NOTICE

All drawings located at the end of the document.

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KAISER•HILL
COMPANY

Operable Unit 7 Revised Draft IM/IRA Decision Document and Closure Plan

RMRS Rocky Mountain Remediation Services, LLC
...protecting the environment

• Environmental Restoration •
Rocky Flats Environmental Technology Site

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Operable Unit 7
Revised Draft
IM/IRA Decision Document
and Closure Plan

Text

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

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TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION 1-1

1.1 PURPOSE OF REPORT 1-2

1.2 ORGANIZATION OF REPORT 1-2

1.3 OTHER MAINTENANCE AND REMEDIAL ACTIONS 1-4

1.3.1 Leachate Accelerated Action 1-4
1.3.2 Disposition of Investigation-Derived Materials 1-4
1.3.3 Well Abandonment 1-4

1.4 THE PRESUMPTIVE REMEDY APPROACH 1-5

2.0 SITE CHARACTERISTICS 2-1

2.1 DESCRIPTION AND OPERATIONAL HISTORY OF OU 7 2-1

2.1.1 Present Landfill (IHSS 114) 2-1
2.1.2 Inactive Hazardous Waste Storage Area (IHSS 203) 2-2
2.1.3 Asbestos-Disposal Areas 2-3
2.1.4 Spray Evaporation Areas (IHSSs 167.2 and 167.3) 2-3
2.1.5 OU 6 Trenches (IHSSs 166.1, 166.2, and 166.3) 2-3
2.1.6 Historical Interim Response Actions 2-4

2.2 GEOLOGY 2-5

2.2.1 General Geologic Framework 2-5
2.2.2 Description of Geologic Units 2-5
2.2.3 Distribution of Geologic Units 2-7
2.2.4 Geotechnical Properties of Geologic Units 2-8
2.2.5 Description of Pond Sediments 2-8

2.3 HYDROLOGY 2-8

2.3.1 Conceptual Flow Model 2-8
2.3.2 Surface-Water Hydrology 2-9
2.3.3 Interactions Between Surface Water and Groundwater 2-10
2.3.4 Groundwater Hydrology 2-11
2.3.5 Water Balance for the Landfill 2-14
2.3.6 No Name Gulch 2-15

2.4 ECOLOGY 2-15

2.4.1 Vegetation 2-16
2.4.2 Wildlife 2-16
2.4.3 Sensitive Habitats and Endangered Species 2-17

2.5 NATURE AND EXTENT OF CONTAMINATION 2-18

2.5.1 Methodology for Background Comparisons and PCOC Identification 2-18
2.5.2 Landfill Gas 2-20
2.5.3 Landfill Leachate at the Seep 2-20
2.5.4 Surface Water in the East Landfill Pond 2-21
2.5.5 Sediments in the East Landfill Pond 2-22
2.5.6 Surface Soils in Spray Evaporation Areas 2-23
2.5.7 Subsurface Geologic Materials Downgradient of the Landfill 2-23
2.5.8 Groundwater Downgradient of the Landfill 2-24

3.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES 3-1

3.1 PRELIMINARY REMEDIAL ACTION OBJECTIVES 3-1

3.2 CONCEPTUAL SITE MODEL 3-2

3.3 EVALUATION OF POTENTIAL RISKS 3-3

3.3.1 Risk Assessment Approach 3-4
3.3.2 Landfill Leachate Emerging as Seep Water 3-5
3.3.3 Surface Soils and Subsurface Soil Downgradient of the Landfill 3-6
3.3.4 Groundwater Downgradient of the Landfill 3-10

3.4 COMPLIANCE WITH ARARS 3-11

3.4.1 Potential Chemical-Specific ARARs 3-12
3.4.2 Potential Location-Specific ARARs 3-14
3.4.3 Potential Action-Specific ARARs 3-15

3.5 FINAL REMEDIAL ACTION OBJECTIVES OR RESPONSE ACTIONS 3-17

3.5.1 Elimination of Preliminary RAOs 3-18
3.5.2 Final RAOs 3-19

4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES 4-1

4.1 GENERAL RESPONSE ACTIONS 4-1

4.2 THE SCREENING PROCESS 4-2

4.2.1 No Action 4-2
4.2.2 Institutional Controls 4-2
4.2.3 Containment 4-3
4.2.4 Collection 4-3
4.2.5 Treatment 4-4
4.2.6 Disposal 4-5

4.3 RESULTS OF SCREENING 4-5

5.0 DEVELOPMENT OF ALTERNATIVES 5-1

5.1 OPTION SCREENING CRITERIA 5-1

5.1.1 Effectiveness 5-1
5.1.2 Implementability 5-1
5.1.3 Cost 5-2

5.2 LANDFILL MASS 5-3

5.2.1 Landfill Cover Design 5-4
5.2.2 Landfill Capping Option Selected for Detailed Analysis 5-18

5.3 LANDFILL GAS 5-19

5.3.1 Gas Collection Options 5-19
5.3.2 Gas Treatment Options 5-20
5.3.3 Gas Collection/Treatment Options Selected for Detailed Analysis 5-20

5.4 LEACHATE 5-20

5.4.1 Leachate Collection Options 5-20
5.4.2 Leachate Collection Options Selected for Detailed Analysis 5-20
5.4.3 Description and Screening of Leachate Treatment Options 5-21
5.4.4 Description and Screening of Leachate Disposal Options 5-26
5.4.5 Summary of Leachate Options Selected for Detailed Analysis 5-27

5.5 GROUNDWATER 5-27

5.6 SUMMARY OF SCREENING 5-28

6.0 DETAILED ANALYSIS OF ALTERNATIVES 6-1

6.1 SCREENING PROCESS 6-1

6.2 EVALUATION OF ALTERNATIVES 6-3

6.2.1 Alternative 1: No Action 6-3
6.2.2 Alternative 2: Cap, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater 6-4
6.2.3 Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater 6-11
6.2.4 Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Surface Water 6-14

6.3 COMPARATIVE ANALYSIS 6-17

6.3.1 Overall Protection of Human Health and the Environment 6-17
6.3.2 Compliance with ARARs 6-18

6.3.3 Long-Term Effectiveness and Permanence 6-18
6.3.4 Reduction of Toxicity, Mobility, and Volume 6-18
6.3.5 Short-Term Effectiveness 6-18
6.3.6 Implementability 6-19
6.3.7 Cost 6-19
6.3.8 Summary of Comparative Analysis 6-19

7.0 RECOMMENDED ALTERNATIVE 7-1

7.1 DESCRIPTION 7-1

7.2 DESIGN REQUIREMENTS 7-2

7.2.1 Compliance with RAOs 7-3
7.2.2 Compliance with ARARs 7-4

7.3 CONCEPTUAL DESIGN 7-6

7.3.1 Proposed Grading Plan 7-6
7.3.2 Surface-Water Control 7-8
7.3.3 Cover Section 7-8
7.3.4 Seep Water Discharge to Groundwater 7-9
7.3.5 Gas Control 7-9
7.3.6 Institutional Controls 7-10
7.3.7 Cost Estimate 7-10

7.4 TITLE II DESIGN 7-10

7.5 JUSTIFICATION FOR RECOMMENDED ALTERNATIVE 7-10

8.0 CLOSURE AND POSTCLOSURE PLANS 8-1

8.1 CLOSURE PLAN 8-2

8.1.1 Facility Description 8-2
8.1.2 Extent of Operations and Management of Maximum Inventory 8-3
8.1.3 Notification of Closure 8-3
8.1.4 Final Cover 8-3
8.1.5 Decontamination Procedures 8-3
8.1.6 Groundwater Monitoring 8-4
8.1.7 Ancillary Closure Activities 8-4
8.1.8 Closure Certification 8-4
8.1.9 Survey Plat 8-5
8.1.10 Record of Wastes 8-5
8.1.11 Deed Notation 8-5
8.1.12 Final Closure Schedule 8-5

8.2 POSTCLOSURE PLAN 8-5

8.2.1 Postclosure Permit 8-5
8.2.2 Postclosure Inspection and Maintenance 8-6

8.2.3 Postclosure Monitoring 8-6
8.2.4 Five-Year Review 8-10
8.2.5 Postclosure Certification 8-10
8.2.6 Financial Assurance and Cost Estimates 8-10

9.0 ENVIRONMENTAL ASSESSMENT 9-1

9.1 SCREENING-LEVEL HUMAN HEALTH RISK ASSESSMENT 9-1

9.1.1 Identification of Potential Contaminants of Concern or Activities of Concern 9-2
9.1.2 Characterization of Exposure 9-2
9.1.3 Identification of Uncertainty 9-4

9.2 ECOLOGICAL RISK 9-5

9.2.1 Wildlife and Vegetation 9-5

9.3 IMPACT TO AIR QUALITY 9-7

9.3.1 Estimation of Potential Fugitive-Dust Emissions 9-7
9.3.2 Comparison to EPA Air Quality Standards 9-10
9.3.3 Estimation of Potential Methane Emissions 9-10

9.4 IMPACT TO SURFACE-WATER QUALITY 9-11

9.4.1 Short-Term (Construction Period) Impacts 9-11
9.4.2 Long-Term Impacts 9-12

9.5 IMPACT TO GROUNDWATER QUALITY 9-12

9.5.1 Short-Term (Construction Period) Impacts 9-12
9.5.2 Long-Term Impacts 9-13

9.6 COMMITMENT OF IRREVERSIBLE AND IRRETRIEVABLE RESOURCES 9-13

9.7 IMPACT TO TRANSPORTATION 9-14

9.8 IMPACT TO CULTURAL, HISTORICAL, AND ARCHAEOLOGICAL RESOURCES 9-15

9.9 CUMULATIVE IMPACTS 9-15

9.10 COMPARISON OF THE PREFERRED IM/IRA TO THE NO-ACTION ALTERNATIVE 9-15

10.0 REFERENCES 10-1

FIGURES

1-1 Location of the Rocky Flats Environmental Technology Site
1-2 Location of Operable Unit No. 7
1-3 Present Landfill and East Landfill Pond (June 1991)
1-4 Location of Other Maintenance and Remedial Actions
2-1 Locations of IHSSs and Historical Interim Response Actions
2-2 Typical Existing Groundwater-Intercept System Section
2-3 Generalized Stratigraphic Section
2-4 Geologic Map of Surficial Materials
2-5 Conceptual Flow Model for OU7
2-6 Saturated Thickness of Unconsolidated Surficial Deposits (2nd Quarter 1995)
2-7 Groundwater Flowpaths from the Landfill
2-8 Hydraulic Conductivity Measurements for Each Geologic Unit
2-9 Potentiometric Map of Surficial Materials Groundwater (2nd Quarter 1995)
2-10 Potentiometric Map of Weathered Bedrock Groundwater (2nd Quarter 1995)
2-11 Distribution of Habitat Types
2-12 Wetland Areas
2-13 Surface-Water and Sediment Sampling Locations
2-14 Soil-Sampling Locations in the Vicinity of Spray Evaporation Areas
2-15 Downgradient Subsurface Geologic Materials and Groundwater Sampling Locations
3-1 Conceptual Site Model for Exposure Pathways at OU 7
3-2 Schematic Diagram of Conceptual Site Model for Exposure Pathways at OU 7
3-3 Human Health Focused Risk Assessment Methodology
5-1 Extent of the Landfill Cap and Fill
5-2 Conceptual Grading Plan with Discharge of Seep Water to Groundwater, Extent of Cover, and Surface Water Control Plan
5-2A Landfill Cover Cross Section A-A'
5-2B Landfill Cover Cross Section B-B' & C-C'
5-3 Conceptual Grading Plan with Discharge of Seep Water to Surface Water, Extent of Cover, and Surface Water Control Plan
5-3A Landfill Cover Cross Section A-A'
5-3B Landfill Cover Cross Section B-B' & C-C'
5-4 Leakage Rates for Cover Alternatives
6-1 Cover Cross Section for Alternative 1: No Action
6-2 Cover Cross Section for Alternatives 2, 3, and 4: Single-Barrier FMC & Low-Permeability Soil
6-3 Alternative 2: conceptual Grading Plan with discharge of Seep Water to Groundwater
6-4 Alternative 3: Conceptual Grading Plan with Slurry Wall and Discharge of Seep Water to Groundwater
6-5 Alternative 4: Conceptual Grading Plan with Engineered Wetlands and Discharge of Seep Water to Surface Water
7-1 Cover Cross Section for Alternatives 2, 3, and 4: Single-Barrier FMC & Low Permeability Soil
7-2 Existing Topography and Surface Features
7-3 Recommended Alternative: Conceptual Grading Plan and Discharge of Seep Water to Groundwater, Extent of Cover, and Surface Water Control Plan
7-3A Landfill Cover Cross Section A-A'
7-3B Landfill Cover Cross Section B-B' & C-C'

8-1 Groundwater Monitoring Wells Remaining During Landfill Closure
8-2 Proposed Postclosure Groundwater Monitoring Wells

TABLES

2-1 Geotechnical Classification Test Results for Soil Samples 2-26
2-2 Analytes Detected in Leachate at the Seep (SW097) 2-27
2-3 Analytes Detected in Surface Water in the East Landfill Pond (SW098) 2-31
2-4 Analytes Detected in Sediment in the East Landfill Pond 2-35
2-5 Analytes Detected in Surface Soils in the Vicinity of Spray Evaporation Areas 2-38
2-6 Analytes Detected in Subsurface Geologic Materials Downgradient of the Landfill 2-40
2-7 Analytes Detected in UHSU Groundwater Downgradient of the Landfill 2-45
2-8 Analytes Detected in LHSU Groundwater Downgradient of the Landfill 2-49
3-1 Preliminary Remediation Goal (PRG) Screen for Leachate Seep Water 3-20
3-2 OU 7 Exposure Screen for Surface-Water Quality for Leachate Seep Water 3-21
3-3 Preliminary Remediation Goal (PRG) Screen for Surface Soils Downgradient of the Landfill 3-22
3-4 Site-Specific Exposure Factors for Incidental Ingestion of Surface Soil Open-space Exposure Scenario 3-23
3-5 Site-Specific Exposure Factors for Particulate Inhalation of Surface Soil Open-Space Exposure Scenario 3-23
3-6 Site-Specific Exposure Factors for External Irradiation of Surface Soil Open-Space Exposure Scenario 3-24
3-7 Potential Risks Associated with Incidental Ingestion of Surface Soil Open-Space Exposure Scenario 3-24
3-8 Potential Risks Associated with Particulate Inhalation from Surface Soil Open-Space Exposure Scenario 3-25
3-9 Potential Risks Associated with External Irradiation from Surface Soil Open-Space Exposure Scenario 3-25
3-10 Vegetation Screen for Subsurface Soil Downgradient of the Landfill 3-26
3-11 Summary of Ecotoxicological Risk to Small Mammals from Incidental Ingestion of Surface Soils Downgradient of the Landfill 3-27
3-12 Radionuclide Screen for Surface Soils and Subsurface Soil Downgradient of the Landfill 3-28
3-13 Small Mammal Burrow Air Screen for Subsurface Soil Downgradient of the Landfill 3-29
3-14 Preliminary Remediation Goal (PRG) Screen for Groundwater Downgradient of the Landfill 3-30
3-15 OU 7 Exposure Screening for Surface-Water Quality for Groundwater Downgradient of the Landfill 3-31
3-16 Surface-Water ARARs 3-32
3-17 Groundwater ARARs 3-35
3-18 Analytes Exceeding Groundwater ARARs at the Seep 3-39
3-19 Analytes Exceeding Surface-Water ARARs at the Seep 3-40
3-20 Analytes Exceeding Groundwater ARARs Downgradient of the East Landfill Pond Dam 3-41
3-21 Analytes Exceeding Groundwater ARARs at Alluvial Well 72293 3-42
3-22 Potential Location-Specific ARARs 3-43
3-23 Potential Federal and State Action-Specific ARARs 3-45

3-24 Regulatory and Technical Guidance To Be Considered 3-49
3-25 Evaluation of Remedial Action Objectives for Developing Response Actions 3-51
4-1 Summary of Screening Criteria 4-7
4-2 Evaluation of Remedial Technologies: Institutional Controls 4-8
4-3 Evaluation of Remedial Technologies: Containment of Landfill Mass 4-9
4-4 Evaluation of Remedial Technologies: Groundwater Containment 4-10
4-5 Evaluation of Remedial Technologies: Landfill Gas Collection 4-11
4-6 Evaluation of Remedial Technologies: Leachate Collection 4-12
4-7 Evaluation of Remedial Technologies: Gas Treatment 4-13
4-8 Evaluation of Remedial Technologies: Leachate Treatment 4-14
5-1 Summary of Landfill Cover Components 5-30
5-2 Comparison of Cover Effectiveness Factors 5-31
5-3 Comparative Analysis of Capping Options Screening 5-32
6-1 Evaluation Criteria for the Detailed Analysis of Alternatives 6-20
6-2 Summary of Cost Estimate 6-21
7-1 Summary of EPA Guidance Criteria for Design of Cover Systems 7-12
7-2 Design Components that meet Closure ARARs 7-13
7-3 Preliminary List of Drawings for the Title II Design 7-15
7-4 Preliminary List of Technical Specifications for Landfill Closure 7-16
8-1 Closure Timeline 8-11
8-2 Postclosure Inspection, Maintenance, and Monitoring Schedule 8-12
8-3 Groundwater-Monitoring Parameters 8-13
9-1 Uncertainties Associated with Assessing Risk 9-17
9-2 Fugitive-Dust Emissions from IM/IRA Construction 9-18
9-3 Modeled and Cumulative PM-10 Concentrations for IM/IRA Construction 9-19
9-4 Summary of Potential Impacts: Preferred IM/IRA Versus No Action 9-20

ACRONYMS AND ABBREVIATIONS

%	percent
mg/kg	micrograms per kilogram
mg/L	micrograms per liter
mg/m^3	micrograms per cubic meter
AC	acute
AG	agricultural
AOS	apparent opening size
APEN	Air Pollutant Emission Notice
AQ	aquatic
ARARs	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
BDT	best demonstrated technology
bgs	below ground surface
BNACLP	base/neutral/acid contract laboratory procedures
CAD	Corrective Action Decision
CAQCC	Colorado Air Quality Control Commission
CCR	Colorado Code of Regulations
CDNR	Colorado Department of Regulations
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act

CERFA	Community Environmental Response Facilitation Act
CFR	Code of Federal Regulations
CGI	combustible gas indicator
CH	chronic
CHWA	Colorado Hazardous Waste Act
cm/sec	centimeters per second
CMS/FS	corrective measures study/feasibility study
CN	curve numbers
CPT	cone penetration testing
CQA	construction quality assurance
CRDL	contract-required detection limit
CWA	Clean Water Act
CWQ	Colorado Water Quality
DCA	dichloroethane
DCE	dichloroethene
DD	Decision Document
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DW	drinking water
DW&F	drinking water and fish
EEC	ecological effects concentrations
ECOC	ecological contaminant of concern
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EqP	equilibrium partitioning
ERAM	ecological risk assessment methodology
FID	flame ionization detector
FFCA	Federal Facility Compliance Agreement
FMC	flexible membrane cover
FS	feasibility study
ft/min	feet per minute
ft^3/lb	cubic feet per pound
ft^3/yr	cubic feet per year
GAC	granular activated carbon
GC	gas chromatogram
GCL	geosynthetic clay liner
gpm	gallons per minute
GRA	general response action
g/s	grams per second
HAP	hazardous air pollutant
HDPE	high-density polyethylene
HEAST	Health Effects Assessment Summary Tables
HELP	Hydrologic Evaluation of Landfill Performance
HH	human health
HI	hazard index
HQ	hazard quotient
IAG	Interagency Agreement
IDL	instrument detection limit
IDM	investigation-derived material
IHSS	individual hazardous substance site
IM/IRA	interim measure/interim remedial action

IRIS	Integrated Risk Information System
KaKl(w)	weathered undifferentiated Cretaceous Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Cretaceous Arapahoe and Laramie Formation
lbs/in^2	pounds per square inch
lb/yd^3	pounds per square inch
LDR	Land Disposal Restrictions
LHSU	lower hydrostratigraphic unit
LOAEL	lowest-observed-adverse-effects level
m	meters
m^2	square meters
MAC	maximum allowed concentration
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
ME	matrix effect
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
Mg/yr	Megagrams per year
MOU	Memorandum of Understanding
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND-GC	no data – gas chromatogram
NFA	no further action
NMOC	non-methane organic compound
NOAEL	no-observed-adverse-effects level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PAM	Proposed Action Memorandum
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
PI	plasticity index
PID	photoionization detector
PM-10	respirable particulate matter
PPCD	Plan for the Prevention of Contaminant Dispersion
PPE	personal protective equipment
ppm	parts per million
PQL	practical quantitation limit
PRG	preliminary remediation goal
PSD	prevention of significant deterioration
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
Qc	Quaternary colluvium
Qvf	Quaternary valley-fill alluvium
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act

RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFFO	Rocky Flats Field Office
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SLRA	screening level risk assessment
SRB	sulfate-reducing bacteria
SVOC	semivolatile organic compound
TBC	guidance or recommendation to be considered
TCA	trichloroethane
TCE	trichloroethene
TSDF	treatment, storage, and disposal facility
TOC	total organic carbon
TOX	total organic halogen
TSP	total suspended particulates
TVS	table value standard
UCL^{95}	95 percent upper confidence limit
UHSU	upper hydrostratigraphic unit
USCS	Unified Soil Classification System
USFWS	U.S. Fish and Wildlife Service
USLE	Universal Soil Loss Equation
UTL	upper tolerance limit
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level
VOACLP	volatile organic analysis contract laboratory procedures
VOC	volatile organic compound
WIN	Well Installation Notification
WSIC	Waste Stream Identification and Characterization
WSRIC	Waste Stream Residue Identification and Characterization
yd^3	cubic yards

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, Present Landfill. As agreed to by the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and Colorado Department of Public Health and Environment (CDPHE), the alternative implemented as the interim action will also comprise the final action for OU 7. 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, also constitutes the OU 7 Closure Plan. Several other maintenance and remedial actions are planned or have been implemented at OU 7, including implementing a leachate accelerated action, disposing investigation-derived material in the landfill prior to closure, 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, Spray Evaporation Areas. The Present Landfill has operated primarily as a municipal waste facility for Rocky 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. Waste codes were not assigned to these waste streams. 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 describes the nature and extent of contamination. 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 approach allows a comparison of all OU 7 exposure pathways to the pathways that will be addressed by implementation of the presumptive remedy. The analysis presented in this document concludes that the presumptive remedy, containment, will address several potential contaminant exposure pathways. The presumptive remedy includes an engineered cap to contain the landfill waste and minimize infiltration of water and leachate generation and migration. It also includes a gas collection system under the cap. In addition to the presumptive remedy, DOE, EPA, and CDPHE have agreed that the East Landfill Pond will be removed and the pond sediments and dam will be removed and consolidated in the landfill under the cap.

Remaining pathways for surface and subsurface soils in spray evaporation areas, landfill leachate discharge to surface water, and groundwater downgradient of the landfill discharge to surface water, were subjected to a focused risk assessment process. This risk assessment consisted of comparing the maximum site concentrations to preliminary remediation goals, quantifying exposure and toxicity values, and comparing to applicable or relevant and appropriate requirements (ARARs). No risks to open-space receptors were identified. Risks to ecological receptors were determined to be minimal.

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

1. Prevent direct contact with landfill contents

2. Minimize infiltration and resulting contaminant leaching to groundwater

3. Control surface-water runoff and erosion

4. Control landfill gas (treat as needed)

5. Control groundwater at the source

6. Collect and treat leachate (as needed)

These RAOs form the basis for identification of appropriate remedial action alternatives for the site. Section 5 of this report describes the alternatives initially identified as supportive of the RAOs. Following EPA guidance, the alternatives were evaluated against three criteria: (1) effectiveness, (2) implementability, and (3) cost. This initial screening process eliminated alternatives from further consideration. The following four alternatives (presented in Section 6) were carried through the detailed screening of alternatives.

Alternative 1: No Action

Alternative 2: Cap, Passive Gas Collection and Monitoring, Seep Water Discharge to Groundwater

Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, Seep Water Discharge to Groundwater

Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, Seep Water Discharge to Surface Water

Alternative 1, the no-action alternative, provides a baseline for comparison of other alternatives in accordance with EPA guidance.

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

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 criteria, a comparative analysis was performed to evaluate the alternatives. This comparison is described and quantified via a ranking system, which is presented in Section 6. Alternative 2 emerged from this multi-step evaluation process as the preferred alternative for the OU 7 remedial action. Alternative 2 achieves the site RAOs and ranks consistently well according to the nine criteria.

Alternative 2 consists of a single-barrier flexible membrane cover (FMC) underlain by a 12-in. 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-in. vegetative layer. Leachate at the seep would be discharged to alluvial groundwater downgradient of the cap. A gravel layer would be constructed under the cap from the seep area downgradient to the east leading to fill in the pond area past the farthest extent of the cap. Existing institutional controls are maintained, including limited site access, and new fencing around the cover is provided.

Postclosure monitoring will be conducted for 30 years under the chosen alternative. This document presents a postclosure monitoring plan for OU 7, which will include semiannual groundwater monitoring both upgradient and downgradient of the landfill, quarterly gas monitoring, and annual cover surveys and facility inspections.

1.0 INTRODUCTION

The Rocky Flats Environmental Technology Site is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (see 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 (see 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 nonradioactive 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 (see 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). A two-phase process was developed to remove these environmental contaminants. 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 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 DOE, the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) dated January 22, 1991 (DOE 1991b). The IAG addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues that pertain to the site. EPA is the lead regulatory agency for remediation of OU 7.

The focus of investigations at OU 7 changed in 1994 as a result of the adoption by DOE, CDPHE, and EPA of a presumptive-remedy strategy for streamlined site characterization and site remediation. 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 has been implemented before closure as an accelerated action (see Section 1.3.1). The landfill closure IM/IRA is addressed in this report.

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).

1.1 PURPOSE OF REPORT

This Phase I IM/IRA Decision Document (IM/IRA DD) presents the proposed alternative for closure of the Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203). The alternative addresses all source areas with risk levels greater than 1E-06 or a hazard index greater than 1. The IM/IRA DD also presents justification for no further action for the Pond Area Spray Field (IHSS 167.2) and South Area Spray Field (IHSS 167.3). As agreed by DOE, CDPHE, and EPA, the interim action will be the final action for closure of OU 7. Therefore, the Phase I IM/IRA DD includes 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 1007-3 265). 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. 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 supplemental 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 the alternatives; summarizes the results of the alternatives screen using

effectiveness, implementability, and cost; and presents the alternatives retained for detailed analysis.

- Section 6, Detailed Analysis of Alternatives, presents an evaluation of the remaining 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; cost; 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.

- Section 8, Closure and Postclosure Plans, details the plans that will be carried out during the closure and postclosure care periods to meet regulations stipulated in CHWA, 6 CCR 1007-3 265.11 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, closure certification requirements, and a schedule for closure. The postclosure plan addresses permit requirements and describes routine inspection activities, gas monitoring, groundwater monitoring, the point-of-compliance, and the postclosure 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, and 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 contains input parameters, results, contaminant distribution maps, and a summary of the contaminant-transport modeling. Appendix E presents settlement estimates. Appendix F presents input parameters, results, and a summary of the HELP modeling. Appendix G provides estimated costs and assumptions. Appendix H provides gas-emission estimates. Appendix I provides annual soil-loss calculations. Appendix J presents CDPHE/EPA responses to comments on the Draft IM/IRA DD. Appendix K contains the wetland assessment for OU 7.

1.3 OTHER MAINTENANCE AND REMEDIAL ACTIONS

Several other actions are planned or have been implemented at OU 7, including implementing a leachate interception and treatment accelerated action, disposing investigation-derived material (IDM) in the landfill prior to closure, and abandoning groundwater-monitoring wells within the landfill (see Figure 1-4).

1.3.1 Leachate Accelerated Action

The seep collection IM/IRA was implemented before closure as an accelerated action. A passive seep interception and treatment system was constructed to eliminate discharge of F039 waste contained in groundwater from the seep to the East Landfill Pond (see 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 is intercepted with perforated pipe and directed to a tank containing carbon-based granular media that separates the F039 waste from seep water. F039 waste is absorbed by the carbon-based media. Treated water is discharged directly to the East Landfill Pond. The modified PAM was approved by CDPHE and EPA on June 27, 1995. Operation of the system began in early 1996.

1.3.2 Disposition of Investigation-Derived Materials

All 237 drums of IDM from the Phase I RFI/RI at OU 7 will be returned to the landfill prior to closure. This action was proposed in an April 28, 1995, letter from DOE to CDPHE and EPA (DOE 1995b). CDPHE and EPA approved the IDM proposal on October 3, 1995 (CDPHE 1995a). Disposal of 173 drums that contain non-hazardous IDM was proposed in accordance with existing operating procedures (4-F99-ENV-OPS-FO.23 [RMRS 1995a]). Disposal of 64 drums that contain RCRA hazardous waste was proposed on the basis that the waste was designated as RCRA hazardous solely because it contains F039 waste and the RCRA risk analysis ratio is greater than one. None of the 64 drums that contain hazardous waste have any other associated waste codes. The RCRA risk analysis evaluates exposure pathways, including direct ingestion of soil, dermal absorption of constituents from soil, inhalation of suspended soil, and ingestion of food grown in contaminated soil.

Because the Present Landfill is undergoing a RCRA-equivalent closure and the waste came directly from characterization efforts at the landfill, DOE proposed returning the waste to the landfill before the cap is constructed. By returning the RCRA hazardous waste IDM to the landfill, the RCRA and CERCLA constituents in the IDM will be controlled to the same extent as the waste already present. After the landfill is capped, the soil pathway will no longer exist. Disposition of IDM in the landfill is protective of human health and the environment.

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 (see 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 1995b). Well 00493, which is within the landfill, was inadvertently left out of the proposal and is included in Figure 1-4 to be

abandoned. Well 6087, which is outside of the landfill, was included in the proposal but does not need to be abandoned because of its location. As shown in Figure 1-4, this well is not designated for abandonment.

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 before closure.

1.4 THE PRESUMPTIVE REMEDY APPROACH

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 initially adopted for OU 7 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 presumptive remedy approach streamlined 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 approach, 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:

- 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

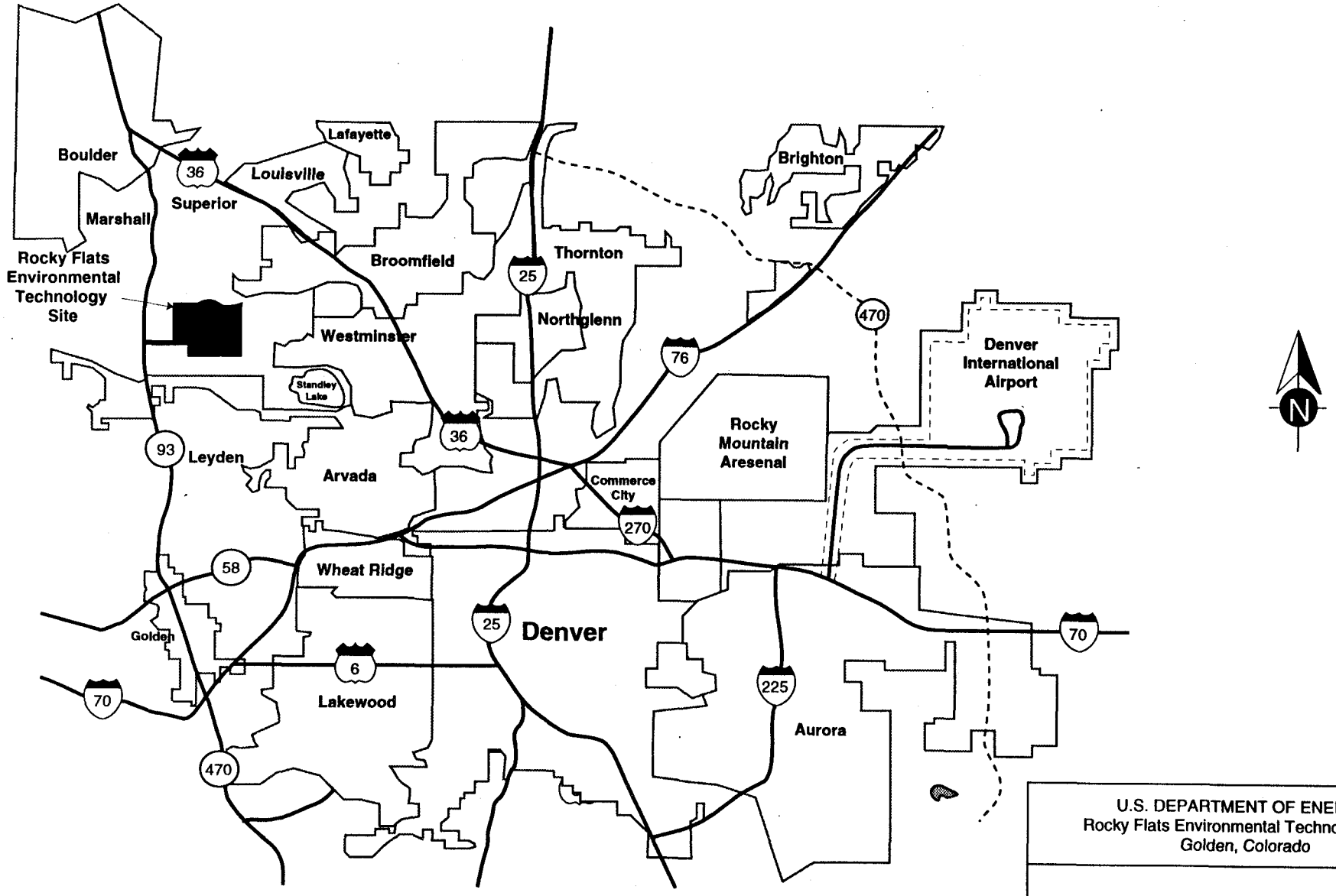
The presumptive remedy limits the alternatives that require detailed analysis to the components listed above. Characterization of the waste material within the landfill is not necessary for selecting a response

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 generally addressed separately. However, a response action for potentially affected media and exposure pathways outside the source area will be selected along with the presumptive remedy to develop a comprehensive response. DOE, EPA, and CDPHE have agreed that the East Landfill Pond will be removed and the dam and pond sediments will be removed and consolidated in the landfill under the cap. The pond will be removed to eliminate potential flood hazards and long-term operation and maintenance costs. The sediments will be removed and consolidated to eliminate potential ecological risks. For OU 7, therefore, the remaining potentially affected media include the following:

- 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.



Map not to scale

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Location of the Rocky Flats Environmental Technology Site

IM/IRA DD and Closure Plan	Operable Unit No. 7
March 1996	Figure 1-1

G95\ES\IM/IRA DD OU 7\Community Samples.ill

G95\ES\Caption Pgs OU7 2510 drw

Figure 1-3
Present Landfill and Eas[illegible]andfill Pond (June 1991)

2.0 SITE CHARACTERISTICS

Sections 2.1 through 2.5 describe the physical characteristics and operational history of OU 7, geology, surface-water and groundwater hydrology, ecology, and nature and extent of contamination. Much of the information in these sections is taken from the OU 7 Final Work Plan (DOE 1994a).

2.1 DESCRIPTION AND OPERATIONAL HISTORY OF OU 7

OU 7 lies north of the industrial area on the western end of No Name Gulch. IHSSs and historical interim response actions are shown in Figure 2-1. OU 7 originally included the Present Landfill (IHSS 114), Inactive Hazardous Waste Storage Area (IHSS 203), and asbestos-disposal areas. In 1991, the boundary of OU 7 was modified to include the East Landfill Pond and adjacent spray evaporation areas (IHSSs 167.2 and 167.3) previously included in OU 6. The locations of these IHSSs were changed based on historical research, including a review of files and photographs from the Rocky Flats repository and employee interviews conducted for the historical release report (DOE 1992a). After the locations were changed, the IHSSs were transferred from OU 6 to OU 7.

Several other OU 6 IHSSs are also located within the No Name Gulch drainage area, including trenches A, B, and C (IHSSs 166.1, 166.2, and 166.3, respectively) and a spray evaporation area (IHSS 167.1). In addition, a surface-water diversion system, groundwater-intercept system, and leachate-collection trench, which are historical interim actions, lie within OU 7. Historical data used to describe OU 7 were compiled from previous landfill investigations (Rockwell International 1988a, 1988b, 1988c; DOE 1991b), the historical release report (DOE 1992a), and the Phase I RFI/RI field investigation (DOE 1994a).

2.1.1 Present Landfill (IHSS 114)

Operation of the Present Landfill began on August 14, 1968, and is expected to continue until the new landfill opens in 1997. A portion of the natural drainage at the headwaters of No Name Gulch was filled with soils from an onsite borrow area to a thickness of approximately 5 ft to construct a surface on which to start landfilling. Waste delivered to the landfill was spread across the work area, compacted, and covered with soil (DOE 1994a).

In 1986 and 1987, studies were conducted to identify waste streams generated at the plant under the Waste Stream Identification and Characterization (WSIC) program. Of the 338 identified waste streams disposed in the landfill, 97 contained hazardous waste or hazardous constituents. However, existing records of the hazardous waste disposed do not include waste codes. As of November 1986, waste streams identified as hazardous were no longer disposed in the landfill. In 1989, waste streams were further characterized under the Waste Stream Residue Identification and Characterization (WSRIC) program. Of the 183 identified waste streams disposed in the landfill since 1989, none are hazardous (DOE 1994a).

Nonhazardous waste streams disposed in the landfill include office trash, paper, rags, personal protective equipment, demolition materials, construction debris, scrap metal, empty flattened drums and containers, used filters, electrical components, dried sanitary-sewage sludge, and solid sump sludge. These sludges may have been radioactively contaminated (plutonium and depleted uranium). Hazardous waste streams disposed in the landfill include containers partially filled with paint, solvents, degreasing agents, and foam polymers; wipes and rags contaminated with these materials; paint and oil filters; and metal cuttings and shavings coated with hydraulic oil and carbon tetrachloride (DOE 1994a). Waste codes were not

assigned to these waste streams. The landfill was also the site of asbestos disposal. Polychlorinated biphenyls (PCBs) were stored at IHSS 203.

The landfill covers an area of approximately 20 acres. Waste material is generally thinnest along the boundaries and thickest along the east-west axis of the landfill. The thickness of waste material ranges from less than 1 ft to approximately 40 ft near the east face of the landfill, which coincides with the deepest portion of the original drainage. Waste material has not been placed beyond the clay barrier in the groundwater-intercept system or beyond the existing slurry walls (DOE 1994a).

Five gas vents are present within the operating landfill (see Figure 2-1). These vents are constructed of polyvinyl chloride (PVC) casing and project approximately 5 ft above the ground surface. The vents were installed in June 1992 to release landfill gases generated by microbial degradation of organic waste. The composition, quantity, and generation rates of the gases depend on factors such as waste quantity and composition, waste placement characteristics, landfill thickness, moisture content, and amount of oxygen present. Carbon dioxide is the principal gas generated during early stages of waste burial, as the waste undergoes aerobic microbial degradation. As oxygen is depleted, anaerobic microbial degradation produces methane and carbon dioxide.

Leachate from landfills is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through waste (EPA 1991a). Leachate has been forming since the landfill opened in 1968. Infiltration/percolation at the ground surface and inflow of groundwater are the primary sources of water to the landfill. The volume of leachate within the landfill is expected to vary as the potentiometric surface fluctuates in response to infiltration/percolation of precipitation through the interim soil cover. The volume is expected to decrease after the landfill cap is in place. The depth to leachate within the landfill is approximately 20 ft at the western end, 16 ft in the middle, and 33 ft at the eastern end. Leachate historically discharges as a seep at the base of the east face of the landfill (SW097) (see Figure 2-1). A temporary seep interception and treatment system was constructed in late 1995 and early 1996 and will operate until landfill closure.

2.1.2 Inactive Hazardous Waste Storage Area (IHSS 203)

The Inactive Hazardous Waste Storage Area is located at the southwest corner of the Present Landfill (see Figure 2-1). The area was actively used in 1986 and 1987 as a hazardous-waste storage area for both drummed liquids and solids. Fifty-five-gallon drums containing liquids were stored in cargo containers; drums containing solids were stored outside cargo containers on the ground. RCRA-listed wastes were stored in some of the cargo containers and included solvents, coolants, machining wastes, cuttings, lubricating oils, organics, and acids. PCB-contaminated soil, debris, and transformer oil were stored in the other cargo containers. All drums and cargo containers were removed in May 1987. Hazardous materials are no longer stored at IHSS 203 (DOE 1994a).

Soil-gas sampling and surface-soil sampling were conducted at IHSS 203 during the Phase I RFI/RI. Soil-gas samples were collected at 35 locations at approximately 5 ft below ground surface and analyzed for volatile organic compounds (VOCs) (Appendix C, DOE 1994a). Concentrations of VOCs in soil gas varied significantly within the sampling area, and distinct sources that could be confidently interpreted as contamination associated with spills or releases during waste storage activities were not identified. Because landfill wastes underlie IHSS 203, VOCs in soil gas in this area are probably associated with the landfill (DOE 1994a).

Surface-soil samples were collected at 49 locations from the 0- to 2-in. soil horizon and at 18 locations from the 0- to 10-in. soil horizon. Samples were analyzed for PCBs, metals, and radionuclides. Two PCBs (Aroclor-1254 and Aroclor-1260) were detected at low concentrations in approximately 20 percent of the soil samples but are not present at depth. All but one of the results for the analysis of PCBs in soil from IHSS 203 were "J" qualified, denoting estimated PCB concentrations below the detection limit of 230 micrograms per kilogram (mg/kg). Metals and radionuclides were generally detected at concentrations or activities less than the maximum background concentration or activity (DOE 1994a).

2.1.3 Asbestos-Disposal Areas

Beginning in 1985, asbestos generated onsite was reportedly disposed in a designated 10-ft-deep pit located east of the landfill. The material containing asbestos was placed in heavy plastic bags, disposed in the pit, and covered with soil when the pit became full. By December 1988, asbestos was disposed in several pits within the asbestos disposal areas (see Figure 2-1). Records indicate that disposal of asbestos continued until April 1990 (DOE 1994a).

Asbestos-disposal areas are presently delineated with warning signs. Bags of friable asbestos were disposed in the northern trench, and it is reported that some of the bags burst during disposal (Blaha 1994). Waste material is disposed in the southern trench; however, it is unclear whether asbestos was also disposed in the southern trench (Blaha 1994). Aerial photographs show that waste material was buried in the vicinity of the asbestos-disposal pits; this area is included in the waste-volume calculations. During the Phase I RFI/RI, two soil samples from the asbestos-disposal pits were collected and analyzed for asbestos (DOE 1994a). A trace (less than 1 percent) of chrysotile asbestos was detected in the surface soil (DOE 1994a). No intrusive work was performed in these areas, and the ground surface appears to be undisturbed.

2.1.4 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 (see 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 x 460 ft for IHSS 167.2 and 120 x 440 ft 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.

2.1.5 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 (see 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). Surface soils and subsurface geologic materials were sampled during the Phase I RFI/RI and no contamination was found. DOE proposed no further action (NFA) for soils in the OU 6 trenches (DOE 1994c).

2.1.6 Historical Interim Response Actions

In 1973, tritium and strontium were detected in leachate draining from the landfill. Interim response actions were undertaken to control the generation and migration of landfill leachate (DOE 1994a). These actions included construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill, a subsurface groundwater-intercept system for diverting groundwater around the landfill, and a subsurface leachate-collection trench (see Figure 2-1). The trench for the leachate collection and groundwater intercept systems varies in depth from 10 to 20 ft. Construction began in October 1974 and was completed in January 1975.

A surface-water diversion ditch was constructed around the perimeter of the landfill in October 1974 to divert surface-water runoff around the landfill and reduce the infiltration of surface water into the landfill, thereby reducing the volume of leachate draining from the landfill (see Figure 2-1). No waste disposal is known to have occurred outside of the surface-water diversion ditch.

As part of the original interim response action, two detention ponds were constructed in 1974 to control leachate generated by the landfill (DOE 1994a). These ponds were formed by constructing temporary berms across the drainage immediately downstream of the landfill. The West Landfill Pond impounded leachate generated by the landfill. The East Landfill Pond provided a backup system for overflow from the West Landfill Pond and was also used to collect intercepted groundwater as needed (DOE 1992a).

A more permanent embankment was eventually constructed for the East Landfill Pond. The new embankment was an engineered dam structure with a spillway. A low-permeability clay core keyed into bedrock was constructed within the embankment to reduce seepage from the pond (DOE 1994a).

A groundwater-intercept system was installed around the perimeter of the landfill in 1974 as an interim response action to divert groundwater around the landfill and thus control generation and migration of leachate (see 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 (see 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 ft from the points of intersection (see Figure 2-1). Based on as-built drawings, the slurry walls vary in depth from 10 to 20 ft. 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 ft of the leachate-collection system trench along the northwest side and 400 ft 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.

2.2 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); the Phase I RFI/RI field investigation (DOE 1994a); and 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 supplemental 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 Epoch. 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 ft of gently dipping (less than 2 degrees) Pennsylvanian- to Upper Cretaceous-aged 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 the pediment at approximately 6,000 ft. 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 ft below the ground surface, 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-aged alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, alluvial deposits of the valley-fill alluvium, and artificial fill (see Figure 2-4). All surficial deposits are part of the upper hydrostratigraphic unit (UHSU) at Rocky Flats, which is described 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. The Rocky Flats Alluvium is 25- to 30-ft thick on the northwest, west, and southwest sides of the landfill and 10- to 15-ft thick 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 clast size recovered during drilling ranges from 1 to 3 in. 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-ft 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 ft.

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-ft 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 ft. 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-aged Arapahoe and Laramie Formations (see 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 (EG&G 1992a). The lowermost 20 ft 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, 1995a). However, sandstones exhibiting the distinctive characteristics of the basal Arapahoe Formation or No. 1 sandstone (see 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 downgradient of the landfill, the elevation of the bedrock is low enough that the bedrock is likely Laramie Formation.

The Laramie Formation is approximately 600 to 800 ft-thick. The lower 300 ft is composed of laterally extensive sandstones, kaolinitic claystones, and coal beds. The upper 300 to 500 ft 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 (see Figure 2-3) (EG&G 1992a, 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 pathways for migration of contaminants (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 frequently interbedded with siltstones. These "coarser-grained" units vary from 10- to 30-ft 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. The colluvium consists of clays and silts. The valley-fill alluvium is composed of gravelly, clayey sand. Geologic units on the groundwater divides adjacent to the landfill consist of Rocky Flats Alluvium, underlain by the undifferentiated Arapahoe and Laramie Formations. The Rocky Flats Alluvium consists of clayey gravels and sands. Lithologies of the undifferentiated Arapahoe and Laramie Formations are typically limited to claystones and siltstones.

Fine-grained sandstones subcrop beneath the alluvium only at well location B207089 (31 ft), which is downgradient of the dam. This sandstone pinches out approximately 500 ft downstream and is not present at well 4287. Shallow sandstones (present within 15 ft of the contact between alluvium and bedrock) were encountered in wells 6487 (25 ft), located within the landfill on the south side, and B206789 (8 ft), 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. Laramie Formation sandstones (sometimes referred to as the No. 2 through No. 5 sandstones) were identified in well 0886 (at a depth of 59 ft), located near the East Landfill Pond; well 6487 (25 ft), located within the landfill; and wells 4187 (81 ft), B207089 (31 ft), B207189 (70 ft), and 53094 (60 ft), located in No Name Gulch downgradient of the dam. Laramie Formation sandstones were also identified in wells 0986, 70293, 70593, and 70893 at depths of 50 to 125 ft 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 (see Figure 2-4). The fault plane dips to the west. Displacement along the fault is reported to be 25 to 50 ft, 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 (see 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 runoff 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 ft thick and consists of clay, silt, and organic matter. The upper 0.2 to 0.5 ft 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 ft 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, 1994a, 1995b; DOE 1992b, 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 runoff, and engineered water transfers.

- Interactions between surface-water flow and groundwater flow include infiltration/percolation, interflow, historical 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 runoff, 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 the surface-water hydrology shown in the conceptual model (see Figure 2-5) are described below.

Surface-Water Features

A surface-water diversion ditch was constructed around the perimeter of the landfill in 1974 to divert surface-water runoff around the landfill and reduce the infiltration of surface water into the landfill, thereby reducing the volume of leachate discharging as seep flow (see 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 ft deep and 5 ft 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 (see 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 spring 1995.

The pond water volume fluctuates seasonally but averages approximately 6,000,000 gallons (DOE 1994a). Recharge to the pond occurs from groundwater baseflow in surficial materials, leachate from the seep, and surface-water runoff 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.

Components of the Conceptual Flow Model

Surface-water hydrology components include precipitation, evapotranspiration, pond evaporation, surface-water runoff, 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 in. (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 in. in December and January to 7 in. in September (DOE 1994a). Total annual pan evaporation for the Rocky Flats area is approximately 65 in. 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 runoff, infiltration, or interflow.

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

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, historical 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, it is assumed that infiltrating water 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 in.). This value is consistent with previous groundwater numerical modeling efforts performed at RFETS (EG&G 1995e; DOE 1995k).

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 historically discharged from the seep located at the base of the east face of the landfill (see 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 originated from the original stream channel in No Name Gulch that was filled in during construction and subsequent waste disposal in the landfill. The seep was 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 area. As stated above, interflow is potentially a major source of the variability of the historical 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 runoff 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 (see 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 historically flowed 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 (see 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 ft 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 (see Figure 2-7) (Appendix C). 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.

Groundwater Flow in the UHSU

The UHSU, which corresponds to the uppermost water-bearing unit 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.

Based on physical properties, groundwater flow in surficial materials is understood 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 ft/day; (2) for artificial fill, the geometric mean is 6.7E-05 cm/sec or 0.19 ft/day; and (3) for all surficial materials combined, the geometric mean is 1.3E-04 cm/sec or 0.36 ft/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 ft/day. The geometric mean of measured hydraulic conductivities in unweathered bedrock is 6.4E-07 cm/sec or 0.0018 ft/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 runoff, and downward seepage from the East Landfill Pond. Discharge occurs through evapotranspiration and surface seepage where the water table intersects the ground 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 ft in No Name Gulch. Groundwater flows to the east within the valley-fill alluvium; however, flow is ephemeral. 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 ft at the western end, 16 ft in the middle, and 33 ft 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 ft.

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 ft 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 historically discharged 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 (i.e., 70093/70193, which is upgradient of the landfill), the potentiometric surfaces for surficial materials and weathered bedrock are almost identical and move together seasonally. For other well clusters (i.e., 70393/70493 and 4087/B206989), head differences in excess of 20 ft 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 Formation sandstone unit (No. 1 sandstone), which can be a significant water-bearing unit, is also absent.

Preferential flow through weathered bedrock fractures or zones of greater hydraulic conductivity can be greater than flow through the weathered bedrock matrix. These zones of greater 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 (see 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 unlikely that the fault serves 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).

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, 1995a).

Hydraulic conductivities in these siltstones and sandstones are very small. 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 (see 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 small 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.

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 40 percent of the inflow is groundwater from the alluvium and 60 percent is recharge by infiltration of precipitation. The water balance is a comparison of modeled inflows and infiltration to modeled outflows. Most of the groundwater inflow occurs on the north side of the landfill. Contributions from the west side (less than 1 percent) and the south side (less than 1 percent) are relatively insignificant. The water balance for the landfill mass is presented in Appendix C.

2.3.6 No Name Gulch

Less information on surface-water hydrology, interactions between surface water and groundwater, and groundwater hydrology is available for the No Name Gulch drainage downgradient of the landfill than for the landfill area itself. It appears that No Name Gulch is a losing stream year-round. There are four surface-water stations downgradient of the landfill. No flow information is available for these stations in the Rocky Flats Environmental Database System (RFEDS), and field personnel confirm no observable surface-water flow in the No Name Gulch drainage during storm events (Berzins 1995).

Based on a detailed study of groundwater and surface-water interactions in Woman Creek (a similar drainage system), the only reaches of the stream where groundwater recharged surface water either year-round or seasonally are located in the western portion of the buffer zone adjacent to large gravel-capped pediments containing substantial subsurface flows. A few isolated gaining reaches are fed by localized seeps. No Name Gulch is located adjacent to the distal ends of the gravel-capped pediment surfaces. Gravels are fairly thin in this area and do not contain substantial subsurface flows. In addition, no seeps flow into No Name Gulch below the existing pond (Berzins 1995).

Two fully dynamic surface-water flow models (including the EPA model Hydrologic Simulation Program Fortran) have been developed for the Walnut Creek and Woman Creek basins. In some of the pervious land segments of these models, subsurface and/or surface seep flow time series were required to be added to pervious land segments to calibrate stream hydrographs. Addition of water to a basin indicates that there is substantial interaction between groundwater and surface water along this reach of the stream. No external flow time series were required to be added to the pervious land segment containing No Name Gulch (Berzins 1995). By inference, this tends to support the conclusion that No Name Gulch is a losing stream.

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 1995c). Additional ecological information is presented in the discussion of the screening-level ecological risk assessment in Chapter 3.

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 annual grasses and forbs (see Figure 2-11).

A large section of OU 7 is disturbed land due to continuous earth moving at the landfill (see Figure 2-11). Plants have little opportunity to germinate, grow, or establish in the bare soil areas. In portions of the IHSS 114 area, most of the original topsoil has been lost through wind and water erosion or buried in the landfill. Annual (weedy) grass and forb communities have become established on other disturbed areas within and beyond IHSS 114. These disturbed sections offer little in terms of wildlife cover and tend to be low in plant species diversity.

Mesic and xeric mixed grasslands are the most prevalent native habitat types at OU 7. The mesic mixed grasslands occur on hillsides and valley floors and the xeric mixed grasslands occur on the pediment (broad flat uplands) and ridge tops (see Figure 2-11). Differences in slope, aspect, soil type, soil moisture, and land-use history determine the difference in dominant grasses and forbs that characterize these two grassland types that are common on the site.

