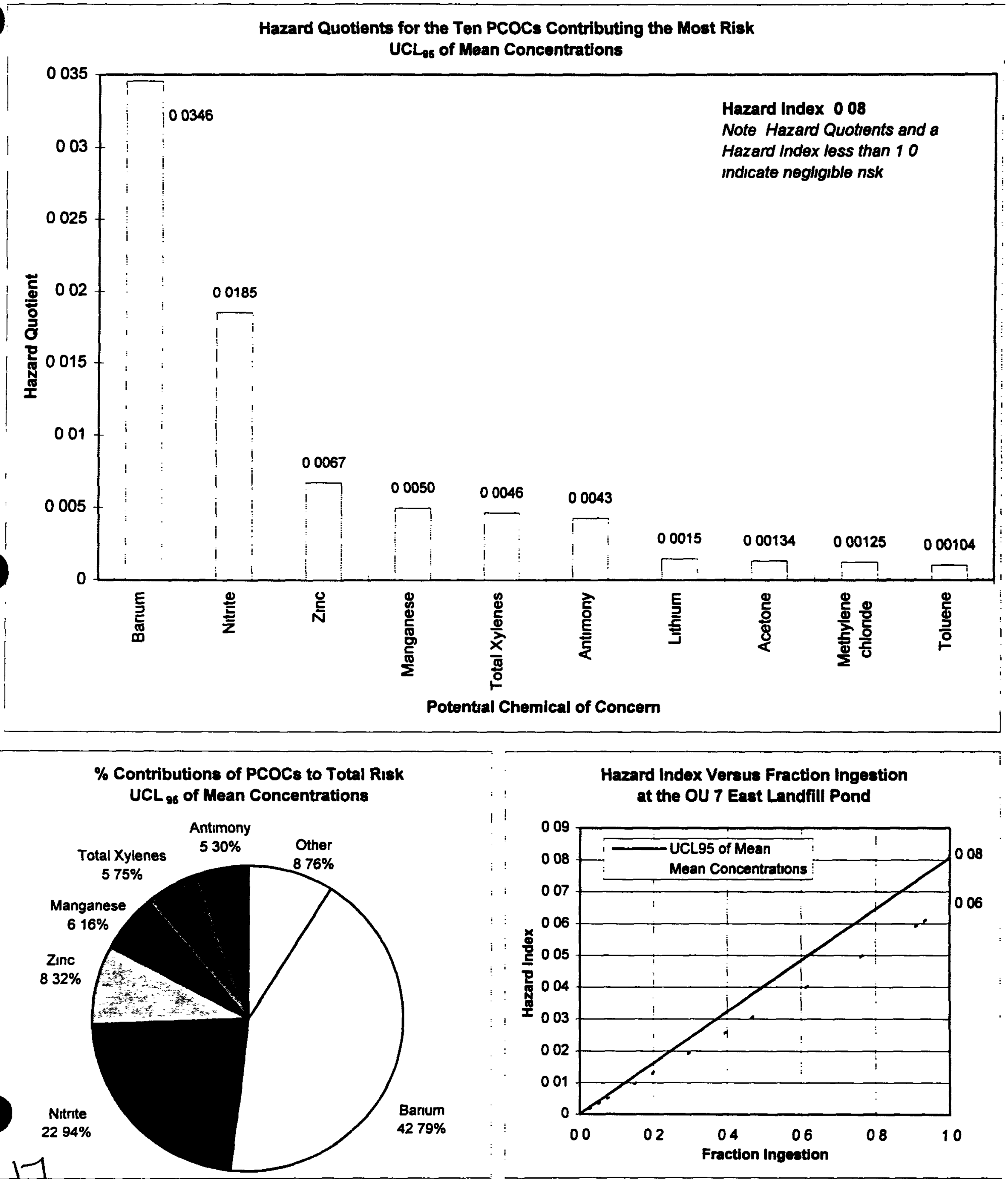

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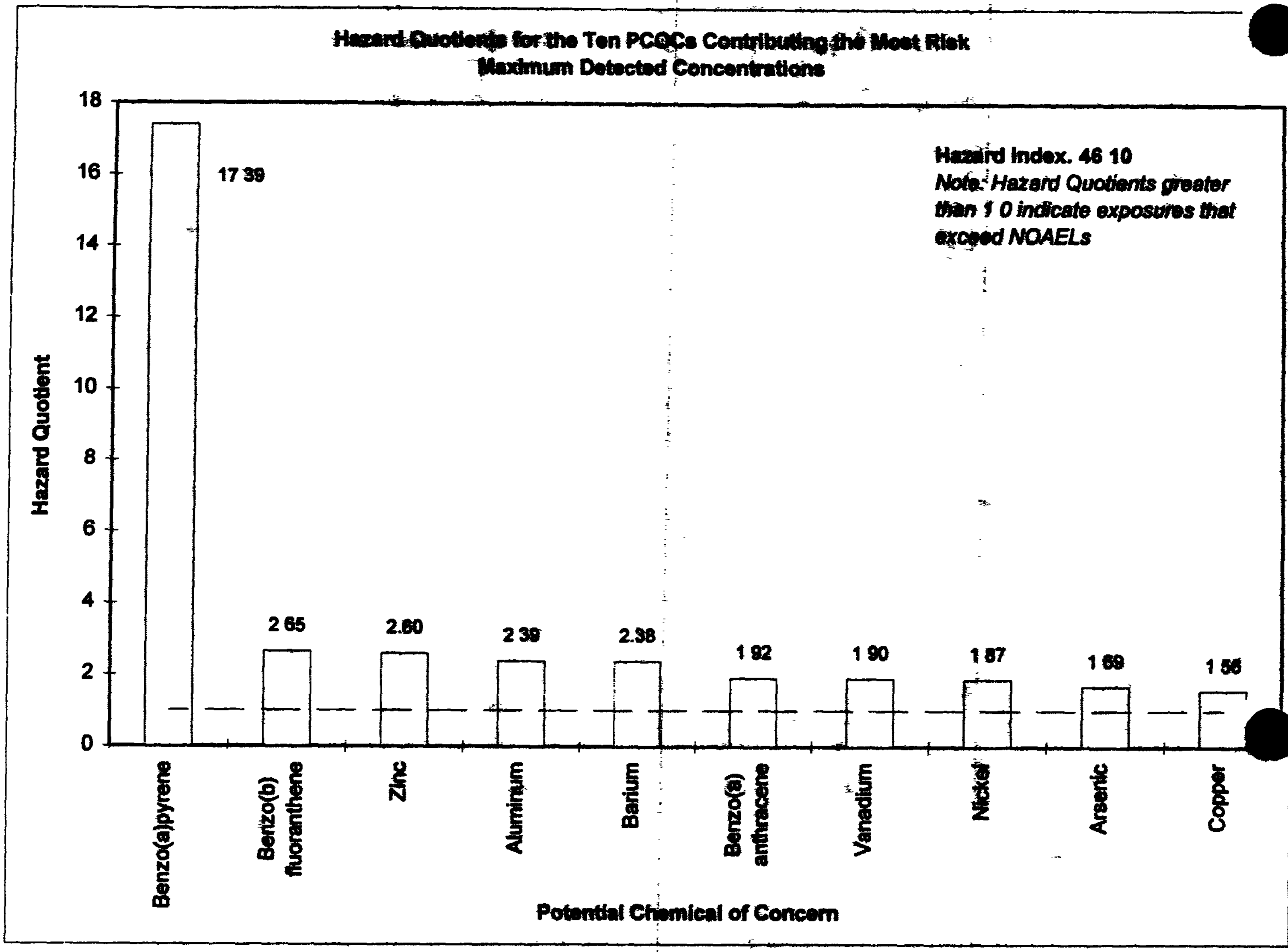
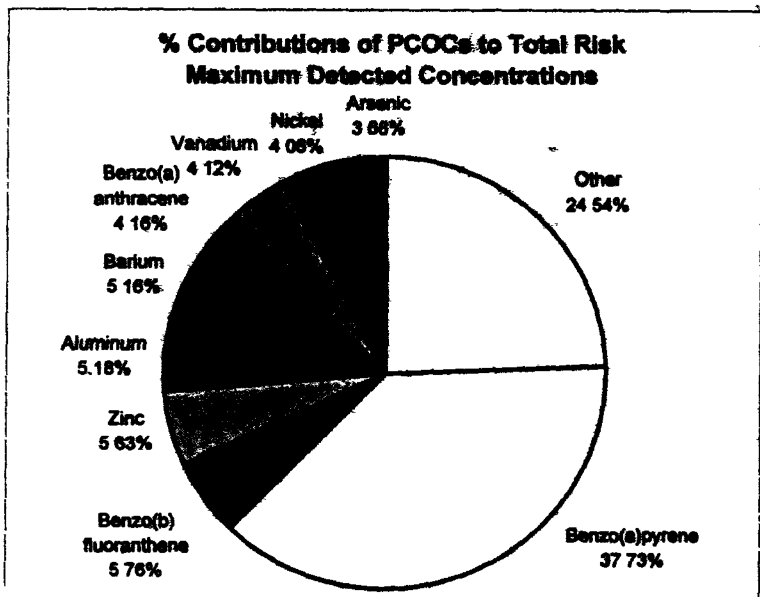
Figure D-14
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Mule Deer - Sediment





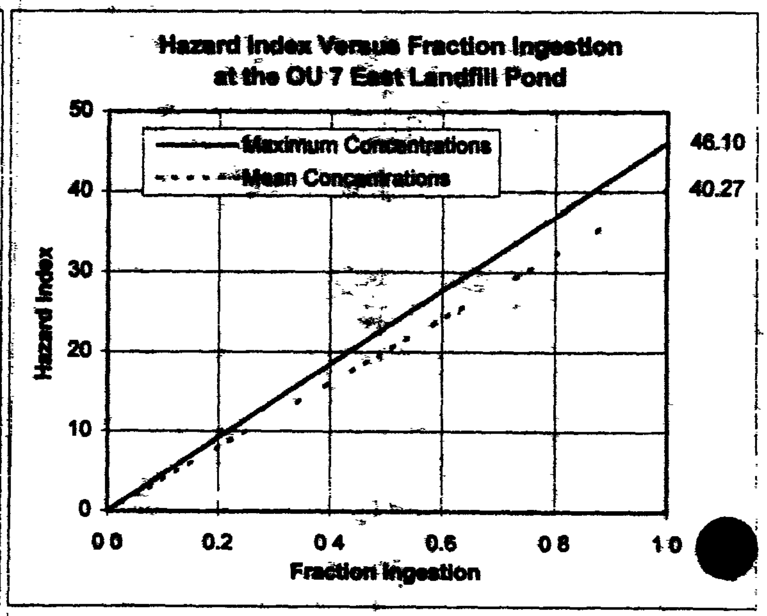


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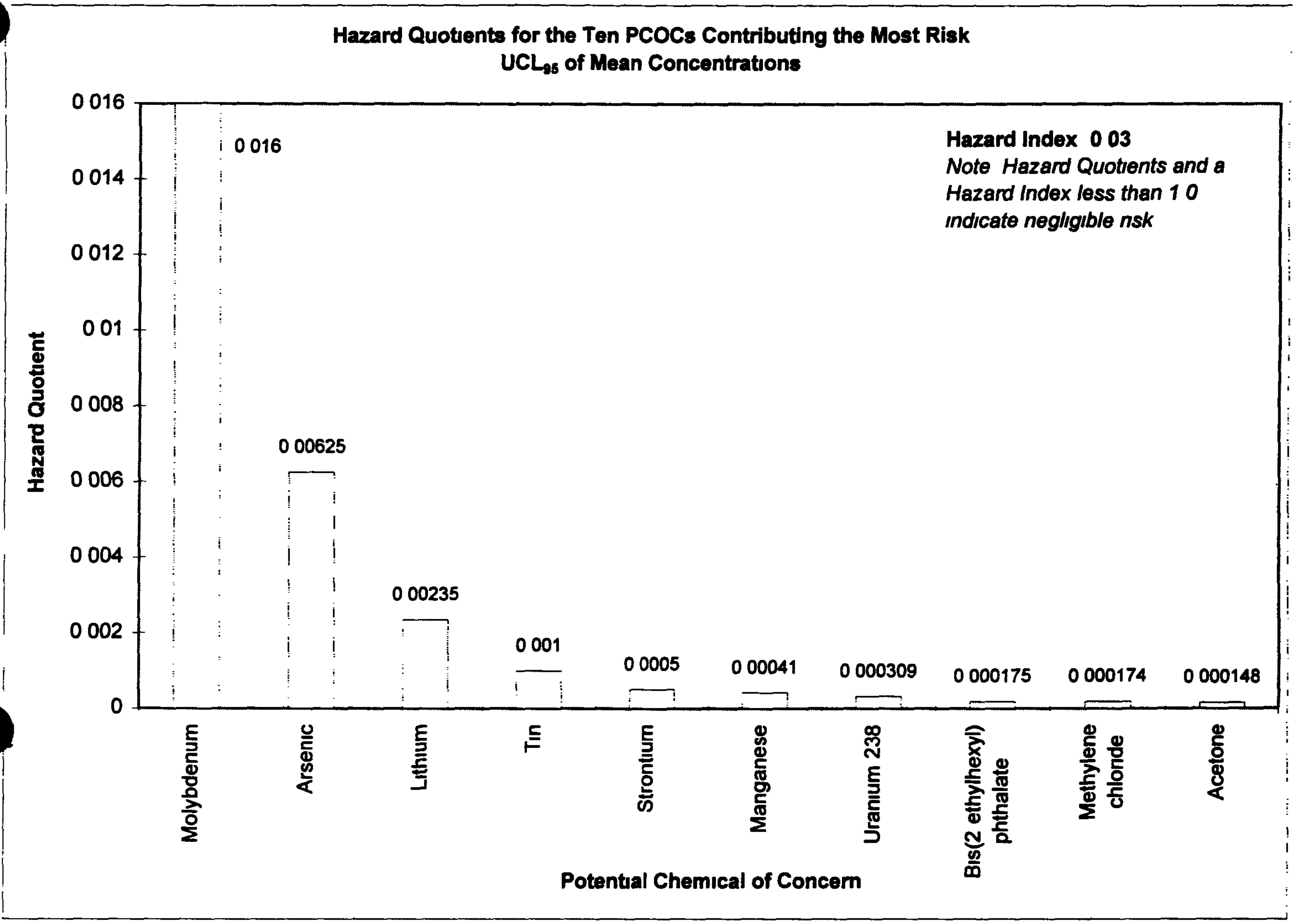
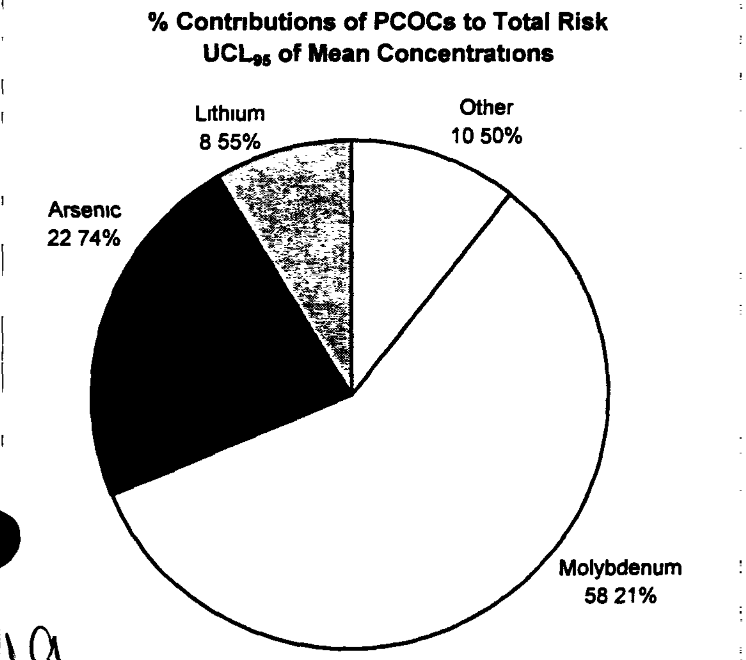
Figure D-15
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Coyotes - Surface Water





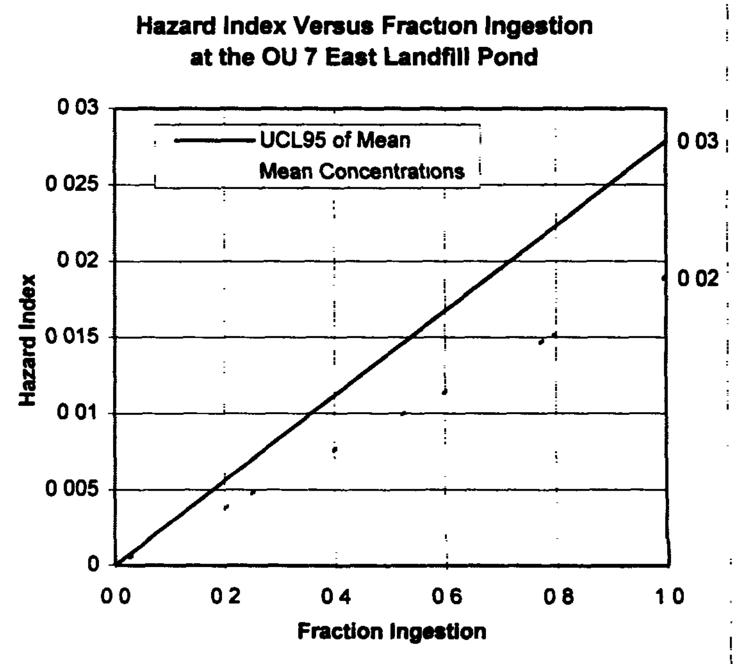


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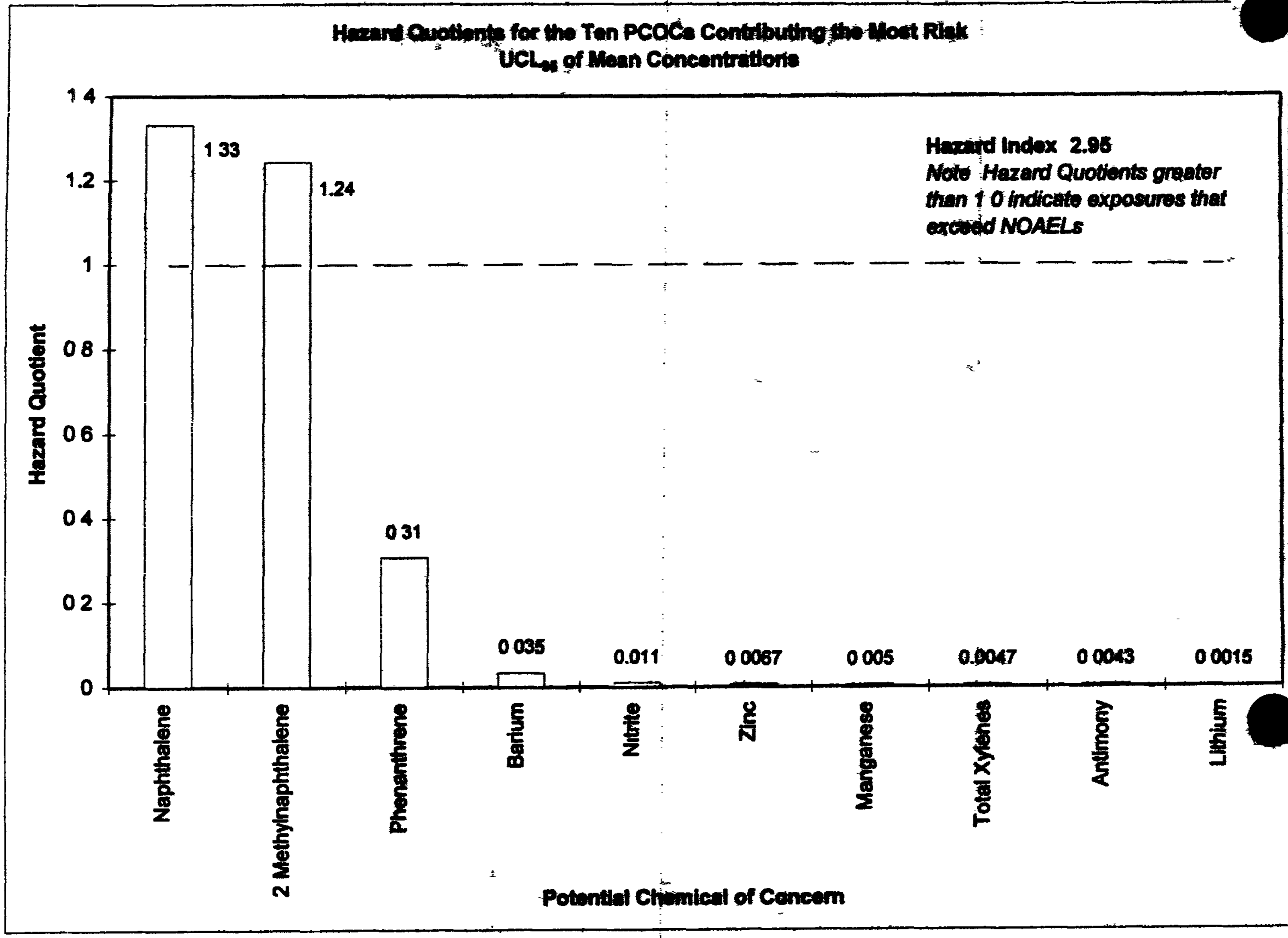
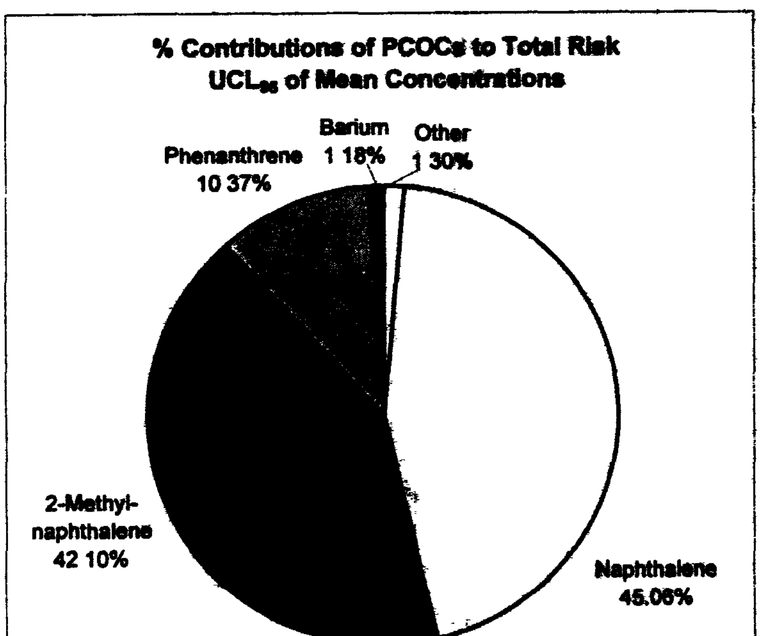
Figure D-16
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Coyotes - Seep Water





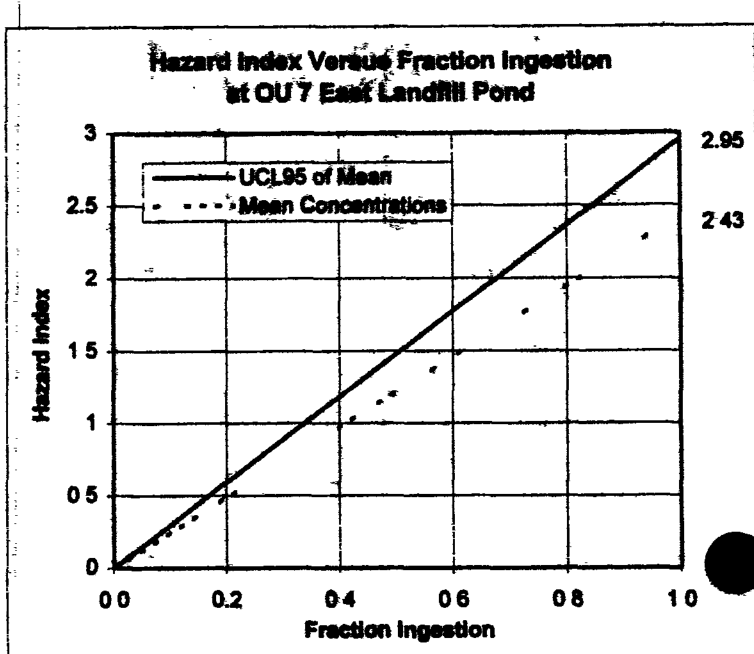


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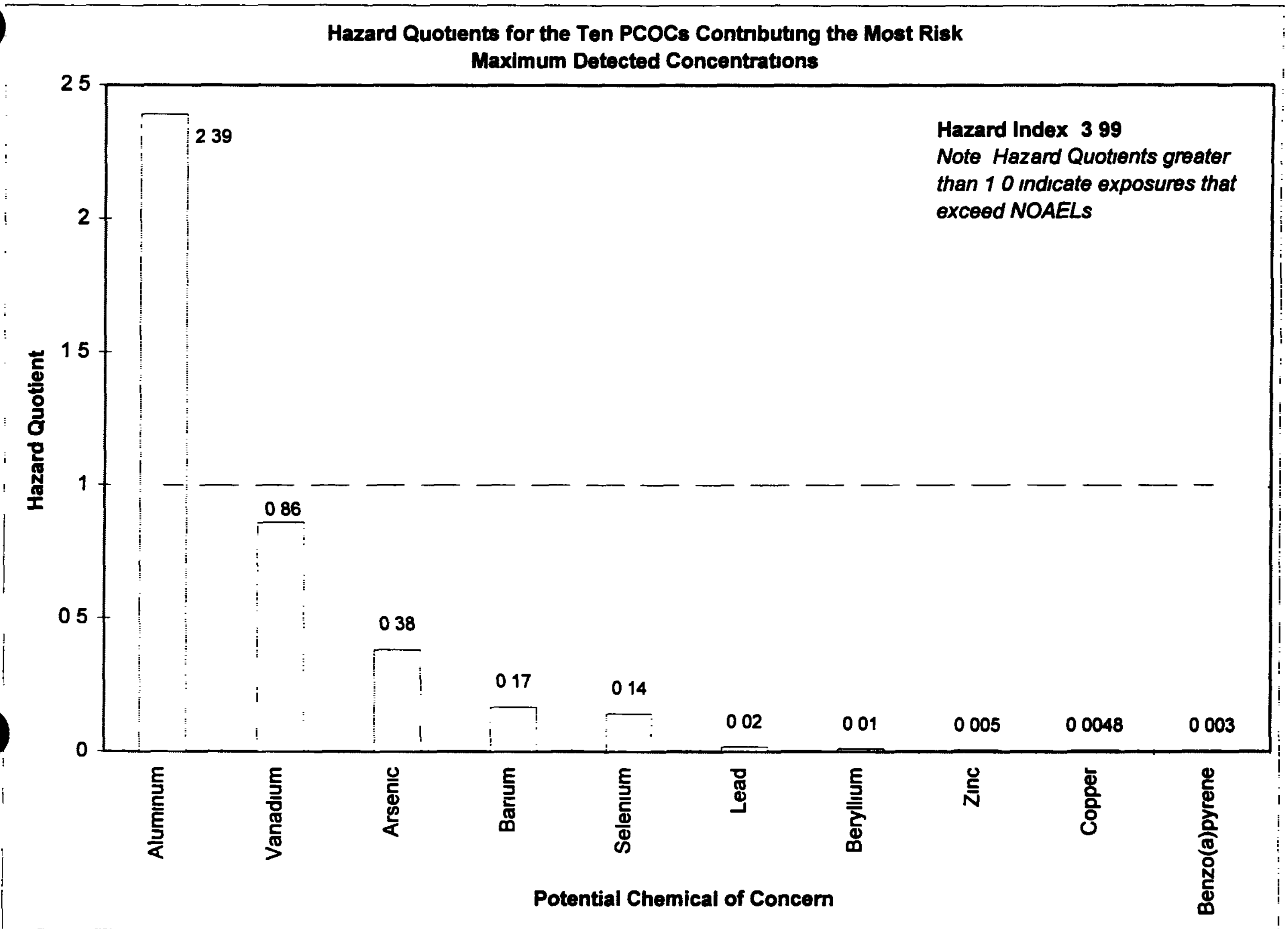
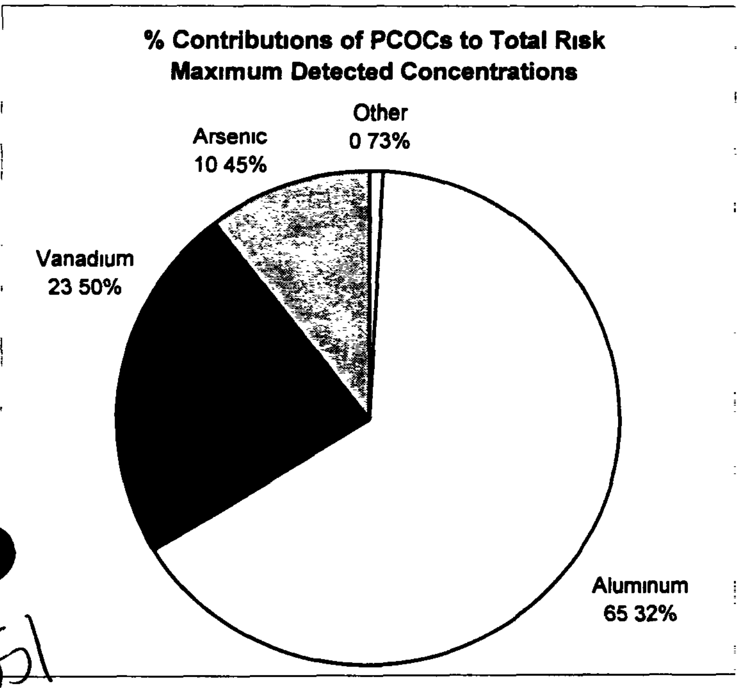
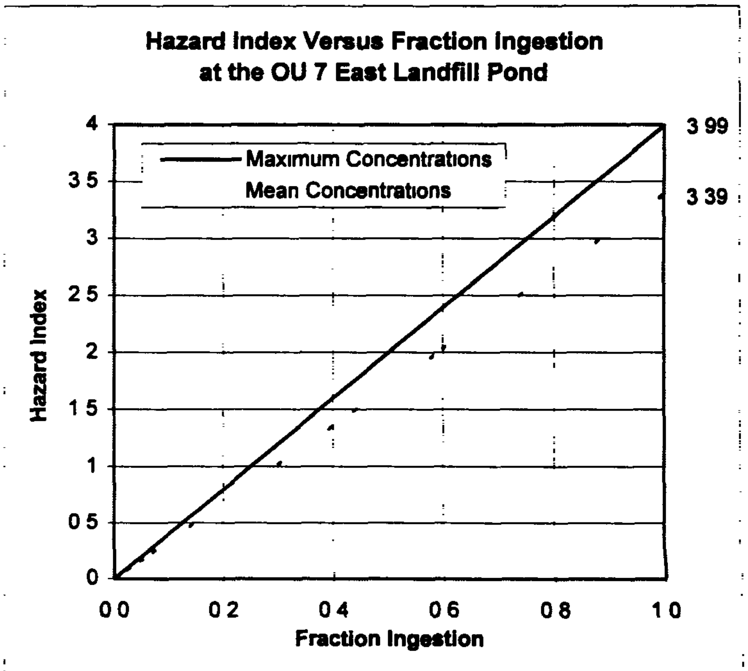
Figure D-17
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Coyotes - Sediment







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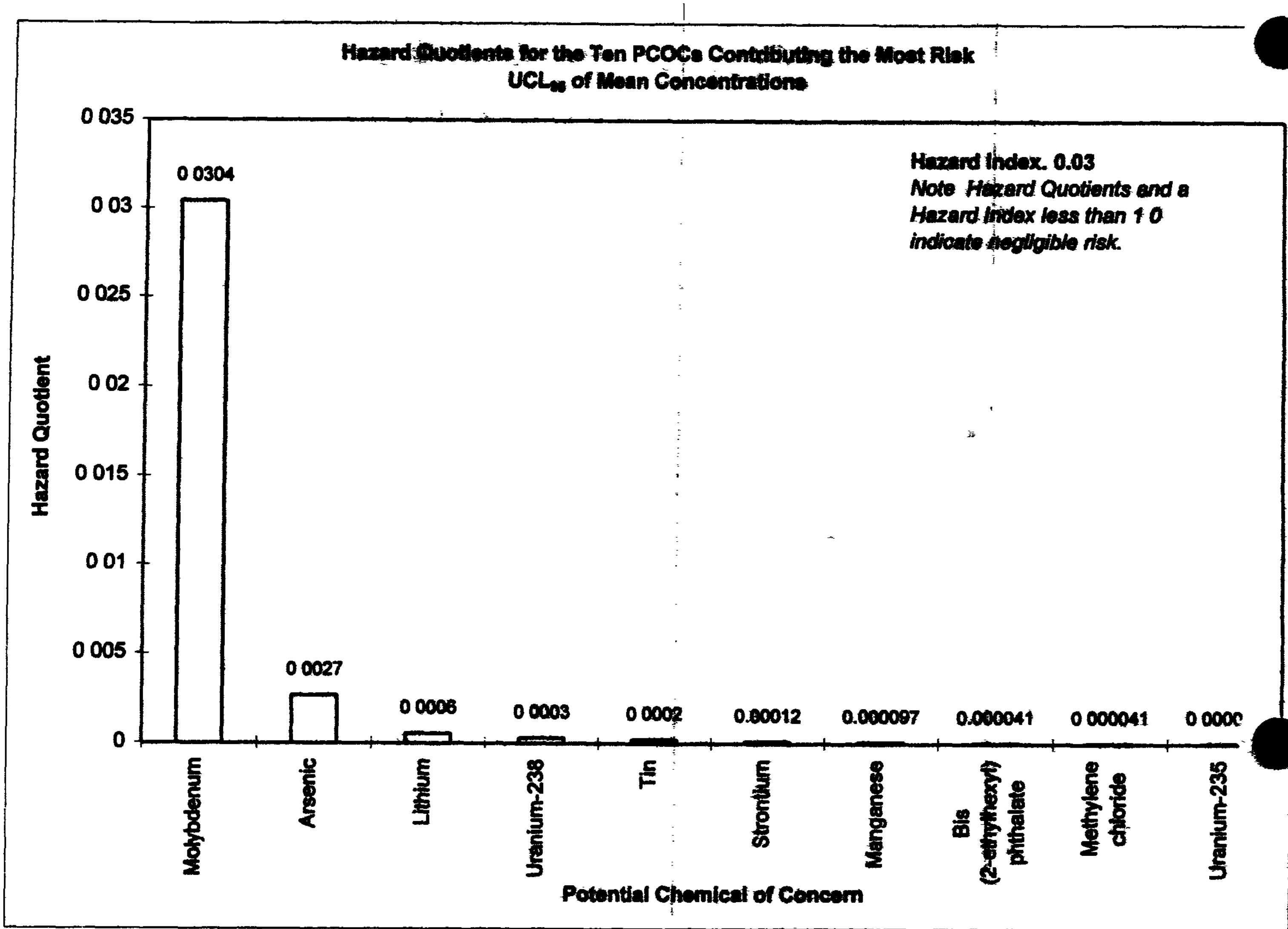
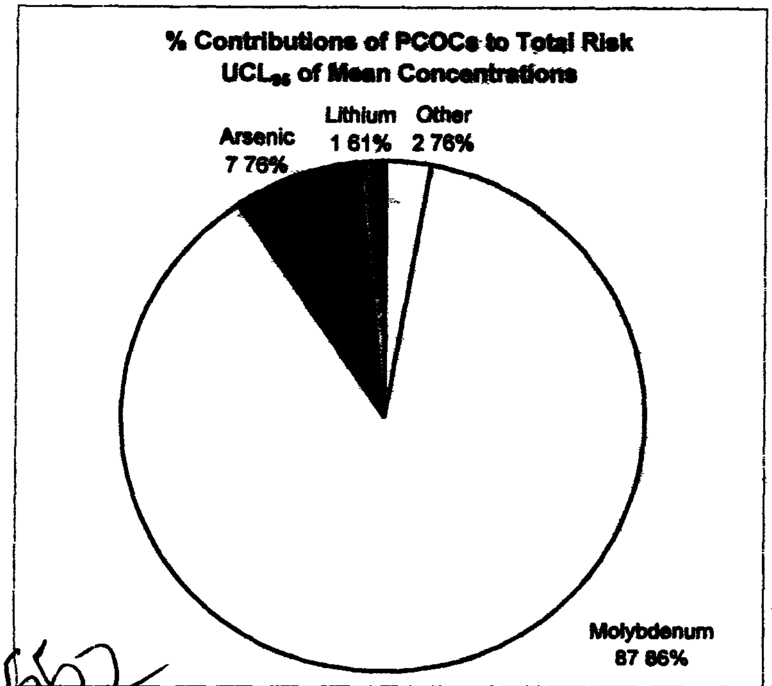
EX_SCRN XLS SED Charts Coyote 5/3/95

Figure D-18
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Preble's Meadow Jumping Mice - Surface Water





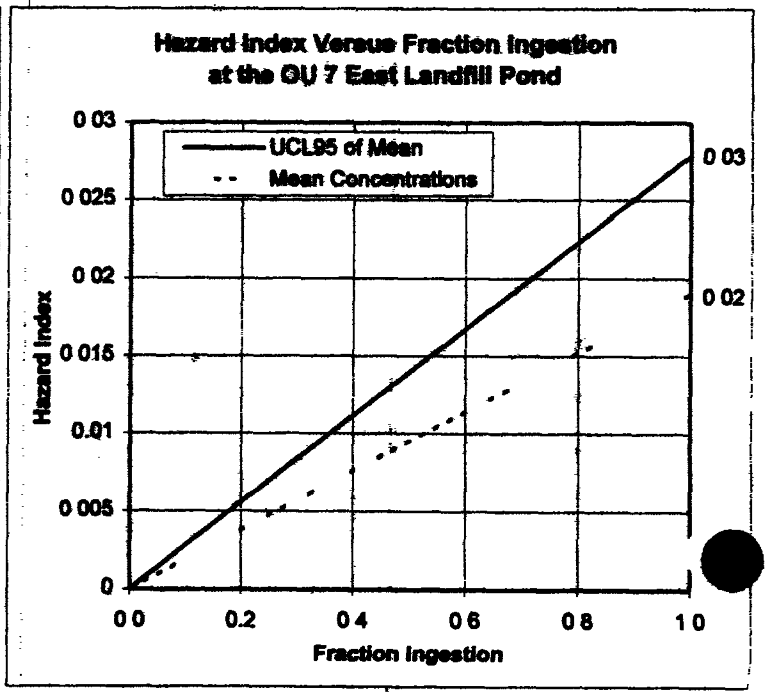


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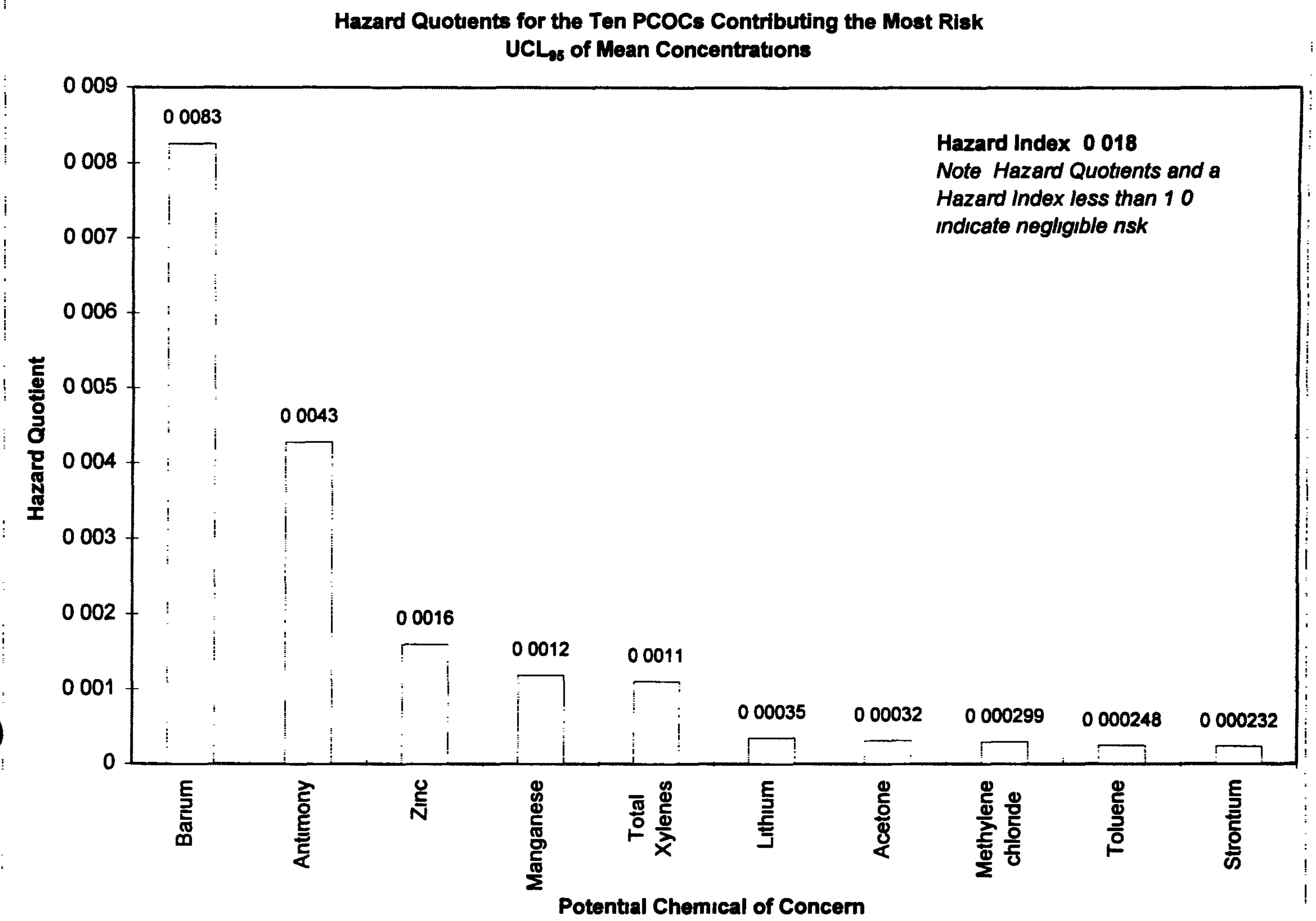
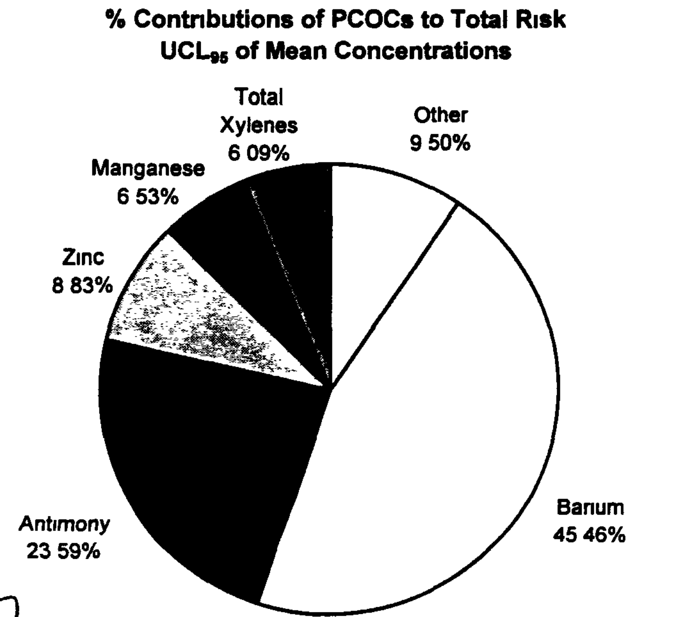
Figure D-19
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Preble's Meadow Jumping Mice - Seep Water





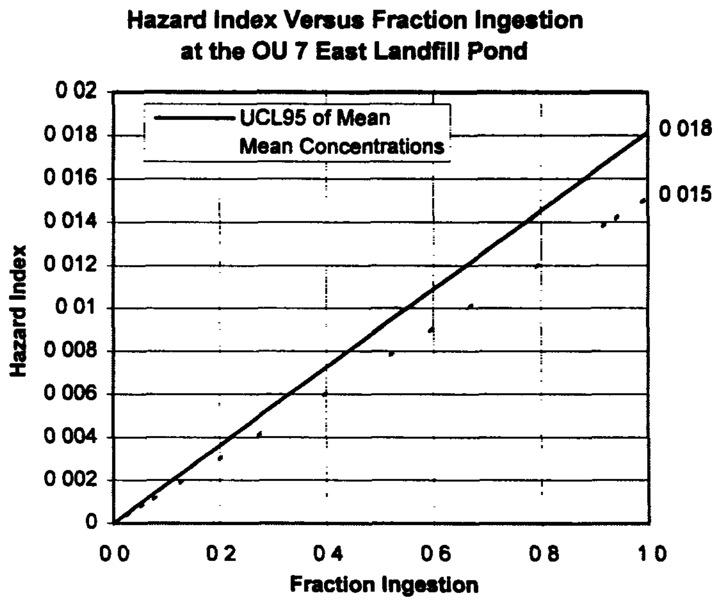


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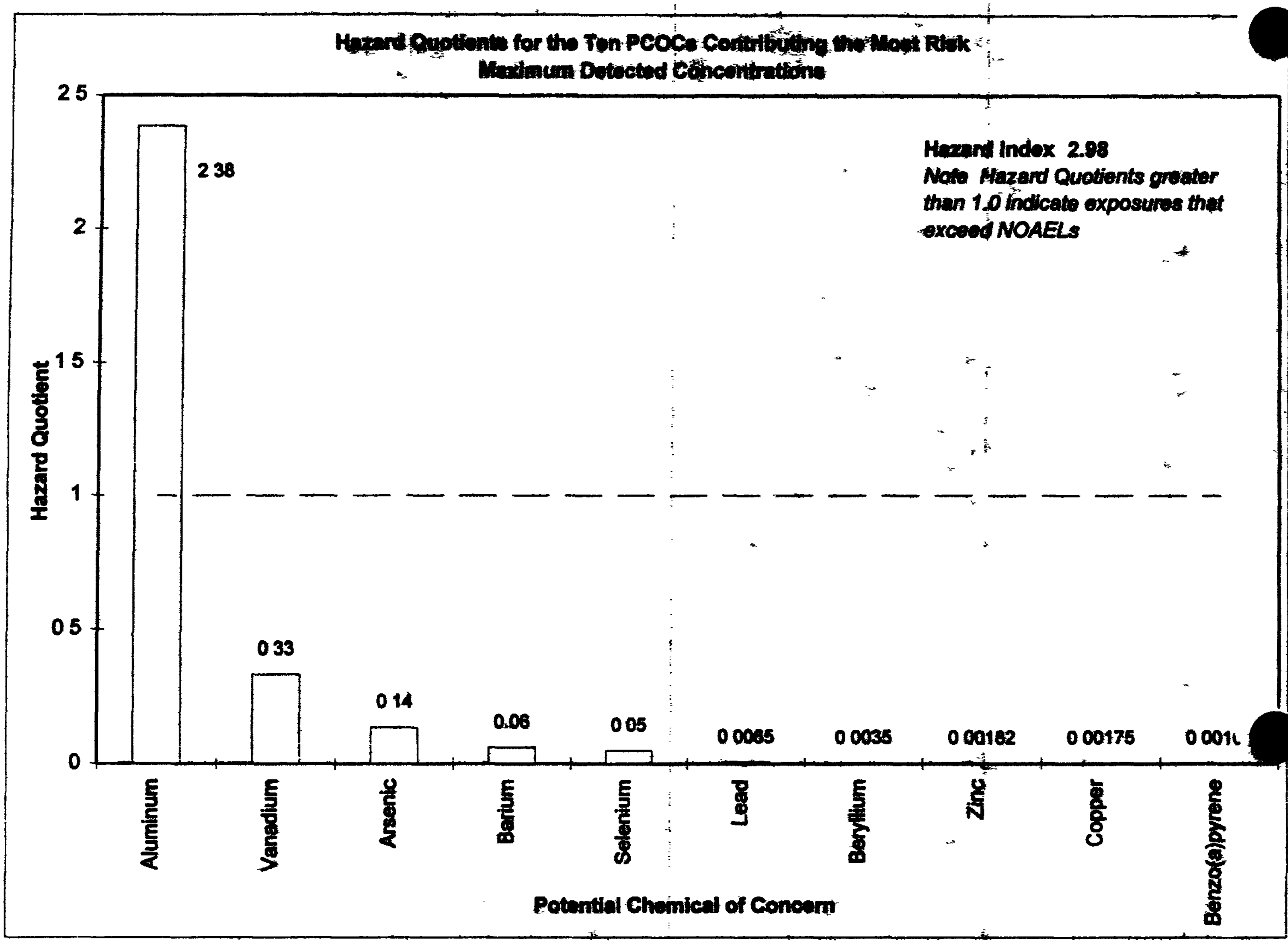
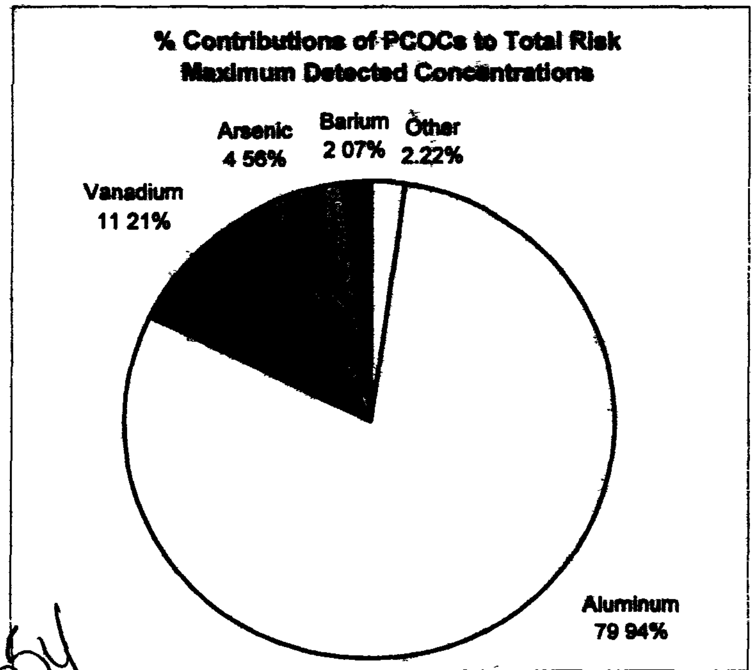
Figure D-20
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Preble's Meadow Jumping Mice - Sediment





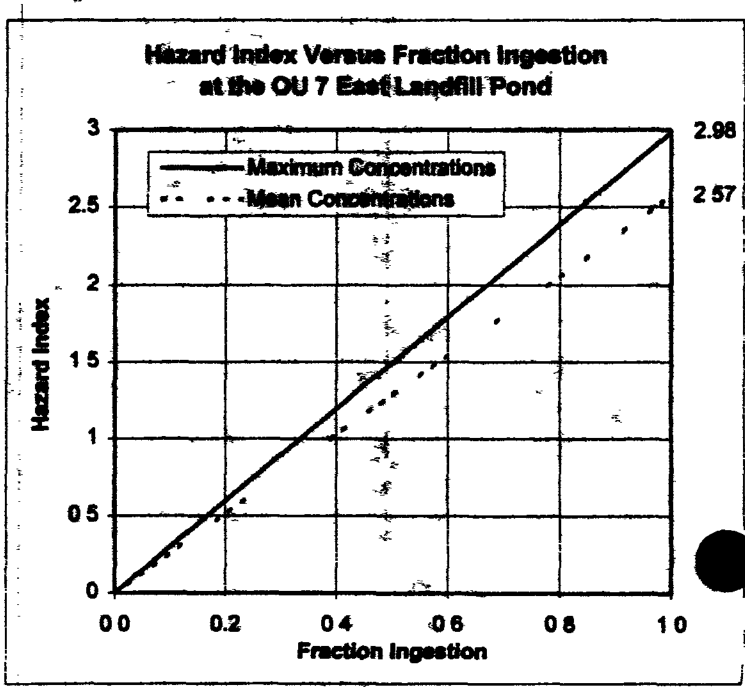


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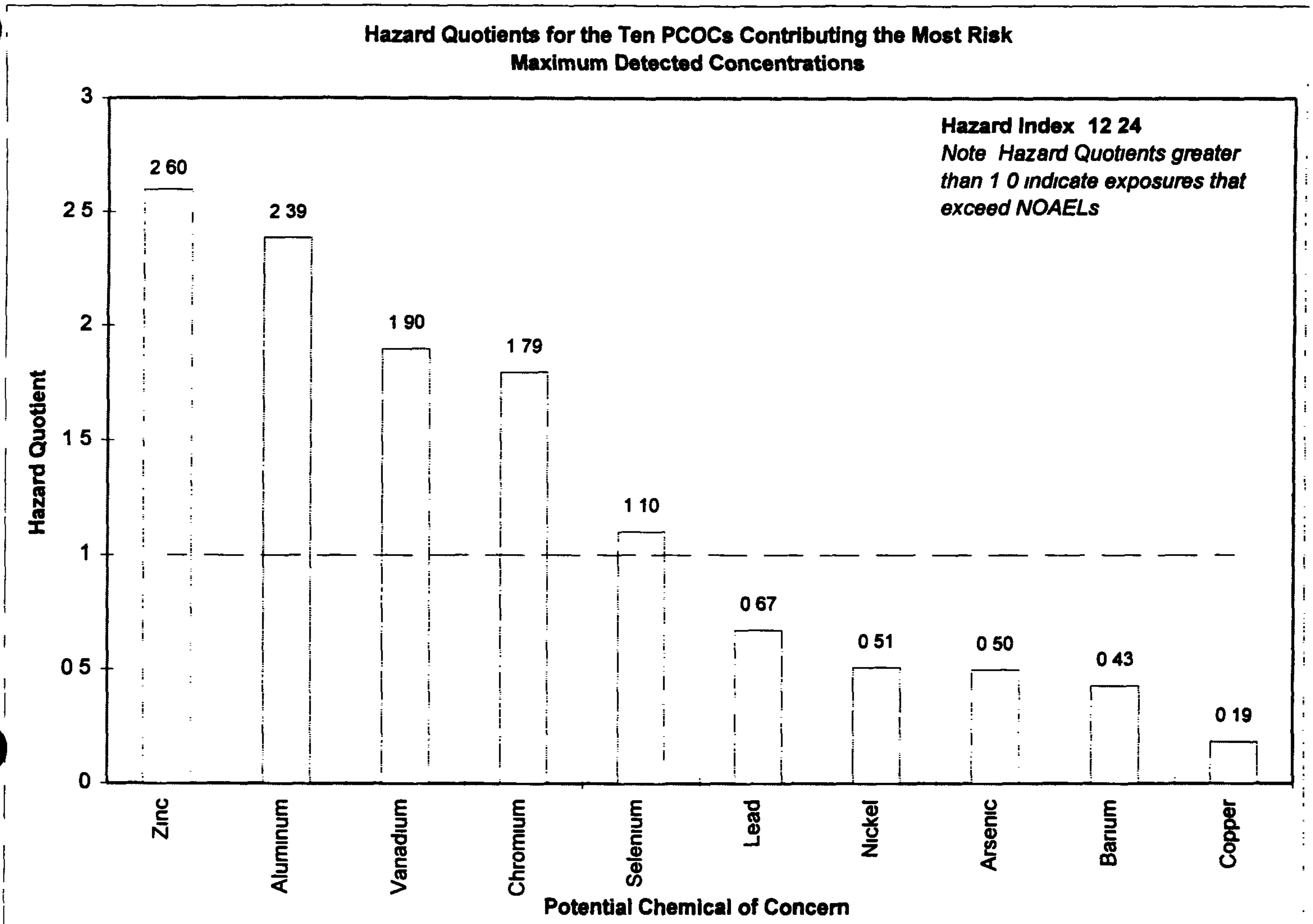
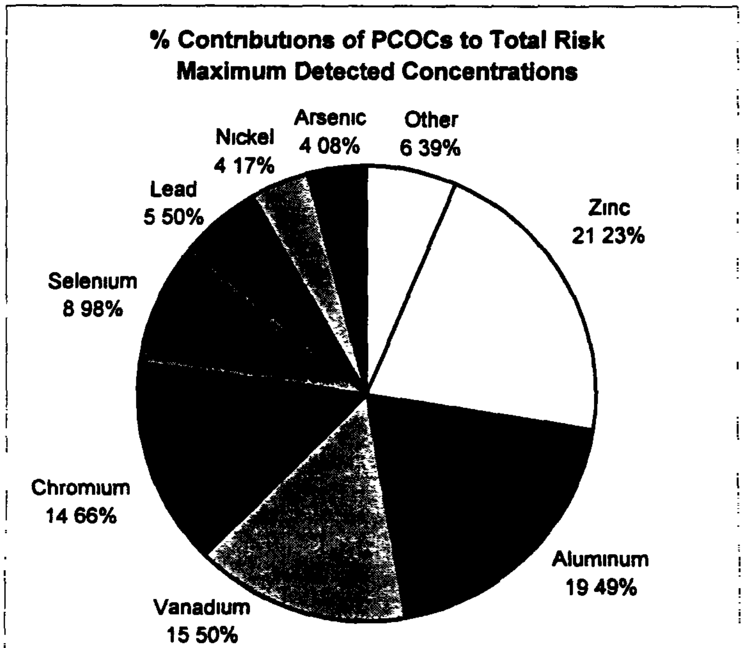
Figure D-21
Tier 3 Exposure Screening for PCOCs at the OU 7 East Landfill Pond
Vegetation - Sediment





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Tier 3 Exposure Screening for PCOCs in Surface Water for RFETS Background

	Background Concentration		Receptor				
			Raccoon	Mallard	Mule Deer	Coyote	Preble s Meadow Jumping Mouse
PCOC	Surface Water UCL_{95} of Mean	Units	C_w [a]	C_w [a]	C_w [b]	C_w [b]	C_w [b]
METALS							
Arsenic	0 40	mg/l	0 07	5 1	0 21	0 22	0 93
Calcium	25 50	mg/l	EN	EN	EN	EN	EN
Lithium	3 97	mg/l	NA	NA	37	37	156
Magnesium	105 15	mg/l	EN	EN	EN	EN	EN
Manganese	0 31	mg/l	411	877	348	346	1458
Molybdenum	3 49	mg/l	0 03	0 21	253	0 43	1 84
Nickel	1 45	mg/l	10	11	158	157	663
Potassium	170 64	mg/l	EN	EN	EN	EN	EN
Sodium	17 57	mg/l	EN	EN	EN	EN	EN
Strontium	22 20	mg/l	1227	117	1040	1035	4358
Thallium	0 62	mg/l	0 03	NA	0 03	0 03	0 12
Tin	3 70	mg/l	115 79	NA	97 33	97 64	418

[a] C_w includes assumption of bioconcentration of contaminants in aquatic food items
[b] C_w based on ingestion of surface water only
EN = Essential Nutrient
NA = Data Not Available

Shading indicates that the background PCOC concentration is greater than the NOAEL based benchmark
For these PCOCs the UCL_{95} of the background concentration will be used in place of the C_w benchmark to estimate risk

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Tier 3 Exposure Screen for PCOCs in Seep Water for RFETS Background

PCOC	Background Concentration Seep Water UCL$_{95}$ of Mean	Units	Receptor: Raccoon C_w [a]	Mallard C_w [a]	Mule Deer C_w [b]	Coyote C_w [b]	Preble's Meadow Jumping Mouse C_w [b]
METALS							
Antimony	6.42	mg/l	0.22	NA	0.21	0.22	0.92
Barium	14.15	mg/l	25.4	175	21.5	21.4	90
Calcium	126.17	mg/l	EN	EN	EN	EN	EN
Iron	297.38	mg/l	EN	EN	EN	EN	EN
Lithium	10.38	mg/l	43.8	NA	37	37	156
Magnesium	144.19	mg/l	EN	EN	EN	EN	EN
Manganese	3.15	mg/l	410.73	877.27	347.87	346.33	1456
Potassium	359.44	mg/l	EN	EN	EN	EN	EN
Silicon	10.06	mg/l	NA	NA	NA	NA	NA
Sodium	13.83	mg/l	EN	EN	EN	EN	EN
Strontium	70.01	mg/l	1227.5	117.35	1039.7	1035	4358
Zinc	1.36	mg/l	746.78	53.45	632.5	629.69	2852

Based on PCOC List of Total Analytes
[a] C_w includes assumption of bioconcentration of contaminants in aquatic food items
[b] C_w based on ingestion of surface water only
NA = Data Not Available
EN = Essential Nutrient

Shading indicates that the background PCOC concentration is greater than the NOAEL based benchmark.
For these PCOCs the UCL$_{95}$ of the background concentration will be used in place of the C_w benchmark to estimate risk.