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. 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 the dominant grasses such as big bluestem, blue grama, 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.

Tall and short marsh occur in the area around the East Landfill Pond (see 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 short marsh type occurs in the spray evaporation areas north and south of the pond where intermittent spraying 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).

2.4.2 Wildlife

Much of OU 7 is either bare soil or recently disturbed due to landfill activities and provides little, if any, usable habitat for terrestrial wildlife. Weedy areas west of the active landfill provide an abundant source of seeds, probably support deer mice populations, and may be used by granivorous songbirds. However, these areas include relatively few plant species and are structurally homogenous. The remaining areas

east of the landfill include grasslands and wetland habitat in and around the pond. (See Section 2.4.3 for wetland description.) Wildlife use of this area is probably typical of species in the Rocky Flats buffer zone. Small mammals and other relatively immobile species may be resident in some portions, but larger or more mobile species probably spend only part of their time there. Wildlife species typical of the buffer zone are briefly described below.

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 (i.e., rodents) present are the thirteen-lined ground squirrel, northern pocket goper, hispid pocket mouse, silky pocket mouse, plains harvest mouse, western harvest mouse, deer mosue, Mexican woodrate, house mouse, prairie vole, meadow vole, and Preble's meadow jumping mouse (EG&G 1995c, DOE 19951). Other nonrodent small mammals include merriam's shrew nd water sdrew (DOE 1992e)

Common grassland birds at Rocky Flats include the vesper sparrow, western meadow lark, horned lark, grasshopper sparrow, and mourning dove. Marshland areas support red-winged blackbird, common yellowthroat, song sparrow, American tree sparrow, and common snipe. In addition, open water areas attract waterfowl and shorebirds. Common birds of prey include the northern harrier, red-tailed hawk, Swainson's hawk, American kestrel, and great horned owl. Occasionally, the bald eagle, rough-legged hawk, golden eagle, prairie falcon, long-eared owls and short-eared owls are observed (EG&G 1995c).

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. Eastern short-horned lizards and Western Painted turtles are also present at Rocky Flats (DOE 1992e and EG&G 1995c).

Aquatic life in the East Landfill Pond includes a relatively diverse benthic macroinvertebrate community including insects, oligochaetes, crustaceans, and molluscs. The benthic community composition suggests that chemicals in sediments may limit the aquatic community to some extent. Species collected in benthic samples include a large number that are at least moderately tolerant of chemical contamination and few sensitive species. The pond also apparently does not support fish; no fish have been collected despite extensive sampling efforts using a variety of techniques.

2.4.3 Sensitive Habitats and Endangered Species

Wetland and deep water habitats have been mapped and described at OU 7 (see Figure 2-12) (COE 1994). Wetlands were delineated according to the 1987 COE Wetland Delineation Manual and characterized using the U.S. Fish and Wildlife Service (USFWS) wetland classification method (Cowardin et al. 1979) by the U.S. Army Corps of Engineers during field surveys conducted in Fall 1993. Historically constant water levels in the pond have resulted in a well-established, vegetated littoral zone at the north, south, and west pond margins.

Palustrine emergent wetlands occupy an area of 0.67 acres around the pond margin and are subject to fluctuations of pond water level. Palustrine emergent wetlands occupy 0.13 acres in the adjacent spray evaporation area on the south side of the pond. Herbaceous species found around the pond margin include common and narrow-leaved cattails, winter cress, torrey's rush, and Canada thistle. Associated substrate and soils are generally saturated within the upper 12 in. of the profile. Species found in the

spray evaporation area include Canada thistle, baltic rush, torrey's rush, and Canada bluegrass. Associated substrate and soils are moist at the surface but not at depth.

Lacustrine unconsolidated bed deep water habitat occupies an area of 2.26 acres at the bottom of the East Landfill Pond. Unconsolidated bed deep water habitat is either barren or supports sparse levels of drawdown vegetation such as algae, needle spikesedge, or barnyard grass.

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.

Slopes around the East Landfill Pond have been identified as potential Preble's meadow jumping mouse habitat (see Figure 2-12) (DOE 1995b). The Preble's meadow jumping mouse, a subspecies of the meadow jumping mouse, is classified as a nongame species by the State of Colorado and a C-2 candidate species by the USFWS. The Colorado statute protects nongame species from take (i.e., hunting) and possession. In 1994 the USFWS received a petition to list the mouse as threatened or endangered pursuant to the Endangered Species Act. No formal decision on listing the species has been made. Although the mouse has not yet attained protected status under federal law, it may become a protected species in the near future. Current DOE Rocky Flats Field Office (RFFO) policy is to protect the mouse as if it were endangered.

Two federally listed endangered species occur at Rocky Flats and may enter OU 7 on a casual basis: the peregrine falcon and the bald eagle (EG&G 1995c). Federal C-2 candidate species that occur at Rocky Flats include the eastern short-horned lizard, northern goshawk, western burrowing owl, ferruginous hawk, black swift, loggerhead shrike, Preble's meadow jumping mouse, and small-footed myotis (RMRS 1995b). None of these species have been documented in OU 7, though suitable habitat exists for the Preble's meadow jumping mouse and eastern short-horned lizard. Colorado species of special concern occurring at Rocky Flats include the long-billed curlew, greater sandhill crane, and American white pelican. None of these species has been observed at OU 7 (EG&G 1995c).

2.5 NATURE AND EXTENT OF CONTAMINATION

The RI/FS and 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 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 for each analyte for each sample location (for every medium) to the upper tolerance limit of the 99th percentile at the 99-percent confidence level (UTL99/99) for background samples. Results were presented for all media using 1990–1994 data in the OU 7 Final Work Plan (DOE 1994a). Because data validation procedures were not implemented until 1991, results presented in this report use 1991–1995 data.

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 potential contaminants of concern (PCOCs). Organic compounds were considered PCOCs if detected in samples from OU 7.

For this report, OU 7 data were aggregated into 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, and groundwater downgradient of the landfill.

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 (1991); four months from Phase I RFI/RI (1992–1993) (EPA Level IV and V)

- Surface water in the East Landfill Pond (SW098) – monthly data (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 in., one event from Phase I RFI/RI (1993); 12 samples from 0 to 2 in., 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 – quarterly data (1991–1995), four months from Phase I RFI/RI wells (1992–1993), four months from 1994 wells, (1994–1995) (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 for 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 in. (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 nonmethane 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. Because 1990 data were never validated, only 1991 data from this program were used. Screening-level data were collected from 16 locations; 26 samples were collected. Methane concentrations in leachate 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 in leachate at OU 7 are consistent with methane concentrations of 25 mg/L observed at other landfills (Baedecker 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. The PCOCs identified and their associated concentration ranges, detection limits, detection frequencies, and qualifiers 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 further review certain analytes after the statistical comparisons were completed (see Table 2-2). Two criteria were used in the professional independent review of analytes: (1) the analytes calcium, iron, magnesium, potassium, and sodium were not considered contaminants because they are essential nutrients (EPA 1989a), and (2) the analytes silicon, bicarbonate as $CaCO_3$, carbonate as $CaCO_3$, carbonate, fluoride, orthophosphate, total dissolved solids, total organic carbon, dissolved organic carbon, gross alpha, and gross beta were not considered contaminants.

The following analytes are identified as PCOCs for leachate at the seep (mean concentrations):

- Metals – barium (540 µg/L), lithium (40 µg/L), manganese (1,400 µg/L), and strontium (890 µg/L)
- Radionuclides – strontium-89/90 (1.4 picocuries per liter [pCi/L]) and tritium (430 pCi/L)
- SVOCs – 2,4-dimethylphenol (3 µg/L), 2-methylnaphthalene (16 µg/L), 4-methyphenol (4µg/L), acenaphthene (3 µg/L), bis(2-ethylhexyl)phthalate (2 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 (7 µg/L), 1,2-dichloroethene (3 µg/L), 2-butanone (5 µg/L), acetone (11 µg/L), benzene (2 µg/L), chloroethane (30 µg/L), chloromethane (5 µg/L), ethylbenzene (13 µg/L), methylene chloride (5 µg/L), toluene (26 µg/L), total xylene (15 µg/L), trichloroethene (2 µg/L), and vinyl chloride (6 µg/L)
- Indicator parameters – chloride (57,000 µg/L) and 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. Because 1990 data were never validated, only 1991 data from this program were used. Surface-water samples were collected from station SW098, located in the central east section of the pond adjacent to the dam (see Figure 2-13). Background comparisons were performed to identify PCOCs using the Gilbert methodology (EG&G 1994b). Metals and radionuclides were detected at concentrations or activities above background. VOCs and SVOCs were detected; however, none of the VOCs or SVOCs were detected frequently. The PCOCs identified and their associated concentration ranges, detection limits, detection frequencies, and qualifiers are presented in Table 2-3. Additional information is presented in the OU 7 Final Work Plan (DOE 1994a).

Professional judgment was used to further review certain analytes after the statistical comparisons were completed (see Table 2-3). Again, two criteria were used in the professional review of analytes: (1) the analytes calcium, iron, magnesium, potassium, and sodium were not considered contaminants because they are essential nutrients (EPA 1989a), and (2) the analytes silicon, bicarbonate as $CaCO_3$, carbonate as $CaCO_3$, carbonate, fluoride, orthophosphate, total dissolved solids, total organic carbon, dissolved organic carbon, gross alpha, gross beta were not considered contaminants.

The following analytes are identified as PCOCs for surface water in the East Landfill Pond (mean concentrations):

- Metals – barium (170 µg/L), lithium (77 µg/L), manganese (100 µg/L), molybdenum (6 µg/L), nickel (8 µg/L), and strontium (460 µg/L)
- Radionuclides – americium-241 (0.007 pCi/L), strontium-89/90 (1.4 pCi/L), tritium (160 pCi/L), uranium-233/234 (1.1 pCi/L), uranium-235 (0.2 pCi/L), and uranium-238 (1.2 pCi/L)
- SVOCs – bis(2-ethylhexyl)phthalate (1 µg/L) and di-n-butyl phthalate (1 µg/L)
- VOCs – methylene chloride (3 µg/L)
- Indicator parameters – chloride (160,000 µg/L)

2.5.5 Sediments in the East Landfill Pond

Sediment samples were collected at three locations in the pond. Samples were analyzed for VOCs, SVOCs, radionuclides, metals, and inorganics (see Figure 2-13). None of the radionuclides exceeded background UTL99/99 values, and the only metal identified as a PCOC was zinc. Three VOCs and several SVOCs were detected in pond sediments. All SVOC results are estimated values below the quantitation limit ("J" qualified); however, they are still included on the PCOC list. The PCOCs identified and their associated concentration ranges, detection limits, detection frequencies, and qualifiers are presented in Table 2-4. Additional information is presented in the OU 7 Final Work Plan (DOE 1994a).

The following analytes are identified as PCOCs for sediments in the pond (mean concentrations):

- Metals – zinc (110 mg/kg)
- SVOCs – acenaphthene (220 µg/kg), anthracene (240 µg/kg), benzo(a)anthracene (300 µg/kg), benzo(a)pyrene (290 µg/kg), benzo(b)fluoranthene (340 µg/kg), benzo(ghi)perylene (250 µg/kg), benzo(k)fluoranthene (230 µg/kg), benzoic acid (540 µg/kg), bis(2-chloroisopropyl)ether (260 µg/kg), bis(2-ethylhexyl)phthalate (210 µg/kg), chrysene (29 µg/kg), fluoranthene (420 µg/kg), fluorene (250 µg/kg), indeno(1,2,3-cd)pyrene (250 µg/kg), phenanthrene (350 µg/kg), and pyrene (390 µg/kg)
- VOCs – 2-butanone (17 µg/kg), acetone (68 µg/kg), and toluene (310 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 (see Figure 2-14). Soil samples were collected at 133 locations from the 0- to 2-in. soil horizon during the Phase I RFI/RI (DOE 1994a) and 12 locations from the 0- to 2-in. soil horizon during the supplemental Phase I field investigation. All samples were analyzed for metals, radionuclides, and indicator parameters.

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. The PCOCs identified and their associated concentration ranges, detection limits, detection frequencies, and qualifiers are presented in Table 2-5. 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 further review certain analytes after the statistical comparisons were completed. Calcium, iron, magnesium, potassium, and sodium were not considered 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 (mean concentrations):

- Metals – antimony (4 mg/kg), barium (190 mg/kg), copper (19 mg/kg), lead (26 mg/kg), mercury (0.1 mg/kg), selenium (1 mg/kg), silver (1 mg/kg), strontium (53 mg/kg), thallium (0.2 mg/kg), vanadium (31 mg/kg), and zinc (56 mg/kg)

- Radionuclides – americium-241 (0.03 pCi/g); plutonium-239/240 (0.06 pCi/g); and radium-226 (1 pCi/g)

- Indicator parameters – nitrate/nitrite (5 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) (see Figure 2-15). Samples were collected at 2-ft increments in colluvium and 4-ft 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. The PCOCs identified and their associated concentration ranges, detection limits, detection frequencies, and qualifiers are presented in Table 2-6. Additional information is presented in the OU 7 Final Work Plan (DOE 1994a).

Calcium, magnesium, potassium, and sodium in colluvium and weathered bedrock are not considered PCOCs because they are essential nutrients (EPA 1989a). All SVOC results are estimated values below the quantitation limit ("J" qualified); however, they are still included on the PCOC list.

The following analytes are identified as PCOCs for subsurface geologic material in colluvium downgradient of the landfill (mean concentrations):

- Metals – barium (230 mg/kg)
- Radionuclides – cesium-137 (0.58 pCi/g)
- SVOCs – chrysene (180 µg/kg), fluoranthene (190 µg/kg), phenanthrene (190 µg/kg), and pyrene (190 µg/kg)
- VOCs – 4-methyl-2-pentanone (17 µg/kg), toluene (850 µg/kg), and total xylenes (3 µg/kg)
- Indicator parameters – nitrate/nitrite (4,000 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 (280 mg/kg), strontium (97 mg/kg), and zinc (70 mg/kg)
- VOCs – 1,1,1-trichloroethane (2 µg/kg) and toluene (310 µg/kg)

2.5.8 Groundwater Downgradient of the Landfill

Nine existing wells are screened across surficial material or weathered bedrock: three near the East Landfill Pond and six downgradient of the dam (see Figure 2-15). 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 1991 to 1995 were used in this report. Appendix B lists the well locations, geologic formation the well is screened across, hydrostratigraphic unit, and date the well was installed.

Background comparisons for inorganic analytes and radionuclides were performed to identify PCOCs using the Gilbert methodology (EG&G 1994b). The results of the statistical tests for groundwater downgradient of the dam are presented in Table 2-7. 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 further review certain analytes after the statistical comparisons. Two criteria were used in reviewing analytes: (1) the analytes calcium, magnesium, potassium, and sodium

were not considered contaminants because they are essential nutrients (EPA 1989a), and (2) the analytes silicon, bicarbonate as $CaCO_3$, carbonate as $CaCO_3$, carbonate, fluoride, orthophosphate, total dissolved solids, total organic carbon, dissolved organic carbon, gross alpha, and gross beta were not considered contaminants.

The following are identified as PCOCs for the UHSU groundwater downgradient of the landfill (mean concentrations):

- Metals – antimony (17 µg/L), lead (4 µg/L), lithium (150 µg/L), selenium (230 µg/L), silver (2 µg/L), and strontium (1,200 µg/L)
- Radionuclides – strontium 89/90 (-0.07 pCi/L)
- SVOCs – bis(2-ethylhexyl)phthalate (3 µg/L)
- VOCs – 1,1-dichloroethane (2 µg/L), 2-butanone (9 µg/L), benzene (2 µg/L), carbon tetrachloride (2 µg/L), chloroethane (4 µg/L), ethylbenzene (2 µg/L), methylene chloride (2 µg/L), tetrachloroethane (2 µg/L), total xylenes (3 µg/L), and trichloroethane (2 µg/L)
- Indicator parameters – chloride (230,000 µg/L), nitrate/nitrite (25,000 µg/L), and sulfate (880,000 µg/L)

Background comparisons for inorganic analytes and radionuclides were performed for LHSU groundwater to determine PCOCs. The results of the statistical tests for LHSU wells downgradient of the landfill are presented in Table 2-8. Calcium, magnesium, potassium, and sodium were not considered PCOCs because they are essential nutrients (EPA 1989a). The PCOCs remaining for LHSU groundwater downgradient of the landfill are barium (300 µg/L), lithium (87 µg/L), manganese (200 µg/L), molybdenum (17 µg/L), strontium (1,200 µg/L), acetone (8 µg/L), methylene chloride (3 µg/L), total xylenes (2 µg/L), bis(2-ethylhexyl)phthalate (4 µg/L), and butylbenzylphthalate (4 µg/L). Given the hydrology of the unweathered bedrock (see Section 2.3.4), 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 (ft)	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

Note:

ASTM American Society for Testing and Materials
USCS Unified Soil Classification System
PI Plasticity index

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 $UTL_{95/95}$ Concentration	Units	PCOC
Metals										
Aluminum	10 - 200	8/9	29	3,800	—	V	6,500	180,000	µg/L	
Antimony	0.05 - 60	1/9	14	15	—	V	12	39,000	µg/L	
Arsenic	0.7 - 10	3/7	1.4	2.3	—	JA	1	4,700	µg/L	
Barium	0.02 - 200	9/9	530	700	—	V	5,930	93,000	µg/L	2
Beryllium	0.2 - 5	2/9	0.5	1.4	—	JA	1	3,000	µg/L	
Calcium	14.5 - 5,000	9/9	126,000	150,000	—	V	140,000	510,000	µg/L	2,3
Chromium	2.4 - 27.5	3/9	2.0	13	—	JA	6	5,000	µg/L	
Cobalt	2.6 - 50	6/9	3.6	9.4	—	JA	5	32,000	µg/L	
Copper	2.4 - 25	4/9	2.0	6.6	—	JA	4	12,000	µg/L	
Iron	4.7 - 100	9/9	70,000	120,000	—	V	86,000	1,900,000	µg/L	2,3
Lead	0.8 - 20	8/8	1.6	11	—	V	5	2,000	µg/L	
Lithium	2 - 100	9/9	34	46	—	V	40	63,000	µg/L	2
Magnesium	0.1 - 5,000	9/9	29,000	33,000	—	V	31,000	1,200,000	µg/L	2,3
Manganese	1 - 15	9/9	1,300	1,500	—	V	1,400	19,000	µg/L	2
Molybdenum	5.7 - 200	4/9	4.0	21	—	JA	8	66,000	µg/L	
Nickel	0.02 - 40	3/9	5.0	31	—	V	11	25,000	µg/L	
Potassium	10 - 5,000	9/9	5,500	7,600	—	V	6,400	2,400,000	µg/L	2,3
Selenium	1.1 - 5	1/9	1.1	1.4	—	JA	2	3,200	µg/L	
Silver	2.6 - 25	3/9	2.7	5.1	—	JA	3,000	6,800	µg/L	
Sodium	10 - 5,000	9/9	55,000	67,100	—	V	63,000	30,000	µg/L	1,2,3
Strontium	3.5 - 200	9/9	810	980	—	V	890	480,000	µg/L	2
Tin	10 - 200	3/9	11	57	—	V	20	63,000	µg/L	
Vanadium	3.2 - 50	6/9	3.1	19	—	JA	7.6	24,000	µg/L	
Zinc	1.8 - 20	9/9	857	2,600	—	V	20	8,600	µg/L	2,5

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 $UTL_{99/95}$ Concentration	Units	PCOC
Radionuclides										
Americium-241	0 - 0.01	9/9	-0.0004	0.02	—	A	0.006	0.06	pCi/L	-
Cesium-137	0.47 - 1	6/6	0.0305	0.61	J	—	0.26	2.0	pCi/L	
Gross alpha	1.5 - 3.5	5/5	0.89	6.6	—	V	3.3	330	pCi/L	
Gross beta	2.9 - 8.7	5/5	7.2	17	—	V	12	11	pCi/L	1,2,6
Plutonium-239/240	0 - 0.013	9/9	0.001	0.016	—	A	0.007	3.00	pCi/L	
Strontium-89/90	0.21 - 1	6/6	0.66	4.1	—	V	1.4	1.6	pCi/L	1,2
Tritium	155 - 450	11/11	190	1,500	—	A	430	4.6	pCi/L	1
Uranium-233/234	0.1 - 0.3	7/7	-0.024	4.2	B	A	0.8	5.00	pCi/L	
Uranium-235	0.033 - 0.27	7/7	-0.012	0.084	J	A	0.033	0.3	pCi/L	
Uranium-238	0.086 - 0.32	7/7	0.039	3	—	A	1	5.3	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
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	2	18	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	11	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	10/11	5	10	—	V	7	—	µg/L	4
1,2-Dichloroethene	5	4/11	4	5	—	—	3		µg/L	4
2-Butanone	10	2/11	6	6	J	—	5		µg/L	4

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 $UTL_{95/95}$ Concentration	Units	PCOC
Acetone	10	3/11	10	25	—	V	11	92	µg/L	4
Benzene	5	4/11	1	2	J	—	2	—	µg/L	4
Chloroethane	10	10/11	10	57	—	V	30	6	µg/L	4
Chloromethane	10	1/11	7	7	J	A	5	—	µg/L	4
Ethylbenzene	5	10/11	5	17	—	V	13	—	µg/L	4
Methylene chloride	5	4/11	3	6	B	—	5	23	µg/L	4
Toluene	5	10/11	5	47	—	—	26	4	µg/L	4
Total xylenes	5	10/11	5	24		V	15	—	µg/L	4
Trichloroethene	5	3/11	1	2	J	—	2	—	µg/L	4
Vinyl chloride	10	2/11	8	11	—	V	6	—	µg/L	4
Indicator Parameters										
Bicarbonate as $CaCO_3$	10,000	11/11	554,000	705,000	—	V	590,000	—	µg/L	
Chloride	2,500 - 50,000	11/11	40,000	66,300	—	V	57,000	88,000	µg/L	2
Dissolved organic carbon	1,000	4/4	14,000	27,000	—	JA	19,000	—	µg/L	
Fluoride	100 - 200	10/10	390	540	—	V	460	—	µg/L	
Nitrate/nitrite	100 - 200	5/7	100	870	—	V	300	5,300	µg/L	
Nitrite	20	4/7	20	63	—	V	30	68	µg/L	2
Oil and grease	5,000 - 11,100	2/7	5,000	42,100	—	V	10,000	—	µg/L	
Orthophosphate	50	1/70	50	99	—	V	36	—	µg/L	
Phosphorus	50	7/7	95	120	—	V	110	—	µg/L	
Silica	400 - 2,000	3/3	7,400	43,000	—	—	19,567	—	µg/L	
Silicon	7.3 - 26	11/11	7,060	18,300	—	V	11,000	—	µg/L	
Solids, nonvolatile suspended	5,000	6/6	10,000	199,000	—	—	83,167	—	µg/L	
Sulfate	500 - 25,000	5/11	460	29,600	—	V	6,280	230,000	µg/L	
Total dissolved solids	10,000	11/11	470,000	820,000	—	V	700,000	—	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 $UTL_{99/99}$ Concentration	Units	PCOC
Total organic carbon	1,000	3/3	19,000	24,500	—	V	20,833	—	µg/L	
Total suspended solids	5,000	8/8	10,000	210,000	—	V	130,000	—	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 or is not considered a contaminant.
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.
$\overline{B}$ 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 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.
$\overline{A}$ 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*

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 95/95 Concentration	Units	PCOC
Metals										
Aluminum	20 - 200	10/15	30	190	—	V	56	39,000	µg/L	
Arsenic	0.7 - 10	5/14	0.9	2.2	—	V	1	3,500	µg/L	
Barium	1.3 - 200	15/15	16	250	—	V	170	64,000	µg/L	2
Beryllium	0.5 - 5	1/15	0.5	0.7	—	JA	1	1,700	µg/L	
Cadmium	2.4 - 5	1/15	1	2.1	—	JA	2	1,800	µg/L	
Calcium	14.3 - 5,000	15/15	3,200	55,000	—	V	39,000	57,000	µg/L	2,3
Cesium	100 - 1,000	1/16	33	50	—	V	180	480,000	µg/L	
Chromium	2.4 - 10	1/15	2	3.2	—	JA	3	3,300	µg/L	
Copper	2.1 - 25	4/15	2	16	—	JA	4	8,300	µg/L	
Iron	4.3 - 100	15/15	16	1,200	—	V	490	17,000	µg/L	
Lead	0.8 - 3	5/14	0.9	5.3	—	JA	2	1,500	µg/L	
Lithium	2 - 100	14/14	7.7	110	—	—	77	36,000	µg/L	2
Magnesium	30 - 5,000	15/15	4,300	45,800	—	V	37,000	1,200,000	µg/L	2,3
Manganese	1 - 15	14/15	2.5	430	—	V	100	3,000	µg/L	2
Mercury	0.2	2/15	0.2	0.54	—	V	0.1	59	µg/L	
Molybdenum	5.7 - 200	1/14	3	13	B	—	6	33,000	µg/L	2
Nickel	3.9 - 40	8/15	6.3	17	—	V	8	13,000	µg/L	2
Potassium	95 - 5,000	15/15	1,400	11,000	—	V	8,400	1,600,000	µg/L	2,3
Silver	2.5 - 10	1/15	2	2.9	—	V	2	3,000	µg/L	
Sodium	21 - 5,000	15/15	20,000	190,000	—	V	160,000	39,000	µg/L	1,2,3
Strontium	2.3 - 200	14/14	45	600	—	V	460	240,000	µg/L	2
Thallium	1.2 - 10	1/14	1	7.4	—	JA	1	6,500	µg/L	
Tin	10 - 200	3/14	10	26	B	—	12	34,000	µg/L	
Vanadium	2 - 50	1/15	2	5.6	B	—	2	17,000	µg/L	

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 95/95 Concentration	Units	PCOC
Zinc	1.8 - 20	12/15	4	26	—	V	10	3,700	µg/L	
Radionuclides										
Americium-241	0 - 0.19	11/11	0.00057	0.031	U	A	0.007	0.03	pCi/L	1
Cesium-137	0.58 - 1.2	6/6	-0.17	-0.044	J	A	-0.11	2.1	pCi/L	
Gross alpha	2 - 8.7	6/6	-0.67	5	U	V	1	29	pCi/L	2,6
Gross beta	2.6 - 6.8	6/6	7.9	16	—	V	11	31	pCi/L	2,6
Plutonium-239	0.14 - 0.03	3/3	0	0.005	U	A	0.002	—	pCi/L	
Plutonium-239/240	0 - 0.01	9/9	-0.00036	0.023	—	A	0.004	0.03	pCi/L	
Radium-226	0.21	1/1	0.23	0.23	—	V	0.23	17	pCi/L	
Strontium-89/90	0.23 - 1	5/5	0.66	1.9	—	A	1.4	4.9	pCi/L	2
Strontium-90	0.36 - 0.58	5/5	0.7084	1.208	—	V	1.02	—	pCi/L	
Tritium	160 - 460	13/13	86	260	J	V	160	730	pCi/L	2
Uranium-233/234	0 - 0.23	5/5	0.76	1.6	—	A	1.1	2.2	pCi/L	2
Uranium-235	0 - 0.26	5/5	0.036	0.3	—	A	0.2	0.3	pCi/L	1,2
Uranium-238	0.094 - 0.263	5/5	0.70	2	—	A	1.2	1.8	pCi/L	1,2
Semivolatile Organic Compounds										
Bis(2-ethylhexyl)phthalate	9 - 11	1/7	1	1	J	A	5	8	µg/L	4
Di-n-butyl phthalate	9 - 11	1/7	1	1	J	A	5	—	µg/L	4
Volatile Organic Compounds										
Methylene chloride	5	2/15	4	8	B	—	3	21	µg/L	4
Indicator Parameters										
Bicarbonate as $CaCO_3$	1,000 - 10,000	14/14	213,000	489,000	—	V	390,000	—	µg/L	
Carbonate	10,000	1/4	10,000	15,300	—	V	7,600	—	µg/L	
Carbonate as $CaCO_3$	1,000 - 10,000	7/10	10,000	77,000	—	V	33,000	—	µg/L	
Chloride	200 - 25,000	14/14	140,000	180,000	—	—	160,000	64,000	µg/L	1,2
Dissolved organic carbon	1,000 - 2,000	6/6	22,000	32,000	—	V	27,000	—	µg/L	

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 95/95 Concentration	Units	PCOC
Fluoride	100 - 200	13/13	590	890	—	—	770	—	µg/L	
Nitrate	100	1/3	100	200	—	JA	100	—	µg/L	
Nitrate/nitrite	20 - 100	6/11	40	320	—	JA	93	3,100	µg/L	
Oil and grease	200 - 7,100	1/10	500	500	—	—	2,500	—	µg/L	
Orthophosphate	10 - 50	1/10	40	40	—	—	27	—	µg/L	
pH	—	4/4	8.2	8.3	—	—	8.2	—	pH	
Phosphorus	50	2/9	50	76	—	V	35	—	µg/L	
Silica	400	1/1	3,100	3,100	—	—	3,100	—	µg/L	
Silicon	7.3 - 100	13/13	300	3,700	—	V	2,300	16,000	µg/L	
Solids, nonvolatile suspended	5,000	2/6	5,000	12,000	—	V	5,000	—	µg/L	
Sulfate	500 - 10,000	14/14	7,000	26,000	—	V	16,000	41,000	µg/L	
Total dissolved solids	10,000	14/14	570,000	810,000	—	V	730,000	—	µg/L	
Total organic carbon	1,000 - 2,000	6/6	26,000	51,000	—	—	34,000	—	µg/L	
Total suspended solids	4,000 - 5,000	1/9	4,000	12,000	—	—	3,500	—	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 or is not considered a contaminant.
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

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 $UTL_{95/95}$ Concentration*	Units	PCOC
Metals											
Aluminum	7.7 - 12	2/2	12,000	17,000	—	V	SED70193	15,000	30,000	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	170	220	—	V	SED70093	200	800	mg/kg	
Beryllium	0.22 - 0.34	3/3	0.81	1.5	—	JA	SED70193	1.2	2.6	mg/kg	
Calcium	7.5 - 12	2/2	6,300	7,900	—	V	SED70193	7,100	81,000	mg/kg	
Chromium	0.64 - 0.99	3/3	12	18	—	V	SED70193	15	30	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	19	—	V	SED70193	16	180	mg/kg	
Iron	1.8 - 2.8	2/2	12,000	15,000	—	V	SED70193	14,000	140,000	mg/kg	
Lead	2.5 - 3.8	3/3	22	34	—	V	SED70193	30	260	mg/kg	
Lithium	0.83 - 1.3	2/2	6.1	9.9	—	V	SED70193	8	—	mg/kg	
Magnesium	9.5 - 15	2/2	2,200	3,300	—	V	SED70193	2,700	6,500	mg/kg	
Manganese	0.59 - 0.91	2/2	150	190	—	V	SED70193	170	—	mg/kg	
Nickel	2.7 - 4.2	3/3	9.3	15	—	V	SED70093	13	35	mg/kg	
Potassium	190 - 300	2/2	1,400	2,600	—	V	SED70193	2,000	3,200	mg/kg	
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	230	340	—	V	SED70193	290	—	mg/kg	
Silver	0.88 - 1.4	1/3	0.88	0.88	—	JA	SED70293	0.7	—	mg/kg	
Sodium	15 - 23	2/2	290	450	—	V	SED70193	370	2,100	mg/kg	
Strontium	1.3 - 2.1	2/2	44	62	—	V	SED70193	53	360	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	29	41	—	V	SED70193	34	86	mg/kg	
Zinc	0.59 - 0.91	3/3	49	190	—	V	SED70093	110	150	mg/kg	1
Radionuclides											
Americium-241	0.0021 - 0.0041	3/3	0.0045	0.018	—	A	SED70093	0.012	—	pCi/g	
Cesium-137	0	3/3	0.29	0.73	X	—	SED70093	0.46	3.5	pCi/g	

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 $UTL_{95/95}$ Concentration*	Units	PCOC
Gross alpha	2.5 - 3.1	3/3	11	16	—	V	SED70193	15	—	pCi/g	
Gross beta	1.9 - 2.1	3/3	28	29	—	V	SED70093	28	—	pCi/g	
Plutonium-239/240	0.0087 - 0.015	3/3	0.0072	0.098	—	A	SED70093	0.045	—	pCi/g	
Strontium-89/90	0.042 - 0.074	3/3	0.12	0.24	—	V	SED70093	0.17	—	pCi/g	
Uranium-233/234	0.042 - 0.098	3/3	0.91	1.1	—	A	SED70093	1.0	—	pCi/g	
Uranium-235	0.05 - 0.062	3/3	0.055	0.074	—	A	SED70193	0.062	—	pCi/g	
Uranium-238	0.056 - 0.076	3/3	0.81	1.4	—	A	SED70093	1.2	—	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	300	—	µg/kg	2
Benzo(a)pyrene	450 - 790	1/3	320	320	J	A	SED70093	290	—	µg/kg	2
Benzo(b)fluoranthene	450 - 790	1/3	450	470	J	A	SED70093	340	—	µg/kg	2
Benzo(ghi)perylene	450 - 790	1/3	200	200	J	A	SED70093	250	—	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	540	—	µg/kg	2
Bis(2-chloroisopropyl)ether	450 - 790	1/3	47	47	J	A	SED70293	260	—	µg/kg	2
Bis(2-ethylhexyl)phthalate	450 - 790	1/3	80	80	J	A	SED70093	210	—	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	420	—	µg/kg	2
Fluorene	450 - 790	1/3	92	92	J	A	SED70093	220	—	µg/kg	2
Indeno(1,2,3-cd)pyrene	450 - 790	1/3	180	180	J	A	SED70093	250	—	µg/kg	2
Phenanthrene	450 - 790	2/3	73	630	J	A	SED70093	350	—	µg/kg	2
Pyrene	450 - 790	2/3	74	750	J	A	SED70093	390	—	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

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
Toluene	10 - 33	3/3	180	440	—	V	SED70293	310	—	µg/kg	2
Indicator Parameters											
% solids	0.1	4/4	42	76	—	V	SED70293	54	—	%	
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	8,400	—	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

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 $UTL_{95/95}$ Concentration	Units	PCOC
Metals											
Aluminum	3.7 - 40	145/145	5,100	23,000	—	V	SS120894	12,000	26,000	mg/kg	
Antimony	3.7 - 15	5/144	5	7.2	—	V	SS701493	4	—	mg/kg	1
Arsenic	0.14 - 2.6	145/145	1.8	13	—	V	SS705393	5	13	mg/kg	1
Barium	0.34 - 40	145/145	56	1,100	—	V	SS705193	190	530	mg/kg	1
Beryllium	0.06 - 1	136/145	0.36	1.5	—	V	SS120894	1	5.0	mg/kg	
Cadmium	0.56 - 1.7	9/144	0.56	1.5	—	V	SS710493	1	5	mg/kg	
Calcium	2.1 - 1,000	144/144	1,900	55,000	—	V	SS705093	9,100	17,000	mg/kg	1,2,3
Chromium	0.47 - 3.3	145/145	4.3	23	—	V	SS120894	12	28	mg/kg	
Cobalt	0.54 - 10	144/145	3.5	16	—	V	SS712093	8	24	mg/kg	
Copper	0.47 - 5	145/145	7.1	640	—	V	SS121394	19	30	mg/kg	1
Iron	0.89 - 20	145/145	4,400	60,000	—	V	SS121594	14,000	29,000	mg/kg	1,3
Lead	0.16 - 17	145/145	6.4	170	—	V	SS708893	26	62	mg/kg	1
Lithium	0.58 - 20	17/20	4.2	16	—	V	SS121094	8.7	22	mg/kg	
Magnesium	5.9 - 1,000	144/144	920	7,900	—	V	SS700293	2,700	7,700	mg/kg	1,3
Manganese	0.16 - 3	144/144	21	1,400	—	V	SS700593	230	2,100	mg/kg	
Mercury	0.076 - 0.17	13/142	0.05	0.13	—	V	SS719793	0.1	—	mg/kg	1
Molybdenum	1.2 - 40	16/92	1.4	4.1	—	V	SS702993	1	37	mg/kg	
Nickel	1.2 - 8	144/145	4.6	24	—	V	SS121394	11	27	mg/kg	
Potassium	97 - 1,000	145/145	770	3,600	—	V	SS711093	2,000	6,200	mg/kg	
Selenium	0.23 - 1	75/133	0.23	2.9	—	V	SS121594	1	1.4	mg/kg	1
Silver	0.51 - 2	66/144	0.53	3	—	V	SS709593	1	—	mg/kg	1
Sodium	5.6 - 1,000	139/145	23	1,300	—	V	SS708293	120	1,100	mg/kg	1,3
Strontium	0.33 - 40	21/21	36	81	—	V	SS720193	53	110	mg/kg	2
Thallium	0.31 - 2	2/144	0.31	2.1	—	V	SS121594	0.2	2.0	mg/kg	1
Vanadium	0.65 - 10	145/145	12	86	—	V	SS705293	31	60	mg/kg	1
Zinc	0.42 - 4	145/145	22	110	—	V	SS120894	56	99	mg/kg	1

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
Radionuclides											
Americium-241	0 - 0.033	130/130	0	1.1	—	V	SS703793	0.03	0.058	pCi/g	1
Cesium-134	0.05 - 0.12	14/14	-0.0077	0.12	—	V	SS120594	0.09	—	pCi/g	
Cesium-137	0.04 - 0.26	140/140	-0.072	2.3	—	V	SS700893	1	3.5	pCi/g	
Gross alpha	1.1 - 9	144/144	7.2	29	—	V	SS120794	16	43	pCi/g	
Gross beta	2 - 5.3	132/132	18	42	—	V	SS120794	26	53	pCi/g	
Plutonium-239/240	0 - 0.06	126/126	-0.00062	0.47	—	V	SS704293	0.06	0.13	pCi/g	1,2
Radium-226	0.26 - 0.51	91/91	0.44	1.8	—	V	SS711193	1	1.5	pCi/g	1,2
Radium-228	0.18 - 0.98	99/99	0.76	2.6	—	V	SS704493	1.7	4.8	pCi/g	
Strontium-89/90	0.02 - 0.5	144/144	-0.004	1.0	—	V	SS708993	0.2	2.1	pCi/g	
Uranium-233/234	0 - 0.3	143/143	0.57	1.5	—	V	SS702593	0.9	1.8	pCi/g	
Uranium-235	0 - 0.3	143/143	-0.0072	0.12	—	V	SS701993	0	0.19	pCi/g	
Uranium-238	0 - 0.2	143/143	0.59	1.6	—	V	SS708293	0.9	2	pCi/g	
Indicator Parameters											
% solids	0.1	133/133	30	91	—	V	SS720093	73	—	%	
Nitrate/nitrite	0.5 - 1	116/145	1	45	—	V	SS710893	5	9.6	mg/kg	1,2
Silicon	1.3 - 1.6	9/9	160	320	—	V	SS720293	280	3,500	mg/kg	
Total organic carbon	0.05 - 500	123/145	0.05	54,000	—	V	SS701193	9,600	—	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 valid result

Data Qualifiers

— data qualifier or validation field in database is blank.

Definitions

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

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 $UTL_{95/95}$ Concentration	Units	PCOC
Colluvial Material (Qc)											
Metals											
Aluminum	6.9 - 7.8	7/7	10,400	16,100	—	V	71093	12657	28,000	mg/kg	
Arsenic	0.24 - 0.36	7/7	3.3	7.9	—	V	70993	5	9	mg/kg	
Barium	1.4 - 1.6	7/7	91.4	620	—	JA	71093	230	470	mg/kg	1
Beryllium	0.2 - 0.22	7/7	0.74	1.2	—	JA	70993	1	25	mg/kg	
Calcium	6.7 - 7.6	7/7	5,620	7,350	—	V	71093	6,404	31,000	mg/kg	
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	110.91	—	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	39,000	mg/kg	
Lead	2 - 2.6	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	2,500	3,500	—	V	71093	2,923	7,900	mg/kg	
Manganese	0.52 - 0.59	7/7	106	262	—	V	70993	198	750	mg/kg	
Nickel	2.4 - 2.7	7/7	13.1	18.4	—	V	71093	15.2	42	mg/kg	
Potassium	169 - 193	7/7	970	1,780	—	V	71093	1,294	3,200	mg/kg	
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 - 15	7/7	84.5	912	—	V	70993	378	3,004	mg/kg	
Strontium	1.2 - 1.4	7/7	49.9	107	—	V	71093	67	140	mg/kg	
Tin	3.6 - 4.1	5/7	3.7	8.9	—	JA	71093	5.6	630	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	130	mg/kg	
Radionuclides											
Americium-241	0 - 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

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 $UTL_{99/95}$ Concentration	Units	PCOC
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	2.18	—	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	460	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
Indicator Parameters											
% solids	0.1 - 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	3/5	1	20,000	—	V	71093	4,001	66	mg/kg	1
Total organic carbon	0.05 - 0.05	5/5	500	21,000	—	V	71093	8,540	—	mg/kg	
pH	0.2 - 0.2	7/7	7.8	8.4	—	V	70993	8.1	—	pH	
Weathered Bedrock Material (KaKI-w)											
Metals											

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 $UTL_{95/95}$ Concentration	Units	PCOC
Aluminum	5.8 - 7.5	11/11	5,320	7,880	—	V	70993	7,035	43,000	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	210	mg/kg	1
Beryllium	0.16 - 0.21	11/11	0.53	1.1	—	JA	71093	1	9	mg/kg	
Benzo(a)anthracene	380 - 440	1/7	48	48		A	70993	180			
Bis(2-ethylhexy)phthalate	370 - 400	1/11	180	180		A	70993	191			
Butylbenzylphthalate	370 - 400	1/11	370	860		V	70993	253			
Cadmium	0.49 - 0.64	4/11	0.49	1.5	—	V	71093	0.5	—	mg/kg	
Calcium	5.6 - 7.3	11/11	2,700	15,900	—	V	71093	6,036	8,300	mg/kg	1,2
Chromium	0.48 - 0.61	11/11	6.4	10.6	—	V	71093	8	53	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	24,600	—	V	71093	13,893	36,000	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	7.1 - 9.2	11/11	1,840	3,130	—	V	71093	2,470	7,200	mg/kg	
Manganese	0.44 - 0.57	11/11	20.2	896	—	JA	71093	275	710	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	38.2	—	V	71093	17	52	mg/kg	
Potassium	143 - 184	11/11	830	1,330	—	V	71093	993	3,400	mg/kg	
Selenium	0.23 - 0.3	7/11	0.27	1.9	—	JA	71093	0.8	—	mg/kg	
Silicon	1.3 - 1.7	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 - 15	11/11	256	939	—	V	70993	495	2,800	mg/kg	
Strontium	1 - 1.3	11/11	46.6	197	—	V	71093	97	32	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	630	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 $UTL_{95/95}$ Concentration	Units	PCOC
Vanadium	0.59 - 0.75	11/11	10	29	—	V	71093	19	91	mg/kg	
Zinc	0.44 - 0.57	11/11	42	84	—	JA	71093	70	68	mg/kg	1
Radionuclides											
Americium-241	0 - 0	11/11	-0.00029	0.009491	J	A	70993	0.00289	—	pCi/g	
Cesium-137	0.1 - 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	0.003724	—	pCi/g	
Radium-226	0.5	11/11	0.9136	1.312	—	—	70993	1.3	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
Toluene	6 - 110	11/11	120	580	—	JA	70993	309	—	µg/kg	3
Indicator Parameters											
% solids	0.1 - 0.1	11/11	83	89.4	—	V	71093	87	—	%	
Total organic carbon	0.05	3/11	500	2,600	—	V	71093	700	—	mg/kg	
pH	0.2 - 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

Table 2-7
Analytes Detected in UHSU 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 UTL95/95 Concentration	Units	PCOC
Metals											
Aluminum	12 - 200	18/20	140	7,200	—	—	53194	1,200	26,000	µg/L	-
Antimony	11 - 60	2/20	8	67	—	JA	B207089	17	52	µg/L	1
Arsenic	1.4 - 10	4/20	1	4.7	—	—	53194	1	8	µg/L	
Barium	0.4 - 200	16/20	16	120	—	—	53194	48	310	µg/L	
Beryllium	0.2 - 5	2/20	0.2	1.1	—	—	53194	1	4	µg/L	
Cadmium	1.6 - 5	2/20	1	2.4	B	V	B207089	1	4	µg/L	
Calcium	3.4 - 5,000	20/20	39,000	170,000	—	V	B266789	120,000	150,000	µg/L	1,2,3
Cesium	20 - 1,000	1/18	20	45	B	Y	B206789	68	870	µg/L	
Chromium	1.8 - 10	7/20	1.8	18	—	V	B207089	5	190	µg/L	
Cobalt	1.4 - 50	1/20	2	2.1	—	—	53194	2	44	µg/L	
Copper	1.1 - 25	5/20	2	14	—	—	53194	5	42	µg/L	
Iron	5 - 100	20/20	120	8,400	—	—	53194	1,300	32,000	µg/L	
Lead	0.9 - 5	7/20	1	51	—	—	53194	4	20	µg/L	1
Lithium	1 - 100	20/20	14	230	—	V	B206789	150	180	µg/L	1,2
Magnesium	13 - 5,000	20/20	11,000	45,000	—	V	B206789	34,000	34,000	µg/L	1,2,3
Manganese	0.5 - 15	18/20	2.8	170	—	—	53194	46	640	µg/L	
Molybdenum	2.5 - 200	2/20	2	7.3	B	V	B207089	4	200	µg/L	
Nickel	3.7 - 40	5/20	3	11	B	V	B206789	6	100	µg/L	
Potassium	360 - 5,000	16/20	1,300	6,700	—	V	B207089	3,800	5,200	µg/L	1,2,3
Selenium	5	12/20	1	815	—	JA	B206789	230	130	µg/L	1,2
Silver	2 - 10	4/19	2	11	N	JA	B206789	2	7	µg/L	1,2
Sodium	18 - 5,000	19/19	23,000	470,000	—	V	B206789	220,000	150,000	µg/L	1,2,3
Strontium	0.2 - 200	19/19	410	1,900	—	V	B207089	1,200	1,100	µg/L	1,2
Thallium	2 - 10	3/19	1	3.7	—	—	53194	1	9	µg/L	

Table 2-7
Analytes Detected in UHSU 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 $UTL_{95/95}$ Concentration	Units	PCOC
Tin	8.9 - 200	4/19	8.9	78	—	—	53194	17	170	µg/L	
Vanadium	1.5 - 50	10/19	2.9	32	B	—	4287	8	71	µg/L	
Zinc	1.1 - 20	14/19	9.1	53	—	JA	B206789	22	180	µg/L	
Radionuclides											
Americium-241	0 - 0.03	23/23	-0.43	0.010	—	A	B207089	-0.015	0.04	pCi/L	
Cesium-134	2.2	1/1	0.64	0.64	—	—	B207089	0.64	—	pCi/L	
Cesium-137	0.74 - 2.4	7/7	-0.50	0.43	J	A	B207089	-0.047	1.1	pCi/L	
Gross alpha	4.8 - 74	2/2	0	19	—	Y	B207089	10	390	pCi/L	
Gross beta	10 - 22	2/2	3.5	13	—	Y	B207089	8	220	pCi/L	
Plutonium-238	0 - 0.014	414	0.00082	0.0029	—	—	53194	0.0021	0.047	pCi/L	
Plutonium-239/240	0 - 0.087	25/25	-0.00027	0.009	J	V	B207089	0.002	0.065	pCi/L	
Radium-226	0.096	1/1	0.64	0.64	B	Y	B207089	0.64	1.3	pCi/L	
Strontium-89/90	1 - 1.6	2/2	-0.14	0	—	Y	B207089	-0.07	1.2	pCi/L	2
Tritium	210 - 840	61/61	-160	370	U	—	B207089	66	13,000	pCi/L	
Uranium-233/234	0.36	1/1	2.8	2.8	—	Y	B207089	2.8	150	pCi/L	
Uranium-235	0.25	1/1	0.082	0.082	—	Y	B207089	0.082	5.2	pCi/L	
Uranium-238	0.37	1/1	1.5	1.5	—	Y	B207089	1.5	110	pCi/L	
Semivolatile Organic Compounds											
Bis(2-ethylhexyl)phthalate	10	1/7	3	3	J	A	B206789	3	—	µg/L	4
Volatile Organic Compounds											
1,1-Dichloroethane	0.1 - 10	1/89	0.1	0.3	—	V	0786	2	3	µg/L	4
2-Butanone	10 - 100	1/48	6	6	—	—	53194	9	6	µg/L	4
Benzene	0.1 - 10	3/89	0.1	0.5	J	A	B266889	2	3	µg/L	4
Carbontetrachloride	0.2 - 10	2/89	0.2	7.1	—	Y	B206889	2	520	µg/L	4
Chloroethane	0.4 - 10	2/90	0.4	3	J	A	0786	4	—	µg/L	4
Ethylbenzene	0.2 - 10	1/90	0.2	0.3	J	A	B206889	2	—	µg/L	4

Table 2-7
Analytes Detected in UHSU 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 $UTL_{90/90}$ Concentration	Units	PCOC
Methylene chloride	0.1 - 10	11/88	0.1	3.2	B	—	B206889	2	16	µg/L	4
Tetrachloroethane	0.1 - 10	1/90	0.1	0.77	—	Y	B206889	2	44	µg/L	4
Total xylenes	0.5 - 10	1/78	0.5	3	J	A	B206889	3	3	µg/L	4
Trichloroethane	0.1 - 10	1/90	0.1	1.4	—	Y	B206889	2	38	µg/L	4
Toluene	0.1 - 10	2/90	0.1	3	J	A	B206889	2	4	µg/L	4
Indicator Parameters											
Ammonia	30 - 100	5/18	80	210	—	Y	B207089	68	—	µg/L	
Bicarbonate as $CaCO_3$	1,000 - 10,000	51/51	38,000	860,000	—	V	0786	330,000	—	µg/L	
Carbonate as $CaCO_3$	1,000 - 10,000	10/36	0	12,000	—	V	4087	1,800	—	µg/L	
Chemical oxygen demand	0 - 10,000	22/26	4,800	55,000	—	V	0786	16,000	—	µg/L	
Chloride	200 - 50,000	48/48	12,000	530,000	—	V	B207089	230,000	64,000	µg/L	1,2
Cyanide	5 - 100	1/27	1	5.6	B	V	B207089	7	12	µg/L	
Fluoride	0 - 100	50/50	230	3,400	—	—	4087	870	2,000	µg/L	1,2,3
Nitrate/nitrite	20 - 10,000	64/72	20	190,000	—	V	B206889	25,000	56,000	µg/L	1,2
Orthophosphate	10 - 50	13/21	6	60	—	JA	B207089	19	—	µg/L	
pH	0.1	1/1	7.7	7.7	—	Y	B207089	7.7	—	pH	
Silica	400	15/15	2,600	9,600	—	V	0786	5,500	—	µg/L	
Silicon	12 - 200	14/15	2,700	22,000	—	—	53194	8,100	63,000	µg/L	
Sodium fluoride	100	1/1	520	520	—	V	B206789	520	—	µg/L	
Sodium sulfate	20,000	1/1	520,000	520,000	—	V	B206789	520,000	—	µg/L	
Solids nonvolatile suspended	5,000	1/1	29,000	29,000	—	JA	B206889	29,000	—	µg/L	
Specific conductivity	1	2/2	3,100	3,100	—	Y	B207089	3,100	—	µmhos/cm	
Sulfate	500 - 250,000	50/50	33,000	19,000,000	—	—	B207089	880,000	610,000	µg/L	1,2
Sulfide	1 - 1,000	2/4	1	73,000	—	—	53194	27,000	—	µg/L	
Total dissolved solids	5,000 - 14,000	51/51	280,000	5,100,000	—	V	B206989	1,500,000	—	µg/L	

Table 2-7
Analytes Detected in UHSU 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 $UTL_{99/99}$ Concentration	Units	PCOC
Total organic carbon	1,000 - 5,000	29/31	190	22,000	—	V	0786	6,400	—	µg/L	
Total suspended solids	1,000 - 5,000	47/50	4,000	590,000	—	—	B206789	75,000	—	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 or is not considered a contaminant.
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 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

Table 2-8
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 $UTL_{99/95}$ Concentration	Units	PCOC
Metals											
Aluminum	12 - 200	6/6	640	2,800	N*	JA	53094	1,600	14,000	µg/L	
Antimony	11 - 60	1/6	11	28	B	JA	4187	18	1,300	µg/L	
Arsenic	1.4 - 10	3/6	1.4	2.5	B	V	53094	2	11	µg/L	
Barium	0.4 - 200	6/6	250	400	—	V	4187	300	1,400	µg/L	2
Beryllium	0.2 - 5	1/16	0.28	0.28	B	V	53094	0	122	µg/L	
Calcium	3.4 - 5,000	6/6	90,000	110,000	—	V	4187	96,000	130,000	µg/L	2,3
Chromium	1.8 - 10	2/6	1.8	61	—	V	4187	14	1,200	µg/L	
Cobalt	1.4 - 50	2/6	1.8	3.1	B	V	4187	2.2	1,200	µg/L	
Copper	1.1 - 25	3/6	2.8	17	B	V	4187	9.4	1,300	µg/L	
Iron	7.3 - 100	6/6	1,100	2,800	N	JA	53094	1,800	18,000	µg/L	
Lead	0.9 - 5	4/6	1	4.4	—	V	4187	2.3	22	µg/L	
Lithium	1 - 100	6/6	83	94	B	V	53094	87	150	µg/L	2
Magnesium	13 - 5,000	6/6	20,000	26,000	—	V	4187	22,000	28,000	µg/L	2,3
Manganese	0.5 - 15	6/6	120	290	—	V	53094	200	620	µg/L	2
Molybdenum	2.5 - 200	5/16	13	24	B	V	4187	17	1,200	µg/L	2
Nickel	3.7 - 40	2/6	8.4	48	—	V	4187	18	1,300	µg/L	
Potassium	360 - 5,000	6/6	5,000	8,500	—	V	53094	7,100	8,800	µg/L	2,3
Selenium	2.6 - 5	2/6	1	3	B	V	4187	1	5	µg/L	
Sodium	18 - 5,000	6/6	420,000	470,000	—	V	53094	440,000	660,000	µg/L	2,3
Strontium	0.2 - 200	6/6	1,100	1,500	—	V	4187	1,200	1,700	µg/L	2
Thallium	4.2 - 10	1/6	1	4.2	B	V	53094	2	11	µg/L	
Vanadium	1.5 - 50	3/6	3.3	13	B	Y	53094	8.7	1,300	µg/L	
Zinc	1.1 - 20	6/6	17	53	E	JA	4187	2.5	1,400	µg/L	

Table 2-8
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 $UTL_{95/95}$ Concentration	Units	PCOC
Radionuclides											
Americium-241	0.0034 - 0.011	5/5	0.00087	0.0070	—	V	53094	0.0045	0.072	pCi/L	
Plutonium-238	0.0096 - 0.016	4/4	-0.0037	-0.0012	J	V	53094	-0.0024	—	pCi/L	
Plutonium-239/240	0.0029 - 0.013	5/5	-0.0012	0.0077	J	V	53094	0.0019	0.031	pCi/L	
Tritium	260 - 910	25/25	-170	300	U	V	B207189	27	1,800	pCi/L	
Semivolatile Organic Compounds											
Bis(2-ethylhexyl)phthalate	10	1/6	1	2	J	A	53094	4	—	µg/L	4
Butylbenzyl phthalate	10	1/6	1	1	J	A	53094	4	—	µg/L	4
Volatile Organic Compounds											
Acetone	10 - 100	1/32	7	7	J	A	B207189	8	12	µg/L	4
Methylene chloride	0.1 - 10	8/40	0.1	16	—	V	0886	3	12	µg/L	4
Total xylenes	5 - 10	1/34	1	1	J	A	4187	2	4	µg/L	4
Indicator Parameters											
Ammonia	30 - 100	2/4	100	510	—	Y	4187	170	—	µg/L	
Bicarbonate as $CaCO_3$	1,000 - 10,000	37/37	10,000	180,000	—	V	0886	120,000	—	µg/L	
Carbonate as $CaCO_3$	1,000 - 10,000	13/29	0	110,000	—	V	B207189	17,000	—	µg/L	
Chemical oxygen demand	5,000 - 10,000	10/10	5,000	37,000	—	V	4187	15,000	—	µg/L	
Chloride	200 - 50,000	35/35	12,000	1,100,000	—	—	4187	590,000	530,000	µg/L	1,2
Fluoride	100	36/36	300	1,700	—	Y	53094	870	2,300	µg/L	
Nitrate/nitrite	20 - 100	34/37	20	2,400	—	V	0886	1,300	4,200	µg/L	2
Orthophosphate	10 - 50	1/9	10	20	—	JA	0886	8.9	51	µg/L	
Silica	400	10/10	2,500	6,200	—	—	0886	3,700	12,000	µg/L	
Silicon	12 - 200	5/5	4,800	9,400	*	JA	53094	6,600	—	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	140,000	140,000	—	JA	B207189	140,000	—	µg/L	

Table 2-8
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 $UTL_{99/99}$ Concentration	Units	PCOC
Specific conductivity	10	2/2	490	3,300	--	Y	4187	1,900	—	µmhos/cm	
Sulfate	500 - 10,000	36/36	6,000	79,000	—	JA	B207189	26,000	990,000	µg/L	
Sulfide	1 - 1,000	2/14	2.7	72,000	—	V	53094	18,000	—	µg/L	
Total dissolved solids	5,000 - 14,000	37/37	230,000	2,000,000	--	V	4187	1,300,000	—	µg/L	
Total organic carbon	1,000 - 5,000	11/13	1,000	4,100	—	Y	0886	2,100	—	µg/L	
Total suspended solids	1,000 - 5,000	35/36	5,000	450,000	—	V	0886	130,000	3,000,000	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.