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Tier 3 Exposure Screen for PCOCs in Sediment for RFETS Background

	Background Concentration		Receptor														
			Raccoon			Mallard			Mule Deer			Coyote			Preble s Meadow Jumping Mouse		
PCOC	Stream Sediment UCL_{95} of Mean	Units	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	NOAEL (mg/kg bw/dy)	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	NOAEL (mg/kg bw/dy)	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	NOAEL (mg/kg bw/dy)	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	NOAEL (mg/kg bw/dy)	Soil/Sed IR (kg/kg bw/dy)	Contaminant IR (mg/kg bw/dy)	NOAEL (mg/kg bw/dy)
METALS																	
Aluminum	6957 18	mg/kg	0 0045	3 13E+01	3 20E-01	0 0014	9 74E+00	5 74E+01	0 23	1 60E+03	1 50E-01	0 0013	9 04E+00	2 60E-01	0 00408	2 84E+01	2 84E+01
Arsenic	2 97	mg/kg	0 0045	1 34E 02	2 10E 02	0 0014	4 16E 03	5 13E+00	0 23	1 29E+01	9 00E-03	0 0013	3 86E 03	1 70E 02	0 00408	1 21E 02	1 50E 01
Barium	90 41	mg/kg	0 0045	4 07E 01	2 03E+00	0 0014	1 27E-01	9 90E+00	0 23	3 93E+02	9 50E-01	0 0013	1 18E 01	1 65E+00	0 00408	3 69E-01	1 42E+01
Beryllium	1 19	mg/kg	0 0045	5 36E-03	2 50E 01	0 0014	1 67E-03	NA	0 23	5 17E+00	1 10E-01	0 0013	1 55E 03	2 00E 01	0 00408	4 86E-03	1 73E+00
Calcium	4686 66	mg/kg	0 0045	2 11E+01	EN	0 0014	6 56E+00	EN	0 23	2 04E+04	EN	0 0013	6 09E+00	EN	0 00408	1 91E+01	EN
Chromium	9 75	mg/kg	0 0045	4 39E 02	1 02E+03	0 0014	1 37E 02	1 03E+00	0 23	4 24E+01	4 76E+02	0 0013	1 27E-02	8 33E+02	0 00408	3 98E-02	7 16E+03
Copper	11 93	mg/kg	0 0045	5 37E 02	6 18E+00	0 0014	1 67E 02	1 58E+01	0 23	5 19E+01	2 88E+00	0 0013	1 55E-02	5 03E+00	0 00408	4 87E 02	4 33E+01
Iron	10216 22	mg/kg	0 0045	4 60E+01	EN	0 0014	1 43E+01	EN	0 23	4 44E+04	EN	0 0013	1 33E+01	EN	0 00408	4 17E+01	EN
Lead	30 49	mg/kg	0 0045	1 37E 01	2 99E+00	0 0014	4 27E 02	1 80E+00	0 23	1 33E+02	1 39E+00	0 0013	3 96E 02	2 43E+00	0 00408	1 24E 01	2 10E+01
Magnesium	1800 04	mg/kg	0 0045	8 10E+00	EN	0 0014	2 52E+00	EN	0 23	7 83E+03	EN	0 0013	2 34E+00	EN	0 00408	7 34E+00	EN
Nickel	8 17	mg/kg	0 0045	3 68E 02	1 50E+01	0 0014	1 14E-02	6 84E+01	0 23	3 55E+01	6 96E+00	0 0013	1 06E 02	1 22E+01	0 00408	3 33E-02	1 05E+02
Potassium	1143 05	mg/kg	0 0045	5 14E+00	EN	0 0014	1 60E+00	EN	0 23	4 97E+03	EN	0 0013	1 49E+00	EN	0 00408	4 66E+00	EN
Selenium	0 85	mg/kg	0 0045	3 83E-03	1 20E 02	0 0014	1 19E 03	3 80E-01	0 23	3 70E+00	6 00E 03	0 0013	1 11E 03	1 00E 02	0 00408	3 47E 03	9 00E 02
Sodium	401 40	mg/kg	0 0045	1 81E+00	EN	0 0014	5 62E-01	EN	0 23	1 75E+03	EN	0 0013	5 22E 01	EN	0 00408	1 64E+00	EN
Strontium	49 90	mg/kg	0 0045	2 25E-01	9 80E+01	0 0014	6 99E 02	6 62E+00	0 23	2 17E+02	4 57E+01	0 0013	6 49E-02	8 00E+01	0 00408	2 04E-01	6 88E+02
Vanadium	21 60	mg/kg	0 0045	9 72E-02	7 10E-02	0 0014	3 02E 02	2 90E-01	0 23	9 39E+01	3 40E-02	0 0013	2 81E 02	6 20E 02	0 00408	8 81E 02	5 00E-01
Zinc	71 95	mg/kg	0 0045	3 24E 01	5 97E+01	0 0014	1 01E 01	3 02E+00	0 23	3 13E+02	2 78E+01	0 0013	9 35E 02	4 87E+01	0 00408	2 94E-01	4 19E+02

Shading indicates that the calculated background intake value is greater than the NOAEL For these PCOCs the calculated background intake replaces the NOAEL as the benchmark

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E 1 Groundwater Contaminant Transport Simulations

Modeling of the groundwater contaminant plume migration from the Present Landfill uses a three-dimensional solute transport solution developed by Domenico and Robbins (1985) and refined by Domenico (1987) The objective of the modeling is to determine the extent of plume migration 30 years after landfill closure Transport modeling focuses on the upper hydrostratigraphic unit (UHSU) which consists of unconsolidated surficial deposits and weathered bedrock only because compiled data indicate the absence of contamination in the lower hydrostratigraphic unit (LHSU) Modeling assumptions are rather simplistic in that they do not account for the landfill cap or the East Landfill Pond dam

Inorganic contaminants of concern (identified as applicable or relevant and appropriate requirements [ARARs] exceedances in Section 3 4 1) include chloride selenium sulfate and nitrate/nitrite In addition 1 1-dichloroethane was also modeled as a point-source contaminant originating from the landfill seep (SW097) Although 1 1-dichloroethane has not been detected in groundwater, elevated concentrations (10 µg/L) exceeding the practical quantitation limit (PQL) of 1 µg/L have been detected in surface water at SW097 The objectives of the modeling simulation are to predict the future groundwater concentrations at the proposed compliance boundary (monitoring well 53194) and predict future plume configurations for remedial and design considerations for landfill closure

E 2 Methodology

The analytical solution developed by Domenico and Robbins (1985) and Domenico (1987) simulates solute transport from a finite source in a continuous flow regime The advantage of this model is that the solution technique allows for a more defined source geometry as opposed to a continuous point-source model

Modeling assumptions include homogeneous and isotropic flow conditions and a constant seepage velocity in the x and y directions The seepage velocity in the z direction was set at zero, resulting in two-dimensional solute transport The contaminant transport simulations were conducted using the TPLUME software package (Golder Associates 1989) The Domenico and Robbins (1985) and Domenico (1987) solution for contaminant concentrations from a continuous source as a function of time and space is governed by the following expression

$$C(x,y,z\ t) = (C_o/8)\ \exp(-kt)\ \mathrm{erfc}[(x-vt)/2(D_x t)^{1/2}]$$
$$\{\mathrm{erf}[(y+Y/2)/2\ (D_{vx}/v)^{1/2} - \mathrm{erf}[(y-Y/2)/2\ (D_{yx}/v)^{1/2}\ ]\}$$

$\{erf[(z+Z/2)/2\ (D_{zx}/v)^{1/2}-erf[(z-Z/2)/2\ (D_{zx}/v)^{1/2}]\}$

where

x = linear distance in the direction of groundwater flow from the source [L]
y = transverse distance from the source [L]
Y = source width [L]
v = average linear velocity of groundwater in the x, y, and z directions (isotropic) [L/T]
D_x = coefficient of longitudinal hydrodynamic dispersion [L^2/T]
D_x = $\alpha_x v_x + D_m$
α_x = longitudinal dispersivity [L]
D_m = molecular diffusion along x axis
D_y = coefficient of lateral hydrodynamic dispersion [L^2/T]
D_y = $\alpha_y v_y + D_m$
α_x = lateral dispersivity [L]
D_m = molecular diffusion along y axis
V_y = average linear groundwater velocity in y direction [L/T]
z = vertical distance from the source [L]
Z = source width in the vertical plane
D_z = coefficient of lateral hydrodynamic dispersion [L^2/T]
D_z = $\alpha_z v_z + D_m$
D_m = molecular diffusion along x axis
α_z = vertical dispersivity [L]
D_m = molecular diffusion along y axis
k = first order decay constant, set equal to zero if no decay
C_o = contaminant concentration at the source [M/L^3]
C = contaminant concentration at the well [M/L^3]

E.3 Input Parameters

Input parameters and initial boundary conditions are based on observed field conditions The saturated zone configurations are based on site characterization data presented in the OU 7 Final Work Plan (DOE 1994). Hydraulic and transport parameters are also based on OU 7 site-specific data as well as information provided in the Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site (EG&G 1995) Input parameters and their values used for the modeling simulations are presented in Table E-1

E 3 1 Source Terms and Hydraulic Parameters

Modeled source geometries for inorganic contaminants (i e areas of greatest contamination) are based on the chloride, nitrate/nitrite selenium and sulfate plume maps presented in Figures E-1 through E-4 Simulated results are predicted at the top of the saturated zone for unconsolidated surficial deposits and weathered bedrock, respectively Identical selenium and sulfate source terms are used for the weathered bedrock and surficial deposits groundwater simulations Although the greatest selenium and sulfate concentrations are detected in weathered bedrock, these analytes are also detected above the corresponding ARARs in surficial deposit groundwater Given that the saturated surficial deposits and weathered bedrock comprise the UHSU and there appears to be hydraulic communication between the surficial deposits and the weathered bedrock (DOE 1994 EG&G 1995), using identical selenium and sulfate source terms for the both units provides a more conservative prediction of plume migration The modeled source geometry for 1,1-dichloroethane is based on the location and area of the leachate seep (SW097) Calibration of source geometries is performed by varying the source width and concentrations Simulated plume configurations are compared to observed plume geometries presented in Figures E-2 through E-4

The surficial deposits and weathered bedrock are modeled with thicknesses of 7 and 20 feet, respectively The geometric mean of site-specific hydraulic conductivity values is used for the weathered bedrock simulations (DOE 1994), and the geometric mean of hydraulic conductivity values for valley-fill alluvium (EG&G 1995) is used for the surficial deposits simulations The seepage velocity is based on the observed hydraulic gradient of 0 03 along No Name Gulch (EG&G 1995) and an estimated effective porosity value of 0 1 for weathered bedrock and unconsolidated surficial deposits (Hurr 1976)

E 3 2 Transport Parameters

The longitudinal dispersivity (α_L) value is based on the chloride plume geometry presented in Figure E-1 Field measured values of α_L presented in the literature suggest that α_L can be estimated at one-tenth of the flow length (Gelhar 1986, Fetter 1993) Therefore, based on the observed flow length of 600 feet (Figure E-1) α_L is estimated at 60 feet (0 1 x 600 feet) The transverse (α_T) and vertical dispersivities (α_Z) are estimated at one-tenth and one-twentieth of α_L respectively These ratios are within the range of values (6 to 20) reported by Fetter (1993) Sensitivity analyses were performed for dispersivity These analyses are discussed in Section E 5 2 Diffusion coefficient (1 x 10^{9} m^2/sec) and tortuosity (0 5 m^2/sec) parameters used for the modeling simulations are typical values reported in the literature (Fetter 1993)

E 3 2 1 Inorganic Contaminants

The modeled inorganic contaminants are generally non-reactive anions with little or no attenuation under normal oxidizing/reducing conditions Therefore, chloride, nitrate/nitrite, and sulfate are modeled with a retardation coefficient of 1 and decay coefficient of zero. Selenium is also modeled with a decay coefficient of zero, however, Kent *et al* (1994) report slight attenuation and suggest using a retardation coefficient of 1 1

E 3.2 2 1,1-Dichloroethane

Similar to many organic compounds, 1,1-dichloroethane has a tendency to adsorb to the solid matrix The distribution of chemical compounds between the groundwater and adjacent solid matrix is referred to as the soil-water distribution coefficient (K_d) The K_d is the ratio of the mass of solute on the solid phase to the concentration of solute in solution Generally, the greater the K_d value, the less mobile the chemical The K_d value can be estimated from the following expression (Fetter 1993)

$$K_d = K_{oc} \times f_{oc}$$

where

K_{oc} = organic carbon coefficient (ml/g)
f_{oc} = fraction of organic carbon in the soil matrix (dimensionless)

This implies a linear relationship between the degree of soil adsorption and organic carbon content Based on the site-specific mean f_{oc} value of 0 0135 for valley-fill alluvium (DOE 1994) and k_{oc} value of 30.2 for 1,1-dichloroethane (Knox *et al* 1993), the K_d value of 0 41 may be estimated from the above expression. Once determined, the K_d value can be used to calculate the retardation coefficient (R) from the following equation

$$R = 1 + \rho K_d/h$$

where

ρ = soil density (g/cm^3)
h = effective porosity (dimensionless)

Using an average soil density of 1 77 g/cm^3 for unconsolidated surficial deposits (DOE 1993), a Kd value of 0 41, and an effective porosity value of 0 1 and substituting into the above equation results in R of 8 26 for 1,1-dichloroethane In general, the computed retardation coefficient predicts contaminant movement at one-eighth of the seepage velocity, assuming chemical equilibrium between the liquid and solid phase

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Other processes that may attenuate 1,1-dichlorethane in groundwater include hydrolysis, oxidation volatilization, and biodegradation Howard *et al* (1991) report a groundwater half-life of 8 to 19 weeks for 1,1-dichloroethane A more conservative half-life value of 19 weeks was used for the modeling simulation resulting in a first order decay rate (k) of 5 21 x 10^{3} day ^{1}

E 4 Modeling Results

E 4 1 Unconsolidated Surficial Deposits Groundwater

Transport simulations were performed for chloride, selenium and sulfate in surficial deposits groundwater The results of these simulations predict plume concentrations 30 years after landfill closure Nitrate/nitrite was not modeled because Figure E-3 shows that the mean concentrations in the surficial deposits groundwater are well below the ARAR of 10 mg/L for nitrate The simulated chloride plume concentrations (Figure E-5) at the proposed compliance boundary (well 53194) approach 150 mg/L which is below the ARAR concentration of 250 mg/L Selenium concentrations at 30 years approach 300 µg/L at the proposed compliance boundary significantly higher than the 10 µg/L ARAR standard (Figure E-6) Simulated sulfate concentrations also exceed the ARAR (250 mg/L) at the proposed compliance boundary with plume concentrations at 30 years exceeding 1 200 mg/L at 53194 (Figure E-7) The selenium and sulfate simulations may be overly conservative, considering the weathered bedrock groundwater concentrations are modeled as a continuous source for the surficial deposits groundwater

The 30-year contaminant transport modeling shows that the predicted selenium and sulfate concentrations in surficial deposits are greater than the corresponding ARARs at the proposed compliance boundary It should be noted that the selenium source is upgradient of the East Landfill Pond dam The clay core of the dam is keyed into bedrock and would likely impede the migration of contaminants in surficial deposits groundwater The presence of the dam was neglected during modeling simulations because of limitations associated with the solution technique Modeling results indicate that inorganic contaminants in weathered bedrock groundwater and 1 1-dichloroethane in unconsolidated surficial deposits groundwater show insignificant movement as simulated concentrations of the respected analytes are well below the corresponding ARARs at the proposed compliance boundary Modeling results indicate that inorganic contaminants in surficial deposits groundwater may exceed ARARs at the proposed compliance boundary, however the modeling neglected the East Landfill Pond dam, which impedes groundwater flow

Predicted 1,1-dichloroethane concentrations show only slight plume migration from the leachate seep source, with simulated concentrations significantly less than the ARAR (59 µg/L) at the compliance boundary (Figure E-8)

E 4 2 Weathered Bedrock Groundwater

Predicted chloride, nitrate/nitrite, selenium, and sulfate concentrations 30 years after landfill closure are presented in Figures E-9 through E-12. The simulated results show insignificant plume migration due to the low seepage velocity of 6.6 x 10^{3} ft/day (2 3 x 10^{-6} cm/sec), suggesting that diffusion is the primary mechanism of contaminant transport The seepage velocity value of 10^{-6} cm/sec is within the range of sitewide values for weathered claystones where solute transport is dominantly controlled by diffusion (significantly less than the Peclet number of 0.02) (EG&G 1995)

E.5 Sensitivity Analysis

E.5 1 Weathered Bedrock

The plume simulation results for weathered bedrock groundwater (Figures E-9 through E-12) do not appear reasonable based on the configuration of the present day plumes (Figures E-1 through E-4) Figures E-1 through E-4 show more plume migration than the results of the modeling analysis for weathered bedrock groundwater (Figures E-9 through E-12) It is possible that the hydraulic conductivity value used (2 2 x 10^{2} ft/day) may not be representative of actual site conditions downgradient of the landfill dam. Therefore, a sensitivity analysis on the hydraulic conductivity value was conducted The upper 95 percent confidence limit value (based on sitewide data) of 0 16 ft/day for weathered sandstones (EG&G 1995) is used for the sensitivity analysis This value provides an upper limit, which is representative of the weathered strata and offers a more conservative prediction of future plume concentrations.

Figures E-13 through E-16 show the 30-year plume migration for chloride, nitrate/nitrite, selenium, and sulfate concentrations. These results appear to be more reasonable given the configuration of the present-day plume geometries The simulation results also show that the plume concentrations for each analyte are significantly less than the corresponding ARARs at the proposed compliance boundary

E.5 2 Dispersivity

A sensitivity analysis of the dispersivity value was also conducted because of the absence of direct measurements from laboratory and/or field tracer tests The sensitivity analysis includes simulations where the original dispersivity values are doubled and halved Figure E-17 shows the results with the dipersivity values doubled

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(α_L= 120 ft α_T = 12 ft, α = 1 2 ft) As expected, there is slightly more spreading of the plume with the greater dispersivity values resulting in lower concentrations at the compliance boundary Figure E-18 displays the plume configuration with the dispersivity values halved (α_L= 30 ft α_T = 3 ft, α_z = 0 3 ft) This simulation result shows a sharper solute front with greater concentrations slightly farther from the source The selenium concentrations (300 µg/L) at the proposed compliance boundary exceed the ARAR of 250 mg/L Although Figures E-6 E-17, and E-18 show slightly different concentrations at the proposed compliance boundary the plume configurations show only subtle variations in geometry

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Table E 1
Parameters for Groundwater Contaminant Transport Model

Simulation/Figure	Analyte	K (ft/day)	dh/dx	q (ft/day)	[illegible]	V (ft/day)	Aquifer Thickness (ft)	Dispersivity (ft) α_L	α_T	α_Z	Molecular Diffusivity (m^2/sec)	[illegible]	Decay Rate (/day)	[illegible]	Solute Sources/Grid Coordinates: Source Type	X	Y	Width	Source Concentration (mg/L)	Flow Rate (ft³/day)	Time (years)
Unconsolidated Surficial Deposits Groundwater																					
Figure E 5	Chloride	7 3	0 03	0 22	0 1	2.2	7	60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	2,200 2,400	800 800	160 40	300 300	270 30	30
Figure E-6	Selenium	7 3	0 03	0.22	0 1	2.2	7	60	6	0 6	1×10^{9}	0 5	0	1 1	Vertically Mixed	2 400 2,450	650 600	160 10	650 600	246 15	30
Figure E 7	Sulfate	7 3	0 03	0 22	0 1	2 2	7	60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	3 150	650	200	2 600	308	30
Figure E-8	1 1 dichloroethane	7 3	0 03	0 22	0 1	2 2	7	60	6	0 6	1×10^{9}	0 5	5 21 $\times 10^{3}$	8 26	Vertically Mixed	2,300 2 310 2 320 2,330	750 750 750 750	15 15 15 15	010 010 010 0 005	23 23 23 23	30
Weathered Bedrock Groundwater																					
Figure E 9	Chloride	0 022	0 03	$6 6 \times 10^{4}$	0 1	$6 6 \times 10^{3}$	20	60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	3 150 3,300 3 400	600 600 600	400 250 40	496 490 400	6 3 5 1 2	30
Figure E 10	Selenium	0 022	0 03	$6 6 \times 10^{4}$	0 1	$6 6 \times 10^{-3}$	20	60	6	0 6	1×10^{9}	0 5	0	1 1	Vertically Mixed	2 400 3 450 2 450 2,425	650 600 650 650	160 20 100 150	660 660 400 500	2 1 0 26 1 3 2 0	30
Figure E 11	Nitrate/ nitrite	0 022	0 03	$6 6 \times 10^{4}$	0 1	$6 6 \times 10^{3}$	20	60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	3 100 3 150 3,250 3,150	500 650 650 500	240 200 100 120	157 50 50 110	3 2 6 1 3 1 6	30
Figure E 12	Sulfate	0 022	0 03	$6 6 \times 10^{4}$	0 1	$6 6 \times 10^{3}$	20	60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	3,200 3 150 3,250 3,175	650 650 700 650	200 200 200 200	2 600 2 600 2 600 1,500	3 3 3 3	30
Sensivity Analysis																					
Figure E 13	Chloride	0 16	0 03	$4 8 \times 10^{3}$	0 1	$4 8 \times 10^{2}$		60	6	0 6	1×10^{9}	0 5	0	1 0	Vertically Mixed	3 150 3 300 3,400	600 600 600	400 250 40	496 490 400	40 24 4	30

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Table E-1
Parameters for Groundwater Contaminant Transport Model

Figure E-14	Selenium	0.16	0.03	4.8×10^{-3}	0.1	4.8×10^{-2}	20	60	6	0.6	1×10^{-6}	0.5	0	1.1	Vertically Mixed	2,400 2,450	650 600	160 10	.650 .600	5.9 0.5	30
Figure E 15	Nitrate/nitrite	0.16	0.03	4.8×10^{-3}	0.1	4.8×10^{-2}	20	60	6	0.6	1×10^{-6}	0.5	0	1.0	Vertically Mixed	3,100 3,150 3,250 3,150	500 650 650 500	240 200 100 120	157 10 10 10	23 19 10 12	30
Figure E 16	Sulfate	0.16	0.03	4.8×10^{-3}	0.1	4.8×10^{-2}	20	60	6	0.6	1×10^{-6}	0.5	0	1.0	Vertically Mixed	3,150 3,250	650 700	200 200	2,600 200	20 20	30
Figure E 17	Selenium	7.3	0.03	0.22	0.1	2.2	20	120	12	1.2	1×10^{-6}	0.5	0	1.1	Vertically Mixed	2,400 2,450	650 600	160 10	.650 .600	246 15	30
Figure E 18	Selenium	7.3	0.03	0.22	0.1	2.2	20	30	3	0.3	1×10^{-6}	0.5	0	1.1	Vertically Mixed	2,400 2,450	650 600	160 10	.650 .600	246 15	30

Grid Coordinates

Length of grid in flow direction 3000 ft. number of spaces: 30
Width of Grid: 1500 ft. number of spaces: 30
Depth of Plume (dz): 0 ft.
(Predicted concentrations on top of aquifer)

Key:

K hydraulic conductivity
dh/dx hydraulic gradient
q Darcy velocity
η effective porosity
v seepage velocity
α_L longitudinal dispersivity
α_T transverse dispersivity
α_V vertical dispersivity
ω tortuosity coefficient
R retardation coefficient
ft feet
m meters
sec second
L liters

Figure E-5
Chloride Concentrations (mg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Seepage Velocity = 2 2 ft/day

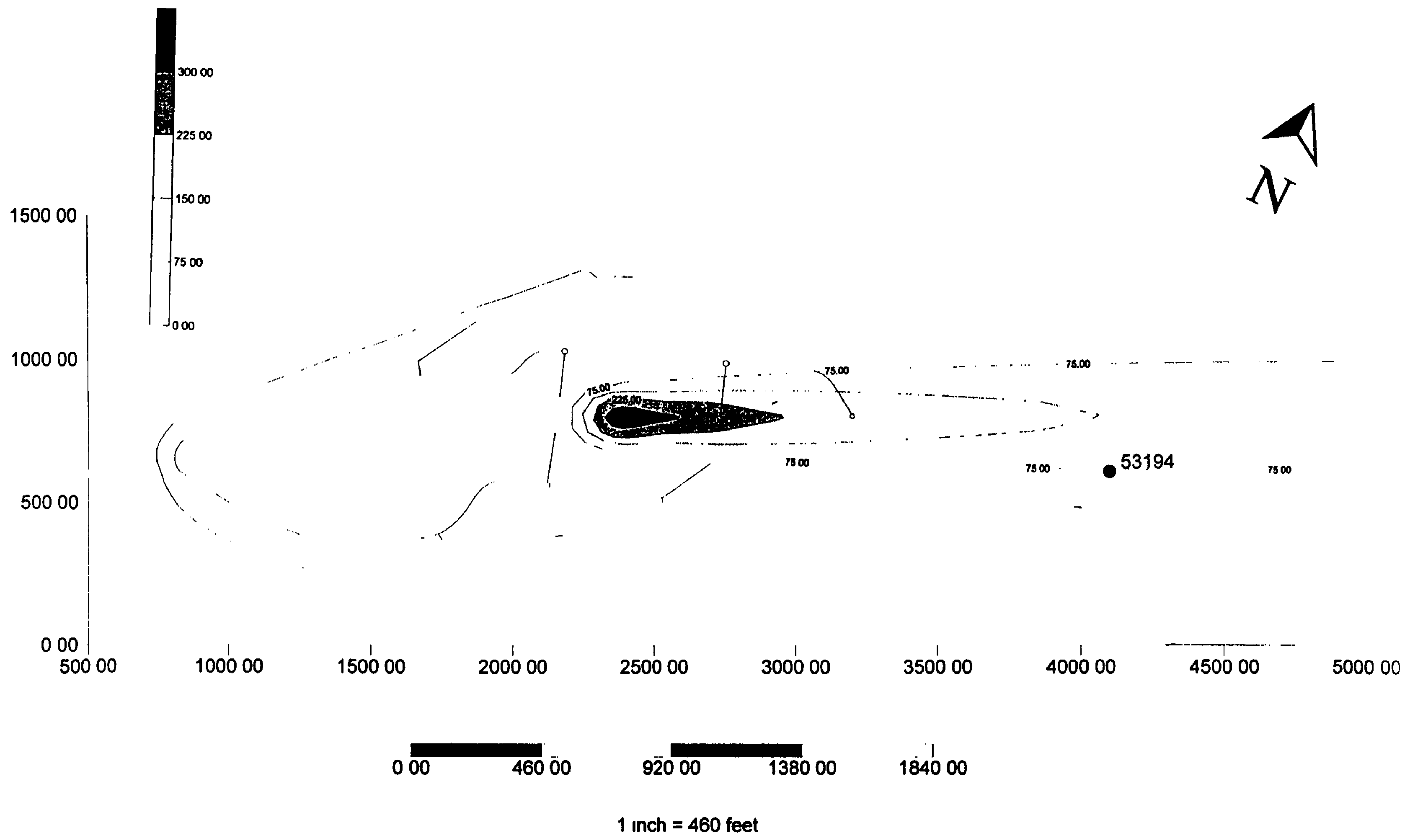

Figure E-6
Selenium Concentrations (µg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Seepage Velocity = 2 2 ft/day

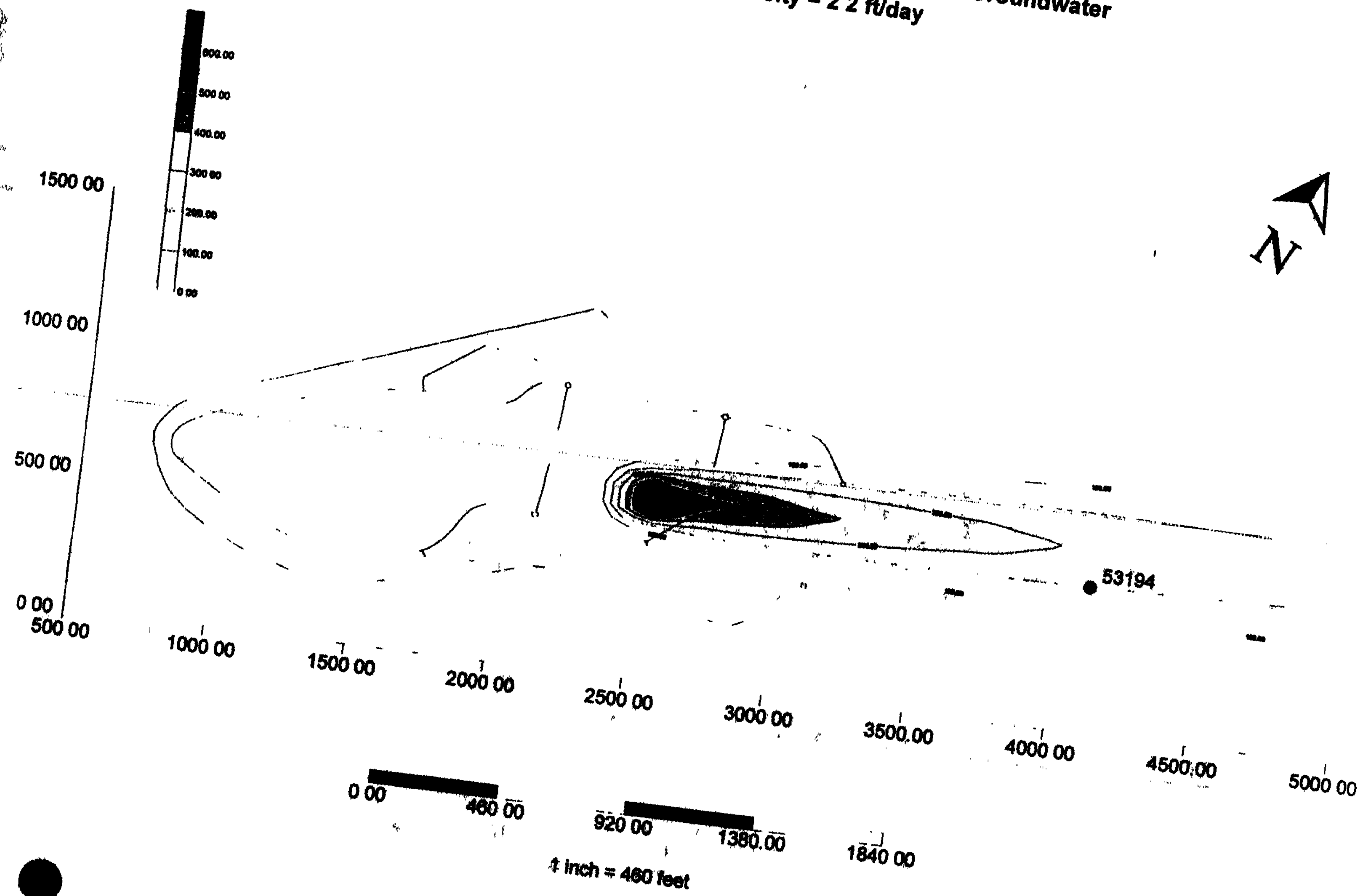

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Figure E-7
Sulfate Concentrations (mg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Seepage Velocity = 2 2 ft/day

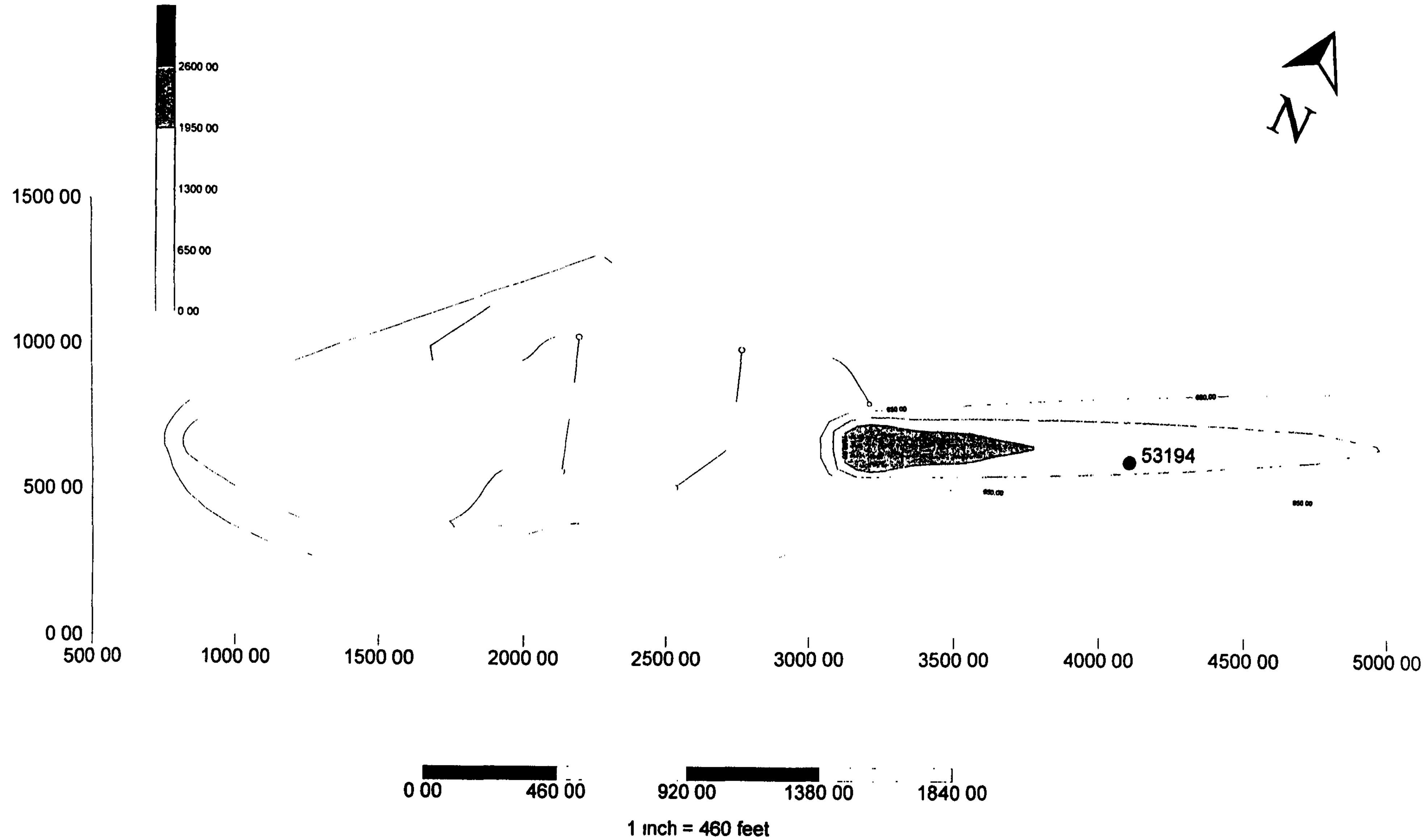

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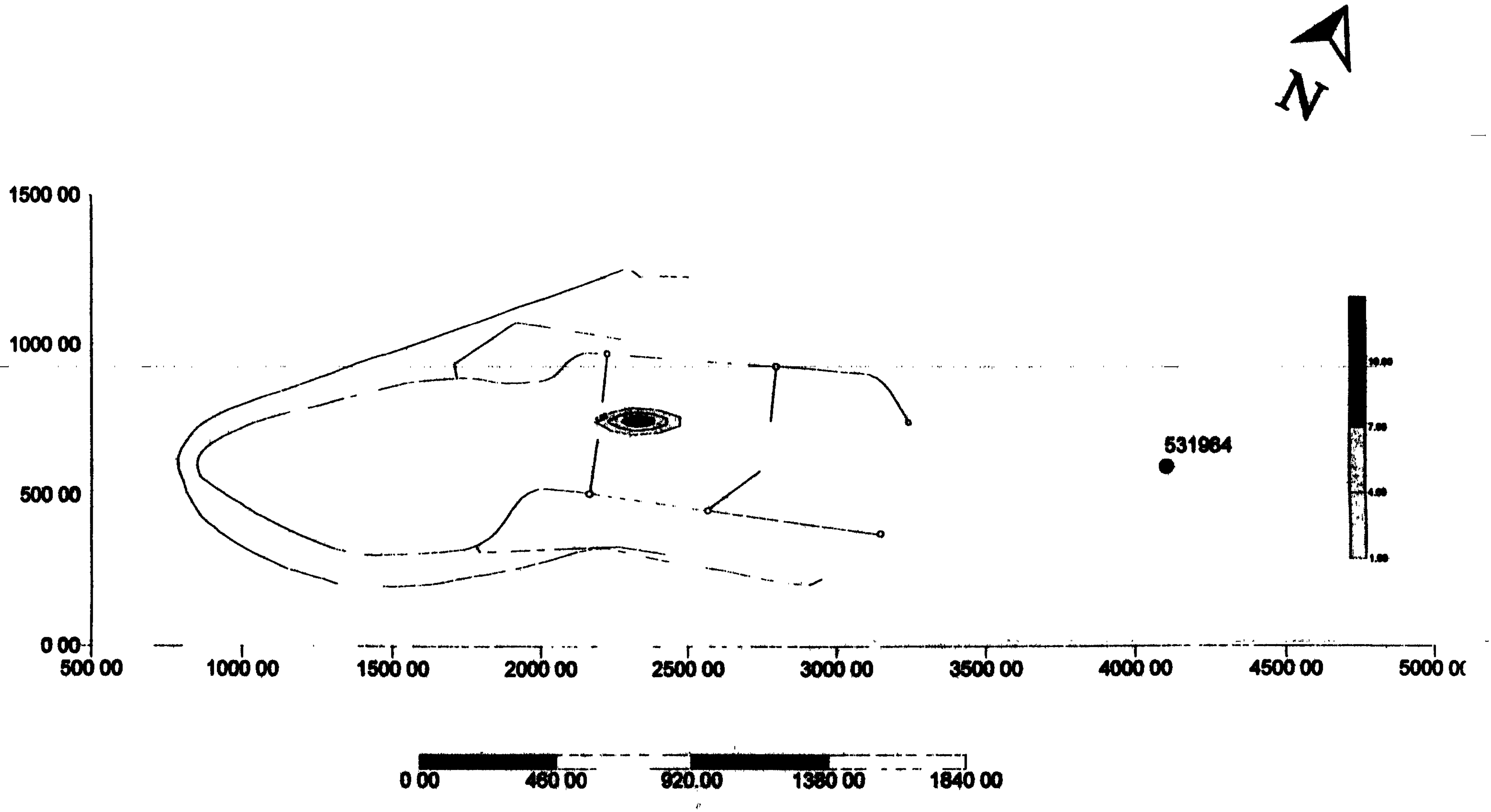
Figure E-8
1,1 Dichloroethane Concentrations (µg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Seepage Velocity = 2 2 ft/day



1 inch = 460 ft

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Figure E-9
Chloride Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Seepage Velocity = 6 6E-03 ft/day

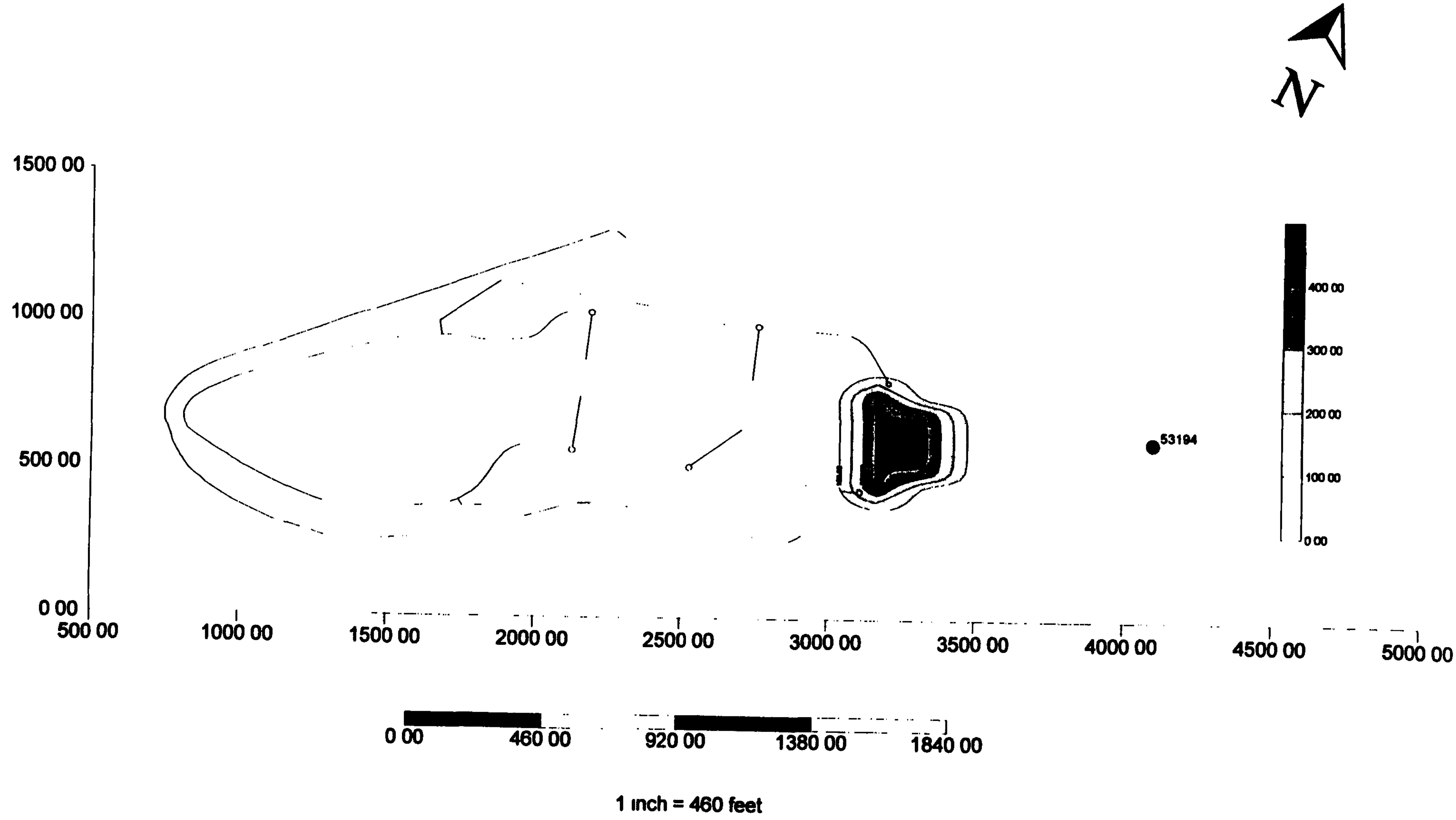

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Figure E-10
Selenium Concentrations (µg/L) in Weathered Bedrock Groundwater
30-year Simulation, Seepage Velocity = 6.6E-03 ft/day

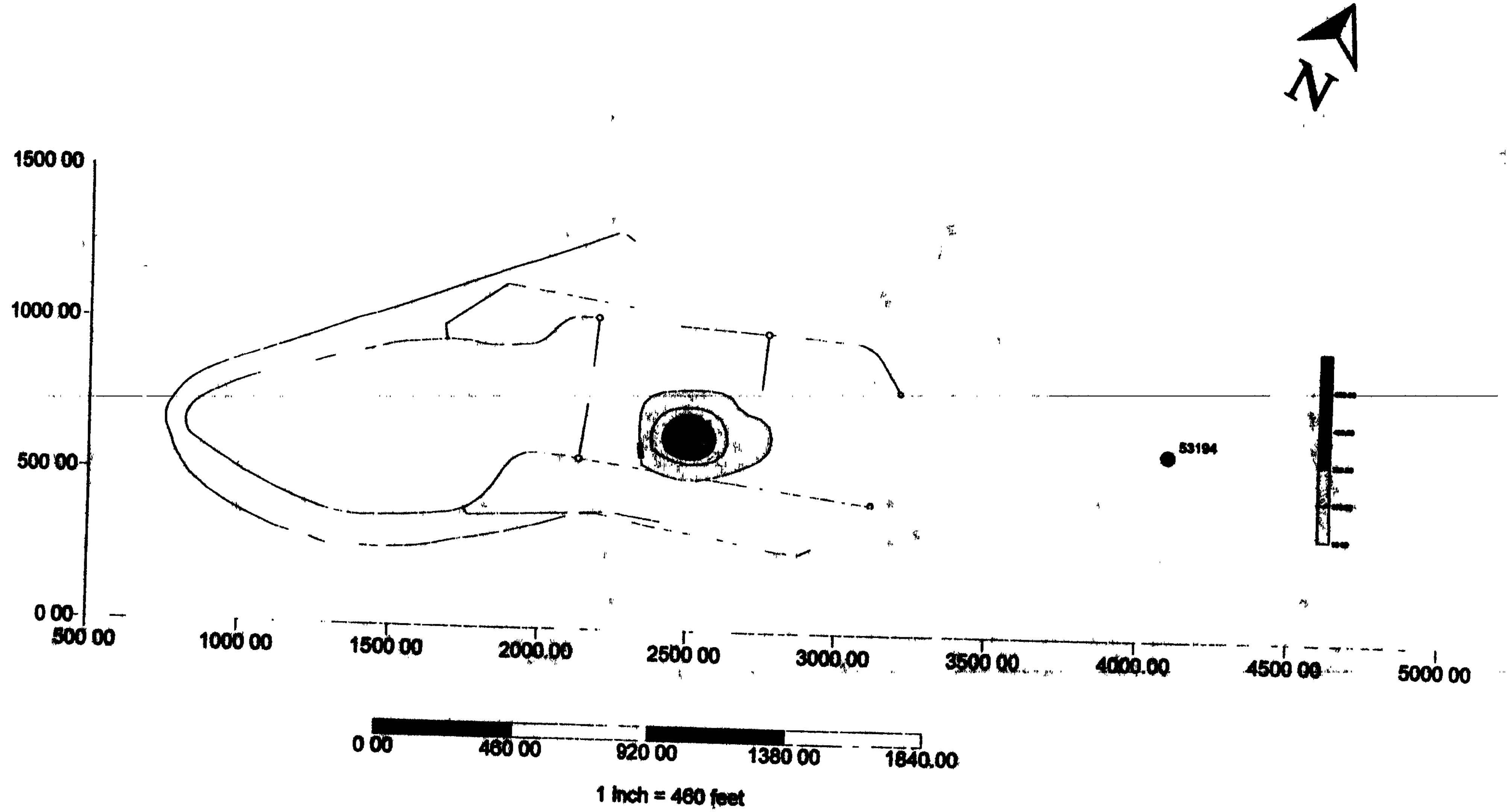

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Figure E-11
Nitrate/Nitrite Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Seepage Velocity = 6 6E-03 ft/day

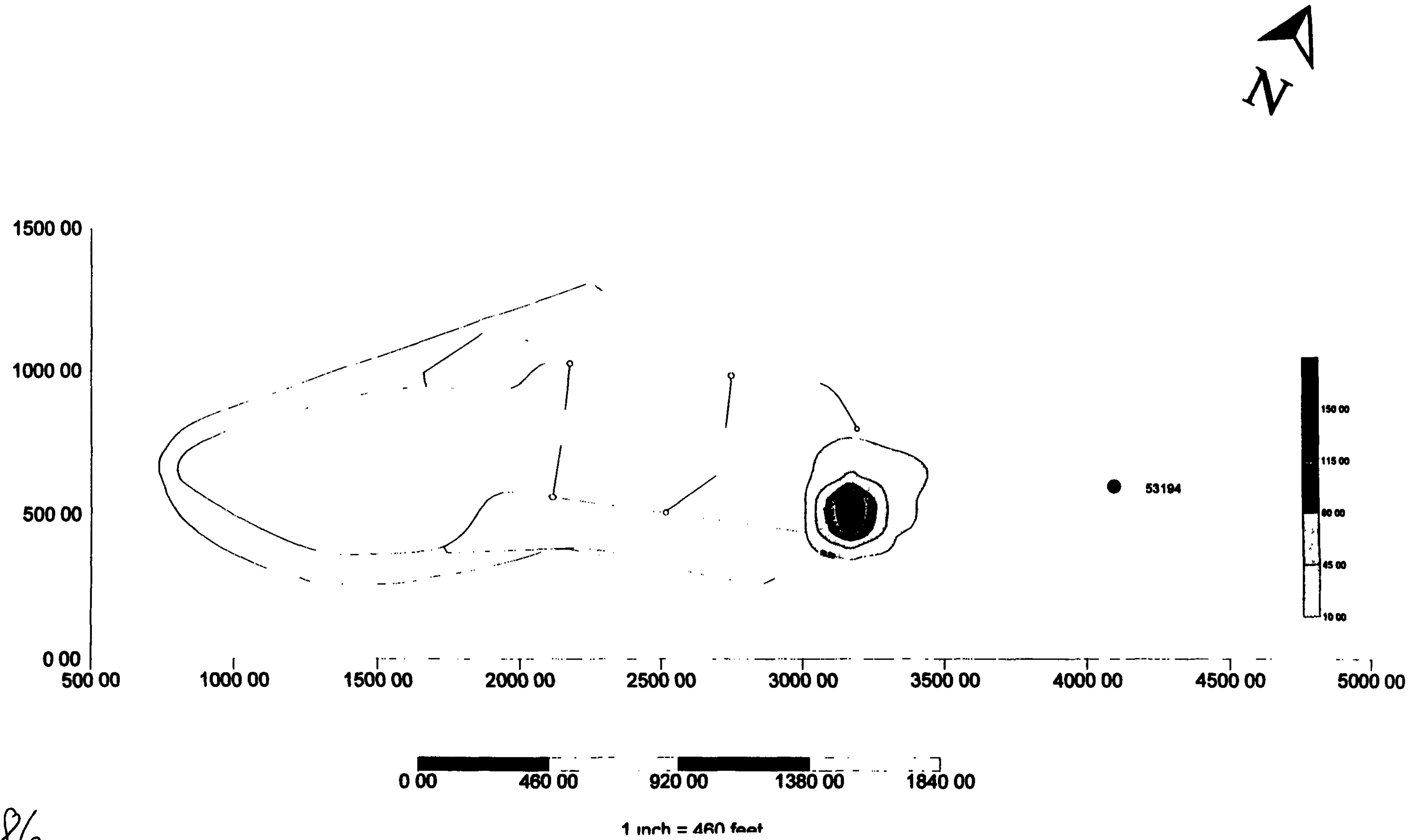

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Figure E-12
Sulfate Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Seepage Velocity = 6 6E-03 ft/day

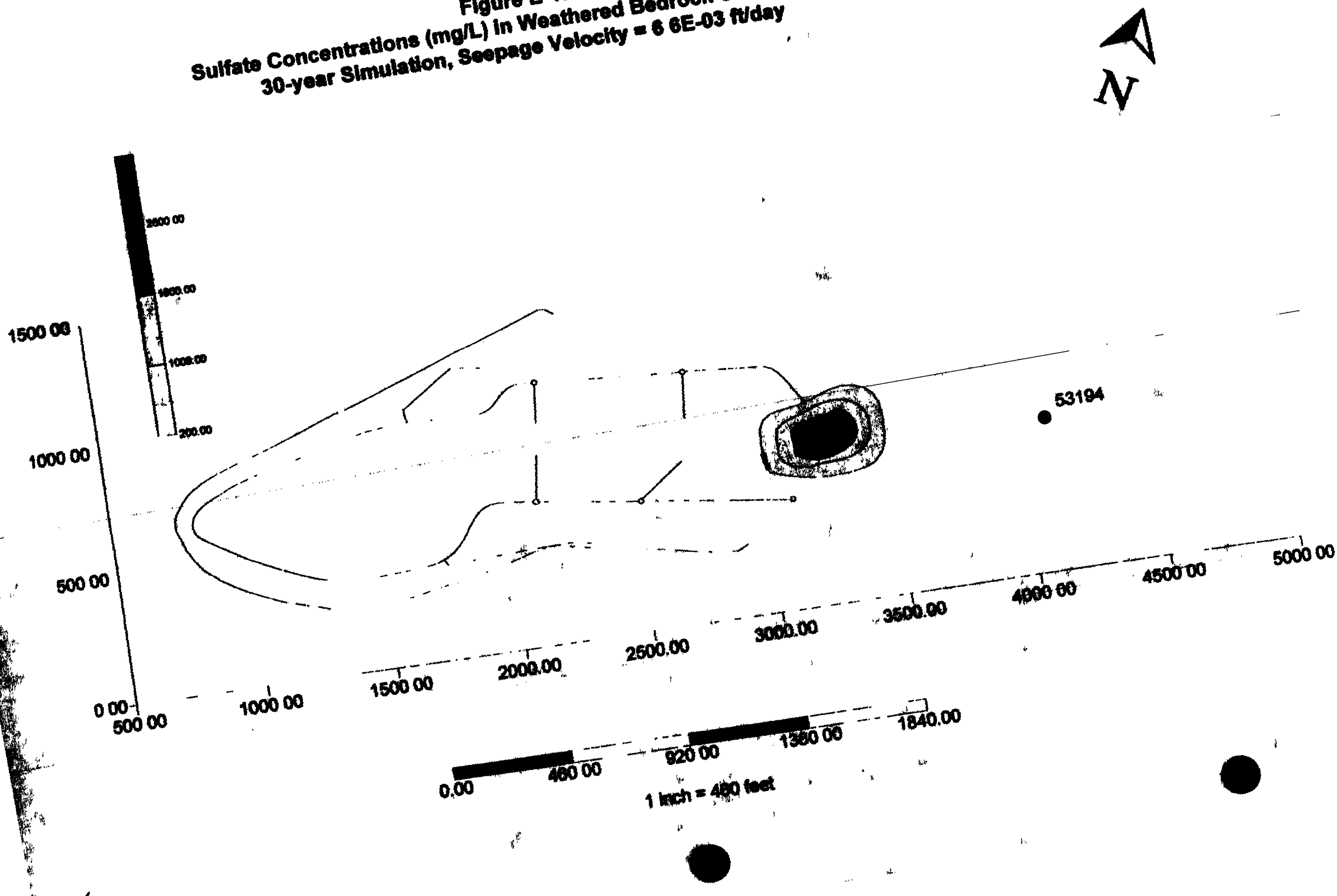

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Figure E-13
Chloride Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Sensitivity Analysis Seepage Velocity = 0 048 ft/day

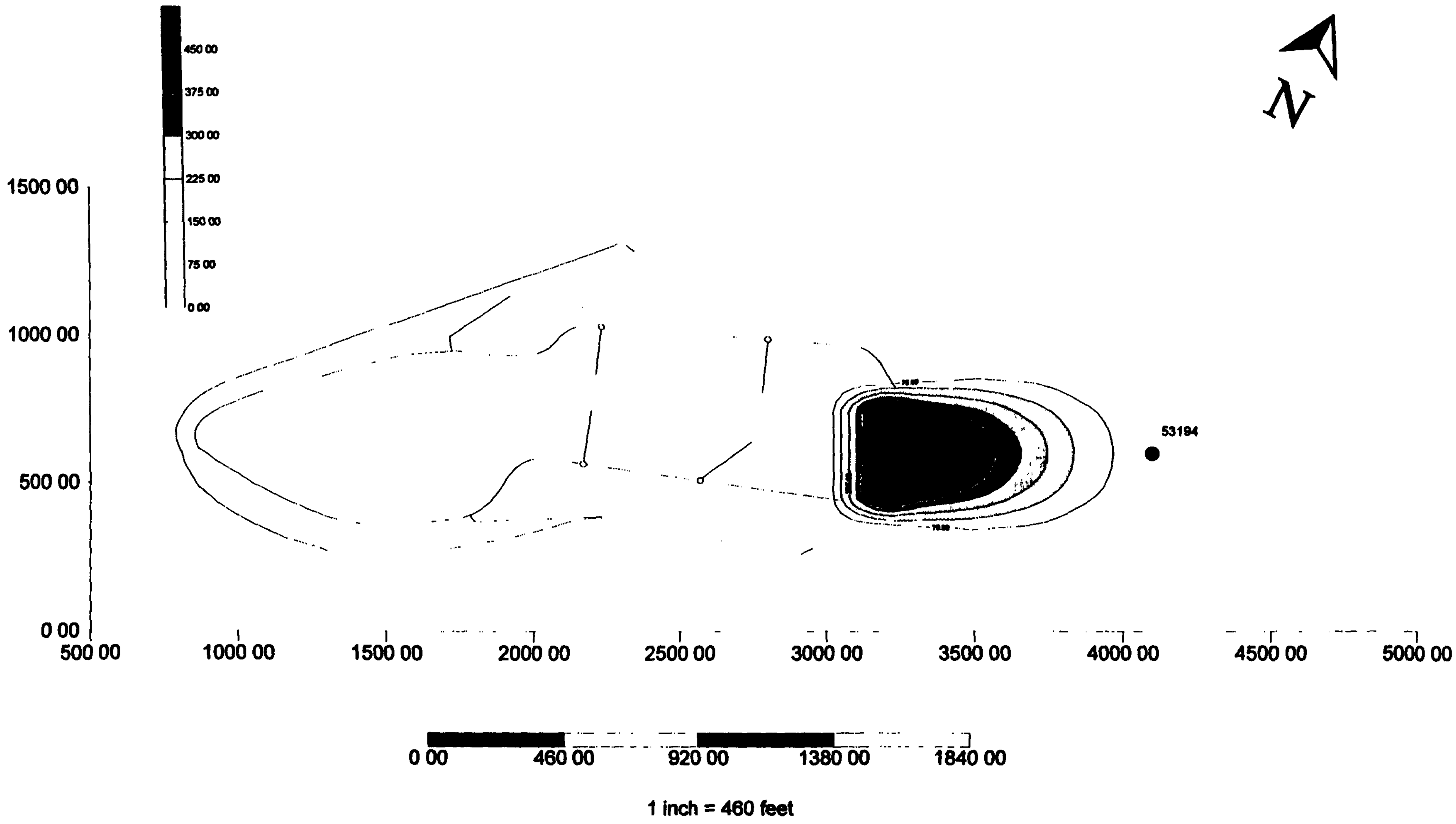

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Figure E-14
Selenium Concentrations (µg/L) in Weathered Bedrock Groundwater
30-year Simulation, Sensitivity Analysis Seepage Velocity = 0 048 ft/day

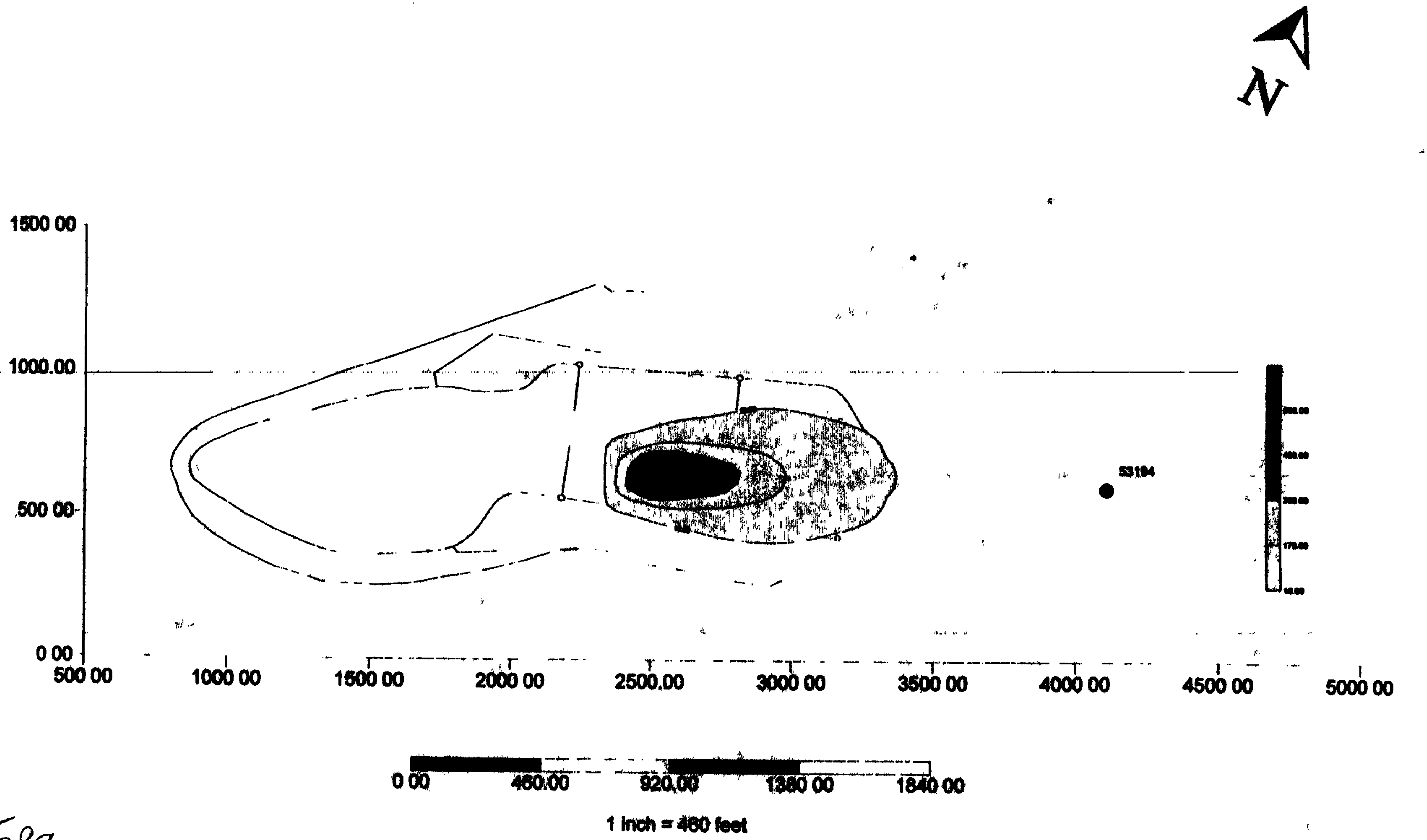

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Figure E-15
Nitrate/Nitrite Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Sensitivity Analysis Seepage Velocity = 0 048 ft/day

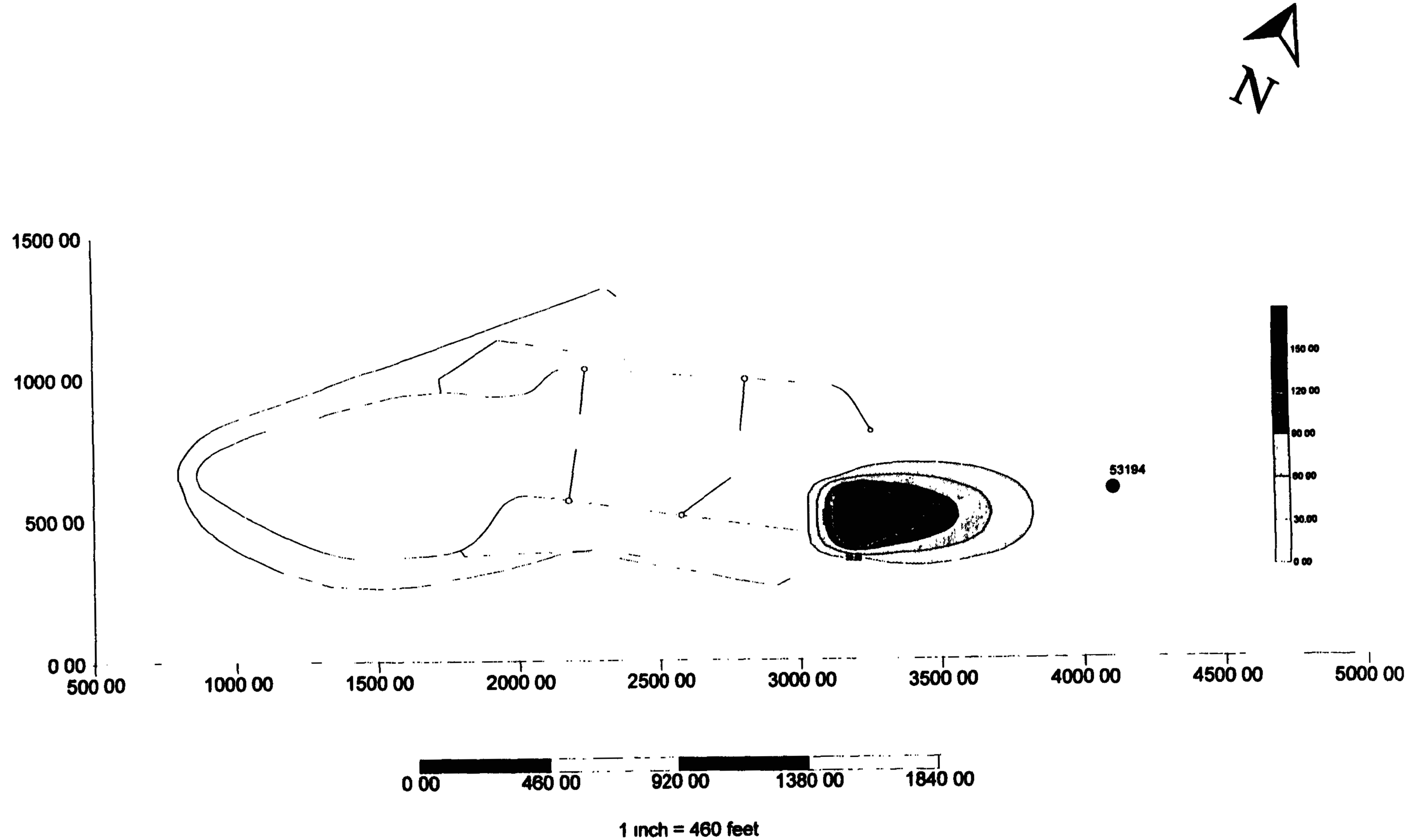

Figure E-16
Sulfate Concentrations (mg/L) in Weathered Bedrock Groundwater
30-year Simulation, Sensitivity Analysis: Seepage Velocity = 0.048 ft/day