1 Analyte determined to be PCOC by hot measurement test.
2 Analyte determined to be a PCOC by inferential statistical tests
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

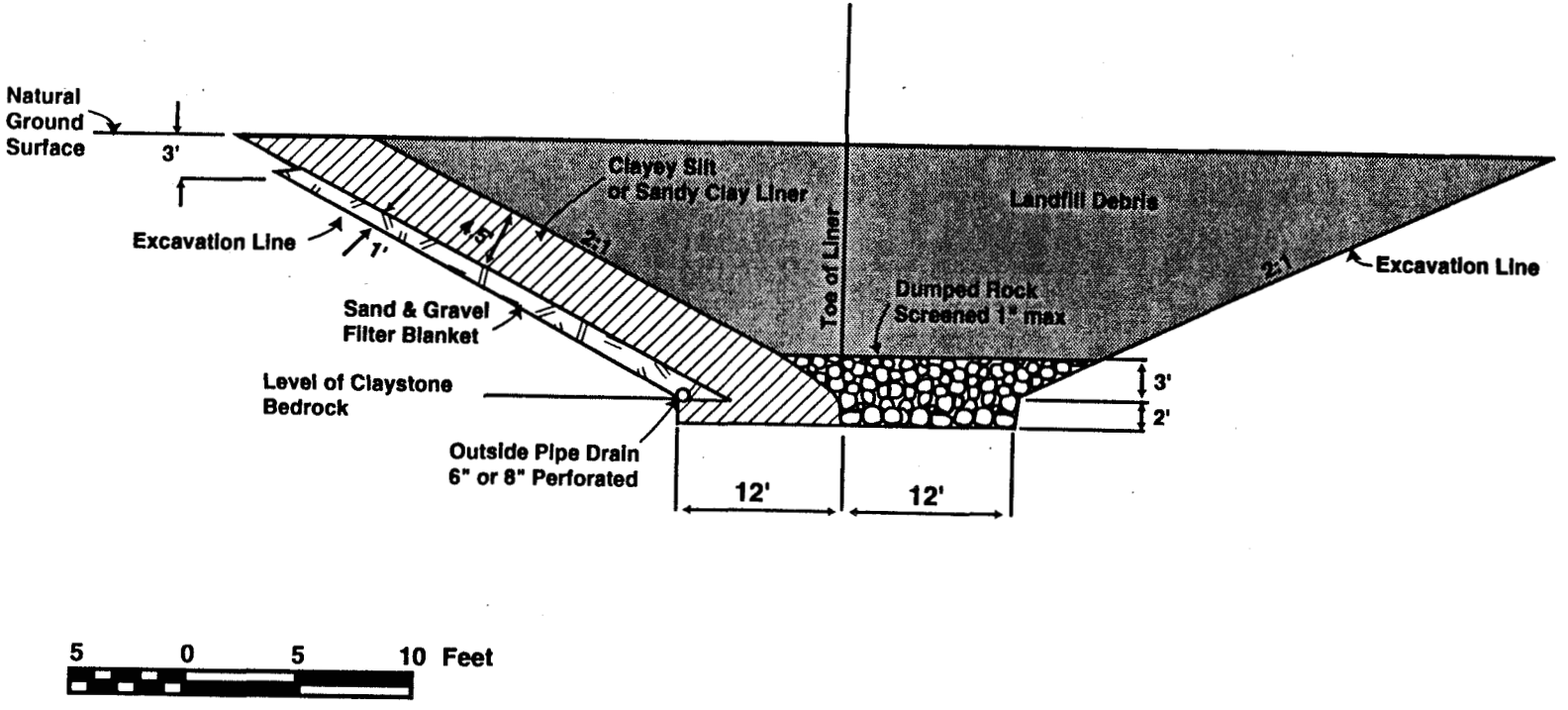
_ data qualifier or field validation field in database is blank.
* for inorganics, duplicate analysis is not within control limits (estimated value).
B for inorganics, reported value is < CRDL but > IDL (estimated value).
B for organics, analyte is also detected in blank; for common lab contaminants 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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Rocky Flats Environmental Technology Site
Golden, Colorado

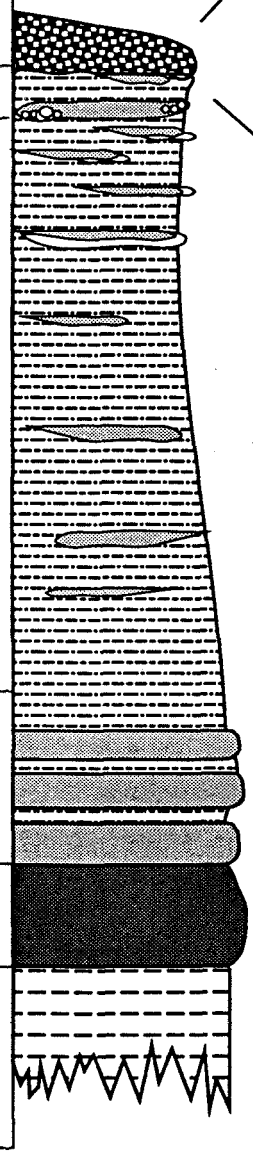
Typical Existing Groundwater-Intercept System Section

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 2-2

G95ES\IM/IRA DD OU 7\Leachate Section-2510.ill

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

Source: EG&G 1992a

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Golden, Colorado

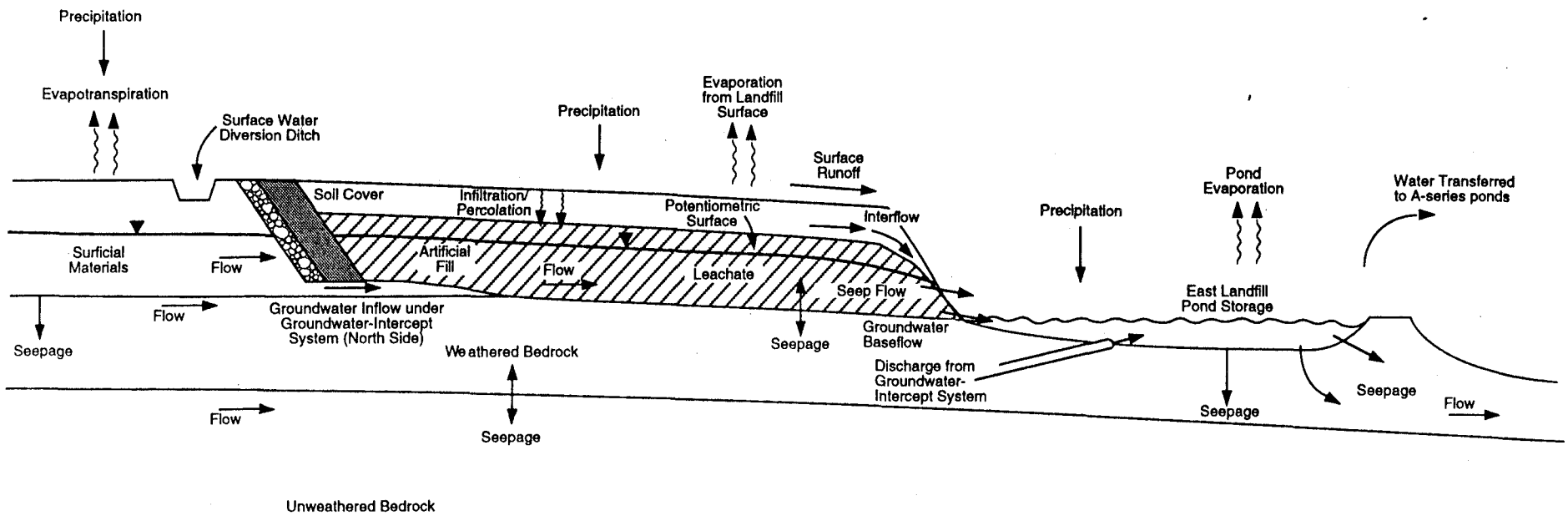
Generalized Stratigraphic Section

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 2-3

G95\ES\IM\IRA DD OU 7\Gen. Strat.-2501.mdw

Present Landfill Area Cross Section



Not to scale

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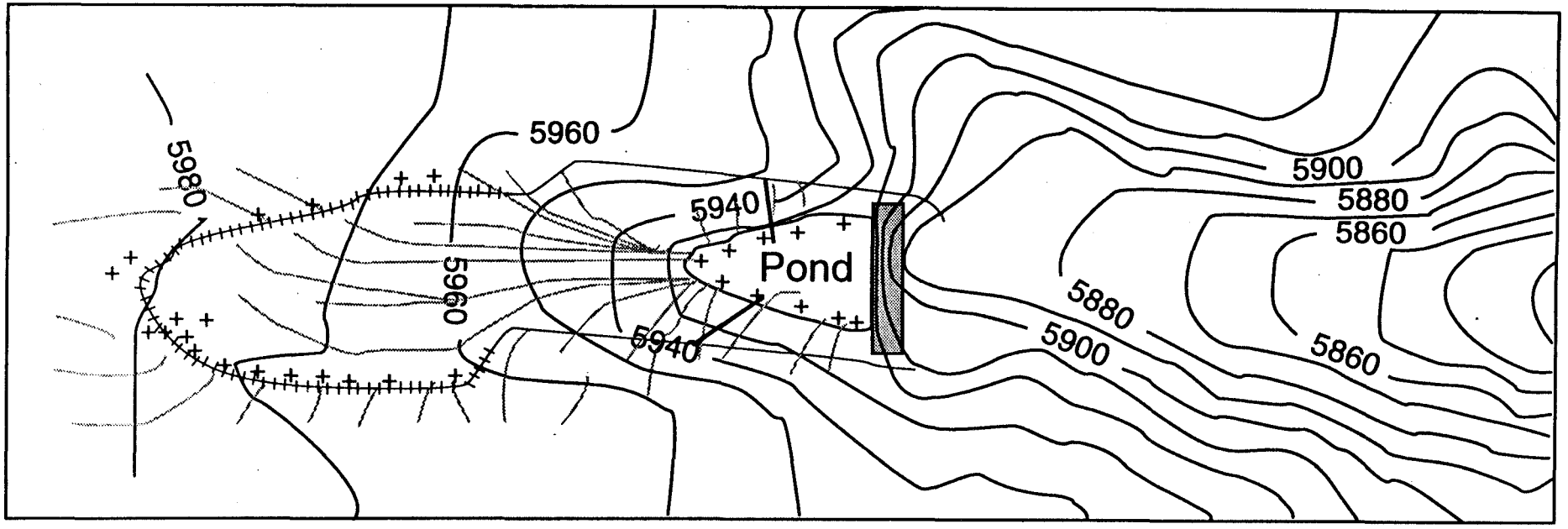
Golden, Colorado

Conceptual Flow Model for OU 7

IM/IRA DD and Closure Plan	Operable Unit No. 7
March 1996	Figure 2-5

G95\ES\IM\RA DD OU 7\Conceptual flow model 2510



Existing groundwater intercept system, perforated

Existing groundwater intercept system, nonperforated

Dam (low hydraulic conductivity)

Particle entering boundary

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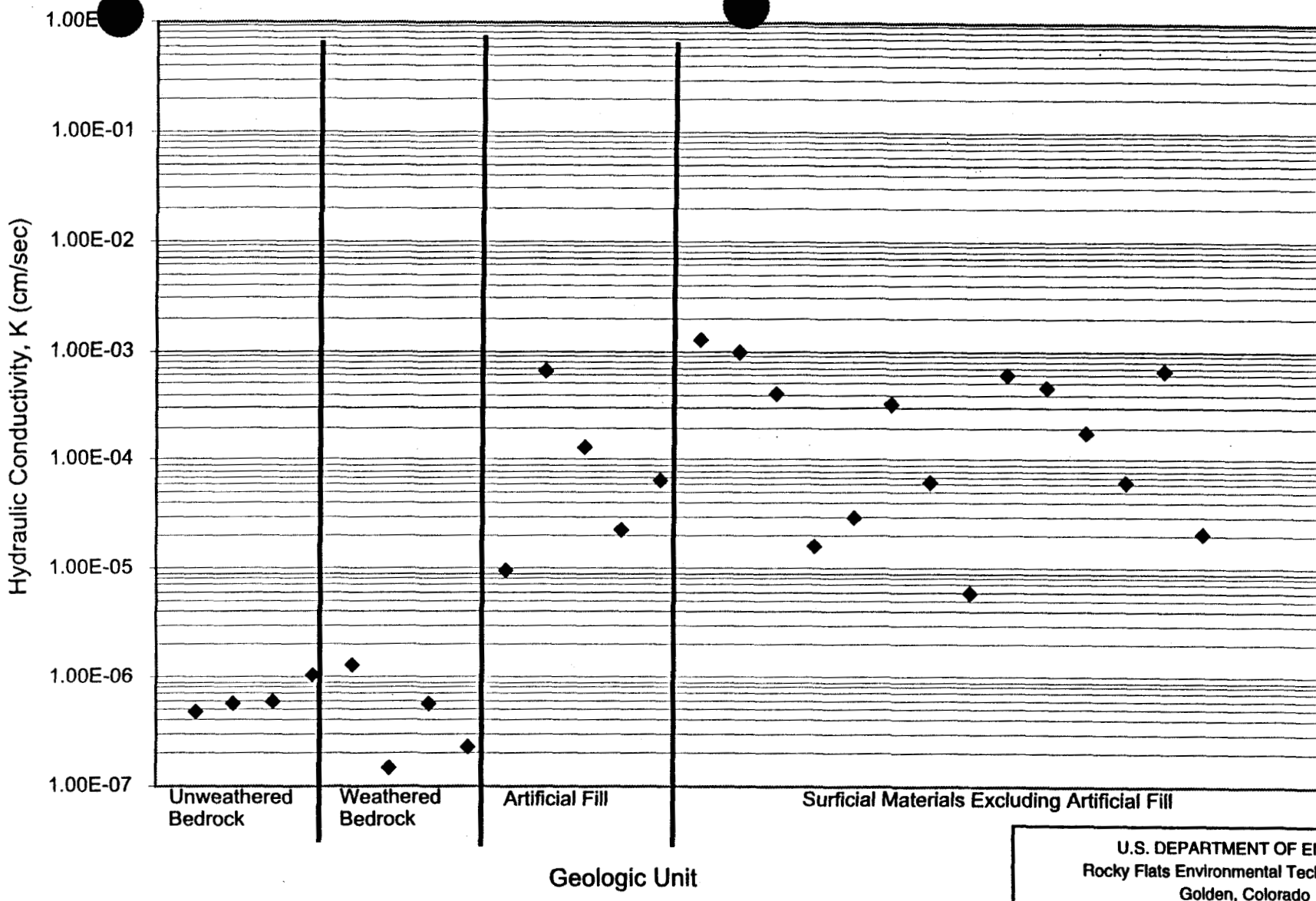
Groundwater Flowpaths from the Landfill

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 2-7

G95\ES\IM/IRA DD OU 7GW Flowpaths-2510.ill



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Hydraulic Conductivity Measurements for Each Geologic Unit

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 2-8

3.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

This section presents the process used to develop RAOs or response actions. Preliminary RAOs were identified for each medium, a conceptual site model was developed, and potential risks to human health and the environment were evaluated using a focused risk assessment approach, as recommended in EPA guidance for presumptive remedies (EPA 1993a). Compliance with ARARs was assessed by comparing chemical-specific ARARs for surface water and groundwater to concentrations in leachate and groundwater at OU 7 and by identifying location-specific and action-specific ARARs. Final RAOs were developed by eliminating preliminary RAOs using the following criteria: (1) for which the exposure pathway is incomplete, (2) for which there is no risk to the potential receptor, or (3) for which analytes do not typically exceed ARARs. Final RAOs are used in Section 4 for the identification and screening of technologies.

3.1 PRELIMINARY REMEDIAL ACTION OBJECTIVES

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). To evaluate alternatives in terms of overall protection of human health and the environment, the manner in which potential site risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls was considered (EPA 1991a).

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 runoff and erosion
- Control landfill gas (treat as needed)
- Collect and treat leachate at the source (as needed)
- Control groundwater at the source

In addition to these RAOs, it has been agreed by DOE, EPA, and CDPHE that the East Landfill Pond will be drained and the dam and pond sediments removed and consolidated in the landfill under the cap. The pond will be removed to eliminate potential long-term flood hazards and operation and maintenance costs. The sediment will be removed to eliminate potential ecological risks.

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

- Remediate surface soils downgradient of the landfill
- Remediate subsurface geologic materials downgradient of the landfill
- Remediate groundwater downgradient of the landfill

Containment will accomplish most of the RAOs for the presumptive remedy components at OU 7 by addressing the pathways associated with the source. RAOs for the other components will be evaluated in terms of potential risks and compliance with ARARs.

3.2 CONCEPTUAL SITE MODEL

The conceptual site model identifies the suspected sources, contaminant release and transport mechanisms, exposure points or affected media, and exposure routes (see Figure 3-1). This information is used to identify important sources of contaminants and risks that require remediation. Figure 3-2 is a schematic diagram of the site that also shows this information.

Contaminant sources at OU 7 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. Because the landfill contents, IHSS 203, and the asbestos-disposal areas will be contained under the presumptive remedy, exposure pathways including direct contact with these sources are considered incomplete and, therefore, are not included in assessment of risk (EPA 1989a, EPA 1993a).

Leachate is liquid that has percolated through or drained from hazardous waste (6 CCR 1007-3 260.10). Leachate resulting from land-disposed hazardous wastes classified by more than one waste code under RCRA Subpart D is designated F039 multisource leachate contained in groundwater (6 CCR 1007-3 261.31) (DOE 1995d). Only leachate within the landfill is considered F039 RCRA-listed waste. Leachate that discharges at the seep, to surface water in the East Landfill Pond, to pond sediments, or to surface soils, subsurface geologic materials, and groundwater downgradient of the landfill constitutes leachate "contained in" environmental media. Therefore, risk-based analyses were performed for all media with potentially complete pathways to determine if these media pose a threat to human health or the environment.

The East Landfill Pond is not formally included under presumptive remedy exclusions. However, because the proposed action includes removal of the pond and sediments, exposure pathways including contact with these media also will be incomplete and not included in the risk assessment.

The remaining potential contaminant release mechanisms include leaching of contaminants to the groundwater or surface water, historical wind dispersal and deposition of contaminants to surface soils, and historical spray evaporation of pond water. The primary transport mechanisms associated with releases in water are migration of contaminants in leachate seep water and groundwater. Spray evaporation activities ceased in 1994; therefore, releases are no longer occurring by this mechanism. Similarly, wind dispersal and contaminant deposition to surface soils will be precluded by the presumptive remedy. However, after water from the pond was sprayed onto the surrounding slopes resulting in contaminant deposition, contaminants may have infiltrated the soil and may subsequently be leached into runoff or infiltrated/percolated into groundwater 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. After the pond is removed, this pathway will be incomplete. 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. However, this migration pathway is not likely because groundwater modeling has shown that migration is slowed considerably or possibly even stopped by the dam. In addition, discharge from groundwater to surface water below the dam is not expected because the ephemeral stream in No Name Gulch is a losing stream that discharges to groundwater.

Groundwater in the UHSU could also migrate slowly downgradient, remaining as groundwater. Although existing information indicates that there is only limited availability of groundwater downgradient of the landfill (see Section 2.3), this migration pathway is the most likely. 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 (see Section 2.3). Contaminants in groundwater may also be deposited in subsurface geologic materials downgradient of the landfill.

Contaminants detected in landfill leachate could be transported by seeps or groundwater. During transport, contaminants in groundwater may be subject to adsorption, hydrolysis, and biological degradation under aerobic or anaerobic conditions. As stated above, discharge to the pond will be an incomplete pathway once the pond is removed and discharge of leachate contained in groundwater to surface water below the dam is not expected.

The anticipated future land use for the area surrounding the landfill is open space, as recommended by the Future Land-Use Working Group and in accordance with The Vision (DOE 1995e; DOE 1996). Residential uses have been eliminated from the future land-use plan (DOE 1995e). In addition, there are no plans for future development of groundwater for any use at OU 7.

Based on this land-use scenario, the potential exposure pathways for humans are (1) inhalation of VOCs in, ingestion of, and dermal contact with leachate seep water; (2) inhalation of VOCs in, ingestion of, and dermal contact with leachate-contaminated groundwater emerging as surface water; and (3) particulate inhalation of, incidental ingestion of, dermal contact with, and external irradiation from surface soils downgradient of the landfill. Pathways associated with subsurface geologic materials are considered incomplete in the open-space exposure scenario. Risks associated with complete exposure pathways for OU 7 are evaluated below.

Pathways evaluated for exposure of ecological receptors include exposure of small mammals to contaminants in soils, inhalation of organic contaminants in subsurface soils by small mammals (in burrows), exposure of vegetation to contaminants in subsurface soils, and exposure of aquatic life to leachate seep water and groundwater downgradient of the landfill emerging as surface water.

Although groundwater does not discharge to surface water, human health and ecological risks based on this pathway were evaluated for conservatism.

3.3 EVALUATION OF POTENTIAL 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. As noted in the previous section, under the presumptive remedy approach, a quantitative baseline risk assessment is not necessary to evaluate whether the containment remedy addresses pathways and contaminants of concern associated with the source. Rather, all potential exposure pathways were identified and compared to the pathways addressed by the containment presumptive remedy (EPA 1993a). For pathways not addressed by the containment presumptive remedy, a focused risk assessment was performed.

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 evaluate potential risks. The focused risk assessment methodology uses PCOCs previously identified following the Gilbert methodology (EG&G 1994b) and

includes risk evaluations to determine if remediation of contaminant sources not included under the presumptive remedy is required. PCOCs are summarized by media in the Section 2 tables.

3.3.1 Risk Assessment Approach

Human Health

The human health focused risk assessment was conducted using the methods shown in Figure 3-3. First, a screening-level evaluation was conducted by comparing PCOC concentrations to preliminary remediation goals (PRGs) developed for use at Rocky Flats (DOE 1995f). If site concentrations exceeded PRGs, a more detailed evaluation of potential exposure, including risk calculations, was performed.

PRGs were developed in conjunction with EPA and are specific to chemicals, environmental media, exposure routes, and exposure scenarios. PRGs are chemical concentrations that would result in cancer risk of 1E-06 or a hazard index (HI) of 1 (DOE 1995f), criteria considered acceptable by EPA (EPA 1989). PRGs were developed for specific exposure scenarios that are consistent with land uses identified by the Future Land-Use Working Group (DOE 1995e). The land-use scenario used for evaluating risk at OU 7 was open space which assumes public citizens visit the site for recreational purposes 25 times per year.

The preliminary risk screen was conducted by comparing the maximum detected concentration of each PCOC, as identified in Section 2.5, to the PRG for that analyte. Maximum detected 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), a screen performed prior to baseline risk assessments at Rocky Flats. If the maximum detected concentration was less than the PRG, exposure to the analyte would result in less than the acceptable maximum cancer risk of 1E-06 or an HI of 1 and the analyte is dropped from further consideration. If the maximum detected concentration was greater than the PRG, the analyte was further evaluated in risk calculations.

Results of PRG screens and detailed risk calculations are presented for each medium. None of the PCOCs in leachate seep water or groundwater downgradient of the landfill exceeded PRGs. Metals and radionuclides in surface soils downgradient of the landfill that exceeded PRGs were subjected to more detailed analysis through risk calculations.

Ecological Receptors

Screening-level exposure and risk calculations were also used in evaluating ecological risk. Soils and leachate seep data were evaluated to determine whether PCOCs were present at potentially ecotoxic concentrations. Unlike assessment of human health risks, evaluation of ecological risk can involve multiple receptor species. The OU 7 analysis was conducted for "limiting" exposure scenarios involving receptor types with the most frequent contact with potentially contaminated media in OU 7. The receptors evaluated were:

- Vegetation exposure to subsurface soils
- Small mammal exposure to burrow air and soils
- Aquatic life exposure to leachate and groundwater seeps

Potential ecological exposures and ecotoxicity estimates are based on the data used to characterize the nature and extent of contamination (see Section 2.5) and the human health screen. The potential ecotoxicity of contaminants was evaluated by comparing chemical concentrations in abiotic media to literature-based ecotoxicological benchmarks developed for various receptor species (DOE 1995c, 1995g). The benchmarks were developed from EPA-supported databases, Colorado surface-water standards for protection of aquatic life (5 CCR 1002-8) EPA Ambient Water Quality Criteria (AWQC), U.S. Fish and Wildlife Service Contaminant Hazard Reviews, Oak Ridge National Laboratory (ORNL) toxicological benchmarks (Suter and Mabrey 1994), and scientific literature. The comparison to the benchmark is expressed as the ratio of the exposure estimate to the benchmark and is expressed as a hazard quotient (HQ).

$$HQ = \frac{\text{exposure estimate}}{\text{benchmark value}}$$

It should be understood that this hazard quotient does not have the same meaning as the noncarcinogenic hazard quotient used in human health risk assessments. Concentrations or exposures exceeding the benchmark (HQ>1) do not necessarily indicate significant risk but that professional judgement should be used to decide what level of further evaluation of the contaminant is warranted.

3.3.2 Landfill Leachate Emerging as Seep Water

Human Health

The PRG screen for landfill leachate was performed using data from the seep at SW097. Results of the PRG screen are presented in Table 3-1. None of the PCOC concentrations in leachate seep water (from Section 2.5.3) exceeded the PRGs for an open-space recreational user, indicating that risk of exposure to PCOCs in leachate seep water is less than the target cancer risk of 1E-06 and an HI of 1 of each chemical. Therefore, no further analysis was performed.

Ecological Receptors

Exposure of aquatic organisms to contaminants in leachate seep water was estimated for direct contact using data from the seep at SW097. To determine if PCOCs in leachate seep water present an unacceptable toxicological risk to aquatic life, ecotoxicological benchmarks were compared to maximum detected concentrations in leachate seep water (see Table 3-2).

Hazard quotients (HQs) exceeded 1 for several PCOCs (see Table 3-2). PCOCs contributing the most to the ecological toxicity estimates were polycyclic aromatic hydrocarbons (PAHs) with HQs greater than 1,000 (see Table 3-2). Because PAHs are hydrophobic, they may pose risk to benthic macroinvertebrates from contamination in sediment. However, an intermittent aquatic community, such as a seep, is not likely to provide adequate habitat for establishment of permanent aquatic communities. In addition, risks from PAHs may be overestimated because risk calculations were performed using total analyte concentrations in leachate seep water. Dissolved concentrations are most appropriate for evaluation of toxicity to pelagic organisms because Colorado water quality standards are based on dissolved concentrations, and transdermal and gill intake are the principal exposure routes for these organisms. It is unlikely that high concentrations of PAHs would be detected in dissolved fraction of water samples.

Barium was the primary inorganic chemical with a maximum detected concentration that exceeded the water-quality standard (see Table 3-2). No aquatic-life-based surface-water standard was available for

barium. The Safe Drinking Water Act (SDWA) set the barium maximum contaminant level (MCL) and maximum contaminant level goal (MCLG) at 2,000 mg/L for human consumption. IRIS reported a human no observed adverse effects level (NOAEL) of 10 mg/L. The Clean Water Act's AWQC chose not to set barium standards for aquatic organisms. Soluble and toxic forms of barium in freshwater or marine ecosystems were thought unlikely due to the physical and chemical properties of barium. Therefore, EPA chose not to set freshwater or marine AWQC. Barium is not believed to be toxic to aquatic life under the freshwater conditions likely to occur at OU 7. The remaining analytes with HQs above 1 include manganese, zinc, and strontium (see Table 3-2).

Results of the screening-level ecological risk evaluation for aquatic life indicate a relatively high potential for toxic effects from chemical concentrations in leachate seep water. However, the presence of aquatic habitat in these areas is seasonally intermittent and represents a small (less than 1 percent) portion of aquatic habitat onsite. Intermittent habitats such as this can be important to amphibian and other semi-aquatic organisms. However, one objective of capping the landfill is to attenuate percolation and leaching of waste materials. As a result, the chemical content of seep water will change. In addition, as the landfill dewaters, the presence of water in downgradient seeps will diminish and the availability for these habitats to semiaquatic and aquatic organisms will also decrease.

3.3.3 Surface Soils and Subsurface Soil Downgradient of the Landfill

Human Health

The PRG screen for surface soils was performed using data collected from the 0- to 2-in. depth interval in the surface soils downgradient of the landfill. Concentrations of arsenic and radium-226 in surface soils exceeded PRGs for the open-space recreational user (see Table 3-3). A PRG value was not available for lead; however, the maximum detected lead concentration (167 mg/kg) was lower than the residential soil screening level of 400 mg/kg identified by EPA in OSWER Directive 9355.4-12 (EPA 1994a). Based on this comparison, lead concentrations do not appear to represent unacceptable risk.

Risk calculations were performed for arsenic and radium-226. Potential exposure pathways for surface soil include particulate inhalation, ingestion, dermal contact, and external irradiation (see Figure 3-1). Risks were not calculated for dermal exposure to surface soils because the surface-soil PCOCs that failed the PRG screen include only a metal (arsenic) and a radionuclide (radium-226) and, in accordance with EPA guidance, dermal exposure to metals and radionuclides should not be quantified (EPA 1989a).

The methodology used to evaluate the risks of exposure to surface soil follows EPA Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A (EPA 1989a) and Part B (EPA 1991b). Exposure factors for each pathway in the open-space exposure scenario are presented in Tables 3-4, 3-5, and 3-6 (DOE 1995h). The UCL95 of the mean was used to estimate risk. Chemical and radionuclide intakes for each pathway were calculated using:

Incidental Ingestion

Noncarcinogenic Chemical Intake (mg/kg-day) = (3-1)

$$\frac{C_s \times IR \times ME \times EF \times ED}{BW \times AT}$$

Carcinogenic Chemical Intake (mg/kg-day) = (3-2)

$$C_s \; x \left[\left(\frac{IR_c \, x \, ED_c}{BW_c} \right) x \left(\frac{IR_a \, x \, ED_a}{BW_a} \right) \right] x \, ME \, x \, EF$$

Radionuclide Intake (pCi) = (3-3)

$$C_s \, x \, [(IR_c \, x \, ED_c) + (IR_a \, x \, ED_a)] \, x \, ME \, x \, EF$$

where

C_s = concentration or activity in soil (mg/kg or pCi/g)
IR = ingestion rate (IR_c for child, IR_a for adult) (mg/visit)
ME = matrix effect in the GI tract (absorption factor) (unitless)
EF = exposure frequency (visits/year)
ED = exposure duration (EDc for child, ED_c for adult) (years)
BW = body weight (BW_c for child, BW_a for adult) (kilograms)
AT = averaging time (days)

Age-Adjusted IRs—Child and adult soil ingestion rates were evaluated in the open-space exposure scenario. For noncarcinogens, child and adult soil ingestion was evaluated separately, using the equation shown above and the parameter values listed in Table 3-4. This approach yields separate HIs for children and adults for the soil ingestion exposure route. The separate HI for children is a more protective estimate of potential noncarcinogenic hazard because it accounts for the greater amount of soil ingested by children relative to body weight.

For carcinogens, a combined child and adult ingestion rate was calculated by combining the ingestion rate, exposure duration, and body weight for both age groups. It is not necessary to calculate separate cancer risk estimates for children and adults because, according to theories of carcinogenesis currently advocated by EPA, a higher dose of a potential carcinogen over a short period of time is thought to have the same carcinogenic potential as a lower dose over a longer period of time.

Matrix Effect—The matrix effect (ME) describes the reduced bioavailability of a chemical bound to a soil matrix compared to the same chemical in solution. The ME may be used to account for decreased bioavailability if "the medium of exposure in the site exposure assessment differs from the medium of exposure assumed by the toxicity value" (EPA 1989a). EPA guidance further states that "a substance might be more completely absorbed following exposure to contaminated drinking water than following exposure to contaminated food or soil (e.g., if the substance does not desorb from soil in the gastrointestinal tract)." The literature values for soil matrix effects for arsenic and radium-226 are discussed in more detail below.

The absolute absorption of inorganics ingested in soil is less than that from water because inorganics only partially desorb from the soil. Arsenic administered to rabbits in soil was much less bioavailable (28 percent) than arsenic administered to rabbits in water (59 percent), corresponding to a soil matrix effect of 0.47 (Freeman et al. 1993). Consequently, an ME of 0.5 was used in calculating intake to account for the decreased toxicity of arsenic in soil relative to that in water or other solutions.

For radionuclides, ingestion slope factors were calculated using gastrointestinal absorption factors for soluble forms of each radionuclide; consequently, it would be appropriate to consider matrix effects as well as mineralized form to estimate carcinogenic effects from ingestion of radionuclides in a soil matrix (Nelson 1995). However, the reduction in potential toxic effects cannot be quantified by simply using a matrix effect because the adjustment must account for differential effects on target organs. Therefore, a matrix effect of 1 has been adopted for radium-226 in the risk calculations, even though this factor probably overestimates the effects of radionuclides ingested in soil.

Particulate Inhalation

Chemical Intake (mg/kg-day) = (3-4)

$$\frac{C_S \; x \, IR \, x \left(\frac{1}{PEF}\right) x \, ET \, x \, EF \, x \, ED}{BW \, x \, AT}$$

Radionuclide Intake (pCi) = (3-5)

$$C_S \; x \, IR \, x \; \frac{1}{PEF} \; x \, ET \, x \, EF \, x \, ED$$

where

Cs = concentration or activity in soil (mg/kg or pCi/g)
IR = inhalation rate (m^3/hour)
PEF = particulate emission factor (standard default [EPA 1991b]) (m^3/kg)
ET = exposure time (hours/visit)
EF = exposure frequency (visits/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days)

External Irradiation

$$Intake\ (pCi\text{-}yr/g) = C_S \times ET \times SF \times EF \times ED \quad (3\text{-}6)$$

where

C_S = activity in soil (pCi/g)
ET = gamma exposure time factor (unitless)
GSF = gamma shielding factor (unitless)
EF = exposure frequency ratio (unitless)
ED = exposure duration (years)

Cancer slope factors and chronic reference doses used in the risk calculations were taken from the Integrated Risk Information System (IRIS) (EPA 1995c) and Health Effects Assessment Summary Tables (HEAST) (EPA 1995d). Results of the risk calculations are presented in Tables 3-7, 3-8, and 3-9. Carcinogenic risk is below the EPA acceptable risk range for incidental ingestion of nonradionuclides (3E-07), incidental ingestion of radionuclides (1E-08), particulate inhalation (5E-11), and external irradiation (6E-09). Noncarcinogenic risk (hazard index) is below 1 for incidental ingestion by a child (HI = 0.004) and incidental ingestion by an adult (HI = 0.0005). These results indicate that there is negligible risk to human health from exposure to surface soils downgradient of the landfill for an open-space receptor and that the requirements to support a No Action or No Further Action (as defined by CERCLA) remedy have been met.

Ecological Receptors

Risks from exposure of ecological receptors to soil downgradient of the landfill were evaluated for vegetation and small mammals. Risks to vegetation were based on direct contact of roots with subsurface soils downgradient of the landfill. Risks to small mammals were evaluated for incidental ingestion of surface soil, exposure to radionuclides in surface and subsurface soils, and inhalation of volatilized organic compounds in burrows.

Risks to vegetation are summarized in Table 3-10. A very high HQ was observed for exposure to a maximum nitrate/nitrite concentration of 20,000 mg/kg. However, the next highest concentration detected was 2 mg/kg, which corresponds to an HQ of 0.1. The reason for the disparate data on nitrate/nitrite concentrations is unclear. However, this high value of nitrate/nitrite is an outlier. Contamination may be restricted to a small area east of the current landfill face, but the lack of extensive subsurface soil data makes distribution difficult to assess.

Other subsurface soil PCOCs with HQ values greater than 1 include naturally occurring metals. For all but lithium, concentrations detected are less than two times natural background concentrations and correspond to HQ values of 1.7 or less (see Table 3-10). Although the HQ values are greater than one, risk from the low magnitude of concentrations appears to be minimal. The TRVs for these metals are based on concentrations resulting in sublethal effects and chemical forms that are highly bioavailable (e.g., readily soluble). The HQ calculation assumes that the metals in soils are 100 percent bioavailable. Bioavailability of most metals is usually less than 50 percent.

Risks to small mammals from incidental ingestion of surface soils downgradient of the landfill appears to be negligible (see Tables 3-11 and 3-12). HQs for all non-radionuclide PCOCs screened were below 0.4

and the hazard index was less than 1, indicating that contaminant concentrations were all below levels that result in toxic exposures (see Table 3-11). The same was true for radionuclides in surface and subsurface soils downgradient of the landfill where the highest HQ was 0.53 (see Table 3-12).

Potential risks of inhalation of volatilized organic compounds were also evaluated for small mammals living in areas immediately east of the landfill face. However, a toxicological benchmark for respiratory exposure was available for only toluene. An airborne concentration of 226 mg/m^3 was obtained from IRIS. The potential concentration of toluene in burrow air was calculated using the maximum detected subsurface soil concentration and Henry's law constant (DOE 1995i). The HQ for toluene calculated from the maximum soil concentration was 5.2 (see Table 3-13). Airborne concentrations for other organic PCOCs are also presented in Table 3-13.

For small mammals and vegetation, the areas of OU 7 with potentially toxic concentrations of PCOCs are small and represent only a fraction of the total communities at Rocky Flats. In addition, these areas are of relatively low quality compared to most of the buffer zone. Thus, the impacts to vegetation communities and wildlife habitat quality appear to be minimal or negligible. In the assessment of the impacts to local ecosystmes, the effects at the population and community levels of biological organization are the most important (Barnthouse 1993).

However, impacts to individuals are important when assessing risks to species of special concern such as federal- or state-designated threatened or endangered species. Although not legally protected, Preble's meadow jumping mouse is a species of special concern in Colorado. Although surveys have not resulted in confirmation of the presence of this mouse at OU 7, the area around the East Landfill Pond has been identified as potential habitat. Thus, risks to Preble's meadow jumping mouse from chemical contamination at OU 7 appear to be minimal unless the onsite distribution of the mouse expands into this area.

3.3.4 Groundwater Downgradient of the Landfill

Human Health

The PRG screen for groundwater downgradient of the landfill was performed assuming the groundwater would emerge as surface water. Results of the PRG screen are presented in Table 3-14. None of the PCOCs for groundwater (see Section 2.5.6) exceeded the PRGs for an open-space recreational user, indicating that risk of exposure to PCOCs in groundwater was within acceptable ranges.

Ecological Receptors

Exposure of aquatic organisms to contaminants in groundwater downgradient of the landfill was estimated for direct contact with groundwater emerging as surface water. The same methods used to evaluate risks to aquatic life from leachate seep water were used to evaluate risks from groundwater downgradient of the landfill emerging as surface water. The screening-level assessment focused on risks to aquatic life by comparing maximum detected groundwater PCOC concentrations to water-quality standards (see Table 3-15). The benchmarks used for comparison to maximum detected concentrations in groundwater were based on Colorado surface-water standards for protection of aquatic life (5 CCR 1002-8), EPA AWQC, or risk-based values derived from other sources such as the environmental restoration program at ORNL (Suter and Mabrey 1994).

Comparisons of maximum detected concentrations in groundwater downgradient of the landfill to water-quality standards indicate that selenium, silver, strontium, and antimony are present at levels exceeding surface-water standards (see Table 3-15).

Groundwater from OU 7 could adversely affect surface-water quality and may pose a risk to aquatic life. However, the risk associated with existing groundwater contamination downgradient of the landfill is limited by several factors. The potential impact is dependent on a complete pathway to a surface-water body. As discussed in the conceptual site model (see Section 3.2), the chance that groundwater will intercept the main stem of Walnut Creek is negligible. In addition, mixing of contaminated groundwater with surface water would dilute contaminant concentrations and reduce risk from exposure.

Also, one objective of capping the landfill is to attenuate percolation and leaching of waste materials. As a result, contaminant concentrations in groundwater downgradient of the landfill will be reduced. In addition, as the landfill dewaters, the presence of water in downgradient areas will diminish and the availability for aquatic habitats will also decrease.

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 the Superfund Amendments and Reauthorization Act (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. According to the CERCLA Compliance with Other Laws manual, "when identifying potential ARARs under a state program which has granted federal authorization...the authorized state requirement is to be documented as the potential ARAR" (EPA 1989b). Additionally, because Rocky Flats is a DOE facility, DOE orders are to be considered (TBCs) which are legally enforceable by DOE against contractors that operate DOE facilities.

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 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 300.5).

The risk assessment process was 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). ARARs may or may not be consistent with the risk-based limits, but the ARARs represent the regulatory standard to be achieved.

OU 7 remediation and closure activities will be conducted in accordance with the IAG (DOE 1991b). Part 18 of the IAG states that response actions conducted entirely onsite are exempted from the procedural requirements to obtain permits. However, these actions must satisfy applicable or relevant

and appropriate federal and state standards, requirements, criteria, or limitations that would have been included in such permits.

There are three types of ARARs: (1) chemical-specific, (2) location-specific, and (3) 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 TBC is identified where appropriate. TBCs are advisories, criteria, or guidance that may be useful in developing CERCLA remedies (40 CFR 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 for analytes identified as PCOCs during the RFI must be complied with when determining appropriate cleanup levels for landfill leachate 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 both groundwater and surface water, the most stringent standard was chosen for each chemical and compared to the practical quantitation limit (PQL), cited in the regulations, for that chemical. The higher value of the two was selected as the potential ARAR. Table 3-16 presents potential chemical-specific ARARs for surface water. Table 3-17 presents potential chemical-specific ARARs for groundwater. These ARARs are very similar for the two media because the groundwater ARARs are based on discharge to surface water. No potential chemical-specific ARARs for surface soils have been identified.

Landfill Leachate at the Seep

Concentrations of analytes detected in landfill leachate at the seep were compared to the potential chemical-specific ARARs for groundwater and surface water. Analytes exceeding groundwater ARARs at the seep are presented in Table 3-18. Total iron, dissolved and total manganese, and dissolved and total zinc exceeded the corresponding ARARs for every sample (nine samples), with iron concentrations ranging up to 117 mg/L (ARAR of 1,000 mg/L). The other metal concentrations were all within an order of magnitude of the ARARs. Napthalene and methylene chloride were the organic constituents that each exhibited at least one exceedance of the groundwater ARARs. For napthalene, all five samples exceeded the ARAR but were no more than two and a half times the ARAR. For methylene chloride, only 1 detection (6 mg/L) out of 11 samples exceeded the ARAR of 4.7 mg/L.

The same exceedances were observed for these analytes with regard to surface-water ARARs (see Table 3-19). This is because the groundwater ARARs are based on discharge of groundwater to surface water.

Groundwater Downgradient of the Landfill

Concentrations of analytes detected in UHSU groundwater in individual wells downgradient of the East Landfill Pond dam were compared to the potential chemical-specific ARARs for groundwater. Analytes currently exceeding groundwater ARARs are presented in Table 3-20. Dissolved chromium and total iron and lead exhibited at least one exceedance of the corresponding ARARs in the alluvial aquifer. Dissolved chromium was detected and exceeded the ARAR of 11 mg/L only once (15.2 mg/L). Total

iron exceeded the ARAR five times out of seven samples at wells 4287 and 53194 but was within an order of magnitude of the ARAR. Total lead exceeded the ARAR of 28 mg/L only once (50.5 mg/L).

The groundwater ARARs are based on surface-water quality standards for Segment 4 (Walnut Creek drainage) because the potential exists (although it is very small) for the groundwater to ultimately discharge to No Name Gulch. Due to institutional controls and future land uses agreed to by the agencies, no drinking water or agricultural use standards are applicable to the groundwater. Therefore, the standards are based on acute and chronic criteria for aquatic life that are dependent on the hardness of the water. However, there has never been any water or aquatic life observed in No Name Gulch, so it is apparent that the groundwater does not discharge to surface water. A modeling evaluation of No Name Gulch has shown that it is a losing stream year-round. Even if the groundwater did discharge to surface water, the human health risk assessment showed that the risk to human receptors (based on an open-space land use and exposure scenario) is acceptable. In addition, the mean values for iron are less than the mean for background, and the maximum values are also less than the background maximum.

Estimation of Future ARARs Exceedances at the Point of Compliance

One-dimensional contaminant transport modeling in the alluvium in No Name Gulch was performed for those analytes that exceeded ARARs at the seep and at alluvial well 72293, the well located upgradient of the seep in the waste material and closest to the seep, to estimate their maximum concentrations at the most upgradient compliance well (well 4087) downgradient of the dam during the next 30 years. Although a summary of the modeling is presented here, a detailed discussion of the modeling methodology, input parameters, assumptions, and results is presented in Appendix D.

Analytes exceeding groundwater ARARs at alluvial well 72293 within the landfill are presented in Table 3-21. Total arsenic, dissolved cadmium, total iron, dissolved and total manganese, and dissolved selenium all exhibited at least one exceedance of the corresponding ARARs. Iron and manganese had the greatest frequencies of exceedances and the highest concentrations relative to the ARARs. Napthalene exhibited two exceedances of the corresponding ARAR out of 11 samples. In addition, ammonia exhibited four ARARs exceedances, the highest of which was more than three orders of magnitude greater than the ARAR.

The one-dimensional contaminant-transport modeling was performed using an analytical solution developed by Domenico and Robbins (1985). Model simulations were performed for VOCs, metals, and major ions identified as ARAR exceedances at monitoring well 72293 and the seep (SW097) located at the toe of the landfill. Although technically considered surface water, contaminated seep water may impact the shallow groundwater because under the current closure strategy the seep will become buried under the cap. Contaminants identified in weathered bedrock groundwater were excluded from the modeling simulations because the weathered bedrock pathway is not considered to be complete with respect to human or environmental receptors.

The results of the contaminant transport modeling showed that the only constituent currently exceeding ARARs at the seep or at alluvial well 72293 that might exceed an ARAR at the point of compliance during the 30-year postclosure period is total iron. The estimated concentration at the point of compliance is 1,771 mg/L, and the ARAR is 1,000 mg/L. The ARAR is based on chronic effects to aquatic life. However, these modeling results are overly conservative because a constant source was assumed. The Domenico and Robbins (1985) solution 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 will reduce groundwater flow through the landfill and contaminant transport out of the landfill.

Based on the flow modeling and particle tracking in Appendix C and the contaminant-transport modeling in Appendix D, 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 4087, B206989, and 53194 will be used to monitor groundwater quality downgradient of the landfill. Exceedance of ARARs at these wells is not projected during the 30-year postclosure period. The carcinogenic risk levels associated with the ingestion of groundwater by an open-space user is less than 1E-06. The noncarcinogenic risk is below the acceptable risk or HI of 1.

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 and their ARAR designation for OU 7 are presented in Table 3-22. Location-specific ARARs most pertinent to OU 7 concern wetlands, floodplains, and endangered species. Also considered are historic, natural, cultural, or archaeological resources.

Wetlands Requirements

Remedial actions at OU 7 will have to be implemented to minimize the destruction, loss, or degradation of wetlands (10 CRF 1022). This ARAR is designated as applicable. As described in Section 2.4.3, wetlands have been designated along the shoreline of the East Landfill Pond by the U.S. Army Corps of Engineers (see Figure 2-12) (COE 1994). Compensatory mitigation for unavoidable impacts to wetlands will be provided, in accordance with ARARs.

A wetlands assessment will be required under 10 CFR 1022. The CWA Section 404, Executive Order 11990, and 10 CFR 1022 have been identified as potential applicable ARARs, and substantive provisions must be met (see Table 3-20).

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 1994f). 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.

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, which is protected under the Colorado Nongame, Endangered, or Threatened Species Conservation Act (CRS 33-2-101 to 107). This act is a potential applicable ARAR for OU 7. DOE is committed to protect natural resources under the

Natural Resource Trustee Memorandum of Understanding (DOE 1994g), within approved scope and funding levels. However, no Preble's meadow jumping mice have been captured at OU 7 to date. Until the mouse is listed, and the presence of the mouse within OU 7 is confirmed, further specific planning for habitat mitigation is unwarranted.

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 3-23 lists the potential federal and state action-specific ARARs that have been identified for OU 7 and their ARAR designation. Table 3-24 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, and postclosure groundwater-monitoring requirements.

Closure Requirements

Because records indicate that some incidental 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 ARARs 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: (1) clean closure and (2) landfill closure. The Present Landfill at OU 7 will be closed under landfill closure standards, which require postclosure 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 1007-3 265.310[a]). Postclosure care includes maintenance of the final cover and maintenance of a groundwater-monitoring system (6 CCR 1007-3 265.117 and 265.228[b]).

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 onsites over 1 acre in a nonattainment 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 applicable ARAR under CERCLA. Additionally, unpaved roadways with vehicle traffic of 150 vehicles per day (in a nonattainment 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. Work at Rocky Flats is conducted in accordance with the Plan for Prevention of Contaminant Dispersion (PPCD), which directs safety measures during construction 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, NOx, 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 nonattainment area, as defined in the regulations. Rocky Flats is located in a nonattainment 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.

Postclosure Groundwater-Monitoring Requirements

Postclosure groundwater monitoring must be conducted to satisfy the requirements under 6 CCR 1007-3 265.310(b)(3). The primary objective of the groundwater-monitoring program is to detect potential future releases that migrate beyond the boundary of OU 7. The groundwater-monitoring program is described in detail in Section 8.2.3.3.

3.5 FINAL REMEDIAL ACTION OBJECTIVES OR RESPONSE ACTIONS

Final RAOs were developed based on preliminary RAOs (see Section 3.1), 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 were identified and 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 landfill gas (see Table 3-25). In addition, DOE, EPA, and CDPHE have agreed that the East Landfill Pond will be removed and the dam and pond sediments will be removed and consolidated in the landfill under the cap. Therefore, exposure pathways for the pond and sediments are not complete, and risk evaluations were not performed.

For media not addressed by the presumptive remedy or removal actions, EPA guidance (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 seep water and surface soils and groundwater downgradient of the landfill. Ultimately, it is necessary to demonstrate that the final remedy addresses all pathways and contaminants of concern.

3.5.1 Elimination of Preliminary RAOs

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

- Remediate surface soils downgradient of the landfill
- Remediate subsurface geologic materials downgradient of the landfill
- Remediate groundwater downgradient of the landfill

The rationale for eliminating each of these RAOs is summarized in Table 3-25 and presented below.

Remediate Surface Soils Downgradient of the Landfill

Carcinogenic risks fall below the EPA acceptable risk range of 1E-04 to 1E-06 and noncarcinogenic risks are below the HI of 1. Ecological risks from surface soils are minimal. Therefore, surface soils do not require a response action (see Table 3-25) and DOE proposes to leave the surface soils downgradient of the landfill undisturbed.

Remediate Subsurface Geologic Materials Downgradient of the Landfill

Exposure of open-space recreational users to subsurface geologic materials downgradient of the landfill is an incomplete pathway. Ecological risks from subsurface geologic materials are minimal. Therefore, DOE proposes to leave the subsurface soils undisturbed.

Remediate Groundwater Downgradient of the Landfill

The potential exposure pathway associated with UHSU groundwater downgradient of the landfill is not complete because the groundwater does not discharge to surface water. Even if the groundwater did emerge as surface water, carcinogenic risks fall below the EPA acceptable risk range of 1E-04 to 1E-06 and noncarcinogenic risks are below the HI of 1. No plans are anticipated for the future development of groundwater for any use at OU 7, which eliminates the exposure route. Ecological risks from groundwater discharging to surface water are minimal.

Existing data and contaminant transport modeling show that the only ARAR exceedances in alluvial groundwater in the vicinity of the point of compliance are for dissolved chromium (only 1 exceedance), total iron, and total lead (only 1 exceedance). The frequency of exceedances for chromium and total lead is very small. With regard to potential impacts to human health, total iron is a conventional, nontoxic constituent that primarily affects the appearance of water and causes staining. The ARAR for total iron is based on chronic effects to aquatic life. However, only the dissolved fraction of the total iron is the bioavailable form and could impact aquatic life. In addition, a temporary modification currently exists for total iron for Stream Segment 5 (Walnut Creek drainage). This value is 13.2 mg/L, well above the existing and modeled iron concentrations. Iron concentrations are also less than background levels and will decrease over time as leachate generation and migration decreases once the cap is in place. Based on these consideration as well as the fact that the groundwater does not discharge to surface water and there are minimal risks from the constituents in the groundwater, remediation of the groundwater downgradient of the dam is not warranted, and no RAOs are defined for this area.

3.5.2 Final RAOs

Final RAOs that will be used for the identification and screening of technologies (see Section 4) and the development of alternatives (see Section 5) 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)
- Collect and treat leachate at the source (as needed)
- Control groundwater at the source

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

PCOC	Max Detected Concentration	Location of Max	Open Space Surface-Water PRG[1]		Max >PRG[2]
Metals					
Barium	759	SW097	2,380,000	mg/L	No
Lithium	46.4	SW097	681,000	mg/L	No
Manganese	1,520	SW097	170,000	mg/L	No
Strontium	976	SW097	20,400,000	mg/L	No
Zinc	2,630	SW097	10,200,000	mg/L	No
Radionuclides					
Strontium-89,90[3]	4.06	SW097	795	pCi/L	No
Tritium	1,500	SW097	622,000	pCi/L	No
Indicator Parameters					
Nitrite	63	SW097	3,410,000	mg/L	No
SVOCs					
2,4-Dimethylphenol	3	SW097	681,000	mg/L	No
2-Methylnaphthalene	23	SW097	—	mg/L	N/A
4-Methylphenol	4	SW097	—	mg/L	N/A
Acenaphthene	3	SW097	2,040,000	mg/L	No
Bis(2-ethylhexyl)phthalate	2	SW097	5,680	mg/L	No
Dibenzofuran	2	SW097	—	mg/L	N/A
Diethyl phthalate	3	SW097	27,300,000	mg/L	No
Fluorene	3	SW097	1,360,000	mg/L	No
Naphthalene	22	SW097	1,360,000	mg/L	No
Phenanthrene	5	SW097	—	mg/L	N/A
VOCs					
1,1-Dichloroethane	10	SW097	3,410,000	mg/L	No
1,2-Dichloroethene	5	SW097	307,000	mg/L	No
2-ButaNone	6	SW097	20,400,000	mg/L	No
Acetone	25	SW097	3,410,000	mg/L	No
Benzene	2	SW097	2,740	mg/L	No
Chloroethane	57	SW097	—	mg/L	N/A
Chloromethane	7	SW097	6,110	mg/L	No
Ethylbenzene	17	SW097	3,410,000	mg/L	No
Methylene chloride	6	SW097	10,600	mg/L	No
Toluene	47	SW097	6,810,000	mg/L	No
Total xylenes	24	SW097	68,100,000	mg/L	No
Trichloroethene	2	SW097	7,230	mg/L	No
Vinyl chloride	11	SW097	41.8	mg/L	No

Note:

[1] PRGs are presented in Programmatic Preliminary Risk-Based Remediation Goals for RFETS (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.

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

— No PRG is available
N/A Not applicable

Table 3-2 OU 7 Exposure Screen for Surface-Water Quality for Leachate Seep Water

PCOC (Total Analytes)	Max Detected Concentration at the Seep (SW097)	Units	Water-Quality Standard[1]	Hazard Quotient[2]
Naphthalene[3]	22	mg/L	0.0028	7,900
Phenanthrene[3]	5	mg/L	0.0028	1,800
Acenaphthene[3]	3	mg/L	0.0028	1,100
Fluorene[3]	3	mg/L	0.0028	1,100
Barium[4]	759	mg/L	4	190
Manganese[5]	1,520	mg/L	50	30
Zinc[6, 7]	2,630	mg/L	350	7.5
Strontium[4]	976	mg/L	620	1.6
Total xylenes[4]	24	mg/L	86.2	0.28
Toluene[4]	47	mg/L	176	0.27
1,1-Dichloroethane[4]	10	mg/L	47	0.21
1,2-Dichloroethene[5, 8]	5	mg/L	31.2	0.16
Bis(2-ethylhexyl)phthalate[9]	2	mg/L	360	<0.01
Methylene chloride[4]	6	mg/L	2,240	<0.01
Acetone[4]	25	mg/L	11,200	<0.01
Trichloroethene[5]	2	mg/L	21,900	<0.01
Strontium-89,90[10]	4.06	pCi/L	270,000	<0.01
Tritium[10]	1,500	pCi/L	190,000,000	<0.01
2,4-Dimethylphenol	3	mg/L	—	NC
2-Butanone	6	mg/L	—	NC
2-Methylnaphthalene	23	mg/L	—	NC
4-Methylphenol	4	mg/L	—	NC
Benzene	2	mg/L	—	NC
Chloroethane	57	mg/L	—	NC
Chloromethane	7	mg/L	—	NC
Dibenzofuran	2	mg/L	—	NC
Diethyl phthalate	3	mg/L	—	NC
Ethylbenzene	17	mg/L	—	NC
Lithium	46.4	mg/L	—	NC
Nitrite	63	mg/L	—	NC
Vinyl chloride	11	mg/L	—	NC

Notes:

1 Based on chronic exposure

2 Hazard quotient is rounded to two significant figures

3 Segment 5 Standards (5 CCR 1002-8, 3.8.0)

4 Oak Ridge Tier II, in EPA Proposed Water Quality Guidance for the Great Lakes System 1993, as cited in Suter and Mabrey 1994

5 Colorado Water Quality Standards

6 5 CCR 1002-8, Table 3, Temporary Modifications, Big Dry Creek, Segment 5

7 Based on "total recoverable" analysis

8 Acute value

9 Integrated Risk Information System

10 Higley and Kuperman 1995

— No standard available; not included in calculations NC Not calculated

Table 3-3 Preliminary Remediation Goal (PRG) Screen for Surface Soils Downgradient of the Landfill

PCOC	Max Detected Concentration	Location of Maximum	Open Space Soil/Sediemnt PRG[1]	Units	Max >PRG[2]
Metals					
Antimony	7.2	SS701493	3,070	mg/kg	No
Arsenic	13.2	SS705393	10	mg/kg	yes
Barium	1,120	SS705193	535,000	mg/kg	No
Copper	640	SS121394	307,000	mg/kg	No
Lead	167	SS708893	—	mg/kg	N/A
Mercury	0.13	SS719793	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	N/A
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/nitrite4	45	SS710893	>1,000,000	mg/kg	No

Notes:

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

[2] If the maximum detected concentration is greater than the PRG, the analyte is evaluated in the risk assessment. PRGs are developed for those analytes with toxicity criteria. Only analytes with PRGs are evaluated in the risk assessment.

[3] The PRG is for radium-226 and daughter products.

[4] The PRG is for nitrate, because it is the dominant species present.

— No PRG is available
NA Not applicable

Table 3-4 Site-Specific Exposure Factors for Incidental Ingestion of Surface Soil[1] Open-Space Exposure Scenario

		Reasonable Maximum Exposure (RME) Value		
Exposure Factor	**Abbreviation**	**Child**	**Adult**	**Units**
Ingestion Rate[2]	IR	100	50	mg/visit
Matrix Effect in GI Tract (Absorption Factor)	ME	Chem Spec[3]	Chem Spec[3]	unitless
Exposure Frequency	EF	25	25	visits/year
Exposure Duration	ED	6	24	years
Body Weight	BW	15	70	kg
Avg Time — Noncarcinogen	ATN	2,190	8,760	days
Avg Time — Carcinogen	ATC	25,550	25,550	days

Notes:

1 Exposure parameters are presented in Open-Space Exposure Parameters (DOE 1995h).
2 For noncarcinogens, child and adult soil ingestion rates were evaluated separately; for carcinogens, a combined child and adult ingestion rate was calculated.
3 A matrix effect of 0.5 was used for arsenic; a matrix effect of 1 was used for radium-226.

Table 3-5 Site-Specific Exposure Factors for Particulate Inhalation of Surface Soil[1] Open-Space Exposure Scenario.

Exposure Factor	Abbreviation	Reasonable Max Exposure (RME) Value	Units
Inhalation Rate	IR	1.4	m^3/hour
Particulate Emission Factor	PEF	4.63E+09	m^3/kg
Exposure Time	ET	5.0	hours/visit
Exposure Frequency	EF	25	visits/year
Exposre Duration	ED	30	years
Body Weight	BW	70	kg
Averaging Time – Carcinogen	ATC	25,550	days

Note:

[1]Exposure parameters are presented in Open-Space Exposure Parameters (DOE 1995h) and Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part B (EPA 1991b).

Table 3-6 Site-Specific Exposure Factors for External Irradiation of Surface Soil[1] Open-Space Exposure Scenario.

Exposure Factor	Abbreviation	Reasonable Max Exposure (RME) Value	Units
Gamma Exposure Time Factor	ET	0.2	Unitless
Gamma Shielding Factor	GSF	1.0	Unitless
Exposure Frequency Ratio	EF	0.07	Unitless
Exposure Duration	ED	30	Years

Note:

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

Table 3-7 Potential Risks Associated with Incidental Ingestion of Surface Soil[1] Open-Space Exposure Scenario

Carcinogenic Risk							
Chemical[2]	**UCL_{95}**		**Intake[3]**		**Oral Cancer Slope Factor[4]**		**Carcinogenic Risk**
Arsenic	5.52	5.52	1.5E-07	mg/kg-day	1.75E+00	$(mg/kg\text{-}day)^{-1}$	3E-07
Total Carcinogenic Risk							3E-07
Radionuclide[2]	**UCL_{95}**		**Intake[3]**		**Oral Cancer Slope Factor[4]**		**Carcinogenic Risk**
Radium-226	1.07	pCi/g	48	pCi	2.95E-10	risk/pCi	1E-08
Total Carcinogenic Risk							1E-08
Noncarcinogenic Effects – Child							
Chemical[2]	**UCL_{95}**		**Intake[3]**		**Oral Chronic Ref Dose[4]**		**Hazard Quotient**
Arsenic	5.52	mg/kg	1.3E-06	mg/kg-day	3E-04	mg/kg-day	0.004
Hazard Index							0.004
Noncarcinogenic Effects – Adult							
Radionuclide[2]	**UCL_{95}**		**Intake[3]**		**Oral Chronic Ref Dose[4]**		**Hazard Quotient**
Radium-226	5.52	mg/kg	1.4E-07	mg/kg-day	3E-04	mg/kg-day	0.0005
Hazard Index							0.0005

Note:

[1]Risks were calculated for those chemicals with oral toxicity criteria. Slight rounding may occur.

[2]COCs were identified from the PRG screen.

[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.

[4]Oral toxicity values are from IRIS (EPA 1995c) and HEAST (EPA 1995d).

Table 3-8 Potential Risks Associated with Particulate Inhalation from Surface Soil [1] Open-Space Exposure Scenario

Carcinogens[2]	UCL_{95}		Intake[3]		Inhalation Cancer Slope Factor[4]		Carcinogenic Risk
Arsenic	5.52	mg/kg	3.5E-12	mg/kg-day	1.51E+01	$(mg/kg\text{-}day)^{-1}$	5E-11
Radium-226	1.07	pCi/g	1.2E-03	pCi	2.72E-09	risk/pCi	3E-12
Total Carcinogenic Risk							5E-11

Note:

[1]Risks were calculated for those chemicals with external exposure toxicity criteria. Slight rounding may occur.
[2]COCs were identified from the PRG screen.
[3]Exposure factors used to calculate external exposure from surface soil in an open-space exposure scenario are presented in Table 3-6.
[4]External exposure toxicity values are from HEAST (EPA 1995d).

Table 3-9 Potential Risks Associated with External Irradiation from Surface Soil [1] Open-Space Exposure Scenario

Carcinogens[2]	UCL_{95}		External Exposure[3]		External Exposure Cancer Slope Factor[4]		Carcinogenic Risk
Radium-226	1.07	pCi/g	0.45	pCi-yr/g	1.31E-08	Risk/yr per pCi/g Soil	6E-09
Total Carcinogenic Risk							6E-09

Note:

[1]Risks were calcualted for those chemicals with external exposure toxicity criteria. Slight rounding may occur.
[2]COCs were identified from the PRG screen.
[3]Exposure factors used to calculate external exposure from surface woil in an open-space expsoure scenario are presented in Table 3-7.
[4]External exposure toxicity values are from HEAST (EPA 1995d)

Table 3-10 Vegetation Screen for Subsurface Soil Downgradient of the Landfill

Subsurface Soil PCOC	Max Detected Concentration in Subsurface Soil (mg/kg)	Units	Vegetation Toxicity Reference Value[1]	Detection Frequency (%)	Hazard Quotient
Nitrate/Nitrite2	20,000	mg/kg	19.1	60	1,047
Lithium	9.9	mg/kg	2	100	5.0
Strontium	107	mg/kg	62.9	100	1.7
Zinc	72.2	mg/kg	50	100	1.4
Barium	624	mg/kg	500	100	1.2
Vanadium	43.6	mg/kg	36.3	100	1.2
Aluminum	16,100	mg/kg	14,600	100	1.1
Arsenic	7.9	mg/kg	10	100	0.79
Chromium	16.9	mg/kg	22.9	100	0.74
Nickel	18.4	mg/kg	30	100	0.61
Lead	27.9	mg/kg	50	100	0.56
Manganese	262	mg/kg	500	100	0.52
Selenium	0.74	mg/kg	1.45	100	0.51
Cobalt	10.9	mg/kg	25	100	0.44
Copper	17.7	mg/kg	100	100	0.18
Beryllium	1.2	mg/kg	10	100	0.12
Nitrate[3]	2	mg/kg	19.1	40	0.10
Toluene	2	µg/kg	200	100	0.010
Total xylenes	0.002	µg/kg	200	20	<0.01
Tin	8.9	mg/kg	—	71	NC
Benzo(a)anthracene	0.048	µg/kg	—	14	NC
Chrysene	0.043	µg/kg	—	14	NC
Fluoranthene	0.11	µg/kg	—	14	NC
Phenanthrene	0.1	µg/kg	—	14	NC
Pyrene	0.11	µg/kg	—	14	NC
4-Methyl-2-pentanone	0.058	µg/kg	—	20	NC
Hazard Index					1,055

Notes:

[1] Toxicity reference value is either the literature benchmark or background concentration, whichever is larger.
[2] The maximum is the only concentration above 2 mg/kg.
[3] Toxicity reference value is estimated from nitrate/nitrite.

— Toxicity reference value not available; not included in calculations
NC Not calculated

Table 3-11 Summary of Ecotoxicological Risk to Small Mammals from Incidental Inlngestion of Surface Soils Downgradient of the Landfill*

Surface Soil PCOC	Max Detected Concen (mg/kg)	Intake	Toxicity Reference Value	Hazard Quotient
Barium	1,120	4.480	14.22	0.32
Vanadium	86.2	0.345	2.31	0.15
Antimony	7.2	0.029	0.35	0.083
Arsenic	13.2	0.053	0.68	0.078
Copper	640	2.560	43.33	0.059
Mercury	0.13	0.001	0.02	0.050
Selenium	2.9	0.012	0.32	0.038
Lead	167	0.668	20.93	0.032
Thallium	2.1	0.008	0.70	0.011
Nitrate/nitrite	45	0.180	34.67	<0.01
Zinc	113	0.452	418.66	<0.01
Strontium	80.6	0.322	688.18	<0.01
Silver	3	0.012	58.63	<0.01
Hazard Index				0.82

Notes:

* Exposure parameters for Preble's meadow jumping mouse were used in calculations.

IR Ingestion rate = 0.004 kg/kg/day. The soil ingestion rate was estimated by multiplying the proportion of soil in the diet (EPA 1993) (0.024 dry weight) by the total dietary ingestion rate (DOE 1995b) (0.17 kg/kg/day). The meadow vole was used as a "reference" species to calculate the soil ingestion rate for Preble's meadow jumping mouse.

SUF Site use factor = 1

Table 3-12 Radionuclide Screen for Surface Soils and Subsurface Soil Downgradient of the Landfill

Surface Soil PCOC	Max Detected Concentration in Surface Soil (pCi/g)	Toxicity Reference Value[1] (pCi/g)	Hazard Quotient
Surface Soil PCOC			
Radium-226	1.787	5.4	0.33
Americium-241	1.076	1,900	<0.01
Plutonium-239/240	0.4692	3,800	<0.01
Hazard Index			0.33
Subsurface Soil PCOC			
Radium-228	1.859	3.5	0.53
Radium-226	1.083	5.4	0.20
Strontium-89,90	0.4153	120	<0.01
Cesium-137	0.2386	84	<0.01
Tritium2	301.5	350,000	<0.01
Uranium-238	1.233	1,600	<0.01
Uranium-233,-234	1.166	1,800	<0.01
Uranium-235	0.05357	1,900	<0.01
Americium-241	0.0143	1,900	<0.01
Plutonium-239/240	0.01842	3,800	<0.01
Hazard Index			0.74

Notes:

1 Toxicity reference values are from Higley and Kuperman (1995), Radiological Benchmarks for Wildlife at Rocky Flats Environmental Technology Site. Toxicity reference value is the ecotoxicological benchmark for small mammals, which represents bounding exposure based on their sensitivity, small home ranges, and continuous contact with soil.

2 Tritium was measured in pCi/L; this screen assumes 1 kg tritium is equivalent to 1 L tritium.

Table 3-13 Small Mammal Burrow Air Screen for Subsurface Soil Downgradient of the Landfill

Subsurface Soil PCOC	Molecular Weight [2] (grams/mole)	Henry's Law Constant [2] (atm m3/ mole)	Max Detected Concentration in Subsurface Soil [1] (mg/kg)	Molar Concentration in Subsurface Soil [3] (mole/m3)	Partial Pressure (v_p) (atm)	Estimated Concentration in Burrow Air (mg/m3)	Inhalation Toxicity Reference Value from IRIS (mg/m3)	Hazard Quotient
Toluene	92	6.70E-03	2.00E+00	4.35E-02	2.91E-04	1.17E+03	226	5.2
4-Methyl-2-pentanone	100	1.49E-05	5.80E-02	1.16E-03	1.73E-08	7.52E-02	ND[3]	NC
Benzo(a)anthracene	228	2.30E-06	4.80E-02	4.21E-04	9.68E-10	9.60E-03	ND[3]	NC
Chrysene	228	7.26E-20	4.30E-02	3.77E-04	2.74E-23	2.72E-16	ND	NC
Fluoranthene	202	1.69E-02	1.10E-01	1.09E-03	1.84E-05	1.62E+02	ND[3]	NC
Phenanthrene	178	3.90E-05	1.00E-01	1.12E-03	4.38E-08	3.39E-01	ND[3]	NC
Pyrene	202	1.09E-05	1.10E-01	1.09E-03	1.19E-08	1.04E-01	ND[3]	NC
Total xylenes	106	6.46E-03	2.00E-03	3.77E-05	2.44E-07	1.12E+00	ND[3]	NC
Hazard Index								5.2

Note:

[1] Source: OU 7 Final Work Plan (DOE 1994a)
[2] Source: Subsurface Transport and Fate Processes (Knox et al. 1993)
[3] Soil density is assumed to be 2,000 kg/m3 .
[4] EPA suggested reference concentration is pending.

IRIS Integrated Risk Information System (1995)
ND No data available
NC Not calculated

Table 3-14 Preliminary Remediation Goal (PRG) Screen for Groundwater Downgradient of the Landfill.

PCOC	Max Detected Concentration	Location of Max	OpenSpace Surface-Water PRG[1]	Units	Maximum >PRG[2]
Metals					
Antimony	66.8	B207089	13,600	µg/L	No
Lead	50.5	53194	—	µg/L	N/A
Lithium	225	B206789	681,000	µg/L	No
Selenium	815	B206789	170,000	µg/L	No
Silver	10.9	B206789	170,000	µg/L	No
Strontium	1,870	B206789	20,400,000	µg/L	No
Indicator Parameters					
Fluoride	3,400	4087	2,040,000	µg/L	No
Nitrate/Nitrate3	190,000	B206889	54,500,000	µg/L	No
SVOCs					
Bis(2-ethylhexyl)phthalate	3	B206789	5,680	µg/L	No
VOCs					
1,1-Dichloroethane	0.3	0786	3,420,000	µg/L	No
2-Butanone	6	53194	20,400,000	µg/L	No
Benzene	0.5	B206889	2,740	µg/L	No
Carbon Tetrachloride	7.11	B206889	611	µg/L	No
Chloroethane	3	0786	—	µg/L	N/A
Ethylbenzene	0.3	B206889	3,410,000	µg/L	No
Methylene Chloride	3.19	B206889	10,600	µg/L	No
Tetrachloroethene	0.769	B206889	1,530	µg/L	No
Toluene	3	B206889	6,810,000	µg/L	No
Total Xylenes	3	B206889	68,100,000	µg/L	No
Trichloroethene	1.43	B206889	7,230	µg/L	No

Note:

[1]PRGs are presented in Programmatic Preliminary Risk-Based Remediatoin Goals for RFETS (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.

[3]The PRG is for nitrate because it is the dominant species present.

— No PRG is available
N/A Not Applicable

Table 3-15 OU 7 Exposure Screening for Surface-Water Quality for Groundwater Downgradient of the Landfill

PCOC (Total Analytes)	Max Detected Concentration for Groundwater	Units	Water-Quality Standard[1]	Hazard Quotient[2]
Selenium[3]	815	mg/L	17	48
Silver[3]	10.9	mg/L	3	3.6
Strontium[5]	1,870	mg/L	620	3.0
Antimony[5]	66.8	mg/L	30	2.2
Carbon tetrachloride[6,7]	7.11	mg/L	18	0.40
Total xylenes[4]	3	mg/L	86.2	0.035
Toluene[4]	3	mg/L	176	0.017
Bis(2-ethylhexyl)phthalate[5]	3	mg/L	360	<0.01
1,1-Dichloroethane[4]	0.3	mg/L	47	<0.01
Lead[8, 9]	50.5	mg/L	27,274	<0.01
Methylene chloride[4]	3.19	mg/L	2,240	<0.01
Tetrachloroethene[8]	0.769	mg/L	840	<0.01
Trichloroethene[8]	1.43	mg/L	21,900	<0.01
2-Butanone	6	mg/L	—	NC
Benzene	0.5	mg/L	—	NC
Chloroethane	3	mg/L	—	NC
Ethylbenzene	0.3	mg/L	—	NC
Fluoride	3,400	mg/L	—	NC
Lithium	225	mg/L	—	NC
Nitrate/Nitrite	190,000	mg/L	—	NC
Hazard Index				57

Notes:

— No standard available; not included in calculations
NC Not calculated

[1] Based on chronic exposure
[2] Hazard quotient is rounded to two significant figures.
[3] Segment 5 Standards (5 CCR 1002-8, 3.8.0)
[4] Oak Ridge Tier II, in EPA Proposed Water Quality Guidance for the Great Lakes System 1993, as cited in Suter and Mabrey 1994
[5] Integrated Risk Information System
[6] 5 CCR 1002-8, Table 3, Temporary Modifications, Big Dry Creek, Segment 5
[7] Final residual value is expressed as total.
[8] Colorado Water Quality Standards
[9] Calculated using the A-series pond's UCL95 for hardness of 51,762 mg/L.

Table 3-16 Surface-Water ARARs

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]				Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5 (pCi/L)	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16										
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life		Agriculture (TR)	Acute	Chronic	Site-Specific Organic Stnds	Section 3.8.5 Table 3[4]				
			Acute	Chronic									
Metals													
Antimony											0.3		
Arsenic	0.05		0.36		0.1						0.01	0.05	0.3600
Barium	1										0.02	1	
Calcium													
Iron				1 (TR)					13.2(TR)			1	
Lithium													
Magnesium													
Manganese				1 (TR)	0.2				0.56(D,a)			0.2	0.5600
Molybdenum													
Nickel			2.9461	0.3053	0.2	2.9554	0.3053				0.05	0.2	0.3053
Potassium													
Selenium	0.01		0.135	0.017	0.2	00.135	0.017				0.02	0.02	0.02
Silicon											0.02		
Sodium													
Strontium													
Thallium				0.0150							0.4		0.0150
Tin											8		
Zinc			0.472	0.3869	2	0.4272	0.3869		.35(TR)		0.02	0.35	0.3869
Radionuclides[5]													
Americium 241										30			
Gross Alpha										15			
Gross Beta													
Plutonium 239, 240										30(A) 2000(B)			
Strontium 89,90										20,000(E,F,4) 1,000(E,5) 10,000(F,5) 800(E,F,4) 40(E,5) 400(F,5)			

Table 3-16 (continued)

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]				Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5 (pCi/L)	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16										
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life		Agriculture (TR)	Acute	Chronic	Site-Specific Organic Stnds	Section 3.8.5 Table 3[4]				
			Acute	Chronic									
Tritium										2,000,000	1,000 (pCi/L)	2,000,000 (pCi/L)	
Uranium 235										600(C) 5000(D)		600(pCi/L,C)	
Uranium 238										600(C) 6000(D)		600(pCi/L,C)	
Water Quality Parameters													
Chloride													
Cyanide					0.2							0.2	
Fluoride													
Nitrate/Nitrite					100							100	
Nitrate					10							10	
Sulfate													
Total Dissolved Solids													
VOCs													
1,1-Dicholorethane											0.001		
2-Butanone											0.01		
2-Hexanone											0.05		
4-Methyl-2-Pentanone											0.05		
Acetone											0.1		
Benzene		5.3(AC)									0.001	5.3	
Carbon Disulfide													
Chloroethane											0.005		
Chloromethane											0.001		
Ethylbenzene		32(AC)									0.01	32	
Methylene Chloride								0.0047			0.001	0.0047	
Tetrachloroethene		5.280(AC) 0.84(CH)						0.0008			0.001	0.001 17.5	
Toluene		17.5(AC)									0.001		
Total Xylenes											0.005		
Trichloroethene		45(AC) 21.9(CH)							.066(a)		0.001	0.066	
Vinyl Acetate											0.005		
Vinyl Chloride											0.002		

Table 3-16 (continued)

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]				Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5 (pCi/L)	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16										
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life		Agriculture (TR)	Acute	Chronic	Site-Specific Organic Stnds	Section 3.8.5 Table 3[4]				
			Acute	Chronic									
SVOCs													
2-Methylnaphthalene											0.01		
2,4-Dimethylphenol	2.12(AC)										0.05	2.12	
4-Methylphenol													
Acenaphthene	1.7(AC) 0.52(CH)							2.8E-06			0.01	0.01	
Bis(2-ethylhexyl) phthalate											0.01		
Di-n-Butyl Phthalate											0.01		
Dibenzofuran											0.01		
Diethyl Phthalate											0.01		
Fluorene								2.8E-06			0.01	0.01	
Naphthalene	2.3(AC) 0.62(CH)							2.8E-06			0.01	0.01	
Phenanthrene								2.8E-06			0.01	0.01	

Note:

Hardness = 461

All values are in mg/L unless otherwise stated.

[1] The list of PCOCs used to determine ARARs is found in Table 4-28 for surface water.
[2] Metals are dissolved unless otherwise specified.
[3] When two equations were available, conditions for "trout" were not used.
[4] Temporary Modifications for Big Dry Creek, Segment 5, valid until April 1, 1996.
[5] Only DOE Order 5400.5 was used to determine ARARs.
(a) FRV final residual value is expressed as total

AC Acute
CH Chronic
TR Total Recoverable

Table 3-17 Groundwater ARARs

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water[2,3] (5 CCR 1002-8, 3.1.0)			Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5 (pCi/L)	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16									
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life				Site-Specific Organic Stnds	Section 3.8.5 Table 3[5]				
			Acute	Chronic	Acute	Chronic						
Metals												
Aluminum			0.75									0.7500
Antimony										0.3		
Arsenic	0.05		0.36							0.01	0.05	0.3600
Barium	1									0.02	1	
Beryllium										0.002		
Cadmium	0.01		0.0425	0.0031	0.0425	0.0031				0.001	0.01	0.0031
Calcium												
Chromium(VI)	0.05		0.0164[4]	0.0114[4]	0.0164[4]	0.0114[4]				0.01	0.05	0.0110
Chromium(III)					4.9978	0.5969				0.01	0.1	0.5969
Cobalt										0.01		
Copper			0.060	0.036	0.0600	0.0357		0.023 (TR)		0.6	0.6	0.6
Iron				1(TR)				13.2 (TR)			1	
Lead	0.05		0.7736	0.0243	0.7736	0.0243		0.028 (TR)		0.01	0.028	0.0243
Lithium												
Magnesium												
Manganese				1(TR)				0.56 (D,a)			1	0.5600
Mercury	0.002		0.0024	0.0001(D) 0.00001(T)						0.002	0.002	0.002
Molybdenum	0.01		2.4641	0.2554	2.4719	0.2554				0.05		0.2554
Nickel												
Potassium			0.135	0.017	00.135	0.017				0.02	0.02	0.02
Selenium												
Silicon										0.02		
Silver	0.05		0.0188	0.0030	0.0188	0.0030				0.07	0.07	0.07
Sodium												
Strontium												
Tin										8		
Vanadium										0.04		
Zinc			0.3500	0.3171	0.3500	0.3171		0.35(TR)		0.02	0.35	0.3171
Radionuclides[6]												
Americium 241									30(pCi/L)		30(pCi/L)	
Cesium 137									3,000(pCi/L)		3,000(pCi/L)	
Gross Alpha									15(pCi/L)		15(pCi/L)	
Gross Beta												
Radium 226									100(pCi/L)		100(pCi/L)	

Table 3-17 (continued)

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]			Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16									
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life									
			Acute	Chronic	Acute	Chronic	Site-Specific Organic Stnds	Section 3.8.5 Table 3[5]				
Strontium 89,90									20,000 (pCi/L,E,F,4) 1,000(pCi/L,E,5) 10,000 (pCi/L,F,5) 800(pCi/L,E,F,4) 40(pCi/L,E,5) 400(pCi/L,F,5)			
Tritium									2,000,000(pCi/L)			
Uranium 235									600(pCi/L,C) 5,000(pCi/L,D)			
Water Quality Parameters												
Chloride												
Cyanide												
Fluoride												
Nitrate/Nitrite												
Nitrate												
Sulfate												
Total Dissolved Solids												
VOCs												
1,1,1-Trichloroethane										0.001		
1,1,2-Trichloroethane	9.4(AC)						0.0006			0.001	0.001	
1,1-Dicholorethane										0.001		
1,1-Dicholorethene										0.001		
1,2-Dicholorethene										0.001		
1,2-Dichloropropane	23(AC) 5.7(CH)									0.00	5.7	
1,4-Dichlorobenzene										0.001		
2-Butanone										0.01		
2-Hexanone										0.05		
4-Methyl-2-Pentanone										0.05		
Acetone										0.1		
Benzene	5.3(AC)									0.001	5.3	
Bromodichloromethane	11(AC)						0.0003			0.001	0.001	
Bromoform							0.004			0.001	0.004	
Carbon Disulfide												

Table 3-17 (continued)

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]			Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16									
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life				Site-Specific Organic Stnds	Section 3.8.5 Table 3[5]				
			Acute	Chronic	Acute	Chronic						
Carbon Tetrachloride	35.2(AC)							.018(a)		0.001	0.018	
Chlorobenzene										0.001		
Chloroethane										0.005		
Chloroform	28.9(AC) 1.24(CH)						0.006			0.001	0.006	
Chloromethane										0.001		
Ethylbenzene	32(AC)									0.01	32	
Methylene Chloride							0.0047			0.001	0.0047	
Tetrachloroethene	5.280(AC) 0.84(CH)						0.0008			0.001	0.001	
Toluene	17.5(AC)									0.001	17.5	
Total Xylenes										0.005		
Trichloroethene	45(AC) 21.9(CH)							.066(a)		0.001	0.066	
Vinyl Chloride										0.002		
SVOCs												
2-Chloronaphthalene										0.01		
2-Methylphenol	2.12(AC)											
2,4-Dimethylphenol										0.05	2.12	
2,4,5-Trichlorophenol										0.01		
4-Methylphenol												
4-Nitrophenol										0.01		
Acenaphthene	1.7(AC) 0.52(CH)						2.8E-06			0.01	0.01	
Benzoic Acid												
Bis(2-ethylhexyl) phthalate										0.01		
Di-n-Butyl Phthalate Diethyl Phthalate										0.01 0.01		
Fluorene							2.8E-06			0.01	0.01	
Naphthalene	2.3(AC) 0.62(CH)						2.8E-06			0.01	0.01	
Pentachlorophenol	0.009(AC) 0.0057(CH)									0.05	0.05	

Table 3-17 (continued)

PCOC[1]	RCRA MCLs (40 CFR 264.94)(T)	Colo. Basic Std. for Surface Water (5 CCR 1002-8, 3.1.0)[2,3]			Segment 5 Standards (5 CCR 1002-8, 3.8.0)				DOE Order 5400.5	PQLs	Total ARAR	Dissolved ARAR
		Section 3.1.11	Section 3.1.16									
		Aquatic Life Based	Class II Cold & Warm Water Aquatic Life				Site-Specific Organic Stnds	Section 3.8.5 Table 3[5]				
			Acute	Chronic	Acute	Chronic						
Phenanthrene							2.8E-06			0.01	0.01	
Phenol	10.2(AC) 2.5(CH)									0.05	2.5	

Note:

Hardness = 2.5*98.052 + 4.1*29.099 + 364.4359

All values are in mg/L unless otherwise stated.

[1] The list of PCOCs used to determine ARARs is found in Table 4-28 for groundwater.
[2] Metals are dissolved unless otherwise specified.
[3] When two equations were available, conditions for "trout" were not used.
[4] Unless the stability of chromium valence state is clearly demonstrated, standard is for chromium IV.
[5] Temporary Modifications for Big Dry Creek, Segment 5, valid until April 1, 1996.
[6] Only DOE Order 5400.5 was used to determine ARARs.
(a) FRV final residual value is expressed as total

AC Acute
CH Chronic
TR Total Recoverable

Table 3-18 Analytes Exceeding Groundwater ARARs at the Seep

Analyte	Total/ Dissolved	Detection Limit Range	Frequency of Detection	No. of Detections Exceeding ARARs	Min Result	Mean Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	ARAR	Units
Metals											
Iron	Total	4.7 — 100	9/9	9	69,700	85,722	117,000	—	V	1,000	µg/L
Manganese	Dissolved	1 — 15	9/9	9	1,300	1,417	1,500	—	V	560	µg/L
Manganese	Total	1 — 15	9/9	9	1,320	1,438	1,520	—	V	1,000	µg/L
Zinc	Dissolved	1.8 — 20	9/9	9	381	1,221	2,110	—	—	317.1	µg/L
Zinc	Total	1.8 — 20	9/9	9	857	1,974	2,630	—	V	350	µg/L
SVOCs											
Naphthalene	Total	10 — 10	5/5	5	14	18	22	—	V	10	µg/L
VOCs											
Methylene chloride	Total	5 — 5	4/11	1	3	5	6	B	—	4.7	µg/L

Note:

B Analyte also detected in blank (may be valid result depending on ratio of target sample concentration to blank concentration)
V Valid result

Table 3-19 Analytes Exceeding Surface-Water ARARs at the Seep

Analyte	Total/ Dissolved	Detection Limit Range	Frequency of Detection	No. of Detections Exceeding ARARs	Min Result	Mean Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	ARAR	Units
Metals											
Iron	Total	4.7 — 100	9/9	9	69,700	85,722	117,000	—	V	1,000	µg/L
Manganese	Dissolved	1 — 15	9/9	9	1,300	1,417	1,500	—	V	560	µg/L
Manganese	Total	1 — 15	9/9	9	1,320	1,438	1,520	—	V	200	µg/L
Zinc	Dissolved	1.8 — 20	9/9	9	381	1,221	2,110	—	—	386.9	µg/L
Zinc	Total	1.8 — 20	9/9	9	857	1,974	2,630	—	V	350	µg/L
SVOCs											
Naphthalene	Total	10 — 10	5/5	5	14	18	22	—	V	10	µg/L
VOCs											
Methylene chloride	Total	5 — 5	4/11	1	3	5	6	B	—	4.7	µg/L

Note:

B Analyte also detected in blank (may be valid result depending on ratio of target sample concentration to blank concentration)
V Valid result

Table 3-20 Analytes Exceding Groundwater ARARs Downgradient of the East Landfill Pond Dam

Analyte	Location	Total/ Dissolved	Detection Limit Range	Frequency of Detection	No. of Detections Exceeding ARARs	Min Result	Mean Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	ARAR	Units
	ALLUVIAL											
	Metals											
Chromium	4087	Dissolved	10 — 10	1/2	1	5	9	15.2	—	JA	11	µg/L
Iron	4287	Total	100 – 100	2/2	2	1,860	2,375	2,890	—	—	1,000	µg/L
Iron	53194	Total	7.3 – 100	5/5	3	724	3,297	8,380	—	Y	1,000	µg/L
Lead	53194	Total	0.9 – 5.0	3/5	1	1.0	12.9	50.5	—	JA	28	µg/L
	WEATHERED BEDROCK											
	Metals											
Cadmium	B207089	Dissolved	2 – 5	3/16	2	1.1	2	4.1	B	V	3.1	µg/L
Chromium	B207089	Dissolved	3 – 10	4/16	2	2	5	18.5	—	V	11	µg/L
	Radionuclides											
Gross Alpha	B207089	Total	4.8 – 74.07	2/2	1	0	10	19	—	Y	15	pCi/L
	Indicator Parameters											
Ammonia	B207089	Total	20.0 – 100.0	5/12		80.00	82	214,000	—	Y	100	pCi/L

Note:

B Analyte also detected in blank (may be valid result depending on ratio of target sample concentration to blank concentration)
JA Acceptable result (for estimated value)
Y Analytical results in validation process
V Valid result

Table 3-21 Analytes Exceeding Groundwater ARARs at Alluvial Well 72293

Analyte	Total/ Dissolved	Detection Limit Range	Frequency of Detection	No. of Detections Exceeding ARARs	Min Result	Mean Result	Maximum Detection	Qualifier for Maximum Detection	Validation for Maximum Detection	ARAR	Units
Metals											
Arsenic	Total	1.2 – 10	8/8	2	8.5	33.9	74.7	—	V	50	µg/L
Cadmium	Dissolved	2 – 5	1/10	1	1.8	3	13.8	—	JA	3.1	µg/L
Iron	Total	5 – 100	8/8	8	36,400	62,663	150,000	—	V	1,000	µg/L
Manganese	Dissolved	1 – 15	9/9	9	1,160	2,617	8,320	—	V	560	µg/L
Manganese	Total	1 – 15	8/8	8	1,260	2,749	8,000	N	JA	1,000	µg/L
Selenium	Dissolved	1.2 – 5	1/10	1	1	3	22.7	—	Y	20	µg/L
SVOCs											
Naphthalene	Total	0.2000 – 12	6/11	2	0.2	12	31	—	V	10	µg/L
Indicator Parameters											
Ammonia	Total	100.0	4/5	4	50.00	2,182	3095.000	—	V	100	µg/L

Note:

N Inorganics: spiked sample recovery is not within control limits (estimated value)
JA Acceptable result (for estimated value)
Y Analytical results in validation process
V Valid result

Table 3-22 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.

Table 3-22 (continued)

Law/Regulation	Citation	Description	ARAR Designation	Comments
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.

Note:

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

Table 3-23 Potential Federal and State Action-Specific ARARs

Law/Regulation	Citation	Description	ARAR Designation	Comments
Federal Laws				
RCRA	42 USC § 9621, *et seq.*			
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.
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 Postclosure 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 postclosure environmental issues.

Table 3-23 (continued)

Law/Regulation	Citation	Description	ARAR Designation	Comments
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 postclosure 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 postclosure 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.

Table 3-23 (continued)

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 postclosure maintenance requirements are relevant and appropriate to the Present Landfill because they apply to facilities that are sufficiently similar to OU 7.

Table 3-23 (continued)

Law/Regulation	Citation	Description	ARAR Designation	Comments
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.

Note:

ß	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

Table 3-24 Regulatory and Technical Guidance To Be Considered

Guidance Source	Citation	Description	ARAR Designation	Comments
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 DOE 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.

Table 3-24 (continued)

Guidance Source	Citation	Description	ARAR Designation	Comments
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.
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.

Note:

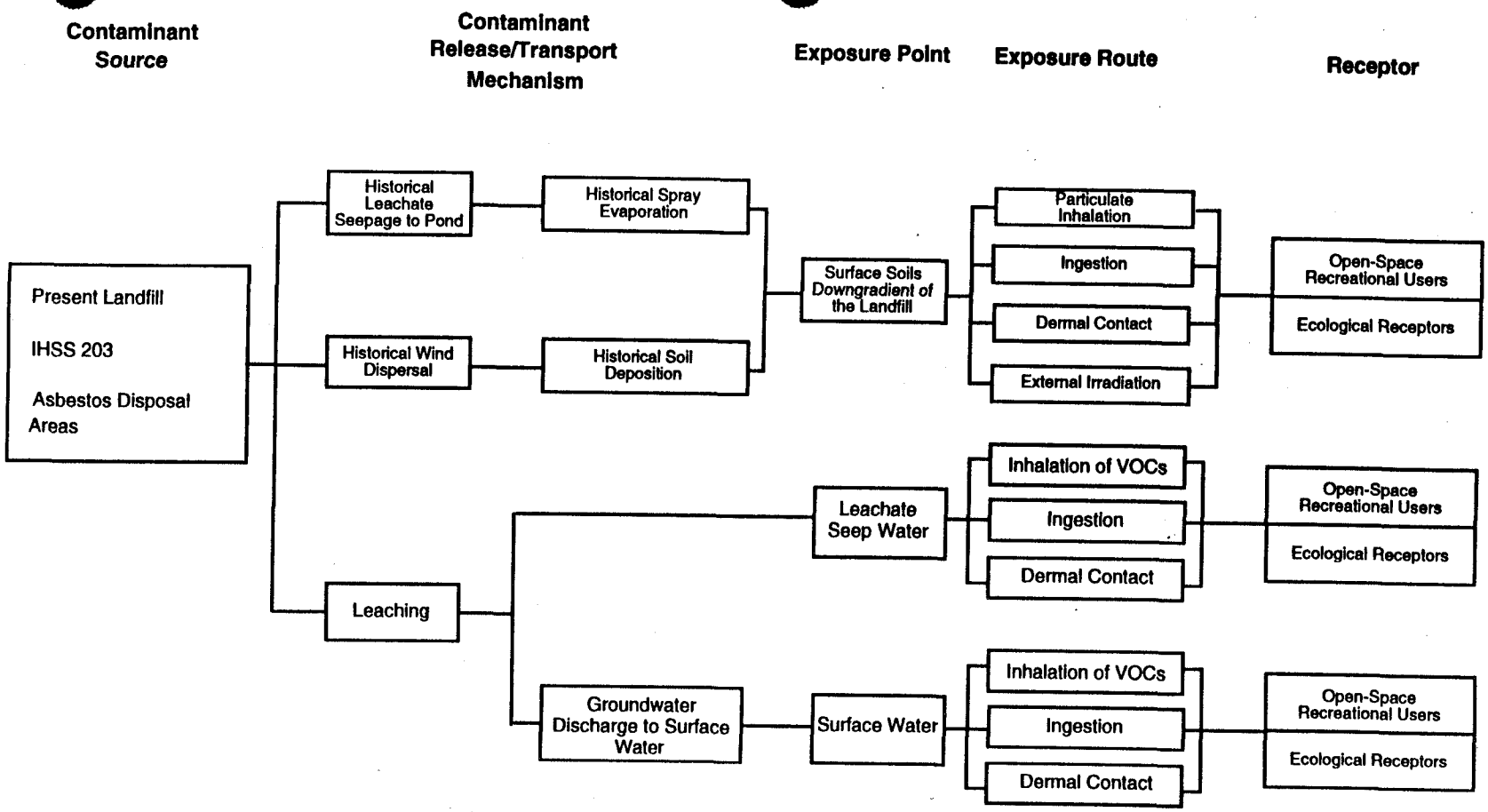
ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DOE	Department of Energy
EPA	U.S. Environmental Protection Agency
FR	Federal Register
MAC	Maximum allowed concentration
NMOC	Non-methane organic compound
OSWER	Office of Solid Waste and Emergency Response
OU	Operable unit
RCRA	Resource Conservation and Recovery Act
TBC	Guidance or recommendation to be considered

Table 3-25 Evaluation of Remedial Action Objectives for Developing Response Actions

Media Addressed by Remedial Action Objective (RAO)	Potential Exposure Pathways	Analytes Exceed PRGs	Risk Calculations Required?	Human Health Risk Carcinogenic: HI > 1E-04 Noncarcinogenic: HI > 1	Ecological Risk HQ > 1	ARARs Exceedances	Response Action
Present Landfill/ IHSS 203/ Asbestos-Disposal Areas	Eliminated under containment presumptive remedy	N/A	N/A	N/A	N/A	Cover to be determined by closure ARARs	Presumptive remedy
Landfill Gas	Eliminated under containment presumptive remedy	N/A	N/A	N/A	N/A	Gas emissions to be determined by air-emission ARARs.	Presumptive remedy
Landfill Leachate at the Seep	Discharge to groundwater or to surface water	No	No	None	PAHs, barium, manganese, zinc, strontium	Iron, manganese, zinc, naphthalene, methylene chloride	No action required - pathway incomplete
Surface Water in the East Landfill Pond	Eliminated under all remedial actions	N/A	N/A	N/A	N/A	N/A	Action required based on agency agreements
Sediments in the East Landfill Pond	Eliminated under all remedial actions	N/A	N/A	N/A	N/A	N/A	Action required based on agency agreements
Surface Soils Downgradient of the Landfill	Inhalation, ingestion, dermal contact, external irradiation	Yes	Yes	None	N/A	No ARARs for soils	No action required - no risk
Subsurface Geologic Materials Downgradient of the Landfill	Incomplete pathway for an open-space receptor	N/A	N/A	N/A	Nitrate/nitrite, lithium, strontium, zinc, barium, vanadium, aluminum	No ARARs for soils	No action required - no risk
Groundwater Downgradient of the Landfill	Inhalation, ingestion, dermal contact	No	No	None	Selenium, silver, strontium, antimony	Chromium, lead	No action required - pathway incomplete

Note:

PRG Preliminary remediation goal
HI Hazard index
ARAR Applicable or relevant and appropriate requirement
IHSS Individual hazardous substance site
N/A Not applicable



Includes presumptive remedy and other removal actions.

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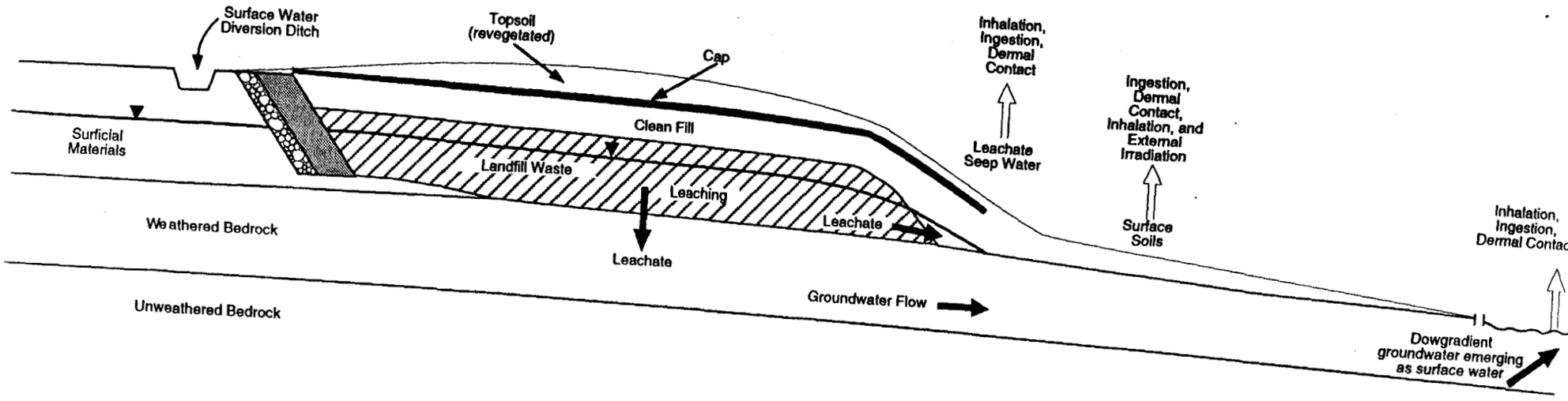
Conceptual Site Model for Exposure Pathways at OU 7

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 3-1



Exposure Route

Release/Transport Mechanism

Not to scale

Includes presumptive remedy and other removal actions.

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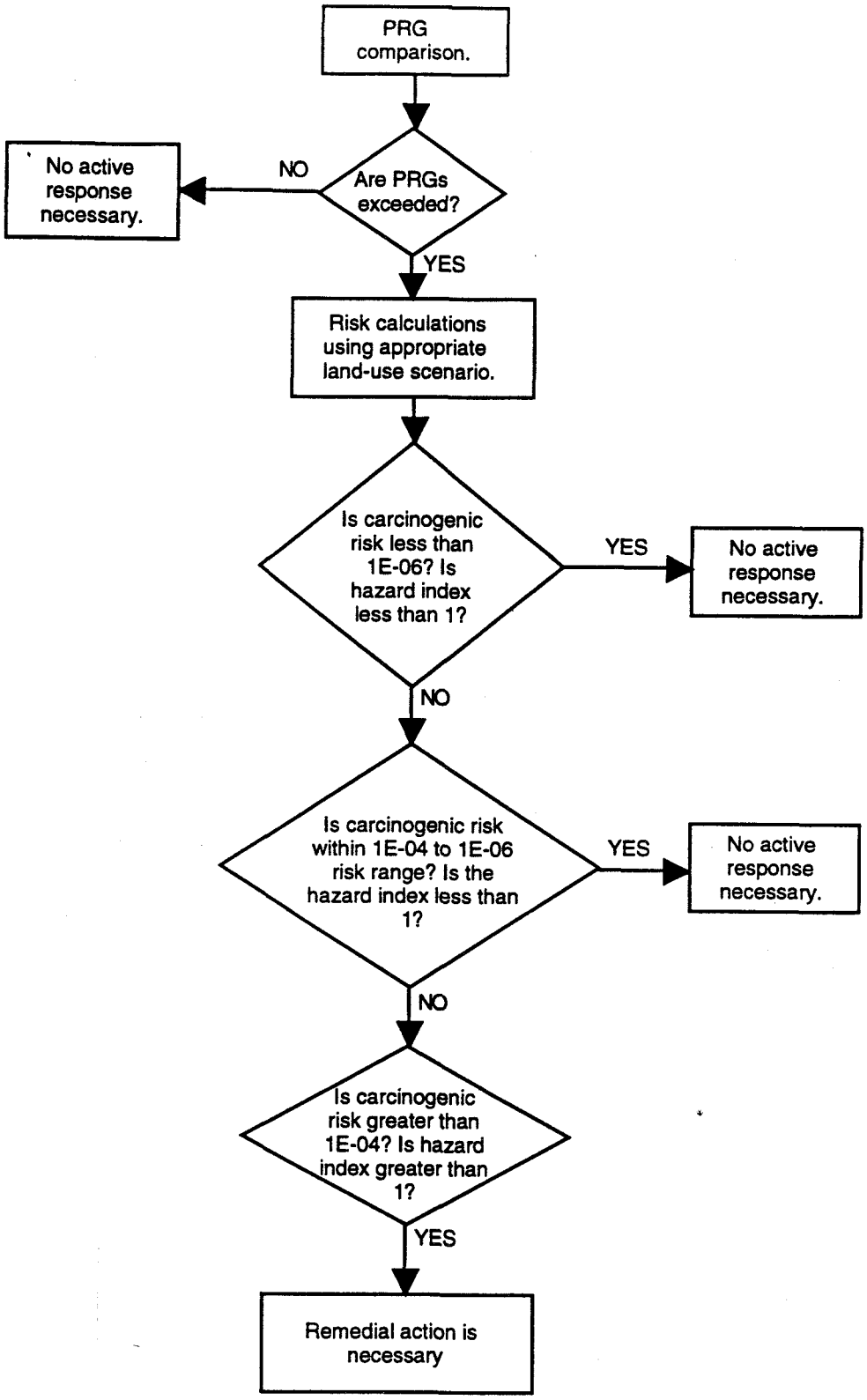
Schematic Diagram of Conceptual Site Model for Exposure Pathways at OU 7

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 3-2



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Human Health Focused Risk Assessment Methodology

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 3-3

g95\ESI\IM\IRA DD OU 7\OU7 Treatm't Det. vertical.CD

4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Technologies were identified and screened to develop a set of usable remedial action options that will ensure protection of human health and the environment. The primary purpose was to streamline the selection process to allow the most promising alternatives to be selected for further scrutiny in the detailed analysis (EPA 1988).