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Figure E-17
Selenium Concentrations (µg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Sensitivity Analysis Dispersivity Values Doubled

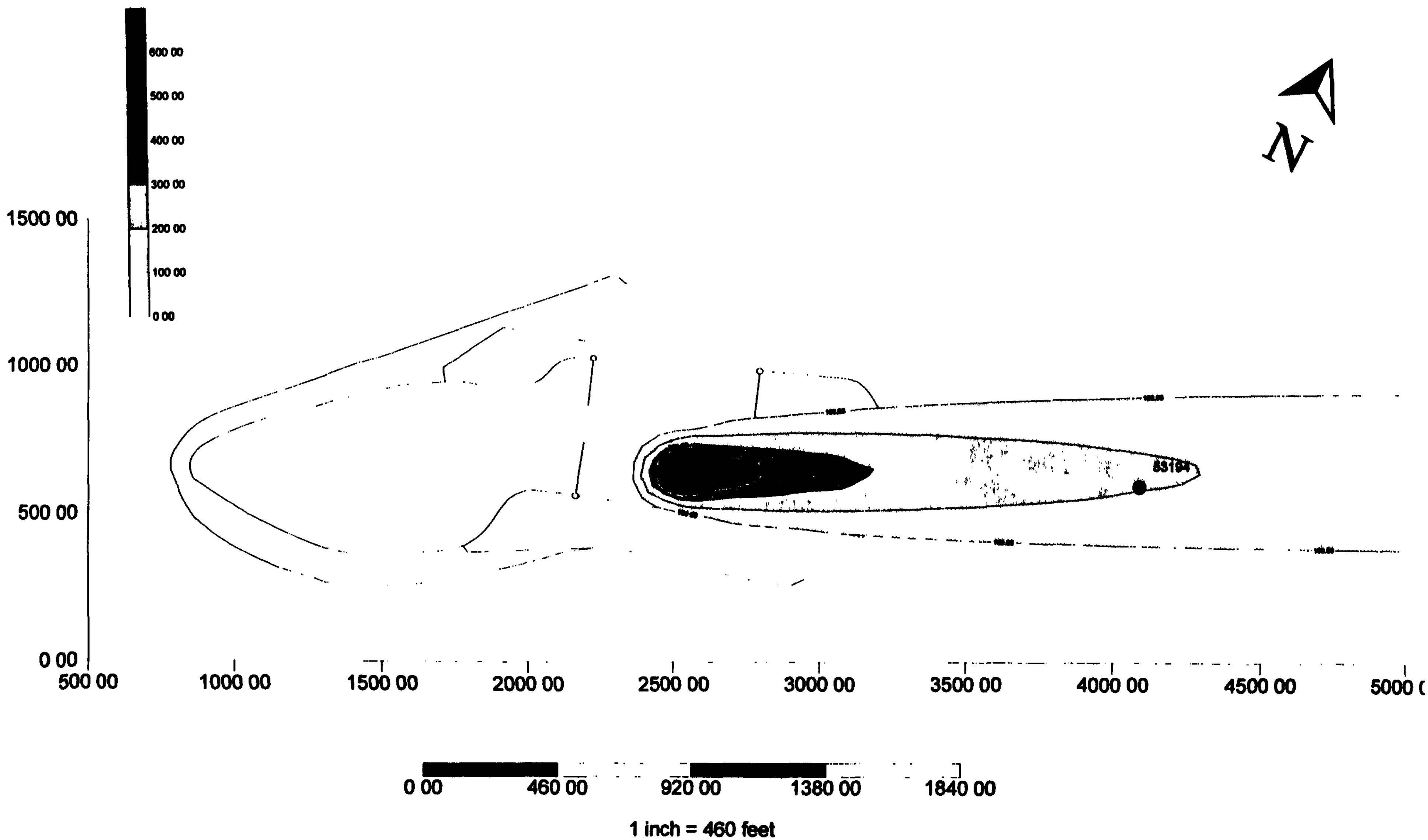

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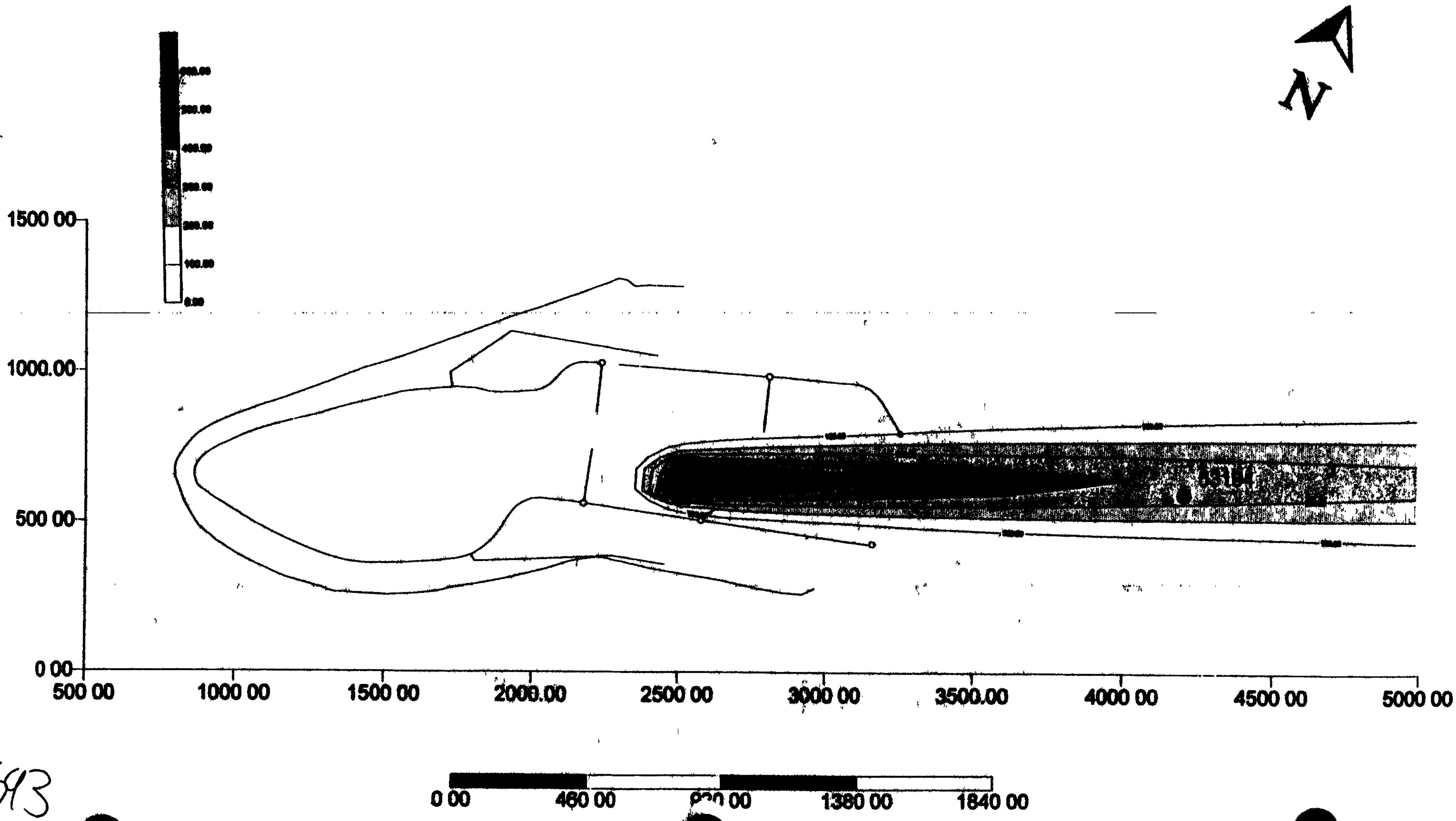
Figure E-18
Selenium Concentrations (µg/L) in Unconsolidated Surficial Deposits Groundwater
30-year Simulation, Sensitivity Analysis· Dispersivity Values Halved (x 0 5)



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F 1 Purpose of the Analysis

The purpose of the waste settlement analysis is to assess the impact waste settlement might have on the drainage characteristics of the proposed cover design for the Present Landfill at Operable Unit (OU) 7

Literature sources suggest that waste settlement in municipal landfills can approach 33 percent of the waste thickness (Brunner 1972) Settlement of this magnitude at OU 7 could conceivably affect the drainage patterns on the cover surface by changing the slope or direction of flow in localized areas Changes in drainage patterns could result in erosion or local ponding necessitating costly repairs to the vegetative layer

Settlement models used to estimate the changes in surface elevation as a result of waste and fill consolidation included a simple percent of thickness assessment, Sower's method, Gibson and Lo model, and the power creep law

F.2 Description of Grading Plan

The proposed grading plan has a rectangular-shaped mound along the central longitudinal axis of the landfill The 7-percent slopes of this mound are designed to shed water off the cover surface radially to perimeter drainage ditches To achieve this configuration up to 15 feet of general fill material may potentially be required in the central portion of the landfill Because the landfill base is a v-shaped trough following the former drainage along the central longitudinal axis the thickest sections of the waste (and fill material) are also found along this axis Settlement in this area can be expected to be greater than in other areas

F 2 1 Landfill Settlement

Landfill settlement occurs as a result of waste decomposition, filtering of fine materials and consolidation under the weight of the waste material Settlement is also influenced by the thickness of soil cover material used, compressibility of the waste compaction during waste placement age of the waste and the amount of water present to promote biodegradation (Brunner 1972) Other factors such as initial waste density, waste composition, pH, temperature, and depth are also considered to affect settlement (Fasset 1993)

F 2 2 Differences Between Typical Municipal Solid Waste and OU 7 Waste

The waste composition of the landfill at OU 7 is reported to consist of construction debris nonhazardous industrial wastes sludges and wastes generated by maintenance

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operations This differs from municipal landfills, which commonly contain a heterogeneous mixture of materials primarily composed of household refuse, commercial wastes such as plastics, and inert material such as glass and metals (DOE 1994) Because the composition of waste at OU 7 differs from typical municipal waste, the amount of biodegradation and resulting settlement may also be reduced.

The amount of daily cover soil used at OU 7 is reported to be as high as 30 percent (DOE 1994) Although municipal landfills have been known to use daily cover amounts as high as 30 percent, this generally is not the case Because soils are generally more dense, less compressible, and less subject to biodegradation than municipal wastes, the higher percentage of soil at OU 7 will tend to reduce the amount of settlement compared to a municipal landfill.

As mentioned above, the landfill cover design requires a substantial amount of fill material to be placed on the central portion of the landfill. An estimated 230,000 yd^3 will be necessary to create the central mound. This will increase the elevation of the surface of the landfill by approximately 15 feet above the present elevation in certain areas Placement of this fill material will surcharge the existing waste layers and initiate a new "primary settlement" phase. Literature sources suggest, however, that this settlement will take place within the first three months of load placement (Fasset 1993) This additional compression of the existing waste prior to construction of the final cover will reduce the ultimate settlement after closure

F.3. Methodology

In general, the methodology to evaluate surface settlement involves selecting points on the cover surface, computing the settlement at each point, and evaluating the resultant change in surface elevation

Points were selected from cross sections located at four representative locations transverse to the longitudinal axis The cross sections were positioned where the waste and fill material is thickest Several points are selected along each cross section for settlement evaluation These points are generally located along the central longitudinal axis, at the outer edges of the landfill, and at a position generally between these two points At each point, the settlement is computed using the four settlement methods, a simple percent settlement based on waste thickness, Sowers method, Gibson and Lo model, and the power creep law

Sharma and Lewis present methods by Sowers, Gibson and Lo, and the power creep law for determining settlement in landfills (Sharma and Lewis 1994) These methods are based on general soils consolidation theory, which relates settlement to layer thickness and changes in void ratio Although these methods are similar in form, they

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use change in overburden pressure time of load application and compressibility factors instead of change in void ratio in the general consolidation theory equation

F 3 1 Percent Settlement

This simple approach asserts that waste settlement is a uniform function of waste thickness For example, if a 15-percent waste settlement is assumed, then the settlement at each point is 0 15 times the waste thickness at that point

As mentioned above, waste settlement at OU 7 may be significantly less than typical municipal landfills due to differences in waste composition, amount of soil cover, and surcharging the waste with additional fill For the purposes of this comparative study, 15 percent settlement was used

F 3 2 Sowers Method

The Sowers method consists of summing functions representing primary settlement and secondary compression As mentioned above the primary settlements of the OU 7 waste fill will most likely occur before the cover is constructed Therefore, only the secondary compression relationship was used in estimating settlement in this case The form of this relationship is as follows

$$S_s = H\,C_\alpha/(1+e_0)\log(t_2/t_1)$$

Where

S_s = secondary compression occurring in layer under consideration
H = initial thickness of waste layer under consideration
C_α = secondary compression index
e_0 = initial void ratio
t_2 = starting time for long-term time period under consideration
t_1 = ending time for the long-term period under consideration

Fasset (1993) discusses the problems associated with using the secondary compression index and void ratio term $C_\alpha/(1+e_0)$ and suggests the use of a modified secondary compression index term defined as

$$C_{\alpha m} = C_\alpha/(1+e_0)$$

Using this term the Sowers equation then becomes

$$S_s = H\,C_{\alpha m}\log(t_2/t_1)$$

Fasset (1993) also states that typical values for the modified secondary compression index term reported in the literature range from 0 001 to 0 59 with the majority of the values ranging between 0.01 and 0 1

The modified secondary compression index value selected for the OU 7 settlement analysis is 0 04 This value was reported for the Burlingame landfill in Fasset's database (Fasset 1993) The Burlingame landfill has waste thicknesses ranging from 6 to 30 feet and waste age ranging from 5 to 15 years The OU 7 landfill is similar in age and waste thickness Because the Burlingame landfill is a municipal waste facility, these compression assumptions are felt to be conservative for the OU 7 analysis

As with the other settlement methods used, the time frame considered for secondary waste settlement is 30 years

F.3.3 Gibson and Lo Model

The Gibson and Lo model for refuse is as follows (Sharma and Lewis 1994)

$$S(t) = H \Delta\sigma \{a + b[1-\exp(-\lambda/b)]\}$$

Where

$S(t)$ = settlement at time t
H = initial height of refuse
$\Delta\sigma$ = change in overburden pressure
a = primary compressibility parameter
b = secondary compressibility parameter
λ/b = rate of compression
t = time since load application

Sharma and Lewis (1994) also present a series of point plots, developed by Edil *et al.* (1990), which provide a means to estimate the primary compressibility factor, a, the secondary compressibility factor, b, and the rate of secondary compression, λ/b

The compressibility factors, a and b, are plotted as a function of applied stress, $\Delta\sigma$ Since this value in the OU 7 waste settlement analysis is point specific and dependent on the thickness of the waste mass, it is necessary, for ease of computation, to assume a best-fit line through the point plots and establish a linear equation that can be used to calculate the compressibility factors at each settlement point The linear equations used are as follows

$$Ln(a) = -0\ 03442\ (\Delta\sigma) - 7\ 155$$
$$Ln(b) = -0\ 01386\ (\Delta\sigma) - 4\ 8283$$

The value for the rate of secondary compression, l/b, was selected from the midpoint of the data presented in the point plot This value is 0 0007/day

F 3 4 Power Creep Law

The power creep law presented is expressed in the following form (Sharma and Lewis 1994)

$$S(t) = H\ \Delta\sigma\ m\ (t_r/t\}^n$$

Where

$S(t)$ = settlement at time t
H = initial height of refuse
$\Delta\sigma$ = change in overburden pressure
m = reference compressibility
t_r = compression rate
t = reference time used to make time dimensionless
n = time since load application

As with the Gibson and Lo model above, the power creep law uses empirically derived values for factors m and n (Edil *et al* 1990) For the OU 7 waste settlement analysis, a value corresponding to old refuse is used for m and a mid-range value is selected for n as follows

$m = 3\ 4 \times 10^{5}$ (1/kPa)
$n = 0\ 65$

It should be noted that with the power creep law settlement is directly proportional to the length of time since the load (additional waste placement) is applied to a given layer Thus as the time duration is extended, the settlement increases This may not be a reasonable assumption when long time periods are considered because at some point consolidation will reach a maximum and settlement will cease

F 4 Results

Table F-1, Settlement Method Comparison, lists the initial waste and fill thicknesses, elevation change due to settlement, and percent settlement as a function of initial waste thickness for points located on four representative cross sections through the landfill The percent settlement method at 15 percent settlement results in the greatest settlements compared to the other settlement methods As previously stated, this method is a simple approach based on historical municipal landfill settlement data and

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is considered conservative in this application The other analytical methods predict lesser settlements.

It is not surprising that the point that all methods predict will undergo the greatest settlement is in the area where the waste and fill is thickest. Settlement values at this point range from 5.5 feet (percent method) to 2 19 feet (Sowers method). If the 5 5 feet settlement is considered and changes in surface slope are developed by comparing this value to settlements in adjacent areas, the proposed design slope changes 7 percent to between 3 and 5 percent. A slope change of this magnitude will have little effect on the drainage flow or velocity characteristics of surface runoff In addition, these post settlement surface slopes remain within the recommended EPA guidance for covers (EPA 1989)

F.5. References

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Sharma, Hari D , Ph D , P E , Lewis, Sangeeta P 1994 "Waste Containment Systems, Waste Stabilization, and Landfills. Design and Evaluation," John Wiley & Sons, Inc , New York, New York

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Table F-1
Settlement Method and Comparison

Grid Points			Method Comparison							
Section	Pt. Number	Initial Waste Thickness H_o(ft)	Percent Method Delta Elev	Percent Method % Settlement	Sowers Method Delta Elev	Sowers Method % Settlement	Gibson & Lo Method Delta Elev	Gibson & Lo Method % Settlement	Power Creep Law Method Delta Elev	Power Creep Law Method % Settlement
2 2	1	6	0 90	15 00%	0 35	5 91%	0 08	1 36%	0 14	2 27%
(S N)	2	15	2 25	15 00%	0 89	5 91%	0 20	1 36%	0 34	2 27%
	3	23	3 45	15 00%	1 36	5 91%	0 61	2 65%	1 04	4 54%
	4	24	3 60	15 00%	1 42	5 91%	0 93	3 88%	1 63	6 80%
	5	15	2 25	15 00%	0 89	5 91%	0 40	2 65%	0 68	4 54%
	6	3	0 45	15 00%	0 18	5 91%	0 05	1 79%	0 09	3 02%
3 3	1	10	1 50	15 00%	0 59	5 91%	0 14	1 36%	0 23	2 27%
(S N)	2	20	3 00	15 00%	1 18	5 91%	0 27	1 36%	0 45	2 27%
	3	35	5 25	15 00%	2 07	5 91%	0 63	1 79%	1 06	3 02%
	4	27	4 05	15 00%	1 60	5 91%	0 94	3 47%	1 63	6 05%
	5	17	2 55	15 00%	1 00	5 91%	0 38	2 22%	0 64	3 78%
	6	8	1 20	15 00%	0 47	5 91%	0 11	1 36%	0 18	2 27%
4 4	1	13	1 95	15 00%	0 77	5 91%	0 18	1 36%	0 29	2 27%
(S N)	2	17	2 55	15 00%	1 00	5 91%	0 66	3 88%	1 16	6 80%
	3	23	3 45	15 00%	1 36	5 91%	1 50	6 51%	2 78	12 10%
	4	37	5 55	15 00%	2 19	5 91%	2 67	7 20%	5 04	13 61%
	5	25	3 75	15 00%	1 48	5 91%	1 54	6 15%	2 84	11 34%
	6	19	2 85	15 00%	1 12	5 91%	0 66	3 45%	1 15	6 05%
	7	10	1 50	15 00%	0 59	5 91%	0 14	1 36%	0 23	2 27%

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Table F-1
Settlement Method and Comparison

Grid Points			Method Comparison							
Section	PL Number	Initial Waste Thickness H_0(ft)	Percent Method Delta Elev.	Percent Method % Settlement	Sowers Method Delta Elev.	Sowers Method % Settlement	Gibson & Lo Method Delta Elev.	Gibson & Lo Method % Settlement	Power Creep Law Method Delta Elev.	Power Creep Law Method % Settlement
5'-5	1	7	1.05	15.00%	0.41	5.91%	0.19	2.65%	0.32	4.54%
(S-N)	2	15	2.25	15.00%	0.89	5.91%	0.58	3.88%	1.02	6.80%
	3	22	3.30	15.00%	1.30	5.91%	0.94	4.27%	1.66	7.56%
	4	34	5.10	15.00%	2.01	5.91%	1.45	4.27%	2.57	7.56%
	5	21	3.15	15.00%	1.24	5.91%	0.73	3.47%	1.27	6.05%
	6	9	1.35	15.00%	0.53	5.91%	0.26	3.06%	0.48	5.29%

Notes

Based on Cover Design Option Alternative 9
Based on fill values at section grid points on Design Grading Option
Waste Zone Settlement Assumptions:
A Percent Settlement Use 15 percent
Literature sources cite waste settlement ranges from 10 percent to 50 percent depending on factors such waste type time duration since deposition, overburden pressures, amount of soil cover etc OU 7 Work Plan cites soil cover usages of 30 percent, median age of waste of 15 years, and waste consisting of a blend of municipal and hazardous wastes. Fifteen percent settlement assumed in this analysis is consistent with waste fills of this age and soil content.
B Sowers
Use C alpha modified = 0.04 Burlingame (1985): LF in Chicago with similar waste thickness and age (Fassett et al.)
C Gibson & Lo
Use a = EXP((-0.03442 x DELTA OVERBURDEN PRESSURE) 7.155) (1/kPa)
Use b = EXP((-0.01386 x DELTA OVERBURDEN PRESSURE) 4.8383) (1/kPa)
Use lambda/b = 0.0007: based on mid range strain rate per day of 2.0: (1/DAY)
D Power Creep Law
Use m = 3.4×10^{-5} (1/kPa)
Use: n = 0.65: average value (Edil 1990)

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Help Output Files

G 1 Engineered Cover Performance Modeling

The primary purpose of an engineered cover is to minimize infiltration of precipitation and to limit percolation of water through contaminated soils and liner materials In determining the most effective engineered cover design, calculation of the amount of infiltration percolating through the engineered cover system is necessary to select the most viable cover components Infiltration is also important in prediction of the potential for contaminant leaching and migration through the underlying vadose zone soils The Hydrologic Evaluation of Landfill Performance (HELP), computer model Version 3 03 was used to estimate the amount of infiltration that would percolate through the final engineered cover design for OU 7 The HELP model was developed by the U S Army Corps of Engineers Waterways Experiment Station for the U S Environmental Protection Agency (EPA) It was developed to facilitate rapid and economical estimations of the water movement through and out of landfills HELP was chosen because of its widespread acceptance in the engineering community

The HELP model prediction of the infiltration rate was used to evaluate the relative effectiveness of several engineered cover designs It was also used to test the sensitivity of several input variables on the amount of leakage through the covers HELP is a quasi-two-dimensional computer code that models landfill performance with respect to the hydrologic cycle Figure G-1 presents a conceptual model of the hydrologic input and output data The model accepts weather, soil, and design data, and uses solution techniques that account for the effects of surface storage snowmelt runoff infiltration, evapotranspiration vegetative growth soil moisture storage, lateral subsurface drainage leachate recirculation unsaturated vertical drainage, and leakage through soil geomembrane or composite liners Landfill systems, including various combinations of vegetation cover soils waste cells lateral drain layers, low-permeability barrier soils and synthetic geomembrane liners may be modeled (HELP Model User's Guide for Version 3 1994) HELP does not account for capillary flow in the variably saturated cover components and as a consequence provides a conservative estimate of percolation through the engineered cover (Nichols 1991)

Eight engineered cover sections were modeled with HELP The eight proposed engineered cover design alternatives are shown in Figure G-2 All eight covers were modeled for comparison purposes to evaluate the relative performance of the different configurations The seven engineered cover designs were modeled using normal climatological and vegetation data for the Rocky Flats area Final HELP output files for the eight proposed cover design alternatives are provided in Attachment G1

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G 1 1 Soil Input

HELP allows the user to enter soil characteristics for a layer by either the default option or the manual option The HELP manual provides default soil types and the soil texture classification assigned using the Unified Soil Classification System (USCS) The defaults include values for geocomposite clay liners (GCLs), flexible membrane covers (FMCs), drainage nets, and numerous other lining materials Under the default option, the user selects soil textures for each layer HELP calculates the initial soil water content for each layer at a near equilibrium level

If the default parameters do not meet the project conditions, site-specific values can be entered as outlined below

The manual input option allows the user to enter values for porosity, wilting point, field capacity, initial soil water content (volumetric), saturated hydraulic conductivity, water content, and curve number These properties are defined below

- Porosity—the (volumetric) soil water content at saturation
- Field Capacity—the (volumetric) soil water content after a prolonged period of gravity drainage
- Wilting Point—the lowest (volumetric) soil water content that can be achieved by plant transpiration
- Hydraulic Conductivity—the rate at which water drains vertically through a saturated soil with no pressure gradient
- Soil Water Content—the ratio of the volume of water in soil to the total soil volume

SCS Runoff-Curve Number The concept of runoff-curve numbers was developed by the Soil Conservation Service (SCS) to permit estimation of the relative amount of surface-water runoff that would result from a rainfall event. Runoff-curve numbers are a function of soil permeability, the antecedent moisture conditions, and the amount of rainfall intercepted by vegetation of structures (ASI 1991) Runoff-curve numbers can theoretically range from zero (an infinite retention and infiltration capacity) to 100 (no retention and infiltration capacity) Typical values range from 40 to 50 percent for well-drained soils and up to 98 percent for developed areas (pavement etc.) (ASI 1991) Curve numbers (CN) have been developed for each soil type for various land characteristics and land-use designations at Rocky Flats by ASI (1991) The CN can be entered in three ways

- The user can enter the CN directly
- The user can enter the CN for a soil type and have HELP modify it for a given slope and slope length
- HELP will generate a CN given a soil texture, slope slope length, and vegetation condition

A sensitivity analysis was performed on the effect of drainage layer slope on seepage through the vertical percolation layer and is presented as Attachment G2

G 1 2 Site-Specific Soil Characteristics

The input soil data for the specific layers of the OU 7 engineered covers are summarized in the following paragraphs and in Table G-1

- Vegetative Layer—It was assumed that local soils could be procured for the vegetative layer Soil properties for cover alternatives 1 and 3 use manual input to create soil texture #53, which is a well-graded sandy soil with a permeability of 1E-02 centimeters per second (cm/sec), that simulates the soil used as a daily cover at OU 7 Cover alternatives 4, 5, 6 7 8 and 9 use default soil texture #7 for the vegetative layer This is a silty sand with a permeability of 5 2E-04 cm/sec, which is similar to the native soils of this area It also has a larger difference between the field capacity and wilting point, which indicates it has plant water storage capabilities needed to support vegetation The vegetative layer was not compacted to allow for vegetative growth
- Drainage Layer—Cover alternatives 4 5 6 7 8 and 9 use a geocomposite drainage layer This is modeled using default geosynthetic material #20 which is a 0 5-cm-thick drainage net with a hydraulic conductivity of 1E+01 cm/sec
- Flexible Membrane Cover (FMC)—Cover alternatives 5 7 8 and 9 use an FMC as a barrier component This is modeled using default geosynthetic material characteristic #35 which has a hydraulic conductivity of 2E-13 cm/sec A typical thickness for FMCs of 60 mils (06 inches) was used For the liner material, a number of manufacture defects (pinholes) per acre installation defects per acre and the quality of contact with the underlying layer need to be assigned The HELP manual provides typical estimates for these values For manufacturer defects 0 5 to 1 pinhole per acre are recommended as typical values (HELP Model User's Guide for Version 3 1994) A correlation of installation defects to installation quality as determined by construction quality control/construction quality assurance (CQC/CQA) programs is shown in Table G-2

There are six options in the HELP model to describe the contact between the geomembrane and the underlying soil

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- Perfect—Assumes perfect contact between geomembrane and adjacent soil that limits drainage rate (no gap, "sprayed-on" seal between membrane and soil formed in place)

- Excellent—Assumes exceptional contact between geomembrane and adjacent soil that limits drainage rate (typically achievable only in the lab or small field lysimeters).

- Good—Assumes good field installation with well-prepared, smooth soil surface and geomembrane wrinkle control to ensure good contact between geomembrane and adjacent soil that limits drainage rate

- Poor—Assumes poor field installation with a less well-prepared soil surface and/or geomembrane wrinkling, providing poor contact between geomembrane and adjacent soil that limits drainage rate, resulting in a larger gap for spreading and greater leakage

- Worst Case—Assumes that contact between geomembrane and adjacent soil does not limit drainage rate, resulting in a leakage rate controlled only by the hole

- Geotextile separating geomembrane liner and drainage limiting soil—Assumes leakage spreading and rate is controlled by the in-plane transmissivity of the geotextile separating the geomembrane and the adjacent soil layer that would have otherwise limited the drainage This quality would not normally be used with a GCL as the controlling soil layer. Upon wetting, the bentonite swells and extrudes into the geotextile, filling its voids and reducing its transmissivity below the point where it can contribute significantly to spreading of leakage GCLs, when properly placed, tend to have intimate contact with the geomembrane (Schroeder *et al* 1994a)

A sensitivity analysis was performed on a generic cover section to evaluate the effect the defect rate has on leakage through a cap It was assumed that there was one manufacture defect (pinhole), and good contact was achieved during installation Table G-3 shows the effects of installation defect rate on leakage through the cap systems with different underlying soils

The results of this analysis show that the permeability of the soil underlying the FMC has a significant effect on leakage rates through defects in the FMC

The cover sections with FMC in them were analyzed assuming good installation with three defects/acre, one manufacture defect/acre, and good contact with the underlying soil These assumptions are achievable if a conscientious CQC/CQA program is implemented during construction.

Compacted Soil Liner—This term is used as a generic label for a compacted clay liner, a low-permeability bedding layer a GCL, or a combination of the above The compacted soil liner serves two purposes in the cap design First, it serves as a low-permeability barrier to retard vertical migration of fluids Second it serves as a bedding layer for what is placed over it This second function is most important when the soil liner is overlain by a geocomposite, GCL, or FMC Cover alternatives 5, 7, 8, and 9 all have a compacted soil liner as one of their components Default Soil Texture #17 is used for the GCL and Default Soil Texture #16 is used with the compacted clay cover and low-permeability bedding layer Permeabilities of 1E-07 cm/sec and 1E-05 cm/sec were used for the compacted clay cover and low-permeability bedding soil, respectively

Initial Soil Water Content—The HELP model was allowed to estimate an equilibrium water content for the initial soil water content

SCS Runoff-Curve Number—The HELP model was used to calculate the SCS runoff-curve number assuming a slope of 5 percent (after settlement) a slope length of 500 feet, and a fair stand of grass Two different soil textures were used as the top layer of soil One corresponds to the current soil (#53) used as a daily cover and the other corresponds to soil #7 to be used in the final cover for the vegetative soil layer

G 1 3 Cover Design Input Data

Input parameters for the engineered cover surface area slope, and lateral drainage distance are shown below

- Engineered cover surface area = 1 acre
- Slope of top layer = 5 percent (after settlement)
- Maximum lateral drainage distance along slope = 500 feet

G 1 4 Climate-Related Input Parameters

Three options are available to generate climatologic data a default option, a manual option and a synthetic option For the purpose of this performance assessment, the synthetic option was used to generate the precipitation, temperature, and solar radiation data

Normal (mean) monthly temperature data shown in Table G-4, from the Rocky Flats Plant Site Environmental Report for 1992 (EG&G 1992) was used to adjust HELP s synthetic temperature generator to approximate actual temperatures at the Rocky Flats site more closely

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G 1.5 Precipitation Input

Under the synthetic precipitation option the user has the option of entering normal mean monthly precipitation values to adjust for specific locations. The first column in Table G-5 shows the average, monthly precipitation values for Rocky Flats The second column presents the monthly values input into the model to synthetically generate the measured Rocky Flats values. The third column shows the average, monthly precipitation values generated and used by the HELP model

G 1 6 Growing Season

The default growing season for the Denver area of 164 days was used for modeling purposes. The season is shown below in Julian date form.

Start of growing Season (Julian Date) = 122 (May 2)
End of growing season (Julian Date) = 286 (October 13)

G 1 7 Evapotranspiration Input

Evapotranspiration is a significant factor in determining infiltration through the engineered cover HELP model evapotranspiration has three components: evaporation of water from the surface, from the soil, and from the plants. HELP overestimates the amount of evapotranspiration in arid and semi-arid environments (Schroeder *et al.* 1994b) To counter overestimation of evapotranspiration, conservative values were used for the parameters that affect evapotranspiration the most in the HELP model evaporative zone depth and maximum leaf area index (vegetative cover) These are discussed in detail below

G 1 7 1 Evaporative Zone Depth

Evaporative zone depth is the maximum depth from which water can be removed by evapotranspiration Where vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration The actual evaporative zone depth is slightly greater than this due to capillary action (Schroeder *et al.* 1994b) Loamy or clayey soils in the Rocky Flats area with slopes less than 3H 1V have an effective root depth of up to 60 inches (SCS 1980) The main plant species on these soils consist of tall-prairie grasses. western wheatgrass, blue grama, green needlegrass, and little bluestem (SCS 1993) HELP designates a value of 28 inches and 14 inches as a typical root depth value for a fair stand of grass and no vegetation, respectively, in Denver, Colorado For the purpose of this evaluation, an evaporative zone depth value of 28 inches was used to simulate fair vegetation A sensitivity analysis of the effects of evaporative zone depth was performed and is presented in Attachments G5, G6, and G7 The results of this analysis show that an evaporative zone depth of 28 inches is

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reasonable in that it does not allow excess percolation of water through the vegetative layer nor does it restrict percolation to a minimum

G 1 7 2 Maximum Leaf Area Index

Maximum leaf area index is the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing Typical values used in the HELP model (Schroeder *et al* 1994b) are

- 0 0 for bare ground
- 1 0 for poor grass
- 2 0 for fair grass
- 3 3 for good grass
- 5 0 for excellent grass

As the leaf area index increases, the amount of evapotranspiration increases (Schroeder *et al* 1994b) Given the precipitation values and the length of the growing season, the maximum leaf area index for Denver, Colorado, is 2 5, without irrigation A value of 1 75 was used as the maximum leaf area index for the fair grass vegetation This is a conservative estimate considering the maximum leaf area index value for Denver is about 2 5 A sensitivity analysis was performed on the effect of leaf area index on seepage through the vertical percolation layer, and is presented in Attachment G2 and G3 This indicates that an index value of 1 75 is neither overly conservative or under conservative with respect to allowing water to percolate through the vertical percolation layer

G 1 8 Latitude

The latitude used for solar radiation data generation for normal conditions is 39 77 degrees North the latitude of Denver Colorado

G 1 9 Summary

Results of the HELP modeling runs for each cover section option are summarized in Table G-6

G 2 References

ASI (Advanced Sciences Inc) 1991 Storm-Water Runoff Quantity for Various Design Events Rocky Flats Plant January

EG&G Rocky Flats, Inc 1992 Rocky Flats Plant Site Environmental Report for 1992

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Nichols, W.E 1991. Comparative Simulations of a Two-Layer Landfill Barrier Using the HELP Version 2.0 and Unsat-H Version 2 0 Computer Codes. Pacific Northwest Laboratory, Richland, Washington PNL-7583.

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SCS (Soil Conservation Survey) 1980 Soil Survey of Golden Area. U S Department of Agriculture Soil Conservation Service, Washington, D.C.

SCS (Soil Conservation Survey) 1993 Plant Species Information for Loamy or Clayey Soils in the Area of Rocky Flats Plant. Lakewood, Colorado

Table G-1
Summary of HELP Input Data - OU 7 Cover Sections

Layer Description	HELP Default Soil Number	Thickness (inches)	Layer Type	Porosity (Vol/Vol)[1]	Field Capacity (Vol/Vol)[1]	Wilting Point (Vol/Vol)[1]	Saturated Hydraulic Conductivity (cm/sec)[2]
Vegetative Layer	53 and 7	12 to 36	Vertical	0 473	0 222	0 104	1E 02/5 2E 04
Drainage Layer	20	1	Lateral Drainage	0 85	0 01	0 005	1E+01
Compacted Clay Layer	16	24	Barrier	0 427	0 418	0 367	1E 07
GCL	17	0 2	Barrier	0 75	0 747	0 4	3E 09
FMC	35	0 06	Barrier	—	—	—	2E 13
Low Permeability Bedding Layer	16[3]	12	Barrier	0 427	0 418	0 367	1E 05

Notes

1 Volume per volume
2 Centimeters per second
Soil layer permeability modified to 1x10-5 cm/sec

Definitions

cm/sec centimeter per second
GCL geosynthetic clay liner
FMC flexible membrane cover

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Table G-2
Installation Defects

Installation Quality	Defect Density (number per acre)	Frequency (%)
Excellent	Up to 1	10
Good	1 to 4	40
Fair	4 to 10	40
Poor	10 to 20	10

Table G-3
Leakage Rates vs. Defects

HDPE Liner Installation Defects per Acre	Leakage Rate (cubic feet/acre/year) Corresponding With Different Underlying Soils			
	5x10-9 cm/sec GCL	1x10-7 cm/sec Clay Soil	[illegible] Soil	[illegible]
1	0.0222	0.044	5,498	370
2	0 029	0 064	42,801	6,661
3	0 037	0.085	56,256	9,191
4	0 044	0 106	68,977	11,306
6	0 059	0 146	87,198	14,712
8	0 074	0 188	100,537	17,256
10	0 089	0.229	109,889	19,199
18	0 148	0 393	118 765	23,661

Definitions

cm/sec centimeters per second
GCL Geosynthetic clay liner

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Table G-4
Temperature Data Summary

Month	Normal (Mean) Monthly Temperatures °F
JAN	31 0
FEB	33 0
MARCH	37 0
APRIL	45 5
MAY	55 5
JUNE	64 5
JULY	71 5
AUG	70 5
SEPT	61 5
OCT	52 5
NOV	40 0
DEC	33 5

Notes

F degrees Fahrenheit

Table G-5
Precipitation Data

Month	Normal (Mean) Monthly Precipitation at Rocky Flats (inch)	Average Monthly Precipitation Input into HELP (inch)	Synthetically Generated Average (30 year) Monthly Precipitation Output from HELP (inch)
JAN	0 46	0 60	0 46
FEB	0 48	0 43	0 48
MARCH	1 22	1 33	1 22
APRIL	1 13	1 80	1 13
MAY	2 74	3 32	2 75
JUNE	1 85	1 77	1 85
JULY	1 49	1 39	1 48
AUG	1 52	1 53	1 52
SEPT	1 49	1 24	1 49
OCT	0 92	1 24	0 92
NOV	0 79	0 86	0 79
DEC	0 64	0 57	0 64
TOTAL	**15 33**	**16 08**	**15 33**

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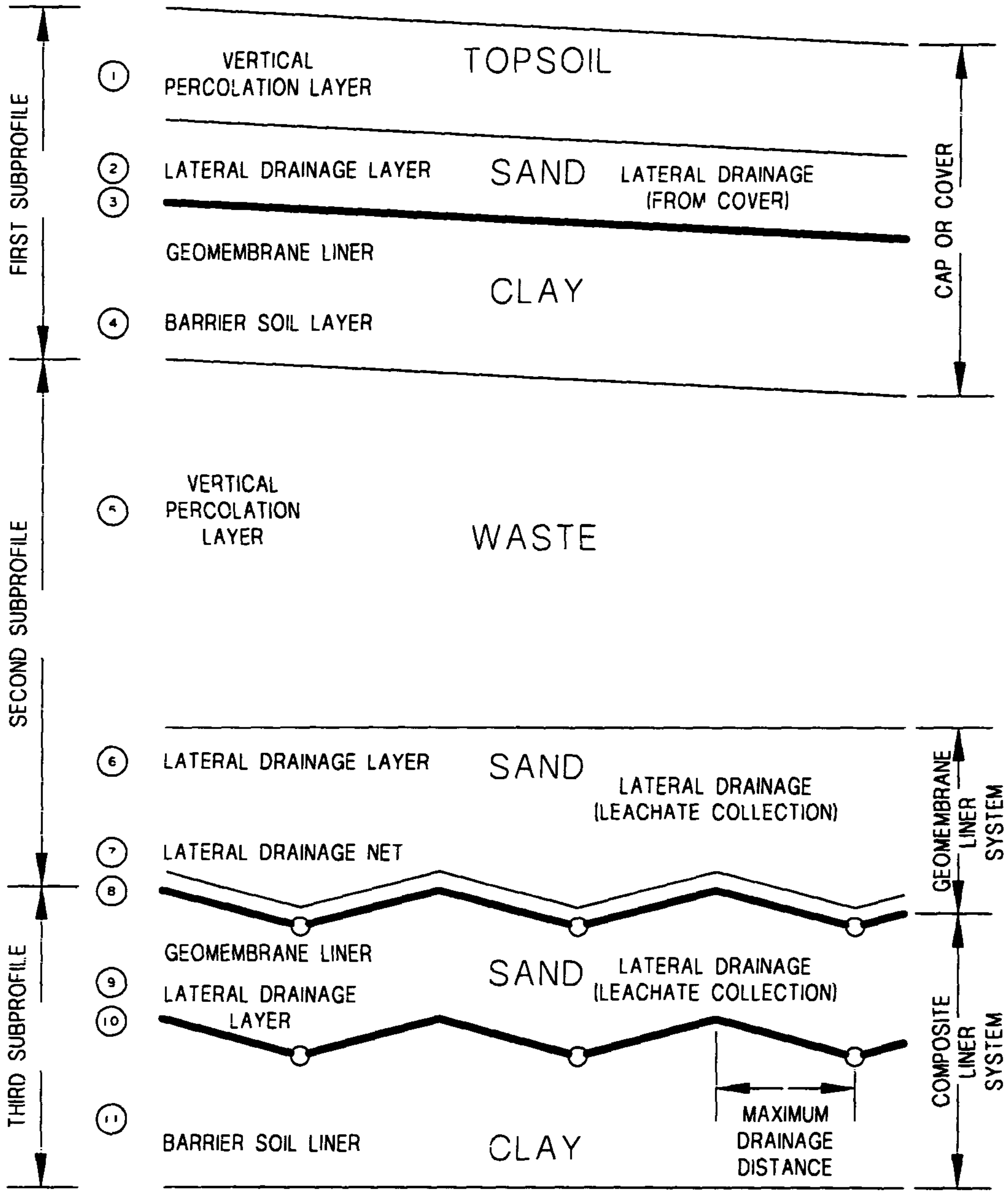
Table G-6
Summary of HELP Modeling Results

	Cover Alternatives 1 and 2	Cover Alternative 3	Cover Alternative 4	Cover Alternative 5	Cover Alternative 6	Cover Alternative 7	Cover Alternative 8	Cover Alternative 9
Precipitation[1]	15 33	15 33	15.33	15 33	15 33	15 33	15.33	15 33
Runoff[1]	0 033	0 027	0 036	0 036	0 036	0.036	0 036	0.036
Evaporation[1]	13 896	14 211	9 467	9 467	9.467	9 467	9 467	9.467
Lateral Drainage[1]	0	0	4.809	5 827	5 813	5.849	5.849	5.849
Leakage[1]	$1\ 4x10^{-9}$	$1\ 1x10^{-9}$	$1\ 0x10^{-9}$	$2\ 1x10^{2}$	$3\ 5x10^{2}$	$1\ 6x10^{-4}$	$2\ 0x10^{-8}$	$1x10^{-5}$
Head on Barrier[1]	0.001	0 001	0 006	0 007	0 007	0.007	0.007	0.007

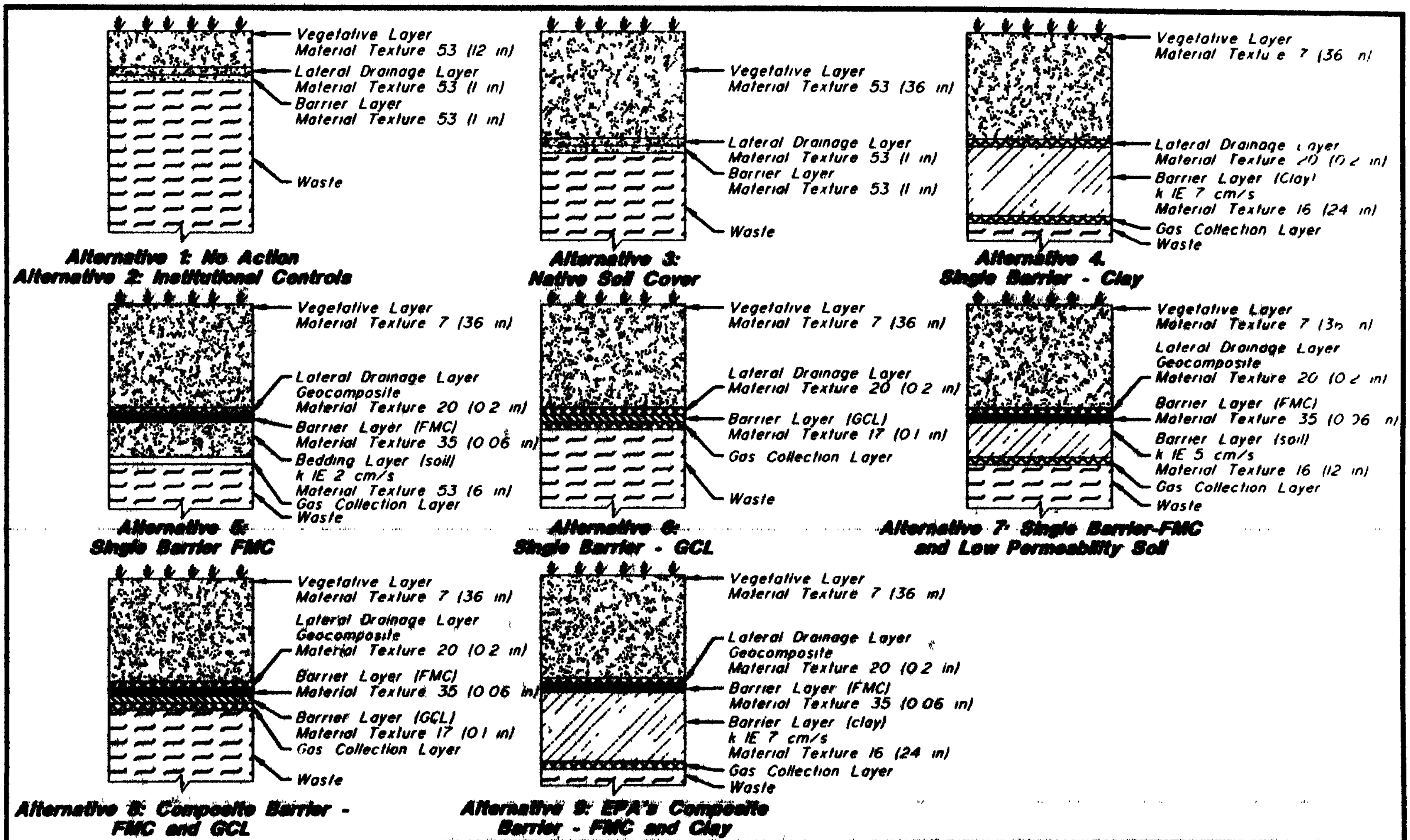
Notes

1 Average annual totals (inches)



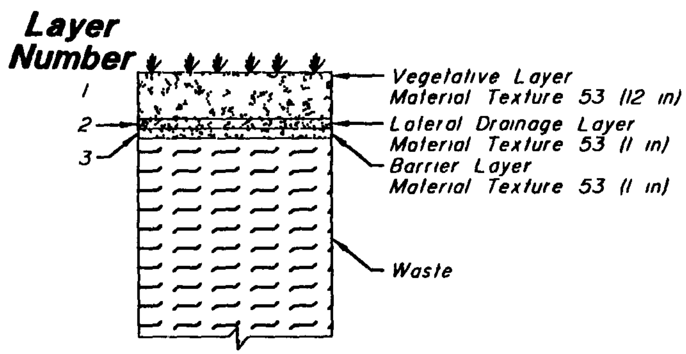
Project No 601	Design By P Corser	Scale NA	U S Department of Energy Rocky Flats Environmental Technology Site Golden Colorado
File Figa1DWG	Drawn By W Parker	Date April 19 1995	
TerraMatrix Engineering & Environmental Services	Figure G-1		Schematic Profile View of a Typical Hazardous Waste Landfill

622



Project No. 801	Design By P. Corser	Scale NA	US Department of Energy Rocky Flats Environmental Technology Site Golden Colorado
File COVERS.DWG	Drawn By P Pellicer	Date April 18, 1995	
TerraMatrix	Figure G-2		OU7 Cover Options Analyzed With The HELP Model

623



Cover Alternative 1 & 2 (Existing Conditions & Institutional Controls)

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 53 k IE 2 cm/s
- ☒ 2 Lateral Drainage Layer Texture 53 k IE 2 cm/s Slope 2% Length 500 ft
- ☐ 3 FMC Texture NA k NA
- ☐ 4 FMC Conditions NA Pinholes/acre NA defects/acre Good Contact
- ☒ 5 Barrier Soil Texture 53 k IE 2 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 1 Fair Grass Slope 5/ Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 13 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft³)	Peak Daily (in) (ft³)
Precipitation	15 33	3 34
Runoff	0 033	0 331
Evaporation	13 896	NA
Lateral Drainage	0 000	0 000
Leakage	1 41 [5117 5]	1 57 [5695 9]
Head on Barrier Layer	0 001	0 611

Project No 601	Design By P Corser	Scale NA
File COVER1DWG	Drawn By P Pellicer	Date April 19 1995

TerraMatrix Engineering & Environmental Services

Figure 1

US Department of Energy Rocky Flats Environmental Technology Site Golden Colorado

HELP Run - Cover Alternative 1 & 2 Input Summary

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE      C \HELP3\WETHOU7\IN\SYN30M D4
TEMPERATURE DATA FILE        C \HELP3\WETHOU7\IN\SYN30M D7
SOLAR RADIATION DATA FILE    C \HELP3\WETHOU7\IN\SYN30M D13
EVAPOTRANSPIRATION DATA      C \HELP3\WETHOU7\IN\SYN30M D11
SOIL AND DESIGN DATA FILE    C \HELP3\PATOU7\IN\RFNC30RP D10
OUTPUT DATA FILE             C \HELP3\PATOU7\OUT\RFNC30RP OUT

TIME   13 59     DATE    4/11/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU 7   No Cover   RFNC30RP

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                 LAYER  1
                   TYPE 1   VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =      12 00    INCHES
          POROSITY                   =       0 4370 VOL/VOL
          FIELD CAPACITY             =       0 0620 VOL/VOL
          WILTING POINT              =       0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 0405 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =   0 999999978000E 02 CM/SEC

                                 LAYER  2
                     TYPE 2   LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =       1 00    INCHES
          POROSITY                   =       0 4370 VOL/VOL
          FIELD CAPACITY             =       0 0620 VOL/VOL
          WILTING POINT              =       0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 0308 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =   0 999999978000E 02 CM/SEC
          SLOPE                      =       2 00    PERCENT
          DRAINAGE LENGTH            =     500 0     FEET

                                 LAYER  3
                       TYPE 3   BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =       1 00    INCHES
          POROSITY                   =       0 4370 VOL/VOL
          FIELD CAPACITY             =       0 0620 VOL/VOL
          WILTING POINT              =       0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 4370 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =   0 999999978000E 02 CM/SEC
```

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	13 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.517	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5 681	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.312	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	0.954	INCHES
TOTAL INITIAL WATER	=	0 954	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	= 1 75
START OF GROWING SEASON (JULIAN DATE)	= 122
END OF GROWING SEASON (JULIAN DATE)	= 286
AVERAGE ANNUAL WIND SPEED	= 8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	= 54.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	= 50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	= 49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	= 54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1.33	1 80	3.32	1 77
1 39	1 53	1 24	1.24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55.50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 008	0 021	0 000	0 000	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 009	0 024	0 088	0 000	0 000	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 496	0 438	0 887	1 543	2 166	2 042
	1 491	1 224	1 533	0 831	0 672	0 573
STD DEVIATIONS	0 306	0 216	0 472	0 706	0 916	1 049
	0 765	0 848	0 746	0 532	0 501	0 267
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0 0000	0 0020	0 0480	0 2359	0 7079	0 1953
	0 0248	0 0699	0 0409	0 0149	0 0408	0 0294
STD DEVIATIONS	0 0002	0 0108	0 1463	0 3442	0 7423	0 2506
	0 0955	0 1808	0 0849	0 0812	0 1055	0 0673

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0 0000	0 0000	0 0005	0 0023	0 0069	0 0021
	0 0003	0 0006	0 0004	0 0002	0 0004	0 0003
STD DEVIATIONS	0 0000	0 0001	0 0017	0 0032	0 0070	0 0026
	0 0011	0 0017	0 0008	0 0012	0 0011	0 0007

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3.026)	55661.2	100 00
RUNOFF	0 033	(0 0888)	120 19	0 216
EVAPOTRANSPIRATION	13 896	(2 5932)	50443 06	90 625
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0.00000)	0 004	0.00001
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 40978	(1 07644)	5117 511	9 19403
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 005	(0 3958)	19 56	-0 035

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT.)
PRECIPITATION	3 34	12124 199
RUNOFF	0.331	1201 7882
DRAINAGE COLLECTED FROM LAYER 2	0.00000	0.01415
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.569141	5695.98291
AVERAGE HEAD ACROSS LAYER 3	0 611	
SNOW WATER	1.19	4320.8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0.2216
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0055

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	0 3314	0.0276
2	0 0240	0 0240
3	0.4370	0 4370
SNOW WATER	0 000	

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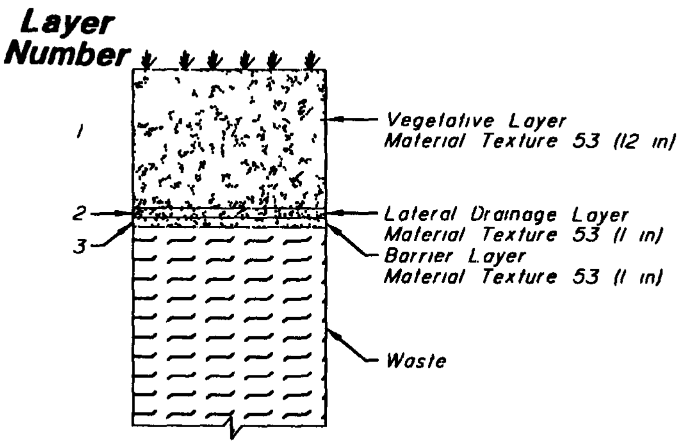
****



Cover Alternative 3
Native Soil Cover

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 53 k IE 2 cm/s
- ☒ 2 Lateral Drainage Layer Texture 53 k IE 2 cm/s Slope 2% Length 500 ft
- ☐ 3 FMC Texture NA k NA
- ☐ 4 FMC Conditions NA Pinholes/acre NA defects/acre Good Contact
- ☒ 5 Barrier Soil Texture 53 k IE 2 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 1 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 13 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft^3)	Peak Daily (in) (ft^3)
Precipitation	15 33	3 34
Runoff	0 027	0 256
Evaporation	14 211	NA
Lateral Drainage	0 000	0 000
Leakage	1 09 [3955 8]	1 57 [508 4]
Head on Barrier Layer	0 001	0 053

Project No	Drawn By	Scale	
601	P Corser	NA	US Department of Energy Rocky Flats Environmental Technology Site Golden Colorado
File COVER9 DWG	Drawn By P Pellicer	Date April 19 1995	
TerraMatrix Engineering & Environmental Services	Figure 2		HELP Run - Cover Alternative 3 Input Summary

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**                                                                           **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**              USAE WATERWAYS EXPERIMENT STATION                            **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
*******************************************************************************
*******************************************************************************

PRECIPITATION DATA FILE     C \HELP3\wethou7\in\SYN30M D4
TEMPERATURE DATA FILE       C \HELP3\wethou7\in\SYN30M D7
SOLAR RADIATION DATA FILE   C \HELP3\wethou7\in\SYN30M D13
EVAPOTRANSPIRATION DATA     C \HELP3\wethou7\in\SYN30M D11
SOIL AND DESIGN DATA FILE   C \HELP3\patou7\in\COVER1B D10
OUTPUT DATA FILE            C \HELP3\patou7\out\cover1b OUT

TIME    9 31     DATE    6/9/95
*******************************************************************************

     TITLE   Rocky Flats Cover Options OU 7   3ft  soil cover1b

*******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                              LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER 53
        THICKNESS                  =      36 00    INCHES
        POROSITY                   =       0 4370 VOL/VOL
        FIELD CAPACITY             =       0 0620 VOL/VOL
        WILTING POINT              =       0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =       0 0470 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E 02 CM/SEC

                              LAYER  2
                    TYPE 2   LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER 53
        THICKNESS                  =       1 00    INCHES
        POROSITY                   =       0 4370 VOL/VOL
        FIELD CAPACITY             =       0 0620 VOL/VOL
        WILTING POINT              =       0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =       0 0620 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E 02 CM/SEC
        SLOPE                      =       2 00    PERCENT
        DRAINAGE LENGTH            =     500 0     FEET

                              LAYER  3
                      TYPE 3   BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =       1 00    INCHES
        POROSITY                   =       0 4370 VOL/VOL
        FIELD CAPACITY             =       0 0620 VOL/VOL
        WILTING POINT              =       0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =       0 4370 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E 02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400. FEET

SCS RUNOFF CURVE NUMBER	=	40.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.672	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2.192	INCHES
TOTAL INITIAL WATER	=	2.192	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1.75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1.39	1.53	1 24	1 24	0 86	0.57

NOTE. TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 002	0 007	0 017	0 000	0 000	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 070	0 000	0 000	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 472	0 425	0 930	1 458	2 124	2 262
	1 721	1 358	1 375	0 907	0 660	0 519
STD DEVIATIONS	0 307	0 262	0 445	0 735	0 990	1 026
	0 876	0 810	0 731	0 536	0 517	0 262
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0 0366	0 0297	0 0280	0 0753	0 1510	0 2583
	0 2413	0 0821	0 0556	0 0509	0 0384	0 0426
STD DEVIATIONS	0 0360	0 0291	0 0260	0 0817	0 1099	0 2607
	0 1701	0 0326	0 0263	0 0253	0 0322	0 0419

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0 0004	0 0004	0 0003	0 0008	0 0016	0 0029
	0 0026	0 0009	0 0006	0 0006	0 0004	0 0005
STD DEVIATIONS	0 0004	0 0003	0 0003	0 0009	0 0012	0 0029
	0 0018	0 0004	0 0003	0 0003	0 0004	0 0005

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3.026)	55661.2	100 00
RUNOFF	0 027	(0 0714)	97.87	0 176
EVAPOTRANSPIRATION	14 211	(2 9308)	51587 32	92 681
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 08974	(0 50658)	3955 751	7 10683
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 006	(0 3132)	20 28	0 036

****
****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124.199
RUNOFF	0.256	930.8232
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0.00034
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 140044	508 36081
AVERAGE HEAD ACROSS LAYER 3	0 053	
SNOW WATER	1 19	4320 8433
MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1709	
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0175	

****
****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 8610	0 0517
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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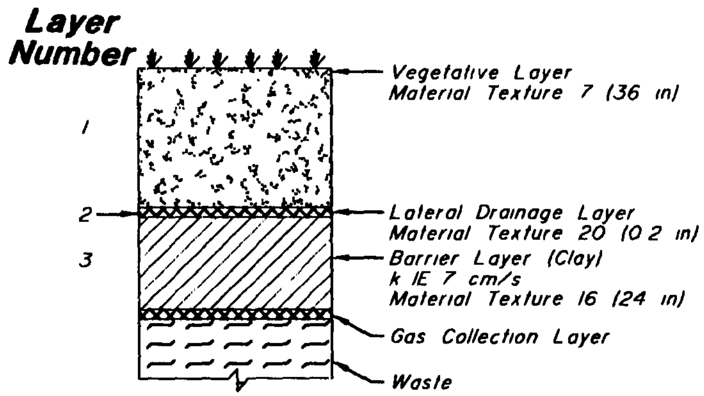
****



Cover Alternative 4
Single Barrier - Clay

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k IE 1 cm/s
  Slope 2% Length 500 ft
- ☐ 3 FMC Texture NA k NA
- ☐ 4 FMC Conditions NA Pinholes/acre
  NA defects/acre Good Contact
- ☒ 5 Barrier Soil Texture 16 k IE 7 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft³)	Peak Daily (in) (ft³)
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	4 809	0 294
Leakage	1 0398 [3774 7]	0 0034 [12 41]
Head on Barrier Layer	0 006	0 13

Project N	Design By	Scale
601	P Corser	NA
File	Drawn By	Date
COVER4.DWG	P Pellicer	April 19 1995

TerraMatrix Engineering & Environmental Services

Figure 3

U S Department of Energy Rocky Flats Environmental Technology Site Golden Colorado

HELP Run - Cover Alternative 4 Input Summary

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**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \HELP3\WETHOU7\IN\SYN30M D4
TEMPERATURE DATA FILE        C \HELP3\WETHOU7\IN\SYN30M D7
SOLAR RADIATION DATA FILE    C \HELP3\WETHOU7\IN\SYN30M D13
EVAPOTRANSPIRATION DATA      C \HELP3\WETHOU7\IN\SYN30M D11
SOIL AND DESIGN DATA FILE    C \HELP3\PATOU7\IN\RFCLAYP D10
OUTPUT DATA FILE             C \HELP3\PATOU7\OUT\RFCLAYP OUT

TIME   13 11     DATE    4/11/95


******************************************************************************

     TITLE   Rocky Flats Cover Options OU7   File  RFCLAY

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                 LAYER  1
                    TYPE 1   VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   7
          THICKNESS                  =     36 00    INCHES
          POROSITY                   =      0 4730 VOL/VOL
          FIELD CAPACITY             =      0 2220 VOL/VOL
          WILTING POINT              =      0 1040 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0 1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND   = 0 520000001000E 03 CM/SEC
         NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                 LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  20
          THICKNESS                  =      0 20    INCHES
          POROSITY                   =      0 8500 VOL/VOL
          FIELD CAPACITY             =      0 0100 VOL/VOL
          WILTING POINT              =      0 0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0 0224 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =    10 0000000000      CM/SEC
          SLOPE                      =      2 00    PERCENT
          DRAINAGE LENGTH            =    500 0     FEET


                                 LAYER  3
                        TYPE 3   BARRIER SOIL LINER
                        MATERIAL TEXTURE NUMBER  16
          THICKNESS                  =     24 00    INCHES
          POROSITY                   =      0 4270 VOL/VOL
          FIELD CAPACITY             =      0 4180 VOL/VOL
          WILTING POINT              =      0 3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0 4270 VOL/VOL
          EFFECTIVE SAT  HYD  COND   = 0 100000001000E 06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 400 FEET.

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	16 254	INCHES
TOTAL INITIAL WATER	=	16 254	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER, COLORADO

MAXIMUM LEAF AREA INDEX	=	1.75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1.80	3.32	1 77
1 39	1 53	1 24	1.24	0.86	0 57

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37.00	45.50	55.50	64 50
71 50	70 50	61 50	52.50	40 00	33 50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0994	0 0501	0 0681	0 3978	0 9391	0 7787
	0 5295	0 4224	0 4668	0 4810	0 3066	0 2695
STD DEVIATIONS	0 1128	0 0711	0 0967	0 2741	0 4724	0 5033
	0 3057	0 2988	0 3521	0 2276	0 2253	0 1996
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0 0739	0 0484	0 0600	0 0873	0 1027	0 0972
	0 0996	0 0977	0 0922	0 0975	0 0884	0 0949
STD DEVIATIONS	0 0286	0 0314	0 0278	0 0168	0 0041	0 0072
	0 0069	0 0082	0 0136	0 0140	0 0239	0 0187

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0 0014	0 0008	0 0010	0 0059	0 0134	0 0115
	0 0075	0 0060	0 0069	0 0068	0 0045	0 0038
STD DEVIATIONS	0 0016	0 0011	0 0014	0 0040	0 0067	0 0074
	0 0044	0 0043	0 0052	0 0032	0 0033	0 0028

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661.2	100.00
RUNOFF	0 036	(0.0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2.0334)	34364.64	61.739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4 80893	(1 21152)	17456.404	31 36188
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 03985	(0 08169)	3774.654	6.78148
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 006	(0 001)		
CHANGE IN WATER STORAGE	-0 018	(0 3105)	-65 05	-0.117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT.)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0.29392	1066 91162
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 003420	12.41423
AVERAGE HEAD ACROSS LAYER 3	0 130	
SNOW WATER	1 19	4320 8433
MAXIMUM VEG SOIL WATER (VOL/VOL)		0 2542
MINIMUM VEG. SOIL WATER (VOL/VOL)		0 1172

****

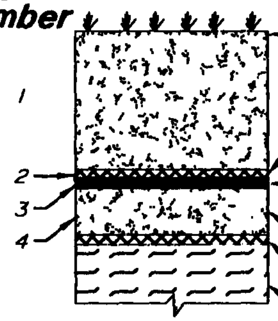
****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0048	0 0239
3	10 2480	0.4270
SNOW WATER	0 000	

****
****

Layer Number



Cover Alternative 5
Single Barrier - FMC

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k IE 1 cm/s Slope 2% Length 500 ft
- ☒ 3 FMC Texture 35 k IE 13 cm/sec
- ☒ 4 FMC Conditions 0 5 Pinholes/acre 2 defects/acre Good Contact
- ☐ 5 Barrier Soil Texture NA k NA cm/s
- ☒ 6 Bedding Soil For FMC Texture 53 k IE 2 cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) [ft³]	Peak Daily (in) [ft³]
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	5 827	0 297
Leakage	0 0213 [77 14]	0 00016 [0 568]
Head on Barrier Layer	0 007	0 131

Project No	Drawn By	Scale
601	P Corser	NA
File	Drawn By	Date
COVERS DWG	P Pellicer	April 19 1995

TerraMatrix
Engineering & Environmental Services

Figure 4

US Department of Energy Rocky Flats Environmental Technology Site Golden Colorado

HELP Run - Cover Alternative 5 Input Summary

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                    **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                          **
**           USAE WATERWAYS EXPERIMENT STATION                              **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \HELP3\patou7\IN\SYN30M D4
TEMPERATURE DATA FILE        C \HELP3\PATOU7\IN\SYN30M D7
SOLAR RADIATION DATA FILE    C \HELP3\PATOU7\IN\SYN30M D13
EVAPOTRANSPIRATION DATA      C \HELP3\PATOU7\IN\SYN30M D11
SOIL AND DESIGN DATA FILE    C \HELP3\PATOU7\IN\RFFMC30P D10
OUTPUT DATA FILE             C \HELP3\PATOU7\OUT\RFFMC30P OUT

TIME    7 42     DATE    4/12/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU7   File RFFMC

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM


                              LAYER  1
                   TYPE 1   VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =     36 00    INCHES
        POROSITY                   =      0 4730 VOL/VOL
        FIELD CAPACITY             =      0 2220 VOL/VOL
        WILTING POINT              =      0 1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 1667 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 520000001000E 03 CM/SEC

         NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                     TYPE 2   LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =      0 20    INCHES
        POROSITY                   =      0 8500 VOL/VOL
        FIELD CAPACITY             =      0 0100 VOL/VOL
        WILTING POINT              =      0 0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 0286 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =    10 0000000000     CM/SEC
        SLOPE                      =      2 00    PERCENT
        DRAINAGE LENGTH            =    500 0     FEET


                              LAYER  3
                     TYPE 4   FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
        THICKNESS                  =      0 06    INCHES
        POROSITY                   =      0 0000 VOL/VOL
        FIELD CAPACITY             =      0 0000 VOL/VOL
        WILTING POINT              =      0 0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 0000 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 199999996000E 12 CM/SEC
        FML PINHOLE DENSITY        =      0 50    HOLES/ACRE
        FML INSTALLATION DEFECTS   =      2 00    HOLES/ACRE
        FML PLACEMENT QUALITY      =  3   GOOD
```

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LAYER 4

TYPE 1 VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 53

```
THICKNESS                  =      6 00   INCHES
POROSITY                   =      0 4370 VOL/VOL
FIELD CAPACITY             =      0 0620 VOL/VOL
WILTING POINT              =      0 0240 VOL/VOL
INITIAL SOIL WATER CONTENT =      0 0654 VOL/VOL
EFFECTIVE SAT  HYD. COND   =  0.999999978000E-02 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

```
SCS RUNOFF CURVE NUMBER              =    74 80
FRACTION OF AREA ALLOWING RUNOFF     =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =     1.000  ACRES
EVAPORATIVE ZONE DEPTH               =    28.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =     4.040  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =    13 244  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =     2 912  INCHES
INITIAL SNOW WATER                   =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     6 400  INCHES
TOTAL INITIAL WATER                  =     6 400  INCHES
TOTAL SUBSURFACE INFLOW              =     0 00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

```
MAXIMUM LEAF AREA INDEX                  =  1 75
START OF GROWING SEASON (JULIAN DATE)    =   122
END OF GROWING SEASON (JULIAN DATE)      =   286
AVERAGE ANNUAL WIND SPEED                =  8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY    = 54.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY    = 50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY    = 49.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY    = 54 00 %
```

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1.33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1728	0 0981	0 1273	0 4830	1 0385	0 8730
	0 6269	0 5181	0 5570	0 5765	0 3934	0 3629
STD DEVIATIONS	0 1318	0 0955	0 1122	0 2839	0 4730	0 5060
	0 3077	0 3014	0 3575	0 2341	0 2388	0 2101
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0 0008	0 0005	0 0006	0 0018	0 0033	0 0029
	0 0023	0 0019	0 0020	0 0021	0 0016	0 0015
STD DEVIATIONS	0 0005	0 0004	0 0004	0 0009	0 0012	0 0012
	0 0009	0 0008	0 0010	0 0007	0 0008	0 0007
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0025	0 0024	0 0024	0 0013	0 0006	0 0008
	0 0013	0 0016	0 0015	0 0015	0 0019	0 0020
STD DEVIATIONS	0 0007	0 0006	0 0005	0 0007	0 0004	0 0005
	0 0005	0 0007	0 0007	0 0008	0 0008	0 0007

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	0 0024	0 0015	0 0018	0.0071	0 0148	0 0128
	0 0089	0 0074	0 0082	0 0082	0 0058	0 0052
STD DEVIATIONS	0 0019	0 0015	0 0016	0 0042	0 0067	0 0074
	0 0044	0 0043	0 0053	0 0033	0 0035	0 0030

****

****

AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661.2	100 00
RUNOFF	0 036	(0 0822)	130.55	0.235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364.64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 82752	(1 23574)	21153 914	38.00476
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	0.02125	(0 00338)	77 144	0 13859
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 007	(0 001)		
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 01998	(0 00431)	72 516	0 13028
CHANGE IN WATER STORAGE	0 017	(0 3120)	60 42	0 109

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0.268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29672	1077 09302
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 000597	2 16766
AVERAGE HEAD ACROSS LAYER 3	0 131	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000156	0 56802
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL) 0 2542

MINIMUM VEG SOIL WATER (VOL/VOL) 0 1172

****

****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0301
3	0 0000	0 0000
4	0 4305	0 0717

SNOW WATER 0 000

****

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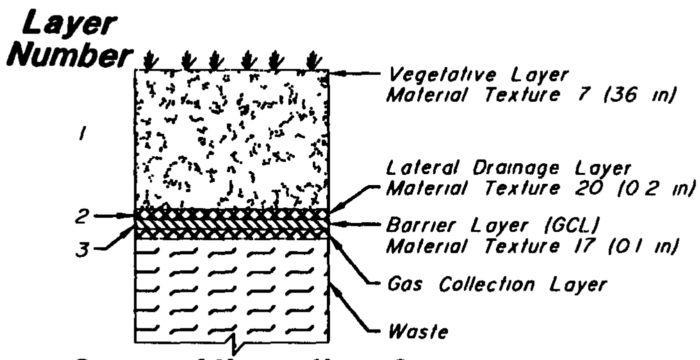

Cover Alternative 6
Single Barrier - GCL

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k lE l cm/s Slope 2% Length 500 ft
- ☐ 3 FMC Texture NA k NA
- ☐ 4 FMC Conditions NA Pinholes/acre NA defects/acre Good Contact
- ☒ 5 Barrier Soil (GCL) Texture 17 k 3E 9 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft^3)	Peak Daily (in) (ft^3)
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	5 813	0 297
Leakage	0 035 [127 5]	0 00017 [0 61323]
Head on Barrier Layer	0 007	0 131

Project No	Design By	Scale
601	P Corser	NA
File	Drawn By	Date
COVER6 DWG	P Pellicer	April 19 1995

TerraMatrix
Engineering & Environmental Services

Figure 5

US Department of Energy Rocky Flats
Environmental Technology Site Golden Colorado

HELP Run - Cover
Alternative 6 Input Summary

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******************************************************************************
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**            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**            HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \TEMP\HELP3\patou7\in\SYN30M D4
TEMPERATURE DATA FILE        C \TEMP\HELP3\patou7\in\SYN30M D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\patou7\in\SYN30M D13
EVAPOTRANSPIRATION DATA      C \TEMP\HELP3\patou7\in\SYN30M D11
SOIL AND DESIGN DATA FILE    C \TEMP\HELP3\patou7\in\RFGCL30 D10
OUTPUT DATA FILE             C \TEMP\HELP3\patou7\out\rfgcl30p OUT

TIME    8  1      DATE    4/12/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU7 30 yrs   RFGCL30

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                   LAYER  1
                      TYPE 1   VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
           THICKNESS                  =      36 00    INCHES
           POROSITY                   =       0 4730 VOL/VOL
           FIELD CAPACITY             =       0 2220 VOL/VOL
           WILTING POINT              =       0 1040 VOL/VOL
           INITIAL SOIL WATER CONTENT =       0 1667 VOL/VOL
           EFFECTIVE SAT  HYD  COND   =  0 520000001000E 03 CM/SEC

         NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                   LAYER  2
                        TYPE 2   LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
           THICKNESS                  =       0 20    INCHES
           POROSITY                   =       0 8500 VOL/VOL
           FIELD CAPACITY             =       0 0100 VOL/VOL
           WILTING POINT              =       0 0050 VOL/VOL
           INITIAL SOIL WATER CONTENT =       0 0285 VOL/VOL
           EFFECTIVE SAT  HYD  COND   =    10 0000000000      CM/SEC
           SLOPE                      =       2 00    PERCENT
           DRAINAGE LENGTH            =     500 0     FEET


                                   LAYER  3
                         TYPE 3   BARRIER SOIL LINER
                          MATERIAL TEXTURE NUMBER  17
           THICKNESS                  =       0 20    INCHES
           POROSITY                   =       0 7500 VOL/VOL
           FIELD CAPACITY             =       0 7470 VOL/VOL
           WILTING POINT              =       0 4000 VOL/VOL
           INITIAL SOIL WATER CONTENT =       0 7500 VOL/VOL
           EFFECTIVE SAT  HYD  COND   =  0 300000003000E 08 CM/SEC
```

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400. FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	6 158	INCHES
TOTAL INITIAL WATER	=	6.158	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER, COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1.77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70.50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1711	0 0968	0 1255	0 4818	1 0384	0 8727
	0 6260	0 5168	0 5560	0 5754	0 3920	0 3613
STD DEVIATIONS	0 1318	0 0951	0 1121	0 2845	0 4741	0 5070
	0 3085	0 3021	0 3583	0 2346	0 2392	0 2106
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0 0026	0 0018	0 0024	0 0030	0 0034	0 0032
	0 0033	0 0032	0 0030	0 0032	0 0029	0 0031
STD DEVIATIONS	0 0007	0 0010	0 0007	0 0003	0 0001	0 0002
	0 0001	0 0001	0 0004	0 0004	0 0006	0 0004

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0 0024	0 0015	0 0018	0 0071	0 0148	0 0128
	0 0089	0 0074	0 0082	0 0082	0 0058	0 0051
STD DEVIATIONS	0 0019	0 0015	0 0016	0 0042	0 0067	0 0075
	0 0044	0 0043	0 0053	0 0033	0 0035	0 0030

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3.026)	55661 2	100 00
RUNOFF	0 036	(0.0822)	130 55	0.235
EVAPOTRANSPIRATION	9.467	(2.0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 81364	(1.23815)	21103 520	37.91422
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	0 03513	(0 00209)	127 537	0 22913
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 007	(0 001)		
CHANGE IN WATER STORAGE	-0 018	(0 3106)	-65 05	-0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT)
PRECIPITATION	3 34	12124.199
RUNOFF	0.268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0.29716	1078 70459
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000169	0 61323
AVERAGE HEAD ACROSS LAYER 3	0 131	
SNOW WATER	1.19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0.2542
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0.1518
2	0 0060	0 0300
3	0 1500	0 7500
SNOW WATER	0 000	

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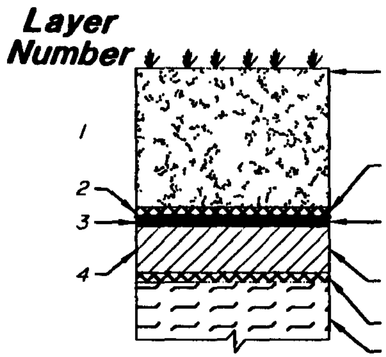

Cover Alternative 7
Single Barrier - FMC
and Low Permeability Soil

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k IE I cm/s Slope 2% Length 500 ft
- ☒ 3 FMC Texture 35 k 2E 13 cm/sec
- ☒ 4 FMC Conditions 0 5 Pinholes/acre 2 defects/acre Good Contact
- ☒ 5 Barrier Soil Texture 16 k IE 5 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft³)	Peak Daily (in) (ft³)
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	5 848	0 297
Leakage	0 00016 [0 591]	0 000006 [0 02329]
Head on Barrier Layer	0 007	0 131

Project No	Design By	Scale	
601	P Corser	NA	US Department of Energy Rocky Flats Environmental Technology Site Golden Colorado
File COVER7 DWG	Drawn By P Pellicer	Date April 19 1995	
TerraMatrix Engineering & Environmental Services		Figure 6	HELP Run - Cover Alternative 7 Input Summary

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                    **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \HELP3\WETHOU7\IN\SYN30M D4
TEMPERATURE DATA FILE        C \HELP3\WETHOU7\IN\SYN30M D7
SOLAR RADIATION DATA FILE    C \HELP3\WETHOU7\IN\SYN30M D13
EVAPOTRANSPIRATION DATA      C \HELP3\WETHOU7\IN\SYN30M D11
SOIL AND DESIGN DATA FILE    C \HELP3\PATOU7\IN\RFC2 5 D10
OUTPUT DATA FILE             C \HELP3\RFC2 5P OUT

TIME    7 48     DATE    4/12/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU7   File  RFC2 5

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                              LAYER  1
                 TYPE 1   VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
          THICKNESS                  =      36 00   INCHES
          POROSITY                   =       0 4730 VOL/VOL
          FIELD CAPACITY             =       0 2220 VOL/VOL
          WILTING POINT              =       0 1040 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 520000001000E 03 CM/SEC

         NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                   TYPE 2   LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  20
          THICKNESS                  =       0 20   INCHES
          POROSITY                   =       0 8500 VOL/VOL
          FIELD CAPACITY             =       0 0100 VOL/VOL
          WILTING POINT              =       0 0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 0287 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =    10 0000000000     CM/SEC
          SLOPE                      =       2 00   PERCENT
          DRAINAGE LENGTH            =     500 0    FEET


                              LAYER  3
                   TYPE 4   FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
          THICKNESS                  =       0 06   INCHES
          POROSITY                   =       0 0000 VOL/VOL
          FIELD CAPACITY             =       0 0000 VOL/VOL
          WILTING POINT              =       0 0000 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0 0000 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 199999996000E 12 CM/SEC
          FML PINHOLE DENSITY        =       0 50   HOLES/ACRE
          FML INSTALLATION DEFECTS   =       2 00   HOLES/ACRE
          FML PLACEMENT QUALITY      =  3    GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET.

SCS RUNOFF CURVE NUMBER	=	74 80
FRACTION OF AREA ALLOWING RUNOFF	=	100 0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000 ACRES
EVAPORATIVE ZONE DEPTH	=	28 0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.912 INCHES
INITIAL SNOW WATER	=	0 000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 132 INCHES
TOTAL INITIAL WATER	=	11 132 INCHES
TOTAL SUBSURFACE INFLOW	=	0 00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0.57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40.00	33.50

651

NOTE   SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   DENVER   COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   1 THROUGH   30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1736	0 0986	0 1279	0 4847	1 0417	0 8759
	0 6292	0 5200	0 5590	0 5786	0 3949	0 3644
STD DEVIATIONS	0 1323	0 0959	0 1125	0 2847	0 4742	0 5072
	0 3086	0 3022	0 3585	0 2348	0 2396	0 2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0025	0 0016	0 0018	0 0071	0 0148	0 0129
	0 0090	0 0074	0 0082	0 0082	0 0058	0 0052
STD DEVIATIONS	0 0019	0 0015	0 0016	0 0042	0 0067	0 0075
	0 0044	0 0043	0 0053	0 0033	0 0035	0 0030

****

****

AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3.026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84861	(1 23901)	21230 469	38.14230
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 00016	(0 00003)	0 591	0 00106
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	-65 05	0 117

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT.)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29733	1079 30469
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000006	0 02329
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320 8433
MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542	
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172	

****

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

****

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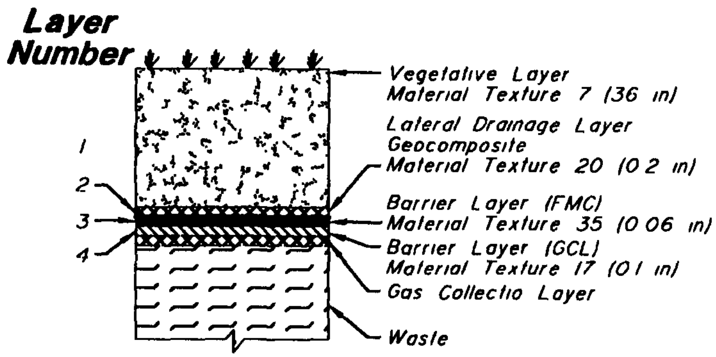
1053



Cover Alternative 8
Composite Barrier
FMC - GCL

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k IE I cm/s
  Slope 2% Length 500 ft
- ☒ 3 FMC Texture 35 k 2E 13 cm/sec
- ☒ 4 FMC Conditions 0 5 Pinholes/acre
  2 defects/acre Good Contact
- ☐ 5 Barrier Soil (GCL) Texture 17 k 3E 9 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) [ft^3]	Peak Daily (in) [ft^3]
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	5 849	0 297
Leakage	0 00000002 [0 01]	0 000 [0 00012]
Head on Barrier Layer	0 007	0 131

Proj No	Dsgn By	Scale	
601	P Corser	NA	U S Department of Energy Rocky Flats Environmental Technology Site Golden Colorado
File	Drawn By	Date	
COVER68 DWG	P Pellicer	April 19 1995	

TerraMatrix Engineering & Environmental Services

Figure 7

HELP Run - Cover Alternative 8 Input Summary

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**        FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                   **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE     C \HELP3\PATOU7\IN\SYN30M D4
TEMPERATURE DATA FILE       C \HELP3\PATOU7\IN\SYN30M D7
SOLAR RADIATION DATA FILE   C \HELP3\PATOU7\IN\SYN30M D13
EVAPOTRANSPIRATION DATA     C \HELP3\PATOU7\IN\SYN30M D11
SOIL AND DESIGN DATA FILE   C \HELP3\PATOU7\IN\RFC3 D10
OUTPUT DATA FILE            C \HELP3\PATOU7\OUT\PFC3P OUT

TIME    8 5     DATE    4/12/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU7   File  RFC3

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                 LAYER  1
                    TYPE 1   VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   7
          THICKNESS                  =    36 00   INCHES
          POROSITY                   =     0 4730 VOL/VOL
          FIELD CAPACITY             =     0 2220 VOL/VOL
          WILTING POINT              =     0 1040 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 520000001000E 03 CM/SEC

          NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                 LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  20
          THICKNESS                  =     0 20   INCHES
          POROSITY                   =     0 8500 VOL/VOL
          FIELD CAPACITY             =     0 0100 VOL/VOL
          WILTING POINT              =     0 0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 0287 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =   10 0000000000      CM/SEC
          SLOPE                      =     2 00   PERCENT
          DRAINAGE LENGTH            =   500 0    FEET


                                 LAYER  3
                      TYPE 4   FLEXIBLE MEMBRANE LINER
                        MATERIAL TEXTURE NUMBER  35
          THICKNESS                  =     0 06   INCHES
          POROSITY                   =     0 0000 VOL/VOL
          FIELD CAPACITY             =     0 0000 VOL/VOL
          WILTING POINT              =     0 0000 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 0000 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 199999996000E 12 CM/SEC
          FML PINHOLE DENSITY        =     0 50   HOLES/ACRE
          FML INSTALLATION DEFECTS   =     2 00   HOLES/ACRE
          FML PLACEMENT QUALITY      =  3  GOOD
```

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LAYER 4

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.20 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0 7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 7500 VOL/VOL
EFFECTIVE SAT HYD. COND	=	0 300000003000E 08 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400. FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4.880	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.912	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	6.158	INCHES
TOTAL INITIAL WATER	=	6.158	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0.86	0.57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   1 THROUGH   30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1736	0 0986	0 1279	0 4847	1 0417	0 8759
	0 6292	0 5200	0 5591	0 5786	0 3950	0 3644
STD DEVIATIONS	0 1323	0 0959	0 1125	0 2847	0 4742	0 5072
	0 3086	0 3022	0 3585	0 2348	0 2396	0 2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0025	0 0016	0 0018	0 0071	0 0148	0 0129
	0 0090	0 0074	0 0082	0 0082	0 0058	0 0052
STD DEVIATIONS	0 0019	0 0015	0 0016	0 0042	0 0067	0 0075
	0 0044	0 0043	0 0053	0 0033	0 0035	0 0030

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661.2	100 00
RUNOFF	0 036	(0.0822)	130.55	0 235
EVAPOTRANSPIRATION	9 467	(2.0334)	34364.64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84877	(1 23905)	21231 047	38.14333
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00000	(0.00000)	0 010	0.00002
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007	(0 001)		
CHANGE IN WATER STORAGE	-0 018	(0 3106)	-65 05	-0 117

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3.34	12124 199
RUNOFF	0 268	974 4893
DRAINAGE COLLECTED FROM LAYER 2	0 29734	1079 32874
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000000	0 00012
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320.8433

MAXIMUM VEG SOIL WATER (VOL/VOL) 0 2562

MINIMUM VEG SOIL WATER (VOL/VOL) 0.1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0.0000
4	0 1500	0 7500
SNOW WATER	0 000	

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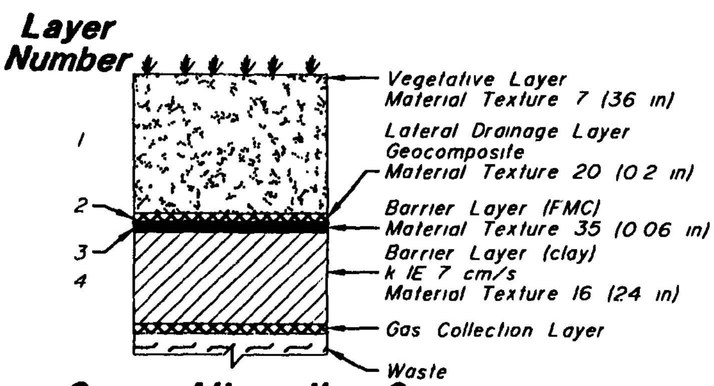

Cover Alternative 9
EPA's Composite Barrier
FMC and Clay

Input Parameters

- ☒ 1 Vegetative Cover Soil Texture 7 k 5E 4 cm/s
- ☒ 2 Lateral Drainage Layer Texture 20 k IE I cm/s
  Slope 2% Length 500 ft
- ☒ 3 FMC Texture 35 k 2E 13 cm/sec
- ☒ 4 FMC Conditions 0 5 Pinholes/acre
  2 defects/acre Good Contact
- ☒ 5 Barrier Soil Texture 16 k IE 7 cm/s
- ☐ 6 Bedding Soil For FMC Texture NA k NA cm/s
- ☒ 7 CN (Texture 7 Fair Grass Slope 5% Length 400 ft) 74 8
- ☒ 8 Evaporative Zone Depth 28 in
- ☒ 9 Leaf Area Index 1 75
- ☒ 10 Evaporation Data Synthetic (1) 30 years
- ☒ 11 Precipitation Data Synthetic (1) 30 years
- ☒ 12 Temperature Data Synthetic (1) 30 years
- ☒ 13 Solar Radiation Data Synthetic (1) 30 years
- ☒ 14 Time Period of Model 30 years

Notes
1) Based on Rocky Flats Meteorological Data
2) NA Not Applicable

Results

	Average Annual (in) (ft^3)	Peak Daily (in) (ft^3)
Precipitation	15 33	3 34
Runoff	0 036	0 268
Evaporation	9 467	NA
Lateral Drainage	5 849	0 297
Leakage	0 00001 [0 028]	0 000 [0 00082]
Head on Barrier Layer	0 007	0 131

Project N	Design By	Scal
601	P Corser	NA
File	Drawn By	Date
COVER9 DWG	P Pellicer	April 19 1995

TerraMatrix Engineering & Environmental Services

Figure 8

US Department of Energy Rocky Flats
Environmental Technology Site Golden Colorado

HELP Run - Cover
Alternative 9 Input Summary

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \HELP3\wethou7\in\SYN30M D4
TEMPERATURE DATA FILE        C \HELP3\wethou7\in\SYN30M D7
SOLAR RADIATION DATA FILE    C \HELP3\wethou7\in\SYN30M D13
EVAPOTRANSPIRATION DATA      C \HELP3\wethou7\in\SYN30M D11
SOIL AND DESIGN DATA FILE    C \HELP3\patou7\in\RFC1 D10
OUTPUT DATA FILE             C \HELP3\patou7\out\rfc1p OUT

TIME   10 9     DATE    6/22/95

******************************************************************************

     TITLE   Rocky Flats Cover Options OU7   File  RFC1

******************************************************************************

     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                LAYER  1
                    TYPE 1   VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER 7
        THICKNESS                  =     36 00    INCHES
        POROSITY                   =      0 4730 VOL/VOL
        FIELD CAPACITY             =      0 2220 VOL/VOL
        WILTING POINT              =      0 1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 1667 VOL/VOL
        EFFECTIVE SAT  HYD  COND   = 0 520000001000E 03 CM/SEC
    NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =      0 20    INCHES
        POROSITY                   =      0 8500 VOL/VOL
        FIELD CAPACITY             =      0 0100 VOL/VOL
        WILTING POINT              =      0 0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 0287 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =   10 0000000000      CM/SEC
        SLOPE                      =      2 00    PERCENT
        DRAINAGE LENGTH            =    500 0     FEET


                                LAYER  3
                      TYPE 4   FLEXIBLE MEMBRANE LINER
                        MATERIAL TEXTURE NUMBER  35
        THICKNESS                  =      0 06    INCHES
        POROSITY                   =      0 0000 VOL/VOL
        FIELD CAPACITY             =      0 0000 VOL/VOL
        WILTING POINT              =      0 0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 0000 VOL/VOL
        EFFECTIVE SAT  HYD  COND   = 0 199999996000E 12 CM/SEC
        FML PINHOLE DENSITY        =      0 50    HOLES/ACRE
        FML INSTALLATION DEFECTS   =      2 00    HOLES/ACRE
        FML PLACEMENT QUALITY      = 3    GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD COND	=	0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET.

SCS RUNOFF CURVE NUMBER	=	74.80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	28.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4.040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.912	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	16.256	INCHES
TOTAL INITIAL WATER	=	16.256	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER, COLORADO

MAXIMUM LEAF AREA INDEX	=	1.75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.60	0.43	1.33	1.80	3.32	1.77
1.39	1.53	1.24	1.24	0.86	0.57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1 48	1 52	1 49	0 92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0 018	0 000	0 008	0 000
	0 000	0 000	0 000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1736	0 0986	0 1279	0 4847	1 0417	0 8759
	0 6292	0 5200	0 5590	0 5786	0 3950	0 3644
STD DEVIATIONS	0 1323	0 0959	0 1125	0 2847	0 4742	0 5072
	0 3086	0 3022	0 3585	0 2348	0 2396	0 2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	0 0025	0.0016	0.0018	0 0071	0.0148	0 0129
	0 0090	0 0074	0.0082	0 0082	0.0058	0 0052
STD DEVIATIONS	0 0019	0 0015	0.0016	0.0042	0.0067	0 0075
	0 0044	0 0043	0.0053	0.0033	0 0035	0 0030

****

****

AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	15 33	(3.026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130.55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84877	(1 23904)	21231 031	38 14331
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 00001	(0 00000)	0.028	0 00005
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007	(0 001)		
CHANGE IN WATER STORAGE	-0 018	(0 3106)	-65 05	0 117

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29734	1079 32812
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000000	0.00082
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320.8433
MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542	
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172	

****

****

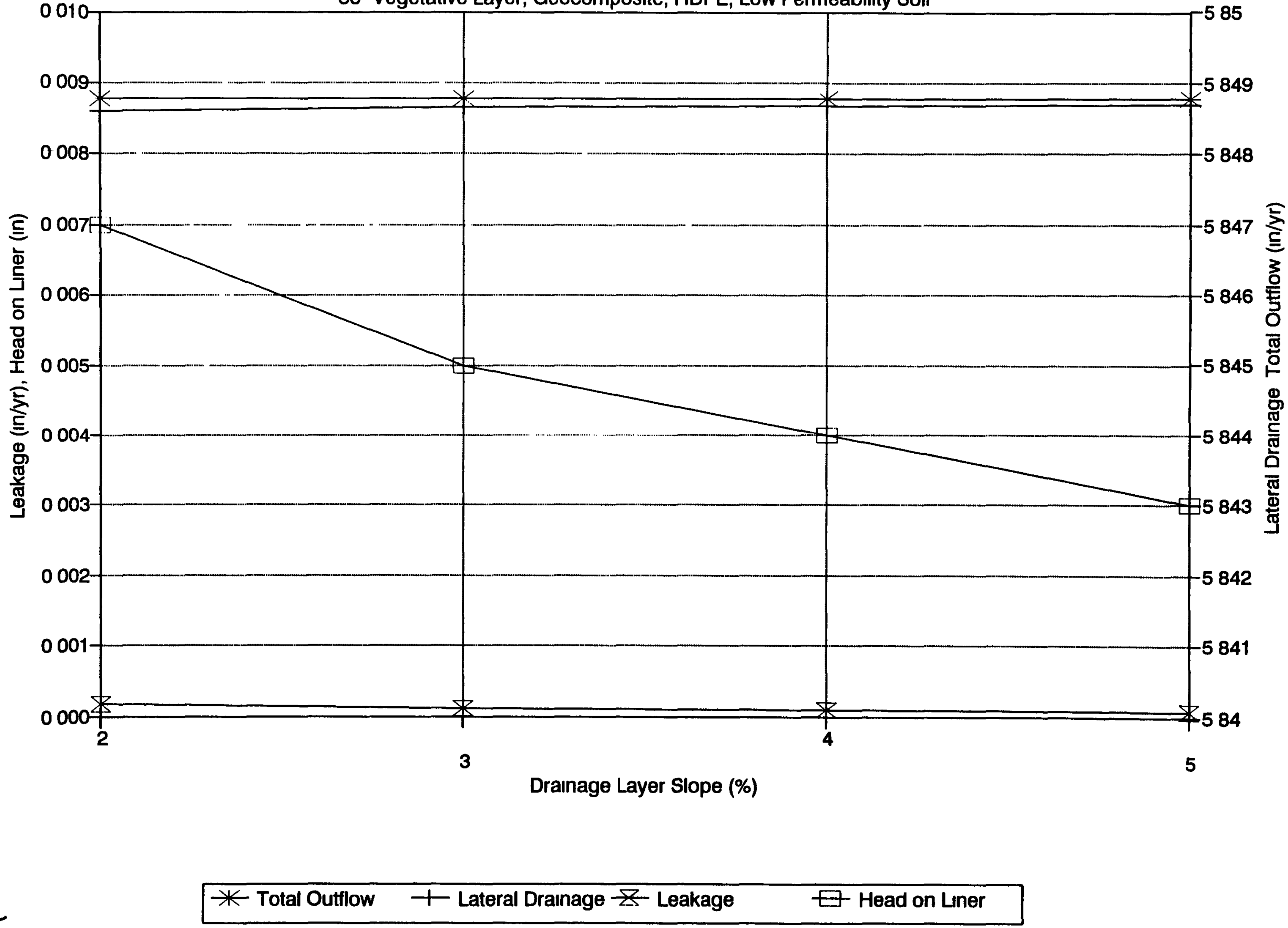
FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0 0000
4	10 2480	0 4270
SNOW WATER	0 000	

****
****

SECTION 3, DRAINAGE LAYER SLOPE

36" Vegetative Layer, Geocomposite, HDPE, Low Permeability Soil



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**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**           HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                    **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                          **
**           USAE WATERWAYS EXPERIMENT STATION                              **
**       FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                    **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D4
TEMPERATURE DATA FILE•       C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D13
EVAPOTRANSPIRATION DATA      C:\TEMP\HELP3\LDLSLOPE\IN\SYN30M.D11
SOIL AND DESIGN DATA FILE:   C \TEMP\HELP3\LDLSLOPE\IN\SSEC3_2.D10
OUTPUT DATA FILE             C \TEMP\HELP3\LDLSLOPE\OUT\SSEC3_2 OUT

TIME   8 27    DATE.  4/17/95

******************************************************************************

    TITLE•  LDL SLOPE SENSITIVIY ANALYSIS SEC3  FILE  .SSEC3_2

******************************************************************************

    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                               LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   7
         THICKNESS                  =     36 00   INCHES
         POROSITY                   =     0 4730 VOL/VOL
         FIELD CAPACITY             =     0 2220 VOL/VOL
         WILTING POINT              =     0 1040 VOL/VOL
         INITIAL SOIL WATER CONTENT =     0.1667 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 520000001000E-03 CM/SEC

       NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE

                               LAYER  2
                  TYPE 2   LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  20
         THICKNESS                  =     0 20    INCHES
         POROSITY                   =     0 8500 VOL/VOL
         FIELD CAPACITY             =     0 0100 VOL/VOL
         WILTING POINT              =     0 0050 VOL/VOL
         INITIAL SOIL WATER CONTENT =     0 0287 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =    10 0000000000     CM/SEC
         SLOPE                      =     2 00    PERCENT
         DRAINAGE LENGTH            =   500 0     FEET

                               LAYER  3
                  TYPE 4   FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
         THICKNESS                  =     0.06    INCHES
         POROSITY                   =     0 0000 VOL/VOL
         FIELD CAPACITY             =     0 0000 VOL/VOL
         WILTING POINT              =     0 0000 VOL/VOL
         INITIAL SOIL WATER CONTENT =     0 0000 VOL/VOL
         EFFECTIVE SAT. HYD  COND   =  0 199999996000E-12 CM/SEC
         FML PINHOLE DENSITY        =     0.50    HOLES/ACRE
         FML INSTALLATION DEFECTS   =     2 00    HOLES/ACRE
         FML PLACEMENT QUALITY      =  3  GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80
FRACTION OF AREA ALLOWING RUNOFF	=	100 0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000 ACRES
EVAPORATIVE ZONE DEPTH	=	28 0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912 INCHES
INITIAL SNOW WATER	=	0 000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 132 INCHES
TOTAL INITIAL WATER	=	11 132 INCHES
TOTAL SUBSURFACE INFLOW	=	0 00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 75	2.75	1 85
	1 48	1 52	1 49	0.92	0.79	0 64
STD DEVIATIONS	0.36	0 25	0 80	1.01	1 50	1 11
	0 83	0 94	0 64	0.46	0 58	0 38
RUNOFF						
TOTALS	0 003	0 007	0.018	0.000	0.008	0 000
	0 000	0 000	0.000	0.000	0.000	0 001
STD DEVIATIONS	0 008	0 023	0 072	0.000	0 042	0.000
	0.000	0 000	0.000	0.000	0 000	0.003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1 325
	0 959	0 953	0 757	0 553	0 448	0 363
STD DEVIATIONS	0 292	0 259	0 384	0.600	0 803	0 786
	0 481	0 653	0 321	0.374	0 402	0.204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1736	0 0986	0 1279	0.4847	1 0417	0 8759
	0 6292	0 5200	0 5590	0.5786	0.3949	0 3644
STD DEVIATIONS	0 1323	0 0959	0 1125	0 2847	0.4742	0.5072
	0 3086	0 3022	0 3585	0.2348	0 2396	0 2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0.0000	0.0000	0.0000
	0.0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0.0000	0 0000	0.0000
	0 0000	0 0000	0 0000	0 0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0.0025	0 0016	0 0018	0.0071	0 0148	0 0129
	0 0090	0.0074	0 0082	0.0082	0.0058	0 0052
STD DEVIATIONS	0.0019	0 0015	0 0016	0.0042	0 0067	0 0075
	0 0044	0 0043	0 0053	0 0033	0 0035	0.0030

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84861	(1 23901)	21230 469	38 14230
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00016	(0 00003)	0 591	0 00106
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007 (	0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 05	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29733	1079 30469
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000006	0 02329
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                    **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**               USAE WATERWAYS EXPERIMENT STATION                          **
**         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                  **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\TEMP\HELP3\LDLSLOPE\IN\SYN30M.D4
TEMPERATURE DATA FILE.      C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D7
SOLAR RADIATION DATA FILE:  C:\TEMP\HELP3\LDLSLOPE\IN\SYN30M D13
EVAPOTRANSPIRATION DATA:    C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D11
SOIL AND DESIGN DATA FILE:  C:\TEMP\HELP3\LDLSLOPE\IN\SSEC3_3.D10
OUTPUT DATA FILE:           C \TEMP\HELP3\LDLSLOPE\OUT\SSEC3_3.OUT

TIME    8 52     DATE    4/17/95

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     TITLE   LDL SLOPE SENSITIVIY ANALYSIS SEC3  FILE  SSEC3_3

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     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                               LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   7
          THICKNESS                   =    36 00    INCHES
          POROSITY                    =     0 4730 VOL/VOL
          FIELD CAPACITY              =     0 2220 VOL/VOL
          WILTING POINT               =     0.1040 VOL/VOL
          INITIAL SOIL WATER CONTENT  =     0 1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =  0.520000001000E 03 CM/SEC

        NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                               LAYER  2
                    TYPE 2   LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  20
          THICKNESS                   =     0 20    INCHES
          POROSITY                    =     0 8500 VOL/VOL
          FIELD CAPACITY              =     0 0100 VOL/VOL
          WILTING POINT               =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT  =     0 0224 VOL/VOL
          EFFECTIVE SAT. HYD  COND    =  10 0000000000       CM/SEC
          SLOPE                       =     3 00    PERCENT
          DRAINAGE LENGTH             =   500 0     FEET


                               LAYER  3
                    TYPE 4   FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
          THICKNESS                   =     0 06    INCHES
          POROSITY                    =     0 0000 VOL/VOL
          FIELD CAPACITY              =     0 0000 VOL/VOL
          WILTING POINT               =     0 0000 VOL/VOL
          INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY         =     0 50    HOLES/ACRE
          FML INSTALLATION DEFECTS    =     2 00    HOLES/ACRE
          FML PLACEMENT QUALITY       =  3   GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00	INCHES
POROSITY	=	0 4270	VOL/VOL
FIELD CAPACITY	=	0 4180	VOL/VOL
WILTING POINT	=	0 3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270	VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 130	INCHES
TOTAL INITIAL WATER	=	11 130	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39.77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD. DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.007	0.018	0.000	0.008	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD. DEVIATIONS	0.008	0.023	0.072	0.000	0.042	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.393	0.401	0.736	1.011	1.567	1.325
	0.959	0.953	0.757	0.553	0.448	0.363
STD. DEVIATIONS	0.292	0.259	0.384	0.600	0.803	0.786
	0.481	0.653	0.321	0.374	0.402	0.204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1732	0.0985	0.1287	0.4864	1.0447	0.8737
	0.6276	0.5206	0.5595	0.5775	0.3945	0.3638
STD. DEVIATIONS	0.1324	0.0960	0.1138	0.2851	0.4748	0.5041
	0.3081	0.3030	0.3577	0.2339	0.2390	0.2104
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0.0016	0.0010	0.0012	0.0048	0.0099	0.0086
	0.0060	0.0049	0.0055	0.0055	0.0039	0.0035
STD. DEVIATIONS	0.0013	0.0010	0.0011	0.0028	0.0045	0.0049
	0.0029	0.0029	0.0035	0.0022	0.0023	0.0020

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84867	(1 23916)	21230 656	38 14264
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00011	(0 00002)	0 413	0 00074
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 005	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 06	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 31918	1158 63452
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000005	0 01719
AVERAGE HEAD ACROSS LAYER 4	0 094	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0047	0 0234
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**      FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                     **
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PRECIPITATION DATA FILE·      C:\TEMP\HELP3\LDLSLOPE\IN\SYN30M D4
TEMPERATURE DATA FILE         C \TEMP\HELP3\LDLSLOPE\IN\SYN30M.D7
SOLAR RADIATION DATA FILE     C \TEMP\HELP3\LDLSLOPE\IN\SYN30M.D13
EVAPOTRANSPIRATION DATA       C \TEMP\HELP3\LDLSLOPE\IN\SYN30M.D11
SOIL AND DESIGN DATA FILE·    C \TEMP\HELP3\LDLSLOPE\IN\SSEC3_4 D10
OUTPUT DATA FILE              C.\TEMP\HELP3\SSEC3_4 OUT

TIME   9·16     DATE   4/17/95

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    TITLE   LDL SLOPE SENSITIVIY ANALYSIS SEC3  FILE·  SSEC3_4

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    NOTE.  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                  LAYER  1
                       TYPE 1   VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
          THICKNESS                    =      36 00    INCHES
          POROSITY                     =      0 4730 VOL/VOL
          FIELD CAPACITY               =      0 2220 VOL/VOL
          WILTING POINT                =      0 1040 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND     =   0 520000001000E-03 CM/SEC

        NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                  LAYER  2
                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
          THICKNESS                    =      0 20    INCHES
          POROSITY                     =      0 8500 VOL/VOL
          FIELD CAPACITY               =      0 0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0 0193 VOL/VOL
          EFFECTIVE SAT  HYD  COND     =     10 0000000000      CM/SEC
          SLOPE                        =      4 00    PERCENT
          DRAINAGE LENGTH              =    500 0     FEET


                                  LAYER  3
                        TYPE 4   FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0 06    INCHES
          POROSITY                     =      0 0000 VOL/VOL
          FIELD CAPACITY               =      0 0000 VOL/VOL
          WILTING POINT                =      0 0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT  HYD  COND     =   0 199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0 50    HOLES/ACRE
          FML INSTALLATION DEFECTS     =      2 00    HOLES/ACRE
          FML PLACEMENT QUALITY        =   3 - GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 130	INCHES
TOTAL INITIAL WATER	=	11 130	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE   SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   1 THROUGH   30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2.75	1.85
	1 48	1 52	1 49	0 92	0 79	0.64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0.58	0.38
RUNOFF						
TOTALS	0 003	0 007	0 018	0.000	0 008	0.000
	0 000	0 000	0.000	0 000	0.000	0.001
STD DEVIATIONS	0 008	0 023	0.072	0 000	0 042	0 000
	0 000	0 000	0 000	0 000	0 000	0.003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1 567	1.325
	0 959	0 953	0 757	0 553	0 448	0.363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0 786
	0 481	0 653	0 321	0 374	0 402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 1729	0 0985	0.1291	0 4873	1 0462	0.8725
	0 6268	0 5210	0.5597	0 5769	0 3943	0 3635
STD DEVIATIONS	0 1325	0 0960	0 1144	0 2853	0 4752	0 5024
	0 3079	0 3035	0 3571	0.2335	0 2387	0.2102
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0.0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0.0000	0 0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0012	0 0008	0 0009	0 0036	0 0075	0 0064
	0 0045	0 0037	0 0041	0 0041	0 0029	0.0026
STD DEVIATIONS	0 0009	0 0008	0 0008	0 0021	0 0034	0 0037
	0 0022	0 0022	0 0026	0 0017	0 0018	0 0015

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84869	(1 23925)	21230 756	38 14281
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00009	(0 00002)	0 320	0 00058
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 004	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 07	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 33826	1227 89905
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000004	0 01399
AVERAGE HEAD ACROSS LAYER 4	0 075	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL) 0 2542
MINIMUM VEG SOIL WATER (VOL/VOL) 0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0040	0 0201
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE      C \TEMP\HELP3\LDLSLOPE\IN\SYN30M.D4
TEMPERATURE DATA FILE        C \TEMP\HELP3\LDLSLOPE\IN\SYN30M.D7
SOLAR RADIATION DATA FILE    C:\TEMP\HELP3\LDLSLOPE\IN\SYN30M.D13
EVAPOTRANSPIRATION DATA      C \TEMP\HELP3\LDLSLOPE\IN\SYN30M D11
SOIL AND DESIGN DATA FILE    C:\TEMP\HELP3\LDLSLOPE\IN\SSEC3_5 D10
OUTPUT DATA FILE.            C \TEMP\HELP3\LDLSLOPE\OUT\SSEC3_5.OUT

TIME·   9.43      DATE·   4/17/95

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    TITLE·  LDL SLOPE SENSITIVITY ANALYSIS SEC3 - FILE·  SSEC3_5

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      NOTE·  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                  LAYER  1
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   7
         THICKNESS                    =    36 00    INCHES
         POROSITY                     =     0 4730 VOL/VOL
         FIELD CAPACITY               =     0 2220 VOL/VOL
         WILTING POINT                =     0 1040 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 1667 VOL/VOL
         EFFECTIVE SAT  HYD  COND.    =  0 520000001000E-03 CM/SEC

      NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                                  LAYER  2
                       TYPE 2   LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
         THICKNESS                    =     0.20    INCHES
         POROSITY                     =     0 8500 VOL/VOL
         FIELD CAPACITY               =     0 0100 VOL/VOL
         WILTING POINT                =     0 0050 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 0175 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =   10 0000000000     CM/SEC
         SLOPE                        =     5.00    PERCENT
         DRAINAGE LENGTH              =    500 0    FEET


                                  LAYER  3
                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                         MATERIAL TEXTURE NUMBER  35
         THICKNESS                    =     0 06    INCHES
         POROSITY                     =     0 0000 VOL/VOL
         FIELD CAPACITY               =     0.0000 VOL/VOL
         WILTING POINT                =     0 0000 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0.0000 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =  0 199999996000E-12 CM/SEC
         FML PINHOLE DENSITY          =     0 50    HOLES/ACRE
         FML INSTALLATION DEFECTS     =     2 00    HOLES/ACRE
         FML PLACEMENT QUALITY        =  3  GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS = 12 00 INCHES
POROSITY = 0 4270 VOL/VOL
FIELD CAPACITY = 0 4180 VOL/VOL
WILTING POINT = 0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0 4270 VOL/VOL
EFFECTIVE SAT HYD COND = 0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER = 74 80
FRACTION OF AREA ALLOWING RUNOFF = 100 0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 1 000 ACRES
EVAPORATIVE ZONE DEPTH = 28 0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 4 040 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 13 244 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 2 912 INCHES
INITIAL SNOW WATER = 0 000 INCHES
INITIAL WATER IN LAYER MATERIALS = 11 129 INCHES
TOTAL INITIAL WATER = 11 129 INCHES
TOTAL SUBSURFACE INFLOW = 0 00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX = 1 75
START OF GROWING SEASON (JULIAN DATE) = 122
END OF GROWING SEASON (JULIAN DATE) = 286
AVERAGE ANNUAL WIND SPEED = 8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39.77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.007	0.018	0.000	0.008	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.072	0.000	0.042	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.393	0.401	0.736	1.011	1.567	1.325
	0.959	0.953	0.757	0.553	0.448	0.363
STD DEVIATIONS	0.292	0.259	0.384	0.600	0.803	0.786
	0.481	0.653	0.321	0.374	0.402	0.204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1728	0.0984	0.1294	0.4878	1.0472	0.8718
	0.6263	0.5212	0.5598	0.5766	0.3941	0.3634
STD DEVIATIONS	0.1325	0.0961	0.1147	0.2854	0.4754	0.5014
	0.3078	0.3039	0.3568	0.2332	0.2385	0.2101
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0.0010	0.0006	0.0007	0.0029	0.0060	0.0051
	0.0036	0.0030	0.0033	0.0033	0.0023	0.0021
STD DEVIATIONS	0.0008	0.0006	0.0007	0.0017	0.0027	0.0030
	0.0018	0.0017	0.0021	0.0013	0.0014	0.0012

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84871	(1 23930)	21230 814	38 14292
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00007	(0 00001)	0 264	0 00047
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 003	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 07	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 34942	1268 39832
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000003	0 01180
AVERAGE HEAD ACROSS LAYER 4	0 062	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0036	0 0181
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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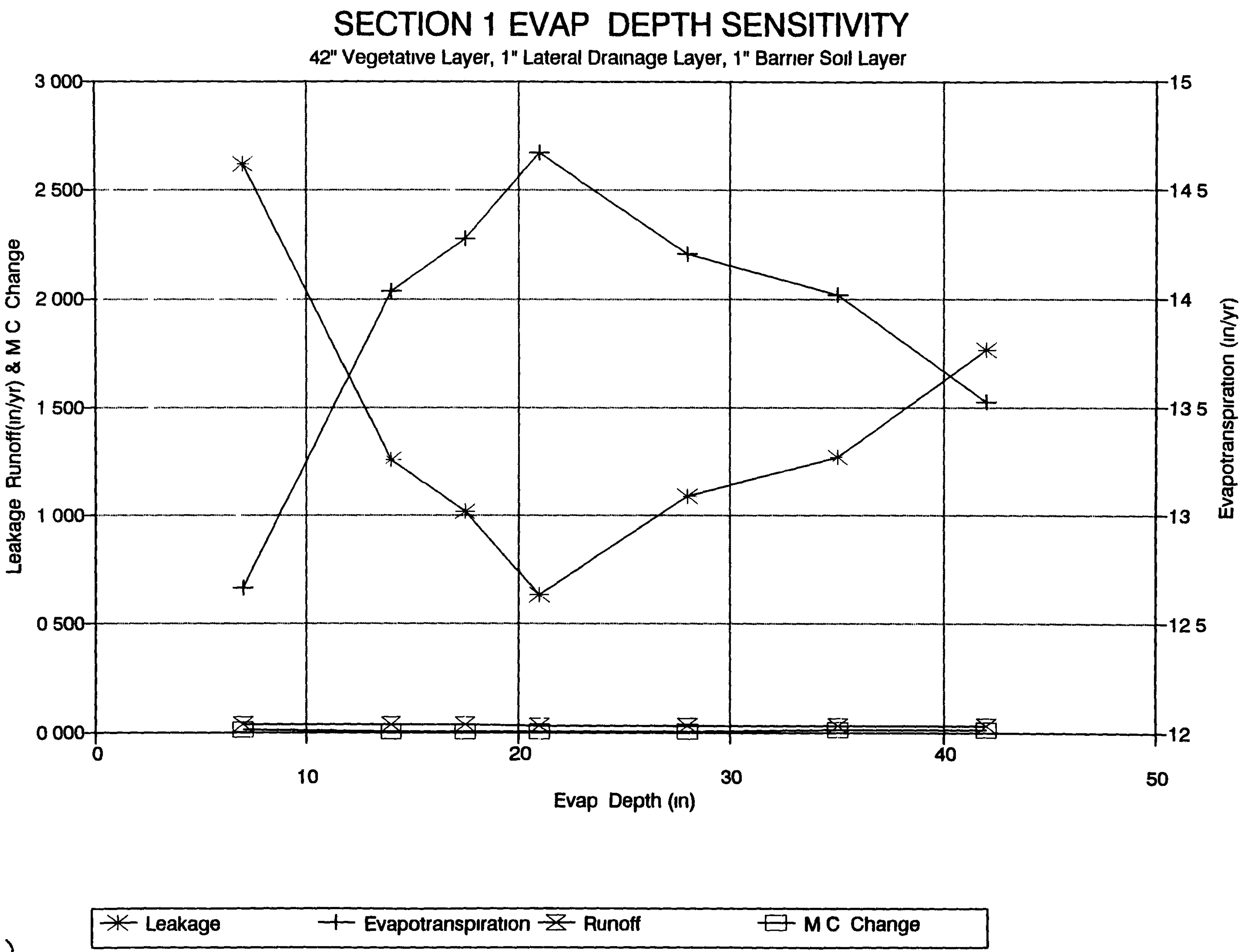
SECTION 1 EVAP DEPTH SENSITIVITY
42" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer
Leakage Runoff(in/yr) & M C Change
3 000
2 500
2 000
1 500
1 000
0 500
0 000
Evapotranspiration (in/yr)
15
14 5
14
13 5
13
12 5
12
0
10
20
30
40
50
Evap Depth (in)
Leakage
Evapotranspiration
Runoff
M C Change

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**                                                                          **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**             USAE WATERWAYS EXPERIMENT STATION                            **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
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PRECIPITATION DATA FILE      C \HELP3\EVAPSEN\IN\EVAP1.D4
TEMPERATURE DATA FILE        C.\HELP3\EVAPSEN\IN\EVAP1.D7
SOLAR RADIATION DATA FILE·   C \HELP3\EVAPSEN\IN\EVAP1.D13
EVAPOTRANSPIRATION DATA·     C:\HELP3\EVAPSEN\IN\EVAP1.D11
SOIL AND DESIGN DATA FILE:   C.\HELP3\EVAPSEN\IN\SEC1 D10
OUTPUT DATA FILE·            C \HELP3\EVAPSEN\OUT\SEC1 1 OUT

TIME   13·22    DATE·   4/13/95

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    TITLE   OUT EVAP  DEPTH SENSITIVETY ANALYSIS  FILE. SEC1

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                                LAYER  1
                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =     42 00    INCHES
        POROSITY                   =      0 4370 VOL/VOL
        FIELD CAPACITY             =      0.0620 VOL/VOL
        WILTING POINT              =      0.0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0.0765 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC


                                LAYER  2
                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =      1 00    INCHES
        POROSITY                   =      0 4370 VOL/VOL
        FIELD CAPACITY             =      0 0620 VOL/VOL
        WILTING POINT              =      0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 0620 VOL/VOL
        EFFECTIVE SAT. HYD  COND   =  0 999999978000E-02 CM/SEC
        SLOPE                      =      2 00    PERCENT
        DRAINAGE LENGTH            =    500 0     FEET


                                LAYER  3
                        TYPE 3   BARRIER SOIL LINER
                        MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =      1 00    INCHES
        POROSITY                   =      0 4370 VOL/VOL
        FIELD CAPACITY             =      0 0620 VOL/VOL
        WILTING POINT              =      0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0 4370 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	14 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 575	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6 118	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 336	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	3 712	INCHES
TOTAL INITIAL WATER	=	3 712	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.021	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.009	0.024	0.086	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.516	0.421	0.886	1.524	2.171	2.179
	1.487	1.231	1.549	0.828	0.651	0.600
STD DEVIATIONS	0.296	0.282	0.465	0.729	0.938	0.992
	0.765	0.860	0.756	0.532	0.498	0.267
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0468	0.0415	0.0416	0.0335	0.1568	0.2871
	0.2058	0.1349	0.0984	0.0862	0.0705	0.0559
STD DEVIATIONS	0.0204	0.0206	0.0193	0.0139	0.3489	0.4429
	0.1542	0.0717	0.0589	0.0559	0.0392	0.0278

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0005	0.0005	0.0004	0.0004	0.0017	0.0032
	0.0022	0.0014	0.0011	0.0009	0.0008	0.0006
STD. DEVIATIONS	0.0002	0.0002	0.0002	0.0002	0.0037	0.0049
	0.0016	0.0008	0.0007	0.0006	0.0004	0.0003

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 033	(0 0874)	119 02	0 214
EVAPOTRANSPIRATION	14 042	(2 6068)	50971 29	91 574
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 25884	(0 93753)	4569 576	8 20962
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 000	(0 4067)	1 32	0 002

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 325	1178 8231
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00116
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 298615	1083 97266
AVERAGE HEAD ACROSS LAYER 3	0 101	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2371
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0095

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3 2241	0 0768
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
******************************************************************************
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PRECIPITATION DATA FILE      C·\HELP3\EVAPSEN\IN\EVAP2 D4
TEMPERATURE DATA FILE        C \HELP3\EVAPSEN\IN\EVAP2 D7
SOLAR RADIATION DATA FILE    C \HELP3\EVAPSEN\IN\EVAP2.D13
EVAPOTRANSPIRATION DATA·     C \HELP3\EVAPSEN\IN\EVAP2 D11
SOIL AND DESIGN DATA FILE    C:\HELP3\EVAPSEN\IN\SEC1.D10
OUTPUT DATA FILE             C \HELP3\EVAPSEN\OUT\SEC1-2 OUT

TIME   13·29     DATE.   4/13/95

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    TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE· SEC1

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                LAYER 1
                   TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                    =    42 00    INCHES
         POROSITY                     =     0 4370 VOL/VOL
         FIELD CAPACITY               =     0 0620 VOL/VOL
         WILTING POINT                =     0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 0535 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =  0 999999978000E-02 CM/SEC

                                LAYER 2
                   TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                    =     1 00    INCHES
         POROSITY                     =     0 4370 VOL/VOL
         FIELD CAPACITY               =     0 0620 VOL/VOL
         WILTING POINT                =     0.0240 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 0620 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =  0 999999978000E 02 CM/SEC
         SLOPE                        =     2 00    PERCENT
         DRAINAGE LENGTH              =   500 0     FEET

                                LAYER 3
                   TYPE 3   BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                    =     1.00    INCHES
         POROSITY                     =     0 4370 VOL/VOL
         FIELD CAPACITY               =     0 0620 VOL/VOL
         WILTING POINT                =     0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 4370 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 672	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 744	INCHES
TOTAL INITIAL WATER	=	2 744	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.017	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.070	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.472	0.425	0.930	1.458	2.124	2.262
	1.721	1.358	1.375	0.907	0.660	0.519
STD DEVIATIONS	0.307	0.262	0.445	0.735	0.990	1.026
	0.876	0.810	0.731	0.536	0.517	0.262
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0449	0.0341	0.0262	0.0439	0.0997	0.2225
	0.2649	0.1166	0.0749	0.0662	0.0475	0.0474
STD DEVIATIONS	0.0398	0.0253	0.0204	0.0480	0.0718	0.2479
	0.1851	0.0431	0.0218	0.0225	0.0197	0.0337

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0005	0.0004	0.0003	0.0005	0.0011	0.0025
	0.0029	0.0013	0.0008	0.0007	0.0005	0.0005
STD DEVIATIONS	0.0004	0.0003	0.0002	0.0005	0.0008	0.0028
	0.0020	0.0005	0.0002	0.0002	0.0002	0.0004

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 027	(0 0714)	97 87	0 176
EVAPOTRANSPIRATION	14 211	(2 9308)	51587 32	92 681
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 08893	(0 50571)	3952 824	7 10158
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 006	(0 3198)	23 21	0 042

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 256	930 8232
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00019
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 112218	407 35193
AVERAGE HEAD ACROSS LAYER 3	0 038	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1709
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0175

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2 4373	0 0580
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                    **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**               USAE WATERWAYS EXPERIMENT STATION                          **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                          **
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PRECIPITATION DATA FILE:     C·\HELP3\EVAPSEN\IN\EVAP3.D4
TEMPERATURE DATA FILE:       C \HELP3\EVAPSEN\IN\EVAP3 D7
SOLAR RADIATION DATA FILE    C \HELP3\EVAPSEN\IN\EVAP3 D13
EVAPOTRANSPIRATION DATA      C \HELP3\EVAPSEN\IN\EVAP3.D11
SOIL AND DESIGN DATA FILE    C·\HELP3\EVAPSEN\IN\SEC1 D10
OUTPUT DATA FILE             C \HELP3\EVAPSEN\OUT\SEC1-3 OUT

TIME   13·31      DATE    4/13/95


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    TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC1

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                             LAYER  1
                   TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =     42.00   INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0.0297 VOL/VOL
         EFFECTIVE SAT  HYD. COND   =  0 999999978000E-02 CM/SEC


                             LAYER  2
                   TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1 00   INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 0620 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
         SLOPE                      =      2.00   PERCENT
         DRAINAGE LENGTH            =     500 0   FEET


                             LAYER  3
                   TYPE 3   BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1.00   INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0.0620 VOL/VOL
         WILTING POINT              =      0.0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 4370 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E 02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	42 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1 246	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	18 354	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1 008	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	1 745	INCHES
TOTAL INITIAL WATER	=	1 745	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.85	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.016	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.065	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.443	0.420	0.876	1.337	2.025	2.114
	1.752	1.303	1.326	0.834	0.616	0.479
STD DEVIATIONS	0.287	0.247	0.448	0.719	0.993	1.040
	0.928	0.817	0.646	0.510	0.489	0.247
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0407	0.0405	0.1172	0.2781	0.3349	0.3576
	0.2378	0.0677	0.0999	0.0538	0.0775	0.0638
STD DEVIATIONS	0.0536	0.0431	0.0888	0.1411	0.1528	0.1448
	0.1851	0.0543	0.1008	0.0742	0.1007	0.0883

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0005	0.0013	0.0031	0.0037	0.0041
	0.0027	0.0009	0.0013	0.0007	0.0009	0.0007
STD DEVIATIONS	0.0006	0.0005	0.0010	0.0015	0.0017	0.0016
	0.0021	0.0007	0.0012	0.0008	0.0011	0.0009

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 026	(0 0668)	94 18	0 169
EVAPOTRANSPIRATION	13 525	(2 9238)	49096 30	88 206
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 001	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 76947	(0 38786)	6423 182	11 53978
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 002	(0 000)		
CHANGE IN WATER STORAGE	0 013	(0 3871)	47 55	0 085

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 235	852 3436
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00038
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 159539	579 12592
AVERAGE HEAD ACROSS LAYER 3	0 054	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1248
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0211

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 6390	0 0390
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                    **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                          **
**           USAE WATERWAYS EXPERIMENT STATION                              **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                          **
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PRECIPITATION DATA FILE       C.\HELP3\EVAPSEN\IN\EVAP4 D4
TEMPERATURE DATA FILE·        C·\HELP3\EVAPSEN\IN\EVAP4.D7
SOLAR RADIATION DATA FILE     C·\HELP3\EVAPSEN\IN\EVAP4 D13
EVAPOTRANSPIRATION DATA·      C \HELP3\EVAPSEN\IN\EVAP4 D11
SOIL AND DESIGN DATA FILE     C·\HELP3\EVAPSEN\IN\SEC1 D10
OUTPUT DATA FILE·             C \HELP3\EVAPSEN\OUT\SEC1-4 OUT

TIME· 13 47    DATE·  4/13/95

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     TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE  SEC1

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     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                              LAYER  1
                     TYPE 1   VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =     42 00    INCHES
          POROSITY                   =      0 4370 VOL/VOL
          FIELD CAPACITY             =      0 0620 VOL/VOL
          WILTING POINT              =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0 0571 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC


                              LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =      1.00    INCHES
          POROSITY                   =      0 4370 VOL/VOL
          FIELD CAPACITY             =      0.0620 VOL/VOL
          WILTING POINT              =      0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.0622 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC
          SLOPE                      =      2.00    PERCENT
          DRAINAGE LENGTH            =    500.0     FEET


                              LAYER  3
                        TYPE 3   BARRIER SOIL LINER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =      1 00    INCHES
          POROSITY                   =      0.4370 VOL/VOL
          FIELD CAPACITY             =      0 0620 VOL/VOL
          WILTING POINT              =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0 4370 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE   SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A
FAIR STAND OF GRASS A SURFACE SLOPE OF 5 %
AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	21 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 505	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	9 177	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 504	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 896	INCHES
TOTAL INITIAL WATER	=	2 896	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE   EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE   PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE   TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE   SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.007	0.018	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.076	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.005
EVAPOTRANSPIRATION						
TOTALS	0.534	0.458	0.994	1.534	2.174	2.387
	1.578	1.373	1.407	0.932	0.740	0.611
STD DEVIATIONS	0.330	0.254	0.471	0.703	0.981	1.045
	0.818	0.810	0.741	0.534	0.528	0.285
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0304	0.0263	0.0265	0.0218	0.0369	0.1372
	0.1085	0.0704	0.0515	0.0463	0.0390	0.0336
STD DEVIATIONS	0.0080	0.0056	0.0061	0.0057	0.0573	0.2917
	0.1656	0.0610	0.0322	0.0221	0.0148	0.0106

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0003	0.0003	0.0003	0.0002	0.0004	0.0015
	0.0012	0.0008	0.0006	0.0005	0.0004	0.0004
STD DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0006	0.0032
	0.0018	0.0007	0.0004	0.0002	0.0002	0.0001

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 028	(0 0772)	103 37	0 186
EVAPOTRANSPIRATION	14 673	(2 7519)	53262 25	95 690
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 62846	(0 57471)	2281 326	4 09859
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 004	(0 3443)	14 26	0 026

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 283	1028 9380
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00029
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 138481	502 68530
AVERAGE HEAD ACROSS LAYER 3	0 047	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1930
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0146

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2 5141	0 0599
2	0 0623	0 0623
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
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PRECIPITATION DATA FILE      C \HELP3\EVAPSEN\IN\EVAP5 D4
TEMPERATURE DATA FILE        C \HELP3\EVAPSEN\IN\EVAP5.D7
SOLAR RADIATION DATA FILE    C \HELP3\EVAPSEN\IN\EVAP5 D13
EVAPOTRANSPIRATION DATA      C \HELP3\EVAPSEN\IN\EVAP5 D11
SOIL AND DESIGN DATA FILE    C \HELP3\EVAPSEN\IN\SEC1 D10
OUTPUT DATA FILE:            C \HELP3\EVAPSEN\OUT\SEC1-5.OUT

TIME  13 49     DATE  4/13/95


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    TITLE -- OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC1

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    NOTE  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM.