RAOs are described for various media in Section 3. Based on these RAOs, general response actions (GRAs) were developed for each medium. Potential remedial technologies and process options were then identified for each GRA. The technologies and process options that were considered for this screening were 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 was performed to eliminate those that are technically not feasible. The remaining process options, grouped by technology type, were then evaluated against each other based on effectiveness, implementability, and cost. Technologies carried forward in the screening process are evaluated in more detail 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, treatment, and disposal. For each GRA, a number of potentially effective technologies exist for each medium.

Under the presumptive remedy, certain GRAs were determined to be most effective for CERCLA landfills. The primary components of the presumptive remedy at OU 7 are:

- Containment
  - Landfill mass by capping
  - Groundwater
- Collection
  - Landfill gas
  - Leachate
- Treatment
  - Landfill gas
  - Leachate
- Disposal
  - Leachate

Institutional controls are also recommended to supplement engineering technologies.

4.2 THE SCREENING PROCESS

A number of applicable technologies exist for each GRA identified under the presumptive remedy. The technically feasible technologies identified in the OU 7 Technology Literature Research Report (EG&G 1994d) were evaluated relative to each other and screened to reduce the number of technologies evaluated in Section 5.

In the screening process, technologies were evaluated in terms of effectiveness, implementability, and cost (Table 4-1). Comparisons during screening were 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 were 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 was given the greatest weight. The cost criteria were used only to distinguish between two similarly rated technologies.

The effectiveness criteria included 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 included a determination of the technical and administrative feasibility of implementing the technology. Technical feasibility was used in the OU 7 Technology Literature Research Report (EG&G 1994c) as an initial screen of technology types to eliminate those that are clearly ineffective or unworkable at OU 7. Technical issues evaluated in regard to implementation included availability of materials, ease of construction, and post-construction repairs. Administrative feasibility addressed the ability to obtain approval from regulatory agencies. The initial screening also emphasized 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 played a limited role in the screening of technologies; it was used primarily to distinguish between two similarly rated technologies. The cost analyses were based on engineering judgment of the relative direct and indirect capital and operation and maintenance (O&M) costs.

4.2.1 No Action

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

4.2.2 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 compliance orders, 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—was 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.

4.2.3 Containment

Containment actions restrict contact with and migration of contaminants.

Landfill Mass Containment

Under the presumptive remedy, a landfill cap is the preferred containment technology. Table 4-3 identifies three types of capping technologies: (1) a native soil cover, (2) a single-barrier cap, and (3) a composite-barrier cap. Although composite-barrier caps were 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.

Groundwater Containment

As discussed in Section 1.3.2, the perimeter groundwater-intercept system has failed along the north side. The system was originally designed to divert groundwater around the landfill to decrease saturation and thus control generation and migration of leachate.

Table 4-4 shows the evaluation of hydraulic and physical groundwater containment technologies. Subsurface drains rate the highest among the hydraulic controls, whereas slurry walls rate the highest for physical controls. Both technologies have been used at the site with mixed results. However, in analyzing the failures (see Section 1.3.2), it is believed that proper design and quality assurance/quality control (QA/QC) make either option highly effective. In order to key the subsurface drain into bedrock, a large trench with shoring and dewatering would be required, significantly increasing costs and short-term impacts due to excavation. Therefore, only slurry walls were carried forward to alternative development in Section 5.

4.2.4 Collection

Collection response actions partially or completely remove contaminants from their original location.

Landfill Gas Collection

In landfills, gas is generally collected to protect the integrity of the cap and prevent offsite migration. Landfill gas may also be collected prior to treatment (see Section 4.2.6).

Table 4-5 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 significant quantities of gas. Although active gas-extraction wells have been used in municipal landfills, they have had only limited success collecting gas effectively 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 can 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 (see Section 1.3.2). This will prevent offsite migration of gas, forcing collection of the gas under the cover.

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

Passive vents and permeable layers were carried forward to the development of alternatives in Section 5.

Leachate Collection

Two technologies are identified in Table 4-6: (1) Subsurface drains and (2) extraction wells. Extraction wells and subsurface drains would draw groundwater and would require a downgradient barrier to prevent collection of downstream water. Extraction wells would also have a low radius of influence. The subsurface drain was retained for detailed analysis because it could effectively collect all of the seep flows.

4.2.5 Treatment

Treatment response actions reduce the toxicity, mobility, and/or volume of contaminants through physical or chemical alteration.

Landfill Gas Treatment

Table 4-7 shows the evaluation of landfill gas treatment systems.

As discussed in Section 3.4, landfill gas is not expected to exceed ARARs. However, the proposed closure of the landfill may affect gas generation by limiting the migration of gas and decreasing the infiltration of surface water. Because of 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, or until treatment requirements can be determined, installation of a gas-collection system that would allow for postclosure monitoring of gas composition, concentration, and flowrate is recommended. The collection system should also be designed to be compatible with gas-treatment units, if required.

The passive gas-collection system will have vent pipes or gravel columns at various locations across the cover. The determination between pipes or columns will be made during Title II design. The vent pipes or gravel columns will extend through the cover and will be located where required to monitor emissions from the landfill. If required after some period of monitoring, the vent pipes could be routed directly to a treatment system to reduce emissions from the landfill.

Leachate Treatment

Table 4-8 identifies 26 potential treatment technologies from the OU 7 Technology Literature Review. The effectiveness screening was based primarily on the ability to treat metals and organic constituents. If the technology is implementable at OU 7, preference was then given to low-cost technologies, particularly those with low O&M costs. The process options that passed this screening are carbon adsorption, ion exchange, air stripping, filtration, precipitation/flocculation, oxidation, electrolytic processes, permeable treatment beds, and engineered wetlands.

A number of these treatment technologies are already in use at Rocky Flats at the OU 1/OU 2 treatment facility, including carbon adsorption, ion exchange, precipitation/filtration, and oxidation. Therefore, trucking the leachate to the OU 1/OU 2 facility was carried forward to detailed analysis to represent these technologies. A conventional treatment system located onsite at OU 7, which would incorporate precipitation/flocculation, electrolytic processes, and carbon adsorption, is evaluated in more detail in Section 5. The two passive systems, permeable treatment beds and engineered wetlands, are also evaluated further.

4.2.6 Disposal

Leachate disposal may be accomplished by discharging to surface water or groundwater. Both of these options may be viable at OU 7 depending on the circumstances. Discharge to surface water would require that surface-water ARARs are met at the point of compliance or discharge and that ecological risks be minimized.

4.3 RESULTS OF SCREENING

Based on the screening presented in this section, the following technologies are considered in alternatives development:

- Institutional Controls (included in all alternatives)
  - Use restrictions
  - Access restrictions
  - Water-use controls
  - Public education
- Containment of Landfill Mass
  - Native soil cover
  - Single-barrier cap
  - Composite-barrier cap
- Groundwater Containment
  - Slurry wall
- Landfill Gas Collection
  - Permeable layer
  - Vents

- Leachate Collection
  - Subsurface drain
- Landfill Gas Treatment
  - Postclosure gas monitoring and treatment, if needed
- Leachate Treatment
  - Trucking to OU 1/OU 2
  - Conventional treatment at OU 7
  - Permeable treatment beds
  - Engineered wetlands
- Disposal
  - Discharge to surface water
  - Discharge to groundwater

Table 4-1 Summary of Screening Criteria

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 • Postconstruction 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

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
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-ft-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 Reg	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	Wells will be plugged and abandoned under separate action before closure.
Public Education	Increase public awareness of site conditions and remedies through written notices, meetings, and news releases.	Low	High	Low	The draft 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.

Table 4-3 Evaluation of Remedial Technologies: Containment of Landfill Mass

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
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	High	High	Minimizes infiltration of precipitation. Creates relatively high volume of clean runoff. Meets RCRA capping criteria.

Note:

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

Table 4-4 Evaluation of Remedial Technologies: Groundwater Containment

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Containment Actions					
Hydraulic Controls – Subsurface Drains	Underground, gravel-filled trenches used to intercept and channel groundwater or leachate to a sump, wet well, or surface discharge.	High	Moderate	Moderate	A groundwater intercept and leachate collection trench exists at OU 7 but is only partially effective.
– Injection Wells	Facilitate groundwater movement or containment by injecting clean water into uppermost aquifer.	Low	Low	High	Potential for increasing the volume of contaminated groundwater. Small radius of influence. Requires regular O&M.
– Extraction Wells	Wells installed to capture leachate or groundwater. Pump rate must be high enough to ensure flow toward wells.	Moderate	Low	High	Small radius of influence. Requires regular O&M.
Physical Controls – Slurry Walls	Low permeability, fixed walls installed in a trench to contain or divert flow of groundwater and/or leachate.	High	Moderate	Moderate	Provides consistent barrier to lateral flow. Existing slurry walls only partially effective.
– Grout Curtains	Fixed, impermeable barriers formed by injecting grout into the ground through well points.	Low	Moderate	High	Difficult to ensure complete coverage, especially at depth.
– Sheet Piling	Thin, impermeable barrier to groundwater/leachate flow constructed by driving lengths of interlocking steel into the ground.	Moderate	Low	Moderate	Difficult to install in rocky soils or at depths greater than 30 ft.

Note:

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

Table 4-5 Evaluation of Remedial Technologies: Landfill Gas Collection

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

Table 4-6 Evaluation of Remedial Technologies: Leachate Collection

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Collection Actions					
Hydraulic Collection					
– Subsurface Drains	Leachate is collected in a trench containing gravel and perforated pipe, then transferred by pumping or gravity flow.	High	Low	Low	Existing subsurface drain at OU 7.
– Extraction Wells	Leachate is pumped to the surface using a series of wells drilled through the uppermost aquifer.	Moderate	Moderate	Moderate	Radius of influence is small. A high number of wells would be required.

Note:

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

Table 4-7 Evaluation of Remedial Technologies: Gas Treatment

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
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:

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

Table 4-8 Evaluation of Remedial Technologies: Leachate Treatment

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Treatment Actions					
Physical Treatment					
– Sedimentation	Uses gravity to allow suspended solids in an aqueous solution to settle.	Low	Moderate	Moderate	Removes settleable material; high potential for leachate treatment; use in conjunction with precipitation.
– Centrifugation	Solids in a fluid are separated by rapidly rotating the fluid in a vessel.	Low	High	High	Accelerated sedimentation used in conjunction with flocculation.
– Carbon Adsorption	Dissolved organics are adsorbed onto carbon as contaminated water is passed through column.	High	High	Moderate	Applicable to a variety of organics; well-developed; spent carbon must be disposed or regenerated.
– Ion Exchange	Remove heavy metals by using synthetic resins that exchange a less harmful ion for a heavy metal ion in solution.	Moderate	High	Moderate	Removes dissolved inorganics, including radionuclides; low energy; less efficient for high concentrations of inorganics; best as a polishing stage; currently in use at OU 1. Iron and manganese can foul cation exchange resin.
– Reverse Osmosis	Separate dissolved materials by high-pressure filtration through a semi-permeable membrane.	Moderate	Low	High	Best as polishing stage for dissolved heavy metals; requires pretreatment for solids removal; requires extensive bench/pilot tests. Iron and manganese can foul membrane.

Table 4-8 (continued)

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Treatment Actions					
Physical Treatment					
– Air/Steam Stripping	Air or steam is used to strip VOCs from liquid, concentrating them in the condensate.	Moderate	High	Moderate	Air stripping is a possible pretreatment for adsorption; possible air emissions problems; steam stripping applicable to high concentrations of volatile compounds. Iron can precipitate and foul media.
– Filtration	Precipitated solids containing metals are filtered out of solution.	Moderate	Moderate	Moderate	Pretreatment or polishing technique for suspended solids removal.
– Ultrafiltration	Separate high molecular weight dissolved materials using low pressure over a semi-permeable membrane.	High	Moderate	High	Applicable for high molecular weight dissolved materials; possible polishing step; used for product recovery.
Chemical Treatment					
– Neutralization	Use pH adjustment to render an acid or caustic waste non-corrosive.	Low	High	Low	Can be used in conjunction with other treatment processes.
– Precipitation/ Flocculation	Remove dissolved heavy metals by altering the ionic equilibrium to produce insoluble precipitates.	High	High	Low	Use for removal of suspended solids; removes heavy metals. Presence of chloride, sulfate, carbonate may interfere.
– Oxidation	Destroy organics by adding an oxidant for oxidation of the compounds to less toxic compounds.	Moderate	Moderate	Moderate	May also reduce toxicity of some inorganics; oxidants include ozone and hydrogen peroxide.

Table 4-8 (continued)

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Treatment Actions					
– Electrolytic Process	Cathodes and anodes are immersed in water using a DC current to plate out dissolved metals.	Moderate	Moderate	Moderate	Applicable for heavy metals, not organics; can operate at neutral pH. Not recommended for low metals concentrations
– Reduction	Reduce toxicity or enhance precipitation of metals by transferring electrons from a reducing agent to the contaminant.	Low	Moderate	Moderate	Potential for introducing hazardous ions into solution. Best for reduction of hexavalent chromium.
– Hydrolysis	Displacement of a functional group on an organic molecule with a hydroxyl group from water.	Low	Low	High	Requires pH and temperature adjustment; potential formation of toxic by-products.
– Ultraviolet (UV) Oxidation	Contaminants are oxidized and dechlorinated using oxidizers such as hydrogen peroxide or ozone in the presence of ultraviolet light.	Moderate	High	High	Use for low-concentration organics, especially chlorinated hydrocarbons; dissolved minerals in water reduce effectiveness of UV light; currently in use at OU 1.
Biological Treatment					
– Permeable Treatment Beds	Trenches constructed perpendicular to groundwater flow are filled with a reactive, permeable medium to remove organics.	Moderate	High	Low	Innovative. Used primarily for halogenated organic compounds. Additives may be used to precipitate metals.
– Activated Sludge	Break down organics by aerobic oxidation and hydrolysis in an above-ground aerated tank; recirculate biomass.	Low	Moderate	High	Not suited for low organic concentrations; some metals and organics may be toxic to organisms; possible air emissions problems.

Table 4-8 (continued)

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Treatment Actions					
– Sequencing Batch Reactor	Aeration, digestion, and settling take place in two parallel reactors.	Low	Moderate	Moderate	Not suitable for low concentrations of organics.
– Fluidized Bed Reactor	Contaminated water and air flow in an up-flow pattern through a medium consisting of loose particles that become fluidized.	Low	Moderate	Low	Not suitable for low concentrations of organics.

Note:

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

Table 4-8 (continued)

	Description	Effectiveness	Implementability	Cost	Comments
Response Action					
Remedial Technology • Process Option					
Treatment Actions					
– Sequencing Batch Reactor	Aeration, digestion, and settling take place in two parallel reactors.	Low	Moderate	Moderate	Not suitable for low concentrations of organics.
– Fluidized Bed Reactor	Contaminated water and air flow in an up-flow pattern through a medium consisting of loose particles that become fluidized.	Low	Moderate	Low	Not suitable for low concentrations of organics.

Note:

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

5.0 DEVELOPMENT OF ALTERNATIVES

Process options retained after the initial screening presented in Section 4 were evaluated further with regard to specific media at OU 7. The options can be implemented individually or in combinations designed to meet RAOs, such that human health and the environment are protected, to the extent necessary, from exposure to contaminated media. The technologies and process options were grouped by GRAs in Section 4. In this section, they were regrouped by media to facilitate development of alternatives that completely address the contamination.

The various options for each medium were refined and screened based on the following three evaluation criteria: (1) effectiveness, (2) implementability, and (3) cost. Options were compared at an equal level of analysis with sufficient detail to be able to distinguish among the various alternatives (EPA 1988). Options that rated the highest were combined into alternatives that address the site as a whole.

5.1 OPTION SCREENING CRITERIA

The options retained were further screened with regard to providing sitewide protectiveness based on effectiveness, implementability, and cost. The screening of options in this section examined each criterion in greater detail than was used in Section 4. This served to limit the number of options to be considered in the development and detailed analysis of alternatives.

5.1.1 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. Options that are not protective of human health and the environment were eliminated from further consideration.

RAOs for OU 7 include the following (as described in Section 3.5):

- 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)
- Collect and treat leachate at the source (as needed)
- Control groundwater at the source

5.1.2 Implementability

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

Technical issues relating to implementation include availability of materials, ease of construction, and postconstruction repairs. Administrative feasibility addresses the ability to obtain approvals from regulatory agencies and coordinate with other agencies.

5.1.3 Cost

A preliminary cost estimate was developed for each option. 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, construction, and monitoring during closure. Indirect costs include project and construction management, construction quality assurance (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 postclosure period. Cost estimates and associated assumptions are provided in Appendix G.

Institutional Controls

Institutional controls are generally physical or legal methods designed to limit exposure. Many institutional controls are already in place at Rocky Flats and OU 7. Institutional controls will be included in all alternatives developed at the end of this section.

A 6-ft chain-link fence and warning signs limit access to the landfill. In addition, the entire 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 (NPL) 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).

Under this option, the existing restrictions on groundwater use 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 postclosure 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.

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 decisionmaking process during the public comment period for the Draft Phase I IM/IRA DD.

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 SARA remedy, upon attainment of the 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 LANDFILL MASS

Based on the presumptive remedy, containment is the only GRA that will be evaluated for the landfill mass, as discussed in Section 4. The three capping process options presented in Section 4 (native soil cover, single barrier cap, and composite barrier cap) were refined and evaluated in more detail by using different materials and combinations of materials for the barrier layers.

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 most important requirement for the evaluation of the capping options is that the cover have a permeability less than the underlying bedrock. The weathered bedrock has a permeability of 1E-06 to 1E-07 cm/sec, as described in Section 2.3. Each of the capping options was evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model (EPA 1994b). A description of the HELP model, input parameters, assumptions, and results is presented in Appendix F.

5.2.1 Landfill Cover Design

A number of design parameters are common to all capping options. These include (1) extent of the landfill cover, (2) the grading plan, (3) surface-water management, and (4) basic cover components.

Extent of 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 in Figure 5-1, and encompasses approximately 21 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.

Grading Plan

The grading plan is determined by the extent of the landfill cover, the removal of the dam and pond (as discussed in Section 3), and regrading of the valley to form a natural drainage.

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

The existing side slopes extending down into the East Landfill Pond 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, regrading the slopes to approximately 20 percent is assumed. This is considered to be a stable slope to prevent slumping and erosion.

Minimum slope angles were selected to provide adequate drainage after settlement. Conservative settlement estimates were made based on a variety of landfill-settlement models as summarized in Appendix E. 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.

There are two grading plans under consideration. Figures 5-2, 5-2a, and 5-2b show the proposed grading plan for the discharge of leachate at the seep to surface water. Figures 5-3, 5-3a, and 5-3b show the proposed grading plan for the discharge of leachate at the seep to groundwater. Both plans show the grading and cover crowned in the center and sloping outward. 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.

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 toward the east. 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 to No Name Gulch. 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.

Cover System 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: (1) vegetative cover, (2) lateral drainage, (3) barrier, (4) gas collection, and (5) grading fill. The purpose of each layer and the materials that may be used are discussed in the following sections. In addition, the lateral drainage layer will also serve as a biotic barrier layer. A drainage layer of gravel will also be constructed under the fill from the seep at SW097 to a location downgradient to the east past the extent of the cap. This gravel will allow drainage of leachate from the seep to an area downgradient of the cap to prevent water buildup under and contact with the cap. Collection of this leachate at a point downgradient is discussed in Section 5.5.1. Table 5-1 presents a summary of the cover components, including the objectives and materials considered for each component.

Vegetative-Cover Layer

The vegetative-cover layer is intended to provide a suitable growth media for revegetation 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 at the Rocky Flats site is approximately 3 ft.

A 36-in. vegetative-soil layer is included in all cover options. The vegetative layer is made up of 2.5 ft of soil under 0.5 ft of topsoil. A detailed revegetation plan that provides a native seed mixture and that addresses past revegetation problems in other OUs will be included in the Title II design document. A site ecologist will determine the proper native seed mixture once the source of top soil has been determined. Soil characteristics and erosion control will be considered in selecting the mixture. The revegetation success should be evaluated periodically to determine the need for reapplication of seed and weed control.

Lateral-Drainage/Biotic Barrier 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.

The lateral-drainage layer will also serve as the biotic barrier layer. A biotic barrier will provide protection from plant roots and burrowing animals that may disrupt the integrity of the impermeable layers within the cover system.

Materials considered for the lateral-drainage/biotic barrier 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 in their use toward 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. Granular soil biotic barrier layers with 3 ft of cobbles may be effective in stopping root penetration of some deep rooted plants.

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. Geotextiles have been effective in providing protection against root penetration but have limited effectiveness in providing protection against burrowing animals.

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. The placement of a layer of high-density polyethylene (HDPE) geonet between the barrier and vegetative layers would provide protection against burrowing animals. The Kettleman Hills hazardous waste landfill facility in California successfully used a geonet in 1989 as a biotic barrier for the cover system.

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. The

geocomposite provides the best option for protection against biotic intrusion. With the combination of the geonet and geotextile materials, the geocomposite provides protection against burrowing animals and plant root penetration, respectively.

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

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.

Flexible Membrane Cover—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 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.

Geosynthetic Clay Layer—A GCL is composed of a commercial bentonite layer sandwiched between sheets of woven or nonwoven 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 ft), they can accommodate minor settlement and some surface cracking or deterioration without complete failure.

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

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 options. As discussed under lateral drainage, a geocomposite is a geonet drainage layer with geotextile bonded to both sides to prevent infiltration of fine soils.

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, including the East Landfill Pond sediments and dam (EG&G 1994d).

Description and Screening of Capping Options

Options were 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 5.2.2:

- 36-in. vegetative cover layer
- Geocomposite lateral-drainage and biotic barrier layer
- Various combinations of barrier layers
- Geocomposite gas-collection layer and venting system
- Grading fill

Option A: Native Soil Cover

Description—Option A consists of a 36-in. 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 5.2.3.

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 waste and groundwater. The HELP model shows an average annual leakage rate of 1.1 in./year (Figure 5-4). The leakage rate for this option is slightly less than the leakage

rate for the no-action option. This option does not include treatment of waste or leachate, so there is no reduction in toxicity, mobility, or volume through treatment. The option 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.

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, Option A is unlikely to be approved by the regulatory agencies because it does not meet closure requirements.

Cost—The conceptual cost estimate for Option A, Native Soil Cover, is as follows:

Total Capital Cost	$428,000
Annualized O&M Cost	$38,800/year
Total Present Worth Cost	$5,455,000

Cost estimates and associated assumptions are provided in Appendix G.

Option B: Single-Barrier Clay Cover

Description—Option B consists of a single-barrier clay cover and institutional controls. The cover section consists of the following layers (Figure 5-3):

- 36-in. vegetative-soil layer
- Geocomposite lateral-drainage and biotic barrier layer
- 24-in. 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.

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, biotic intrusion, 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 option 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 in., 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.

Implementability—Implementation of this cover option requires the identification of a borrow source of fine-grained soil that meets the design specifications. At this time, there are no known borrow sources at Rocky Flats that meet the 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 in. 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 in.) 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/biotic barrier 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 option 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.

Cost—The conceptual cost estimate for Option B, Single-Barrier Clay Cover, is as follows:

Total Capital Cost	$9,369,000
Annualized O&M Cost	$39,000/year
Total Present Worth Cost	$10,395,000

Cost estimates and associated assumptions are provided in Appendix G.

Option C: Single-Barrier FMC Cover

Description—Option C consists of a single-barrier FMC cover and institutional controls. The cover section consists of the following layers (see Figure 5-3):

- 36-in. vegetative-soil layer
- Geocomposite lateral-drainage and biotic barrier layer
- FMC barrier layer
- 6-in. 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 in. 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.

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, biotic intrusion, 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 requirement.

This option 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 in., 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.

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/biotic barrier and gas collection are also readily available and relatively easy to install, as discussed under Option B.

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 option 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.

Cost—The conceptual cost estimate for Option C, Single-Barrier FMC, is as follows:

Total Capital Cost	$7,034,000
Annualized O&M Cost	$39,000/year
Total Present Worth Cost	$8,060,000

Cost estimates and associated assumptions are provided in Appendix G.

Option D: Single-Barrier GCL Cover

Description—Option D consists of a single-barrier GCL cover and institutional controls. The cover consists of the following layers (see Figure 5-3):

- 36-in. vegetative-soil layer
- Geocomposite lateral-drainage and biotic barrier 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.

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 option does not reduce toxicity, mobility, or volume through treatment. However, the cover reduces infiltration by reducing the average annual leakage rate to 0.035 in. 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.

Implementability—GCL materials are generally available as composites of geotextile or HDPE. Geosynthetic drainage/biotic barrier 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.

Because of 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 in. 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.

Postconstruction 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 option 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.

Cost—The conceptual cost estimate for Option D, Single-Barrier GCL, is as follows:

Total Capital Cost	7,530,000
Annualized O&M Cost	$39,000/year
Total Present Worth Cost	$8,557,000

Cost estimates and associated assumptions are provided in Appendix G.

Option E: Single-Barrier FMC with a Low-Permeability Cover

Description—Option E consists of institutional controls and a cover with an FMC barrier and a 12-in. layer of low-permeability soil. The cover consists of the following layers (Figure 5-3):

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

The presence of the low-permeability (approximately 1E-05 to 1E-07 cm/sec) soil 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.

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 option 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 in., 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: (1) to provide a good bedding layer for the FMC and (2) 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.

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 Option C.

The low-permeability soil required in this option 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 Option B or G, 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.

Option E 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/biotic barrier, 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 Option D.

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.

Cost—The conceptual cost estimate for Option E, Single-Barrier FMC Cover with Low-Permeability Soil Cover, is as follows:

Total Capital Cost	$7,769,000
Annualized O&M Cost	$39,000/year
Total Present Worth Cost	$8,796,000

Cost estimates and associated assumptions are provided in Appendix G.

Option F: Composite-Barrier FMC and GCL Cover

Description—Option F is a true composite barrier with both FMC and GCL. Institutional controls are also included in this option. The cover consists of the following layers (Figure 5-3):

- 36-in. vegetative-soil layer
- Geocomposite lateral-drainage and biotic barrier 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.

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 option 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 in., 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.

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

This cover system could be constructed in two separate layers: (1) GCL and (2) an FMC. The implementability criteria would be similar to those described for Option C (single FMC cover) and Option D (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 Option E.

Postconstruction repairs to this cover system would be made to each component individually as described in Options E and F. 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 option 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 option.

Cost—The conceptual cost estimate for Option F, Composite-Barrier FMC and GCL Cover, is as follows:

Total Capital Cost	$8,082,000
Annualized O&M Cost	$39,000/year
Total Present Worth Cost	$9,109,000

Cost estimates and associated assumptions are provided in Appendix G.

Option G: Composite-Barrier FMC and Clay Cover

Description—Option G 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-in. vegetative-soil layer
- Geocomposite lateral-drainage and biotic barrier layer
- FMC barrier layer
- 24 in. 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 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.

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 1989c, 1989d). 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 option 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 in., 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.

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 Option D. Equipment, labor, and CQA requirements for installation are similar to those previously discussed for Options B and C.

Postconstruction repairs are complicated by having two barrier layers. Repair of the clay layer is discussed in Option B; repair of the FMC is discussed in Option C.

Based on the construction process discussed above, this option 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.

Cost—The conceptual cost estimate for Option G, Composite-Barrier FMC and Clay Cover, is as follows:

Total Capital Cost	$9,883,000
Annualized O&M cost	$39,000/year
Total Present Worth Cost	$10,910,000

Cost estimates and associated assumptions are provided in Appendix G.

5.2.2 Landfill Capping Option Selected for Detailed Analysis

The screening of capping options was based on effectiveness, implementability, and cost as described in Section 5.1. Table 5-2 summarizes the permeability and leakage rates for each of the capping options. These parameters, in addition to long-term permanence, were used to compare the effectiveness of each option. Figure 5-4 shows leakage rates for each option graphically. Table 5-3 presents a summary of the comparative analysis of the options.

The native soil cover and the single-barrier clay cap were eliminated from further evaluation because they do not meet the 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 the joints over the long term. Therefore, options with GCLs were eliminated from further evaluation.

The focus for evaluating the remaining capping options is on the soil layer beneath the geomembrane, which is the only difference among the options. For 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

Options C and E have similar degrees of effectiveness. The soil bedding layer of Option C serves to support the FMC as do the low-permeability soil layer of Option E and the clay-barrier layer of Option G; 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, Option C presents a higher effectiveness risk than the other two options.

Options E and G have leakage rates approaching zero. The leakage rate for Option G is the highest of the remaining capping options.

During the life of the project, the key difference between the low-permeability soil and clay barrier is resistance to desiccation cracking. 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 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 due to its resistance to desiccation.

Capping Option E, Single-Barrier FMC with a Low-Permeability Cover, affords the highest degree of effectiveness and was selected for further evaluation in the detailed analysis.

5.3 LANDFILL GAS

Landfill gas process options were evaluated to address the RAO under the presumptive remedy of controlling landfill gas and treating as necessary. They also provide protection of the cap's integrity and protection against potential offsite gas migration.

5.3.1 Gas Collection Options

In Section 4, process options were identified and screened to develop usable gas collection options. The only option retained was a passive gas-extraction system consisting of a permeable layer with vents. The passive gas collection option consists of a system of gas venting pipes connected to a permeable gas collection layer within the engineered cover system. The permeable layer provides a preferential flow pathway for migrating gas and transmits the gas to the discharge points where it is vented through the cover.

A geocomposite is used for the permeable layer. The geocomposite consists of a layer of geonet sandwiched between two layers of filter fabric to prevent fines from clogging the geonet. The vents consist of PVC or HDPE pipe (depending on the FMC material selected) or gravel columns.
The gas collection layer with vents is included in the design of all capping options with a barrier layer. The costs were also incorporated in the capping costs.

5.3.2 Gas Treatment Options

As discussed in Section 3, it is not anticipated that landfill gas will exceed ARARs. However, the proposed closure of the landfill may affect gas generation by limiting the migration of gas and decreasing the infiltration of surface water. Therefore, as discussed in Section 4, postclosure monitoring will be performed, and the monitoring data will be evaluated to determine if gas treatment is necessary.

5.3.3 Gas Collection/Treatment Options Selected for Detailed Analysis

The permeable layer with vents is included in the design of all capping options with a barrier layer. Post-closure monitoring of gas composition, concentration, and flow rate is recommended until treatment requirements can be determined. The system will be designed with the capability for adding gas treatment as needed.

5.4 LEACHATE

Leachate collection, treatment, and disposal options were evaluated to address the RAO to collect and treat leachate at the source, as needed. Leachate collection options were narrowed down to a subsurface drain in Section 4. Leachate treatment includes onsite and offsite conventional and passive options. Disposal options include discharge of the leachate to surface water and discharge to groundwater.

5.4.1 Leachate Collection Options

In Section 4, technologies for leachate collection were identified and screened to develop usable options with the most effective option being a subsurface drain.

For the most effective option, a shallow subsurface drain would be constructed to collect leachate from the seep as it exits the gravel drainage layer, as discussed in Section 5.3.2. The drain would be installed in the area of the East Landfill Pond immediately downgradient of the edge of the landfill cap. The drain, constructed of coarse-grained material such as gravel, would be approximately 200-ft long and oriented perpendicular to the No Name Gulch valley. The drain could be keyed into the weathered bedrock with an average total depth of 2 ft and a nominal trench width of 40 ft. Perforated pipe would be installed near the bottom of the trench leading to a sump that would collect water for transfer to a storage or treatment system.

Geosynthetic filter fabric would be used to line the trench walls to minimize infiltration of fine materials. An impermeable liner would be placed on the downgradient wall of the trench to prevent clean groundwater from flowing into it. A pump could be installed to remove water from the sump if power is provided to the site. Cleanout ports would be installed at the ends of the trench to allow maintenance of the trench.

5.4.2 Leachate Collection Options Selected for Detailed Analysis

The subsurface drain was retained for further evaluation and will be included in some of the alternatives developed for detailed analysis.

5.4.3 Description and Screening of Leachate Treatment Options

The leachate treatment options that passed the initial screening in Section 4 were combined into the following treatment options: transfer and treatment at the OU 1/OU 2 facility; a conventional treatment facility at OU 7; a permeable treatment wall; and engineered wetlands.

Existing OU 1/OU 2 Facility

Description—Leachate would be pumped from the subsurface drain to the storage tanks. Tanker trucks would be used to transport the leachate to the OU 1/OU 2 facility. Influent storage tanks at the treatment facility equalize flows and smooth variations in contamination. The treatment facility is designed so that a variety of treatment trains could be used to treat the leachate. Ion exchange and precipitation are the primary processes for metals removal; GACs and ultraviolet oxidation are the primary processes used for organics. Because of the complexity of the facility, a bench-scale study would be required to optimize the treatment process. The treated water would be discharged to the South Interceptor Ditch.

Effectiveness—Preliminary analysis and discussions with the operator indicate that the OU 1/OU 2 treatment facility is capable of treating the leachate contamination, except for iron. The high concentrations of iron in the leachate would require pretreatment. The available capacity at the OU 1/OU 2 treatment facility is dependent on commitments to treat flows from other sources and the effluent storage capacity. Both of these issues would need to be addressed during design.

Implementability—Treatment at the OU 1/OU 2 facility is technically and administratively feasible. Collection and storage facilities would be required onsite; however, the treatment facility itself exists. Various modes of transferring the leachate to the OU 1/OU 2 facility were considered. Trucking was determined to be the most cost-effective method. Because a number of different treatment trains are available, modifications to the system to accommodate changing concentrations or ARARs would be relatively simple. For example, different resins can be used in the ion exchange units to remove different contaminants.

O&M and residual generation would be dependent on the treatment train used. The ion exchange units require regeneration of spent resins, treatment of regeneration water, and disposal of the solids. Filtration units must be cleaned by flushing periodically. The flushing water must be treated and the solids disposed. The GAC column requires regeneration and disposal of spent carbon. UV oxidation destroys organics without creating a waste product. Oxidation products include carbon dioxide, water, and various salts or organic acids.

Cost—The conceptual cost estimate for the OU 1/OU 2 facility including storage tanks and providing electricity at OU 7 is as follows:

Total Capital Cost	$676,000
Annualized O&M Cost	$491,000/year
Total Present Worth Cost	$13,660,000

These costs assume an average flow of 2 gpm. Cost estimates and associated assumptions are provided in Appendix G.

OU 7 Conventional Facility

A conceptual design for an onsite conventional treatment system was developed using the process options identified in Section 4.

Description—For an onsite conventional treatment facility, leachate would be pumped from the subsurface drain to onsite storage tanks and then piped to the treatment system. The leachate enters an electrochemical cell for metals removal. After pH adjustment, a polymer is added to promote flocculation in the clarifier. The sludge produced in the clarifier is filtered, and excess water is recirculated back to the influent tank. A polishing multimedia filter follows the filter press. The organics are then removed in a GAC unit by adsorption.

Effectiveness—The treatment system has the capability to treat the OU 7 leachate contaminants to meet ARARs. Metals are removed by the electrochemical cells and organics by the GAC. Both are proven technologies. The effectiveness of the GAC is dependent on contact time, contaminant concentration, temperature, and humidity.

Implementability—The conventional facility is technically and administratively feasible. Collection and storage facilities would have to be constructed and electricity brought to the site. An NPDES permit would probably be required for discharge to No Name Gulch. Alternatively, only the administrative requirements of a National Pollution Discharge Elimination System (NPDES) permit would have to be met. The treatment process will produce a filtered sludge requiring disposal. The GAC column requires regeneration and changeout and disposal of spent carbon with time.

Cost—The conceptual cost estimate for the OU 7 conventional facility including storage tanks and providing electricity at OU 7 is as follows:

Total Capital Cost	$855,000
Annualized O&M Cost	$43,000/year
Total Present Worth Cost	$2,000,000

Cost estimates and associated assumptions are provided in Appendix G.

Permeable Treatment Wall (The Environmental Treatment Wall)

A number of permeable treatment walls exist. Two were looked at in detail, the Enviromental and the FORAGER™. Although both are capable of treating organics and inorganics, the Enviromental iron rung wall has been used primarily to treat organics, the FORAGER™ to treat inorganics.

Description—A permeable treatment wall developed by Enviromental Technologies, Inc., consists of a trench containing primarily iron filings to reduce contamination. The trench is constructed perpendicular to the leachate or groundwater flow path. The filings are a zero valant iron ion which has been ground and heated in a furnace.

VOCs are degraded as they migrate slowly through the wall under natural flow conditions. The degradation process is believed to be abiotic and electrochemical, involving the oxidation of the iron and reductive dechlorination of the organics.

Metals might also be removed by adding calcium carbonate to the reactive media to promote precipitation. Organic carbon may also be required for zinc removal. Alternatively, there are several vendors of metal absorptive materials that could be suitable for use in a permeable treatment wall.

The permeable treatment wall at OU 7 would be approximately 200 ft long and 1 ft wide. The depth is approximately 20 ft, but may vary across the drainage. A funnel (slurry wall, metal sheeting) and gate system is not proposed because the No Name Gulch valley acts as a natural funnel and Envirometal's recent experience indicates that this type of system tends to increase the width of the wall required. Therefore, construction of an impermeable funnel is not required.

The most probable construction sequence would be placement of the fill in the area of the pond, then subsequent driving of sheet piles and installation of large diameter well casings.

Effectiveness—The technology is innovative. Few full-scale walls have been in place long enough to optimize design parameters and determine long-term operational requirements. Although the walls are used primarily to remove organics, both of the organics exceeding ARARs at the seep, napthalene and methylene chloride, are not treated by this technology. In addition, metals removal has only been evaluated at the bench-scale stage. It is estimated that the wall will have to be "rejuvenated" every 5 to 10 years to remove precipitates formed during metals removal. Precipitates reduce wall porosity and effectiveness. Regeneration consists of flushing, mixing, or replacement of the affected media.

Implementability—Treatability testing would be required to determine the dimensions of the wall, percent of iron filing required, potential for mineral precipitation, and geotechnical and hydraulic considerations. The permeable treatment wall for organics removal is technically feasible. It is simple to construct and operate and does not require a source of energy. Disposal of affected media may be required every 5 to 10 years due to rejuvenation. However, because the wall does not specifically address the organic or metals contamination in the seep water, it is not considered administratively feasible.

Cost—The conceptual cost estimate for the Envirometal Treatment Wall is as follows:

Total Capital Cost	$1,113,000
Annualized O&M cost	$2,600/year
Total Present Worth Cost	$1,182,000

Cost estimates and associated assumptions are provided in Appendix G.

FORAGER™ Permeable Treatment Wall

Description—One of the most promising permeable treatment walls is the FORAGER™ sponge developed by Dynaphore, Inc., of Richmond, Virginia. The metal adsorptive permeable treatment wall consists of a funnel and gate system utilizing sheet pilings or other impermeable material for the funnel and 6-in. to 1-ft casings (similar to well casings) at the "gate" of the funnel filled with the FORAGER™ sponge material. The material consists of 1-cubic-centimeter pieces of an organic polymer and is packaged in mesh bags for easy insertion into and removal from the casings.

The FORAGER™ sponge material adsorbs metals and some short chain hydrocarbons (trichloroethane, chloroform, and carbon tetrachloride). Larger organic molecules and ringed compounds such as benzene and naphthalene are not adsorbed. The adsorption of metals, in order of decreasing affinity, is cadmium, mercury, lead, copper, manganese, zinc, iron, and aluminum. Each cubic ft of FORAGER™ sponge can

absorb approximately 200 grams of metals before saturation is reached. Metals that have greater affinity for the sponge will displace metals already absorbed that have lesser affinity. For example, iron may initially absorb onto the FORAGER™ sponge, but as the absorption capacity is neared, zinc or manganese will be absorbed and re-release previously absorbed iron (Rainer 1996).

Effectiveness—For permeable walls for metals treatment, several pilot-scale operations are in place, and the one full-scale implementation was limited to the batch treatment of 4,500 gallons of contaminated groundwater. The analytical results from the one full-scale treatment system show good removal (approximately 90 percent) of cadmium, copper, and lead; less removal for chromium and zinc (32 percent and 8 percent, respectively); and no removal of manganese, iron, and aluminum (EPA's VISITT 4.0 Database, 1995). Removal of manganese, iron, and aluminum in theory could have been achieved by increasing the volume of FORAGER™ sponge in the system (reducing the loading per cubic foot of absorptive material).

Periodic changeout of the FORAGER™ sponge is required. The required changeout time could be as low as a few days or as high as one year. The sponge is not suitable for placement for long periods such as five years because of concerns about degradation of the organic polymer matrix (Rainer 1996). The sponge can either be regenerated or disposed by incineration or by solidification and disposal in a nonhazardous landfill (EPA's VISITT 4.0 Database, 1995). Initial calculations for the seep water show that a 100-cubic-ft volume of FORAGER™ sponge would require the following changeout times to treat 2 gpm (analytes listed in order of decreasing affinity, based on Rainer [1996] and analytical data in EPA's VISITT 4.0 Database, 1995):

- Remove 90 percent of cobalt, lead, copper, chromium, barium, nickel, manganese, zinc, and iron—time between changeout = 17 days

- Remove 90 percent of cobalt, lead, copper, chromium, barium, nickel, manganese, and zinc—time between changeout = 365 days

Implementability—For permeable walls for metals treatment, the required changeout frequency and accompanying high costs indicate that the FORAGER™ sponge treatment wall is not feasible for the removal of all metals up to and including iron. The treatment wall might be feasible if reduction of iron concentrations is not required, with a calculated changeout time of 365 days. Actual changeout times cannot be established without pilot-scale or full-scale testing but will likely be more frequent.

Cost—The conceptual cost estimate for the FORAGER™ permeable treatment wall is as follows:

Total Capital Cost	$427,000
Annualized O&M Cost	$126,000/year
Total Present Worth Cost	$2,900,000

Cost estimates and associated assumptions are provided in Appendix G.

Engineered Wetlands

Description—Engineered or constructed wetlands for passive biological water treatment can be either aerobic (surface type) wetlands or anaerobic (subsurface type) wetlands and are generally considered an innovative technology. Sulfate-reducing bacteria (SRB) bioreactors are a variation of an anaerobic wetland. Passive treatment with SRB reactors, anaerobic wetlands, and aerobic wetlands have all been

successful at removing metals from mine drainage. The primary mechanism for SRB reactors and anaerobic engineered wetlands is microbial reduction of metals and precipitation as sulfides. Therefore, the presence of sulfate in the influent is critical to system performance. The mechanism for aerobic engineered wetlands appears to be primarily coprecipitation with iron, adsorption, and filtration.

All of the potential mechanisms for metals removal include:

1) Adsorption and complexation of metals by organic substrates

2) Microbial sulfate reduction followed by precipitation of metals as sulfides

3) Precipitation of ferric and manganese oxides

4) Adsorption of metals by ferric hydroxides

5) Metal uptake by plants

6) Filtration of suspended and colloidal materials

For the contaminants present above ARARs in the leachate at the seep, such as iron and manganese, an aerobic, surface-type wetland is preferred. This type of system would require an influent collection system with piping, water distribution system using a piping network, and an effluent collection and discharge system. The treatment area would have to be graded to the proper slope with a downgradient berm to contain the water. A soil substrate/growth media would be required for the wetland vegetation. A liner would be required on the bottom of the wetland under the substrate to prevent infiltration to groundwater and discharge of groundwater to the wetland. Operation and maintenance activities would include harvesting and replanting the vegetation as required to prevent short-circuiting of the system and piping might also require periodic cleaning.

Effectiveness—Numerous pilot studies and a few full-scale systems using SRB reactors or engineered wetlands have been implemented in recent years for removal of heavy metals from mine drainages. Engineered wetlands have also been used successfully for removal of conventional pollutants (such as biochemical oxygen demand and nutrients) from municipal and agricultural wastewaters. They have not been designed or used specifically for the removal of toxic organics. Many wetland treatment systems have been designed and built in the United States, but none have operated more than 10 years. Therefore, the long-term effectiveness and costs of these systems are not well established. High seasonal or storm flows that pass through the system might not be treated as effectively as long-term baseflows. Therefore, ARARs might not always be achieved.

Implementability—Standardized, well-accepted design procedures for SRB reactors and engineered wetlands are not available and are still very much in the development stage and continuously evolving. However, some general feasibility and design guidelines developed for metals removal using wetlands are available and can be used as a feasibility screening tool.

The engineered wetlands are technically and administratively feasible. An NPDES discharge permit would probably be required for discharge of the effluent to No Name Gulch. The wetland vegetation that is harvested from the system every few years might require management and disposal as a hazardous waste due to high metals content.

Cost—The conceptual cost estimate for engineered wetlands is as follows:

Total Capital Cost	$1,025,000
Annualized O&M cost	$25,000/year
Total Present Worth Cost	$1,687,700

Cost estimates and associated assumptions are provided in Appendix G.

Treatment Options Selected for Detailed Analysis

The OU 1/OU 2 facility was eliminated from further evaluation due to high cost. The conventional treatment system was eliminated because of high cost and power and O&M requirements. The permeable treatment wall was not carried forward because it does not treat the organics in the leachate and removal of the metals in the leachate is very expensive. The engineered wetlands can remove the metals in the seep water, probably with some coincident removal of the organics, if properly designed. In addition, the wetlands have relatively few O&M requirements. Therefore, the engineered wetlands will be evaluated in more detail for the alternatives development.

5.4.4 Description and Screening of Leachate Disposal Options

Discharge to Surface Water

Description—As discussed in Section 5.5.1, a gravel drainage layer will be constructed under the fill and cap from the seep at SW097 to a location downgradient east of the seep below the edge of the cap. The layer will allow drainage of leachate and prevent build-up of water under and contact with the cap. The gravel layer and leachate would daylight at the surface/east slope of the fill directly into a small open channel in No Name Gulch. The channel would be trapezoidal with a minimum slope of 2 percent. Figure 5-2 shows a grading plan for discharge of the leachate to surface water.

Effectiveness—This option would be effective in preventing subsurface water build-up under the cap and diverting and discharging the leachate to a surface-water channel. However, the leachate will probably not meet ARARs at the point of discharge to surface water. The risk evaluation in Section 3 also indicates potential unacceptable risks to ecological receptors in a surface-water channel. Therefore, this option is not effective in meeting RAOs without treatment of the seep water.

Implementability—The surface-water discharge option can only be implemented if the seep water is treated to meet ARARs prior to discharge. Construction of the surface-water discharge is straightforward and would be similar to constructing a subsurface drain. This option is technically feasible and all the equipment, materials, and labor required for construction are commonly available. This option alone will not meet the RAOs; however, this option combined with treatment could meet RAOs.

Cost—The conceptual cost estimate for the surface discharge option is as follows:

Total Capital Cost	$459,000
Annualized O&M Cost	$4,800/year
Total Present Worth Cost	$587,000

Cost estimates and associated assumptions are provided in Appendix G.

Discharge to Groundwater

Description—The seep will be covered with fill and contained under the landfill cap, similar to the surface-water discharge option. Most of the pond would be covered with 10 to 20 ft of fill that would contain the seep water in the subsurface. Figure 5-3 shows a grading plan for discharge of the leachate to groundwater. The fill would consist of a granular material with a permeability of 1E-02 cm/sec. The fill would be placed in an area of the pond approximately 800 ft long by 50 ft wide near the edge of the landfill and 180 ft wide on the east side near the dam location. The fill may also contain organic material, such as animal manure or peat, to promote attenuation and degradation of the leachate contaminants. The volume and hydraulic conductivity of the fill is adequate to allow the leachate to flow from the seep location to the existing alluvial groundwater flow system.

Effectiveness—This option would be effective in preventing subsurface water build-up under the cap and diverting and discharging the leachate to groundwater. By discharging the leachate to groundwater, risks to ecological receptors would be eliminated. This option does not explicitly provide for treatment of the leachate; however, the contaminant transport modeling (see Appendix D) shows that the leachate contaminant concentrations are greatly attenuated and generally meet ARARs by the time the water in the subsurface reaches the point of compliance. The addition of organic material will enhance this degradation.

Implementability—Construction of the option for leachate discharge to groundwater is straightforward and would be similar to constructing a large subsurface drain system or septic system. This option is technically feasible and all the equipment, materials and labor required for construction are commonly available.

Cost—The conceptual cost estimate for the leachate discharge to groundwater option is as follows:

Total Capital Cost	$1,460,000
Annualized O&M Cost	$4,800/year
Total Present Worth Cost	$1,587,000

Cost estimates and associated assumptions are provided in Appendix G.

Leachate Discharge Options Selected for Detailed Analysis

The surface-water and groundwater discharge options for the leachate were retained and are included in the alternatives developed for detailed analysis. The surface-water discharge option is only included in conjunction with a treatment option in order to meet ARARs.

5.4.5 Summary of Leachate Options Selected for Detailed Analysis

The representative process options for leachate are collection using a subsurface drain, treatment using engineered wetlands, and discharge to either groundwater or surface water.

5.5 GROUNDWATER

The presumptive remedy RAOs include controlling groundwater at the source. In Section 4, the groundwater containment process options were narrowed down to a slurry wall.

As discussed in Section 3, the landfill's existing groundwater containment system has failed along the north side allowing clean groundwater to enter the landfill. The new slurry wall would be designed to block this flow thus reducing groundwater flow through the waste and the resulting contaminant leaching.

A 2,100-ft-long slurry wall would be constructed using in situ soil and bentonite. The wall would be 3 ft wide and would vary in depth from 10 to 33 ft with 5 ft being keyed into weathered bedrock. It would be designed to achieve a hydraulic conductivity of 1E-07 cm/sec or less.

The conceptual cost estimate for the slurry wall is as follows:

Total Capital Cost	$1,207,000
Annualized O&M Cost	$0/year
Total Present Worth Cost	$1,207,000

5.6 SUMMARY OF SCREENING

Based on the screening of process options for GRAs for each medium presented in the previous sections, the following process options will be used in developing alternatives:

- Landfill Mass
  - Containment: Cap cross section E: Single-barrier FMC with low-permeability soil
- Landfill Gas
  - Collection: Passive collection layer with venting pipes or gravel columns
  - Treatment: Monitoring of landfill gas with capability to add treatment if needed
- Leachate
  - Collection: Subsurface drain
  - Treatment: Engineered wetlands
  - Disposal: Discharge to groundwater, discharge to surface water in combination with treatment
- Groundwater
  - Containment: Slurry wall

    As recommended under the NCP, a range of alternatives was developed using the process options that passed the effectiveness, implementability, and cost screening. The retained process options listed in Section 5.8 were combined to address the site as a whole. The no action alternative is presented as a baseline for comparison.

- Alternative 1: No action
- Alternative 2: Cap, Passive Gas Collection and Monitoring, Discharge to Groundwater
- Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, Discharge to Groundwater
- Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, Discharge to Surface Water

These four alternatives were carried forward for detailed analysis in Section 6.