                              LAYER  1
                   TYPE 1   VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =    42 00    INCHES
          POROSITY                   =     0 4370 VOL/VOL
          FIELD CAPACITY             =     0 0620 VOL/VOL
          WILTING POINT              =     0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 0406 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC


                              LAYER  2
                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =     1 00    INCHES
          POROSITY                   =     0 4370 VOL/VOL
          FIELD CAPACITY             =     0.0620 VOL/VOL
          WILTING POINT              =     0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 0623 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
          SLOPE                      =     2 00    PERCENT
          DRAINAGE LENGTH            =   500 0     FEET


                              LAYER  3
                      TYPE 3   BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  53
          THICKNESS                  =     1 00    INCHES
          POROSITY                   =     0 4370 VOL/VOL
          FIELD CAPACITY             =     0 0620 VOL/VOL
          WILTING POINT              =     0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0 4370 VOL/VOL
          EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE   SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A
FAIR STAND OF GRASS A SURFACE SLOPE OF 5 %
AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	35 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1 076	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	15 295	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 840	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 203	INCHES
TOTAL INITIAL WATER	=	2 203	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE   EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE   PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE   TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE   SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.016	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.066	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.460	0.404	0.906	1.410	2.113	2.186
	1.813	1.319	1.368	0.883	0.657	0.503
STD DEVIATIONS	0.308	0.251	0.455	0.738	1.017	1.035
	0.938	0.817	0.707	0.530	0.528	0.251
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0336	0.0300	0.0392	0.1074	0.1827	0.2487
	0.3166	0.0984	0.0661	0.0657	0.0462	0.0386
STD DEVIATIONS	0.0305	0.0248	0.0417	0.0899	0.0899	0.1741
	0.1880	0.0386	0.0414	0.0373	0.0444	0.0382

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0004	0.0012	0.0020	0.0027
	0.0035	0.0011	0.0007	0.0007	0.0005	0.0004
STD DEVIATIONS	0.0003	0.0003	0.0004	0.0010	0.0010	0.0019
	0.0020	0.0004	0.0005	0.0004	0.0005	0.0004

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 026	(0 0683)	95 43	0 171
EVAPOTRANSPIRATION	14 022	(2 9807)	50899 16	91 445
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 27321	(0 37353)	4621 758	8 30337
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 012	(0 3713)	44 86	0 081

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 241	876 2462
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00034
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 146034	530 10394
AVERAGE HEAD ACROSS LAYER 3	0 051	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1425
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0193

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2 0752	0 0494
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
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PRECIPITATION DATA FILE      C \HELP3\EVAPSEN\IN\EVAP6.D4
TEMPERATURE DATA FILE.       C:\HELP3\EVAPSEN\IN\EVAP6.D7
SOLAR RADIATION DATA FILE    C.\HELP3\EVAPSEN\IN\EVAP6 D13
EVAPOTRANSPIRATION DATA      C:\HELP3\EVAPSEN\IN\EVAP6 D11
SOIL AND DESIGN DATA FILE·   C \HELP3\EVAPSEN\IN\SEC1 D10
OUTPUT DATA FILE·            C:\HELP3\EVAPSEN\OUT\SEC1-6 OUT

TIME   14 38     DATE·   4/13/95

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    TITLE.  OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC1

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    NOTE·  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                LAYER  1
                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                   =     42 00    INCHES
          POROSITY                    =      0 4370 VOL/VOL
          FIELD CAPACITY              =      0.0620 VOL/VOL
          WILTING POINT               =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0 0929 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =  0 999999978000E-02 CM/SEC


                                LAYER  2
                     TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                   =      1.00    INCHES
          POROSITY                    =      0 4370 VOL/VOL
          FIELD CAPACITY              =      0.0620 VOL/VOL
          WILTING POINT               =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.0620 VOL/VOL
          EFFECTIVE SAT  HYD. COND    =  0 999999978000E 02 CM/SEC
          SLOPE                       =      2 00    PERCENT
          DRAINAGE LENGTH             =    500 0     FEET


                                LAYER  3
                       TYPE 3   BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER  53
          THICKNESS                   =      1.00    INCHES
          POROSITY                    =      0 4370 VOL/VOL
          FIELD CAPACITY              =      0 0620 VOL/VOL
          WILTING POINT               =      0.0240 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0 4370 VOL/VOL
          EFFECTIVE SAT. HYD  COND    =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	7 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 162	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3 059	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 168	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	4 402	INCHES
TOTAL INITIAL WATER	=	4 402	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.023	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.010	0.025	0.097	0.001	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.425	0.407	0.899	1.391	1.944	1.747
	1.379	1.221	1.324	0.805	0.612	0.507
STD DEVIATIONS	0.288	0.206	0.464	0.697	0.906	0.965
	0.670	0.763	0.638	0.507	0.475	0.247
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1122	0.0929	0.0836	0.1212	0.4338	0.5457
	0.3452	0.2479	0.1823	0.1683	0.1500	0.1626
STD DEVIATIONS	0.0445	0.0413	0.0388	0.1240	0.5534	0.4659
	0.2110	0.1506	0.1507	0.1140	0.0903	0.0754

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0012	0.0011	0.0009	0.0013	0.0046	0.0060
	0.0037	0.0027	0.0020	0.0018	0.0017	0.0015
STD DEVIATIONS	0.0005	0.0005	0.0004	0.0014	0.0059	0.0051
	0.0023	0.0016	0.0017	0.0012	0.0010	0.0008

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0978)	129 61	0 233
EVAPOTRANSPIRATION	12 661	(2 5206)	45958 15	82 568
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 001	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	2 62570	(1 26111)	9531 304	17 12378
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 002	(0 001)		
CHANGE IN WATER STORAGE	0 012	(0 3292)	42 14	0 076

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 362	1313 7338
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00244
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 454479	1649 76050
AVERAGE HEAD ACROSS LAYER 3	0 142	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2356
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0044

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	4 2493	0 1012
2	0 0641	0 0641
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**        FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                   **
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PRECIPITATION DATA FILE      C \HELP3\EVAPSEN\IN\EVAP7 D4
TEMPERATURE DATA FILE        C \HELP3\EVAPSEN\IN\EVAP7 D7
SOLAR RADIATION DATA FILE    C:\HELP3\EVAPSEN\IN\EVAP7.D13
EVAPOTRANSPIRATION DATA      C \HELP3\EVAPSEN\IN\EVAP7.D11
SOIL AND DESIGN DATA FILE:   C \HELP3\EVAPSEN\IN\SEC1.D10
OUTPUT DATA FILE.            C \HELP3\EVAPSEN\OUT\SEC1-7.OUT

TIME   14 40    DATE    4/13/95

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    TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE  SEC1

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                               LAYER  1
                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =     42 00   INCHES
         POROSITY                   =      0.4370 VOL/VOL
         FIELD CAPACITY             =      0.0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 0697 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC

                               LAYER  2
                   TYPE 2  LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1.00   INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 0620 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
         SLOPE                      =      2 00   PERCENT
         DRAINAGE LENGTH            =    500 0    FEET

                               LAYER  3
                   TYPE 3  BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1 00   INCHES
         POROSITY                   =      0.4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 4370 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	17 5	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 632	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	7 648	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 420	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	3 426	INCHES
TOTAL INITIAL WATER	=	3 426	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.020	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.009	0.024	0.083	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.495	0.422	0.883	1.488	2.220	2.400
	1.517	1.192	1.579	0.850	0.638	0.600
STD DEVIATIONS	0.269	0.192	0.432	0.699	0.916	1.028
	0.782	0.804	0.769	0.525	0.480	0.254
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0418	0.0332	0.0323	0.0272	0.1114	0.2199
	0.1694	0.1152	0.0799	0.0763	0.0594	0.0491
STD DEVIATIONS	0.0145	0.0102	0.0090	0.0070	0.2458	0.3847
	0.1619	0.0651	0.0413	0.0543	0.0291	0.0201

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0003	0.0003	0.0012	0.0024
	0.0018	0.0012	0.0009	0.0008	0.0007	0.0005
STD DEVIATIONS	0.0002	0.0001	0.0001	0.0001	0.0026	0.0041
	0.0017	0.0007	0.0005	0.0006	0.0003	0.0002

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 032	(0 0842)	115 20	0 207
EVAPOTRANSPIRATION	14 283	(2 6420)	51848 48	93 150
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 01503	(0 80131)	3684 542	6 61958
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 004	(0 3454)	13 00	0 023

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 312	1132 7289
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00064
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 262917	954 39050
AVERAGE HEAD ACROSS LAYER 3	0 073	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2149
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0135

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3 0342	0 0722
2	0 0622	0 0622
3	0 4370	0 4370
SNOW WATER	0 000	

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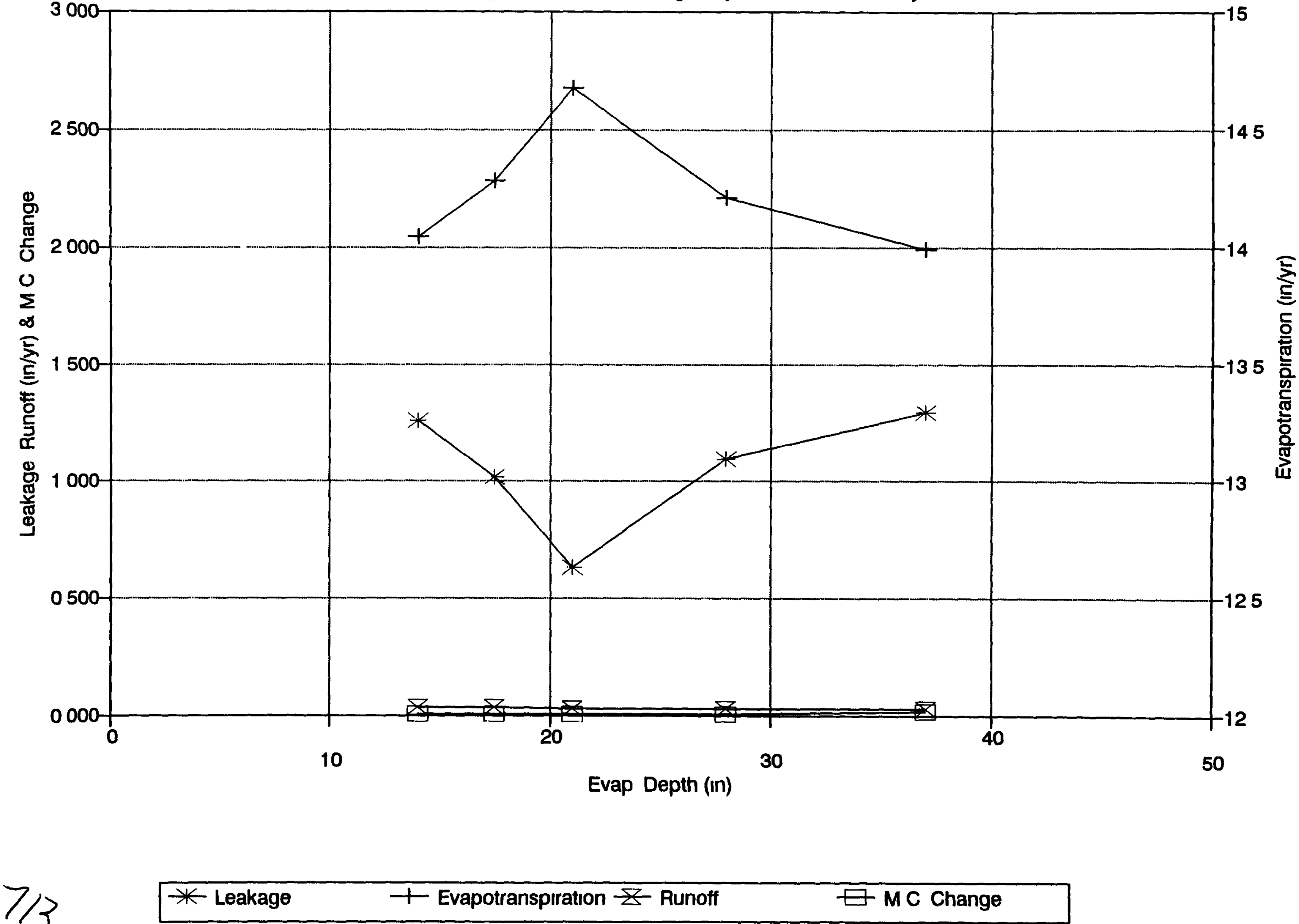
711

SECTION 2 EVAP DEPTH SENSITIVITY

36" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer



713

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
******************************************************************************
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PRECIPITATION DATA FILE       C \HELP3\evapsen\in\EVAP1 D4
TEMPERATURE DATA FILE         C:\HELP3\evapsen\in\EVAP1.D7
SOLAR RADIATION DATA FILE:    C \HELP3\evapsen\in\EVAP1.D13
EVAPOTRANSPIRATION DATA:      C \HELP3\evapsen\in\EVAP1.D11
SOIL AND DESIGN DATA FILE     C:\HELP3\evapsen\in\SEC2.D10
OUTPUT DATA FILE              C:\HELP3\evapsen\out\SEC2-1 OUT

TIME:  15:12     DATE    4/13/95

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    TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE  SEC2

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                              LAYER  1
                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =     36 00    INCHES
         POROSITY                   =      0.4370 VOL/VOL
         FIELD CAPACITY             =      0.0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0.0723 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0.999999978000E 02 CM/SEC

                              LAYER  2
                   TYPE 2   LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1 00    INCHES
         POROSITY                   =      0.4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0.0620 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
         SLOPE                      =      2 00    PERCENT
         DRAINAGE LENGTH            =    500 0     FEET

                              LAYER  3
                   TYPE 3   BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      1 00    INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 4370 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 999999978000E 02 CM/SEC
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714

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	14 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 575	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6 118	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 336	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	3 103	INCHES
TOTAL INITIAL WATER	=	3 103	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

715

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD. DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.021	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.009	0.024	0.086	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.516	0.421	0.886	1.524	2.171	2.179
	1.487	1.231	1.549	0.828	0.651	0.600
STD DEVIATIONS	0.296	0.202	0.465	0.729	0.938	0.992
	0.765	0.860	0.756	0.532	0.498	0.267
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0401	0.0353	0.0342	0.0312	0.2155	0.3265
	0.1967	0.1138	0.0888	0.0735	0.0583	0.0450
STD DEVIATIONS	0.0199	0.0217	0.0172	0.0225	0.4292	0.4125
	0.1270	0.0588	0.0705	0.0483	0.0356	0.0219

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0004	0.0003	0.0023	0.0036
	0.0021	0.0012	0.0010	0.0008	0.0006	0.0005
STD DEVIATIONS	0.0002	0.0003	0.0002	0.0002	0.0047	0.0046
	0.0014	0.0006	0.0008	0.0005	0.0004	0.0002

716

AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS   1 THROUGH   30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 033	(0 0874)	119 02	0 214
EVAPOTRANSPIRATION	14 042	(2 6068)	50971 29	91 574
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 001	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 25902	(0 95523)	4570 246	8 21083
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 000	(0 3911)	0 65	0 001

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 325	1178 8231
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00302
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 471394	1711 16174
AVERAGE HEAD ACROSS LAYER 3	0 174	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2371
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0095

FINAL WATER STORAGE AT END OF YEAR   30

LAYER	(INCHES)	(VOL/VOL)
1	2 6090	0 0725
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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******************************************************************************

PRECIPITATION DATA FILE:     C:\HELP3\EVAPSEN\IN\EVAP2.D4
TEMPERATURE DATA FILE        C:\HELP3\EVAPSEN\IN\EVAP2.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\EVAPSEN\IN\EVAP2.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\EVAPSEN\IN\EVAP2.D11
SOIL AND DESIGN DATA FILE    C:\HELP3\EVAPSEN\IN\SEC2.D10
OUTPUT DATA FILE             C:\HELP3\EVAPSEN\OUT\SEC2-2.OUT

TIME:  15 27     DATE:  4/13/95


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    TITLE   OU7 EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC2

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    NOTE  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
          COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                            LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =    36 00     INCHES
        POROSITY                   =     0 4370 VOL/VOL
        FIELD CAPACITY             =     0.0620 VOL/VOL
        WILTING POINT              =     0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0470 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC


                            LAYER  2
                  TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =     1.00     INCHES
        POROSITY                   =     0 4370 VOL/VOL
        FIELD CAPACITY             =     0.0620 VOL/VOL
        WILTING POINT              =     0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0620 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
        SLOPE                      =     2.00     PERCENT
        DRAINAGE LENGTH            =   500 0      FEET


                            LAYER  3
                     TYPE 3   BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =     1 00     INCHES
        POROSITY                   =     0 4370 VOL/VOL
        FIELD CAPACITY             =     0.0620 VOL/VOL
        WILTING POINT              =     0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.4370 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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718

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 672	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 192	INCHES
TOTAL INITIAL WATER	=	2 192	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

719

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.017	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.070	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.472	0.425	0.930	1.458	2.124	2.262
	1.721	1.358	1.375	0.907	0.660	0.519
STD DEVIATIONS	0.307	0.262	0.445	0.735	0.990	1.026
	0.876	0.810	0.731	0.536	0.517	0.262
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0366	0.0297	0.0280	0.0753	0.1510	0.2583
	0.2413	0.0821	0.0556	0.0509	0.0384	0.0426
STD DEVIATIONS	0.0360	0.0291	0.0260	0.0817	0.1099	0.2607
	0.1701	0.0326	0.0263	0.0253	0.0322	0.0419
AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)						
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0003	0.0008	0.0016	0.0029
	0.0026	0.0009	0.0006	0.0006	0.0004	0.0005
STD DEVIATIONS	0.0004	0.0003	0.0003	0.0009	0.0012	0.0029
	0.0018	0.0004	0.0003	0.0003	0.0004	0.0005

#9720

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 027	(0 0714)	97 87	0 176
EVAPOTRANSPIRATION	14 211	(2 9308)	51587 32	92 681
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 08974	(0 50658)	3955 751	7 10683
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 006	(0 3132)	20 28	0 036

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 256	930 8232
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00034
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 140044	508 36081
AVERAGE HEAD ACROSS LAYER 3	0 053	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1709
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0175

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 8610	0 0517
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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721

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE        C \HELP3\evapsen\in\EVAP3 D4
TEMPERATURE DATA FILE          C:\HELP3\evapsen\in\EVAP3.D7
SOLAR RADIATION DATA FILE      C:\HELP3\evapsen\in\EVAP3.D13
EVAPOTRANSPIRATION DATA        C:\HELP3\evapsen\in\EVAP3 D11
SOIL AND DESIGN DATA FILE      C \HELP3\evapsen\in\SEC2.D10
OUTPUT DATA FILE               C \HELP3\evapsen\out\SEC2-3.OUT

TIME   15:10      DATE    4/13/95

******************************************************************************

  TITLE:  OUT EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC2

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  NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
         COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM.

                          LAYER  1
                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =    36 00    INCHES
        POROSITY                   =     0 4370  VOL/VOL
        FIELD CAPACITY             =     0 0620  VOL/VOL
        WILTING POINT              =     0 0240  VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0295  VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC


                          LAYER  2
                 TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =     1 00    INCHES
        POROSITY                   =     0 4370  VOL/VOL
        FIELD CAPACITY             =     0 0620  VOL/VOL
        WILTING POINT              =     0.0240  VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0620  VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
        SLOPE                      =     2 00    PERCENT
        DRAINAGE LENGTH            =   500 0     FEET


                          LAYER  3
                 TYPE 3   BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  53
        THICKNESS                  =     1 00    INCHES
        POROSITY                   =     0 4370  VOL/VOL
        FIELD CAPACITY             =     0.0620  VOL/VOL
        WILTING POINT              =     0 0240  VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 4370  VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 999999978000E-02 CM/SEC
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722

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	37 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1 122	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	16 169	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 888	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	1 559	INCHES
TOTAL INITIAL WATER	=	1 559	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.016	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD DEVIATIONS	0.008	0.023	0.065	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.447	0.417	0.892	1.367	2.077	2.176
	1.895	1.331	1.391	0.873	0.649	0.477
STD DEVIATIONS	0.298	0.250	0.450	0.724	1.006	1.009
	0.935	0.818	0.691	0.519	0.522	0.228
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0713	0.0486	0.1518	0.2201	0.1622	0.2357
	0.1396	0.0177	0.0279	0.0282	0.0911	0.1010
STD DEVIATIONS	0.1010	0.0495	0.1040	0.1379	0.1248	0.1878
	0.1752	0.0536	0.0502	0.0502	0.1205	0.0950

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0008	0.0006	0.0017	0.0026	0.0018	0.0027
	0.0015	0.0002	0.0003	0.0003	0.0010	0.0011
STD DEVIATIONS	0.0011	0.0006	0.0012	0.0016	0.0013	0.0020
	0.0019	0.0006	0.0006	0.0006	0.0014	0.0010

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 026	(0 0674)	94 93	0 171
EVAPOTRANSPIRATION	13 994	(2 9458)	50797 45	91 262
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 001	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 29524	(0 41866)	4701 708	8 44701
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 018	(0 4114)	67 11	0 121

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 239	866 7422
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00022
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 127537	462 96069
AVERAGE HEAD ACROSS LAYER 3	0 041	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1271
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0191

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 6150	0 0449
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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725

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE.    C:\HELP3\evapsen\in\EVAP4.D4
TEMPERATURE DATA FILE       C:\HELP3\evapsen\in\EVAP4 D7
SOLAR RADIATION DATA FILE   C \HELP3\evapsen\in\EVAP4.D13
EVAPOTRANSPIRATION DATA     C:\HELP3\evapsen\in\EVAP4.D11
SOIL AND DESIGN DATA FILE.  C:\HELP3\evapsen\in\SEC2 D10
OUTPUT DATA FILE:           C:\HELP3\evapsen\out\SEC2-4 OUT

TIME  15:15     DATE   4/13/95

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    TITLE   OU7 EVAP. DEPTH SENSITIVETY ANALYSIS  FILE  SEC2

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM.

                              LAYER  1
                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  53
       THICKNESS                 =     36 00    INCHES
       POROSITY                  =      0.4370 VOL/VOL
       FIELD CAPACITY            =      0 0620 VOL/VOL
       WILTING POINT             =      0 0240 VOL/VOL
       INITIAL SOIL WATER CONTENT =     0 0503 VOL/VOL
       EFFECTIVE SAT  HYD  COND  =  0 999999978000E-02 CM/SEC

                              LAYER  2
                   TYPE 2   LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  53
       THICKNESS                 =      1 00    INCHES
       POROSITY                  =      0 4370 VOL/VOL
       FIELD CAPACITY            =      0 0620 VOL/VOL
       WILTING POINT             =      0 0240 VOL/VOL
       INITIAL SOIL WATER CONTENT =     0 0620 VOL/VOL
       EFFECTIVE SAT  HYD  COND  =  0 999999978000E-02 CM/SEC
       SLOPE                     =      2 00    PERCENT
       DRAINAGE LENGTH           =    500.0     FEET

                              LAYER  3
                     TYPE 3   BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER  53
       THICKNESS                 =      1 00    INCHES
       POROSITY                  =      0 4370 VOL/VOL
       FIELD CAPACITY            =      0 0620 VOL/VOL
       WILTING POINT             =      0 0240 VOL/VOL
       INITIAL SOIL WATER CONTENT =     0 4370 VOL/VOL
       EFFECTIVE SAT  HYD  COND  =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	21 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 505	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	9 177	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 504	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 310	INCHES
TOTAL INITIAL WATER	=	2 310	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD. DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.007	0.018	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.076	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.534	0.458	0.994	1.534	2.174	2.337
	1.578	1.373	1.407	0.932	0.740	0.611
STD DEVIATIONS	0.330	0.254	0.471	0.703	0.981	1.045
	0.818	0.810	0.741	0.534	0.528	0.285
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0260	0.0206	0.0210	0.0215	0.0709	0.1591
	0.1161	0.0575	0.0430	0.0366	0.0289	0.0276
STD DEVIATIONS	0.0071	0.0055	0.0061	0.0066	0.1335	0.2936
	0.1389	0.0407	0.0220	0.0146	0.0089	0.0070

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0003	0.0002	0.0002	0.0002	0.0008	0.0017
	0.0013	0.0006	0.0005	0.0004	0.0003	0.0003
STD DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0014	0.0031
	0.0015	0.0004	0.0002	0.0002	0.0001	0.0001

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 028	(0 0772)	103 37	0 186
EVAPOTRANSPIRATION	14 673	(2 7519)	53262 25	95 690
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 62904	(0 57868)	2283 406	4 10233
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 003	(0 3384)	12 18	0 022

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 283	1028 9380
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00077
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 188181	683 09589
AVERAGE HEAD ACROSS LAYER 3	0 061	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1930
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0146

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 9117	0 0531
2	0 0623	0 0623
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
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PRECIPITATION DATA FILE     C \HELP3\evapsen\in\EVAP7.D4
TEMPERATURE DATA FILE       C \HELP3\evapsen\in\EVAP7.D7
SOLAR RADIATION DATA FILE   C \HELP3\evapsen\in\EVAP7.D13
EVAPOTRANSPIRATION DATA     C \HELP3\evapsen\in\EVAP7.D11
SOIL AND DESIGN DATA FILE   C \HELP3\evapsen\in\SEC2.D10
OUTPUT DATA FILE            C \HELP3\evapsen\out\SEC2-7.OUT

TIME: 15  5      DATE    4/13/95

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    TITLE  OUT EVAP  DEPTH SENSITIVETY ANALYSIS  FILE: SEC2

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                               LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  53
        THICKNESS                    =    36.00   INCHES
        POROSITY                     =     0 4370 VOL/VOL
        FIELD CAPACITY               =     0 0620 VOL/VOL
        WILTING POINT                =     0.0240 VOL/VOL
        INITIAL SOIL WATER CONTENT   =     0 0645 VOL/VOL
        EFFECTIVE SAT  HYD  COND     =  0 999999978000E-02 CM/SEC

                               LAYER  2
                  TYPE 2   LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  53
        THICKNESS                    =     1 00   INCHES
        POROSITY                     =     0.4370 VOL/VOL
        FIELD CAPACITY               =     0 0620 VOL/VOL
        WILTING POINT                =     0.0240 VOL/VOL
        INITIAL SOIL WATER CONTENT   =     0.0620 VOL/VOL
        EFFECTIVE SAT  HYD  COND     =  0.999999978000E 02 CM/SEC
        SLOPE                        =     2 00   PERCENT
        DRAINAGE LENGTH              =   500 0    FEET

                               LAYER  3
                  TYPE 3   BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER  53
        THICKNESS                    =     1 00   INCHES
        POROSITY                     =     0 4370 VOL/VOL
        FIELD CAPACITY               =     0.0620 VOL/VOL
        WILTING POINT                =     0 0240 VOL/VOL
        INITIAL SOIL WATER CONTENT   =     0.4370 VOL/VOL
        EFFECTIVE SAT  HYD  COND     =  0.999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	17 5	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 632	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	7 648	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 420	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 819	INCHES
TOTAL INITIAL WATER	=	2 819	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.020	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.009	0.024	0.083	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.495	0.422	0.883	1.488	2.220	2.400
	1.317	1.192	1.579	0.850	0.638	0.600
STD DEVIATIONS	0.269	0.192	0.432	0.699	0.916	1.028
	0.782	0.804	0.769	0.525	0.480	0.254
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0328	0.0261	0.0250	0.0217	0.1556	0.2603
	0.1722	0.0997	0.0714	0.0637	0.0477	0.0384
STD DEVIATIONS	0.0104	0.0075	0.0065	0.0058	0.3372	0.3889
	0.1257	0.0496	0.0499	0.0450	0.0221	0.0149

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0003	0.0003	0.0003	0.0002	0.0016	0.0028
	0.0018	0.0011	0.0008	0.0007	0.0005	0.0004
STD DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0035	0.0042
	0.0014	0.0005	0.0006	0.0005	0.0002	0.0002

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 032	(0 0842)	115 20	0 207
EVAPOTRANSPIRATION	14 283	(2 6420)	51848 48	93 150
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 01457	(0 81597)	3682 894	6 61662
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 001)		
CHANGE IN WATER STORAGE	0 004	(0 3394)	14 65	0 026

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 312	1132 7289
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00142
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 387852	1407 90405
AVERAGE HEAD ACROSS LAYER 3	0 095	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2149
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0135

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2 4411	0 0678
2	0 0622	0 0622
3	0 4370	0 4370
SNOW WATER	0 000	

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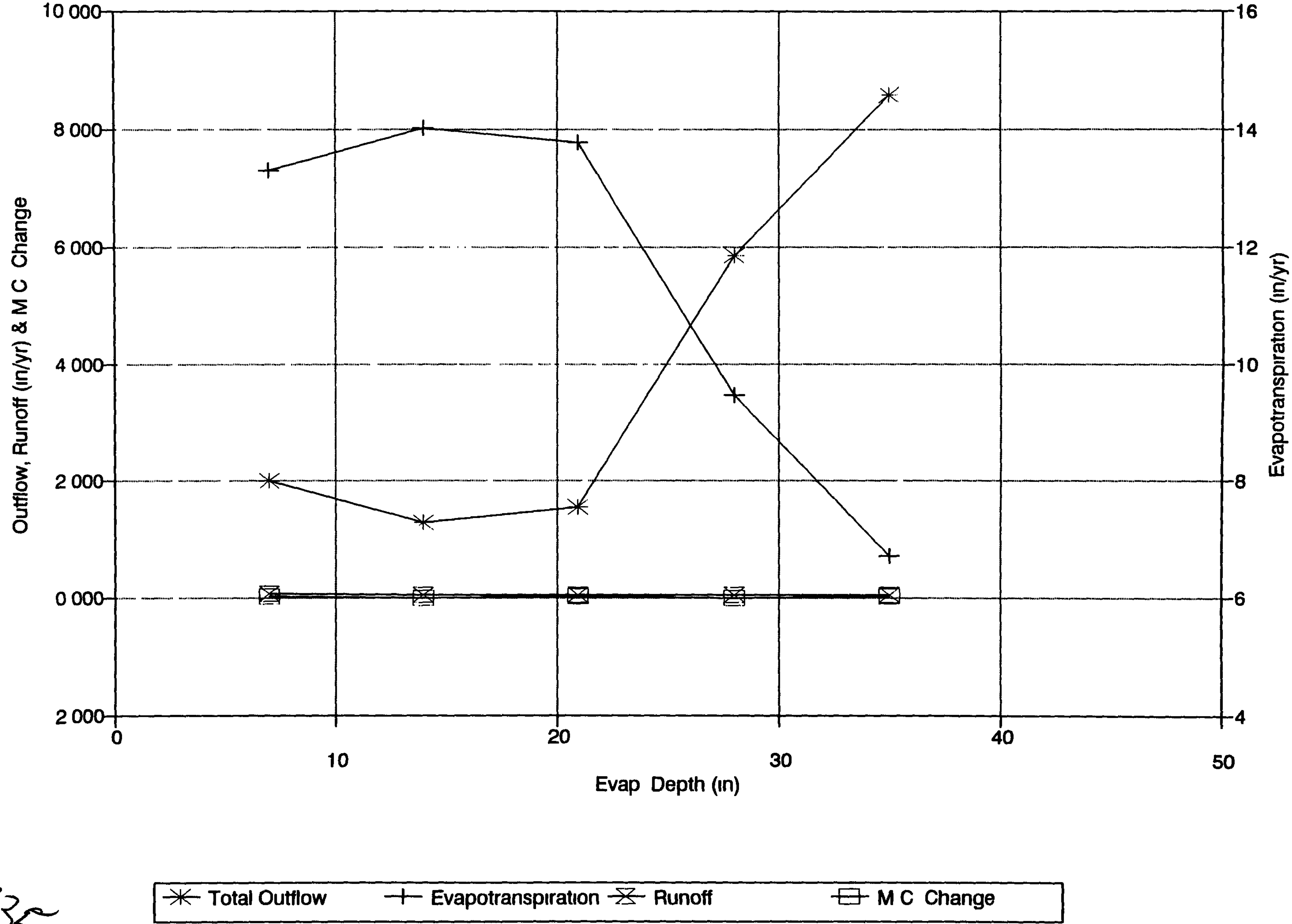
SECTION 3 EVAP DEPTH SENSITIVITY

36" Vegetative Layer, Geocomposite, HDPE, Low Permeability Soil



735

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE      C \TEMP\HELP3\EVAPSEN\IN\EVAP1 D4
TEMPERATURE DATA FILE        C \TEMP\HELP3\EVAPSEN\IN\EVAP1 D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\EVAPSEN\IN\EVAP1.D13
EVAPOTRANSPIRATION DATA      C \TEMP\HELP3\EVAPSEN\IN\EVAP1.D11
SOIL AND DESIGN DATA FILE    C \TEMP\HELP3\EVAPSEN\IN\SEC3.D10
OUTPUT DATA FILE·            C \TEMP\HELP3\EVAPSEN\IN\SEC3-1.OUT

TIME   10 8     DATE·   4/14/95

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    TITLE   Rocky Flats Cover Options OU7 - File· RFC2-5

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM.

                              LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
        THICKNESS                 =     36 00    INCHES
        POROSITY                  =      0 4730 VOL/VOL
        FIELD CAPACITY            =      0 2220 VOL/VOL
        WILTING POINT             =      0 1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 1895 VOL/VOL
        EFFECTIVE SAT  HYD  COND  =  0 520000001000E-03 CM/SEC

      NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY   2 68
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE

                              LAYER  2
                   TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  20
        THICKNESS                 =      0 20    INCHES
        POROSITY                  =      0 8500 VOL/VOL
        FIELD CAPACITY            =      0 0100 VOL/VOL
        WILTING POINT             =      0 0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0100 VOL/VOL
        EFFECTIVE SAT  HYD  COND  =   10 0000000000      CM/SEC
        SLOPE                     =      2 00    PERCENT
        DRAINAGE LENGTH           =    500 0     FEET

                              LAYER  3
                   TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
        THICKNESS                 =      0 06    INCHES
        POROSITY                  =      0 0000 VOL/VOL
        FIELD CAPACITY            =      0 0000 VOL/VOL
        WILTING POINT             =      0 0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0000 VOL/VOL
        EFFECTIVE SAT  HYD  COND  =  0 199999996000E 12 CM/SEC
        FML PINHOLE DENSITY       =      0 50    HOLES/ACRE
        FML INSTALLATION DEFECTS  =      2 00    HOLES/ACRE
        FML PLACEMENT QUALITY     =  3   GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	14 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1 940	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6 622	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1 456	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 950	INCHES
TOTAL INITIAL WATER	=	11 950	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO .

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1.73	2 75	1.85
	1 48	1 52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1.11
	0.83	0 94	0 64	0 65	0 58	0.38
RUNOFF						
TOTALS	0 003	0 008	0 023	0 000	0 012	0 000
	0 000	0 000	0 000	0 000	0 000	0.001
STD DEVIATIONS	0 009	0 024	0 097	0 001	0 046	0 000
	0 000	0 000	0 000	0 000	0 000	0.003
EVAPOTRANSPIRATION						
TOTALS	0 433	0 440	0 859	1 511	2 298	2 156
	1 478	1 158	1 596	0 854	0 644	0.596
STD DEVIATIONS	0 156	0 183	0 485	0 803	1 048	1 004
	0 726	0 928	0 712	0 550	0 483	0 298
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0140	0 0096	0 0168	0 0565	0 2959	0.3956
	0 2333	0 1088	0 0491	0 0492	0 0265	0 0207
STD DEVIATIONS	0 0461	0 0202	0 0259	0 0564	0.3699	0 3839
	0 1277	0 0917	0 0686	0.0654	0 0382	0.0479
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0.0000	0 0000	0.0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0002	0 0002	0 0002	0.0008	0 0042	0 0058
	0 0033	0 0015	0 0007	0 0007	0 0004	0 0003
STD DEVIATIONS	0 0007	0 0003	0.0004	0 0008	0 0053	0 0056
	0 0018	0 0013	0 0010	0 0009	0 0006	0 0007

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 046	(0 1061)	166 84	0 300
EVAPOTRANSPIRATION	14 022	(2 5340)	50900 71	91 447
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1 27595	(0 76860)	4631 708	8 32125
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00004	(0 00002)	0 142	0 00025
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 002	(0 001)		
CHANGE IN WATER STORAGE	0 011	(0 3485)	38 18	0 069

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 365	1324 0475
DRAINAGE COLLECTED FROM LAYER 2	0 15389	558 63672
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000004	0 01287
AVERAGE HEAD ACROSS LAYER 4	0 068	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 3549
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0896

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	6 5070	0 1807
2	0 0032	0 0160
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**           HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                   **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                         **
**           USAE WATERWAYS EXPERIMENT STATION                             **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
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PRECIPITATION DATA FILE      C \TEMP\HELP3\EVAPSEN\IN\EVAP2.D4
TEMPERATURE DATA FILE        C:\TEMP\HELP3\EVAPSEN\IN\EVAP2 D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\EVAPSEN\IN\EVAP2 D13
EVAPOTRANSPIRATION DATA      C \TEMP\HELP3\EVAPSEN\IN\EVAP2.D11
SOIL AND DESIGN DATA FILE    C \TEMP\HELP3\EVAPSEN\IN\SEC3.D10
OUTPUT DATA FILE.            C \TEMP\HELP3\EVAPSEN\IN\SEC3-2 OUT

TIME   10-34     DATE    4/14/95

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     TITLE   Rocky Flats Cover Options OU7   File  RFC2-5

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     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                                  LAYER  1
                      TYPE 1   VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   7
          THICKNESS                   =      36 00    INCHES
          POROSITY                    =       0 4730 VOL/VOL
          FIELD CAPACITY              =       0 2220 VOL/VOL
          WILTING POINT               =       0 1040 VOL/VOL
          INITIAL SOIL WATER CONTENT  =       0 1667 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =   0 520000001000E-03 CM/SEC

        NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                  LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  20
          THICKNESS                   =       0.20    INCHES
          POROSITY                    =       0.8500 VOL/VOL
          FIELD CAPACITY              =       0 0100 VOL/VOL
          WILTING POINT               =       0 0050 VOL/VOL
          INITIAL SOIL WATER CONTENT  =       0 0287 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =   10 0000000000     CM/SEC
          SLOPE                       =       2 00    PERCENT
          DRAINAGE LENGTH             =     500 0     FEET


                                  LAYER  3
                      TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
          THICKNESS                   =       0 06    INCHES
          POROSITY                    =       0 0000 VOL/VOL
          FIELD CAPACITY              =       0 0000 VOL/VOL
          WILTING POINT               =       0 0000 VOL/VOL
          INITIAL SOIL WATER CONTENT  =       0 0000 VOL/VOL
          EFFECTIVE SAT  HYD  COND    =   0 199999996000E-12 CM/SEC
          FML PINHOLE DENSITY         =       0 50    HOLES/ACRE
          FML INSTALLATION DEFECTS    =       2 00    HOLES/ACRE
          FML PLACEMENT QUALITY       =   3 - GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 132	INCHES
TOTAL INITIAL WATER	=	11 132	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39.77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.007	0.018	0.000	0.008	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.072	0.000	0.042	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.393	0.401	0.736	1.011	1.567	1.325
	0.959	0.953	0.757	0.553	0.448	0.363
STD DEVIATIONS	0.292	0.259	0.384	0.600	0.803	0.786
	0.481	0.653	0.321	0.374	0.402	0.204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1736	0.0986	0.1279	0.4847	1.0417	0.8759
	0.6292	0.5200	0.5590	0.5786	0.3949	0.3644
STD DEVIATIONS	0.1323	0.0959	0.1125	0.2847	0.4742	0.5072
	0.3086	0.3022	0.3585	0.2348	0.2396	0.2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0.0025	0.0016	0.0018	0.0071	0.0148	0.0129
	0.0090	0.0074	0.0082	0.0082	0.0058	0.0052
STD DEVIATIONS	0.0019	0.0015	0.0016	0.0042	0.0067	0.0075
	0.0044	0.0043	0.0053	0.0033	0.0035	0.0030

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84861	(1 23901)	21230 469	38 14230
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00016	(0 00003)	0 591	0 00106
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 05	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29733	1079 30469
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000006	0 02329
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320 8433
MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542	
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172	

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**            HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
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PRECIPITATION DATA FILE       C \TEMP\HELP3\EVAPSEN\IN\EVAP4 D4
TEMPERATURE DATA FILE         C \TEMP\HELP3\EVAPSEN\IN\EVAP4.D7
SOLAR RADIATION DATA FILE·    C·\TEMP\HELP3\EVAPSEN\IN\EVAP4 D13
EVAPOTRANSPIRATION DATA·      C \TEMP\HELP3\EVAPSEN\IN\EVAP4 D11
SOIL AND DESIGN DATA FILE:    C·\TEMP\HELP3\EVAPSEN\IN\SEC3.D10
OUTPUT DATA FILE·             C \TEMP\HELP3\EVAPSEN\OUT\SEC3-4 OUT

TIME    9·47    DATE    4/14/95

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    TITLE   Rocky Flats Cover Options OUT   File: RFC2-5.

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    NOTE·  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                              LAYER  1
                   TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =     36 00    INCHES
        POROSITY                   =     0 4730 VOL/VOL
        FIELD CAPACITY             =     0 2220 VOL/VOL
        WILTING POINT              =     0 1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 1532 VOL/VOL
        EFFECTIVE SAT  HYD. COND   =  0 520000001000E 03 CM/SEC

      NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                    TYPE 2   LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =     0 20    INCHES
        POROSITY                   =     0 8500 VOL/VOL
        FIELD CAPACITY             =     0 0100 VOL/VOL
        WILTING POINT              =     0 0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0100 VOL/VOL
        EFFECTIVE SAT  HYD. COND   =   10 0000000000      CM/SEC
        SLOPE                      =     2 00    PERCENT
        DRAINAGE LENGTH            =   500 0     FEET


                              LAYER  3
                    TYPE 4   FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
        THICKNESS                  =     0 06    INCHES
        POROSITY                   =     0 0000 VOL/VOL
        FIELD CAPACITY             =     0 0000 VOL/VOL
        WILTING POINT              =     0 0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0 0000 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0 199999996000E-12 CM/SEC
        FML PINHOLE DENSITY        =     0 50    HOLES/ACRE
        FML INSTALLATION DEFECTS   =     2 00    HOLES/ACRE
        FML PLACEMENT QUALITY      =  3  GOOD
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LAYER 4
TYPE 3 BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	21 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2 185	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	9 933	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 184	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	10 641	INCHES
TOTAL INITIAL WATER	=	10 641	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 73	2 75	1 85
	1.48	1.52	1.49	0.92	0 79	0 64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0 83	0 94	0 64	0 65	0 58	0 38
RUNOFF						
TOTALS	0.002	0 007	0 018	0 000	0 009	0 000
	0 000	0 000	0.000	0.000	0.000	0 000
STD DEVIATIONS	0 008	0 025	0 075	0 000	0 042	0 000
	0 000	0 000	0 000	0.000	0.000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 508	0 438	0.923	1 540	2.344	1 928
	1 358	1 287	1 229	0.921	0 747	0 547
STD DEVIATIONS	0.333	0 248	0 443	0 786	1 097	1.046
	0.698	0 872	0 668	0 532	0 586	0 262
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0348	0 0261	0.0870	0 1232	0 1718	0.2662
	0 2227	0 1811	0 1529	0 1079	0 0765	0 0746
STD DEVIATIONS	0 0513	0 0366	0 0662	0 0607	0 0837	0.3126
	0 0904	0.0633	0.0646	0 0730	0 0509	0.0663
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0.0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0005	0 0004	0 0012	0.0018	0.0024	0 0039
	0 0032	0 0026	0.0022	0 0015	0 0011	0 0011
STD DEVIATIONS	0 0007	0 0006	0.0009	0 0009	0.0012	0 0046
	0 0013	0 0009	0 0009	0.0010	0 0007	0 0009

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 037	(0 0849)	133 12	0 239
EVAPOTRANSPIRATION	13 770	(2 7303)	49986 73	89 805
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1 52482	(0 49130)	5535 080	9 94423
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00005	(0 00001)	0 179	0 00032
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 002	(0 001)		
CHANGE IN WATER STORAGE	0 002	(0 3000)	6 10	0 011

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 286	1038 9980
DRAINAGE COLLECTED FROM LAYER 2	0 15764	572 24786
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000004	0 01315
AVERAGE HEAD ACROSS LAYER 4	0 070	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2650
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0947

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 5650	0 1546
2	0 0020	0 0100
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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747

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
******************************************************************************
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PRECIPITATION DATA FILE      C \TEMP\HELP3\EVAPSEN\IN\EVAP5.D4
TEMPERATURE DATA FILE        C \TEMP\HELP3\EVAPSEN\IN\EVAP5 D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\EVAPSEN\IN\EVAP5 D13
EVAPOTRANSPIRATION DATA·     C \TEMP\HELP3\EVAPSEN\IN\EVAP5 D11
SOIL AND DESIGN DATA FILE.   C.\TEMP\HELP3\EVAPSEN\IN\SEC3.D10
OUTPUT DATA FILE             C \TEMP\HELP3\EVAPSEN\OUT\SEC3 5 OUT

TIME   11 48    DATE    4/14/95

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    TITLE·  Rocky Flats Cover Options OU7 - File  RFC2-5

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM


                              LAYER  1
                    TYPE 1   VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   7
         THICKNESS                     =     36 00    INCHES
         POROSITY                      =      0 4730 VOL/VOL
         FIELD CAPACITY                =      0 2220 VOL/VOL
         WILTING POINT                 =      0 1040 VOL/VOL
         INITIAL SOIL WATER CONTENT    =      0.1481 VOL/VOL
         EFFECTIVE SAT  HYD  COND      =   0 520000001000E-03 CM/SEC

       NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2 68
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                      TYPE 2   LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  20
         THICKNESS                     =      0 20    INCHES
         POROSITY                      =      0 8500 VOL/VOL
         FIELD CAPACITY                =      0 0100 VOL/VOL
         WILTING POINT                 =      0 0050 VOL/VOL
         INITIAL SOIL WATER CONTENT    =      0 0251 VOL/VOL
         EFFECTIVE SAT  HYD  COND      =    10.0000000000       CM/SEC
         SLOPE                         =      2 00    PERCENT
         DRAINAGE LENGTH               =    500 0     FEET


                              LAYER  3
                      TYPE 4   FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
         THICKNESS                     =      0 06    INCHES
         POROSITY                      =      0 0000 VOL/VOL
         FIELD CAPACITY                =      0 0000 VOL/VOL
         WILTING POINT                 =      0 0000 VOL/VOL
         INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
         EFFECTIVE SAT  HYD  COND      =   0 199999996000E-12 CM/SEC
         FML PINHOLE DENSITY           =      0 50    HOLES/ACRE
         FML INSTALLATION DEFECTS      =      2 00    HOLES/ACRE
         FML PLACEMENT QUALITY         =  3   GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	35 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5 086	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	16 555	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3 640	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	10 459	INCHES
TOTAL INITIAL WATER	=	10 459	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0 48	1 22	1 73	2.75	1.85
	1 48	1 52	1 49	0 92	0 79	0.64
STD DEVIATIONS	0 36	0 25	0 80	1.01	1.50	1 11
	0 83	0 94	0 64	0.65	0 58	0.38
RUNOFF						
TOTALS	0 003	0 007	0 017	0.000	0 008	0.000
	0 000	0 000	0.000	0 000	0 000	0 001
STD DEVIATIONS	0 008	0 024	0.070	0.000	0.044	0 000
	0.000	0.000	0.000	0.000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 339	0 394	0 607	0 667	0 881	0 814
	0 787	0 760	0 528	0 312	0 270	0 340
STD DEVIATIONS	0.257	0 249	0 330	0.363	0 467	0 497
	0 389	0 478	0.236	0 206	0 142	0 191
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1671	0 1000	0 3095	0 9262	1 7819	1 2640
	0 7640	0 7226	0.8105	0 8381	0 5764	0 3318
STD DEVIATIONS	0 1974	0 1022	0 3079	0.5842	0 8511	0 7352
	0 4571	0 5661	0 4604	0.3596	0.4170	0 2136
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0 0000	0 0000	0 0000	0 0001	0 0001
	0 0000	0 0000	0.0000	0 0000	0 0000	0 0000
STD DEVIATIONS	0.0000	0 0000	0 0000	0.0000	0.0003	0.0002
	0 0000	0 0000	0 0000	0.0000	0 0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0024	0 0016	0 0044	0 0146	0.1217	0 0443
	0 0109	0 0103	0 0120	0.0119	0 0085	0 0047
STD DEVIATIONS	0 0028	0.0016	0 0044	0 0108	0.3169	0 1410
	0 0065	0 0081	0 0069	0 0051	0 0061	0 0030

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0813)	130 67	0 235
EVAPOTRANSPIRATION	6 702	(1 2427)	24327 75	43 707
LATERAL DRAINAGE COLLECTED FROM LAYER 2	8 59218	(2 09163)	31189 604	56 03471
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00036	(0 00038)	1 305	0 00234
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 021	(0 029)		
CHANGE IN WATER STORAGE	0 003	(0 3229)	11 88	0 021

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 256	929 9605
DRAINAGE COLLECTED FROM LAYER 2	0 45343	1645 96484
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000297	1 07685
AVERAGE HEAD ACROSS LAYER 4	8 599	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2276
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1383

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4273	0 1508
2	0 0060	0 0302
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                  **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**             USAE WATERWAYS EXPERIMENT STATION                            **
**         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                  **
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PRECIPITATION DATA FILE       C.\HELP3\evapsen\in\EVAP6 D4
TEMPERATURE DATA FILE         C \HELP3\evapsen\in\EVAP6 D7
SOLAR RADIATION DATA FILE:    C:\HELP3\evapsen\in\EVAP6 D13
EVAPOTRANSPIRATION DATA       C:\HELP3\evapsen\in\EVAP6.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\evapsen\in\SEC3.D10
OUTPUT DATA FILE              C \HELP3\evapsen\out\sec3-6.OUT

TIME   10 59     DATE   6/22/95

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    TITLE:  Rocky Flats Cover Options OU7   File: RFC2-5

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                             LAYER  1
                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  7
      THICKNESS                  =    36.00   INCHES
      POROSITY                   =     0 4730 VOL/VOL
      FIELD CAPACITY             =     0 2220 VOL/VOL
      WILTING POINT              =     0 1040 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0 2102 VOL/VOL
      EFFECTIVE SAT. HYD  COND   =  0 520000001000E 03 CM/SEC

   NOTE.  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2.68
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                             LAYER  2
                  TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  20
      THICKNESS                  =     0 20   INCHES
      POROSITY                   =     0 8500 VOL/VOL
      FIELD CAPACITY             =     0 0100 VOL/VOL
      WILTING POINT              =     0 0050 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0 0100 VOL/VOL
      EFFECTIVE SAT  HYD. COND   =   10 0000000000      CM/SEC
      SLOPE                      =     2 00    PERCENT
      DRAINAGE LENGTH            =   500 0     FEET


                             LAYER  3
                  TYPE 4   FLEXIBLE MEMBRANE LINER
                     MATERIAL TEXTURE NUMBER  35
      THICKNESS                  =     0.06   INCHES
      POROSITY                   =     0.0000 VOL/VOL
      FIELD CAPACITY             =     0 0000 VOL/VOL
      WILTING POINT              =     0 0000 VOL/VOL
      INITIAL SOIL WATER CONTENT =     0 0000 VOL/VOL
      EFFECTIVE SAT  HYD  COND   =  0 199999996000E-12 CM/SEC
      FML PINHOLE DENSITY        =     0 50    HOLES/ACRE
      FML INSTALLATION DEFECTS   =     2 00    HOLES/ACRE
      FML PLACEMENT QUALITY      =  3 - GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	7 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1 130	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3 311	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 728	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	12 694	INCHES
TOTAL INITIAL WATER	=	12 694	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39.77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0.008	0.026	0.000	0.016	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.010	0.024	0.111	0.001	0.052	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.432	0.459	0.820	1.374	2.152	1.876
	1.447	1.187	1.473	0.839	0.658	0.571
STD DEVIATIONS	0.188	0.238	0.429	0.787	0.996	1.022
	0.761	0.894	0.695	0.557	0.502	0.274
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0559	0.0257	0.0207	0.0830	0.3884	0.5253
	0.3518	0.2108	0.1188	0.0892	0.0585	0.0640
STD DEVIATIONS	0.0947	0.0494	0.0464	0.0900	0.3982	0.4525
	0.1876	0.1183	0.1274	0.1115	0.0935	0.0769
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0.0008	0.0004	0.0003	0.0012	0.0055	0.0077
	0.0050	0.0030	0.0017	0.0013	0.0009	0.0009
STD DEVIATIONS	0.0013	0.0008	0.0007	0.0013	0.0057	0.0067
	0.0027	0.0017	0.0019	0.0016	0.0014	0.0011

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 052	(0 1209)	187 78	0 337
EVAPOTRANSPIRATION	13 289	(2 5525)	48240 40	86 668
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1 99131	(1 03594)	7228 448	12 98651
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 00006	(0 00003)	0 216	0 00039
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 002	(0 001)		
CHANGE IN WATER STORAGE	0 001	(0 3340)	4 36	0 008

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 412	1496 3047
DRAINAGE COLLECTED FROM LAYER 2	0 29096	1056 17444
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000006	0 02285
AVERAGE HEAD ACROSS LAYER 4	0 128	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 3816
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0573

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	7 6028	0 2112
2	0 0036	0 0182
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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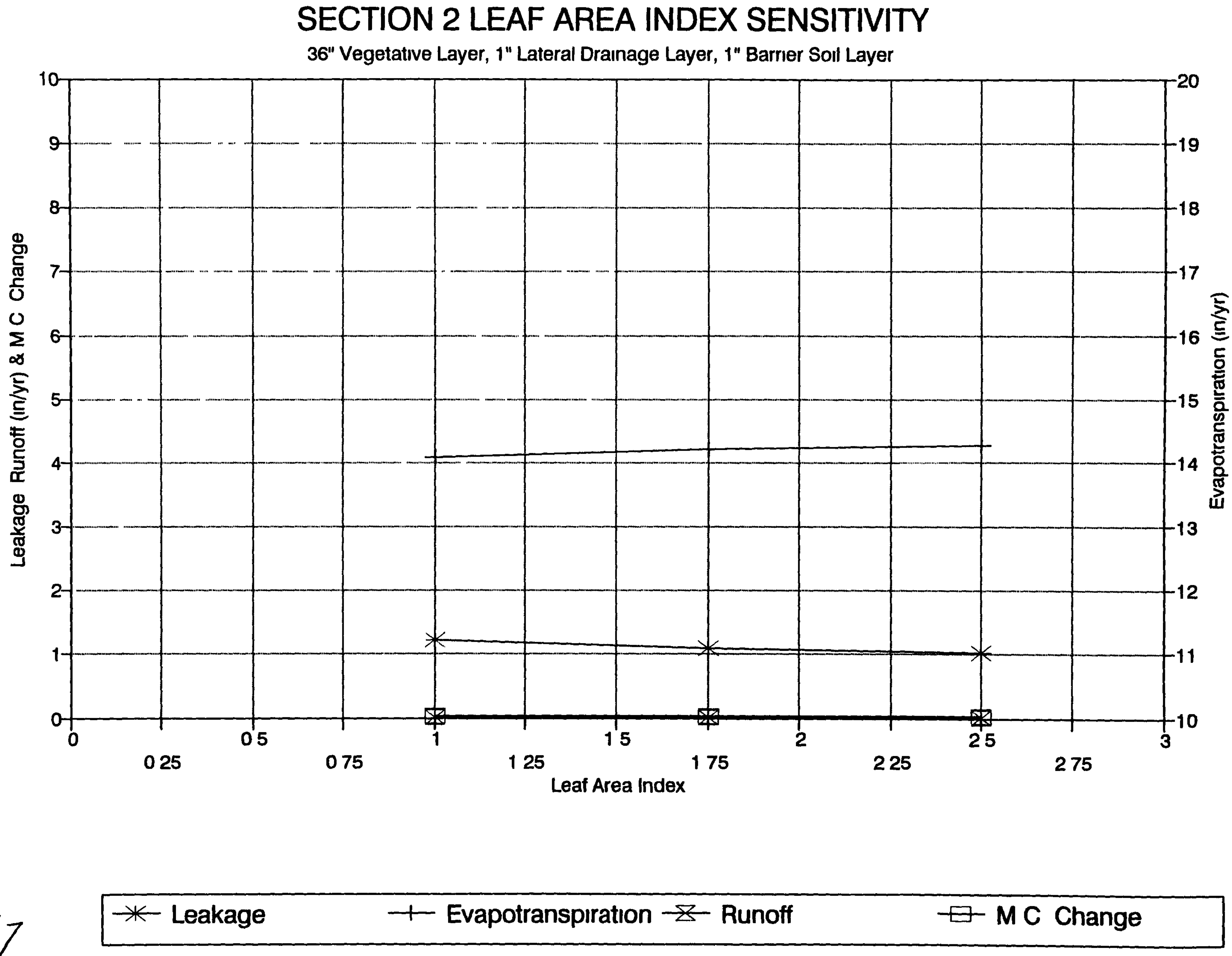
SECTION 2 LEAF AREA INDEX SENSITIVITY
36" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer
Leakage Runoff (in/yr) & M C Change
Evapotranspiration (in/yr)
Leaf Area Index
0
0 25
0 5
0 75
1
1 25
1 5
1 75
2
2 25
2 5
2 75
3
10
9
8
7
6
5
4
3
2
1
0
20
19
18
17
16
15
14
13
12
11
10
Leakage
Evapotranspiration
Runoff
M C Change

757

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**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**            HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**         FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                  **
******************************************************************************
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PRECIPITATION DATA FILE      C \HELP3\LEAFSEN\IN\LEAF1 D4
TEMPERATURE DATA FILE·       C \HELP3\LEAFSEN\IN\LEAF1.D7
SOLAR RADIATION DATA FILE    C·\HELP3\LEAFSEN\IN\LEAF1 D13
EVAPOTRANSPIRATION DATA      C \HELP3\LEAFSEN\IN\LEAF1 D11
SOIL AND DESIGN DATA FILE    C.\HELP3\LEAFSEN\IN\SEC2L.D10
OUTPUT DATA FILE:            C·\HELP3\LEAFSEN\OUT\SEC2L-1 OUT

TIME   11 52     DATE    4/14/95

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    TITLE·  OU7 LEAF AREA INDEX SENSITIVITY ANALYSIS FILE· SEC2L

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                               LAYER  1
                   TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                 =     36 00    INCHES
         POROSITY                  =     0 4370 VOL/VOL
         FIELD CAPACITY            =     0 0620 VOL/VOL
         WILTING POINT             =     0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =    0 0470 VOL/VOL
         EFFECTIVE SAT. HYD  COND  =  0 999999978000E-02 CM/SEC

                               LAYER  2
                     TYPE 2  LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                 =      1.00    INCHES
         POROSITY                  =     0 4370 VOL/VOL
         FIELD CAPACITY            =     0 0620 VOL/VOL
         WILTING POINT             =     0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =    0 0620 VOL/VOL
         EFFECTIVE SAT. HYD  COND  =  0 999999978000E-02 CM/SEC
         SLOPE                     =      2 00    PERCENT
         DRAINAGE LENGTH           =    500 0     FEET

                               LAYER  3
                      TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  53
         THICKNESS                 =      1 00    INCHES
         POROSITY                  =     0 4370 VOL/VOL
         FIELD CAPACITY            =     0 0620 VOL/VOL
         WILTING POINT             =     0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =    0 4370 VOL/VOL
         EFFECTIVE SAT  HYD  COND  =  0 999999978000E-02 CM/SEC
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758

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 672	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 192	INCHES
TOTAL INITIAL WATER	=	2 192	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.017	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.070	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.472	0.425	0.930	1.458	2.124	2.262
	1.721	1.358	1.375	0.907	0.660	0.519
STD DEVIATIONS	0.307	0.262	0.445	0.735	0.990	1.026
	0.876	0.810	0.731	0.536	0.517	0.262
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0366	0.0297	0.0280	0.0753	0.1510	0.2583
	0.2413	0.0821	0.0556	0.0509	0.0384	0.0426
STD DEVIATIONS	0.0360	0.0291	0.0260	0.0817	0.1099	0.2607
	0.1701	0.0326	0.0263	0.0253	0.0322	0.0419

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0003	0.0008	0.0016	0.0029
	0.0026	0.0009	0.0006	0.0006	0.0004	0.0005
STD DEVIATIONS	0.0004	0.0003	0.0003	0.0009	0.0012	0.0029
	0.0018	0.0004	0.0003	0.0003	0.0004	0.0005

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 027	(0 0714)	97 87	0 176
EVAPOTRANSPIRATION	14 211	(2 9308)	51587 32	92 681
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 08974	(0 50658)	3955 751	7 10683
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 006	(0 3132)	20 28	0 036

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 256	930 8232
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00034
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 140044	508 36081
AVERAGE HEAD ACROSS LAYER 3	0 053	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1709
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0175

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 8610	0 0517
2	0 0620	0 0620
3	0 4370	0 4370
SNOW WATER	0 000	

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**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**          HELP MODEL VERSION 3 03  (31 DECEMBER 1994)                     **
**          DEVELOPED BY ENVIRONMENTAL LABORATORY                           **
**          USAE WATERWAYS EXPERIMENT STATION                               **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
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PRECIPITATION DATA FILE      C \HELP3\LEAFSEN\IN\LEAF2.D4
TEMPERATURE DATA FILE        C \HELP3\LEAFSEN\IN\LEAF2.D7
SOLAR RADIATION DATA FILE    C \HELP3\LEAFSEN\IN\LEAF2.D13
EVAPOTRANSPIRATION DATA      C \HELP3\LEAFSEN\IN\LEAF2.D11
SOIL AND DESIGN DATA FILE    C \HELP3\LEAFSEN\IN\SEC2L.D10
OUTPUT DATA FILE             C:\HELP3\LEAFSEN\OUT\SEC2L-2.OUT

TIME  11.54    DATE  4/14/95

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    TITLE   OU7 LEAF AREA INDEX SENSITIVITY ANALYSIS FILE  SEC2L

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                               LAYER  1
                     TYPE 1   VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =      36 00    INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 0463 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC

                               LAYER  2
                     TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =       1 00    INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0 0622 VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0.999999978000E-02 CM/SEC
         SLOPE                      =       2 00    PERCENT
         DRAINAGE LENGTH            =     500 0     FEET

                               LAYER  3
                     TYPE 3 - BARRIER SOIL LINER
                       MATERIAL TEXTURE NUMBER  53
         THICKNESS                  =       1 00    INCHES
         POROSITY                   =      0 4370 VOL/VOL
         FIELD CAPACITY             =      0 0620 VOL/VOL
         WILTING POINT              =      0 0240 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0.4370 VOL/VOL
         EFFECTIVE SAT  HYD. COND   =  0.999999978000E-02 CM/SEC

               GENERAL DESIGN AND EVAPORATIVE ZONE DATA
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NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 935	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 672	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 167	INCHES
TOTAL INITIAL WATER	=	2 167	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 00
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

763

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.017	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.070	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.471	0.424	0.939	1.457	2.107	1.944
	1.872	1.381	1.401	0.915	0.666	0.520
STD DEVIATIONS	0.314	0.260	0.446	0.726	0.985	0.903
	0.812	0.826	0.726	0.541	0.528	0.268
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0417	0.0339	0.0324	0.0687	0.1307	0.2258
	0.2732	0.1509	0.0784	0.0721	0.0519	0.0457
STD DEVIATIONS	0.0316	0.0318	0.0299	0.0862	0.0993	0.2499
	0.1824	0.0916	0.0451	0.0367	0.0471	0.0391

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0004	0.0004	0.0004	0.0008	0.0014	0.0025
	0.0029	0.0016	0.0009	0.0008	0.0006	0.0005
STD DEVIATIONS	0.0003	0.0004	0.0003	0.0009	0.0011	0.0028
	0.0020	0.0010	0.0005	0.0004	0.0005	0.0004

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 027	(0 0715)	97 98	0 176
EVAPOTRANSPIRATION	14 093	(2 8511)	51157 47	91 909
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 20556	(0 52142)	4376 175	7 86216
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 008	(0 4014)	29 58	0 053

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 256	930 6218
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00026
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 132577	481 25348
AVERAGE HEAD ACROSS LAYER 3	0 043	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1700
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0184

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 9113	0 0531
2	0 0629	0 0629
3	0 4370	0 4370
SNOW WATER	0 000	

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765

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**                                                                          **
**           HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                  **
**           HELP MODEL VERSION 3 03  (31 DECEMBER                          **
**           DEVELOPED BY ENVIRONMENTAL LABORATORY                          **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:     C \HELP3\LEAFSEN\IN\LEAF3.D4
TEMPERATURE DATA FILE        C:\HELP3\LEAFSEN\IN\LEAF3.D7
SOLAR RADIATION DATA FILE·   C.\HELP3\LEAFSEN\IN\LEAF3.D13
EVAPOTRANSPIRATION DATA·     C \HELP3\LEAFSEN\IN\LEAF3.D11
SOIL AND DESIGN DATA FILE.   C·\HELP3\LEAFSEN\IN\SEC2L.D10
OUTPUT DATA FILE:            C.\HELP3\LEAFSEN\OUT\SEC2L-3.OUT

TIME   11·56     DATE·   4/14/95

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     TITLE   OUT LEAF AREA INDEX SENSITIVITY ANALYSIS FILE· SEC2L

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     NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM.

                               LAYER  1
                     TYPE 1   VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                    =     36.00    INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0 0620 VOL/VOL
          WILTING POINT                =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0 0481 VOL/VOL
          EFFECTIVE SAT  HYD. COND     =  0.999999978000E-02 CM/SEC


                               LAYER  2
                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                    =      1 00    INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0 0620 VOL/VOL
          WILTING POINT                =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0 0620 VOL/VOL
          EFFECTIVE SAT. HYD  COND     =  0 999999978000E-02 CM/SEC
          SLOPE                        =      2 00    PERCENT
          DRAINAGE LENGTH              =    500.0     FEET


                               LAYER  3
                       TYPE 3   BARRIER SOIL LINER
                        MATERIAL TEXTURE NUMBER  53
          THICKNESS                    =      1 00    INCHES
          POROSITY                     =      0 4370 VOL/VOL
          FIELD CAPACITY               =      0 0620 VOL/VOL
          WILTING POINT                =      0 0240 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0 4370 VOL/VOL
          EFFECTIVE SAT  HYD  COND     =  0 999999978000E-02 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 1 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	40 60	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0 996	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12 236	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0 672	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2 232	INCHES
TOTAL INITIAL WATER	=	2 232	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	2 50
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

STATION LATITUDE = 39 77 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.46	0.48	1.22	1.73	2.75	1.85
	1.48	1.52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0.36	0.25	0.80	1.01	1.50	1.11
	0.83	0.94	0.64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.002	0.007	0.017	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD DEVIATIONS	0.008	0.023	0.070	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.475	0.421	0.940	1.461	2.154	2.442
	1.549	1.367	1.375	0.894	0.661	0.538
STD DEVIATIONS	0.313	0.257	0.445	0.734	0.996	1.086
	0.821	0.820	0.740	0.528	0.519	0.266
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0310	0.0263	0.0270	0.0689	0.1414	0.3244
	0.1704	0.0718	0.0496	0.0472	0.0304	0.0347
STD DEVIATIONS	0.0282	0.0266	0.0280	0.0787	0.1245	0.3061
	0.1116	0.0250	0.0154	0.0258	0.0141	0.0332

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	0.0003	0.0003	0.0003	0.0008	0.0015	0.0036
	0.0019	0.0008	0.0006	0.0005	0.0003	0.0004
STD DEVIATIONS	0.0003	0.0003	0.0003	0.0009	0.0013	0.0034
	0.0012	0.0003	0.0002	0.0003	0.0002	0.0004

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 027	(0 0719)	98 23	0 176
EVAPOTRANSPIRATION	14 277	(2 8785)	51825 16	93 108
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0 00000	(0 00000)	0 000	0 00000
PERCOLATION/LEAKAGE THROUGH LAYER 3	1 02314	(0 47533)	3714 005	6 67252
AVERAGE HEAD ACROSS TOP OF LAYER 3	0 001	(0 000)		
CHANGE IN WATER STORAGE	0 007	(0 3513)	23 81	0 043

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 258	936 2756
DRAINAGE COLLECTED FROM LAYER 2	0 00000	0 00034
PERCOLATION/LEAKAGE THROUGH LAYER 3	0 143690	521 59631
AVERAGE HEAD ACROSS LAYER 3	0 053	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 1713
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0167

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1 9284	0 0536
2	0 0631	0 0631
3	0 4370	0 4370
SNOW WATER	0 000	

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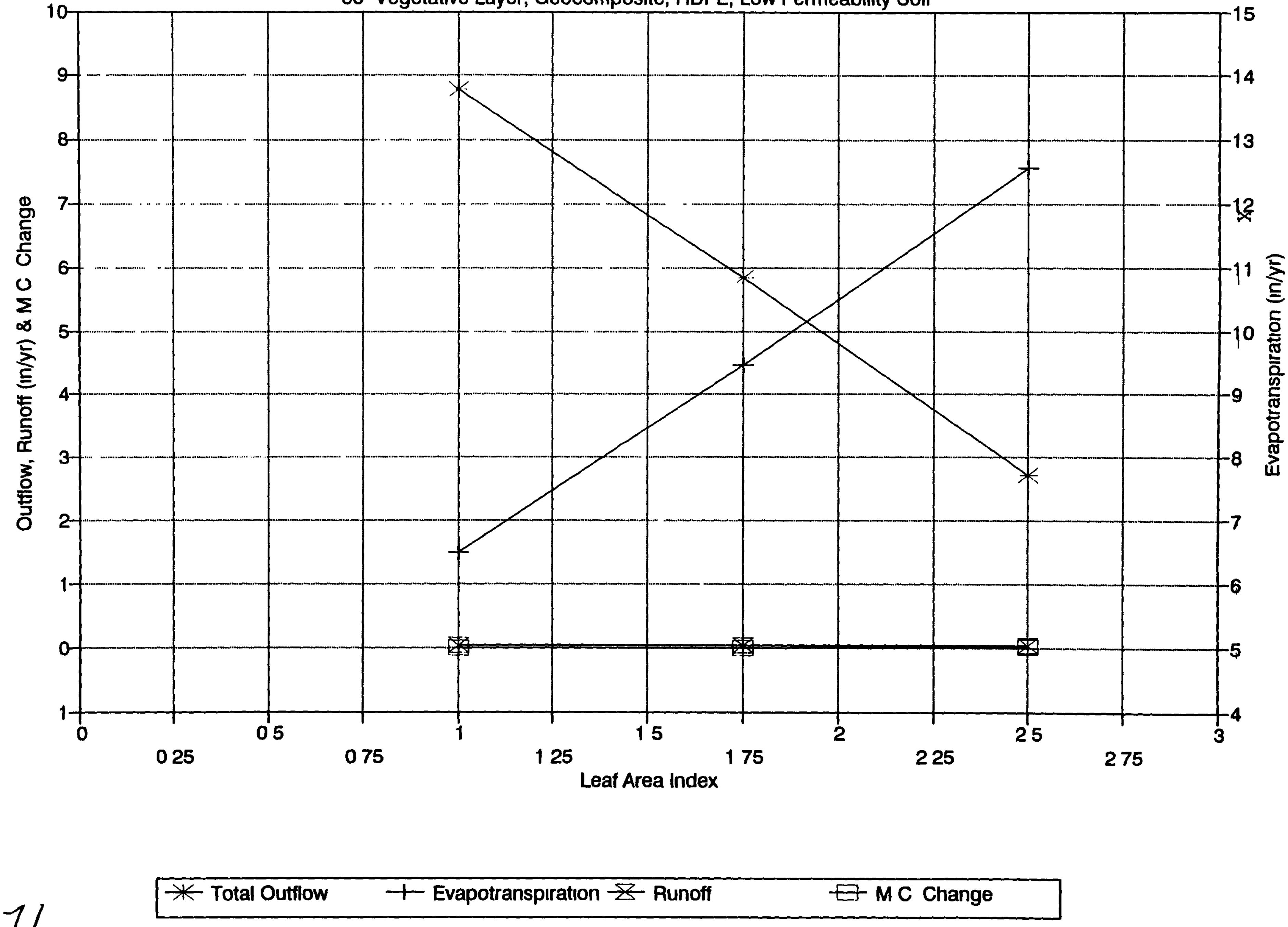
769

SECTION 3 LEAF AREA INDEX SENSITIVITY

36" Vegetative Layer, Geocomposite, HDPE, Low Permeability Soil



711

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******************************************************************************
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**                                                                          **
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**          HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                     **
**          DEVELOPED BY ENVIRONMENTAL LABORATORY                           **
**          USAE WATERWAYS EXPERIMENT STATION                               **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\TEMP\HELP3\LEAFSEN\IN\LEAF1.D4
TEMPERATURE DATA FILE       C.\TEMP\HELP3\LEAFSEN\IN\LEAF1.D7
SOLAR RADIATION DATA FILE   C \TEMP\HELP3\LEAFSEN\IN\LEAF1.D13
EVAPOTRANSPIRATION DATA·    C \TEMP\HELP3\LEAFSEN\IN\LEAF1 D11
SOIL AND DESIGN DATA FILE:  C \TEMP\HELP3\LEAFSEN\IN\SEC3L D10
OUTPUT DATA FILE            C \TEMP\HELP3\LEAFSEN\OUT\SEC3L-1.OUT

TIME   13 54     DATE    4/14/95


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    TITLE   Rocky Flats Cover Options OU7   File  RFC2-5.

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    NOTE   INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM


                              LAYER  1
                  TYPE 1   VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
         THICKNESS                  =    36 00    INCHES
         POROSITY                   =     0 4730  VOL/VOL
         FIELD CAPACITY             =     0 2220  VOL/VOL
         WILTING POINT              =     0.1040  VOL/VOL
         INITIAL SOIL WATER CONTENT =     0 1667  VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 520000001000E-03 CM/SEC

       NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 2 68
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                  TYPE 2   LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  20
         THICKNESS                  =     0 20    INCHES
         POROSITY                   =     0 8500  VOL/VOL
         FIELD CAPACITY             =     0 0100  VOL/VOL
         WILTING POINT              =     0 0050  VOL/VOL
         INITIAL SOIL WATER CONTENT =     0 0287  VOL/VOL
         EFFECTIVE SAT  HYD  COND   =   10 0000000000      CM/SEC
         SLOPE                      =     2 00    PERCENT
         DRAINAGE LENGTH            =   500 0     FEET


                              LAYER  3
                  TYPE 4   FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
         THICKNESS                  =     0 06    INCHES
         POROSITY                   =     0.0000  VOL/VOL
         FIELD CAPACITY             =     0 0000  VOL/VOL
         WILTING POINT              =     0 0000  VOL/VOL
         INITIAL SOIL WATER CONTENT =     0 0000  VOL/VOL
         EFFECTIVE SAT  HYD  COND   =  0 199999996000E-12 CM/SEC
         FML PINHOLE DENSITY        =     0 50    HOLES/ACRE
         FML INSTALLATION DEFECTS   =     2 00    HOLES/ACRE
         FML PLACEMENT QUALITY      =  3 - GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4 040	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	11 132	INCHES
TOTAL INITIAL WATER	=	11 132	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 75
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

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NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1 22	1 78	2 75	1.85
	1 48	1 52	1.49	0.92	0.79	0.64
STD DEVIATIONS	0 36	0 25	0 80	1 01	1 50	1 11
	0.83	0 94	0 64	0.65	0.58	0.38
RUNOFF						
TOTALS	0.003	0 007	0 018	0 000	0 008	0.000
	0 000	0 000	0 000	0 000	0.000	0 001
STD DEVIATIONS	0.008	0 023	0 072	0.000	0.042	0 000
	0.000	0 000	0 000	0 000	0 000	0 003
EVAPOTRANSPIRATION						
TOTALS	0 393	0 401	0 736	1 011	1.567	1 325
	0.959	0 953	0.757	0 553	0 448	0.363
STD DEVIATIONS	0 292	0 259	0 384	0 600	0 803	0.786
	0 481	0 653	0 321	0 374	0.402	0 204
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.1736	0 0986	0 1279	0 4847	1 0417	0.8759
	0 6292	0 5200	0.5590	0 5786	0 3949	0 3644
STD DEVIATIONS	0 1323	0 0959	0 1125	0 2847	0 4742	0 5072
	0 3086	0 3022	0 3585	0 2348	0 2396	0 2108
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0 0000	0.0000	0.0000	0.0000
	0.0000	0 0000	0.0000	0 0000	0.0000	0.0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0.0000	0 0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0025	0 0016	0 0018	0.0071	0 0148	0.0129
	0 0090	0 0074	0 0082	0.0082	0 0058	0.0052
STD DEVIATIONS	0.0019	0.0015	0 0016	0.0042	0 0067	0 0075
	0 0044	0 0043	0 0053	0 0033	0 0035	0.0030

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774

AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0822)	130 55	0 235
EVAPOTRANSPIRATION	9 467	(2 0334)	34364 64	61 739
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5 84861	(1 23901)	21230 469	38 14230
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00016	(0 00003)	0 591	0 00106
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 007	(0 001)		
CHANGE IN WATER STORAGE	0 018	(0 3106)	65 05	0 117

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 268	974 4993
DRAINAGE COLLECTED FROM LAYER 2	0 29733	1079 30469
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000006	0 02329
AVERAGE HEAD ACROSS LAYER 4	0 131	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2542
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1172

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4640	0 1518
2	0 0060	0 0302
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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775

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**                                                                          **
**            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
**            HELP MODEL VERSION 3 01   (14 OCTOBER 1994)                   **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**                USAE WATERWAYS EXPERIMENT STATION                         **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE      C:\TEMP\HELP3\LEAFSEN\IN\LEAF2.D4
TEMPERATURE DATA FILE        C \TEMP\HELP3\LEAFSEN\IN\LEAF2.D7
SOLAR RADIATION DATA FILE    C \TEMP\HELP3\LEAFSEN\IN\LEAF2.D13
EVAPOTRANSPIRATION DATA      C \TEMP\HELP3\LEAFSEN\IN\LEAF2 D11
SOIL AND DESIGN DATA FILE.   C:\TEMP\HELP3\LEAFSEN\IN\SEC3L D10
OUTPUT DATA FILE:            C \TEMP\HELP3\LEAFSEN\OUT\SEC3L-2.OUT

TIME   12:13     DATE    4/14/95

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     TITLE:  Rocky Flats Cover Options OU7 - File: RFC2-5.

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY STATE VALUES BY THE PROGRAM

                           LAYER  1
              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =    36 00   INCHES
        POROSITY                   =    0 4730 VOL/VOL
        FIELD CAPACITY             =    0 2220 VOL/VOL
        WILTING POINT              =    0 1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =    0 1478 VOL/VOL
        EFFECTIVE SAT  HYD  COND   =  0.520000001000E-03 CM/SEC

       NOTE.  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1 80
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE

                           LAYER  2
                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =    0 20    INCHES
        POROSITY                   =    0 8500 VOL/VOL
        FIELD CAPACITY             =    0.0100 VOL/VOL
        WILTING POINT              =    0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =    0.0263 VOL/VOL
        EFFECTIVE SAT  HYD  COND.  =  10 0000000000     CM/SEC
        SLOPE                      =    2.00    PERCENT
        DRAINAGE LENGTH            =   500 0    FEET


                           LAYER  3
                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
        THICKNESS                  =    0 06    INCHES
        POROSITY                   =    0.0000 VOL/VOL
        FIELD CAPACITY             =    0 0000 VOL/VOL
        WILTING POINT              =    0 0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =    0 0000 VOL/VOL
        EFFECTIVE SAT  HYD. COND   =  0 199999996000E 12 CM/SEC
        FML PINHOLE DENSITY        =    0 50    HOLES/ACRE
        FML INSTALLATION DEFECTS   =    2 00    HOLES/ACRE
        FML PLACEMENT QUALITY      =  3   GOOD
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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00	INCHES
POROSITY	=	0 4270	VOL/VOL
FIELD CAPACITY	=	0 4180	VOL/VOL
WILTING POINT	=	0 3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270	VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3 461	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	10 451	INCHES
TOTAL INITIAL WATER	=	10 451	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	1 00
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

777

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39.77 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

		JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION							
	TOTALS	0 46	0 48	1 22	1.75	2 75	1.85
		1 48	1 52	1 49	0.92	0 79	0.64
	STD DEVIATIONS	0 36	0 25	0 80	1.01	1.50	1 11
		0 83	0 94	0 64	0.65	0.58	0.38
RUNOFF							
	TOTALS	0 002	0.007	0 018	0.000	0.008	0.000
		0 000	0 000	0 000	0 000	0 000	0 001
	STD DEVIATIONS	0 008	0 023	0.075	0 000	0.042	0.000
		0 000	0 000	0 000	0.000	0 000	0.003
EVAPOTRANSPIRATION							
	TOTALS	0 332	0 398	0.605	0 652	0.979	0 871
		0 686	0 592	0 499	0.287	0.271	0 331
	STD DEVIATIONS	0 263	0 252	0 318	0 410	0 496	0 511
		0 298	0 325	0 268	0.187	0 177	0 189
LATERAL DRAINAGE COLLECTED FROM LAYER 2							
	TOTALS	0 2033	0 1069	0 2569	0.9257	1 6052	1.2842
		0.8426	0 9082	0 8446	0.8701	0 5581	0.3860
	STD DEVIATIONS	0 1825	0 1024	0 3123	0 5722	0 7763	0.7172
		0 5117	0 6768	0.4302	0 3809	0 4057	0 2276
PERCOLATION/LEAKAGE THROUGH LAYER 4							
	TOTALS	0 0000	0 0000	0.0000	0 0000	0 0001	0 0001
		0 0000	0 0000	0.0000	0 0000	0 0000	0.0000
	STD DEVIATIONS	0 0000	0 0000	0 0000	0 0001	0 0003	0 0001
		0 0000	0 0001	0.0000	0 0000	0 0000	0 0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4							
	AVERAGES	0 0029	0 0017	0 0037	0 0320	0 1005	0.0360
		0 0120	0 0255	0 0124	0 0124	0 0082	0 0055
	STD DEVIATIONS	0 0026	0 0016	0.0044	0 0747	0.2641	0 0714
		0 0073	0 0740	0 0063	0 0054	0.0060	0 0032

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1778

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0833)	130 11	0 234
EVAPOTRANSPIRATION	6 501	(1 2168)	23600 26	42 400
LATERAL DRAINAGE COLLECTED FROM LAYER 2	8 79172	(2 07055)	31913 945	57 33605
PERCOLATION/LEAKAGE THROUGH	0 00037	(0 00034)	1 334	0 00240
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 021	(0 026)		
CHANGE IN WATER STORAGE	0 004	(0 2885)	15 56	0 028

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 275	996 9226
DRAINAGE COLLECTED FROM LAYER 2	0 38885	1411 52979
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000265	0 96276
AVERAGE HEAD ACROSS LAYER 4	7 651	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2290
MINIMUM VEG SOIL WATER (VOL/VOL)	0 1200

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4500	0 1514
2	0 0058	0 0288
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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**                                                                          **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**             HELP MODEL VERSION 3 01    (14 OCTOBER 1994)                 **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**             USAE WATERWAYS EXPERIMENT STATION                            **
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C \TEMP\HELP3\LEAFSEN\IN\LEAF3 D4
TEMPERATURE DATA FILE       C \TEMP\HELP3\LEAFSEN\IN\LEAF3.D7
SOLAR RADIATION DATA FILE:  C \TEMP\HELP3\LEAFSEN\IN\LEAF3.D13
EVAPOTRANSPIRATION DATA:    C \TEMP\HELP3\LEAFSEN\IN\LEAF3.D11
SOIL AND DESIGN DATA FILE   C:\TEMP\HELP3\LEAFSEN\IN\SEC3L.D10
OUTPUT DATA FILE            C:\TEMP\HELP3\LEAFSEN\OUT\SEC3L-3 OUT

TIME   12 36     DATE   4/14/95

******************************************************************************

    TITLE   Rocky Flats Cover Options OU7 - File: RFCZ-5

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    NOTE.  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM

                              LAYER  1
                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   7
         THICKNESS                    =    36 00   INCHES
         POROSITY                     =     0 4730 VOL/VOL
         FIELD CAPACITY               =     0 2220 VOL/VOL
         WILTING POINT                =     0 1040 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 1472 VOL/VOL
         EFFECTIVE SAT  HYD  COND     =  0.520000001000E-03 CM/SEC
      NOTE   SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3 63
             FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE


                              LAYER  2
                    TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER  20
         THICKNESS                    =     0 20   INCHES
         POROSITY                     =     0 8500 VOL/VOL
         FIELD CAPACITY               =     0 0100 VOL/VOL
         WILTING POINT                =     0 0050 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 0240 VOL/VOL
         EFFECTIVE SAT. HYD  COND     =   10 0000000000      CM/SEC
         SLOPE                        =     2 00   PERCENT
         DRAINAGE LENGTH              =   500 0    FEET