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/Biotic Barrier Layer	Allows drainage of water that infiltrates through vegetative cover Controls head build up on barrier layer Discharges water to perimeter drainage ditch Prevents intrusion by plants and burrowing animals into the underlying barrier layer(s).	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

Table 5-2 Comparison of Cover Effectiveness Factors

Alternative		Permeability (cm/sec)	Average Annual Leakage (in./year)
Option A	Native Soil	1E-02	1.1
Option B	Single-Barrier Clay	1E-07	1.0
Option C	Single-Barrier FMC	1E-13	0.021
Option D	Single-Barrier GCL	3E-09	0.035
Option E	Single-Barrier FMC with Low-Permeability Soil	1E-13	0.00016
Option F	Composite-Barrier FMC and GCL	1E-13	0.00000002
Option G	Composite-Barrier FMC and Clay	1E-13	0.00001

Note:

cm/sec centimeters per second
in./year inches per year
FMC flexible membrane cover
GCL geosynthetic clay liner

Table 5-3 Comparative Analysis of Capping Options Screening

Capping Option		Effective-ness[1]	Implement-ability[2]	Subtotal[3]	Cost (Millions)	Action
Option A	Native Soil	—	—	0	$6.4	Eliminate
Option B	Single-Barrier Clay	1	2	3	$11.2	Eliminate
Option C	Single-Barrier FMC	2	2	4	$8.9	Eliminate
Option D	Single-Barrier GCL	2	1	3	$9.4	Eliminate
Option E	Single-Barrier FMC with Low-Permeability Soil	3	2	5	$9.6	Selected
Option F	Composite-Barrier FMC and GCL	3	1	4	$9.9	Eliminate
Option G	Composite-Barrier FMC and Clay	3	3	6	$11.7	Eliminate

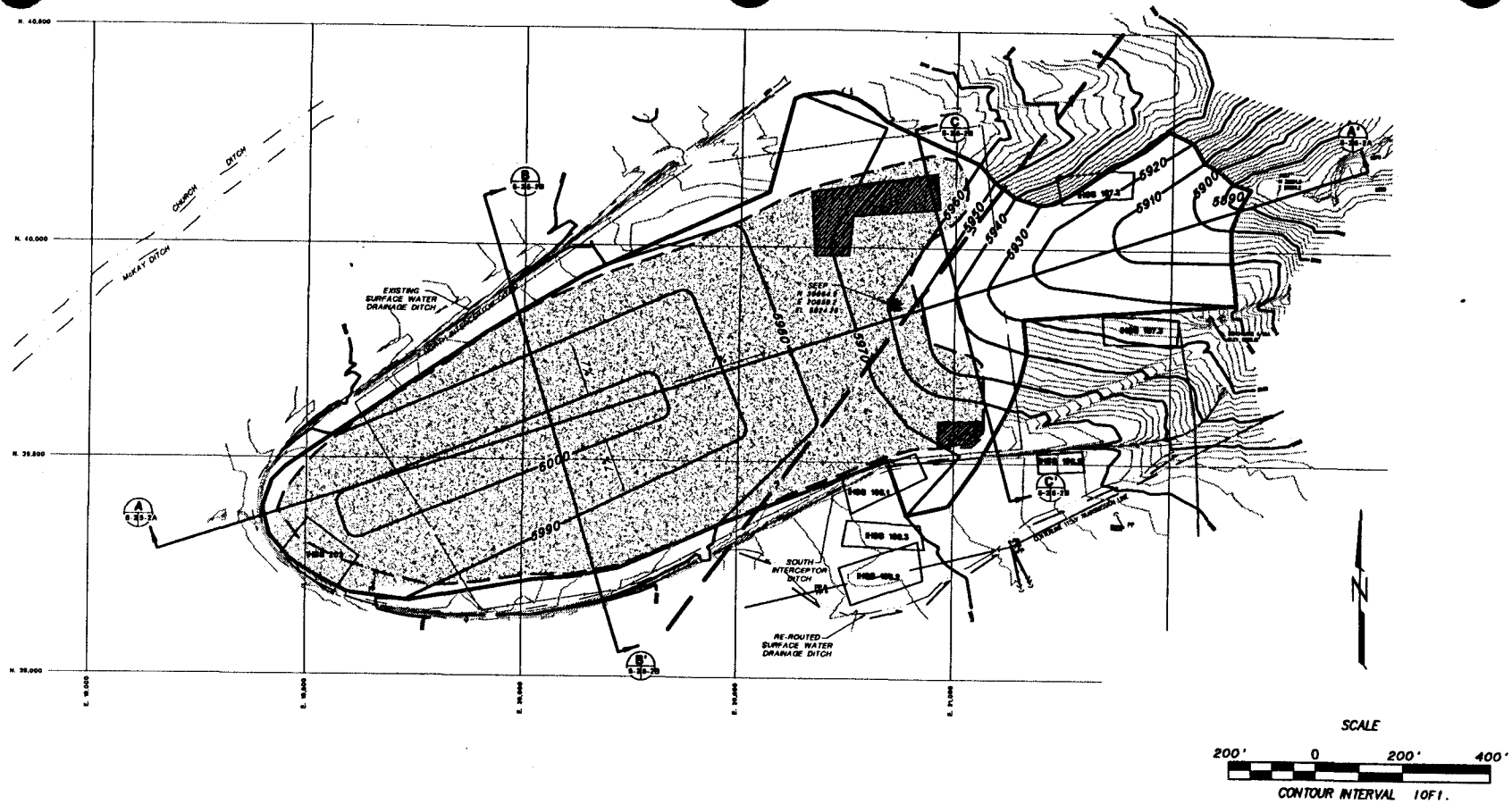
Note:

[1] No rating was given to alternatives that did not meet basic effectiveness criteria. For alternatives that meet basic criteria, a rating of 1, 2, or 3 was made. Ratings are defined below.
1 Infiltration 1 in./year or more
2 Infiltration between 1 and 1E-03 in./year
3 Infiltration between 1E-03 and 1E-08 in./year

[2] No rating was given to Alternatives that did not meet basic implementability criteria. A rating of 1, 2, or 3 was indicated for alternatives that met basic implementability criteria. Ratings are defined below.
1 Includes nonproven construction material
2 Includes components that are similar to those in EPA guidance
3 Follows existing EPA guidance documents

[3] Subtotal is addition of ratings for effectiveness and implementability. The higher the subtotal the better the alternative.

FMC flexible membrane cover
GCL geosynthetic clay liner



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA (AREA : 1,296,912 FT.^{2})
- EDGE OF LANDFILL (AREA : 902,395 FT.^{2})
- ASBESTOS AREA
- COVER AREA (AREA : 919,150 FT.^{2})

NOTES:

1.) REFERENCED ON DRAWINGS 5-2A AND 5-2B
2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

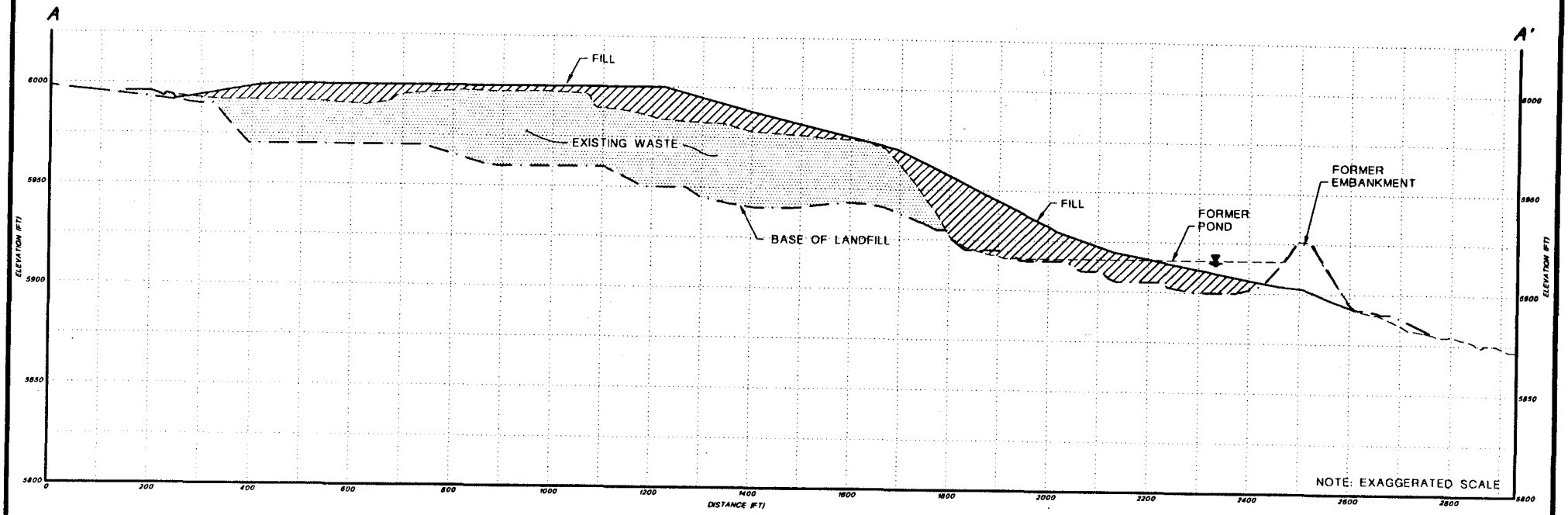
DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

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

Conceptual Grading Plan with Discharge of Seep Water to Groundwater, Extent of Cover, and Surface Water Control Plan

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 5-2



See Note No.1 — A 5-2A

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

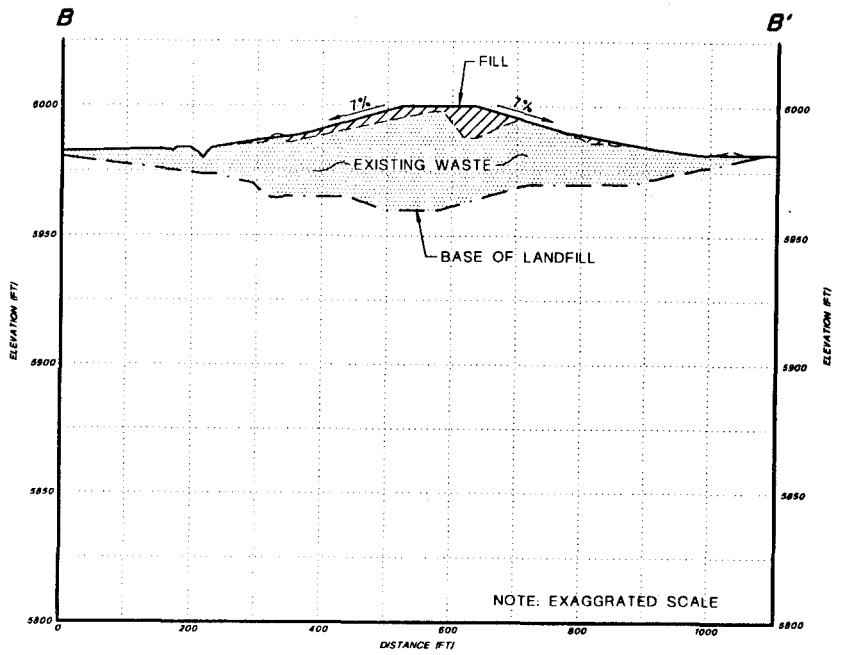
A 8 6
DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

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

Landfill Cover Cross Section A-A'

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 5-2A

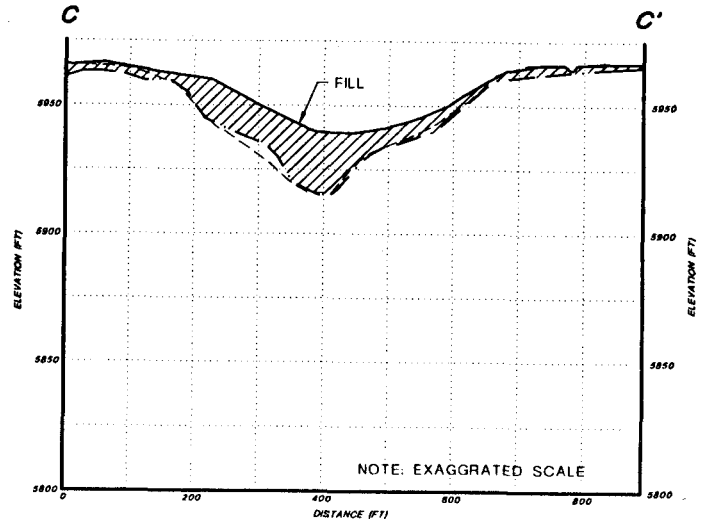


See Note No.1 — B 5-2B

CROSS-SECTION B-B'

HORIZONTAL SCALE
0 100' 200'

VERTICAL SCALE
0 25' 50'



See Note No.1 — C 5-2B

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

A 6 8

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

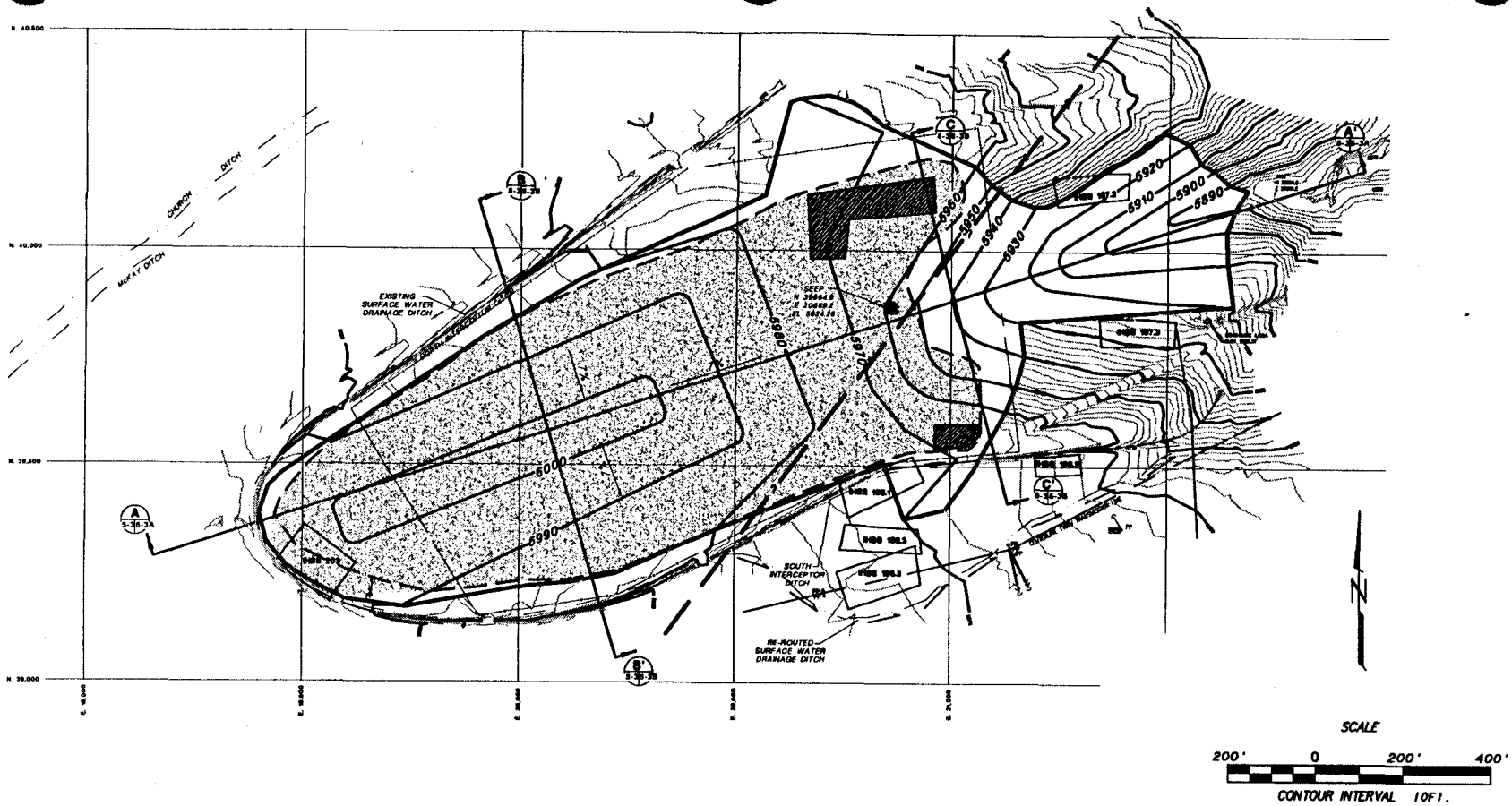
Landfill Cover Cross Section B-B' & C-C'

Phase I IM/IRA

Operable Unit No.7

March 1996

Figure 5-2B



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA (AREA = 1,296,912 FT.^{2})
- EDGE OF LANDFILL (AREA = 902,395 FT.^{2})
- ASBESTOS AREA
- COVER AREA (AREA = 919,150 FT.^{2})

NOTES:

1.) REFERENCED ON DRAWINGS 5-3A AND 5-3B

2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

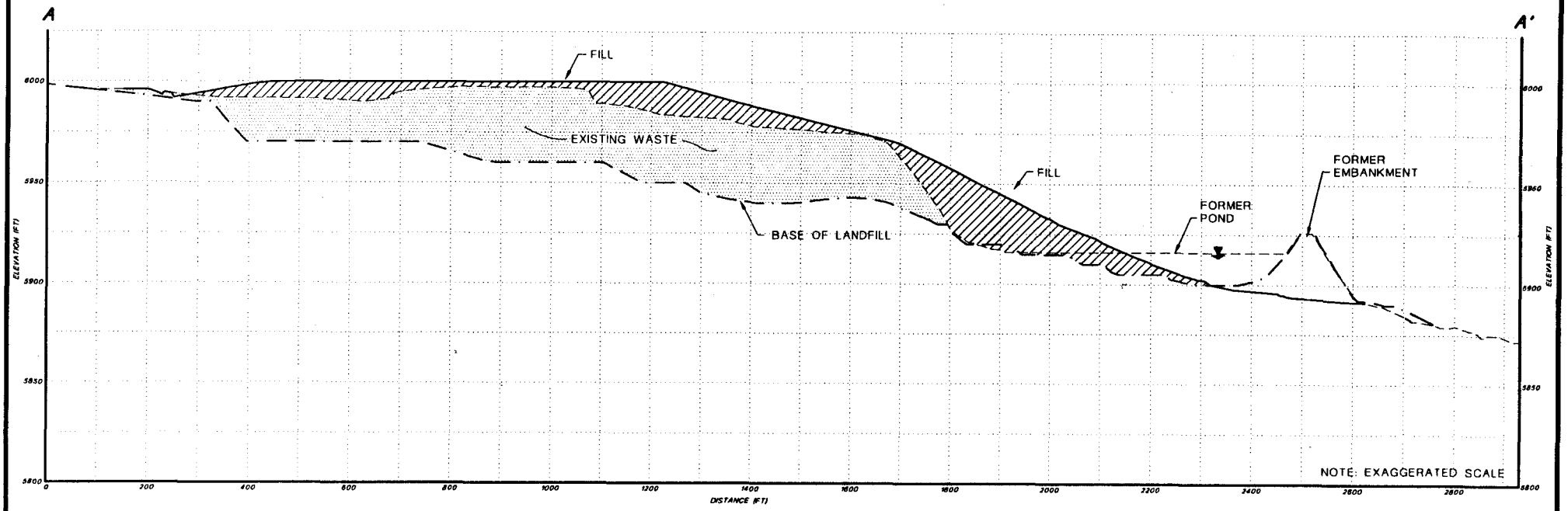
A 6 | 8 — DETAIL/SECTION NUMBER; DRAWING No. WHERE DETAIL/SECTION IS REFERENCED; DRAWING No. WHERE DETAIL/SECTION IS SHOWN

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

Conceptual Grading Plan with Discharge of Seep Water to Surface Water, Extent of Cover, and Surface Water Control Plan

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 5-3



See Note No.1 → A 5-3A

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, 5-3

A 6 6
- 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

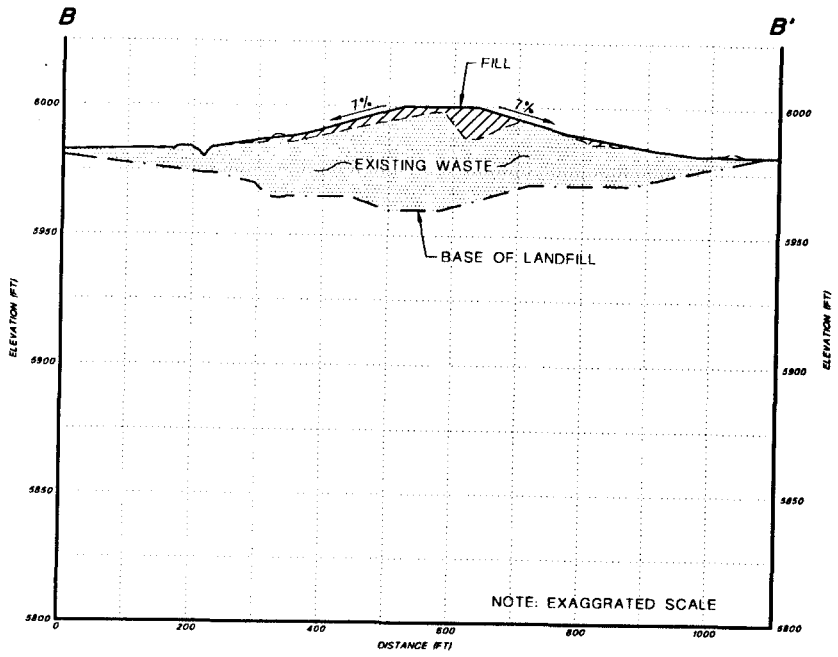
Landfill Cover Cross Section A-A'

Phase I IM/IRA

Operable Unit No.7

March 1996

Figure 5-3A

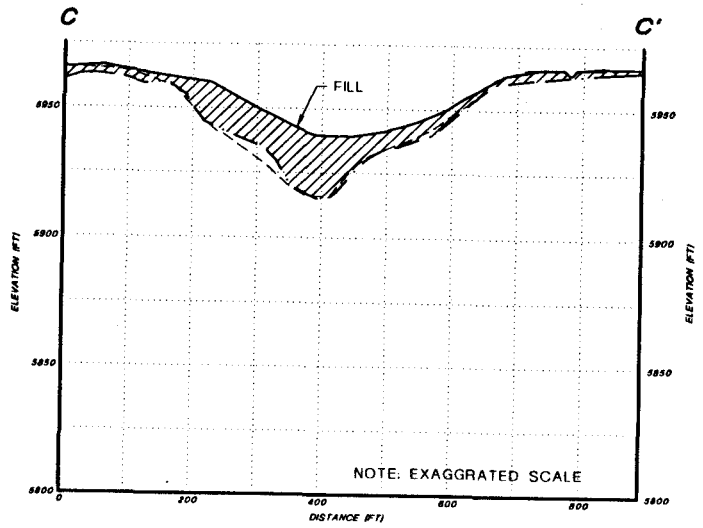


See Note No.1 — B 5-3B

CROSS-SECTION B-B'

HORIZONTAL SCALE
0 100' 200'

VERTICAL SCALE
0 25' 50'



See Note No.1 — C 5-3B

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, 5-3

A 6 6

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

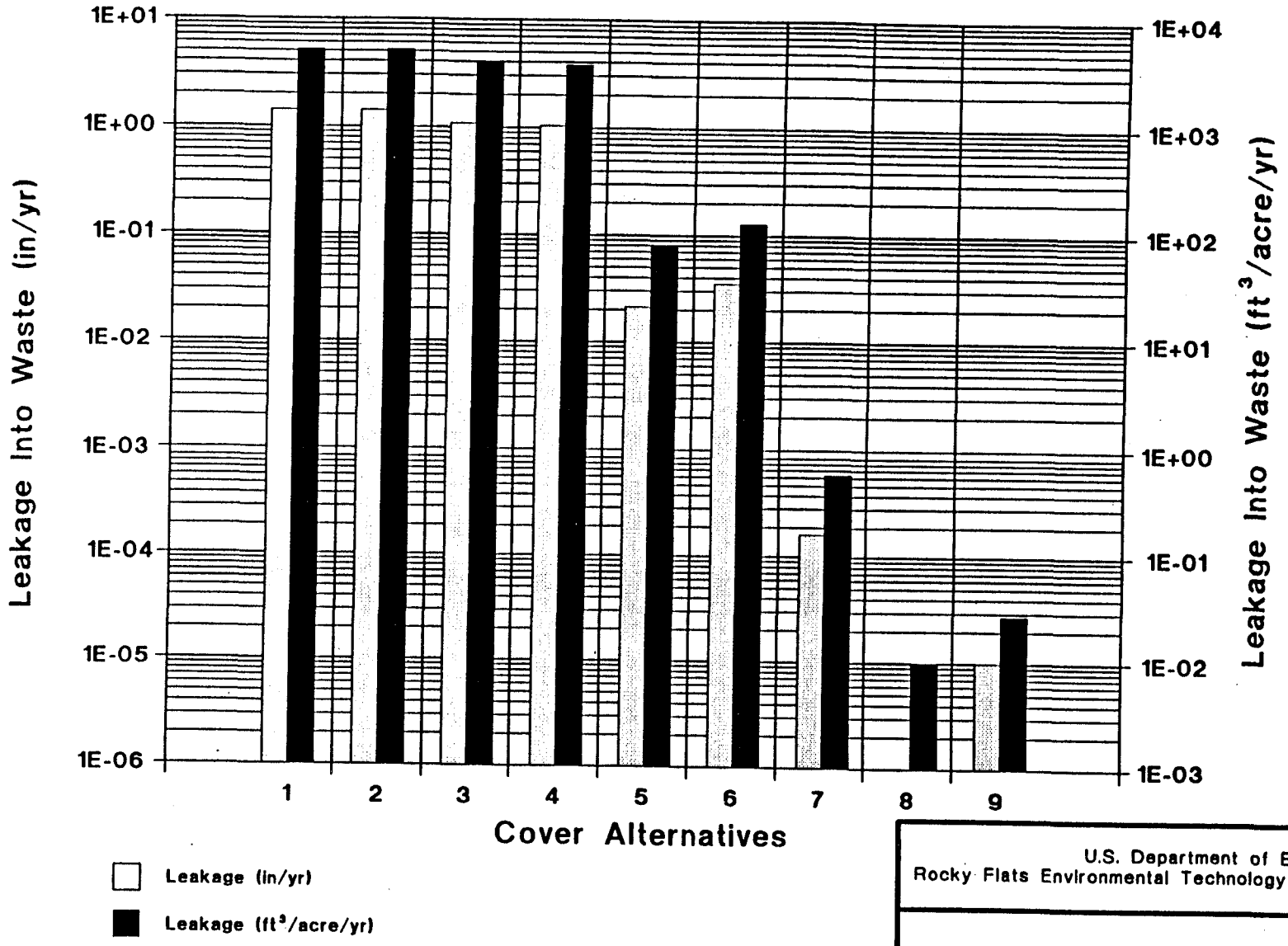
Landfill Cover Cross Section B-B' & C-C'

Phase I IM/IRA

Operable Unit No.7

March 1996

Figure 5-3B



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

Leakage Rates for Cover Alternatives

Phase I IM/IRA DD

Operable Unit No. 7

March 1996

Figure 5-4

6.0 DETAILED ANALYSIS OF ALTERNATIVES

The purpose of the detailed analysis of alternatives is to analyze existing data and provide decisionmakers 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 sufficient 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 evaluation process presented here is more detailed than the effectiveness, implementability, and cost screening presented in Section 5.

Three alternatives were developed through the screening process presented in Section 5. The no-action alternative was retained as a baseline for comparison. Institutional controls are part of all alternatives except No Action. The alternatives evaluated during the detailed analysis include the following:

- Alternative 1: No Action
- Alternative 2: Cap, Passive Gas Collection and Monitoring, Seep Water Discharge to Groundwater
- Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, Seep Water Discharge to Groundwater
- Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, Seep Water Discharge to Surface Water

As discussed in Section 3, removal of the East Landfill Pond and removal and consolidation of the pond sediments and dam under the cap have been agreed to by the regulatory agencies and are included in all alternatives. In addition, mitigation of the wetlands is required for all alternatives. Therefore, these actions will not be discussed in the evaluation of alternatives; however, they are included in the cost estimates.

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 Corrective Action Decision/Record of Decision (CAD/ROD). The nine criteria are as follows:

A. Threshold Criteria

1) Overall protection of human health and the environment

2) Compliance with ARARs

B. 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

C. 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 includes 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 based on the RAOs.

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 postclosure 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.

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 postclosure period. The detailed cost estimates are a combination and refinement of the conceptual cost estimates presented in Section 5.

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 Revised Draft 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 was 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

Description

Under Alternative 1, no action is taken. The cover for the no-action alternative consists of existing interim soil cover material of variable thickness (see Figure 6-1). Under existing conditions, the waste and fill material in the landfill has a permeability of approximately 1E-02 cm/sec. Leachate at the seep will continue to be discharged, although the pond, sediments, and dam will be removed as agreed to by the agencies. The no-action alternative is required under the NCP and provides a baseline for comparison of other alternatives.

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 from construction activities.

Compliance with ARARs—The no-action alternative will not meet chemical-specific ARARs for surface water or groundwater with regard to leachate at the seep. The leachate exceeds standards for iron, manganese, zinc, naphthalene and methylene chloride. 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), postclosure maintenance requirements (6 CCR 1007-3 Part 265.117), and postclosure 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 any of the risks at the site. The existing interim cover and fencing will degrade and become ineffective over time. The average annual leakage rate through the existing soil cover for the no-action alternative is 1.4 in. A description of leakage rates is included in Appendix F.

Reduction of Toxicity, Mobility, and Volume Through Treatment—The no-action alternative relies on natural degradation of contaminants, primarily in the subsurface, 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.

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 as follows:

Total Capital Cost	$0
Annualized O&M Cost	$0/year
Total Present Worth Cost	$0

6.2.2 Alternative 2: Cap, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater

Description

Alternative 2 consists of institutional controls, a single-barrier FMC cap with a 12-in. layer of low-permeability soil, passive gas collection with monitoring, and discharge of the seep water to groundwater. 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 barrier layer is an FMC with a permeability of approximately 1E-13 cm/sec. This cover section is illustrated in Figure 6-2.

The seep will be covered with fill and contained under the landfill cap. This option includes filling most of the pond with up to 10 to 20 ft of fill that would contain the seep water in the subsurface. The fill would consist of a granular material with a permeability of 1E-02 cm/sec and would be placed in an area of the pond approximately 800 ft long by 50 ft wide near the edge of the landfill and 180 ft wide on the east side near the dam location. The fill may also contain organic material, such as peat, to promote attenuation and degradation of the leachate contaminants. The volume and hydraulic conductivity of the fill is adequate to allow the leachate to flow from the seep location to the existing alluvial groundwater flow system.

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—The East Landfill Pond will be removed, and the pond sediments and dam will be removed and used as general fill under the capped area of the landfill. The existing passive seep water collection and treatment system installed as part of the PAM will be removed and disposed in the landfill. The proposed grading plan is shown on Figure 6-3. The location of the existing seep would be covered with fill and capped.

Soil material will be required to buttress unstable slopes. The material will be placed by first establishing a bench of material on the lower toe of slope areas. Additional material will then be 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 gravel layer will be constructed below the grading fill or cover section.

A storage area will be designated near the construction zone for geosynthetic material. Geotextile material will be shipped in plastic covers to protect the material from truck exhaust fumes, road grit, and solar degradation. Deliveries will be inspected and sampled for conformance testing. Rolls of geosynthetic material will be stacked on heavy wooden pallets above the ground surface to protect the material from dirt and mud. The stacks will be arranged to allow easy access for handling and sampling.

Rerouting of the Surface-Water Drainage Ditch—The existing perimeter surface-water drainage ditch was incorporated into the cover design to collect surface-water runoff from the cover and to intercept surface-water run-on to the landfill. The capacity of the existing ditch is adequate for the expected design flows from the cap and surrounding area. Select portions of the perimeter ditch will be rerouted to accommodate the grading plan (see Figure 6-3).

Landfill Cap—The cover cross section recommended in Section 5 consists of five layers: (1) general fill, (2) gas collection, (3) low-permeability soil, (4) FMC, and (5) drainage/biotic and vegetative. The purpose of these layers is discussed in Section 5. Construction of individual cover layers is described below.

Fill Layer—Construction of the cover will begin with placement of general fill. Thickness varies from 3 to 15 ft, 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 will be thickest. In lower elevation areas near the perimeter of the cell, fill will be thinner.

The grading of the fill layer was determined by two factors: (1) the upper bound for the slope is based on stability and (2) erosion control and the lower bound is based on adequate surface-water drainage after settlement, as discussed in Section 5.3.1. Based on these conditions, approximately 52,400 yd^3 of fill will be placed over the capped area.

The thickness of the general fill may also be affected by the final waste configuration. It is assumed that the OU 7 landfill will be closed in April 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 in. of the placed layer. In this area, the fill material should be free of rocks or particles larger than 1 in. 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 will be rolled out over the general fill for gas collection. The geonet will be sandwiched between two layers of filter fabric to prevent fines from clogging the geonet. The composite panels will be overlapped, heat bonded, or tied together.

Gas vents will 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 postclosure plan.

Low-Permeability Soil Layer—The low-permeability soil layer will be placed in a single 1-ft lift using low ground pressure bulldozers. Subsequently, this surface will be compacted using sheepsfoot or wedgefoot compactors. The surface of the soil will then be trimmed. Material placed will be tested for moisture content, compaction, and conformance with source material index tests.

FMC Layer—The FMC geomembrane will be rolled out and seamed using both fusion-welding and extrusion-welding techniques. Long, straight seams will be fusion seamed while extrusion welding will be 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 will be performed on the geomembrane seams to document seam strength and seam integrity. Samples of the seam will be extracted and pulled apart in a tensiometer to test the weld strength. Vacuum box tests and seam air-pressure tests will be used to determine if the seam is airtight.

Drainage/Biotic Layer—The drainage layer composite geonet and filter fabric will be placed over the FMC. The lower filter fabric will provide a cushion so that the geonet does not damage the FMC. Panels will be overlapped, heat bonded, or tied together.

Vegetative and Topsoil 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 ft, 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.

Topsoil, fertilizer, and seeding complete the cover construction. Topsoil 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). Once the borrow areas are determined, a revegetation plan will be developed.

Seep Water Discharge to Groundwater—The conceptual design for discharge of seep water to groundwater includes up to 10 to 20 ft of granular fill with a permeability of approximately 1E-2 cm/sec extending approximately 800 ft down the drainage. Near the edge of the landfill, the fill would be 50 ft wide and then expand to 180 ft wide on the east end near the dam location. During Title II design, consideration would be given to adding organic material, such as animal manure or peat (probably 1 to 3 percent by weight), to promote natural attenuation of the leachate contaminants prior to reaching the point of compliance.

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 will be decontaminated at the main decontamination facility at Rocky Flats as needed. Air quality monitoring will be 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) will be used, and decontamination procedures will be 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. will be included in this report.

Evaluation

Overall Protection of Human Health and the Environment—Alternative 2 provides protection of human health and the environment by meeting all RAOs, except controlling the groundwater at the source. The cap will prevent direct contact with the landfill contents. Security measures will limit access to Rocky Flats. Fencing and other institutional controls will limit access to the landfill at OU 7. The cap will minimize infiltration and limit leaching and contaminant loading to groundwater. The cover was designed to direct the majority of the surface-water runoff to the surface-water drainage ditch and the remainder down the drainage to No Name Gulch. The cover will be graded and revegetated to limit erosion to 2 tons/acre/year. A landfill gas-collection layer and venting system will be installed to protect the integrity of the cap. The design accommodates future landfill gas treatment if needed. Leachate treatment will not be needed because ARARs will be met at the point of compliance and the human health exposure pathway (discharge to surface water) will be eliminated by discharging the seep water to the alluvial groundwater system. The exposure pathway for ecological receptors would also be eliminated.

The cap, gravel layer, and fill downgradient of the cap are relatively straightforward to construct. The low-permeability layer will provide an additional barrier without the strict installation requirements of clay. The alternative provides protection of human health and the environment over the 30-year postclosure 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—Chemical-specific ARARs for surface water and groundwater with regard to the leachate at the seep would be met. The leachate would not be discharged to surface water, and the contaminant transport modeling indicates that ARARs will not be exceeded at the point of compliance. Location-specific ARARs that are generally applicable for OU 7 would be met. The cap and regrade area extends over areas designated as wetlands by COE (see Figure 2-12). OU 7 is eligible for inclusion in the bank as described by the "Memorandum of Agreement for the Administration of a Wetlands Bank at Rocky Flats" (DOE 1995j) which has been approved by EPA and is being reviewed by COE. Dredge and fill requirements under Section 404 of the CWA are applicable. Alternative 2 meets substantive requirements of permitting under the CWA.

Action-specific ARARs under the CHWA, including closure requirements (6 CCR 1007-3 Part 265.310), postclosure maintenance requirements (6 CCR 1007-3 Part 265.117), and postclosure groundwater-monitoring requirements (6 CCR 1007-3 Part 265.228) will be met for Alternative 2.

The 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 (1E-06 to 1E-07 cm/sec)

The single-barrier FMC with low-permeability soil cover has a permeability of approximately 1E-13 cm/sec.

The cover for Alternative 2 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).

Long-Term Effectiveness and Permanence—The landfill mass, which is the source of contamination, will remain in place. However, risks due to direct contact with waste material and leaching of source contaminants into the groundwater will be minimized by the cap and institutional controls. Potential risks to human and ecological receptors from the discharge of the seep water to surface water would be minimized by eliminating the exposure pathway.

The FMC barrier is considered a proven technology and, if properly installed and maintained, will be effective over the 30-year life of the project. In addition, this alternative has a second, low-permeability layer to act as backup, which increases the reliability of the technology. The average annual leakage rate for Alternative 2 is 0.00016 in./acre. A description of cap leakage rates is included in Appendix F.

Maintenance of the cap is not difficult or labor intensive but inspections must be conducted on a periodic basis. If portions of the cap are damaged, these areas must be repaired immediately. DOE is responsible for conducting routine semi-annual 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 as outlined in the OU 7 Closure Plan (see Section 8).

The effectiveness of the remedial action will initially be evaluated every five 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 five 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—There is no active treatment with this option. However, leachate generation and migration will be reduced because the cap will virtually eliminate vertical infiltration of precipitation and surface-water flows. As presented in Appendix C, a water balance was performed for the landfill mass using the MODFLOW (McDonald and Harbough 1991) computer model with site-specific data. The water balance shows that the proposed engineered cover system would reduce water flows into the landfill and leachate generation.

Total inflows and outflows will be reduced from 2 to 1gpm by capping. A significant reduction in saturated thickness of the waste material (from approximately 15 to 8 ft) and the elimination of much of the seasonal variability of leachate flow rates are expected. This reduction of saturated waste thickness, elimination of seasonal variability, and elimination of vertical infiltration flows through waste above the water table will result in reduced contaminant loading to groundwater.

There will be a decrease in toxicity and mobility over time due to natural attenuation processes including dispersion, biodegradation, hydrolysis, oxidation, and volatilization.

Short-Term Effectiveness—No excavation into contaminated areas is required to implement this alternative. The contaminants are currently under a 12- to 36-in.-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 will be generated during excavation, transport, and placement of fill, the gravel layer for seep discharge, the low-permeability soil layer, and the vegetative layer. The dust emissions will be controlled by water spraying or possibly soil binders.

During construction, there is potential for increased erosion and, therefore, increased solids loading to the surface-water drainage ditch. Erosion of the cover soil will diminish as vegetation becomes established on the surface. Until that time, however, berms and hay bales will be used to intercept surface-water runoff and prevent the offsite transport of solids. Erosional features such as rills and gullies will need to be repaired. This postclosure 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.

Construction of Alternative 2 would be complete within 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. The FMC component will be covered with a 36-in.-thick vegetative soil that prevents exposure of the FMC to ultraviolet radiation and prevents punctures by 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 will be nonhazardous and the gases are expected to contain only low concentrations of hazardous components.

The low-permeability soil will be placed on top of the gas-collection layer and spread in a single 1-ft lift. The surface of the 1-ft lift will be 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 will increase the reliability of the technology because the low-permeability soil acts as a backup barrier for the FMC layer.

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 construction of the gravel layer and fill for discharge of the seep water to groundwater is straightforward and would be similar to constructing a large French drain or septic system. All the equipment, materials, and labor required for construction are commonly available. A comprehensive evaluation of the proposed system, including a contingency plan for sampling and mitigating potential water seeps, will be performed as part of the Title II design.

The effectiveness of the remedy will be monitored by postclosure monitoring programs as described in Section 8.

Cost—The costs for Alternative 2, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater, are:

Total Capital Cost	$9,370,000
Annualized O&M Cost	$62,000/year
Total Present Worth Cost	$371,000

Detailed cost estimates are provided in Appendix G.

6.2.3 Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater

Description

Alternative 3 consists of institutional controls, a single-barrier FMC cap with a 12-in. layer of low-permeability soil, a passive gas collection and monitoring system, an upgradient slurry wall, and discharge of seep water to groundwater. This alternative is the same as Alternative 2 with the addition of the slurry wall. The slurry wall was added to divert clean groundwater entering the landfill through the failed groundwater intercept system along the north side of the landfill. The slurry wall would have a permeability of 1E-07. The location of the slurry wall is shown in Figure 6-4.

Construction of the cap and gravel layer and fill for discharge of seep water to groundwater are the same as for Alternative 2. The slurry wall will be constructed in a vertical trench that is hydraulically shored by the addition of a slurry to prevent collapse. A 2,100-ft-long, 3-ft-wide trench will be excavated using a backhoe. Bentonite slurry will be pumped into the trench just after it is opened and maintained at a level near the top of the excavation. The trench will be keyed 5 ft into weathered bedrock. The depth of the trench will be verified by examination of the excavated materials by a geologist. After a sufficient length of the trench has been dug to the required depth, it will be backfilled with a mixture of soil and bentonite. A bulldozer will be used to mix the excavated soil and bentonite slurry into a consistency similar to wet concrete and push it back into the trench. Excavation and backfilling will be phased to make the operation continuous with relatively small volumes of slurry.

The slurry wall will not be physically tied into the existing groundwater intercept system because the tie in would require excavation of existing waste that was used to backfill the leachate collection trench. Instead the slurry wall will extend 100 to 200 ft beyond the groundwater divide on the west side of the landfill where groundwater flow splits and is diverted to the north and to the south. On the east, the new slurry wall will end near the end of the existing slurry wall. Particle tracking shows that flows diverted to this point will flow into No Name Gulch downgradient of the eastern edge of the landfill mass.

Evaluation

Overall Protection of Human Health and the Environment—Alternative 3 directly addresses all RAOs. The cap, fence, and institutional controls will prevent direct contact with the landfill contents. The cap has a permeability of approximately 1E-13 cm/sec and therefore minimizes infiltration and the resulting leaching to groundwater. The surface will be graded and revegetated to control surface-water runoff and erosion. A gas-collection system will be designed to control landfill gas. Gas treatment may be added if warranted during postclosure monitoring. Treatment of leachate is addressed indirectly through natural attenuation by discharge of the seep water to groundwater. The slurry wall will divert groundwater around the landfill thus decreasing leachate generation and potentially contaminant concentrations and loadings.

The cap and slurry wall will provide protection over the 30-year life of the project. Because there is no planned excavation into the landfill waste, short-term impacts are minimal.

Compliance with ARARs—Chemical-specific ARARs for surface water and groundwater with regard to the leachate at the seep would be met. The leachate would not be discharged to surface water, and contaminant transport modeling indicates that ARARs will not be exceeded at the point of compliance.

Location-specific ARARs applicable to OU 7 would be met. The wetlands area designated by COE will be mitigated. OU 7 is included in the "Memorandum of Agreement for the Administration of a Wetland Bank at Rocky Flats" (DOE 1995j), which has been approved by EPA and is presently being reviewed by COE. The alternative will meet dredge and fill requirements under Section 404 of the CWA.

Action-specific requirements under the CHWA, including closure requirements and postclosure maintenance and groundwater-monitoring requirements, would be met. The cap design does not comply with EPA guidance for Subtitle C. However, it is equally protective. Construction procedures will meet the requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101).

Long-Term Effectiveness and Permanence—The landfill mass, which is the source of contamination, will remain in place. However, risks associated with direct contact with waste and leaching of source contaminants into the groundwater will be minimized by the cap, slurry wall, and institutional controls. As discussed for Alternative 2, the effectiveness of discharging seep water to the alluvial groundwater will be heavily dependent upon the final design of the system. It is possible that the flow could surface during high-flow conditions or that the effectiveness of natural attenuation could decrease due to accumulation of loadings. An in-depth analysis and design to address these issues will be part of the Title II design. However, the groundwater contaminant transport modeling (Appendix D) provides very conservative concentration estimates by simulating continuous mass loading at the source. The results of the modeling indicate low concentrations at the compliance boundary. Potential risks to human and ecological receptors from the discharge of the seep water to surface water would be minimized by eliminating the exposure pathway.

The cap is considered a proven technology and is expected to be effective over the 30-year life of the project. The slurry wall is an EPA-approved technology for containment and, if properly installed, will be effective during the postclosure period.

It is not anticipated that any of the components will need to be replaced during the postclosure period, provided the cap receives periodic inspections and repairs as described under Alternative 2. Groundwater monitoring and five-year reviews are also discussed under Alternative 2.

Reduction of Toxicity, Mobility, and Volume Through Treatment—There is no active treatment with this option. However, leachate generation and migration will be reduced because the cap eliminates vertical infiltration of precipitation and surface-water flows and the north slurry wall will reduce horizontal inflow through the alluvium and artificial fill.

As presented in Appendix C, 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 scenario, the water balance calculations indicate that approximately 40 percent of the inflow to the landfill is upgradient groundwater from the alluvium and 60 percent is recharge by infiltration of precipitation. Most of the groundwater inflow (93 percent) occurs on the north side of the landfill. Contributions from the west side (less than 1 percent) and the south side (7 percent) are relatively insignificant. The water balance for Alternative 3 (the cap and slurry wall scenario) indicates that the construction of a 1E-07 cm/sec slurry wall on the north side of the landfill would reduce horizontal inflow from 0.8 to 0.3 gpm. Total inflows and outflows would be reduced from 2.0 gpm for the no-action scenario to 0.4 gpm for Alternative 3. The water balance shows that the proposed engineered cover system combined with the north slurry wall would effectively reduce water inflow and leachate generation.

A significant reduction in saturated thickness (from approximately 15 ft to 4 ft) of the waste material and the elimination of much of the seasonal variability of leachate flow rates are expected. This reduction of saturated waste thickness, elimination of seasonal variability, and elimination of vertical infiltration flows through waste above the water table and horizontal groundwater flows will result in reduced contaminant loading to groundwater.

There will also be a decrease in toxicity and mobility of contaminants over time due to natural attenuation processes including dispersion, biodegradation, hydrolysis, oxidation, and volatilization in the alluvial groundwater.

Short-Term Effectiveness—Because the slurry wall is not keyed into the existing groundwater intercept system, no excavation into potentially contaminated areas is anticipated. Therefore, with proper use of PPE, risks to the community and site workers are minimal.

Dust will be generated during construction of the cap and slurry wall. Dust emissions will be controlled by water spraying and possibly soil binders. During construction, there is potential for increased erosion and, therefore, increased solids loading to the surface-water drainage ditch. Berms and hay bales will be used to intercept surface-water runoff and prevent the offsite transport of solids. Erosional features such as rills and gullies will be repaired.

Construction of Alternative 3 would be completed in approximately one year and three months.

Implementability—All aspects of the alternative are technically and administratively feasible. Both the cap and slurry wall require extensive QA/QC during construction. However, industry standards for both are well developed, and companies specializing in this type of construction are readily available.

The implementability of the cap and construction of a gravel layer and fill for discharge of the seep water to groundwater is discussed under Alternative 2.

The site conditions at OU 7 are conducive to construction of the slurry wall. The area where the slurry wall will be installed is relatively level. This is necessary because both the slurry and the backfill will flow under stress. There is sufficient work area along the trench for mixing and placing the backfill. The depth required to key the slurry wall into weathered bedrock will not require any special equipment.

As with the cap, proper quality control is essential. The integrity of the slurry wall is dependent on trench continuity including the key into bedrock and the quality and uniformity of the backfill mixture. A CQA plan will be part of the Title II design.

Laboratory testing has been conducted for OU 7 groundwater and soil to determine the mix required to produce the design permeability of 1E-7 and to ensure compatibility with any chemicals present in the groundwater. Two types of bentonite were mixed with soil collected from the site at 2, 4, and 6 percent by weight. Permeability testing was performed at two different hydraulic gradients: 2 psi and 4 psi (equal to approximately 4.6 and 9.2 ft of differential hydraulic head, respectively). Groundwater from the site was collected and used as the permanent fluid to measure the bentonite soil mixture's permeability. The results of this testing indicate that laboratory mixed samples could attain permeability values in the range of E-8 cm/sec for both types of bentonite.

The effectiveness of the alternative would be evaluated as part of the postclosure monitoring program as described in Section 8.

Cost—The costs for Alternative 3, Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater, are as follows:

Total Capital Cost	$10,529,000
Annualized O&M Cost	$62,000/year
Total Present Worth Cost	$11,735,000

Detailed cost estimates are provided in Appendix G.

6.2.4 Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Surface Water

Description

Alternative 4 consists of institutional controls, a single-barrier FMC with a 12-in. layer of low-permeability soil, passive gas collection and monitoring, engineered wetlands, and discharge of seep water to surface water. The engineered wetlands would be designed so that the discharge will meet surface-water ARARs. The approximate location of the wetlands is shown in Figure 6-5.

Construction of the cap is the same as for the other alternatives.

A gravel drainage layer would be constructed under the fill and cap from the seep downgradient to the east to the inlet of the wetlands treatment system below the edge of the cap. The conceptual design indicates that this drainage layer would consist of an area approximately 40-ft wide, 100-ft long (sloped at a minimum 2 percent), and 2- to 4-ft thick using a free-draining clean gravel with a permeability of 1E-1 cm/sec. The gravel layer would daylight near the east slope of the fill directly into a subsurface drain and inlet piping system for the wetlands treatment system. This layer will allow drainage of seep water to the treatment system and prevent build-up of liquids under the cap.

A manifold would distribute influent flow to the wetland area. The wetlands would consist of basins or channels with a soil/substrate and shallow water as required to support the wetlands vegetation. An impermeable liner under the substrate is used to prevent seepage. The basins are sloped at a minimum 2 percent to the outlet to provide passive flow through the system while maintaining adequate detention time.

The outlet structure controls the water level in the wetland. During the Title II design, consideration will be given to using a portion of the existing dam as the downgradient barrier.

The exact size and location of the wetlands would be determined during the Title II design. The wetlands would be located upgradient of the point of compliance. The treated water from the wetlands system would be discharged by an effluent pipe directly into a small open channel leading to No Name Gulch. This channel would be trapezoidal with a minimum 2 percent slope.

Evaluation

Overall Protection of Human Health and the Environment—Alternative 4 directly addresses all RAOs except controlling groundwater at the source. The cap, fence, and institutional controls will prevent direct contact with the landfill contents. The cap has a permeability of approximately 1E-13 cm/sec and, therefore, minimizes infiltration and resulting leaching to groundwater. The surface will be graded and

revegetated to control surface-water runoff and erosion. The gas-collection system is designed to control landfill gas. Gas treatment may be added if warranted during postclosure monitoring. Treatment of leachate is addressed by the engineered wetlands.

Potential risks to human and ecological receptors would be minimized by treating the leachate prior to discharge to surface water.

The cap and engineered wetlands will provide protection over the 30-year life of the project.

Because there is no planned excavation into the landfill waste, short-term impacts are minimal.

Compliance with ARARs—Because little long-term operational data for engineered wetlands exist, compliance with chemical-specific ARARs for surface water is not certain. Pilot testing, a conservative design, or modifications to optimize operation may be required to ensure compliance. High seasonal or storm flows may also have a detrimental effect on the wetland's ability to consistently meet ARARs.

Location-specific ARARs applicable to OU 7 would be met. Wetlands area designated by the COE will be mitigated. OU 7 is eligible for inclusion in the Wetland bank as described by the "Memorandum of Agreement for the Administration of a Wetland Bank at Rocky Flats" (DOE 1995j), which has been approved by EPA and is presently being reviewed by COE. The alternative will meet dredge and fill requirements under Section 404 of the CWA.

Action-specific requirements under the CHWA, including closure requirements and postclosure maintenance and groundwater-monitoring requirements, would be met. The cap design does not comply with EPA guidance for Subtitle C. However, it is equally protective. Construction procedures will meet the requirements of the Soil Erosion Dust Blowing Act (CRS 35-72-101). An NPDES permit would probably also be required for discharge of effluent to No Name Gulch.

Long-Term Effectiveness and Permanence—The landfill mass, which is the source of contamination, will remain in place. However, risks associated with direct contact with waste and leaching of source contaminants into the groundwater will be minimized by the cap and institutional controls. Long-term risks to human and ecological receptors would be minimized by treating the leachate prior to surface-water discharge.

As discussed for Alternative 2, the cap is considered a proven technology and is expected to be effective over the 30-year life of the project. However, engineered wetlands are generally considered innovative because of the lack of long-term operating experience.

Groundwater monitoring and five-year reviews are also discussed under Alternative 2.

Reduction of Toxicity, Mobility, and Volume Through Treatment—Leachate would be treated using the engineered wetlands. Several mechanisms are responsible for the removal of contaminants in wetlands systems. Some of these may be reversible, such as resuspension of precipitates during high flow conditions. Residuals of the process include metal precipitates and plants and sediment with high metals concentrations.

In addition, leachate generation and migration will be reduced because the cap will eliminate vertical infiltration of precipitation and surface-water flows. As presented in Appendix C, a water balance was performed for the landfill mass using the MODFLOW (McDonald and Harbough 1991) computer model

with site-specific data. The water balance shows that the proposed engineered cover system would reduce water flows in the landfill and leachate generation.

Total inflows and outflows would be reduced from 2 gpm to 1 gpm by capping. A significant reduction in saturated thickness of the waste material (from approximately 15 ft to 8 ft) and the elimination of much of the seasonal variability of leachate flow rates are expected. This reduction of saturated waste thickness, elimination of seasonal variability, and elimination of vertical infiltration flows through waste above the water table will result in reduced contaminant loading to groundwater.

Short-Term Effectiveness—The wetland vegetation will take approximately two years to become fully established.

No excavation into potentially contaminated areas is anticipated. Therefore with proper use of PPE, risks to the community and site workers will be minimal.

Dust will be generated during construction of the cap and wetlands. Dust emissions will be controlled by water spraying and possibly soil binders.

During construction, there is potential for increased erosion and, therefore, increased solids loading to the surface-water drainage ditch. Berms and hay bales will be used to intercept surface-water runoff and prevent the offsite transport of solids. Erosional features such as rills and gullies will be repaired.

Construction of Alternative 4 would be completed in one year.

Implementability—All aspects of the alternative are technically and administratively feasible. Although well-established design criteria are not available for the engineered wetlands, general guidelines are available.

The cap requires extensive QA/QC during construction. However, industry standards are well developed, and companies specializing in this type of construction are readily available. The implementability of the cap is discussed under Alternative 2.

Construction techniques for the engineered wetlands and surface-water discharge are relatively straightforward. Establishing the 1 to 3 percent slope should require little fill and regrade. Installing the liner will be labor intensive and will require extensive CQA. However, contractors specializing in installation of geosynthetics are readily available. Establishing vegetation may be the most difficult aspect of construction. However, with adequate watering and good weather, vegetation growth should not be a problem.

The alternative operates in a passive mode. It requires no power, additional reactants, or any continuous maintenance. Periodic maintenance includes vegetation harvesting, revegetation, and removal of sediments.

The reliability of the engineered wetlands is uncertain. The technology is considered innovative and adequate long-term operating data are not available to optimize the design and operation for consistent compliance with ARARs.

The ease of undertaking additional actions if the wetlands do not meet ARARs is dependent on the extent

of the failure. Increasing the size of the wetlands would be relatively straightforward. However, construction of an alternate treatment facility would be time consuming and costly.

Regulatory agency and public perception of wetlands tends to be very positive. No difficulty in getting approvals is anticipated.

The effectiveness of the alternative would be evaluated as part of the postclosure monitoring program as described in Section 8.

Cost—The costs for Alternative 4, Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Groundwater, are as follows:

Total Capital Cost	$9,470,000
Annualized O&M Cost	$102,000/year
Total Present Worth Cost	$11,464,000

Detailed cost estimates are provided in Appendix G.

6.3 COMPARATIVE ANALYSIS

In the previous sections, each of the alternatives was evaluated individually using 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.

6.3.1 Overall Protection of Human Health and the Environment

Alternatives 2, 3, and 4 are protective of human health and the environment. Alternative 3 is the only alternative that directly addresses the RAO to control groundwater at the source. However, groundwater modeling shows that while the cap eliminates over half of the 2 gpm total flow, the slurry wall decreases groundwater flow by only an additional 1 gpm. The cap alone is expected to reduce the saturated thickness of the waste, eliminate much of the seasonal variability of the flows out of the landfill, and virtually eliminate vertical infiltration flows through unsaturated waste above the water table. The only benefit of the slurry wall is some additional reduction of saturated thickness in the waste. Generally, decreasing the flow is desirable to decrease associated treatment costs. However, in all alternatives, treatment is passive or by natural attenuation, and savings due to such a small decrease in flow are minimal or nonexistent.

The groundwater model was calibrated to March 1993 water levels, which is consistent with a low to moderate flow condition at the landfill. This condition exists for most of the year. High-flow conditions exist for a few months in the spring, usually peaking in April and falling rapidly after the peak. It is postulated that the major contributor to high-flow conditions is infiltration and not increased groundwater inflow (greatly increased precipitation combined with low to moderate evapotranspiration dramatically increases recharge in the spring while the groundwater inflow paths and hydraulic gradients remain relatively constant). Measured and simulated water elevations indicate that the following saturated thicknesses exist or could exist in the center of the landfill: (1) no action, approximately 15 ft saturated thickness, which would increase seasonally due mainly to increased infiltration; (2) cap only, approximately 8 ft saturated thickness, which would stay relatively constant seasonally; and (3) cap and north slurry wall, approximately 4 ft saturated thickness, which would stay relatively constant seasonally.

The cap will therefore be more effective in reducing flows and contaminant concentrations than the slurry wall for the following reasons: (1) the cap will prevent much of the seasonal variation in flows and saturated thickness currently observed, and (2) the cap will decrease the elevation of the water table within the waste (reduce the saturated thickness) and will prevent virtually all of the vertical infiltration through the waste located above the water table, eliminating most if not all contaminant loading from these wastes. In contrast, the slurry wall contribution to reduced flow is more constant throughout the year. The slurry wall reduces flows and contaminant concentrations only by reducing the saturated thickness within the waste.

Because there is little long-term operating experience for wetlands, it is not known if this alternative will consistently meet chemical-specific ARARs.

6.3.2 Compliance with ARARs

Alternatives 2 and 3 are expected to meet chemical-specific ARARs at the point of compliance, except for iron, with regard to discharge of the seep water to groundwater under Alternative 4, the wetlands would be designed to comply with chemical-specific ARARs. However, the innovative nature of engineered wetlands makes long-term compliance uncertain. All alternatives will meet location- and action-specific ARARs.

6.3.3 Long-Term Effectiveness and Permanence

The source of contamination remains in place for all alternatives as part of the presumptive remedy. Although the possibility exists that water may surface and that natural attenuation may decrease over time for Alternatives 2 and 3, uncertainties associated with the long-term performance of the wetlands system are greater. Alternative 4 would also require periodic maintenance.

Potential long-term human health and ecological risks from leachate discharging to surface water would be eliminated with Alternatives 2 and 3 by eliminating the exposure pathway. They would also be minimized with Alternative 4 by treating the leachate, but the long-term effectiveness of this option is not known.

6.3.4 Reduction of Toxicity, Mobility, and Volume

Only Alternative 4 (with engineered wetlands) includes treatment explicitly. However, Alternatives 2 and 3 reduce toxicity through natural attenuation. All three alternatives reduce volume and toxicity by capping. The cap eliminates over one half of the 2 gpm total flow. The slurry wall proposed in Alternative 3 will decrease groundwater flow by an additional 0.6 gpm. Capping may also reduce toxicity by reducing the average depth of saturated waste from 15 to 8 ft (as estimated by MODFLOW modeling), eliminate much of the seasonal variability of the flows out of the landfill, and virtually eliminate vertical infiltration flows through unsaturated waste above the water table. The slurry wall will reduce the depth of saturated waste an additional 4 ft.

6.3.5 Short-Term Effectiveness

None of the alternatives present a significant danger to the community, construction workers, or the environment during construction. Fugitive dust and erosion are readily mitigated using standard construction techniques.

6.3.6 Implementability

Alternative 2 rates the highest with regard to implementability. Alternative 3 is the same as Alternative 2 with the addition of the slurry wall which, once constructed, requires no Operation and Maintenance. The wetlands alternative requires that vegetation be established and that sediments and vegetation be removed and disposed (possibly as a RCRA waste) on a periodic basis. Necessary equipment and specialists are available for all alternatives.

Wetlands are often favored by the public and regulatory agencies. However, approval would be expected for all alternatives.

Monitoring the condition of the cover will be the same for all alternatives. Details of inspections and maintenance are presented in the OU 7 Postclosure Plan (see Section 8).

6.3.7 Cost

Table 6-2 summarizes the detailed cost estimate. The total present worth costs for the alternatives are as follows:

Alternative 1:	No Action	$0
Alternative 2:	Cap, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater	$10,570,000
Alternative 3:	Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater	$11,735,000
Alternative 4:	Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Surface Water	$11,464,000

6.3.8 Summary of Comparative Analysis

Based on the above comparison, Alternative 2, Single-Barrier FMC with Low-Permeability Soil Cover, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater, rates the highest and is the preferred IM/IRA for OU 7. This alternative is discussed in detail in Section 7

Table 6-1 Evaluation Criteria for the Detailed Analysis of Alternatives

Seven CERCLA Criteria	Assessment Components	Discussion of Evaluation
Threshold Criteria		
Overall Protection of Human Health and the Environment	Addresses RAOs, 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, water 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 (TMV) Through Treatment	Treatment process used and materials treated	Treatment of landfill waste is not part of the presumptive remedy Reduction in TMV of leachate based on modeling and engineering judgment Reduction in TMV of leachate also based on treatment using engineered wetlands and natural attenuation in groundwater
	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	

Table 6-1 (continued)

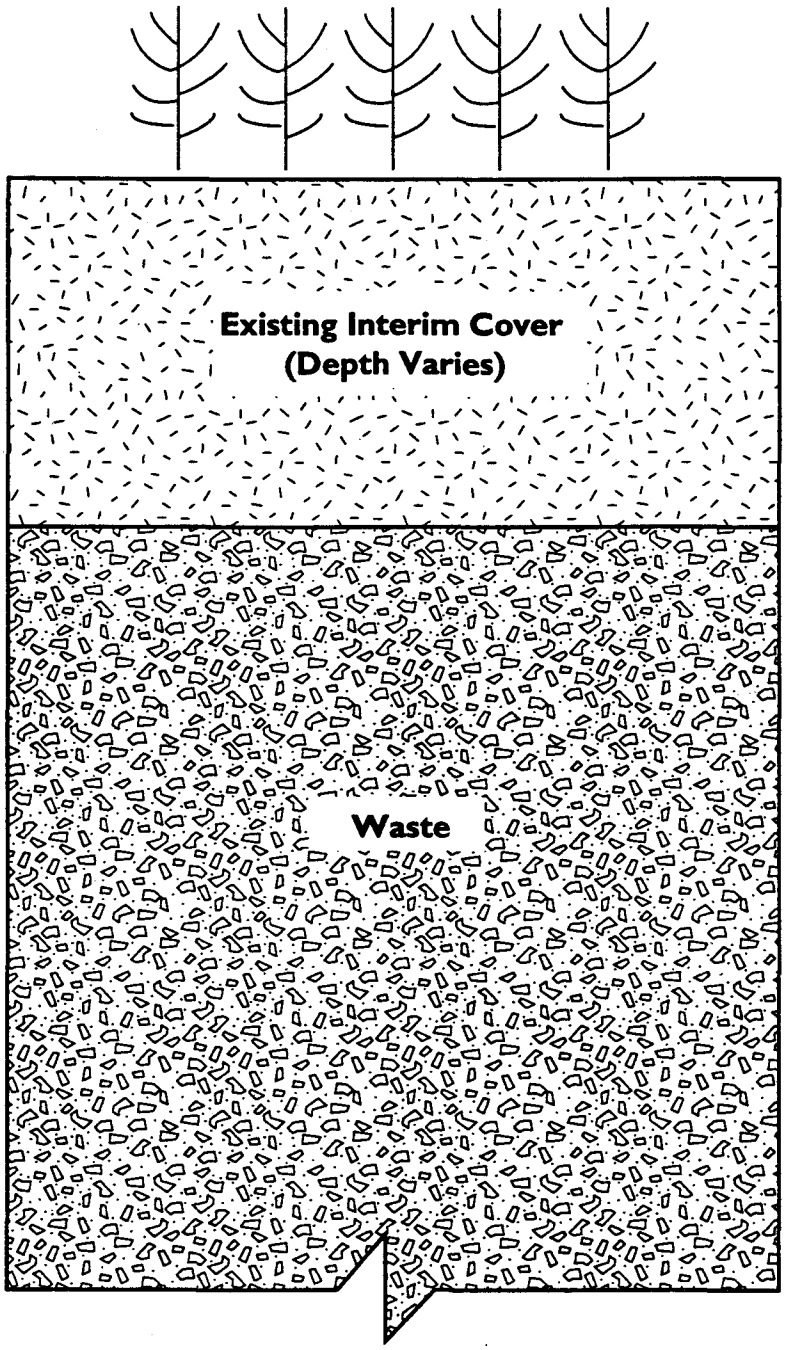
Seven CERCLA Criteria	Assessment Components	Discussion of Evaluation
Implementability	Technical feasibility	Construction and operation, reliability, monitoring effectiveness, and ease of additional remedial action
	Administrative feasibility	Regulatory approval and coordination with other agencies
	Availability 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	

Table 6-2 Summary of Cost Estimate

Alternative	Annualized O&M Cost	O&M Present Worth	Capital Cost	Total Present Worth Cost
1 — No Action	$0	$0	$0	$0
2 — Cap, Passive Gas Collection, Seep Water Discharge to Groundwater	$61,500	$1,206,400	$9,370,500	$10,576,900
3 — Cap, Passive Gas Collection, Slurry Wall, Seep Water Discharge to Groundwater	$61,500	$1,206,400	$10,528,800	$11,735,200
4 — Cap, Passive Gas Collection, Engineered Wetlands, Seep Water Discharge to Surface Water	$102,200	$1,994,300	$9,469,900	$11,464,200

Note:

O&M Operation and Maintenance



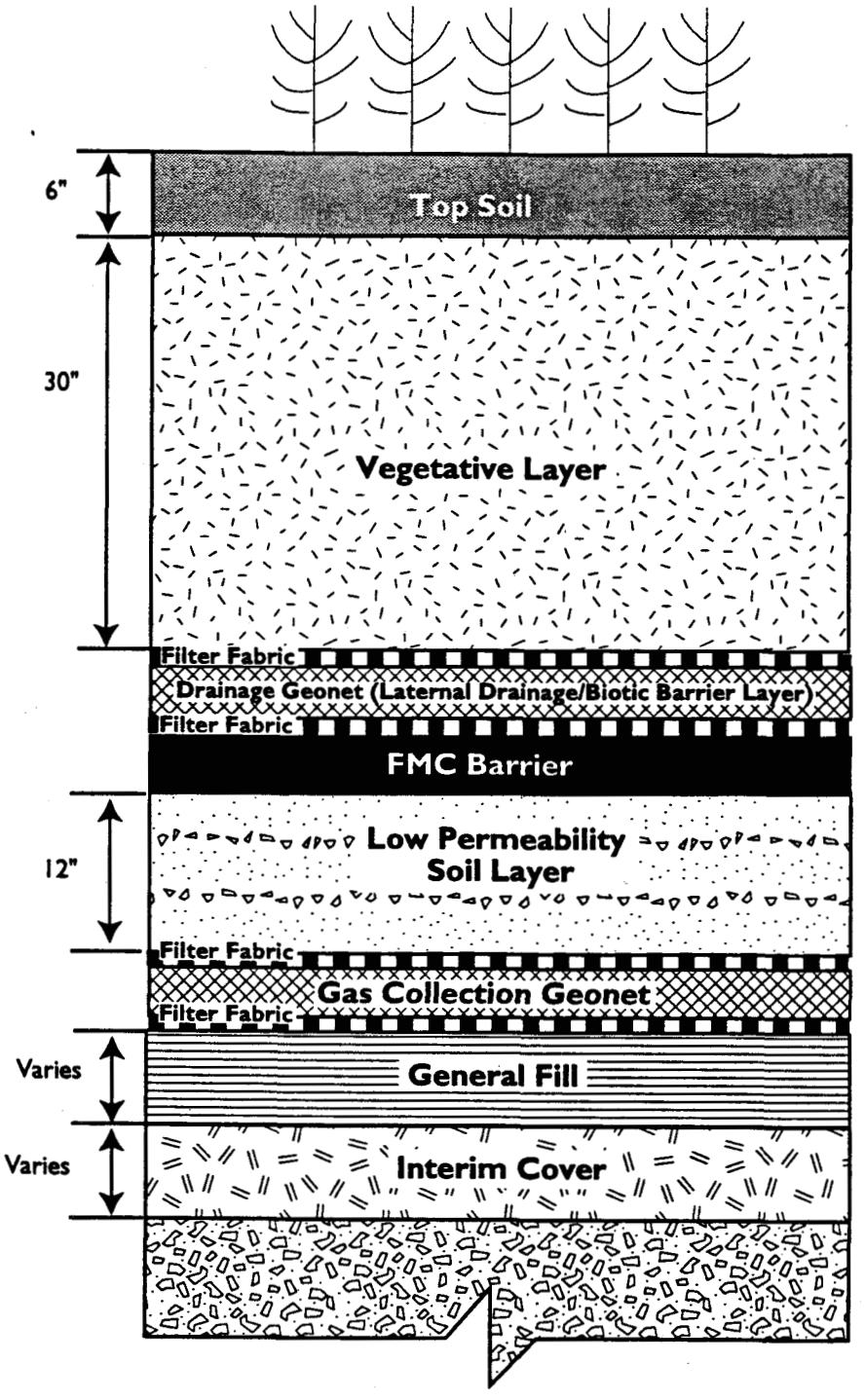
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Cover Cross Section for Alternative 1: No Action

IM/IRA DD and Closure Plan | Operable Unit No. 7

March 1996 | Figure 6-1

G95\ES\IM/IRA DD OU7/Cover Alt.-No Action-2510.ill



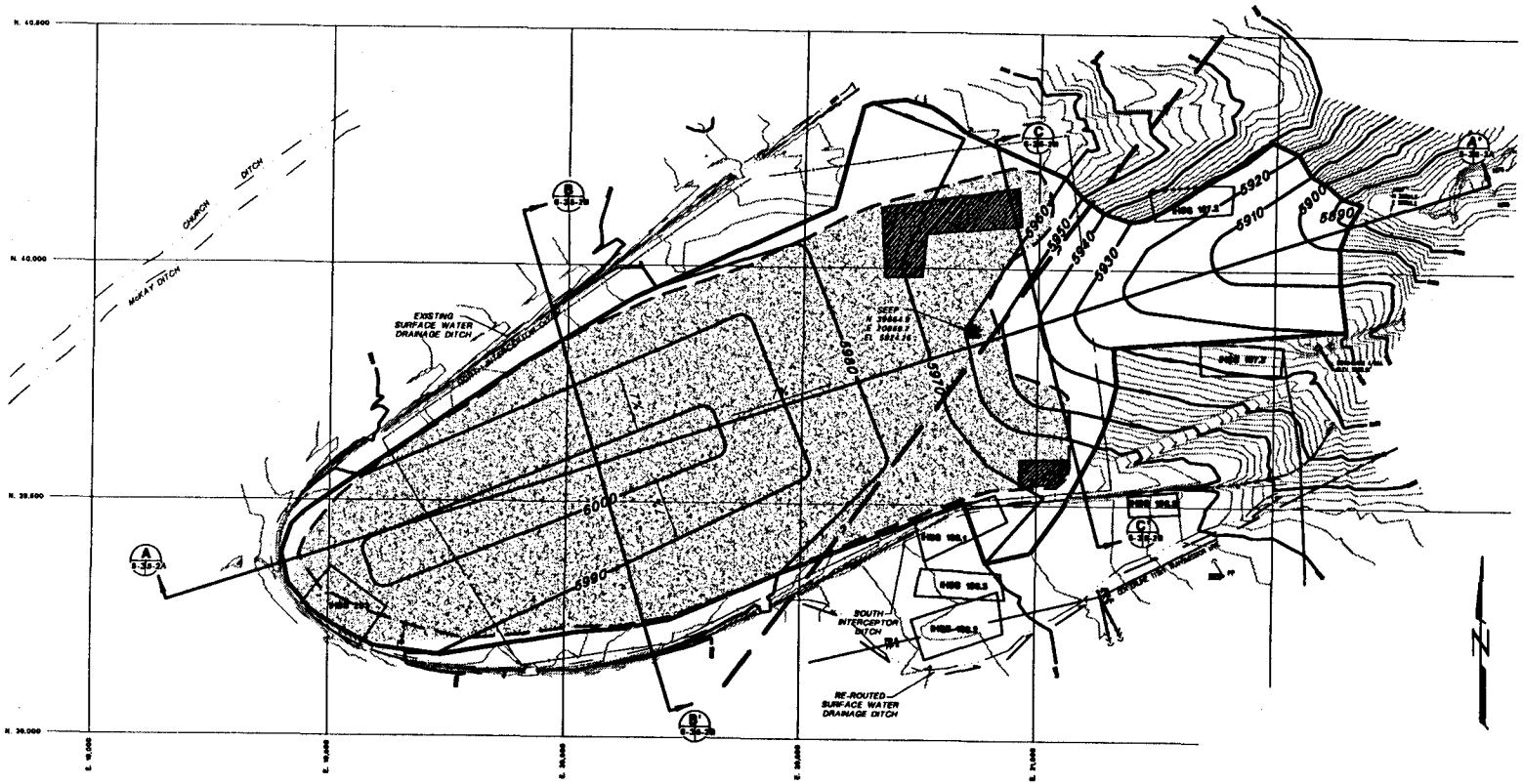
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Cover Cross Section for Alternatives 2, 3, and 4: Single-Barrier FMC & Low-Permeability Soil

IM/IRA DD and Closure Plan — Operable Unit No. 7

March 1996 — Figure 6-2

G95IESUM/IRA DD OU7/Cover Alt #7-2510.ill



SCALE

200' 0 200' 400'

CONTOUR INTERVAL 10FT.

LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA (AREA = 1,296,912 FT.²)
- EDGE OF LANDFILL (AREA = 902,395 FT.²)
- ASBESTOS AREA
- COVER AREA (AREA = 919,150 FT.²)

NOTES:

1.) REFERENCED ON DRAWINGS 5-2A AND 5-2B
2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

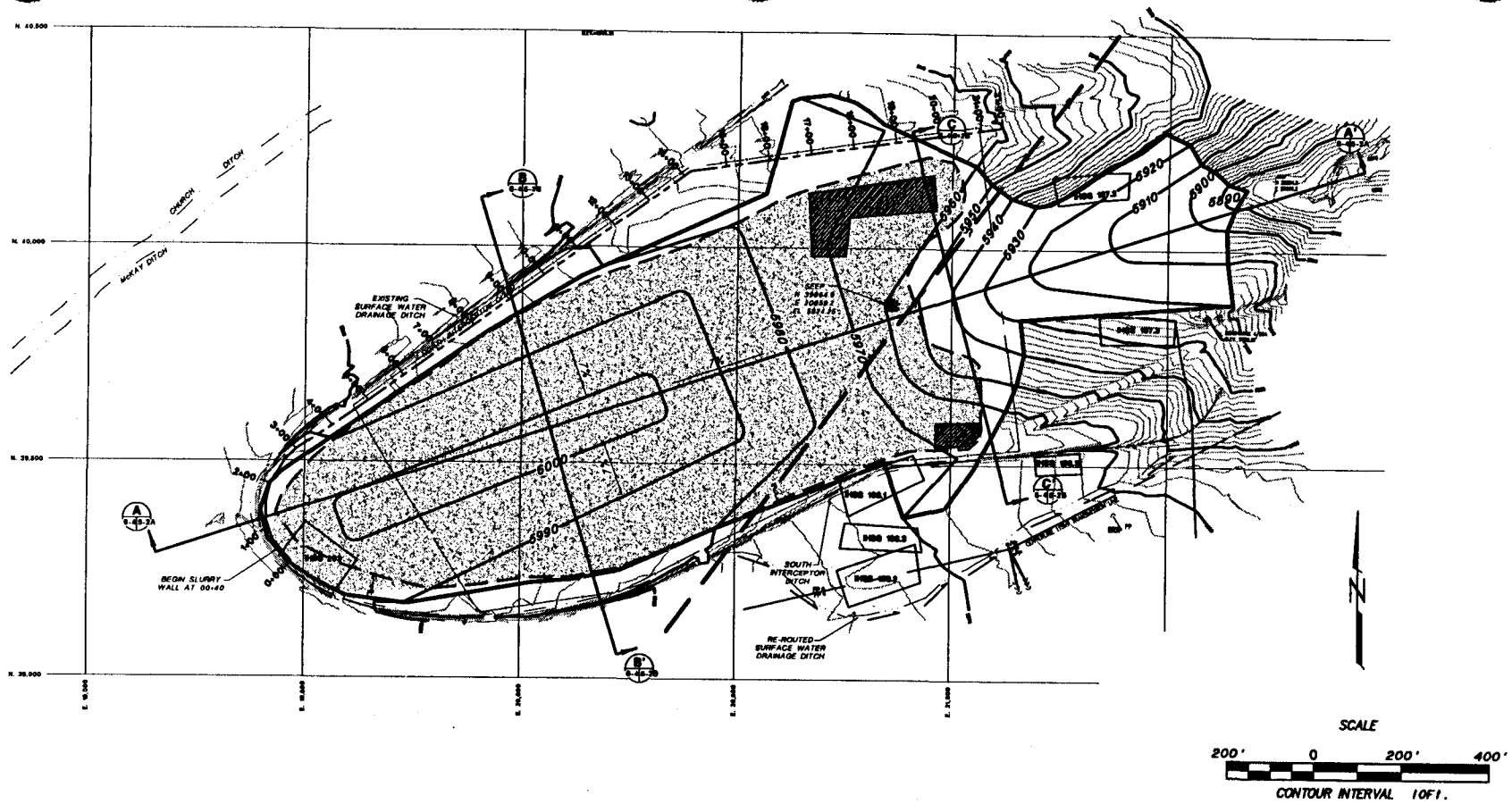
DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

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

Alternative 2: Conceptual Grading Plan with Discharge of Seep Water to Groundwater

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 6-3



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- SLURRY WALL
- EDGE OF REGRADE AREA (AREA = 1,296,912 FT.^{2})
- EDGE OF LANDFILL (AREA = 902,395 FT.^{2})
- ASBESTOS AREA
- COVER AREA (AREA = 919,150 FT.^{2})

NOTES:

1.) REFERENCED ON DRAWINGS 5-2A AND 5-2B

2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

DETAIL/SECTION NUMBER

DRAWING No. WHERE DETAIL/SECTION IS REFERENCED

DRAWING No. WHERE DETAIL/SECTION IS SHOWN

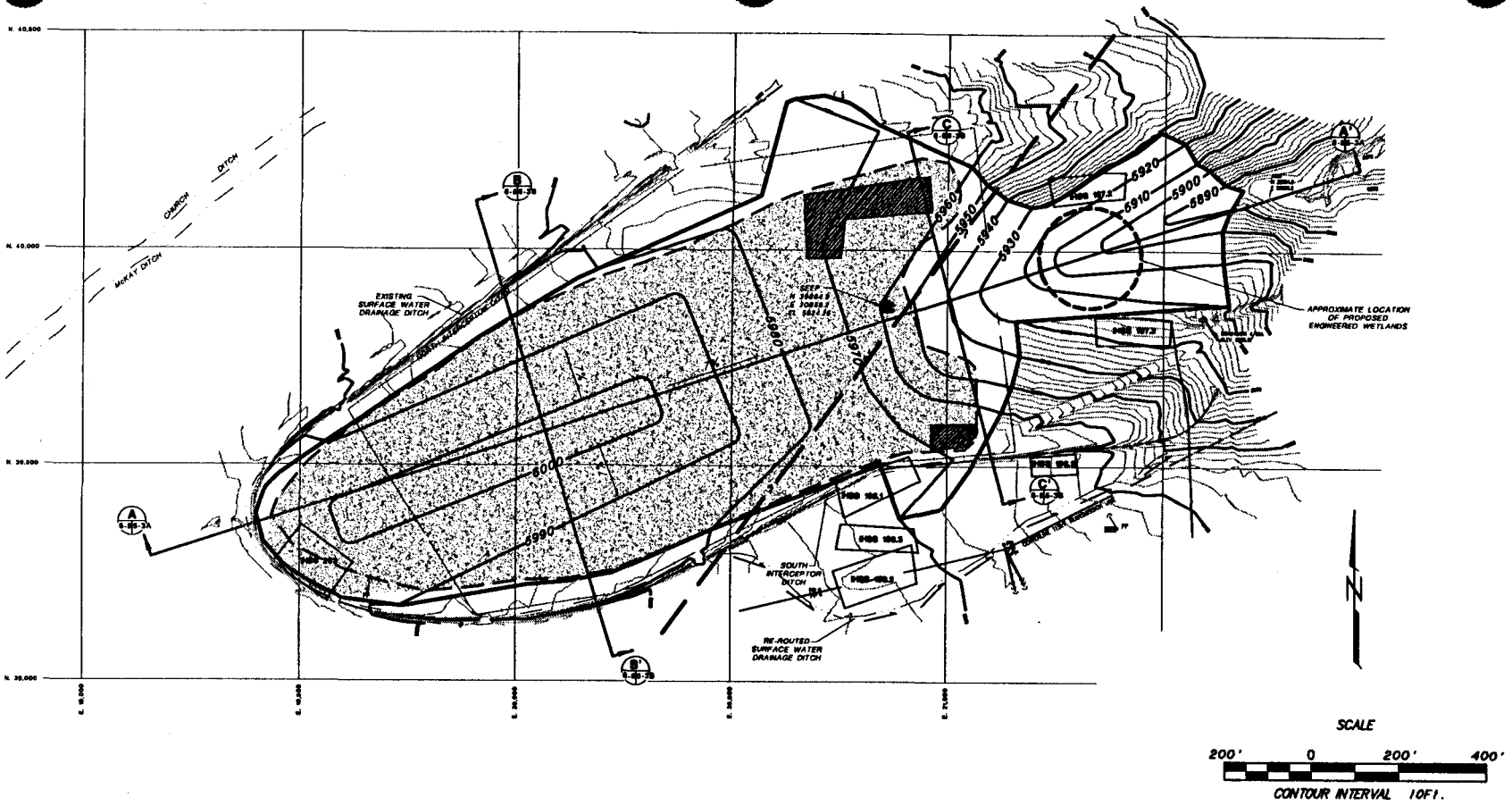
U.S. Department of Energy
Rocky Flats Environmental Technology Site, Golden, Colorado

Alternative 3: Conceptual Grading Plan with Slurry Wall and Discharge of Seep Water to Groundwater

Phase I IM/IRA — Operable Unit No.7

March 1996

Figure 6-4



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA (AREA : 1,296,912 FT.²)
- EDGE OF LANDFILL (AREA : 902,395 FT.²)
- ASBESTOS AREA
- COVER AREA (AREA : 919,150 FT.²)

NOTES:

1.) REFERENCED ON DRAWINGS 5-3A AND 5-3B

2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

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

Alternative 4: Conceptual Grading Plan with Engineered Wetlands and Discharge of Seep Water to Surface Water

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 6-5

7.0 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 2, a single-barrier cap with FMC and low-permeability soil. A draft Proposed Plan was developed to present the selection of the recommended alternative and is an attachment to this report. The Draft Phase I IM/IRA DD, along with the Proposed Plan, is scheduled for public review and comment in the summer of 1996. 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. Preliminary design analyses have been completed to support the selection for most of the major design components that are described in this section. Additional, more detailed design analyses will be completed as part of the Title II design.

7.1 DESCRIPTION

The recommended alternative for OU 7 is Alternative 2, which consists of a single-barrier cover over the Present Landfill (IHSS 114), Inactive Hazardous Waste Storage Area (IHSS 203), and asbestos-disposal areas; institutional controls to prevent unauthorized access; and discharge of seep water to groundwater. The recommended institutional controls, as previously discussed in Section 5.2, consist of the following components:

- Land use and access restrictions
- Groundwater use restrictions
- Groundwater monitoring
- Landfill gas monitoring
- Public education
- EPA reviews

The cover consists of the following layers:

- 36-in. vegetative-soil layer/biotic barrier
- Geocomposite lateral-drainage/biotic barrier layer (geonet and filter fabric)
- FMC barrier layer
- 12-in. low-permeability soil layer

- Grading fill

This cover section is shown in Figure 7-1. The presence of the low-permeability soil gives the cover system many of the benefits of a composite cover, without the rigorous installation requirements, costs, and potential for desiccation of a fully compacted clay layer.

The conceptual site model for the source area shown in Figure 3-1 shows that the containment presumptive remedy using a cover eliminates the exposure pathways for landfill waste and dust. The cap covers an area of approximately 21 acres, most of which encompasses the landfill.

As shown in Figures 3-1 and 3-2, there are two potential exposure points for leachate: (1) seep water and (2) groundwater. Leachate is currently intercepted at the seep and treated using a passive system as a separate accelerated action for OU 7. This system will be removed prior to closure. The East Landfill Pond will be removed and the dam and sediments within the pond will be removed and used as general fill under the capped area of the landfill. The existing seep area would be covered with fill and included inside the area of the capped landfill. A gravel drainage layer will be constructed under the cap from the seep downgradient to the east just past the extent of the cap. This will allow leachate at the seep to drain and discharge to the fill down the valley. The East Landfill Pond will be filled with up to 10 to 20 ft of engineered fill that will serve as a conduit for seep water to percolate to groundwater. The engineered fill will generally consist of granular fill with a permeability of approximately 1E-02 cm/sec. The fill will be placed in the pond area with dimensions of approximately 800 ft long by 50 ft wide near the edge of the landfill and 180 ft wide on the east end near the dam location.

The landfill cap eliminates infiltration of almost all of the incident precipitation, which will greatly reduce leachate generation and migration and contaminant loading to groundwater.

At the point of compliance (well 53194), current ARARs exceedances are not significant. Therefore, groundwater downgradient of the landfill does not require remediation at this time. Potential exposure pathways associated with UHSU groundwater (see Figure 3-1) are incomplete because there are no plans for future development of groundwater for any use at OU 7. Although the groundwater does not discharge to surface water in No Name Gulch, human health risks based on an open-space scenario are acceptable, and potential ecological risks are minimal. A slurry wall upgradient of the landfill is not cost effective because groundwater downgradient of the landfill does not require remediation and the resultant reduction in leachate generation is minimal relative to the reduction due to the cap. Groundwater will be monitored at the point of compliance for a postclosure period of 30 years.

Soil downgradient of the landfill does not require remediation because human health risks are insignificant and risks to ecological receptors are minimal.

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

To meet the overall objective of protecting human health and the environment, RAOs developed in Section 3 must be met. All of the RAOs 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. Media-specific RAOs were eliminated from the final response action because (1) there is no risk to the potential receptor, (2) analytes do not typically 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 runoff and erosion
- Control landfill gas (treat as needed)
- Collect and treat leachate at the source (as needed)
- Control groundwater at the source

Alternative 2 addresses all of the RAOs except the last two. Control of groundwater at the source and collection and treatment of leachate are not required.

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. Contaminant leaching is decreased by reducing infiltration of precipitation through the landfill cover and controlling surface-water flow by diverting it around the landfill.

Grading of the landfill surface requires minimum slopes to provide adequate surface-water drainage after settlement. Promoting drainage minimizes erosion or abrasion of 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 routed around the landfill to No Name Gulch.

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 from the source is prevented by the existing slurry wall.

Discharge of seep water to groundwater eliminates potential exposure pathways for leachate contaminants. Although the fill does not directly provide leachate treatment, contaminant transport modeling shows that the seep water contaminant concentrations are greatly reduced and meet ARARs by the time the water in the subsurface reaches the point of compliance. This is a direct result of natural attenuation (see Section 3.4.1).

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.

Chemical-Specific ARARs

The recommended alternative meets almost all chemical-specific ARARs for groundwater. Groundwater downgradient of the landfill has occasionally exceeded ARARs for chromium, iron, and lead. However, these ARARs are based on surface-water quality standards for aquatic life assuming that groundwater discharges to surface water. Groundwater does not discharge to surface water in No Name Gulch, and the frequency of exceedances is very small. For the leachate, ARARs are currently exceeded for iron, manganese, zinc, napthalene, and methylene chloride. However, contaminant transport modeling has shown that these concentrations are greatly attenuated during migration in the alluvial aquifer and will meet ARARs at the point of compliance over the 30-year postclosure period.

Location-Specific ARARs

Location-specific ARARs for OU 7 are met. Construction of the recommended alternative will be conducted in a manner that minimizes destruction, loss, or degradation of wetlands (40 CFR 6.302[a]). 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. A Wetlands Assessment is included as Appendix K.

Action-Specific ARARs

Action-specific ARARs include requirements for closure, air emissions, and groundwater monitoring.

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 almost all of the precipitation incident on the landfill does not infiltrate, 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. Institutional controls are used to limit access and control use to protect the integrity of the cap. The vegetative cover is planted primarily 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, the maximum erosion rate does not exceed guidance requirements (EPA 1989d, 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 (see 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:

- CHWA 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, and 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 postclosure requirements of 6 CCR 1007-3 Parts 265.117 through 265.120 apply. Details of the 30-year postclosure care period are presented in the OU 7 Postclosure 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 H). 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 required. Postclosure gas monitoring is described in the OU 7 Postclosure Plan (Section 8.2).

Groundwater-Monitoring Requirements—Groundwater monitoring is required for all landfills as specified in 6 CCR 1007-3 Subpart F. At minimum, one hydraulically upgradient well and three downgradient wells are required. Well 70093, 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, 4087, B206989, and 53194, located downgradient of the landfill in the No Name Gulch drainage, 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 will continue during closure under the existing sitewide groundwater-monitoring program. A streamlined groundwater-monitoring program is proposed for the 30-year postclosure care period. Two categories of sampling and analysis are required. Indicator parameters, which include pH, specific conductance, TOC, and total organic halogen (TOX), are required semiannually. Water quality parameters, which include chloride, iron, manganese, phenols, sodium, and sulfate, are required annually at a minimum.

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 in Figure 7-2. The limits of the cover are shown in 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, including settlement, soil erosion, buttressing requirements, and general fill. It also incorporates surface-water control, the cover section, seep water discharge to groundwater, gas control, institutional controls, and costs.

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 as proposed 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 7-3a and 7-3b 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 20 percent. The East Landfill Pond will be removed and the dam and sediments within the pond will be removed and used as general fill under the capped area of the landfill. Based on this plan, a total of approximately 62,200 cubic yards of general fill material is required to achieve the design grades.

Settlement

The 7-percent surface grade is established based on the EPA guidance criteria of 3- to 5-percent minimum postclosure 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 E. These methods yielded maximum settlements ranging from 2.9 to 5.5 ft 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.

Soil Erosion

Grasses and topsoil indigenous to Rocky Flats are used for the vegetative cover. Grasses include western wheat grass, blue grama, big blue stem, and side-oats grama. 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 soil formation 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 I. 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.

Buttress East Side

As previously mentioned in 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 15 to 20 ft of material at the base of the slumps and is sloped at approximately 20 percent. This system will be designed as part of the Title II design. It is expected that seep flow will decrease significantly due to the effects of the 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 gravel drainage layer for seep water results in long-term stability.

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 will be 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 runoff 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 downgradient of the landfill area. 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 (see Figure 7-3). These ditches handle surface-water runoff from the cover as well as intercept any run-on to the landfill from the surrounding area.

During final design, the peak runoff from the landfill and run-on to the landfill will be estimated to size the drainage ditches around the perimeter of the landfill. The design analyses will be conducted to determine the flow from a 100-year, 24-hour storm as required by state regulations for hazardous waste landfills (6 CCR 1007-3). The existing ditches will be upgraded as required prior to closure.

7.3.3 Cover Section

As described in Section 6, the recommended alternative, Alternative 2, single-barrier cap with 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 2 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 cap section for Alternative 2 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 approximately 40 percent of the leachate is from inflow through the groundwater-intercept system and 60 percent is from infiltration. The topsoil 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 approximately 62 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 runoff.

Most of the remainder of the precipitation percolates through the soil and geotextile filter fabric into the geonet drainage layer that lies directly on the FMC. Another 38 percent of the percolating water is removed from the system via the drainage geonet.

Of the surface water that originally entered the system, the remaining 0.001 percent is either stored in the interim cover or waste layer or flows out of the landfill as leachate. The leachate will be controlled by discharging the seep water to alluvial groundwater.

7.3.4 Seep Water Discharge to Groundwater

The location of the existing seep will be covered with fill and included inside the area of the capped landfill. A gravel drainage layer will be constructed from the seep area downgradient to the east past the extent of the cap. The seep water will flow into fill placed downgradient of the capped area and percolate to groundwater. The East Landfill Pond will be filled with up to 10 to 20 ft of engineered fill, generally consisting of granular fill with a permeability of approximately 1E-02 cm/sec. The fill will be placed in the pond area with dimensions of approximately 800 ft long by 50 ft wide near the edge of the landfill and 180 ft wide on the east end. The fill might also contain organic material, such as peat, to promote natural attenuation of the seep water contaminants. Detailed design of the fill profile, plan, and material requirements for the gravel layer and fill will be performed as part of the Title II design.

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 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 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 H. This analysis indicates that gas treatment is not required. Because of the potential for changes in gas emissions resulting from construction of the final cover, landfill gas will be monitored during the postclosure care period and gas will be treated, if needed.

7.3.6 Institutional Controls

A 6-ft-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 supply wells will be installed at OU 7.

7.3.7 Cost Estimate

Detailed written cost estimation must be provided for closure and O&M postclosure 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 Postclosure Plans (Subparts G and H) (EPA 1987a) and the Rocky Flats Plant Cost Estimating Handbook (DOE 1994h) 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 and were 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 a landfill closure 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 G.

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 Final IM/IRA DD by EPA and CDPHE. 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 also includes discharge of the leachate at the seep to groundwater.

The single-barrier FMC with low-permeability soil cover meets RAOs and location-specific and action-specific ARARs. There is no risk to human or ecological receptors from leachate or groundwater because

potential exposure pathways are incomplete. Groundwater at downgradient compliance wells 4087, B206989, and 53194 typically meets ARARs.

The single-barrier FMC with low-permeability soil cover best meets the evaluation criteria considered in the IM/IRA screening process. Alternative 2 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 eliminates approximately 60 percent of the water flowing into the landfill by eliminating almost 100 percent of the infiltration. By eliminating this flow, the cap reduces the saturated thickness of waste material in the landfill, eliminates much of the seasonal variability of flows out of the landfill, and virtually eliminates vertical infiltration flow through waste above the water table. The expected result is reduced flowrates, leachate generation and migration, and contaminant concentrations.

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 ft. Minimal erosion and/or maintenance. Vegetative root growth not to extend below 2 ft. 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 runoff across cover without rills and gullies.
Drainage Layer	Thickness greater than or equal to 1 ft. 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 ft. Saturate hydraulic conductivity less than or equal to 1E-07 cm/sec. Installed in 6-in. 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.

USDA U.S. Department of Agriculture
cm/sec centimeters per second
FMC flexible membrane cover

Table 7-2 Design Components that meet Closure ARARs

Regulatory Criteria	Design Components that Address Regulatory Criteria
6 CCR 1007-3 CDPHE CHWA Hazardous Waste Regulation	
Minimize fluid migration through the closed landfill	Based on HELP modeling, the cover system only allows 0.001% 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 > or = to 2 ft Minimize erosion and/or maintenance Vegetative root depth not to extend below 2-ft depth Final top surface slope between 3 to 5% after settlement or subsidence. Slopes greater than 5% not to exceed 2 tons/acre/year. Surface-water drainage system capable of conducting runoff across cover without rills and gullies	The vegetative cover soil is a total of 36-in. 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%. 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 ft Saturated hydraulic conductivity greater than or equal to 1E-03 cm/sec Bottom slope > or = to 2% 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-ft 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.

Table 7-2 (continued)

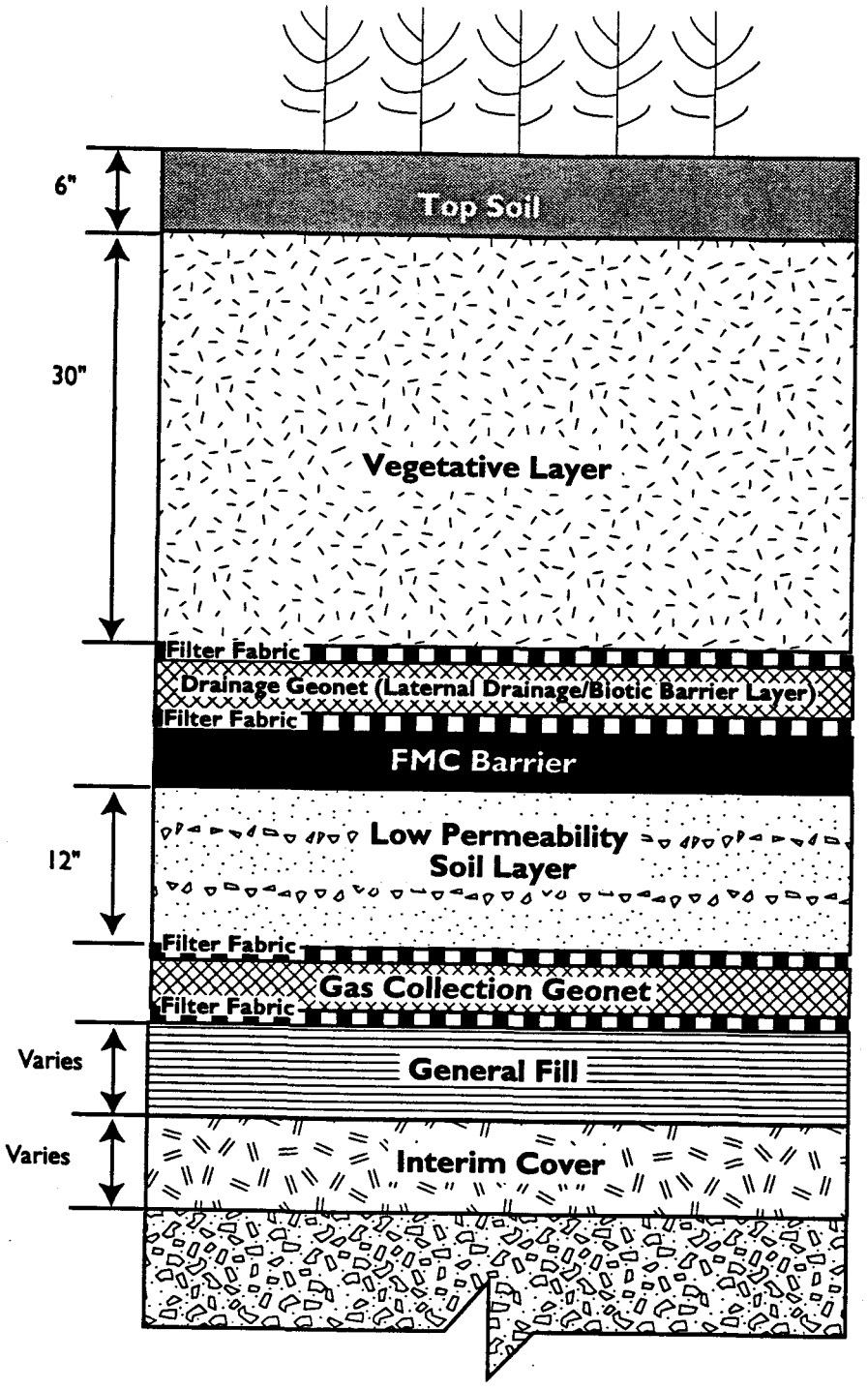
Regulatory Criteria	Design Components that Address Regulatory Criteria
EPA Guidance Documents	
Barrier Layer FMC Component Thickness ≥ to 20 mil Final upper slope greater than or equal to 2% (after settlement) Located wholly below the average depth of frost	The FMC component has a minimum thickness of 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%. The FMC is located under the 36-in. vegetative soil layer, which is the average depth of frost in the area.
Barrier Layer Soil Component Thickness ≥ to 2 ft Saturated hydraulic conductivity less than or equal to 1E-07 cm/sec Installed in 6-in. lifts	The barrier soil layer in the proposed cover section is 1-ft thick and consists of a very low plasticity to nonplastic soil with a permeability of 1E-05 cm/sec or less. The low-permeability soil layer is placed directly over the gas collection geocomposite. 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

Drawing Number	Drawing Title
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 Slop 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 1	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	**Specialities**
10800	Toilet and Bath Accessories
10820	Emergency Eyewash and Body Spray Equipment
Division 11	**Equipment**
11600	Gas Monitoring Instrumentation
11700	Alternative Daily Cover System
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 Mechanical Materials and Methods



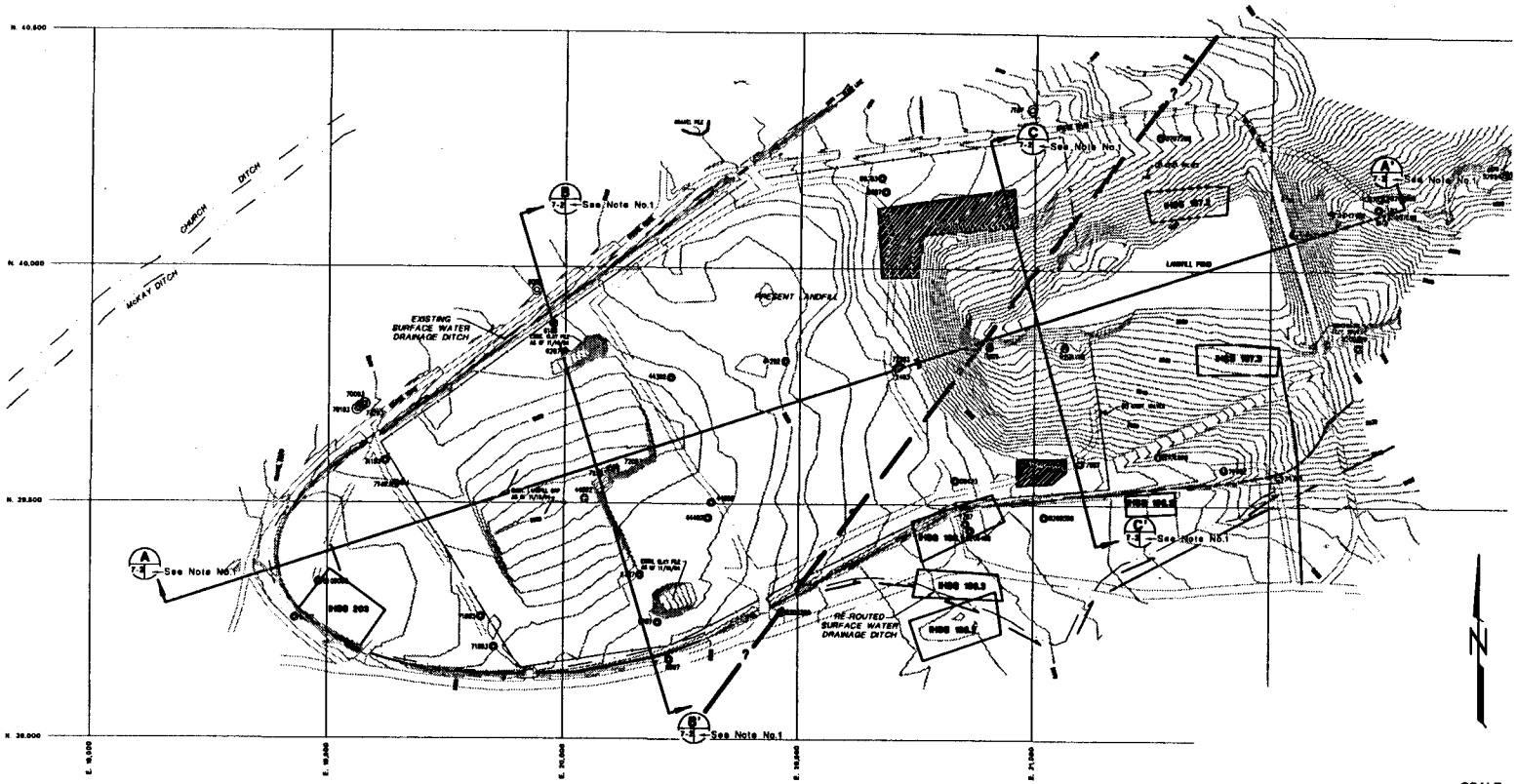
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Cover Cross Section for Alternatives 2, 3, and 4: Single-Barrier FMC & Low-Permeability Soil

IM/IRA DD and Closure Plan — Operable Unit No. 7

March 1996 — Figure 7-1

G95\ES\IM/IRA DD OU7/Cover Alt #2,3,4.ill



SCALE

200' 0 200' 400'

CONTOUR INTERVAL 10FT.

LEGEND

- FAULT
- DITCH
- ROADS
- TRANSMISSION LINE
- ASBESTOS AREA (APPROXIMATE)
- 7189.3 EXISTING WELL OR OR EXPLORATION BOREHOLE

NOTES:

1.) REFERENCED ON DRAWINGS 7-3

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

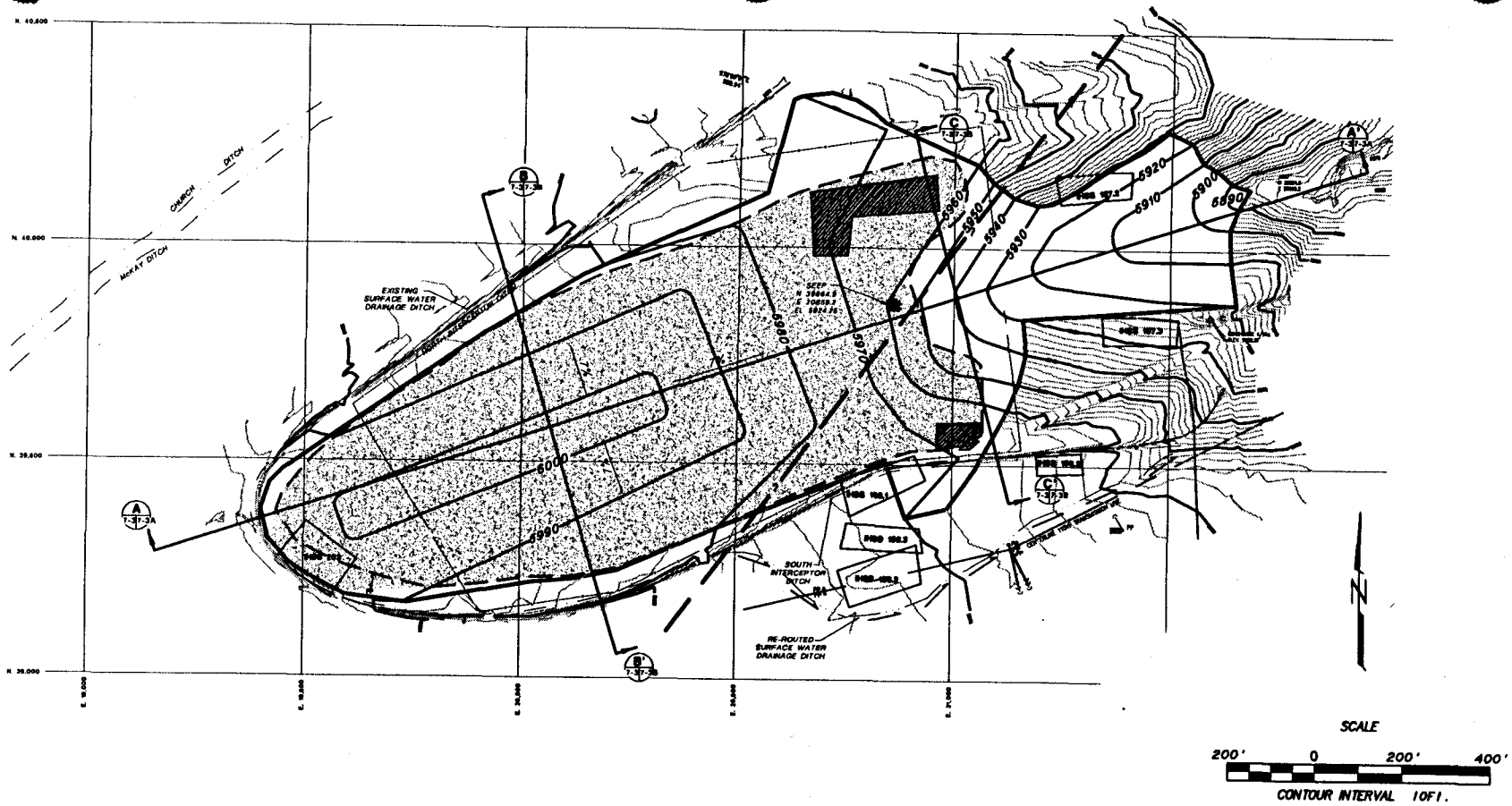
Existing Topography and Surface Features

Phase I IM/IRA

Operable Unit No.7

March 1996

Figure 7-2



LEGEND

- FAULT
- DITCH
- CONCEPTUAL GRADING PLAN CONTOURS
- EDGE OF REGRADE AREA (AREA = 1,296,912 FT.²)
- EDGE OF LANDFILL (AREA = 902,395 FT.²)
- ASBESTOS AREA
- COVER AREA (AREA = 919,150 FT.²)

NOTES:

1.) REFERENCED ON DRAWINGS 7-3A AND 7-3B

2.) BASE TOPOGRAPHY AND FEATURES PROVIDED BY EG & G.