                              LAYER  3
                    TYPE 4   FLEXIBLE MEMBRANE LINER
                     MATERIAL TEXTURE NUMBER  35
         THICKNESS                    =     0 06   INCHES
         POROSITY                     =     0 0000 VOL/VOL
         FIELD CAPACITY               =     0 0000 VOL/VOL
         WILTING POINT                =     0 0000 VOL/VOL
         INITIAL SOIL WATER CONTENT   =     0 0000 VOL/VOL
         EFFECTIVE SAT  HYD  COND.    =  0 199999996000E 12 CM/SEC
         FML PINHOLE DENSITY          =     0 50   HOLES/ACRE
         FML INSTALLATION DEFECTS     =     2 00   HOLES/ACRE
         FML PLACEMENT QUALITY        =  3   GOOD
```

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LAYER 4

TYPE 3 BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12 00 INCHES
POROSITY	=	0 4270 VOL/VOL
FIELD CAPACITY	=	0 4180 VOL/VOL
WILTING POINT	=	0 3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0 4270 VOL/VOL
EFFECTIVE SAT HYD COND	=	0 999999975000E 05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A FAIR STAND OF GRASS A SURFACE SLOPE OF 5 % AND A SLOPE LENGTH OF 400 FEET

SCS RUNOFF CURVE NUMBER	=	74 80	
FRACTION OF AREA ALLOWING RUNOFF	=	100 0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1 000	ACRES
EVAPORATIVE ZONE DEPTH	=	28 0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3 461	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13 244	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2 912	INCHES
INITIAL SNOW WATER	=	0 000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	10 429	INCHES
TOTAL INITIAL WATER	=	10 429	INCHES
TOTAL SUBSURFACE INFLOW	=	0 00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE EVAPOTRANSPIRATION DATA WAS OBTAINED FROM DENVER COLORADO

MAXIMUM LEAF AREA INDEX	=	2 50
START OF GROWING SEASON (JULIAN DATE)	=	122
END OF GROWING SEASON (JULIAN DATE)	=	286
AVERAGE ANNUAL WIND SPEED	=	8 80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	54 00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50 00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49 00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54 00 %

NOTE PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0 60	0 43	1 33	1 80	3 32	1 77
1 39	1 53	1 24	1 24	0 86	0 57

NOTE TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31 00	33 00	37 00	45 50	55 50	64 50
71 50	70 50	61 50	52 50	40 00	33 50

781

NOTE SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DENVER, COLORADO

STATION LATITUDE = 39 77 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0 46	0 48	1.22	1 73	2 75	1.85
	1 48	1 52	1 49	0 92	0 79	0.64
STD. DEVIATIONS	0.36	0 25	0.80	1.01	1 50	1.11
	0.83	0 94	0 64	0.45	0.58	0.38
RUNOFF						
TOTALS	0 002	0 007	0 017	0 000	0 009	0.000
	0 000	0 000	0 000	0.000	0 000	0 001
STD DEVIATIONS	0 008	0 023	0 070	0.000	0 042	0.000
	0 000	0 000	0 000	0.000	0 000	0.003
EVAPOTRANSPIRATION						
TOTALS	0 448	0 416	0 852	1 297	2 051	1 764
	1 479	1 234	1 186	0 781	0 608	0 456
STD DEVIATIONS	0 305	0 253	0 421	0 719	1 043	0.923
	0 726	0 764	0 523	0 439	0 493	0.232
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0 0869	0 0566	0.0854	0 2510	0 5743	0.5186
	0 2760	0 1567	0.1634	0 2013	0 1686	0.1813
STD DEVIATIONS	0 0939	0 0708	0.0618	0 1575	0.2849	0 3901
	0 1443	0 1226	0 1351	0 1543	0 1451	0 1467
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0 0000	0 0000	0.0000	0 0000	0 0000	0.0000
	0 0000	0 0000	0.0000	0 0000	0 0000	0.0000
STD DEVIATIONS	0 0000	0 0000	0 0000	0 0000	0 0000	0.0000
	0 0000	0 0000	0 0000	0 0000	0 0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ACROSS LAYER 4						
AVERAGES	0 0012	0.0009	0 0012	0.0037	0 0082	0 0076
	0 0039	0 0022	0 0024	0 0029	0.0025	0 0026
STD DEVIATIONS	0.0013	0 0011	0 0009	0 0023	0 0041	0.0057
	0 0021	0 0017	0 0020	0 0022	0.0021	0 0021

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AVERAGE ANNUAL TOTALS & (STD DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU FEET	PERCENT
PRECIPITATION	15 33	(3 026)	55661 2	100 00
RUNOFF	0 036	(0 0811)	130 26	0 234
EVAPOTRANSPIRATION	12 572	(2 7183)	45638 13	81 993
LATERAL DRAINAGE COLLECTED FROM LAYER 2	2 72004	(0 58883)	9873 753	17 73902
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0 00008	(0 00002)	0 295	0 00053
AVERAGE HEAD ACROSS TOP OF LAYER 4	0 003	(0 001)		
CHANGE IN WATER STORAGE	0 005	(0 3519)	18 77	0 034

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU FT)
PRECIPITATION	3 34	12124 199
RUNOFF	0 263	955 5568
DRAINAGE COLLECTED FROM LAYER 2	0 33404	1212 57751
PERCOLATION/LEAKAGE THROUGH LAYER 4	0 000007	0 02582
AVERAGE HEAD ACROSS LAYER 4	0 147	
SNOW WATER	1 19	4320 8433

MAXIMUM VEG SOIL WATER (VOL/VOL)	0 2525
MINIMUM VEG SOIL WATER (VOL/VOL)	0 0991

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	5 4544	0 1515
2	0 0057	0 0283
3	0 0000	0 0000
4	5 1240	0 4270
SNOW WATER	0 000	

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****

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List of Tables

H 1 Landfill Closure Cost Estimation Requirements

A detailed cost estimate for landfill closure and for the 30-year post-closure care period is mandated by 40 CFR Parts H 265 142 and 265 144 Subpart H, respectively The numbers must reflect the expenses incurred when hiring a third party and the dollar value at the time of the estimate and must be adjusted annually for inflation thereafter

H 2 Cost Estimate Sources

The cost estimate presented in this section is based on the following sources

- Guidance Manual Cost Estimates for Closure and Post-Closure Plans (Subparts G and H) EPA #530-SW-86-036, OSWER Policy Directive Number 9476 00-6 1987
- Means Building Construction Cost Data 1994
- Vendor quotes
- Professional operator experience
- Previous closure activities

The guidance manual is used as a check list to determine the components applicable for the cost estimate The relevant actions to be implemented during closure are wetland mitigation, Preble s meadow jumping mouse habitat mitigation, landfill cover installation, gas monitoring, and groundwater monitoring Detailed units and frequencies are obtained from vendors operator experience, and previous closure plans

H 3 Assumptions and Calculations

Assumptions and calculations are described for the closure period and the 30-year post-closure care period by unit Unit costs for components of all cover systems are provided in Table H-1 Conceptual cost estimates for the nine alternatives are provided in Tables H-2 through H-11 Detailed cost estimates for Alternatives 5, 7 and 9 are provided in Tables H-12 through H-15 Post-closure costs are the same for each of the detailed estimates and are provided in Table H-12 A risk analysis and assessment form is provided in Table H-16 and Table H-17

H 3 1 Closure Period

Assume 6 months for completion and 21 working days in a month

H 3 1 1 Mobilization/Demobilization

Based on professional experience, a lump sum of $250,000 has been determined to be sufficient to account for the entire closure project

H 3 1 2 Wetland Mitigation

The landfill cap covers approximately 1 09 acres of U.S Army Corps of Engineer classified wetlands (Figure 2-15). EG&G estimates that the area of wetlands destroyed must be replaced three-fold at $40,000 per acre Also, an additional 10 percent is assumed to account for any injury that may occur during excavation

Total wetland acreage required to be built:

x 1 09 acres + 10% = 3.60 acres

H 3 1 3 Potential Preble's Meadow Jumping Mouse Habitat Mitigation

The area designated as Preble's meadow jumping mouse habitat is shown in Figure 2-15 An additional 10 percent of the affected area is included to account for injury that may occur during excavation

Total Preble's meadow jumping mouse habitat mitigation required

6 60 acres + 10% = 7 26 acres

The estimated mitigation cost per acre is $40,000

H 3 1 4 Groundwater Monitoring Wells

- Assume the abandonment of wells in the landfill will be completed in a separate action, therefore, these costs are not included in the cost estimate
- A minimum of four monitoring wells are required, one hydraulically upgradient and three hydraulically downgradient of the landfill at the limit of the waste management area [6 CCR 1007-3 Part 265 91]. Assume there will be four existing monitoring wells that meet the criteria described above and will be available for use, therefore, there will be no associated capital costs
- Assume existing background data are sufficient and additional tests are not required
- During closure, groundwater monitoring must continue. Assume during the six-month closure period, one sampling and analysis event will occur (Section H.3 2)

H 3 1 5 Reroute South Surface-Water Drainage Ditch

The cap extends over the existing south surface-water drainage ditch requiring the diversion ditch to be rerouted Assume 1 300 feet of the diversion ditch will be rerouted at $8 per foot This construction cost is for an unlined, 12-foot-wide by 3-foot-deep trapezoidal ditch Design of the ditch will be undertaken during the final design

H 3 1 6 Landfill Cover

Materials obtained onsite or offsite will vary in cost When such a range exists for the various cover components, the more conservative unit cost is selected The assumptions associated with the different cover components are summarized below

H 3 1 6 1 Vegetative Layer

- The fill material will be obtained onsite or from a nearby offsite source The net fill material required is 131 400 yd^3 and the total surface area is 1,315 600 square feet (30 2 acres) with varying depths across the landfill It is assumed that special preparation of this material is not required

- The 36-inch vegetative cover consists of 6 inches of soil on top of 36 inches of soil

H 3 1 6 2 Lateral-Drainage Layer and Gas Collection Layer

- The geocomposite layer is a combination of geotextiles and geonets sequentially heat bonded in the following order geotextile geonet and geotextile This material will be used for both the gas-collection and drainage layer

H 3 1 6 3 Barrier Layer

- The FMC layer made from a 30-mil PVC is 0 06 inches thick

- GCL is bentonite between two layers of geotextiles and is 0 1 inches thick

- FMC/GCL layer is a bonded composite of both the FMC and the GCL and is 0 16 inches thick

- The soil bedding layer is 6 inches of soil It is assumed that special preparation of this material is not required

- The low-permeability soil layer is 12 inches thick and requires wet table conditioning and compaction

- The 24-inch compacted clay layer requires bentonite additive followed by wet and dry table conditionings and compaction

The RCRA cover area is 885,240 square feet (20 3 acres) The cost per square foot for each cover layer is summarized in Table H-1

The itemized costs include landfill waste grading and trim, procurement, and installation of each component These costs are based on previous experience

H 3 1 7 Landfill Gas-Collection System

Assume existing vents are not compatible with the landfill cap A new gas-collection system will be installed in the landfill.

H 3 1 8 Equipment Decontamination

Excavation of contaminated materials are not anticipated, however to be conservative, decontamination costs are included

- Assume 15 pieces of equipment will require decontamination at $800 per piece
- Assume nonradioactive cleanup and steam clean surface and wheel wells only

H 3 1 9 Security

6 CCR 1007-3 Part 265 14 requires provision for adequate security The existing fence enclosing the landfill is not high enough, and installation of a new fence is required A 6-foot-high chain-link galvanized-steel fence with three strands of barbed wire will be installed. The total length necessary to encircle the landfill is estimated to be 6,000 feet Additionally, a 6-foot-high by 3-foot-wide galvanized-steel gate will be installed, and reflectorized signs will be placed every 500 feet.

H 3 1 10 Notation on Property Deed

After the final closure of the landfill, submittal of the deed notation and waste record will be required Assume two hours for an attorney and four hours for a professional engineer

H 3 1 11 Indirect Costs

In addition to the direct costs discussed above, the following is a list of the indirect costs The indirect costs are a percentage of the total direct costs unless otherwise specified

- Certification of Closure/ Survey Plat / Surveying (2 percent)
- Project/Construction Management (20 percent)
- Contractor Overhead and Profit (25 percent of all activities related to installation of landfill cover)
- CQA (15 percent)
- Health and Safety (5 percent)
- Administration (10 percent)
- Contingency (15 to 25 percent)

During the closure period a survey team supervised by a professional surveyor will be present to perform activities such as staking the landfill, verifying the cap is built to specifications and creating topographic maps The data accumulated in this process will be used in the certification of closure and survey plat All associated costs such as attorney and professional engineer fees are included in this lump sum

Contingency calculations are based on the method described in the Rocky Flats ERM Cost Estimating Handbook (DOE 1994) Conceptual cost estimates use a 25-percent contingency Detailed cost estimates use a 15-percent contingency

H 3 2 Post-Closure Care Period

H 3 2 1 Present Worth

The present worth for each cost component is determined using the following formula The post-closure period is assumed to be 30 years, however, at any time the post-closure period may be shortened or extended as necessary to protect human health and the environment based on indicators such as groundwater monitoring [6 CCR 1007-3 Part 265 117] Also a 3-percent discount rate was used (per RMRS) Some costs occur annually while others occur periodically (such as replacement costs)

Present Worth Cost

$$PW = DC \times \sum \frac{DC_t}{(1+i)^t}$$

where DC = direct annual cost of each component

i = discount rate (3 percent)

t = year(s) in which the cost occurs Annual costs are summed from 1 to 30 years Periodic costs are summed for the years in which the event occurs (i e well replacement costs are incurred in year 20 only)

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H 3 2 2 Landfill Gas Monitoring

Quarterly samples will be taken from the landfill gas monitoring vents costing $300 per sample Forty samples will be taken during the first year, and thirty samples every year thereafter It is assumed the life of the gas-monitoring system is 30 years and replacement will not be required during the post-closure period

H 3 2 3 Groundwater Monitoring Wells

6 CCR 1007-3 Subpart F 265 91 requires collection of two types of data. Indicator parameters, which include chloride, iron, manganese, phenols, sodium, and sulfate, require sampling and analysis at least annually Groundwater contamination parameters, pH, specific conductance, TOC, and TOX, require four replicate samplings and must be performed at least semiannually.

The monitoring wells have an assumed life of 20 years and will require replacement prior to the end of the post-closure period

H 3 2 4 Landfill Cap Maintenance

- Inspections of the cap integrity will take place semiannually Surveying will be performed annually to check for settling and subsidence
- The vegetative cover will require periodic seeding and fertilizing
- Spot soil replacement may also be necessary due to erosion
- Because rodent problems presently do not exist at the landfill, costs for rodent control are not included in this estimate.
- Assume the grass will grow to a maximum height and annual precipitation will be adequate such that mowing and watering will not be required

H 3 2 5 Drainage Ditch Clean Out

Assume annual clearing of drainage ditch debris is adequate maintenance to keep it operable for 30 years

H 3 2 6 Fence Maintenance

Assume the new fence life is 30 years with proper maintenance Assume a cost of $100 per year for maintenance

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H 3 2 7 5-Year Review

Under CERCLA, Section 121 (c) and the National Contingency Plan (NCP) Section 300 430 (f) (4) (ii), Statutory Reviews are required at least every five years Assuming a Level 1 review will be followed, an estimated 160 to 170 man hours are adequate for each review This includes time to prepare the reports visit the site, perform a limited analysis of the site conditions, and gather information Additionally, approximately $8,000 will be allotted for associated costs

H 3 2 8 Certification of Post-Closure

Assume during the post-closure period an independent professional engineer will make two visits per year each visit requiring six hours Time for traveling to and from the site inspection, and documentation are included in this estimate

2 visits/year x 6 hours/visit x 30 years = 360 hours

Additionally four hours will be required for closure review and four hours for final documentation preparation

H 3 2 9 Indirect Costs

In addition to the direct costs discussed above, the following is a list of the indirect costs The indirect costs are a percentage of total direct annual costs

- Administration (10 percent)
- Contingency (15 to 25 percent)

H 4 References

DOE 1994 Rocky Flats Plant Environmental Restoration Management Cost Estimating Handbook Document Number RFP/ERM-94-00009 Rev 1 May

Means 1994 Means Building Construction Cost Data 52nd Annual Edition R S Means Company, Inc Kingston, Massachusetts

Table H-1
Units Costs for Cover System Components

Cover Component	Unit Cost Per Square Foot
Vegetative cover	$ 0 67
Topsoil	$ 0 33
Geocomposite	$ 0 41
FMC	$ 0.28
GCL	$ 0 65
FMC/GCL	$ 0 95
Soil bedding layer	$ 0 10
Low permeability soil layer	$ 0 50
Compacted clay	$ 1 65

Table H-2
Alternative 2 - Conceptual Post-Closure Cost Estimate

Cost Component	Unit	Frequency	Quantity (#/Year)	Unit Cost	Direct Annual Cost	Life of Item (Years)	Present Worth: Annual Costs	Present Worth: Periodic Costs
Direct Annual/Periodic Costs (3% Discount Rate)								
Groundwater Monitoring (4 Wells)								
A. Well Maintenance/Sampling	EA	Annually	1	$3,020	$3,100	30	$60,800	N/A
B Monitoring Well Replacement	EA	At Year 20	4	$20,000	N/A	20	N/A	$44,300
Gas Monitoring	EA	Annually	1	$25,000	$25,000	30	$490,100	N/A
Drainage Ditch Clean Out	EA	Annually	1	$850	$900	30	$17,700	N/A
Fence Maintenance	EA	Annually	1	$100	$100	30	$2,000	
Total Direct Annual Costs					$29,100			
Total Present Worth Of Direct Annual Costs							$570,600	
Total Present Worth Of Direct Periodic Costs								$44,300
Total Present Worth Of Direct Annual/Periodic Costs:								$614,900
Indirect Annual/Periodic Costs (Percentage Of Total Direct Annual Costs)								
Administration (10%)		Annual			$3,000	30	$58,900	N/A
Maintenance Reserve & Contingency Costs (25%)		Annual			$7,300	30	$143,100	N/A
Total Present Worth Of Indirect Annual/Periodic Costs:								$202,000
Total Present Worth Of Direct And Indirect Annual/Periodic Costs								[illegible]

Note
dollar values rounded up to the nearest $100

Table H-3
Alternative 2 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Institutional Controls				
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Security System				
A Chained Linked Fence (6 w/3 Strand Barbed Wire,10 O C)	LF	6,000	$12 54	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				$77 400
Indirect Capital Costs				
Project/Construction Management (20%)	LS			$15,500
CQA (15%)	LS			$11,700
Health & Safety (5%)	LS			$3,900
Administrative (10%)	LS			$7,800
Contingency (25%)	LS			$19,400
Total Indirect Capital Costs				$58 300
Project Totals				$135 700

Note

dollar values rounded up to the nearest $100

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Table H-4
Alternative 3 to 9 - Conceptual Post-Closure Cost Estimate

Cost Component	Unit	Frequency	Quantity (#/year)	Unit Cost	Direct Annual Costs*	Present Worth		
						Life of Item (years)	Annual Cost*	Periodic Costs*
Direct Annual/Periodic Costs (3% Discount Rate)								
Groundwater Monitoring (4 Wells)								
A. Well Maintenance/Sampling	EA	Annually	1	$3,020	$3,100	30	$60,800	N/A
B Monitoring Well Replacement	EA	At Year 20	4	$20,000	N/A	20	N/A	$44,300
Landfill Cap	EA	Annually	1	$7,400	$7,400	30	$145,100	N/A
Gas Monitoring	EA	Annually	1	$25,000	$25,000	30	$490,100	N/A
Drainage Ditch Clean Out	EA	Annually	1	$850	$900	30	$17,700	N/A
Fence Maintenance	EA	Annually	1	$100	$100	30	$2,000	N/A
Total Direct Annual Costs					$36,500			
Total Present Worth of Direct Annual Costs:							$715,700	
Total Present Worth of Direct Periodic Costs:								$44,300
Total Present Worth of Direct Annual/Periodic Costs:								$760,000
Indirect Annual Periodic Costs (Percentage of Total Direct Annual Costs)								
Administration (10%)		Annual			$3,700	30	$72,600	N/A
Maintenance Reserve & Contingency Costs (25%)		Annual			$9,200	30	$100,000	N/A
Total Present Worth of Indirect Annual/Periodic Costs:								$253,000
Total Present Worth of Direct and Indirect Annual/Periodic Costs:								$1,013,000

Note
*dollar values rounded up to the nearest $100

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Table H-5
Alternative 3 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Native Soil Cover				
Mobilization/Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	$98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16 400	$10 00	$164 000
B Placement				
i Fill Layer Placement	CY	131 400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D Vegetation	SF	1 315 556	$0 07	$92,100
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire 10 O C)	LF	6,000	$12 54	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$2,734,300**

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Table H-5
Alternative 3 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification/Survey Plat/Surveying (2%)	LS			$54,700
Project/Construction Management (20%)	LS			$546,900
Contractor Overhead & Profit (25%)	LS			$568,400
CQA (15%)	LS			$410,200
Health & Safety (5%)	LS			$136,800
Administrative (10%)	LS			$273,500
Contingency (25%)	LS			$683,600
Total Indirect Capital Costs				$2,674,100
Project Totals				$5,408,400

Note

dollar values rounded up to the nearest $100

800

Table H-6
Alternative 4 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier-Clay				
Mobilization/Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D Clay Barrier Procure & Install	SF	885,240	$1 65	$1,460,700
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
G Vegetation	SF	1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire,10 O C)	LF	6,000	$12 54	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$5,120,900**

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Table H-6
Alternative 4 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification/Survey Plat/Surveying (2%)	LS			$102,500
Project/Construction Management (20%)	LS			$1,024,200
Contractor Overhead & Profit (25%)	LS			$1,115,100
CQA (15%)	LS			$768,200
Health & Safety (5%)	LS			$256,100
Administrative (10%)	LS			$512,100
Contingency (25%)	LS			$1,280,300
Total Indirect Capital Costs				**$5,058,500**
Project Totals				**$10,179,400**

* Note

dollar values rounded up to the nearest $100

Table H-7
Alternative 5 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier FMC				
Mobilization/Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16 400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC Procure & Install	SF	885,240	$0 28	$247,900
E Soil Bedding Layer Procure & Install	SF	885,240	$0 10	88,600
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
G Vegetation	SF	1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire,10 O C)	LF	6,000	$12 54	$75 300
B Gate 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$3,996,700**

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Table H-7
Alternative 5 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification/Survey Plat/Surveying (2%)	LS			$80,000
Project/Construction Management (20%)	LS			$799,400
Contractor Overhead & Profit (25%)	LS			$834,000
CQA (15%)	LS			$599,800
Health & Safety (5%)	LS			$199,900
Administrative (10%)	LS			$399,700
Contingency (25%)	LS			$999,200
Total Indirect Capital Costs				$3,911,800
Project Totals				$7,908,500

Note

dollar values rounded up to the nearest $100

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Table H-8
Alternative 6 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier GCL				
Mobilization/Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98 400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16 400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262 800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146 172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98 360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D GCL Procure & Install	SF	885,240	$0 65	$575,500
E Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
F Vegetation	SF	1,315 556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire,10 O C)	LF	6,000	$12 54	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$4,235,700**

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Table H-8
Alternative 6 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification/Survey Plat/Surveying (2%)	LS			$84,800
Project/Construction Management (20%)	LS			$847,200
Contractor Overhead & Profit (25%)	LS			$893,800
CQA (15%)	LS			$635,400
Health & Safety (5%)	LS			$211,800
Administrative (10%)	LS			$423,600
Contingency (25%)	LS			$1,059,000
Total Indirect Capital Costs				$4,155,600
Project Totals				$8,391,300

Note

dollar values rounded up to the nearest $100

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Table H-9
Alternative 7 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier FMC With Low Permeability Soil				
Mobilization/Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading and Trim	SY	98 360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$7788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262,800
ii Vegetative Layer	CY	82 000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC Procure & Install	SF	885 240	$0 28	$247,900
E Low Permeability General Fill	SF	885,240	$0 50	$442,700
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
G Vegetation	SF	1,315 556	$0 07	$92,100
Gas Monitoring and Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire,10 O C)	LF	6 000	$12 54	$75,300
B Gate 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$4,350,800**

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Table H-9
Alternative 7 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost
Indirect Capital Costs				
Certification/Survey Plat/Surveying (2%)	LS			$87,100
Project/Construction Management (20%)	LS			$870,200
Contractor Overhead & Profit (25%)	LS			$922,500
CQA (15%)	LS			$652,700
Health & Safety (5%)	LS			$217,600
Administrative (10%)	LS			$435,100
Contingency (25%)	LS			$1,087,700
Total Indirect Capital Costs				**$4,272,900**
Project Totals				**$8,623,700**

Note

dollar values rounded up to the nearest $100

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Table H-10
Alternative 8 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Composite Barrier FMC/GCL				
Mobilization / Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788 400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131 400	$2 00	$262,800
ii Vegetative Layer	CY	82 000	$2 00	$164,000
iii Top Soil	CY	16 400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC/GCL Composite Procure & Install	SF	885,240	$0 95	$841 000
E Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
F Vegetation	SF	1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire,10 O C)	LF	6,000	$12 54	$75,300
B Gate 3 Wide Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$4,501,200**

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Table H-10
Alternative 8 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification / Survey Plat / Surveying (2%)	LS			$90,100
Project / Construction Management (20%)	LS			$900,300
Contractor Overhead & Profit (25%)	LS			$960,100
CQA (15%)	LS			$675,200
Health & Safety (5%)	LS			$225,100
Administrative (10%)	LS			$450,200
Contingency (25%)	LS			$1,125,300
Total Indirect Capital Costs				$4,426,300
Project Totals				$8,927,600

Note

dollar values rounded up to the nearest $100

1810

Table H-11
Alternative 9 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs EPA S Composite Barrier FMC & Clay				
Mobilization / Demobilization	LS			$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$356	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$491	$500
ii Groundwater Contamination	EA	1	$239	$300
iii Validation	EA	2	$52	$200
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131 400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32 800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC Procure & Install	SF	885,240	$0 28	$247,900
E Clay Barrier Procure & Install	SF	885 240	$1 65	$1,460,700
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1 770,480	$0 41	$725,900
G Vegetation	SF	1,312,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Security System				
A Chained Linked Fence (6 w/ 3 Strand Barbed Wire 10 O C)	LF	6,000	$12 54	$75,300
B Gate 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24 X24 , No Post, Reflectorized)	EA	12	$38	$500
Total Direct Capital Costs				**$5,368,800**

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Table H-11
Alternative 9 - Conceptual Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Indirect Capital Costs				
Certification / Survey Plat / Surveying (2%)	LS			$107,400
Project / Construction Management (20%)	LS			$1,073,800
Contractor Overhead & Profit (25%)	LS			$1,177,000
CQA (15%)	LS			$805,400
Health & Safety (5%)	LS			$268,500
Administrative (10%)	LS			$536,900
Contingency (25%)	LS			$1,342,200
Total Indirect Capital Costs				**$5,311,200**
Project Totals				**$10,680,000**

Note

dollar values rounded up to the nearest $100

Table H-12
Detailed Post-Closure Cost Estimate

Cost Component	Unit	Frequency	Quantity (#/Year)	Unit Cost	Direct Annual Cost*	Life of Item (Years)	Present Worth	
							Annual Cost*	Periodic Costs*
Direct Annual/Periodic Costs (3% Discount Rate)								
Groundwater Monitoring (4 Wells)								
A Sampling	EA	Biannually	2	$360	$800	30	$15,700	N/A
B Analytical Costs								
i Groundwater Quality	EA	Annually	1	$500	$500	30	$9,900	N/A
ii Groundwater Contamination	EA	Biannually	2	$240	$500	30	$9,900	N/A
iii Validation	EA	Biannually	2	$60	$200	30	$4,000	N/A
C Maintenance	EA	Annually	4	$300	$1,200	30	$23,600	N/A
D Monitoring Well Replacement	EA	At Year 20	4	$20,000	N/A	20	N/A	$44,300
Landfill Cap								
A Inspection	EA	Biannually	2	$500	$1,000	30	$19,700	N/A
B Surveying	EA	Annually	1	$800	$800	30	$15,700	N/A
C Soil Replacement	CY	Annually	2 000	$2	$4,000	30	$78,500	N/A
D Re Vegetation								
i Seeding	AC	Annually	2	$290	$600	30	$11 800	N/A
ii Fertilizing	AC	Annually	2	$100	$200	30	$4,000	N/A
iii Mulching	AC	Annually	2	$360	$800	30	$15,700	N/A
Gas Monitoring								
A 1st Year Equipment And Training Cost	EA	First Year	1	$13,500	N/A	1	N/A	$13,500
B EPA Air Quality Test	EA	Annually	30	$300	$9,000	30	$176,500	N/A
C Sampling	MH	Quarterly	64	$50	$3 200	30	$62,800	N/A
D Analytical Costs	MH	Quarterly	192	$50	$9,600	30	$188,200	N/A

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Table H-12
Detailed Post-Closure Cost Estimate

Cost Component	Unit	Frequency	Quantity ($/Year)	Unit Cost	Direct Annual Cost	Life of Item (Years)	Present Worth: Annual Cost	Present Worth: Periodic Costs
E. Maintenance	LS	Annually	1	$2,000	$2,000	30	$39,300	N/A
F EPA Meetings	MH	Annually	24	$50	$1,200	30	$23,600	N/A
Drainage Ditch Clean Out	EA	Annually	1	$850	$900	30	$17,700	N/A
Fence Maintenance	EA	Annually	1	$100	$100	30	$2,000	N/A
5 Year Review	EA	Every 5 Years	1	$25,000	N/A	5	N/A	$92,300
Certification Of Post-Closure								
A. Inspection	MH	Biannually	12	$100	$1,200	30	$23,600	N/A
B. Review / Submittal	MH	At Year 30	8	$100	N/A	1	N/A	$400
Total Direct Annual Costs:					$37,800			
Total Present Worth Of Direct Annual Costs							$742,200	
Total Present Worth Of Direct Periodic Costs								$150,500
Total Present Worth Of Direct Annual/Periodic Costs:								$892,700
Indirect Annual/Periodic Costs (Percentage Of Total Direct Annual Costs)								
Administration (10%)		Annual			$3,800	30	$74,500	N/A
Maintenance Reserve & Contingency Costs (15%)		Annual			$5,700	30	$111,800	N/A
Total Present Worth Of Indirect Annual/Periodic Costs:								$186,300
Total Present Worth Of Direct And Indirect Annual/Periodic Costs:								$1,078,900

Note
dollar values rounded up to the nearest $100

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Table H-13
Alternative 5 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier FMC				
Mobilization / Demobilization	LS	1	$250,000	$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
Wetland Mitigation	AC	3 60	$40,000	$144,000
Preble s Meadow Jumping Mouse Habitat Mitigation	AC	7 26	$40,000	$290,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$400	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$500	$500
ii Groundwater Contamination	EA	1	$300	$300
iii Validation	EA	2	$100	$200
Reroute South Diversion Ditch	LF	1,300	$8	$10,400
Landfill Waste Surface Grading And Trim	SY	98 360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82,000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131 400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98,360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC Procure & Install	SF	885,240	$0 28	$247,900
E Soil Bedding Layer Procure & Install	SF	885 240	$0 10	$88,600
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1 770 480	$0 41	$725,900
G Vegetation	SF	1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Equipment Decontamination	PIECE	15	$800	$12,000
Lights Electrical	LS	1	$50,000	$50,000
Communications Systems	LS	1	$20,000	$20,000

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Table H-13
Alternative 5 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Security System				
A. Chained Linked Fence (6' w/ 3 Strand Barbed Wire,10' O.C)	LF	6,000	$13	$75,300
B Gate, 3' Wide, Galv Steel	EA	1	$175	$200
C Signs (24"X24", No Post, Reflectorized)	EA	12	$38	$500
Notation On Property Deed Final Closure	LS	1	$1,000	$1,000
Total Direct Capital Costs				$4,524,500
Indirect Capital Costs				
Certification / Survey Plat / Surveying (2%)	LS			$90,500
Project / Construction Management (20%)	LS			$904,900
Contractor Overhead & Profit (25%)	LS			$834,000
CQA (15%)	LS			$678,700
Health & Safety (5%)	LS			$226,300
Administrative (10%)	LS			$452,500
Contingency (15%)	LS			$678,700
Total Indirect Capital Costs				$3,865,600
Project Totals				$8,390,100

Note

dollar values rounded up to the nearest $100

816

Table H-14
Alternative 7 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Single Barrier FMC With LP Soil Layer				
Mobilization / Demobilization	LS	1	$250,000	$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
Wetland Mitigation	AC	3 60	$40,000	$144,000
Preble s Meadow Jumping Mouse Habitat Mitigation	AC	7 26	$40,000	$290,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$400	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$500	$500
ii Groundwater Contamination	EA	1	$300	$300
iii Validation	EA	2	$100	$200
Reroute South Diversion Ditch	LF	1,300	$8	$10,400
Landfill Waste Surface Grading And Trim	SY	98,360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82 000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164,000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	98 360	$1 00	$98,400
iii Top Soil	SY	98 360	$1 00	$98,400
D FMC Procure & Install	SF	885,240	$0 28	$247,900
E Low Permeability General Fill	SF	885 240	$0 50	$442,700
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1,770,480	$0 41	$725,900
G Vegetation	SF	$1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Equipment Decontamination	PIECE	15	$800	$12,000
Lights, Electrical	LS	1	$50,000	$50,000
Communications Systems	LS	1	$20,000	$20,000

Table H-14
Alternative 7 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Security System				
A Chained Linked Fence (6' w/ 3 Strand Barbed Wire, 10' O C)	LF	6,000	$13	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24"X24 , No Post, Reflectorized)	EA	12	$38	$500
Notation On Property Deed - Final Closure	LS	1	$1,000	$1,000
Total Direct Capital Costs				**$4,878,600**
Indirect Capital Costs				
Certification / Survey Plat / Surveying (2%)	LS			$97,600
Project / Construction Management (20%)	LS			$975,800
Contractor Overhead & Profit (25%)	LS			$922,500
CQA (15%)	LS			$731,800
Health & Safety (5%)	LS			$244,000
Administrative (10%)	LS			$487,900
Contingency (15%)	LS			$731,800
Total Indirect Capital Costs				**$4,191,400**
Project Totals				**$9,070,000**

Note

dollar values rounded up to the nearest $100

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Table H-15
Alternative 9 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Direct Capital Costs Composite Barrier FMC and Clay				
Mobilization / Demobilization	LS	1	$250,000	$250,000
Site Prep, Road Construction, Etc	SY	133,400	$1 00	$133,400
Wetland Mitigation	AC	3 60	$40,000	$144,000
Preble s Meadow Jumping Mouse Habitat Mitigation	AC	7 26	$40,000	$290,400
GW Monitoring During Closure				
A Wells (use 4 existing wells)	EA	4	$0	$0
B Sampling	EA	1	$400	$400
C Analytical Costs				
i Groundwater Quality	EA	1	$500	$500
ii Groundwater Contamination	EA	1	$300	$300
iii Validation	EA	2	$100	$200
Reroute South Diversion Ditch	LF	1,300	$8	$10,400
Landfill Waste Surface Grading And Trim	SY	98 360	$1 00	$98,400
Landfill Cap				
A Procure & Preparation				
i Fill Material	CY	131,400	$6 00	$788,400
ii Vegetative Material	CY	82 000	$4 00	$328,000
iii Top Soil	CY	16,400	$10 00	$164 000
B Placement				
i Fill Layer Placement	CY	131,400	$2 00	$262,800
ii Vegetative Layer	CY	82,000	$2 00	$164,000
iii Top Soil	CY	16,400	$2 00	$32,800
C Trim				
i Fill Layer Surface	SY	146,172	$1 00	$146,200
ii Vegetative Layer Surface	SY	48 360	$1 00	$98,400
iii Top Soil	SY	98,360	$1 00	$98,400
D FMC Procure & Install	SF	885,240	$0 28	$247,900
E Clay Barrier Procure & Install	SF	885,240	$1 65	$1,460,700
F Geocomposite Procure & Install (Drainage & Gas Collection)	SF	1 770,480	$0 41	$725,900
G Vegetation	SF	1,315,556	$0 07	$92,100
Gas Monitoring & Collection System	LS	1	$200,000	$200,000
Equipment Decontamination	PIECE	15	$800	$12,000
Lights Electrical	LS	1	$50,000	$50,000
Communications Systems	LS	1	$20,000	$20,000

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Table H-15
Alternative 9 - Detailed Closure Cost Estimate

Cost Component	Unit	Quantity	Unit Cost	Total Cost*
Security System				
A Chained Linked Fence (6' w/ 3 Strand Barbed Wire,10' O C.)	LF	6,000	$13	$75,300
B Gate, 3 Wide, Galv Steel	EA	1	$175	$200
C Signs (24"X24 , No Post, Reflectorized)	EA	12	$38	$500
Notation On Property Deed Final Closure	LS	1	$1,000	$1,000
Total Direct Capital Costs				$5,896,600
Indirect Capital Costs				
Certification / Survey Plat / Surveying (2%)	LS			$118,000
Project / Construction Management (20%)	LS			$1,179,400
Contractor Overhead & Profit (25%)	LS			$1,177,000
CQA (15%)	LS			$884,500
Health & Safety (5%)	LS			$294,900
Administrative (10%)	LS			$589,700
Contingency (15%)	LS			$884,500
Total Indirect Capital Costs				$5,128,000
Project Totals				$11,024,600

Note

dollar values rounded up to the nearest $100

Table H-16
Risk Analysis Assessment Form for Conceptual Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Total Possible	Comments
Site Characteristics					
Sites	0 3	8 0	2 4	10 0	Multiple IHSSs 114, 203, OU 6 IHSSs
Contamination	0 6	8 0	4 8	10 0	Unknown/undefined hazardous waste deposits prior to 1986 Location and actual presence of asbestos areas is questionable Phase I/II investigations did not delineate the landfill border in order to avoid disturbing asbestos
Media Affected	0 7	8 0	5 6	10 0	Soils sediments pond leachate and groundwater Nature of groundwater contamination at source and below dam are defined but present and potential future sources within landfill have not been identified Extent of groundwater contamination plume below dam has not been defined
Geology/Hydrogeology	0 3	4 0	1 2	10 0	Presence of fault running across site
Infrastructure	0 3	8 0	2 4	10 0	No buildings or utilities improvements Electricity and water required for construction Landfill in secured area
Land Use	0 3	7 0	2 1	10 0	Present use as landfill, future use restricted but unknown
Habitat/Territory	0 9	9 0	8 1	10 0	Wetland mitigation requirements not final Potential habitat for Preble s meadow jumping mouse a candidate for listing as an endangered species Mitigation requirements unknown
Technology					
Maturity	0 1	6 0	0 6	10 0	Cap common technology
Clean up Standards	0 7	8 0	5 6	10 0	Programmatic Preliminary Remediation Goals (PPRGs) below background
Public Acceptance	0 1	3 0	0 3	10 0	Acceptance likely
Regulatory					
ARARS	0 6	9 0	5 4	10 0	Sitewide PPRGs and background levels not final Use of Colorado Department of Public Health and the Environment (CDPHE) screen not approved Assumed Land Disposal Restrictions (LDRs) need not be met
NEPA	0 3	4 0	1 2	10 0	
Permits	0 5	6 0	3 0	10 0	Closure/Post Closure
Regulator Involvement	0 7	8 0	5 6	10 0	Multiple regulators CDPHE, EPA, and Natural Resource Trustees

Table H-16
Risk Analysis Assessment Form for Conceptual Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Total Possible	Comments
Public Involvement	0 3	7 0	2 1	10 0	
Management Constraints					
Funding	0 6	7 0	4.2	10 0	1-year construction, 30-year post-closure, milestones
Political Visibility	0 7	8 0	5 6	10 0	Rocky Flats - high, OU 7 is one of the first OUs to go to construction
Procurement	0 5	8 0	4 0	10 0	Potential difficulties acquiring the volumes and quantities of fill, clay, and soil needed for landfill cover
Organizational Constraints	0 7	8 0	5 6	10 0	Rocky Flats
Priority	0.3	5 0	1 5	10 0	
Waste Management					
Storage Capacity	0 0	0 0	0 0	10 0	
Disposal	0 0	0 0	0 0	10 0	
Weather Conditions					
Susceptibility to Weather	0.3	4.0	1 2	10.0	
Total Weighted Cost Score			72.5		
Total Possible Score			230		
Cost Score Ratio			0.32		
Cost Contingency Calculation					
Maximum Allowable Contingency (80%)			80 0		
Cost Contingency Factor (%)			25 2		

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Table H-17
Risk Analysis and Assessment Form for Detailed Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Comments
Site Characteristics				
Sites	0 3	8 0	2 4	Multiple IHSSs 114, 203, OU 6 IHSSs
Contamination	0 6	3 0	1 8	Unknown/undefined hazardous waste deposits prior to 1986
Media Affected	0 3	8 0	2 4	Soils, sediments, pond, leachate, and groundwater not addressed due to low risk
Geology/Hydrogeology	0 3	4 0	1 2	Presence of fault running across site
Infrastructure	0 3	8 0	2 4	No buildings or utilities improvements Electricity and water required for construction Landfill in secured area
Land Use	0 3	7 0	2 1	Present use as landfill, future use restricted but unknown
Habitat/Territory	0 7	3 0	2 1	Wetland mitigation requirements not final Potential habitat for Preble s meadow jumping mouse a candidate for listing as an endangered species Mitigation requirements unknown
Technology				
Maturity	0 1	6 0	0 6	Cap common technology
Clean up Standards	0 7	8 0	5 6	Cap construction meets regulations but does not meet RCRA guidance
Public Acceptance	0 3	5 0	1 5	Acceptance likely
Regulatory				
ARARS	0 5	5 0	2 5	Risk vs applicable or relevant and appropriate requirements (ARARs) based cleanup EPA s guidance on RCRA cap cross section not followed Meets regulatory requirements
NEPA	0 3	4 0	1 2	
Permits	0 3	6 0	1 8	Closure/Post Closure
Regulator Involvement	0 7	8 0	5 6	Multiple regulators CDPHE, EPA, and Natural Resource Trustees
Public Involvement	0 3	7 0	2 1	
Management Constraints				
Funding	0 6	7 0	4 2	1 year construction, 30-year post closure, Milestones
Political Visibility	0 7	8 0	5 6	Rocky Flats high OU 7 is one of the first OUs to go to construction

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Table H-17
Risk Analysis and Assessment Form for Detailed Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Comments
Procurement	0 5	8 9	4 9	Potential difficulties acquiring the volumes and quantities of fill, clay and soil needed for landfill cover
Organizational Constraints	0 7	8 0	5 6	Rocky Flats
Priority	0.3	5.0	1 5	
Waste Management				
Storage Capacity	0 0	0.0	0 0	
Disposal	0 0	0.0	0.0	
Weather Conditions				
Susceptibility to Weather	0.3	4 0	1.2	
Total Weighted Cost Score			57 4	
Total Possible Score			230	
Cost Score Ratio			0.25	
Cost Contingency Calculation				
Maximum Allowable Contingency (Preliminary 10-60%)			60.0	
Cost Contingency Factor (%)			15	

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I 1 Introduction

The closure of the Present Landfill at OU 7 could potentially trigger some air pollution control and permitting requirements Placement of the cap will require standard construction project dust-control measures The final capped facility could potentially release regulated quantities of volatile organic compounds (VOCs) and other regulated air pollutants Therefore, an evaluation of applicable federal and Colorado regulations governing these types of facilities relative to air permitting was completed

I 2 Air Pollution Control and Permitting

I 2 1 Construction Project Requirements

Colorado Air Regulation No 1 requires new construction projects on sites over 1 acre in a non-attainment area to implement dust control measures defined in the regulations Placement of the cap as part of a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) action meets the definition of new construction under Regulation No 1 Therefore, the requirements for dust control would be considered an applicable or relevant and appropriate requirement (ARAR) under CERCLA Additionally unpaved roadways with vehicle traffic of 150 vehicles per day (in a non-attainment area) and haul roads exceeding 40 haul loads or 200 vehicles per day are required to submit a control and abatement plan describing the control measures that will be taken to minimize such fugitive-dust generation Some standard dust-control measures are provided in Regulation No 1 and include basic activities such as application of dust suppressants, covering hauled loads, and daily compaction of the construction site that should not greatly impact the planned activities

I 2 2 Air Pollution Emission Notices and Permits

Air pollution control permits for sources in Colorado are issued by the Air Pollution Control Division of the Colorado Department of Public Health and Environment (CDPHE) Requirements are outlined in Colorado Air Quality Control Commission (CAQCC) Regulation No 3 (Air Pollution Emission Notices, Construction Permits and Fees, Operating Permits and including the Prevention of Significant Deterioration) and include requirements for operating permits and for prevention of significant deterioration (PSD) Facilities subject to these requirements, including any facility or activity disturbing more than 25 acres, must file an Air Pollution Emission Notice (APEN) for each source or group of sources of uncontrolled emissions Facilities that

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file an APEN must then determine whether they will require a construction permit under Regulation No 3. Applicability can be triggered in three ways

First, for each potential emission point, a determination is made whether actual uncontrolled emissions of criteria pollutants (CO, NO_x, SO_2, particulates [PM-10], total suspended particulates [TSP], ozone [O_3], volatile organic compounds [VOCs], lead, fluorides, H_2SO_4 mist, H_2S, total reduced sulfur, reduced sulfur compounds, and municipal waste combustion products) are above established *de minimis* levels Determinations are based on either actual measured data or on estimates developed by approved methods

Secondly, Colorado has developed its own system for estimating the actual uncontrolled emissions of a designated set of hazardous air pollutants (HAPs) based on the location of the emission point, its distance from the property line, the height of the release point, and the reporting "bin", or category, of the pollutant being evaluated If any HAPs are emitted above *de minimis* levels, the facility must file an APEN

Finally, specific categories of sources are required to file for permits based on standards developed for their operations No specific requirements for municipal solid waste (MSW) landfills currently exist in Colorado regulations, and there are no plans to include specific requirements for those sources until federal regulations are finalized.

Thresholds for triggering required reporting and permitting activity are based on whether the source is located in an attainment or non-attainment area as defined in the regulations. Rocky Flats is located in a non-attainment area. The threshold limit requiring an APEN for uncontrolled emissions of criteria pollutants is 1 ton/year If it can be demonstrated that emissions of criteria pollutants from the entire facility are less than 1 ton/year, then no APEN is required

I.3. Applicability at OU 7

I.3 1 Specific Landfill Standards

Requirements for air pollution control and permitting for landfills are contingent on the type of landfill operation At the federal level, landfills considered MSW landfills (those receiving "household" wastes) have been the subject of a rulemaking process that resulted in a proposed rule (56 Fed Reg 24468, May 30, 1991), a revision to the proposed rule (58 Fed Reg 33790, June 21, 1993), and significant internal and external review and comment. No final rule has been published at this time

Hazardous waste landfills permitted under RCRA are not covered under the proposed rules but are subject to specific requirements at the time of closure in terms of cap design and other monitoring There are no specific provisions in the RCRA treatment, storage and disposal facility (TSDF) regulations for air pollution controls, however

Based on this regulatory status, no specific landfill air pollution control standards apply to the landfill at OU 7

I 3 2 Criteria Pollutants

The criteria pollutant most likely to trigger permitting or notification requirements at OU 7 is VOCs VOCs are compounds of carbon that participate in atmospheric photochemical reactivity, although the regulatory definition specifically excludes a number of volatile compounds, including methane

The non-methane organic compounds (NMOCs) measured at the site are made up largely of VOCs as defined in the regulations and can serve as a surrogate for VOC emission estimates Methods for estimating NMOC emissions from the landfill are described in the proposed federal regulations for MSW landfills

I 3 2 1 EPA Proposed Standards

In May of 1991 EPA proposed standards of performance for new MSW landfills and emission guidelines for existing MSW landfills The rules included a threshold for applicability based on estimated or measured emissions of NMOCs of 150 Megagrams/year (Mg/yr) or approximately 167 tons/year Formulas for estimating NMOC emissions were included in the regulation and best demonstrated technology (BDT) for control of those emissions was described BDT is not provided as a specific technology but, instead in terms of reduction of NMOCs by 98 weight-percent This standard would apply to both new and existing sources EPA identified several control systems that they believed could meet the 98-percent reduction criterion, including active collection and flare systems

I 3 2 2 NMOC Emission Calculations

Formulas for estimating NMOC emissions were presented in the proposed federal regulation At the initial level estimates of NMOC emissions can be made based solely on the annual waste acceptance rates at the facility, without any sampling or monitoring data from the site If that preliminary calculation shows the facility to be over the threshold of 150 Mg/yr then additional calculations can be made following site-specific sampling

If the year-to-year acceptance rate is known, a cumulative year-by-year formula is used

$$Q_T = \sum_{I=1}^{n}$$

$$2\,k\,L_o\,M_i\,(e^{kt}{}_i)\,(C_{NMOC})\,(3.595 \times 10^{9})$$

where

Q_T	=	total NMOC emission rate from the landfill, Mg/yr
L_o	=	refuse methane generation potential, m^3/Mg refuse
k	=	landfill gas generation rate constant, 1/yr
t_i	=	age of i^{th} section of landfill, yrs
C_{NMOC}	=	concentration of NMOC, ppmv as hexane
$3\,595 \times 10^{9}$	=	conversion factor

If annual rates are not known, an average annual waste acceptance rate is estimated based on total waste receipts and the life of the facility The receipt of the waste is unknown, this formula assumes a maximum amount of NMOCs generated

$$M_{NMOC} = 2\,L_o\,R\,(1 - e^{-kt})\,(C_{NMOC})\,(3\,595 \times 10^{9})$$

where

M_{NMOC}	=	mass emission rate of NMOC, Mg/yr
L_o	=	refuse methane generation potential, m^3/Mg refuse
R	=	average annual acceptance rate, Mg/yr
k	=	methane generation rate constant, 1/yr
t	=	age of landfill, yrs
C_{NMOC}	=	concentration of NMOC, ppmv as hexane
$3\,595 \times 10^{9}$	=	conversion factor

In the absence of site specific data, the values to be used in the equation are

k	=	0 02/yr
L_o	=	230 m^3/Mg
CNMOC	=	8,000 ppmv as hexane

Using these factors, an estimate of NMOC emissions can be and compared to the trigger values for VOC criteria pollutant emissions.

Data from the OU 7 Final Work Plan (DOE 1994) provides some measured and anecdotal data on waste quantities placed in the landfill over its life Two different calculations were made, one based on estimated annual volumes and one based on the total volume placed over the life of the facility Table I-1 presents the results of those two estimates

If estimates of yearly volumes of waste are used, the total annual predicted NMOC emissions are less than 1 Mg/year, well below the threshold level of 150 Mg/yr for the MSW proposed regulations and below the 1 ton/yr criteria pollutant level necessary to trigger an APEN (1 Mg = 1 1 tons) Alternatively, when the total waste volume anticipated in the landfill is used to determine an average annual acceptance rate, the predicted NMOC emissions are approximately 54 Mg/yr, still below the MSW regulatory trigger level, but above the 1 ton/yr criteria pollutant level

These estimates can be compared to the measured NMOC concentrations from the methane survey conducted during the Phase I RFI/RI at OU 7 (DOE 1994) These concentrations varied widely from one part of the landfill to another, with peak concentrations as high as 147 000 ppm (mg/L) Even at this highest recorded concentration, however gas emission rates would need to be approximately 2,800 liters/day to lead to NMOC levels exceeding the 150 Mg/yr trigger level Most NMOC levels measured were well below that peak level

Based on the more accurate annual waste volume calculations, the facility is not expected to exceed either the 1 ton/yr criteria pollutant level triggering an APEN or the 150 Mg/yr level triggering coverage under the as yet not promulgated MSW landfill requirements

I 3 3 Hazardous Air Pollutants

HAP emissions may also trigger APEN and permitting requirements The methodology for determining applicability of permitting based on HAPs involves determining which of three scenarios applies to the emission points identifying the type of HAP by reporting bin and comparing estimated emission levels to the threshold or *de minimis* levels defined in the regulations Because emissions from the capped landfill will occur more than 500 meters from the facility boundary Scenario 3 limits are assumed to apply The chemicals listed in the OU 7 Final Work Plan (DOE 1994) as being identified during soil gas sampling that are included on the HAP lists in Regulation No 3 are shown in the Table I-2 along with their reporting bin and the *de minimis* threshold levels of annual emissions

Soil gas sampling was conducted at several points throughout the landfill to determine concentrations of HAPs Concentrations were reported as ppm (mg/L) but no corresponding emission rates for generated gases were reported HAPs detected at the landfill and covered by Colorado Air Regulation No 3 are shown in Table I-3 along with their corresponding *de minimis* levels of emissions An estimate of the gas emission rates that would be necessary to exceed the *de minimis* levels in the

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regulations, and thereby trigger Colorado air permitting requirements, are also included in Table I-3

Many of the highest sampled concentrations shown in Table I-3 are significantly higher than other sampling points for the same parameter. To make a more realistic comparison, the average of the five highest sampling points were calculated for each parameter and the estimated gas emission rates that would be necessary to exceed the *de minimis* levels in the regulations were again calculated

As shown in Table I-3, most of the parameters sampled would require extremely high gas emission rates to trigger HAP permitting levels. The highest levels detected were for methylene chloride, 1,2-DCE, hydrogen sulfide, and 1,1,1-trichloroethane For these parameters, APEN requirements could be triggered at gas emission rates as low as 109 liters/day

I.3 4 Pollution Control Requirements

There is little potential for the Air Pollution Control Division of CDPHE to require any specific technology for air pollution control at the landfill because there are no air pollution control standards promulgated at this time for new or existing landfills Even under proposed regulations, emission rates at the landfill would not trigger any required controls

I 4 Summary

Capping of the landfill for closure will require an APEN, a construction permit, development of a Fugitive Emission Control Plan, and implementation of standard dust control procedures during construction Specific controls for emitted gases from the capped landfill are not expected to be required based on estimated emission rates of non-methane organic compounds.

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Table I-1
Estimated NMOC Emissions from the Present Landfill

Year	Waste Volume (yd^3)	k (1/yr)	L_o (m^3/Mg)	M_i (Mg)	t_i (yrs)	C_{NMOC} (ppmv)	Conversion Factor	NMOC (Mg/yr)[7]	NMOC (Mg/yr) based on average loading[8]
1968	7,300[1]	0 02	230	6,555[4]	29	8,000	3 95E-09	0 0148	–
1969	7,300[1]	0 02	230	6,555[4]	28	8,000	3 95E-09	0 0145	–
1970	7,300[1]	0 02	230	6,555[4]	27	8,000	3 95E-09	0 0142	–
1971	7,300[1]	0 02	230	6,555[4]	26	8,000	3 95E-09	0 0139	–
1972	7,300[1]	0 02	230	6,555[4]	25	8,000	3 95E-09	0 0137	–
1973	7,300[1]	0 02	230	6,555[4]	24	8,000	3 95E-09	0 0134	–
1974	8,615[2]	0 02	230	7,737[4]	23	8,000	3 95E-09	0 0155	–
1975	8,615[2]	0 02	230	7,737[4]	22	8,000	3 95E-09	0 0152	–
1976	8,615[2]	0 02	230	7,737[4]	21	8,000	3 95E-09	0 0149	–
1977	8,615[2]	0 02	230	7,737[4]	20	8,000	3 95E-09	0 0146	–
1978	8,615[2]	0 02	230	7,737[4]	19	8,000	3 95E-09	0 0143	–
1979	8,615[2]	0 02	230	7,737[4]	18	8,000	3 95E-09	0 0140	–
1980	8,615	0 02	230	7,737[4]	17	8,000	3 95E-09	0 0137	–
1981	8,615[2]	0 02	230	7,737[4]	16	8,000	3 95E-09	0 0135	–
1982	8,615[2]	0 02	230	7,737[4]	15	8 000	3 95E-09	0 0132	–
1983	8,615[2]	0 02	230	7,737[4]	14	8,000	3 95E-09	0 0129	–
1984	8,615	0 02	230	7,737[4]	13	8,000	3 95E-09	0 0127	–
1985	8,615[2]	0 02	230	7,737[4]	12	8,000	3 95E-09	0 0124	–
1986	8,615[2]	0 02	230	7,737[4]	11	8,000	3 95E-09	0 0122	–
1987	8,615[2]	0 02	230	7,737[4]	10	8,000	3 95E-09	0 0119	–
1988	8,615[2]	0 02	230	7,737[4]	9	8,000	3 95E-09	0 0117	–
1989	8,615[2]	0 02	230	7,737[4]	8	8,000	3 95E-09	0 0115	–
1990	8 615[2]	0 02	230	7,737[4]	7	8,000	3 95E-09	0 0112	–
1991	8,615[2]	0 02	230	7,737[4]	6	8,000	3 95E-09	0 0110	–
1992	12,000[3]	0 02	230	10,776[4]	5	8,000	3 95E-09	0 0151	–
1993	12 000[3]	0 02	230	10,776	4	8,000	3 95E-09	0 0148	–
1994	12,000[3]	0 02	230	10 776[4]	3	8,000	3 95E-09	0 0145	–
1995	12,000[3]	0 02	230	10,776[4]	2	8,000	3 95E-09	0 0142	–
1996	12,000[3]	0 02	230	10,776[4]	1	8,000	3 95E-09	0 0139	–
1997	12,000[3]	0 02	230	10,776[4]	0	8,000	3 95E-09	0 0136	–
total[5]	270 877		243 247			Σ each year's contribution =		0 41	53 66
total[6]	539 000		484 022						106 77

Notes

Based on 20 yd received per day for 365 days/year from 1968 to 1978 (OU ˜ Final Work Plan p 4 7 DOE 1994)
2 Based on total 160 000 yd averaged annually from 1974 to 1986 (OU 7 Final Work Plan p 4-7 DOE 1994)
Based on EG&G monitoring from November 1992 to April 1993 -- 1 000 yd per month (OU 7 Final Work Plan p 4-8)
Based on one ton/c bic yard 898 Meg grams/to
Based on annual loadings calculated
Based on total volume of material expected in landfill at closure including fill (OU 7 Final Work Plan p 4-8 DOE 1994)
Form I ( )(1)( ) from 56 Fed Reg 24503
Formula (a)(1)(u) from 56 Fed Reg 24503

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Table I-2
HAP *De Minimis* Levels

Chemical	CAS No.	Reporting Bin	Section 1 De Minimis Level (pounds/year)
1,2 DCE (ethylene dichloride)	107-06-2	A	250
1,1,1 TCA (methyl chloroform)	71-55-6	C	5,000
TCE (trichloroethylene)	79-01-6	C	5,000
Methylene chloride (dichloromethane)	75-09-2	A	250
2-Butanone (MEK)	78-93-3	C	5,000
Toluene	108-88-33	C	5,000
Xylenes	1330-20-7	C	5,000
Hydrogen sulfide	7783-06-4	A	250

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Table I-3
Estimated Flow Rates Required to Exceed HAP *De Minimis* Levels

Chemical	CAS No	Reporting Bin	Scenario 3 *De Minimis* Level (lbs/year)	Highest Sampled Concentration (ppm)	Gas Emission Rate Required to Exceed *De Minimis* Emission Level (liter/day)	Average of Five Highest Readings (ppm)	Gas Emission Rate Required to Exceed *De Minimis* Emission Level (liter/day)
Methylene chloride (dichloromethane)	75 09 2	A	250	3 438	90 45	2 849 2	109 14
1 2 DCE (ethylene dichloride)	107 06-2	A	250	680	457 29	295	1,054 1
Hydrogen sulfide	7783 06 4	A	250	79	3,936 19	17 32	17,953 75
1,1,1 TCA (methyl chloroform)	71 55 6	C	5,000	1,304	4,769 31	392 2	15 857 16
2 Butanone (MEK)	78 93 3	C	5,000	26	239,199 16	13 52	459,998 38
Xylenes	1330 20 7	C	5,000	9 1	683,426 16	6 73	924,372 49
Toluene	108 88 33	C	5 000	3 8	1 636,625 81	2 74	2 269 773 02
TCE (trichloroethylene)	79 01 6	C	5,000	1 29	4,821,068 28	0 98	6 320 302 93

Civil Software Design -- SEDCAD+ Version 3.1

Company Name. ACZ, INC
Filename: D'\TOM\RFLATS\SL7PERCT User' TEL
Date· 06-20-1995 Time. 15 12 47
ROCKY FLATS OU-7 SOIL LOSS 7 SLOPES
Storm 3 20 inches, 10 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	12.70	81	M	0.044	0 000	0 000	0 0	1 55	19.73
			Type· Null		Label: 7 % SLOPES					
111	Structure	12 70							1 55	
111	Total IN/OUT	12.70							1.55	19 73

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Sedimentology-

SED Sediment
SCp Peak Sediment Concentration
SSp Peak Settleable Concentration
24VW: Volume Weighted Average Settleable Concentration - Peak 24 hours
24AA Arithmetic Average Settleable Concentration - Peak 24 hours

	JBS	SWS	K	L (ft)	S (%)	CP	Tt (hrs)	PS #	SED (tons)	SCp (mg/l)	SSp (ml/l)	24VW (ml/l)	24AA (ml/l)
R	111	1	0 05	300 0	7 0	0 100	0 000	1	4 8				
					Type. Null		Label		7 % SLOPES				
	111	Structure							4 8				
	111	Total IN/OUT							4 8	4273	2 80	1.48	0 35

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List of Tables

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J 1 SEDCAD+ Sedimentation Computer Model

Sediment yield was determined for a single storm event (10-year 24-hour) and converted to an annual yield

The calculations to determine the storm sediment yield were performed using the SEDCAD+ computer model developed by Civil Software Design

The SEDCAD+ model determines soil loss using the Revised Universal Soil Loss Equation (RUSLE) with the following input parameters

$$Y = 95 \times (V \times Q_p)^{0\ 56} \times K \times LS \times CP$$

Where

Y = Sediment yield (tons)
V = Runoff volume (acre-feet)
Q_p = Peak discharge (cubic feet per second)
K = Soil erodibility factor
LS = Representative length-slope factor
CP = Control practice factor

The length-slope factor for the RUSLE subroutine is as follows

$$LS = \frac{\lambda^m}{72\ 6} \times (\text{slope factor})$$

Where

λ = Representative slope length (feet)
m = 0 6 for slope > 10 percent
m = 0 5 for slope >4 percent and <10 percent
m = 0 4 for slope = 4 percent
m = 0 3 for slope <4 percent

The slope factor is a piecewise linear relationship with the slope breakpoint at 8 percent as shown on Figure 5 5, Slope Factor for the RUSLE, contained in the SEDCAD+ Users Manual

Inputs for the sedimentology portion of the SEDCAD+ routine are

- Runoff volume
- Peak discharge
- Soil erodibility factor
- Representative slope length
- Average slope
- Control practice factor
- Sediment specific weight

J 1 1 Runoff Volume, V, and Peak Discharge, Q

The runoff volume and peak discharge were calculated by the SEDCAD+ computer model in the hydrologic modeling routine using inputs shown in Table J-1

J 1 2 Soil Erodibility Factor, K

The U S Department of Agriculture—Soil Conservation Service (USDA-SCS) has determined K values for designated soil types Based on the most recent SCS listing, the K value for Rocky Flats soils are as follows

Soil Type	Flatirons
K factor	05

J 1 3 Representative Slope Length, λ

The slope length is representative of the typical slope length found on the subwatershed. It is the distance from the point of origin of overland flow to the point where the slope decreases such that significant deposition occurs or the flow enters a defined channel All slope lengths are shown on the SEDCAD+ computer printouts attached (Attachment J1)

J 1 4 Average Slope

The average slope is entered as a percent and is the representative slope for overland flow for each subwatershed. All slopes are shown on the SEDCAD+ computer printouts attached (Attachment J1).

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J 1 5 Control Practice Factor, CP

The control practice factor is defined as the ratio of sediment loss from an area with a given cover and conservation practice to that of a field in continuous fallow Using the tables in SEDCAD the following value was determined

Type and Height of Canopy None
Percent Ground Cover 40 percent
CP 0 10

J 1 5 1 Annual Sediment Yield V_{annual}

Sediment yields calculated by SEDCAD+ for single storm events can be converted to annual yields by the following equation

$$V_{annual} = \frac{R_{annual}}{R_{storm}} x Y$$

Where

V_{annual}	=	Annual sediment yield (tons/year)
R_{annual}	=	Single storm rainfall factor
R_{storm}	=	Single storm rainfall factor
Y	=	Settlement yield for 10-year 24-hour storm event (tons)

For a SCS Type II storm

$$R_{annual} = 27 x (P_{2 6})^{2 2}$$

Where

$P_{2 6}$ = 2-year 6-hour precipitation in inches =1 6 inches

$$R_{storm} = \frac{19 25}{D^{0 4672}} x (P_{10 24})^{2 2}$$

Where

$P_{10 24}$ = 10-year, 24-hour precipitation in inches = 3 2 inches
D = Storm Duration = 24 hours

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J 1.6 Results

Soil loss analyses were conducted for both slope areas (Table J-2) The following are the results

6H.1V Slopes	1 8 tons/acre/year
7 Percent Slopes	0.5 tons/acre/year

Table J-1
Runoff Volume and Peak Discharge for the OU 7 Cover

Hydrology Inputs		
Hydrology Input Values	6H 1V Slopes	7% Slopes
Precipitation Distribution	SCS Type II	SCS Type II
Storm Duration (hours)	24	24
Precipitation Amount 10-yr, 24 hr event (in)	3 2	3 2
Hydrograph Response Shape	Medium	Medium
Drainage Basin Area (acres)	12 7	12 7
Curve Number Soil Type Vegetation Cover	81 C Herbaceous (fair)	81 C Herbaceous (fair)
Hydrology Results		
10-yr 24-hr event Peak Discharge (cfs) Runoff Volume (ac ft)	 19 0 1 5	 19 7 1 6

Table J-2
Results of Soil-Loss Calculations

[illegible]	[illegible]	[illegible]
Storm Yield (tons)	16.4	4.8
R_{annual}	75.9	75.9
R_{storm}	56 4	56.4
Annual Yield (tons/year)	22 1	6.5
Annual Yield per Acre (tons/acre/year)	1 8	0.5

846

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

ROCKY FLATS OU-7 SOIL LOSS 6H·1V SLOPES

by

Name: TEL

Company Name   ACZ, INC
File Name   D \TOM\RFLATS\SL6H1V

Date: 06-20-1995

847

Soil Loss For Final Cover

Method SEDCAD (RUSLE)
Inputs

Soil Type (45) Flatirons	Hyde Type C
K factor	0 05 (SCS)

Curve Number (CN)	
Vegetative Type	Herbaceous
Cover	Fair
Soil Group	C
CN	81

Area (measured)	
7 percent Area =	12 7
6H 1V =	12 2

Control Practice (CP) Factor	
Canopy	None
Cover	40 percent
CP	0 10 (grass)

Tc

	Distance	Slope
7 percent Area	300 feet	7 percent
6H 1V		
S-61	500 feet	7 percent
S-62	400 feet	16 6 percent

Rainfall	
10-year, 24-hour	3 2 (NOAA)
2-year, 6-hour	1 6 (NOAA)

Results

6H 1V Storm Yield = 16 4 tons

Annual Yield = $\frac{\text{R annual}}{\text{R storm}}$ (storm yield)

R storm = $27 (P_{2\,6})^{2\,2} = 27\,(1\,6)^{2\,2} = 75\,9$

848

$$R\ storm = \frac{19.25 x P^{2.2}}{D^{0.4672}} = \frac{19.25 x 3.2^{2.2}}{24^{0.4672}} = 56.4$$

$$\text{Annual Yield} = \frac{75.9}{56.4} \times 16.4 = 22.1 \text{ tons/year}$$

$$\text{Annual Yield Per Acre} = \frac{22.1}{12.2} = 1.8 \text{ tons/acre/year}$$

7 percent Storm Yield = 4.8 tons

$$\text{Annual Yield} = \frac{75.9}{56.4} \times 4.8 = 6.5 \text{ tons/year}$$

$$\text{Annual Yield Per Acre} = \frac{6.5}{12.7} = 0.5 \text{ tons/acre/year}$$

Civil Software Design -- SEDCAD+ Version 3.1

Company Name· ACZ, INC.
Filename: D:\TOM\RFLATS\SL6H1V User: TEL
Date: 06-20-1995 Time. 15:00 48
ROCKY FLATS OU-7: SOIL LOSS 6H 1V SLOPES
Storm 3 20 inches, 10 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0 1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	12.20	81	M	0.113	0.000	0.000	0.0	1.49	18 95
		Type.	Null		Label	6H:1V SLOPES				
111	Structure	12 20							1 49	
111	Total IN/OUT	12 20							1.49	18 9[illegible]

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Sedimentology-

SED. Sediment
SCp Peak Sediment Concentration
SSp: Peak Settleable Concentration
24VW Volume Weighted Average Settleable Concentration - Peak 24 hours
24AA Arithmetic Average Settleable Concentration - Peak 24 hours

	JBS	SWS	K	L (ft)	S (%)	CP	Tt (hrs)	PS #	SED (tons)	SCp (mg/l)	SSp (ml/l)	24VW (ml/l)	24AA (ml/l)
R	111	1	0.05	300.0	16.6	0.100	0.000	1	16.4				
					Type·	Null	Label	6H·1V SLOPES					
	111	Structure							16.4				
	111	Total IN/OUT							16 4	15252	10.00	5 29	1 26

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CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

ROCKY FLATS OU-7: SOIL LOSS 7 SLOPES

by

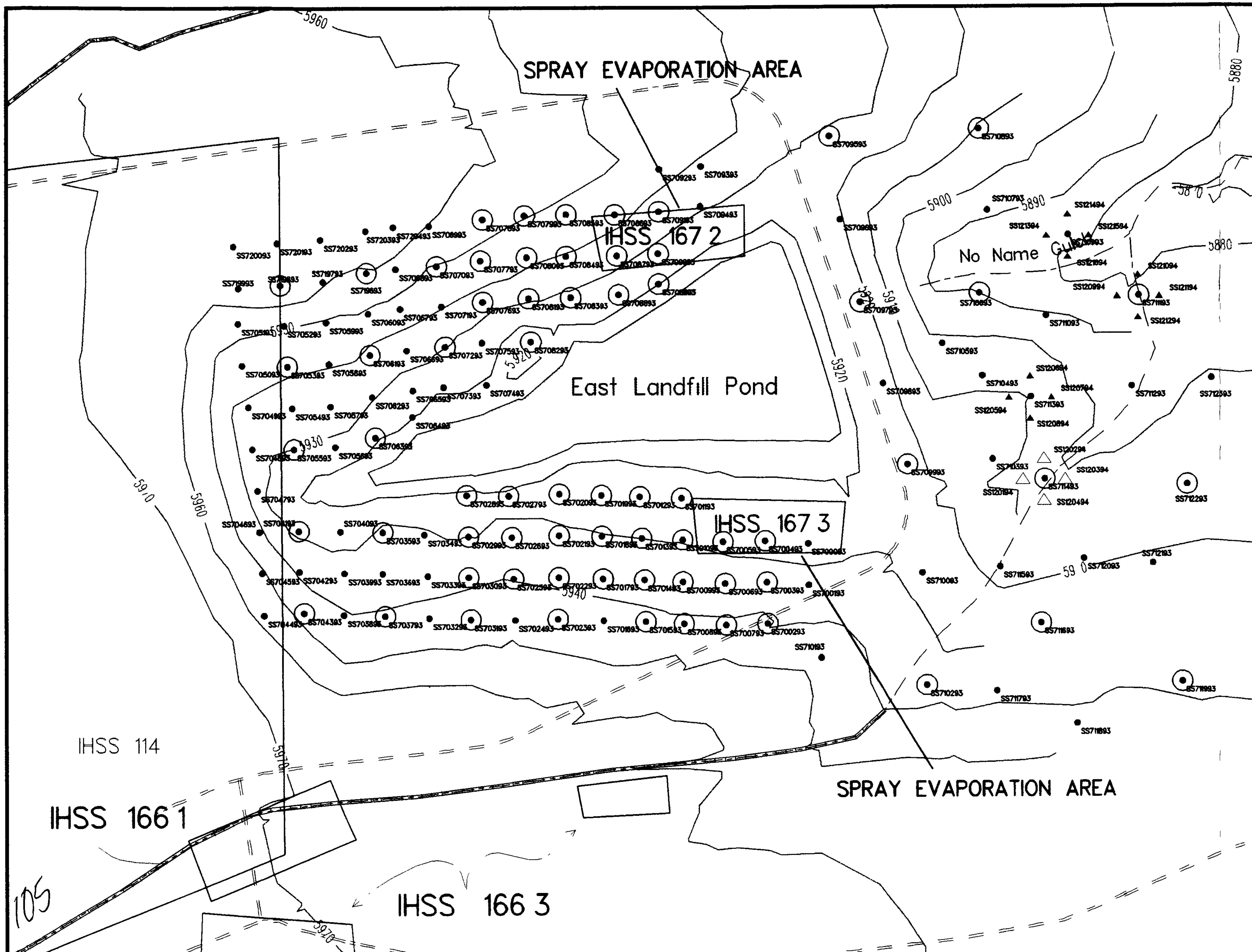
Name. TEL

Company Name ACZ, INC

File Name D \TOM\RFLATS\SL7PERCT

Date: 06-20-1995

851 | 851



EXPLANATION

- ● Phase I Surface–Soil Sampling Location
- ▲ Additional Surface–Soil Sampling Location
- ○ Phase I Subsurface–Soil Sampling Location
- △ Additional Subsurface–Soil Sampling Location
- Intermittent Stream
- Dirt Road
- Surface–Water Diversion Ditch
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

0 Feet 120 240

Topographic Contour Interval 20 Feet

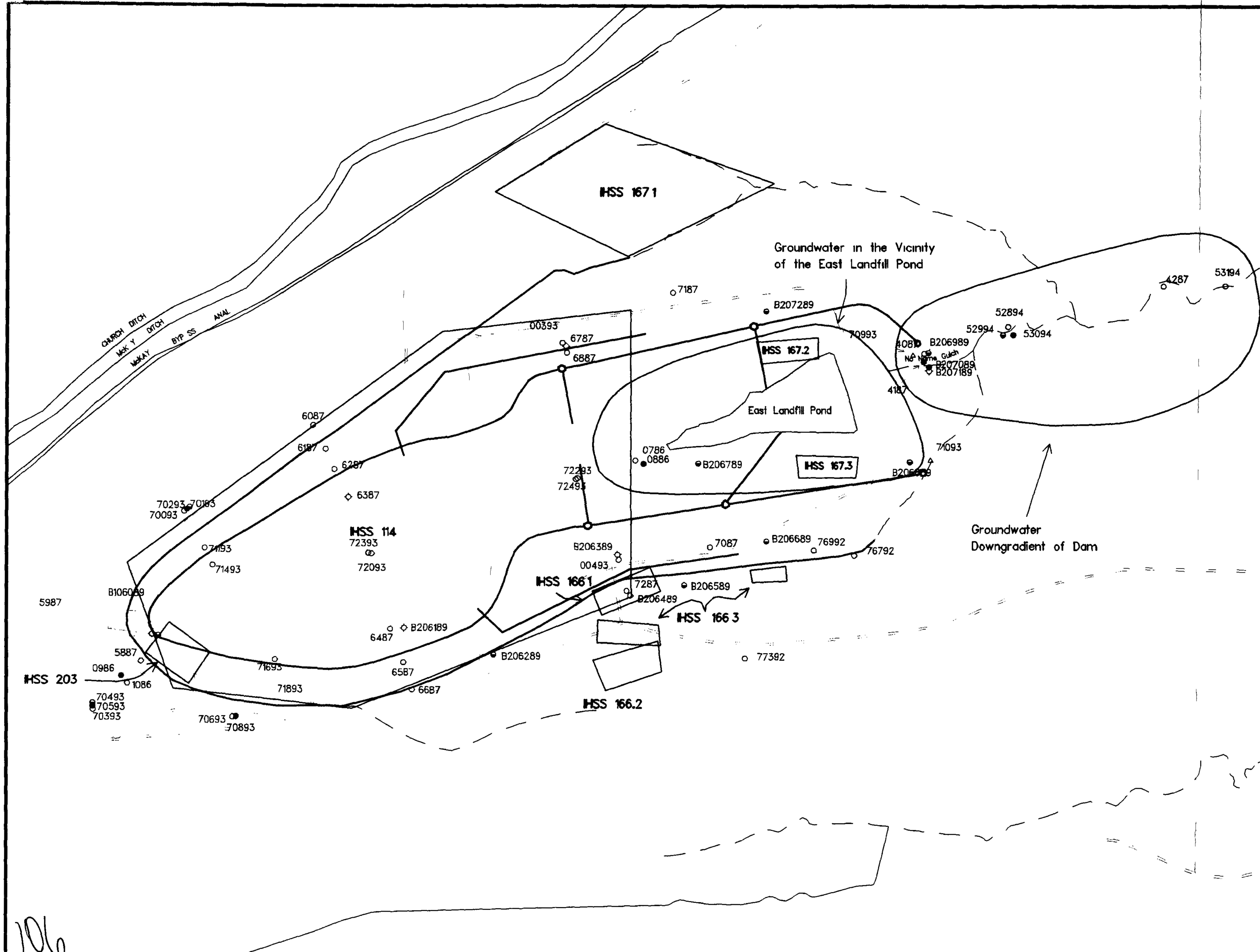
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Soil Sampling Locations in the Vicinity of Spray Evaporation Areas

Phase I IM/IRA DD | Operable Unit No. 7

July 1995 | Figure 2–14

07/10/95 SOILSAM.MAP



EXPLANATION

- ○ Alluvial/Artificial Fill Well
- ◒ Weathered Bedrock Well
- ● Unweathered Bedrock Well
- ⌖ Abandoned Well
- △ Borehole
- —— Ditch
- — - Intermittent Stream
- = = Dirt Road
- —— OU 7 IHSS Boundary
- —— OU 6 IHSS Boundary
- —— Landfill Structures

0 Feet 300 600

U.S. DEPARTMENT OF ENERGY
Rocky Flat Environmental Technology Site, Golden, Colorado

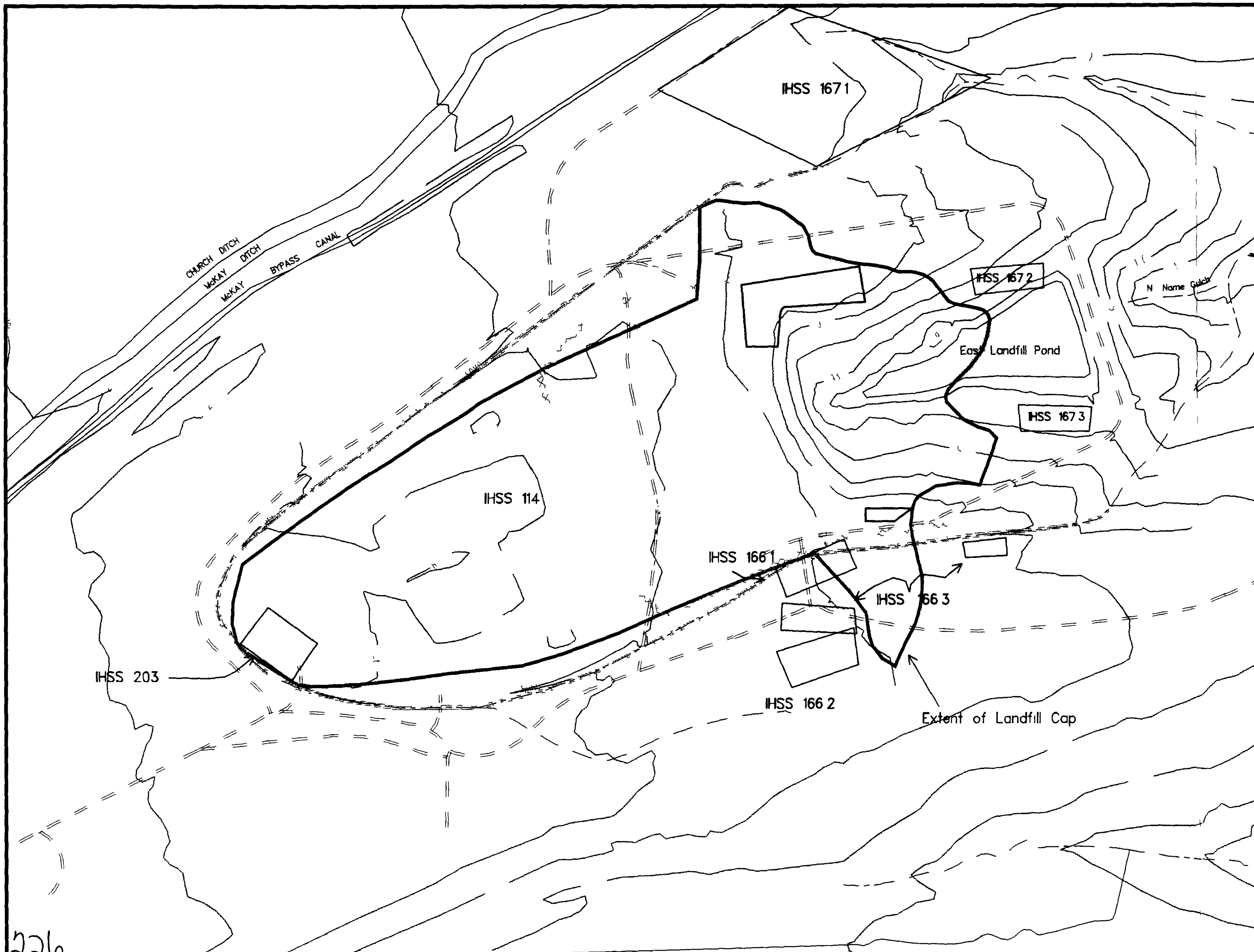
Downgradient Subsurface Geologic Materials and Groundwater Sampling Locations

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure 2–15

10b

07/24/95 STATWATERMAP



EXPLANATION

- OU 6 IHSS Boundary
- OU 7 IHSS Boundary
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Approximate Extent of Asbestos Disposal
- Extent of Landfill Cap

0 Feet 250 500

Topographic Contour Interval 20 Feet

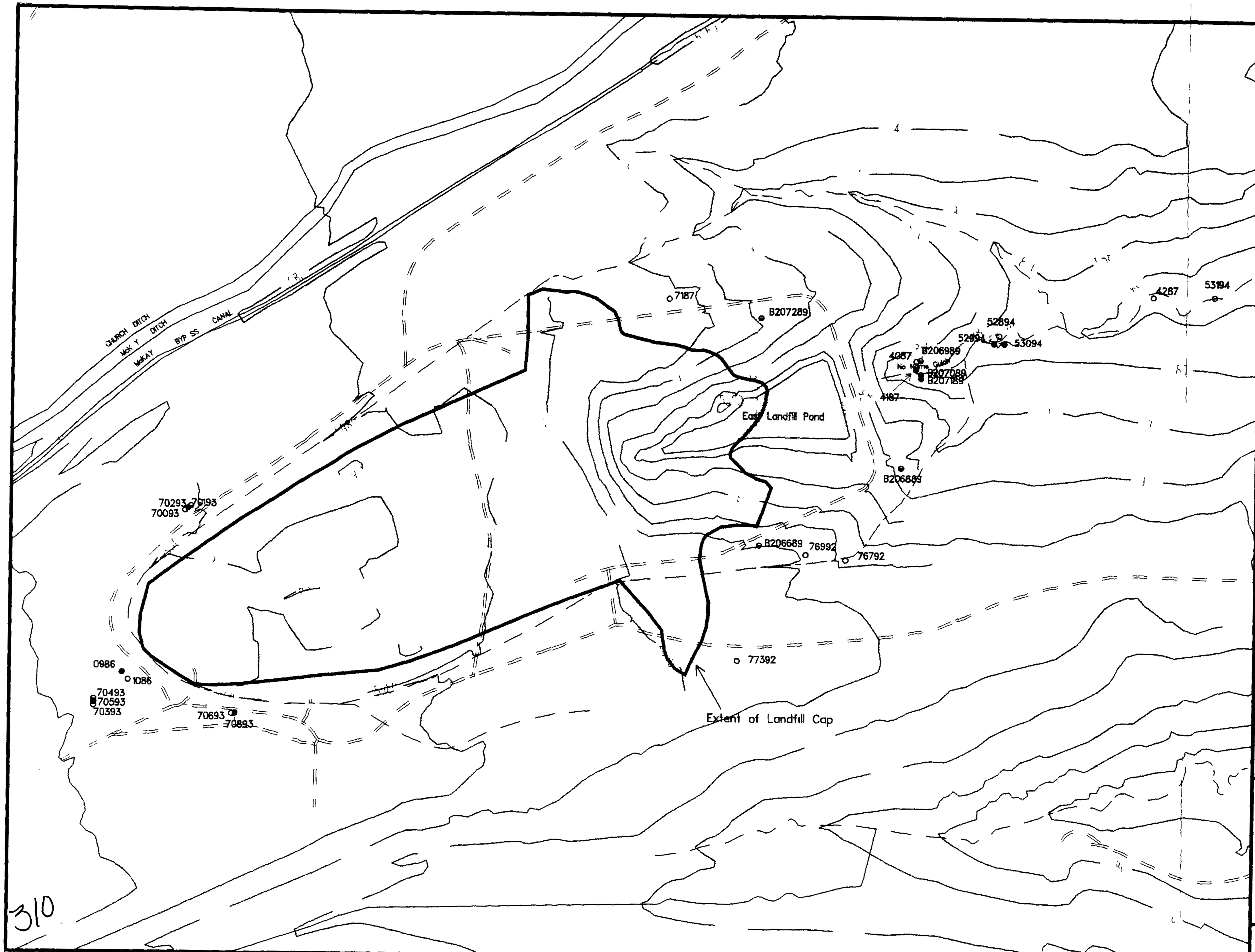
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Extent of the Landfill Cap

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure 5-1

07/10/95 CAP.MAP



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Groundwater Monitoring Wells Remaining During Landfill Closure

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 8-1

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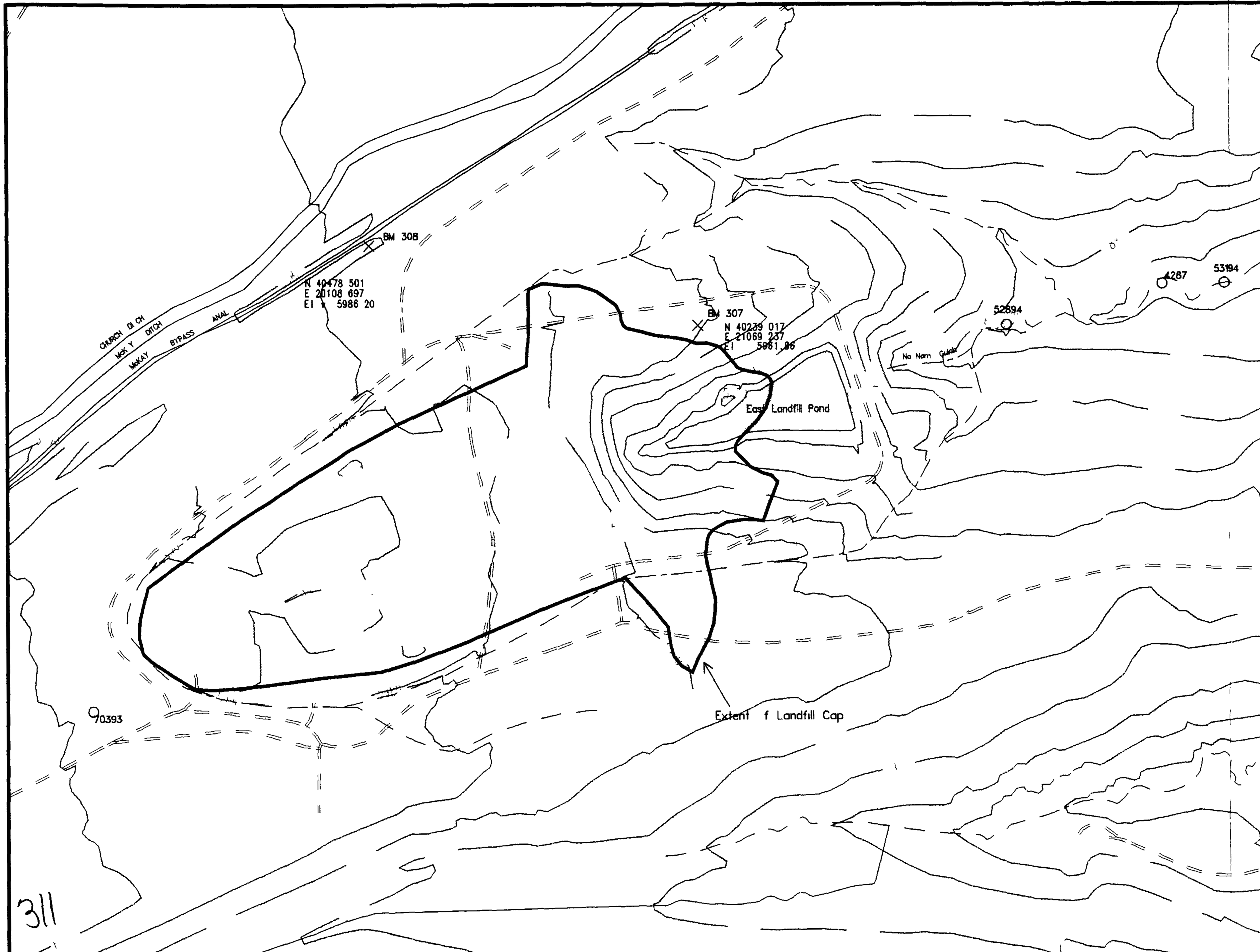
07/17/95 MONITORING.MAP



EXPLANATION

- ○ Alluvial Well
- —— Ditch
- — - Intermittent Stream
- = = Dirt Road
- ▬ Extent of Landfill Cap

BM Temporary Benchmark

*Note Coordinates are listed in Rocky Flats local coordinate system

0 Feet 300 600

Topographic Contour Interval 20 Feet

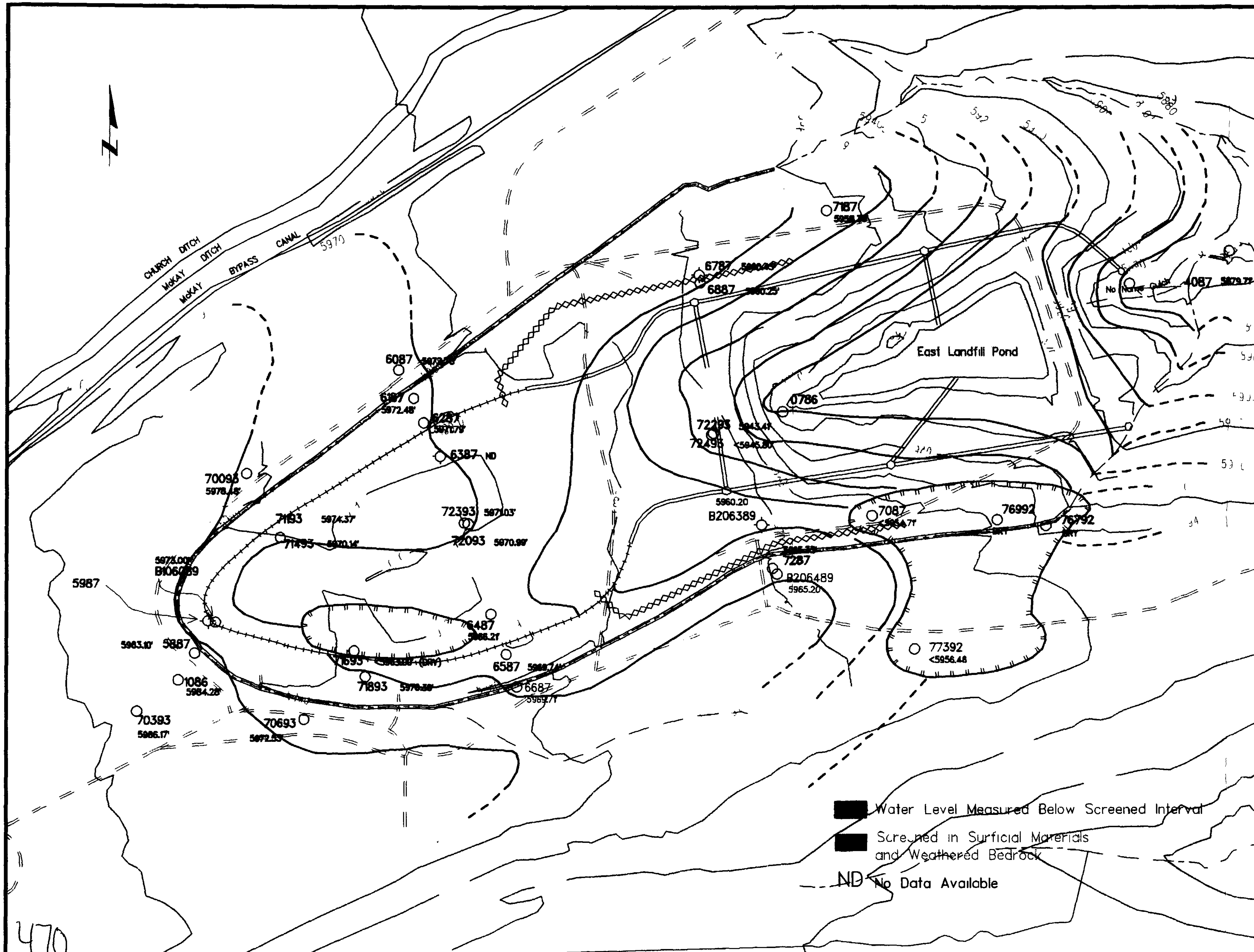
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Proposed Post Closure Groundwater Monitoring Wells

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure 8-2

07/11/95 POSTMON.MAP



EXPLANATION

- Alluvial Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred

(Contour Interval = 10 feet)

- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Potentiometric Map of Surficial Material (March 1993)

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure C-7

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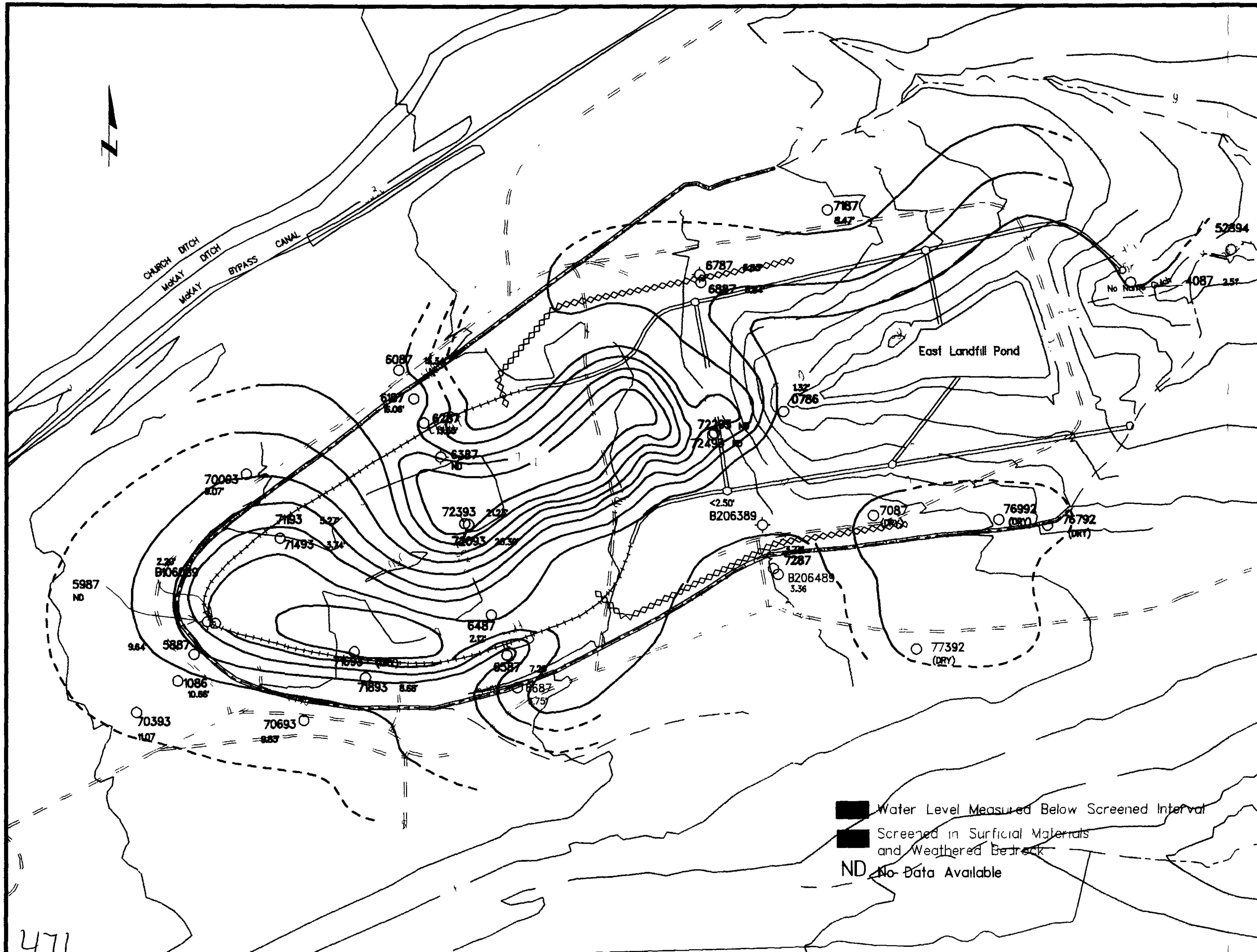
07/10/95 MAR93SURF.MAP



EXPLANATION

- ○ Alluvial Well
- ⌖ Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Saturated Thickness Dashed Where Inferred

(Contour Interval = 2.5 feet)

- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

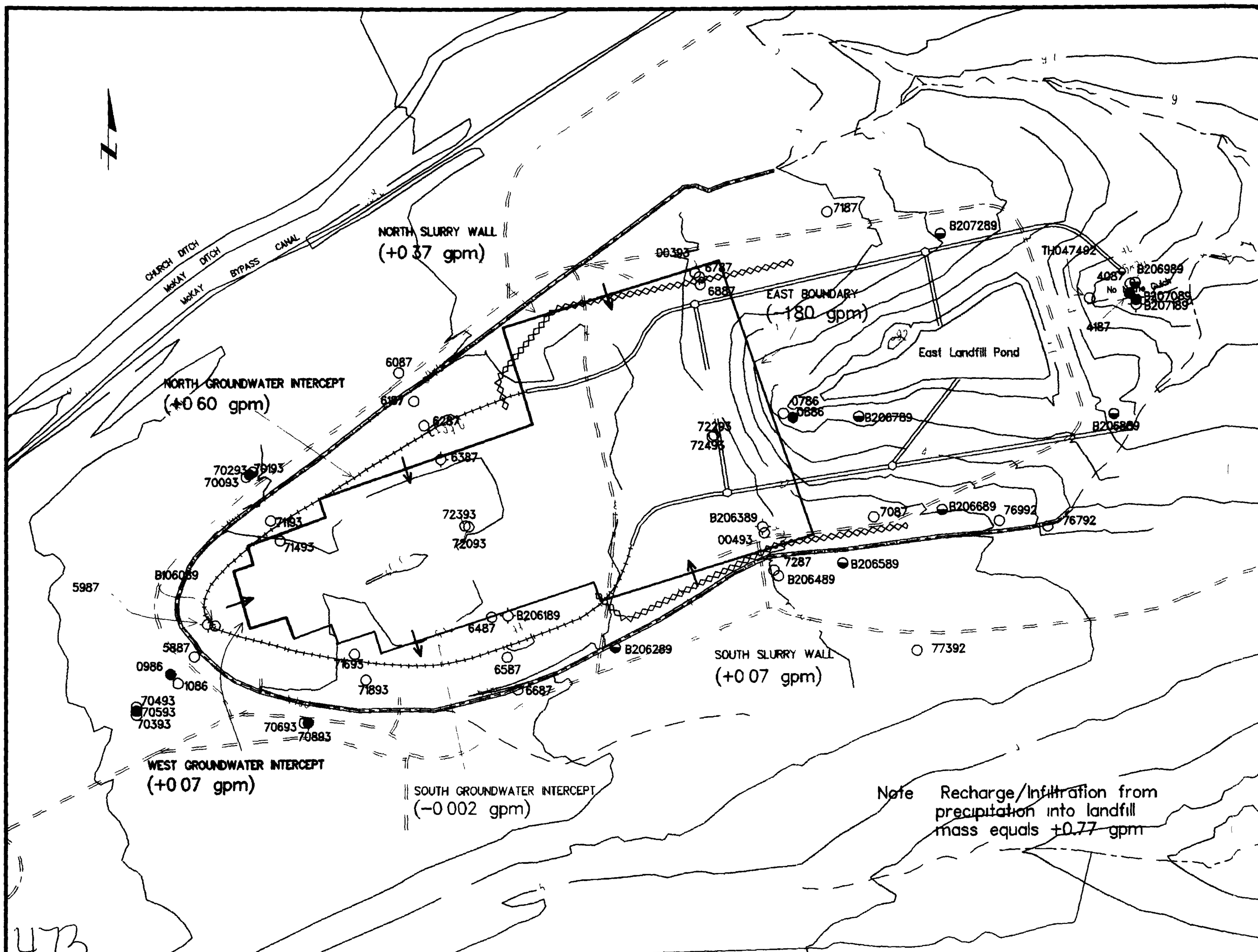
Saturated Thickness of Surficial Material (March 1993)

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure C-8

471

07/10/95 MAR93SM.MAP



EXPLANATION

- ○ Alluvial Well
- ◒ Weathered Bedrock Well
- ● Unweathered Bedrock Well
- ⌖ Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Indicates a cell face used to define the boundary of the landfill mass

*Note Arrow indicates direction of flow in the landfill

0 Feet 250 500

Topographic Contour Interval 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Water Balance for Landfill Mass

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure C-10

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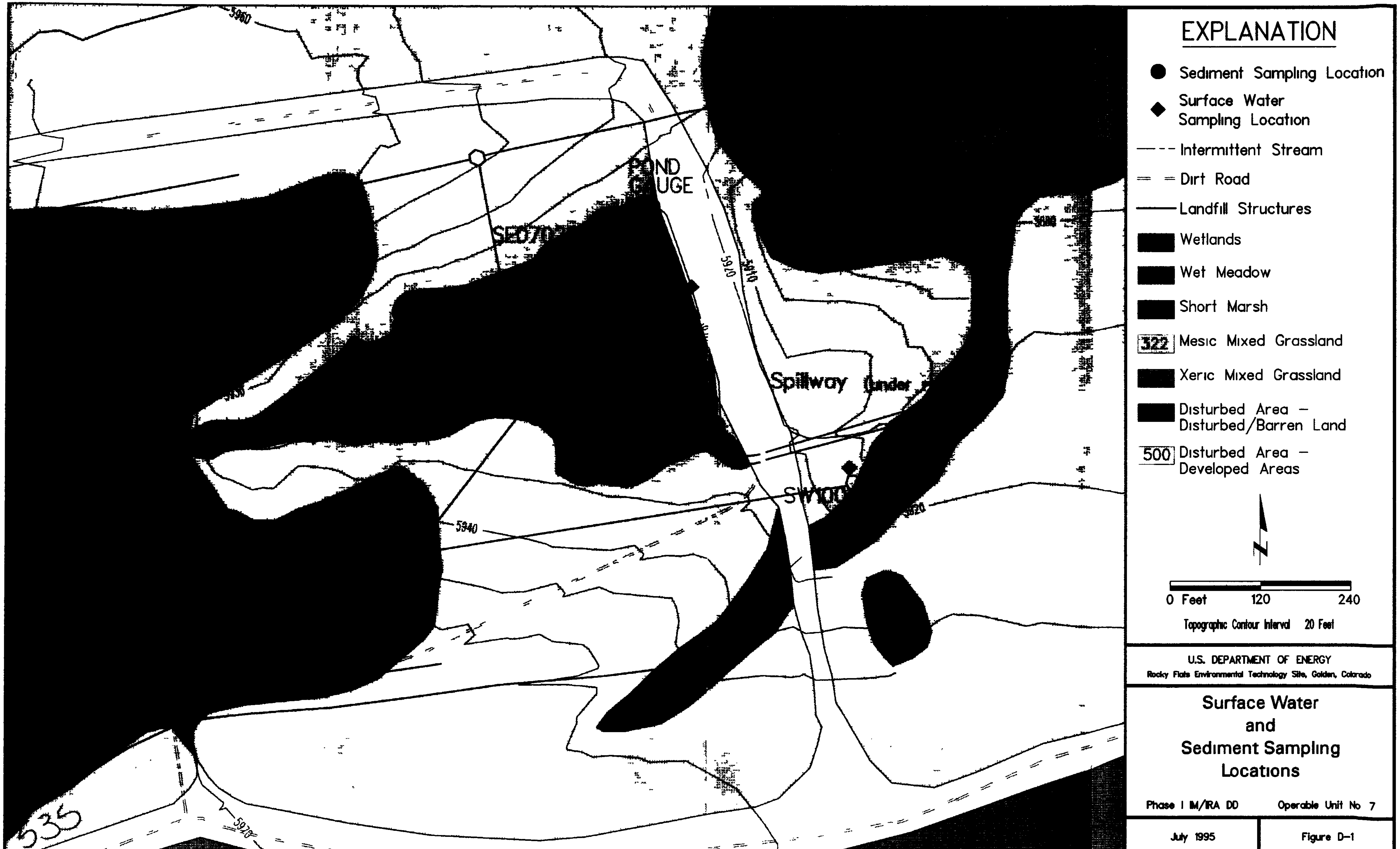
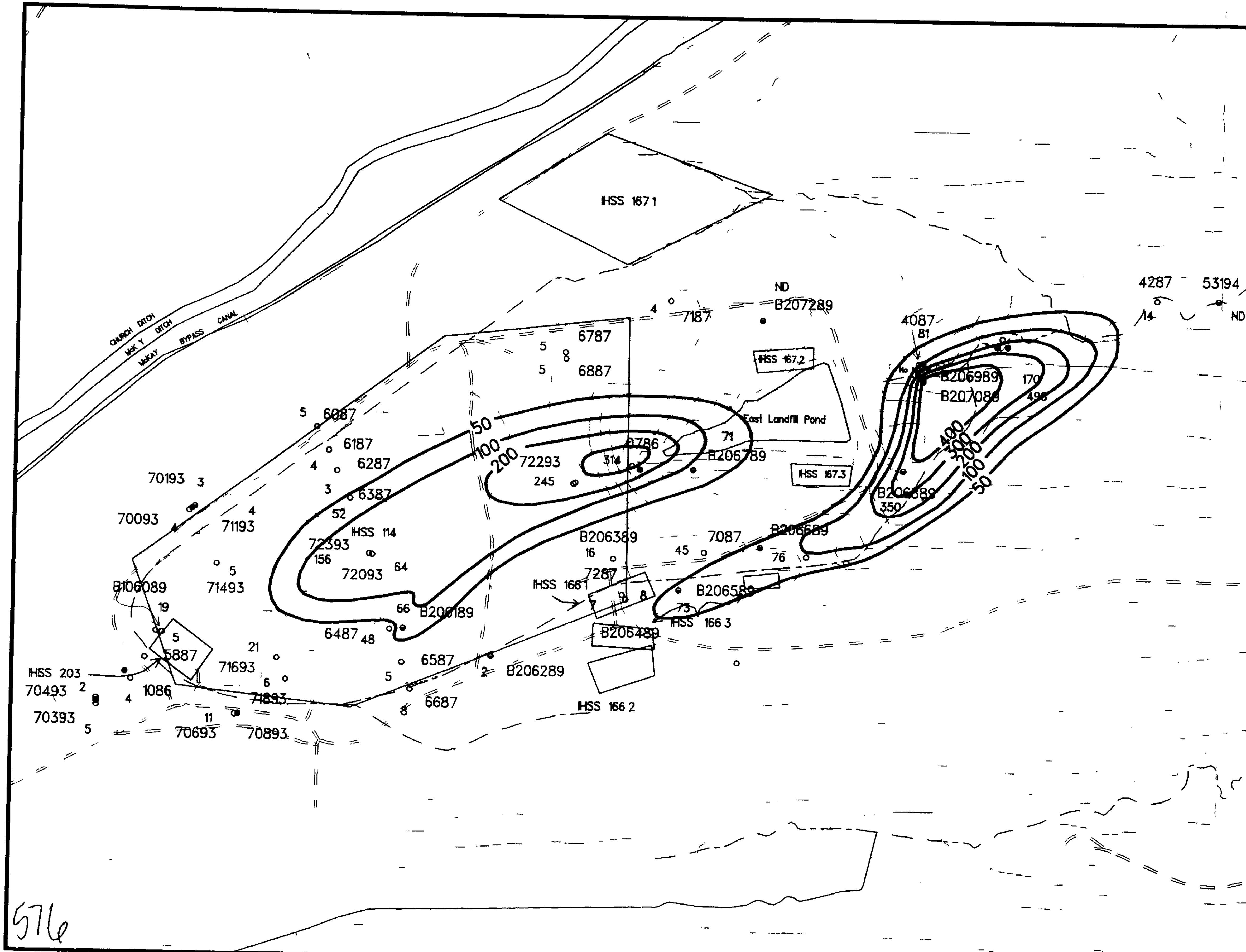
07/10/95 WATERBALANCE.MAP



07/17/95 WETVEG.MAP



EXPLANATION

UHSU Wells

○ Alluvial Well

◐ Weathered Bedrock Well

LHSU Wells

● Unweathered Bedrock Well

OU 6 IHSS Boundary

OU 7 IHSS Boundary

Ditch

Intermittent Stream

Dirt Road

Line of Equal Concentration (dashed where inferred)

ND No Data Available

0 Feet 300 600

Topographic Contour Interval 20 Feet

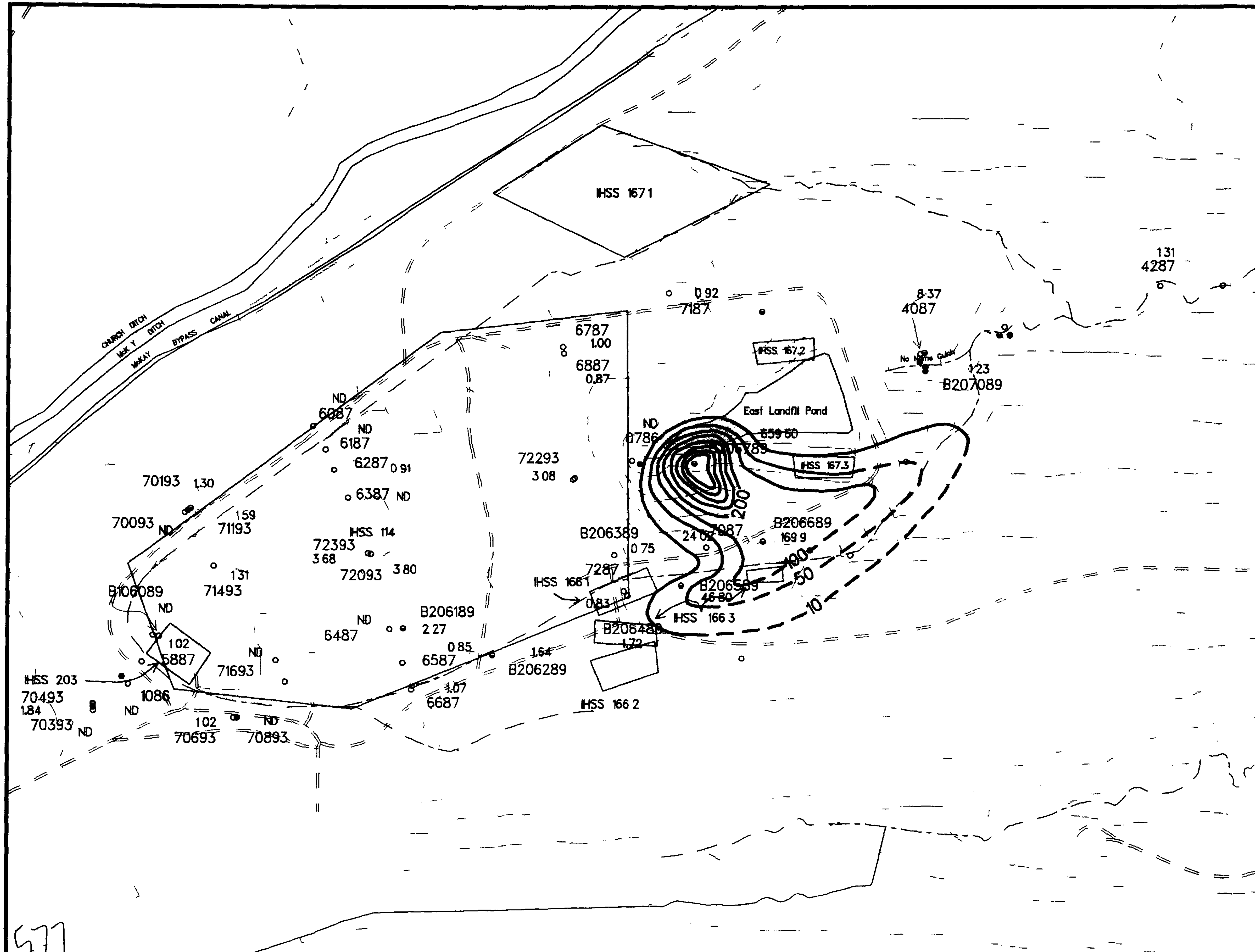
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Mean Chloride Concentrations in UHSU Groundwater (mg/L)

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure E-1

07/13/95 CHLORIDE.MAP



EXPLANATION

UHSU Wells

- ○ Alluvial Well
- ◒ Weathered Bedrock Well

LHSU Wells

- ● Unweathered Bedrock Well

- OU 6 IHSS Boundary
- OU 7 IHSS Boundary
- Ditch
- Intermittent Stream
- Dirt Road
- Line of Equal Concentration (dashed where inferred)

ND No Data Available

0 Feet 300 600

Topographic Contour Interval 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Mean Selenium Concentrations in UHSU Groundwater (µg/L)

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure E-2

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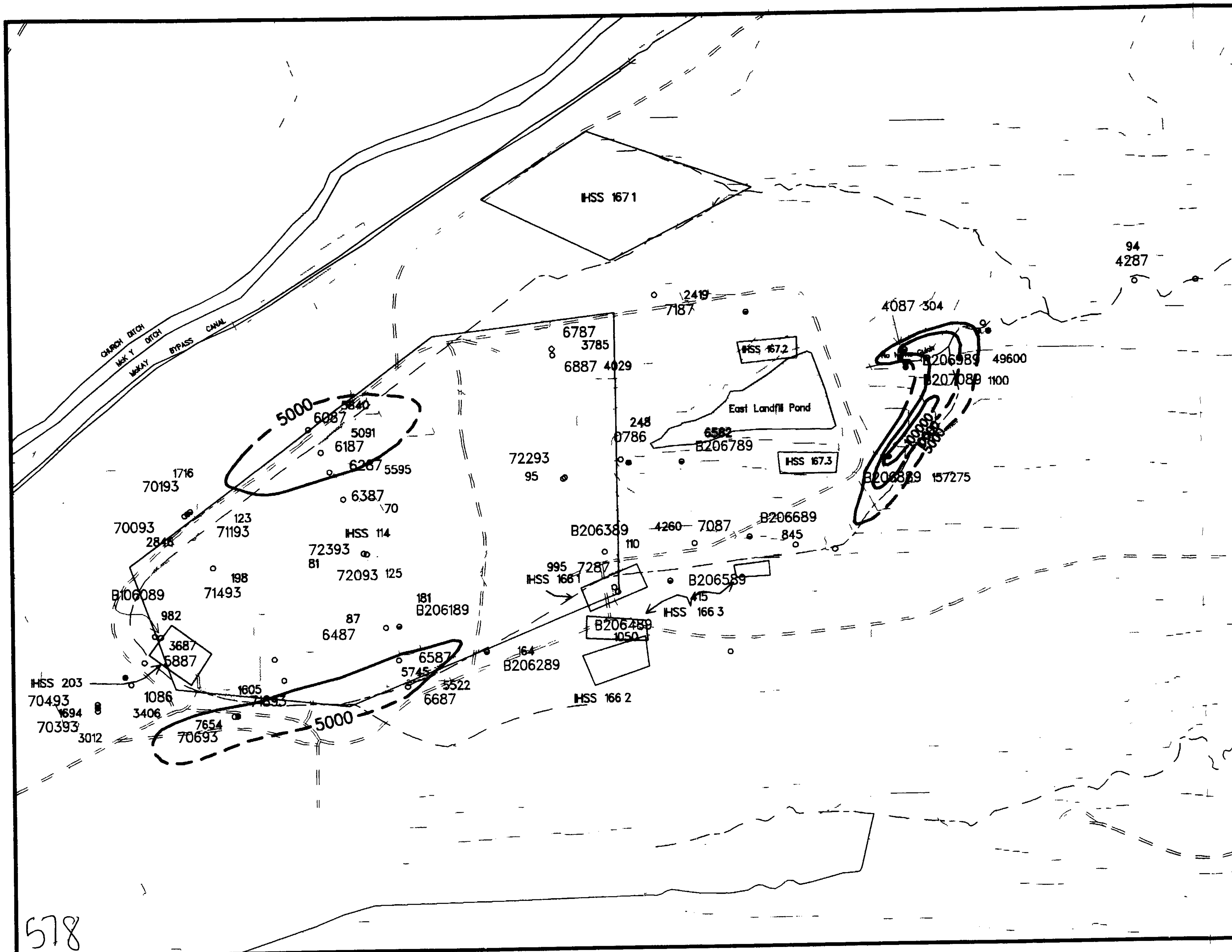
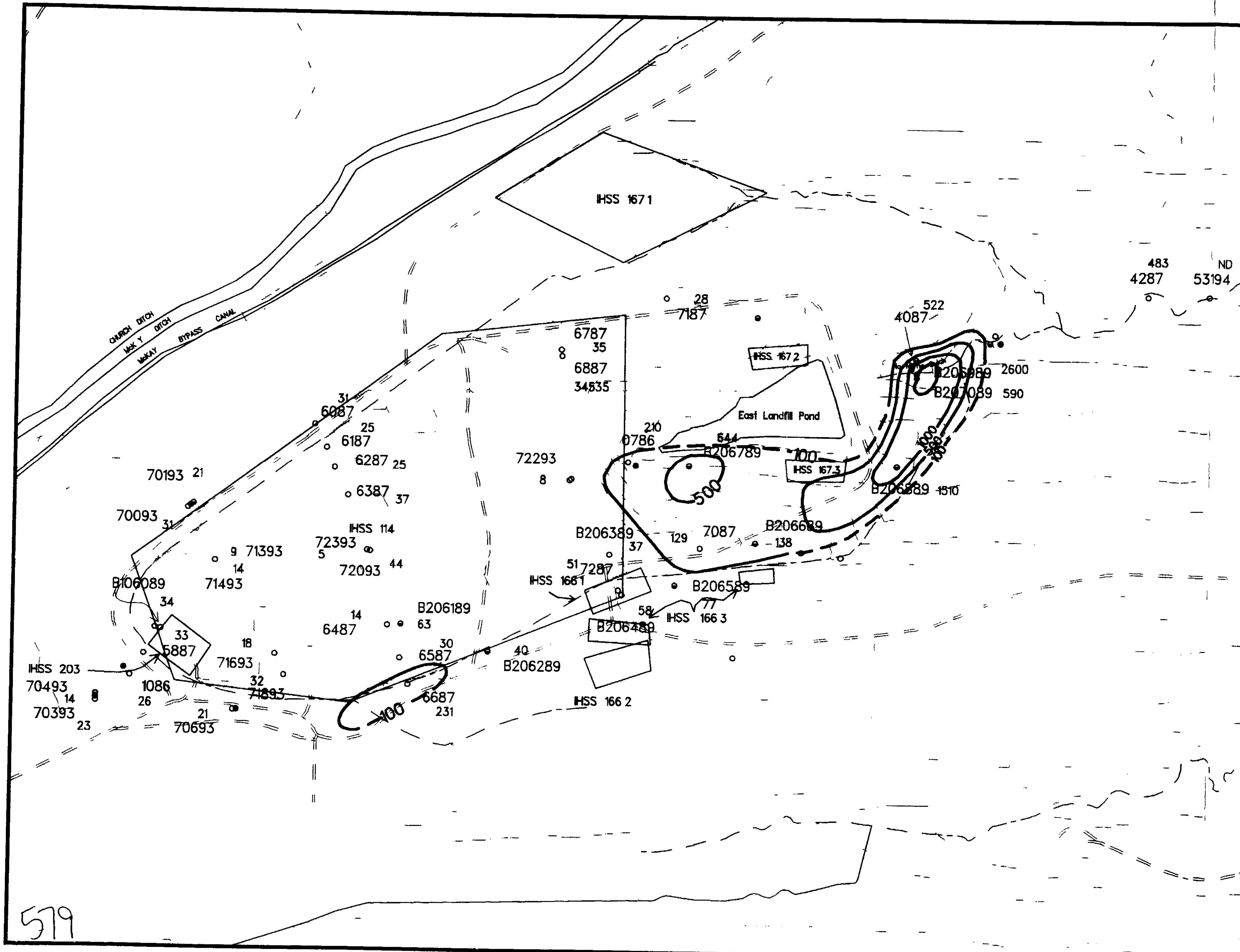
07/13/95 SELENIUMMAP



578
07/13/95 NITRATE.MAP



EXPLANATION

UHSU Wells

- ○ Alluvial Well
- ◒ Weathered Bedrock Well

LHSU Wells

- ● Unweathered Bedrock Well

- OU 6 IHSS Boundary
- OU 7 IHSS Boundary
- Ditch
- Intermittent Stream
- Dirt Road
- Line of Equal Concentration (dashed where inferred)

ND No Data Available

0 Feet 300 600

Topographic Contour Interval 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Mean Sulfate Concentrations in UHSU Groundwater (mg/L)

Phase I IM/IRA DD Operable Unit No 7

July 1995 Figure E-4

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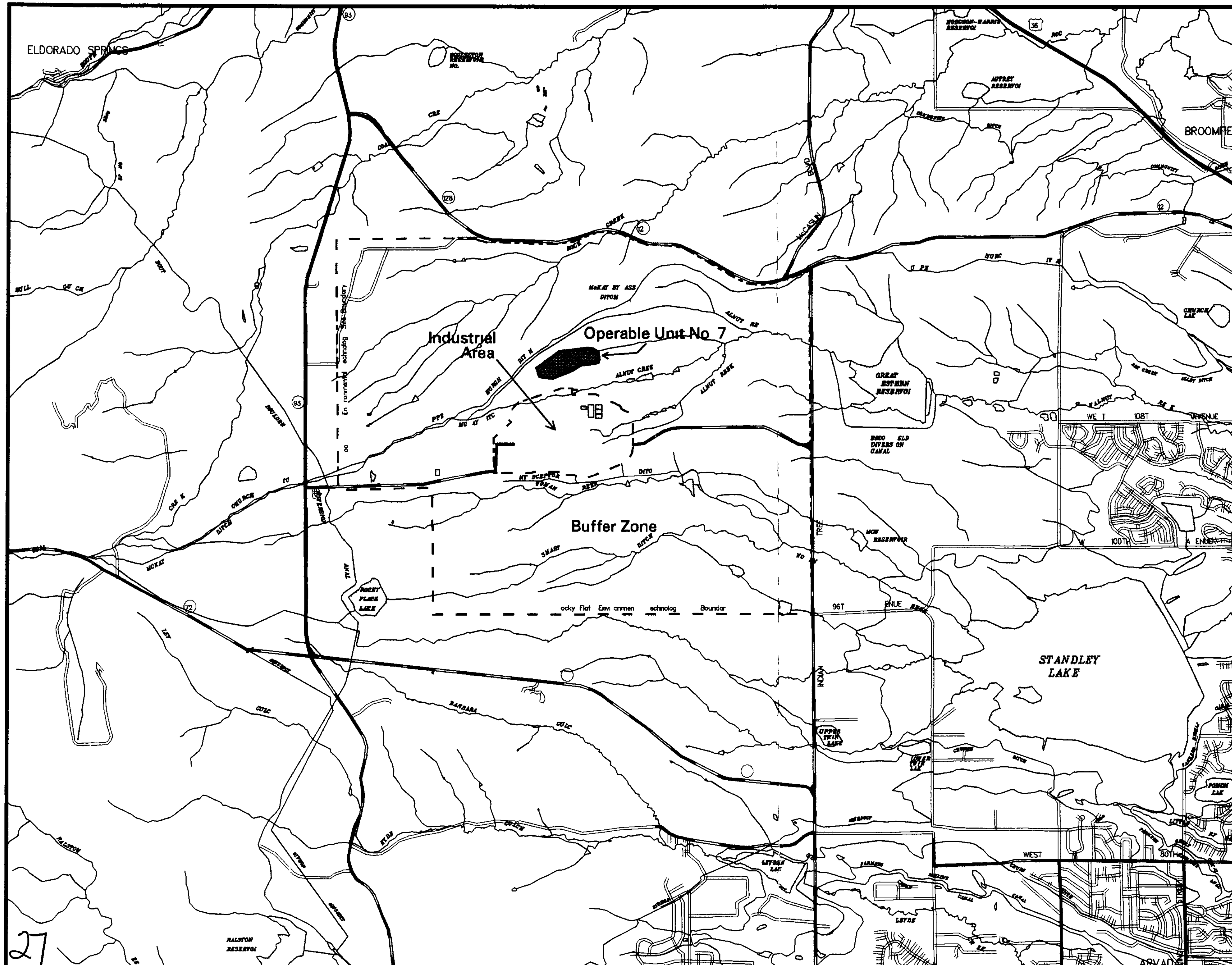
07/13/95 SULFATE.MAP



EXPLANATION

- Streams
- Rocky Flats Environmental Technology Site Boundary
- Primary Roads
- Secondary Roads
- Light-Duty Roads
- OU 7

0 Miles 1 2

0 Feet 4500 9000

Scale 1 inch = 4500 feet

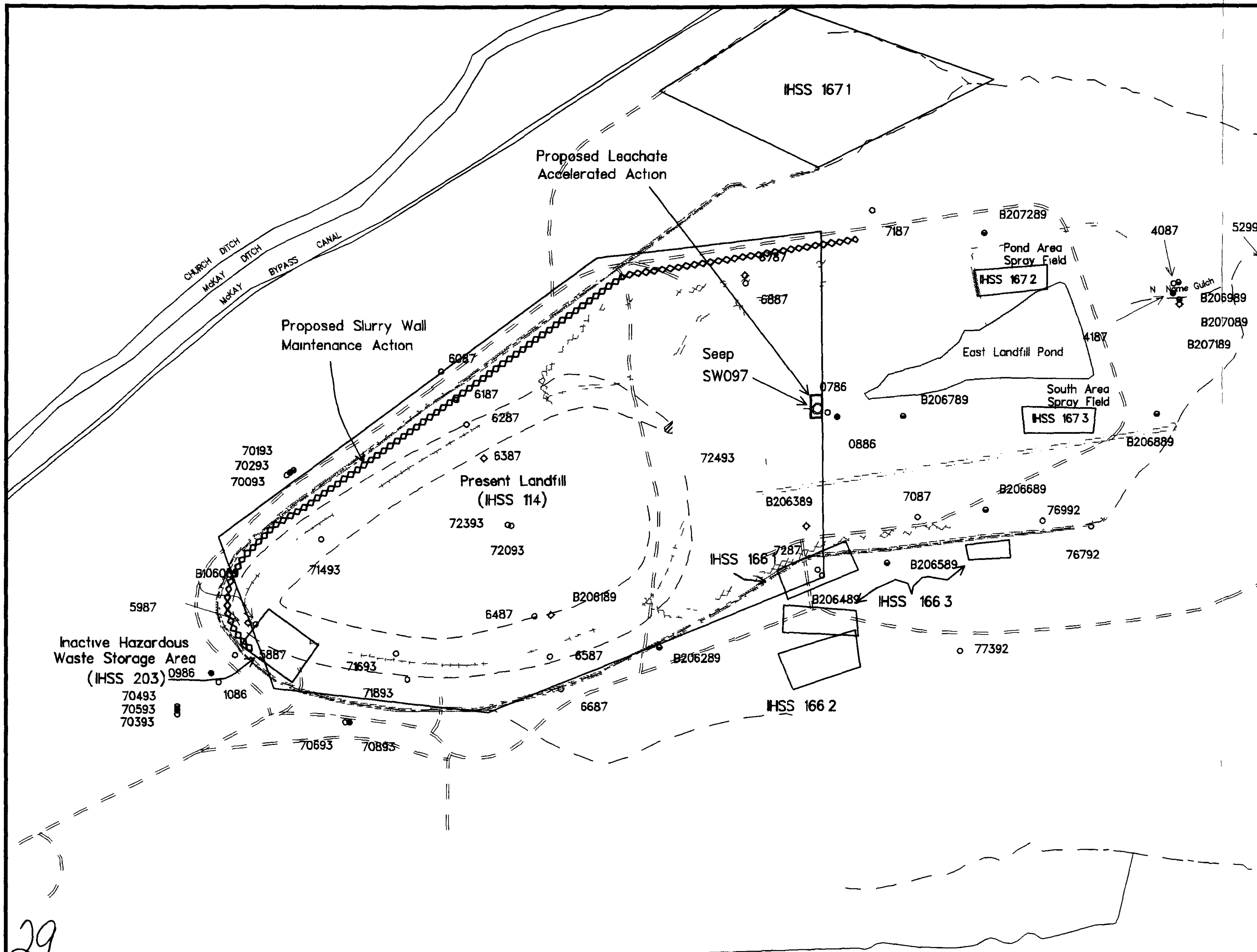
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site Golden, Colorado

Location of Operable Unit No 7

Phase I IM/IRA DD | Operable Unit No 7
July 1995 | Figure 1-2

07/10/95 VICINITY2.MAP

27



EXPLANATION

- OU 6 IHSS Boundary
- OU 7 IHSS Boundary
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Existing Groundwater Intercept System (perforated) (non-perforated)
- Leachate Collection Trench

0 Feet 250 500

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Location of Other Maintenance and Remedial Actions

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 1-4

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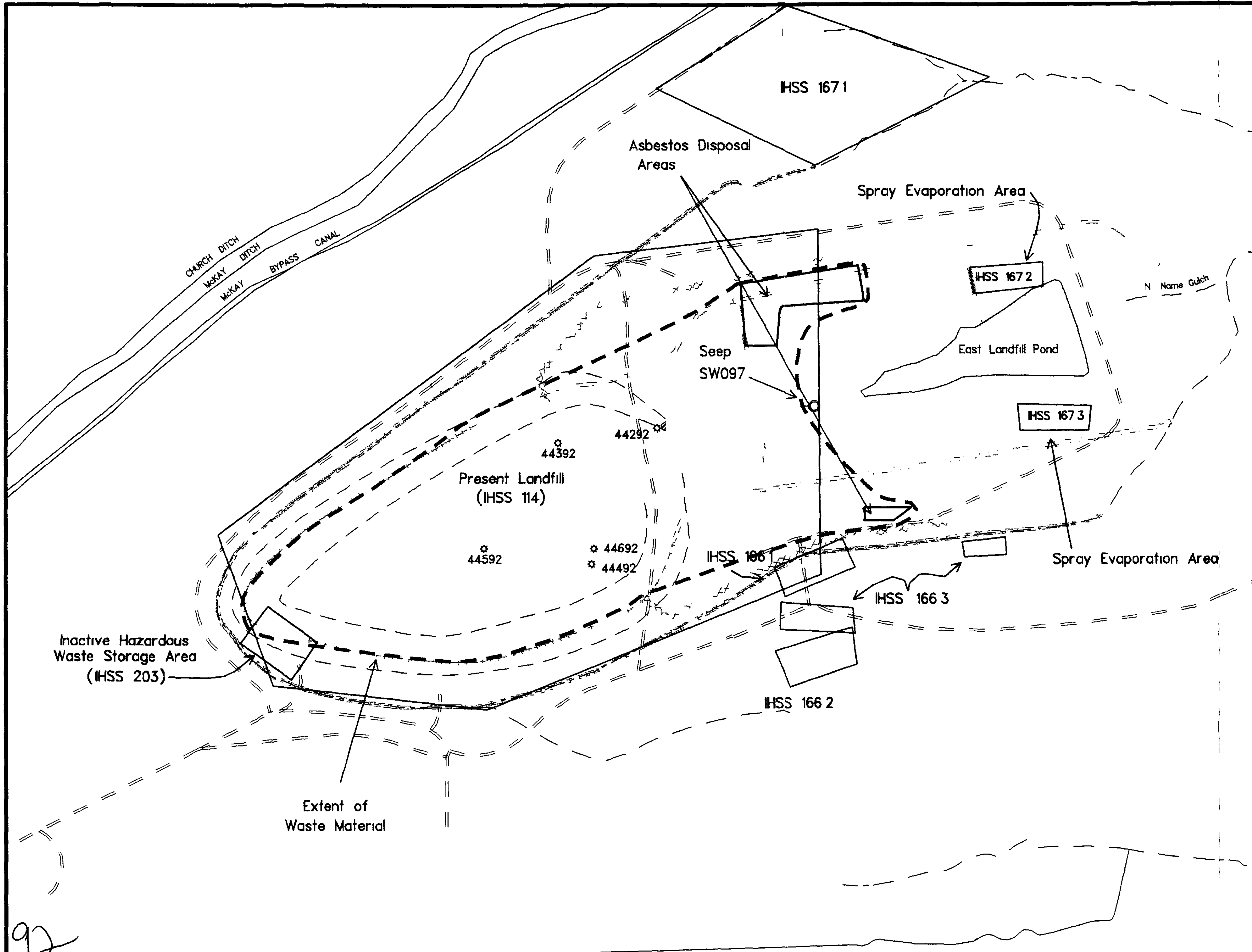
07/13/95 MAINTENANCE.MAP



EXPLANATION

- OU 6 IHSS Boundary
- OU 7 IHSS Boundary
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Leachate Collection Trench
- Approximate Extent of Asbestos Disposal
- Extent of Waste Material

0 Feet 250 500

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Locations of IHSSs and Historical Interim Response Actions

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 2-1

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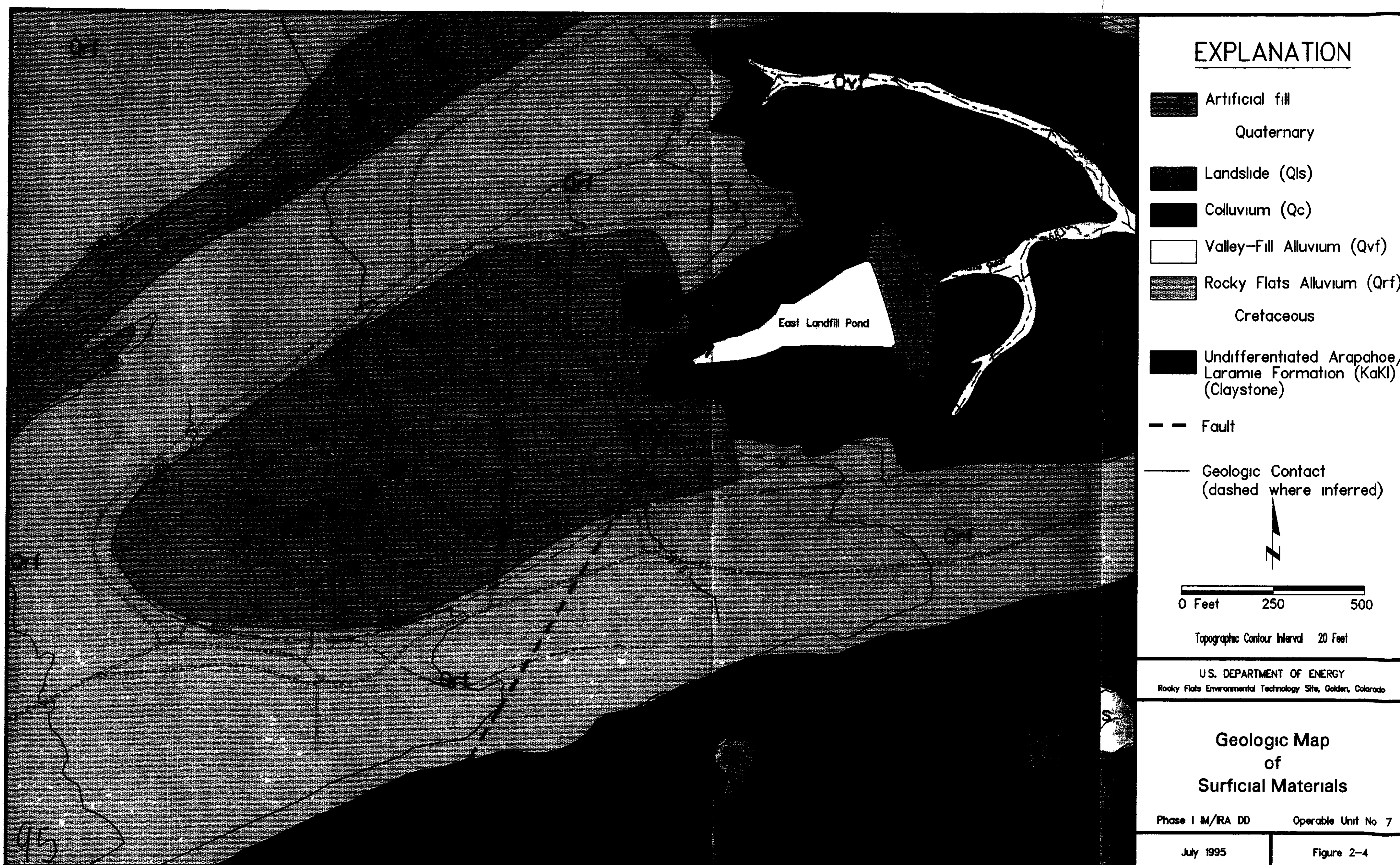
07/13/95 IHSS.MAP



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Geologic Map of Surficial Materials

Phase I IM/IRA DD Operable Unit No 7

July 1995 | Figure 2-4

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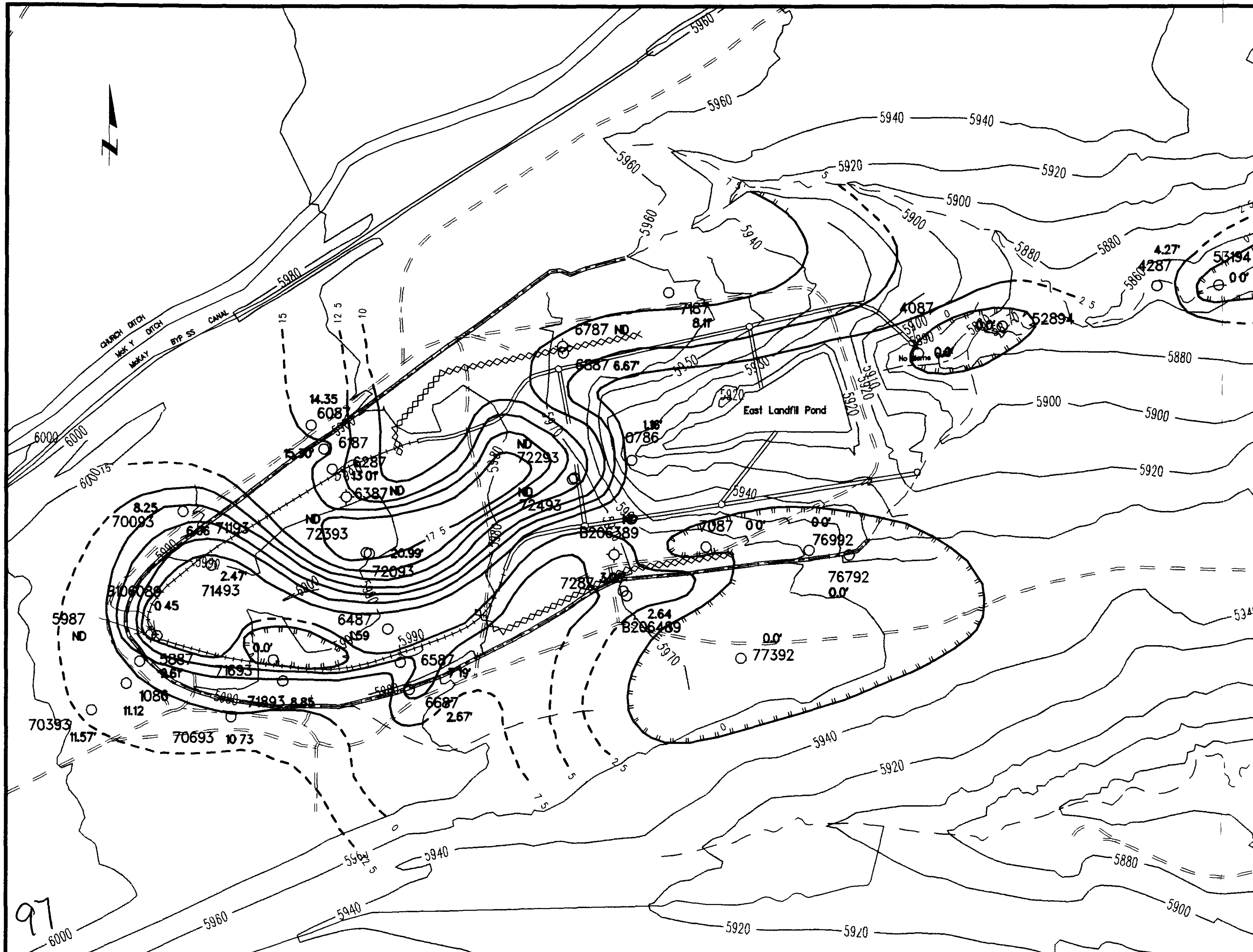
07/10/95 GEOLOGY MAP



EXPLANATION

- Alluvial Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Line of Equal Saturated Thickness (dashed where inferred)

(Contour Interval = 2 5 feet)

- Unsaturated Areas (dashed where inferred)

ND Not deep enough to penetrate entire saturated thickness

0 Feet 300 600

Topographic Contour Interval 20 Feet

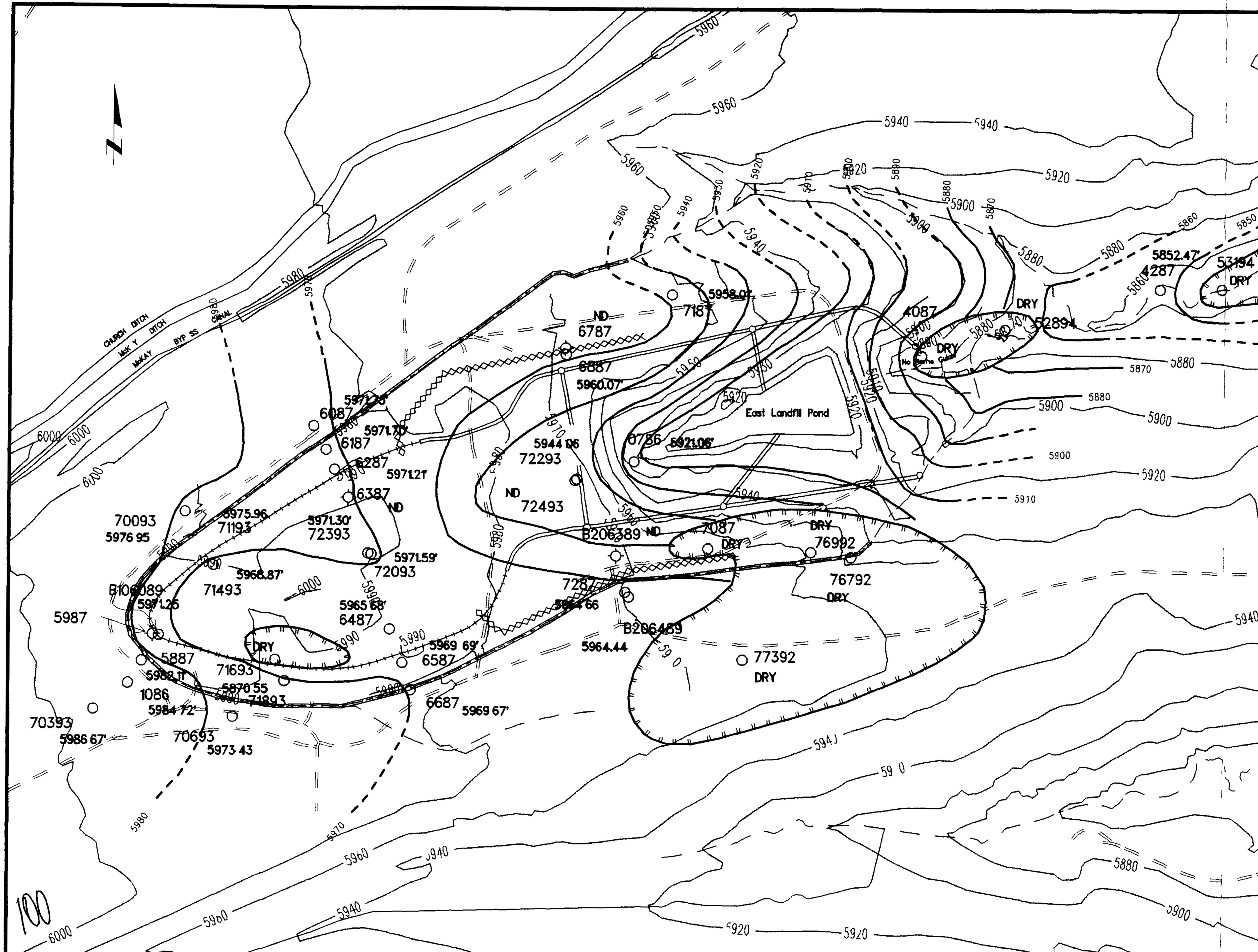
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Saturated Thickness of Unconsolidated Surficial Deposits (2nd Quarter 1995)

Phase I IM/IRA DD | Operable Unit No 7

July 1995 | Figure 2-6

07/10/95 Q295ISM.MAP



EXPLANATION

○ Alluvial Well

⌖ Abandoned Well

Ditch

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall

Groundwater Intercept System
(perforated)
(non-perforated)

Line of Equal Potentiometric Surface (feet above sea level) (dashed where inferred)

(Contour Interval = 10 feet)

Unsaturated Areas (dashed where inferred)

0 Feet 300 600

Topographic Contour Interval 20 Feet

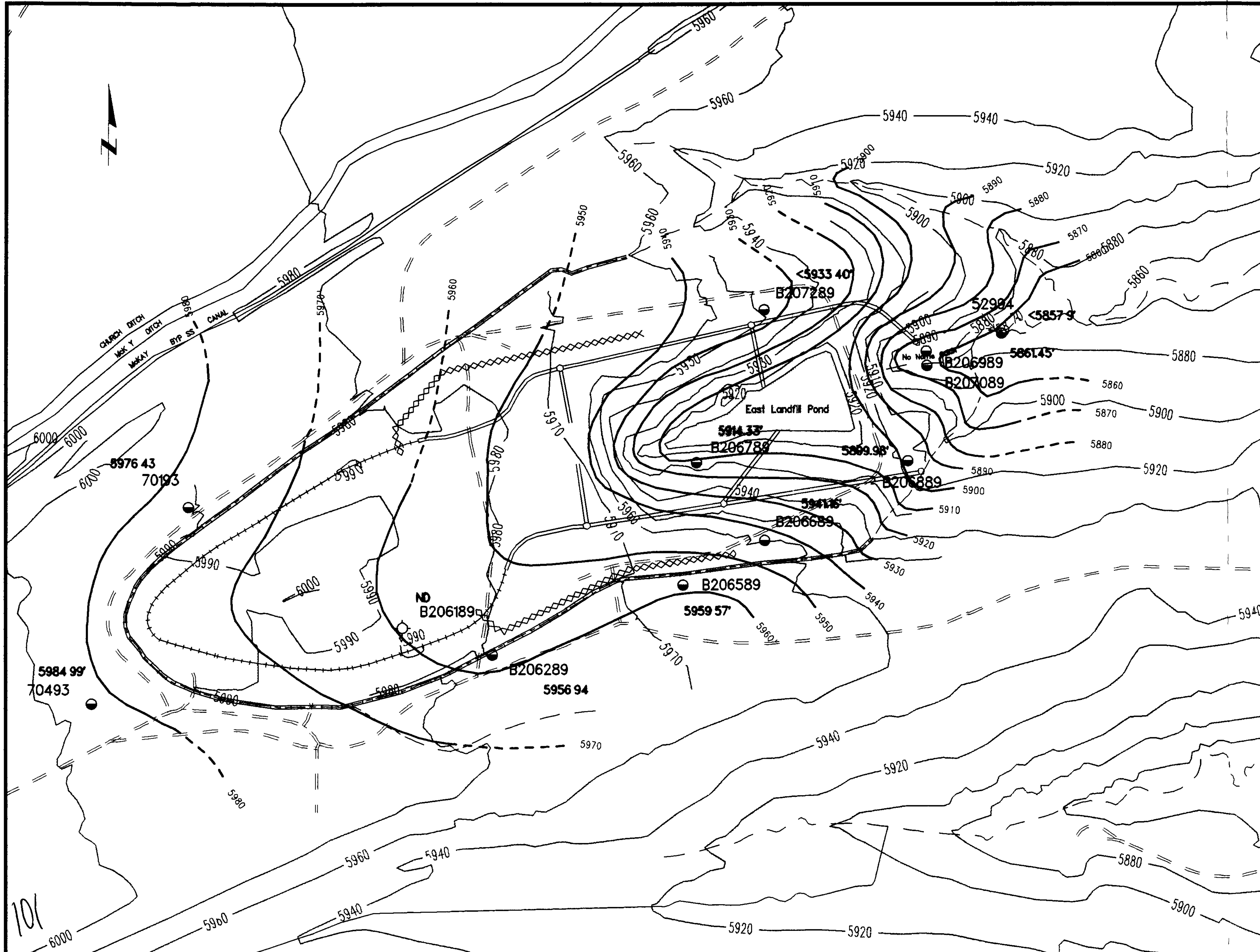
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Potentiometric Map of Surficial Materials Groundwater (2nd Quarter 1995)

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 2-9

07/13/95 Q295SURF.MAP



EXPLANATION

- Weathered Bedrock Well
- Abandoned Well
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Line of Equal Potentiometric Surface (feet above sea level) (dashed where inferred)

(Contour Interval = 10 feet)

- Unsaturated Areas (dashed where inferred)

0 Feet 300 600

Topographic Contour Interval 20 Feet

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Rocky Flats Environmental Technology Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock Groundwater (2nd Quarter 1995)

Phase I IM/IRA DD — Operable Unit No 7

July 1995 — Figure 2-10

07/10/95 Q295WB.MAP

EXPLANATION

- ◆ Mammal and Vegetation Transects
- —— Ditch
- - - - Intermittent Stream
- = = Dirt Road
- Wetlands
- Wet Meadow
- Short Marsh
- 322 Mesic Mixed Grassland
- Xeric Mixed Grassland
- Disturbed Area – Disturbed/Barren Land
- 500 Disturbed Area – Developed Areas

0 Feet 250 500

Topographic Contour Interval 20 Feet

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Distribution of Habitat Types

Phase I IM/IRA DD | Operable Unit No 7

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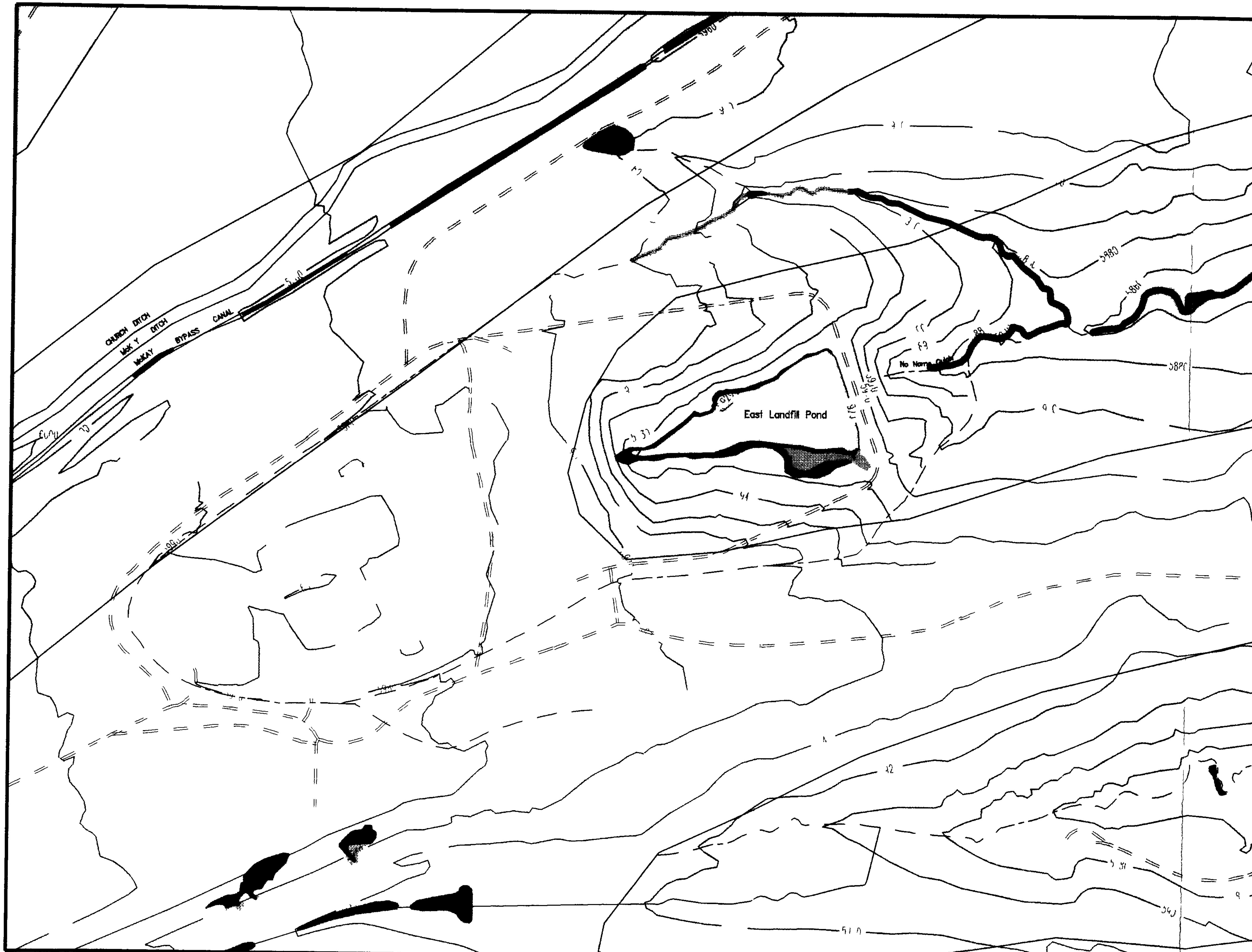
07/10/95 HABITAT.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Probable Preble s Meadow Jumping Mouse Habitat

WETLANDS

- PEMA (Palustrine Emergent, Temporarily Flooded)
- PEMB (Palustrine Emergent Saturated)
- PEMC (Palustrine Emergent Seasonally Flooded)
- L1UBH (Lacustrine Limnetic Unconsolidated Bottom, Permanently Flooded)

0 Feet 300 600

Topographic Contour Interval 20 Feet

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Wetland Areas and Preble s Meadow Jumping Mouse Habitat

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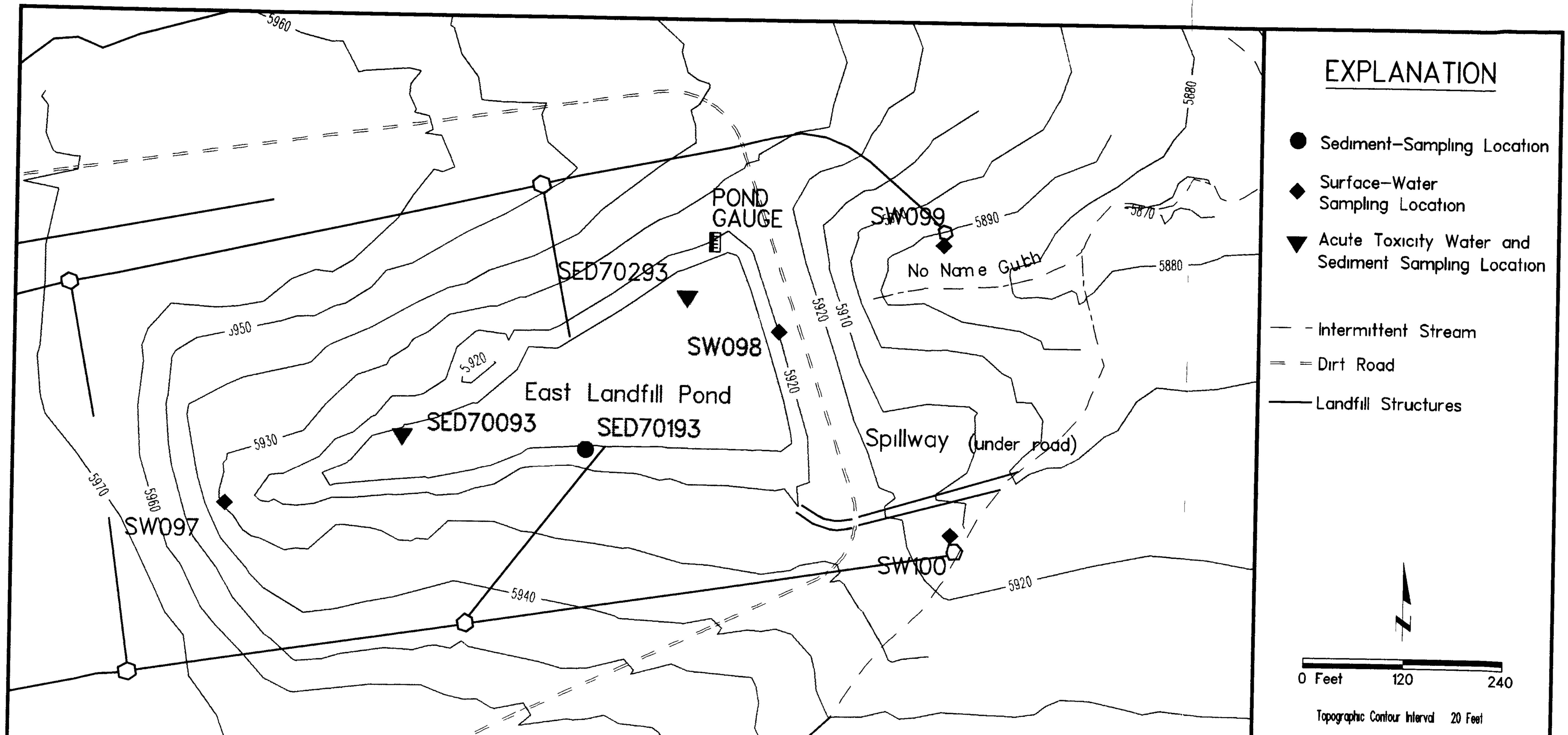
07/10/95 WETPREB.MAP



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Surface Water and Sediment Sampling Locations

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07/10/95 SWSED.MAP