DETAIL/SECTION NUMBER

DRAWING No. WHERE DETAIL/SECTION IS REFERENCED

DRAWING No. WHERE DETAIL/SECTION IS SHOWN

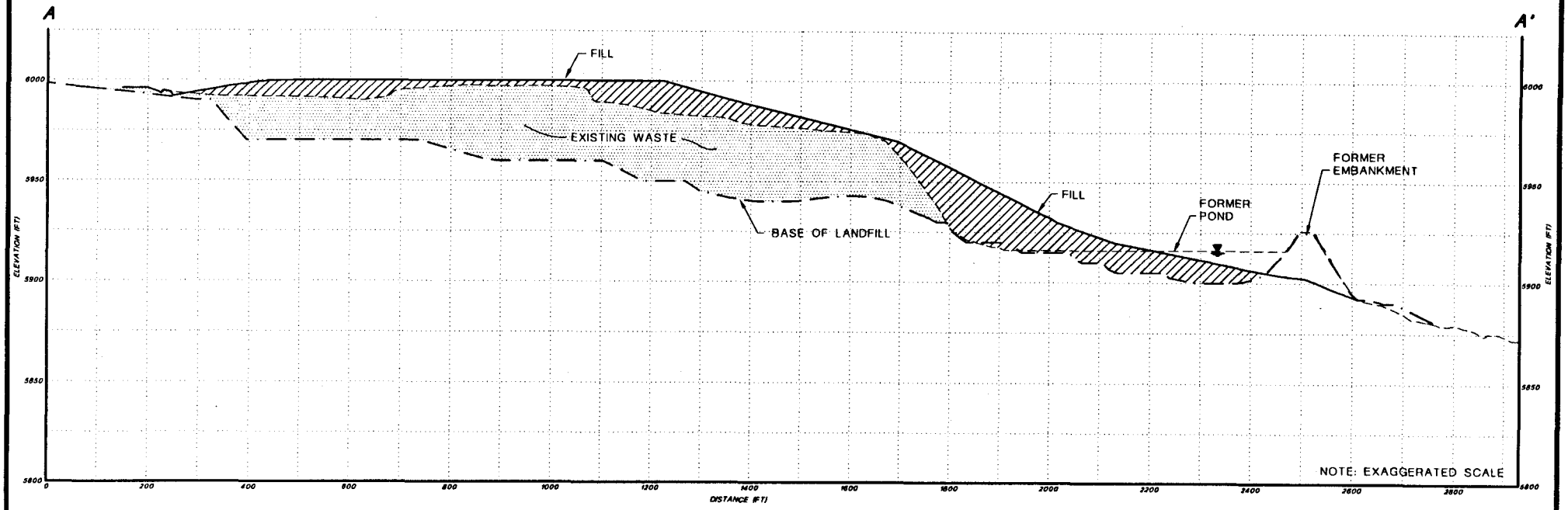
U.S. Department of Energy
Rocky Flats Environmental Technology Site, Golden, Colorado

Recommended Alternative: Conceptual Grading Plan with Discharge of Seep Water to Groundwater, Extent of Cover, and Surface Water Control Plan

Phase I IM/IRA — Operable Unit No.7

March 1996

Figure 7-3



See Note No.1 — A 7-3A

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, 7-3

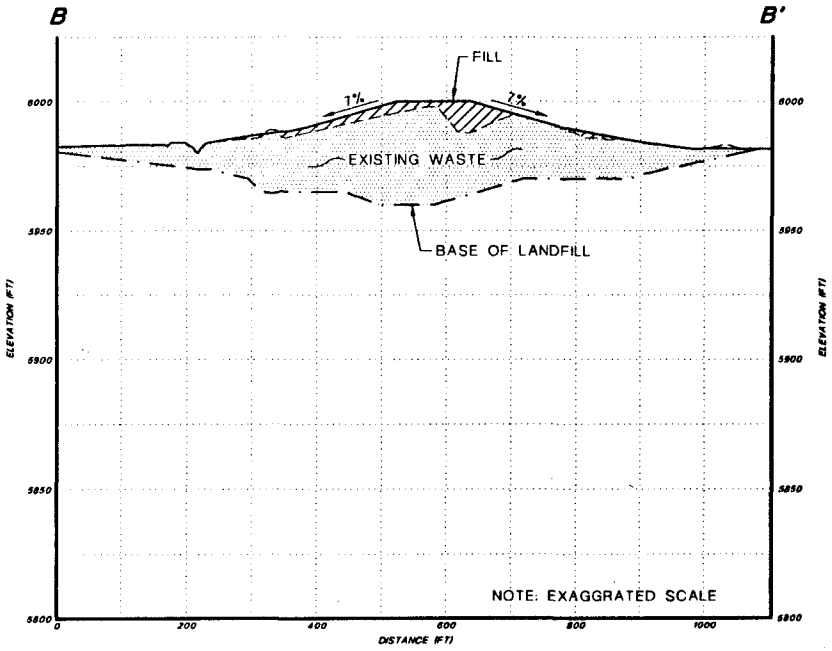
A — DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

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

Landfill Cover Cross Section A-A'

Phase I IM/IRA — Operable Unit No.7

March 1996 — Figure 7-3A

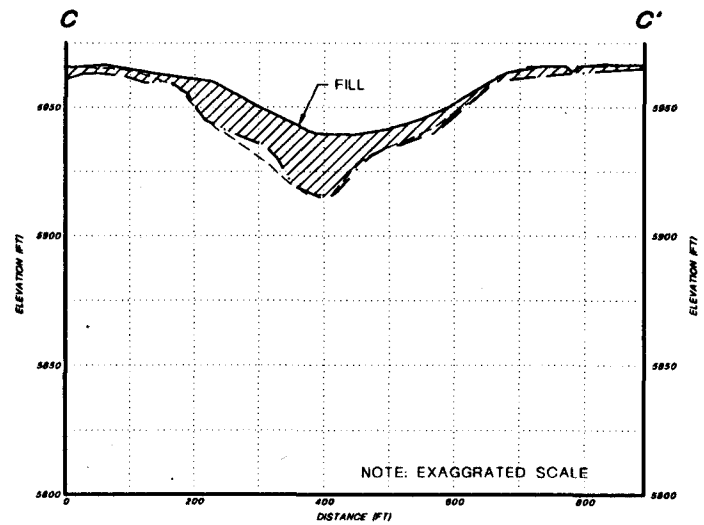


CROSS-SECTION B-B'

See Note No.1 — 7-3B

HORIZONTAL SCALE
0 100' 200'

VERTICAL SCALE
0 25' 50'



CROSS-SECTION C-C'

See Note No.1 — 7-3B

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, 7-3

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

Landfill Cover Cross Section B-B' & C-C'

Phase I IM/IRA

Operable Unit No.7

March 1996

Figure 7-3B

8.0 CLOSURE AND POSTCLOSURE 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 allow for final closure of OU 7 (CDPHE 1992). Therefore, the OU 7 Closure Plan is included in this document. 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, Subpart N. There are no specific closure requirements for hazardous storage units.

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 postclosure residual risk assessment, if needed
- Development of a postclosure plan
- Implementation of the postclosure plan through the CAD/ROD
- Certification of completion of postclosure 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 postclosure requirements of 6 CCR 1007-3 265.117-265.120 apply. The Inactive Hazardous Waste Storage Area (IHSS 203) falls within the boundaries of the landfill and will be closed along with the Present Landfill (IHSS 114).

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 postclosure residual risk assessment is not needed. The evaluation of risks presented in Section 3.3 shows that the risk to human health is below the acceptable risk range for carcinogens (1E-04 to 1E-06) and below the HI of 1 for noncarcinogens for leachate at the seep, surface soils downgradient of the landfill, and groundwater downgradient of the landfill emerging as surface water. Risks to ecological receptors were calculated for leachate at the seep, surface soils downgradient of the landfill, subsurface geologic materials, and groundwater emerging as surface water. These risk calculations indicate that for ecological receptors, HIs greater than 1 exist for seep water, groundwater, and subsurface soils. These HIs are mitigated by various factors. The focused ecological risk assessment is discussed in detail in Section 3.3.

This section also presents the postclosure plan for OU 7, which addresses CHWA requirements for the 30-year postclosure period.

8.1 CLOSURE PLAN

Closure of the Present Landfill (IHSS 114) and the Inactive Hazardous Waste Storage Area (IHSS 203) 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, postclosure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere (6 CCR 1007-3 265.111). The final action complies with closure requirements of 6 CCR 1007-3 265, Subpart G and Subpart N, 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, 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 (IHSS 114) 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 (IHSS 203) 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 (IHSS 167.2) and South Area Spray Field (IHSS 167.3) 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 ft in No Name Gulch east of the landfill. Groundwater flows to the east within the valley-fill alluvium; however, flow is ephemeral. Some of the 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 ft. Leachate and groundwater discharge from the landfill at a seep located at the base of the east face of the landfill. Seep water historically flowed into the East Landfill Pond. A passive leachate collection and treatment system was constructed in February 1996 to capture and treat seep flow. The passive leachate collection and treatment system is an interim measure; its operation will be discontinued as part of the final closure. The system may be buried in place or may be removed. This decision will be made as part of the OU 7 Title II design document.

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. IHSS 203 will be closed within the confines of the landfill.

The spray evaporation areas, IHSS 167.2 and IHSS 167.3, will also be closed as part of this closure plan. These IHSSs require no further action because risk assessment calculations show no risk above acceptable levels to either human or ecological receptors. The cap does not cover these areas, and soil in these areas will not be removed and placed under the cap. Fill material may incidentally cover these areas, but this cover is not necessary for the closure of these IHSSs.

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 1007-3 265.112[d]). 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 at the landfill. 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.

QC and 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 1995d); 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 will be abandoned before the cap is constructed. Of the 28 remaining groundwater-monitoring wells, 12 wells will continue to be sampled during closure (see 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 performed 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 postclosure 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, surface-water management, and site security. Compensatory mitigation for unavoidable impacts to wetlands will be provided, in accordance with ARARs. Surface-water runoff 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 runoff from 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 and to allow removal of the East Landfill Pond dam by transferring water to the A-series ponds. Leachate management will be performed as a continuation of the accelerated action until construction of the final action begins. Gas monitoring will not be performed until after closure. 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 Closure Certification

DOE will submit a certification that closure of the Present Landfill (IHSS 114), the Inactive Hazardous Waste Storage Area (IHSS 203), the Pond Area Spray Field (IHSS 167.2), and the South Area Spray Field (IHSS 167.3) 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.

8.1.9 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 and IHSS 203 with respect to surveyed benchmarks. Locations of temporary benchmarks in the vicinity of OU 7 are shown in Figure 8-2.

8.1.10 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.

8.1.11 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 1007-3 265.119(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 waste disposal facility, the date the landfill began to receive 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 property, a reference to the survey plat and record of waste, and a notarized signature of the owner or operator. 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. To ensure adequate institutional controls, the state may issue a compliance order to limit future development.

8.1.12 Final Closure Schedule

The schedule for final closure was developed in accordance with the RCRA Guidance Manual for Subpart G: Closure and Postclosure 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 POSTCLOSURE PLAN

This OU 7 Postclosure Plan addresses the requirements for postclosure care outlined in 6 CCR 1007-3 265.117-120 and describes the monitoring and maintenance activities that will be performed during the 30-year postclosure care period.

8.2.1 Postclosure Permit

A postclosure permit is required for all landfills under 40 CFR 270.1(c) to detail the requirements of postclosure care. The landfill closure action must comply only with the substantive aspects of this requirement. Postclosure permits generally include a copy of the postclosure inspection schedule, the

postclosure 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 provide information on the potential for the public to be exposed to wastes released from the site.

The Draft Proposed Plan is included as an attachment to this report.

8.2.2 Postclosure Inspection and Maintenance

Postclosure inspection and maintenance activities include routine facility inspections and repairs, evaluate the revegetation success, 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, 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 postclosure care period before the vegetation becomes established.

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 postclosure 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 seven years. Warning signs posted around the landfill will be replaced periodically.

8.2.3 Postclosure Monitoring

Postclosure monitoring consists of gas monitoring to determine if gas treatment is needed, identification of a point of compliance, and groundwater monitoring to detect future releases from the landfill at the point of compliance.

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 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.

Point of Compliance

Postclosure groundwater-monitoring requirements are relevant and appropriate to interim status facilities such as the Present Landfill and include implementation of a groundwater-monitoring program capable of determining the impact of the landfill on groundwater quality in the UHSU (6 CCR 1007-3 265.90[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 1007-3 264.92).

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 and fill extends eastward to achieve design grade required for closure. As a result, the downgradient limit of the waste-management area shifts to the east. Wells immediately downgradient of the dam are currently used as compliance wells for the annual RCRA groundwater-monitoring report and are proposed as compliance monitoring wells for OU 7 closure.

Wells 4087 and B206989 are proposed as the compliance wells. 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 1007-3 264.93 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 1007-3 264.95). Well 53194 is also included as monitoring wells for the detection-monitoring program at OU 7 to detect releases from the landfill.

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 1995e). Groundwater will not be used as a source of drinking water. Deed restrictions and/or state orders will prohibit future development of groundwater. In addition, No Name Gulch is a losing stream year-round (see Section 2.3.6), 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. As discussed in Section 3.4.1, there is a potential that a few ARARs could be exceeded in groundwater downgradient of the dam. However, focused risk assessments have shown that these analytes do not pose a threat to human health and the environment.

Groundwater-Monitoring Program

This section describes the proposed groundwater-monitoring program that will serve as the detection-monitoring program for postclosure activities. The primary objective of the groundwater-monitoring program is to detect potential future releases that migrate beyond the boundary of OU 7. Groundwater monitoring must be conducted to satisfy the postclosure care requirements under 6 CCR 1007-3 265.310(b)(3).

Two upgradient alluvial wells are used to determine upgradient water quality for the landfill during postclosure monitoring. The proposed upgradient monitoring wells are 70093 and 5887. One UHSU bedrock well is also included in the upgradient monitoring network. This well is 70193. These wells are shown in Figure 8-2. These locations will provide information on groundwater quality upgradient of the landfill. The proposed downgradient alluvial monitoring wells are 4087 and 53194. One UHSU bedrock well will be monitored. This well is B206989. 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.

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 performed 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 analytes for the groundwater-monitoring program in accordance with historical detections in groundwater at the landfill and 6 CCR 1007-3 265.92. Groundwater samples will be collected quarterly and analyzed as part of the RCRA Groundwater report. The methodology for statistical analysis and reporting will follow those currently used in generating the RCRA Report. When sufficient data have been collected to determine the effectiveness of the proposed remedial actions, the monitoring frequency and analyte suite may be re-evaluated.

Analytical data for groundwater sampled at monitoring wells located hydraulically upgradient of the unit will be compared to those data for monitoring wells located downgradient of the unit. This comparison provides a qualitative and quantitative assessment of contaminants released into the uppermost "aquifier" from the regulated unit. Statistical methods used to compare upgradient to downgradient groundwater

quality are based on procedures in the Interim Final Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 1989) and the Draft Addendum to Interim Final Guidance, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 1992a).

Chemical concentrations from upgradient and downgradient wells are compared using analytical data for UHSU groundwater. Data for groundwater in the surficial materials and weathered bedrock at the Present Sanitary Landfill are typically combined for a statistical comparison of groundwater in the total UHSU (i.e., surficial materials plus weathered bedrock). The proportion of detections and number of results from each well are determined for each analyte within the RCRA-regulated unit. Only wells with two or more results for an analyte are included in the statistical evaluation, and only analytes that are detected in more than 50 percent of the sample from the unit are included in the statistical evaluation. If the percentage of quantified results for a particular analyte are less than 50 percent, the detections of that analyte at downgradient wells are reported, but are not subject to statistical testing. If the proportion of detections for a particular analyte exceed 50 percent, an analysis of variance (ANOVA) procedure is performed.

ANOVA is the name given to a wide variety of statistical procedures that compare the means of different groups of observations to determine if significant differences exist between them. Because of its flexibility and power, ANOVA is the preferred method of statistical analysis when groundwater monitoring is based on comparison of background- and compliance-well data (EPA 1989a). The null hypothesis for the parametric ANOVA assumes that the mean analyte concentrations from all wells are equal.

Consistent with EPA guidance for performing parametric ANOVA (EPA 1989a), nondetect rates are between 0 to 15 percent and nondetects in the data are replaced with one-half the detection limit prior to performing the parametric ANOVA. Hypothesis tests with the parametric ANOVA also assume that the errors (residuals) are normally distributed, with equal variance. Residuals are tested for normality using the Shapiro-Wilk test (EPA 1992a), and for homogeneity of variance using Levene's test (EPA, 1992a). If the residuals of the original data do not meet both assumptions, data are transformed using natural logarithms. The Shapiro-Wilk and Levene tests are then performed on the residuals of the log-transformed data.

Analytes having a 50- to 85- percent detection rate are not tested for normality or equality of variance. These analytes are tested using the nonparametric ANOVA Kruskal-Wallis test. Analytes that are neither normally nor lognormally distributed, as indicated by the Shapiro-Wilk and Levene tests, are also evaluated using the nonparametric ANOVA Kruskal-Wallis test. The Kruskal-Wallis test uses the ranks of the data to determine if significant differences exist between group means. The null hypothesis for the Kruskal-Wallis test assumes that the mean concentrations for the upgradient and downgradient wells are equal.

All ANOVA test (parametric and nonparametric) are conducted at the 5-percent significance level (Type I error rate). The observed significance level (p-value) for a statistical test is the probability that differences in means as large as those observed could be attributed to random chance. Therefore, a significance level less than or equal to 5 percent (p-value <=0.05) strongly suggests that differences in the means between analyzed wells are not random.

For analytes with significant differences in mean concentrations, multiple-comparison techniques are used to compare the mean concentrations at compliance wells with the mean concentrations at upgradient wells. These comparisons are used to determine which wells had detections significantly above mean

upgradient concentrations. This is accomplished by calculation of the Bonferroni t-statistic for analytes that are normally or lognormally distributed (EPA 1989a). Multiple comparisons for analytes tested using the nonparametric Kruskal-Wallis test are conducted by comparing differences in mean ranks of compliance and upgradient wells to calculated critical values following EPA guidance (EPA 1989a). Wells that had detections significantly elevated above the mean upgradient concentations for a particular analyte, as indicated by the multiple-comparison tests, are reported.

The groundwater-monitoring data for OU 7 will be evaluated and reported annually in the Annual RCRA Groundwater Report. New groundwater data will be compared to historical data to detect trends in potential groundwater contamination. Changes to the monitoring program at OU 7 will occur through modifications to the Groundwater Monitoring and Assessment Plan, which will govern all future Site groundwater monitoring requirements.

8.2.4 Five-Year Review

Under CERCLA, Section 121(c) and the NCP (Section 300.430[f][4][ii]), statutory reviews are required at least every five 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 Postclosure Certification

DOE will submit a certification that postclosure care has been completed in accordance with the approved OU 7 Postclosure Plan to CDPHE no later than 60 days after completion of the 30-year postclosure care period. The postclosure 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 $9,371,000. The present worth O&M cost for postclosure is $1,206,000 over the 30-year postclosure period. The total present worth cost is $10,577,000. Detailed cost estimates are provided in Appendix G.

Table 8-1 Closure Timeline

Activity	Date
Notification of Closure	02/97
Receipt of Final Volume	04/97
Completion of Closure Activities	10/97
Submittal of Survey Plat	12/97
Submittal of Certification of Closure	12/97
Submittal of Record of Wastes	02/98
Submittal of Deed Notation	12/98

Note:

Assumes final volume of waste received in 04/97.

Table 8-2 Postclosure Inspection, Maintenance, and Monitoring Schedule

Item	Frequency
Inspection and Maintenance	
Routine Facility Inspection	Semiannually
Final Cover Survey	Annually
Drainage Ditch Cleanout	Annually
Fence Inspection	Annually
Gas-Monitoring System	Annually
Groundwater-Monitoring System	Annually
Monitoring	
Gas Monitoring	Quarterly
Groundwater Monitoring	
Water Quality Parameters	Annually
Indicator Parameters	Semiannually

Table 8-3 Groundwater-Monitoring Parameters

Type	Suite	Frequency
VOC	524.2 Complete List	Quarterly
Metals	Ba, Ni, Li, Se, Cr, Ca, Na, Mg, K	Quarterly
RAD	Rad Screen	Quarterly
	Gross Alpha/Beta	Quarterly
	Pu/Am	Quarterly
	Radium 226/228	Quarterly
	Uranium Isotopes	Quarterly
	Tritium	Quarterly
Water Quality	Nitrate/Nitrite	Quarterly
	SO_4, Cl, CO_3, HCO_3	Quarterly
	TDS	Quarterly

9.0 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 postclosure maintenance and monitoring activities, and exposures resulting from possible accidents are analyzed for risks to workers outside of OU 7 IM/IRA activities at Rocky Flats and the public. Potential risks to workers at OU 7 will be addressed separately by a site-specific health and safety plan. Environmental impacts to ecology, 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 removal of the East Landfill Pond, removal of pond sediments and the dam and placement in the landfill, placement of general fill and regrading to achieve adequate surface drainage, construction of the engineered cover system, placement of the final vegetative cover, and upgrading the runoff/run-on drainage-ditch system. A postclosure inspection, maintenance, and monitoring program will be performed for 30 years after landfill closure. The postclosure 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. Postclosure 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:

- Pond dewatering and sediment/dam removal and placement in the landfill
- 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

Postconstruction 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 groundwater downgradient from the landfill. Contact with landfill leachate, pond water, and pond sediments is 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

Potentially Exposed Populations and Exposure Pathways

Potential scenarios and exposure pathways were identified onsite and offsite. Activities planned for OU 7 include capping, inspecting, and maintaining the engineered cover of the closed landfill, and postclosure 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 were considered according to current and future uses, which were 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 was conservatively assumed for this screening-level analysis.

Two potentially exposed human receptors were selected for pathway analysis in this screening-level human health risk assessment: onsite worker and offsite resident.

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 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 (outside of OU 7) and hypothetical offsite receptor is inhalation of nuisance dust.

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 Rocky Flats 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.

9.1.3 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 or contact with groundwater downgradient from the landfill. Contact with landfill leachate, pond water, and pond sediments is 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 1994f). 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 transportation, storage, and placement 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

Short-Term (Construction Period) Impacts

Construction and other remediation activities at OU 7 may result in temporary effects on vegetation communities and wildlife habitat in and around the remediated areas. Temporary effects due to surface disturbance associated with cap construction and noise associated with heavy equipment are expected.

Approximately 41 acres will be affected by construction activities which include resurfacing the landfill (30 acres), borrow area haul road construction (9 acres), and staging area construction and miscellaneous activities (2 acres). Due to ongoing waste disposal and earth moving activities, the landfill area is currently relatively poor quality habitat with about 80 percent bare soil with the remaining area containing primarily non-native weeds (e.g., knapweed, Canada thistle). Therefore, activity in this area does not represent serious loss of habitat from current conditions. Borrow area and staging area sites are located in mid-grass prairie vegetation communities and currently contain a mixture of native and non-native plants.

Detailed revegetation plans for each of these areas will be included in the final design documents. Revegetation of areas outside the landfill cap will include native prairie species. Because of the need to control soil erosion, the landfill cap will be revegetated with sod-forming grasses that provide optimal basal cover at maturity. Where possible, native grasses such as blue grama or side-oats grama will be used. In order to avoid root penetration of the clay cap, measures will be taken to prevent woody species such as shrubs and trees or other deep-rooted phreatophytic species from becoming established on the cap area. Thus, the cap area will be revegetated but will not be restored to the native mid-grass prairie condition that existed prior to landfill construction. The initial establishment of herbaceous vegetation is expected to take two to three years. Establishment of woody species and slower-growing perennials may take up to 10 years.

The temporarily affected areas include 0.8 acres of palustrine wetlands, 2.3 acres of lacustrine wetland and open water habitat combined, and 7.9 acres of Preble's meadow jumping mouse potential habitat. The habitat patch is relatively small and isolated from other suitable areas containing populations of these species. It is currently unclear whether Preble's meadow jumping mice inhabit the areas immediately east of the landfill. Small mammal surveys conducted in the area (400 trap nights) did not result in capture of Preble's meadow jumping mice. Construction activity may result in direct mortality of small mammals and other animals living the area. While loss of individuals is permanent, effects on small mammal populations at Rocky Flats will not be significant.

The period of increased equipment noise, vehicular traffic, and other human activity will last less than one year. During this time, sensitive wildlife species may avoid the area. The area affected is highly variable and dependent on species and individuals. Some animals may habituate to the activity and return to the area. Although wildlife use of the area may be reduced because of this avoidance response, this part of Walnut Creek drainage does not represent critical habitat or breeding areas for site wildlife.

Long-Term Impacts

Long-term impacts on ecological resources include physical alteration of terrestrial and aquatic habitats and residual chemical risks in areas adjacent to the landfill but outside the landfill cap area.

Physical Alteration—Physical alteration of the habitats include degradation and/or permanent loss of existing habitat. The primary areas involved are mid-grass prairie in the borrow and staging sites, the mid-grass prairie immediately surrounding the landfill and the East Landfill Pond, the wetland and aquatic habitats associated with the pond, and the riparian/grassland areas immediately east of the pond.

As noted in the previous section, the borrow area and staging area sites represent only temporary loss of habitat since they will be revegetated with native species after completion of the landfill cap. To some extent, the landfill area represents a permanent loss of native mid-grass prairie because revegetation efforts cannot include a completely native plant community. However, the revegetated cap will be suitable habitat for many wildlife species, especially small mammals, some songbirds, and other grassland wildlife species that do not require a structurally complex vegetation community.

Removal of the East Landfill Pond represents permanent loss of the associated aquatic and wetland habitats. A total of 3.1 acres of wetlands will be lost as a result of pond removal (see Figure 2-12). This includes 0.8 acres of palustrine emergent wetlands at the pond margin and 2.3 acres of lacustrine wetland associated with the pond bottom and open-water habitat combined. In addition, potential habitat for Preble's meadow jumping mouse will be lost or modified as a result of the pond removal. At Rocky Flats, this mouse is typically associated with riparian communities and the adjacent grassland habitats. Removal of the pond will essentially eliminate the riparian component. As noted earlier, live-trapping surveys of the area have not confirmed the presence of Preble's meadow jumping mouse in the OU 7 area. Thus, risks to Preble's meadow jumping mouse from activities at OU 7 may be limited to loss of potential habitat.

The loss of jurisdictional wetlands due to remedial actions will be mitigated as part of the sitewide wetlands bank. Mitigation of other habitat loss is not required by state or federal statutes and is not currently anticipated. However, DOE may include mitigation of wildlife habitat as part of sitewide conservation management plans to be developed in the future.

Chemical Impacts—Potential ecotoxicity of PCOCs in unremediated media is summarized in Section 3.3. In general, impacts to vegetation, small mammal, and aquatic communities appear to be minimal. The magnitude and extent of potential toxicity indicated by preliminary risk calculations is generally low.

High HQ values are indicated for vegetation exposure to nitrate/nitrite in subsurface soils immediately east of the landfill, but toxic concentrations were detected in only one sample.

Potential toxicity was also identified for exposure of aquatic organisms to PCOCs in leachate seep water and groundwater. As noted in Section 3.3, the presence of aquatic habitat in these areas is seasonally intermittent and represents a small (less than 1 percent) portion of aquatic habitat on site. Intermittent habitats such as this can be important to amphibian and other semi-aquatic organisms. However, the expected result of capping the landfill is reduction of saturated thickness in waste materials, reduction of seasonal variability of seep water flow rates, and elimination of vertical infiltration through waste above the water table. This combination of factors will result in reduced flow volumes and reduced contaminant concentrations. The altered grading combined with the dewatering of the landfill will reduce or eliminate the surface expression of water from the landfill, decreasing the availability of these seep habitats to semi-aquatic and aquatic organisms in the immediate vicinity of the landfill.

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 were 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

Fugitive-dust emissions from removal and consolidation in the landfill of the dam and pond sediments are not expected because the dam material is very coarse and the sediment will have a high moisture content. Postconstruction activities include inspection and maintenance of the cover and postclosure

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.

$$\text{Bulldozer EF} = 1.0(s)^{1.5}(M)^{-1.4} \tag{9-1}$$

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 was applied to account for dust control from periodic watering using watering trucks.

$$\text{Dumping EF} = K(0.0032)\left(\frac{U}{5}\right)^{1.3}\left(\frac{M}{2}\right)^{-1.4} \tag{9-2}$$

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 were used. The silt content of soil was assumed to be 10 percent. A 50-percent reduction was applied to account for dust control from watering.

$$\text{Transportation EF} = K(5.9)\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right) \tag{9-3}$$

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 in. = 87 (EPA 1995b)

Approximately 25 to 30 haul trucks were used. A 99-percent reduction was 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.

Haul Road Construction

The construction haul road will be built between a nearby borrow and the landfill. The distance required was assumed to be 2.5 miles. With an approximate width of 30 ft, the total area is approximately 9 acres. The road will be 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 were 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 were entered 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 was 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.

Transport of Fill and Cover Material to the Landfill

An estimated 235,000 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, 78,000 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). The estimation of vehicle miles traveled was 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.

Similar to the discussion in Section 9.3.1, the transport emissions were entered as g/s, the area of emissions was assumed to be 36,400 m^2, and the average distance to the fence line was assumed to be approximately 1,300 m. The estimated airborne particulate concentrations are summarized in Section 9.3.2.

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 was entered into 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 were input to the Screen2 air model as g/s; the area of emissions was assumed to be approximately equal to the area of the landfill, 28 acres or 113,300 m^2; and the distance to the fence line was 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 because of extensive watering by the contractor. The earthen materials of the cover layers are installed in many sublayers as the work progresses. Each sublayer 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 sublayer 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 (mg/m^3) and 50 mg/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 mg/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 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 1994i).

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 No Name Gulch during storm events. The absence of vegetative cover and the steepening of slopes result in increased potential for both sheet and channelized runoff and wind and water erosion, resulting in increased sedimentation of ditches and No Name Gulch.

The proposed action is limited to constructing an engineered cover system for containment of the landfill waste, removal of the East Landfill Pond dam, and the excavation and placement in the landfill of the pond sediments. 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 41 acres, including the area of the landfill to be resurfaced (30 acres), haul roads to the offsite borrow areas (9 acres), and miscellaneous construction activities (2 acres). Surface-water control measures will be 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 will be diverted to existing surface-water drainage ditches along the north and south boundaries of OU 7. Other shallow ditches will be temporarily constructed as needed to prevent sediment-laden stormwater from flowing directly into No Name Gulch.

Newly constructed soil surfaces will be 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, 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 two to three 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 I.

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/runoff 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 will be 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 two to three 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.

Postclosure 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 as effective as planned.

9.5 IMPACT TO GROUNDWATER QUALITY

Current sources of groundwater recharge to the UHSU include infiltration of precipitation, snowmelt, storm runoff, and downward seepage from the East Landfill Pond. The downward seepage from the East Landfill Pond will be eliminated with the removal of the 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 ft; the average saturated thickness is 11 ft.

9.5.1 Short-Term (Construction Period) Impacts

Local impacts to hydraulic gradients are expected because the engineered cover reduces surface-water infiltration. However, enhanced groundwater quality results from reducing water flow through waste. The engineered cover system will cause an increase in surface-water flows after storm events as water is shed laterally instead of allowed to infiltrate.

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 F. 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 in./year. The leakage rate of the existing interim soil cover is estimated to be 1.4 in./year. This indicates that the engineered cover would reduce the amount of infiltration that would potentially flow through the landfill waste by almost 100 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 40 percent of the inflow to the landfill is upgradient groundwater from the alluvium and 60 percent is recharge by infiltration of precipitation. Most of the groundwater inflow (93 percent) occurs on the north side of the landfill. Contributions from the west side (less than 1 percent) and the south side (7 percent) are relatively insignificant. The water balance shows that the proposed engineered cover system would reduce water inflow and leachate generation. A significant reduction in seasonal variability of leachate flow rates is also expected. Water balance calculations are presented in Appendix C.

The surface-water drainage ditch would divert stormwater runoff 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 almost 100 percent reduction (according to HELP modeling) of precipitation reaching the waste. This would cause a significant reduction in saturated thickness of the waste material and eliminate much of the seasonal variability of leachate flow rates. A significant reduction of saturated waste and elimination of vertical infiltration flows through waste above the water table 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 quality 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) will be required for construction activities. Supplies of these materials will be provided by the construction contractor. The preferred alternative requires a permanent commitment of 235,000 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 will be disturbed by construction activities. Many impacts are temporary, pending completion of remedial activities and associated restoration programs.

- Resources that underlie the landfill will be lost. However, there appear to be no commercially exploitable mineral resources at Rocky Flats (DOE 1980).

- The commitment of up to 30 acres of land as a landfill permanently commits and constrains the area to limited land-use options.

- Wetlands and associated natural resources will be reduced at OU 7 but will be mitigated offsite. Long-term direct impacts to the floodplain resulting in changes of flood elevations will not occur.

- Open water habitat at OU 7 will be eliminated.

- Long-term commitment of personnel and funds to perform postclosure inspection, maintenance, and monitoring activities.

- Maintenance activities will be 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 will be required for the duration of the construction activities (less than 1 year). The raw water supply available at Rocky Flats will be 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 will be used temporarily for construction of haul roads. This material would be 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 will be transported using tandem semi-trucks from an offsite borrow source (EG&G 1994d). A construction haul road (approximately 2.5 miles long) will be constructed to accommodate transport of borrow materials. The construction haul road will be 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, will use existing transportation systems. The traffic impacts 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 will have an additive effect on existing workload for site operations. This effect is short-term; however, maintenance and monitoring activities would continue during the postclosure period. The anticipated workload of these personnel would be significantly less than what is currently required.

- Potential waste generated by this proposed action will be 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 that will be generated are insignificant and any impacts negligible.

- Wetlands mitigation will be necessary to replace the 0.8 acres of palustrine wetlands lost due to the remedial action. 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.

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 and is consistent with long-term remediation goals for Rocky Flats.

Where potential impacts may occur, effects are expected to be small and temporary, and appropriate mitigation measures will be 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

Source	Construct Haul Road (g/s)	Transport Fill and Cover (g/s)	Install Fill and Cover (g/s)
Haul Truck	0.132	0.721	Not Applicable
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

Task	Averaging Period	Model Input (g/s)	Modeled Concentration ($\mu g/m^3$)	Background[1] Concentration ($\mu g/m^3$)	Cumulative[2] Concentration ($\mu g/m^3$)
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:

[1] 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.

g/s grams per second
$\mu g/m^3$ micrograms per cubic meter

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 of 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 41 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. The East Landfill Pond and associated wetlands area are removed during the remedial action. Wetlands mitigation involves an exchange from an offsite wetlands mitigation bank. No floodplains are affected.	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 floodplains, critical habitats, or threatened and endangered species are affected.

Table 9-4 (Continued)

Impact	Preferred IM/IRA	No Action
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.
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 changing topography and reducing infiltration 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 runoff. Construction activities disturb surfaces and erosion from storm runoff would impact surface-water quality until vegetation is established.	Potential for surface-water runoff to contact waste and transport contaminants 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.

Table 9-4 (Continued)

Impact	Preferred IM/IRA	No Action
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 the 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, man-hours, construction, and water)	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 not contained or removed such that the exposure to humans and environment exist.
Mitigation Measures	Because the existing wetlands at the East Landfill Pond will be eliminated, it is necessary to mitigate lost or injured wetlands. Potential mitigation of surface runoff and erosion from the construction area may be necessary.	Future mitigation of leachate or groundwater may be necessary.

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DRAFT PROPOSED PLAN
FOR ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
OPERABLE UNIT 7: PRESENT LANDFILL

United States Department of Energy (DOE) | Jefferson County, Colorado | March 8, 1996

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)***, which was negotiated among DOE, the United States Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE). EPA is the lead regulatory agency for this action.

The subject of this document, which is a combination ***Corrective and Remedial Action Proposed Plan (PP)*** 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 (IHSS 114). The remedial action addresses closure of two of the four IHSSs: IHSS 114 and IHSS 203 (Inactive Waste Storage Area). No further action is proposed for the other two IHSSs: IHSS 167.2 (Pond Area Spray Field) and IHSS 167.3 (South Area Spray Field). 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. 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 and treatment was implemented in late 1995 and early 1996. This PP describes 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: October 15, 1996 - December 16, 1996

Public Hearing: October ___, 1996
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

[1] Words shown in italics on the first mention are defined in the glossary at the end of this Proposed Plan.

The preferred alternative for landfill containment proposed in this plan is Alternative 2: Cap, Passive Gas Collection and Monitoring, Seep Water Discharge to Groundwater. This alternative is one of many originally identified and represents the best solution relative to the CERCLA evaluation criteria. The alternatives were screened based on effectiveness, implementability, and cost. Six 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 2 include Alternative 1: No Action, Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater, Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Surface Water.

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 and (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 successful implementation of the RCRA/CERCLA programs.

Although this plan identifies an engineered cap with gas collection and discharge of leachate from the seep to groundwater 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 each alternative can be found in the OU 7 Draft Phase I IM/IRA DD and Closure Plan, 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 and Closure Plan 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 (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 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.

Most site 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 waste such as office trash, construction debris, scrap metal, dried sanitary sewage sludge, and miscellaneous containers has been disposed in the landfill. As is common practice at municipal landfills, waste delivered to the landfill is spread across the work area, compacted, and covered with soil. Landfill operations will continue until the new landfill opens in 1997.

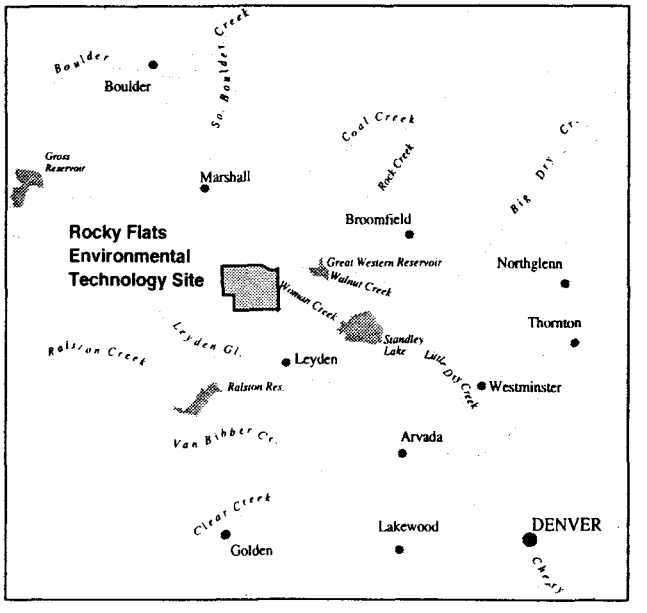


Figure 1

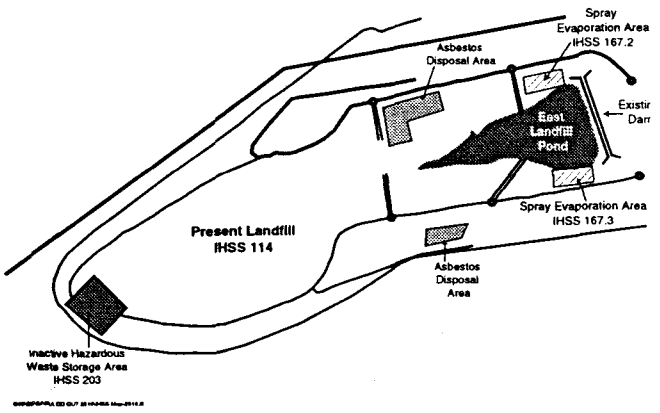


Figure 2

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.

- **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 for landfilling. Rocky Flats hazardous and nonhazardous wastes were disposed at the landfill between 1968 and 1986; only nonhazardous wastes have been disposed at the landfill since 1986. 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. Response actions include construction of a surface-water diversion ditch, two detention ponds east of the landfill, a subsurface groundwater-intercept system, a subsurface leachate-collection trench, and a passive leachate collection and treatment 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 Final Phase I IM/IRA DD and Closure Plan. 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 Final Phase I IM/IRA DD and Closure Plan.

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 chemical occurring at OU 7 against the sitewide preliminary remediation goal (PRG) established for Rocky Flats. Chemicals 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 environmental risks were identified beyond the proposed landfill containment for open-space users. Because there are no risks to open-space users from soils in the spray evaporation areas (IHSSs 167.2 and 167.3), no further action is required for these IHSSs.

Average concentrations of chemicals 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 runoff and erosion
4. control landfill gas (treat as needed)
5. control groundwater in the source area
6. collect and treat landfill leachate (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 2: Cap, Passive Gas Collection and Monitoring, and Seep Water Discharge to Groundwater.** This alternative consists of a single-barrier FMC cover, a passive gas collection system, and institutional controls. The membrane liner material has a permeability of 1×10^{-13} cm/sec and is underlain by a 12-inch low-permeability soil layer (permeability of 1×10^{-5} to 1×10^{-7} cm/sec) and a geocomposite gas collection layer. The cover is overlain by a geocomposite lateral drainage/biotic barrier layer and a 3-foot vegetative cover. As agreed to by DOE, EPA, and CDPHE, the East Landfill Pond will be removed and the dam and pond sediments will be removed and consolidated in the landfill under the cap prior to closure. A gravel layer for discharge of the leachate from the seep would be installed under the cap at the seep location. This layer would allow the water to flow from under the cap and discharge to fill and then alluvial groundwater at a location downgradient from the cap.

- **Alternative 3: Cap, Passive Gas Collection and Monitoring, Slurry Wall, and Seep Water Discharge to Groundwater.** This alternative parallels Alternative 2 in every feature, except that a slurry wall would be constructed upgradient of the landfill where the existing slurry wall has failed. The slurry wall would divert clean groundwater from flowing through the landfill waste.

- **Alternative 4: Cap, Passive Gas Collection and Monitoring, Engineered Wetlands, and Seep Water Discharge to Surface Water.** This alternative is the same as Alternative 2 in every feature, with the addition of a engineered wetland treatment system and discharge to a surface-water channel instead of to groundwater. For Alternative 4, a wetlands treatment system would be constructed to treat the leachate at the seep (primarily to remove metal contaminants). The treated water would then be discharged to a surface-water channel downgradient of the cap.

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. Alternative 3 is the only alternative that addresses the RAO to control groundwater at the source; however, modeling has shown that the benefits of the slurry wall are minimal.

2. **COMPLIANCE WITH ARARs.** Conservative modeling indicates that Alternatives 2 and 3 will meet chemical-specific groundwater ARARs at the Point of Compliance except for iron. The wetlands would be designed to meet chemical-specific surface-water ARARs. However, the innovative nature of the engineered wetlands makes long-term compliance uncertain. All alternatives will meet location- and action-specific ARARs.

3. **LONG-TERM EFFECTIVENESS AND PERMANENCE.** The source of contamination remains in place for all alternatives as part of the presumptive remedy. Although the possibility exists that water may surface or that natural attenuation may decrease over time for Alternatives 2 and 3, uncertainties associated with the long-term performance of the wetlands in Alternative 4 are greater.

4. **REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT.** Only Alternative 4 includes treatment explicitly. However, Alternatives 2 and 3 reduce toxicity through natural attenuation. In all three alternatives, the cap minimizes infiltration into the waste thus decreasing the generation and migration of leachate. The slurry wall in Alternative 3 will also decrease the generation and migration of leachate, but to a lesser extent than the cap.

5. **SHORT-TERM EFFECTIVENESS.** None of the alternatives present a significant danger to the community, construction workers, or the environment during construction. Fugitive dust and erosion are readily mitigated using standard construction techniques.

6. **IMPLEMENTABILITY.** The necessary equipment and specialists are available for all alternatives. Alternative 2 is the easiest to implement. Alternative 3 is slightly more complex with addition of a slurry wall. Alternative 4 is the most complex, requiring that vegetation be established and that sediments and vegetation be removed and disposed (possibly as a RCRA waste) on a periodic basis.

7. **COST.** Cost is a significant distinguishing factor among the three containment alternatives. The total present worth costs are:

Alternative 1	$0
Alternative 2	$10,577,000
Alternative 3	$11,735,000
Alternative 4	$11,464,000

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.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Overall protection of human health and environment	○	◓	●	◓
Compliance with ARARs	○	◓	◓	◒
Long-term effectiveness and permanence	○	◓	◓	◒
Reduction to toxicity, mobility, or volume through treatment	○	◒	◓	●
Short-term effectiveness	●	◒	○	◓
Implementability	●	◓	◒	○
Cost	●	◓	○	◒

● Best
◓ Good
◒ Fair
○ Poor

Figure 3

SUMMARY OF PREFERRED ALTERNATIVE

The OU 7 detailed analysis of alternatives concludes that Alternative 2, Cap, Passive Gas Collection and Monitoring, Seep Water Discharge to Groundwater, 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 proposed remedial action, the IM/IRA document proposes a 30-year post-closure maintenance and monitoring plan to be implemented after 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 and Closure Plan, 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.

RF/ER-96-0009.UN

Operable Unit 7
Revised Draft IM/IRA
Decision Document and Closure Plan

Appendices

Rocky Mountain Remediation Services, L.L.C.

March 1996

Table of Contents

Appendix A Borehole Geologic Logs

Appendix B Drawdown Recovery Test Data and Analytical Solutions

Appendix C Groundwater Flow and Particle Tracking Modeling

Appendix D Groundwater Contaminant Transport Simulations

Appendix E Waste Settlement Analysis

Appendix F HELP Modeling

Appendix G Cost Estimates

Appendix H Gas-Emission Estimates

Appendix I Annual Soil-Loss Calculations, Methodologies, and Assumptions

Appendix J Responses to U.S. Environmental Protection Agency and Colorado Department of Public Health and Environment Comments on Operable Unit 7 Draft IM/IRA Decision Document

Appendix K Wetland Assessment for Operable Unit 7 Interim Measure/Interim Response

SOIL TYPES

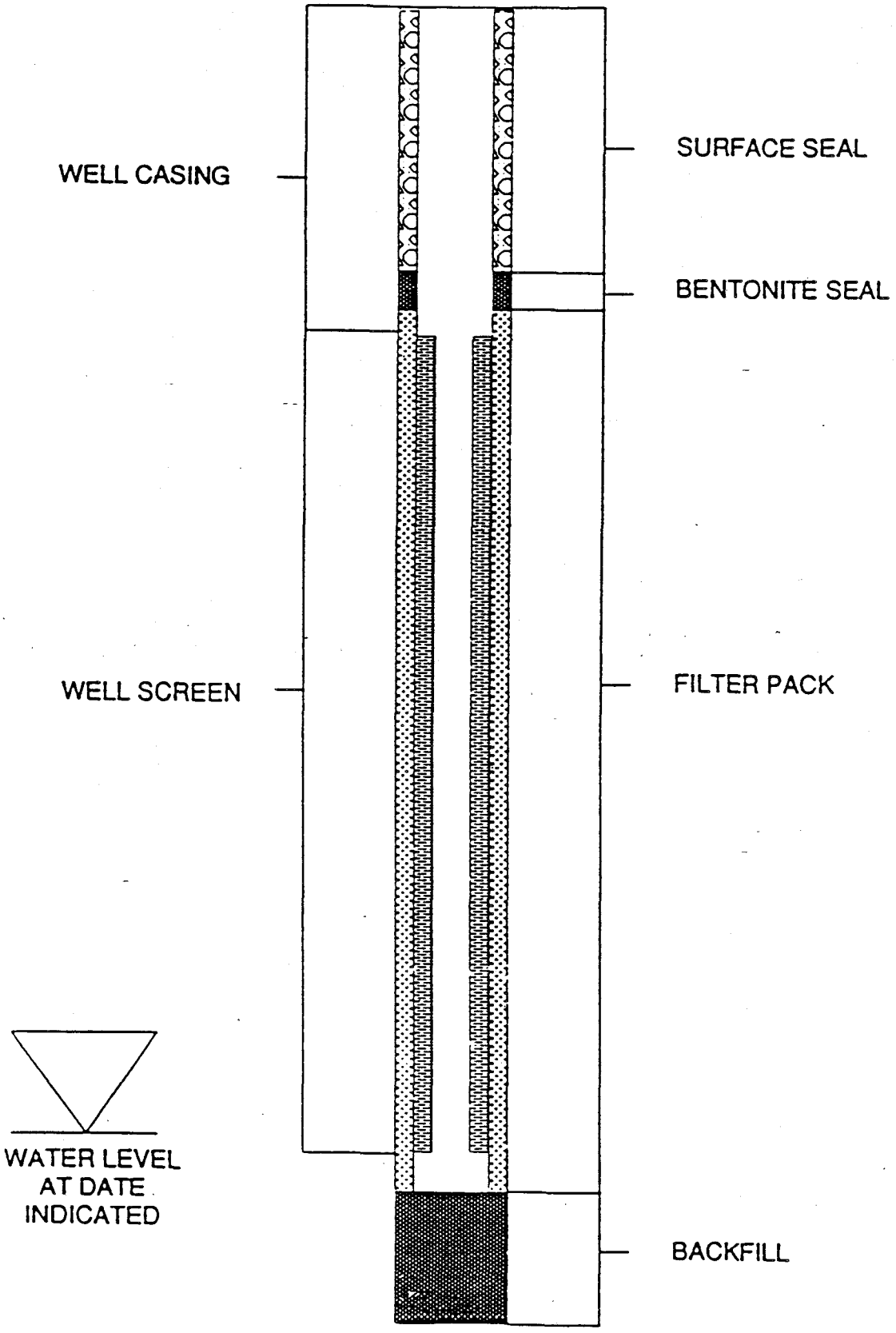
Major Divisions			Letter	Symbol	Description
Coarse Grained Soils	Gravel and Gravelly Soils	Clean Gravels (<5% fines)	GW		Well graded gravels or gravel-sand mixtures, little or no fines. Uc >4 (lab only)
			GP		Poorly graded gravels or gravel sand mixtures, little or no fines.
	More than 50% of coarse fraction retained on no. 4 sieve	Gravel with Fines (>12% fines)	GM		Silty gravels, gravel-sand-silt mixtures.
			GC		Clayey gravels, gravel-sand-clay mixtures.
	Sand and Sandy Soils	Clean Sand (<5% fines)	SW		Well graded sands or gravelly sands, little or no fines. Uc >6 (lab only)
			SP		Poorly-graded sands or gravelly sands, little or no fines.
More than 50% of material is larger than no. 200 sieve size	More than 50% of coarse fraction passed no. 4 sieve	Sands with Fines (>12% fines)	SM		Silty sands, sand-silt mixtures.
			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.
More than 50% of material is smaller than no. 200 sieve size		High Plasticity	MH		Inorganic silts, micaceous or diatomaceous fine sand or silty soils.
			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

WELL OR PIEZOMETER CONSTRUCTION



STATE PLANE COORDINATE:		TOTAL DEPTH (FT): 10.00	GROUND ELEVATION (FT):	5897.90	PROJECT NUMBER:	017-RFI/RI	LOG OF BORING NUMBER:
NORTH:	753013	AREA: 017 PRESENT LANDFILL	CASING DIAMETER (IN):		GEOLOGIST:	D.L. RIGGS	52694
EAST:	2085106	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	DATE DRILLED:	10/12/94	

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.

GRADATIC	SAMPLE	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/ INTERVAL	DATUM(FT)	DEPTH(FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
				0.75 /2.00	5897	0–1			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.
				2.00 /2.00	5896	1–2			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.
				2.00 /2.00	5895	2–3			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.
				2.00 /2.00	5894	3–4				
				2.00 /2.00	5893	4–5				
				2.00 /2.00	5892	5–6				
				2.00 /2.00	5891	6–7				
				2.00 /2.00	5890	7–8			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.
				2.00 /2.00	5889	8–9				
					5888	9–10				Total Depth Drilled 10.00

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. RIGGS	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 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%	1.25 /2.00	5940	0–1			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').
				2.00 /2.00	5939	1–2			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 grysh 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.
				2.00 /2.00	5938	2–3				
				2.00 /2.00	5937	3–4				
				2.00 /2.00	5936	4–5			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.
	6H70-07ST			2.00 /2.00	5935	5–6				
				2.00 /2.00	5934	6–7			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.
				2.00 /2.00	5933	7–8				
				2.00 /2.00	5932	8–9				
					5931	9–10				

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. HIGGIN	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.

SAMPLE	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
		0% 100%			10			CLAYEY SILTSTONE	Clayey Siltstone with some sand. Lt olv brn (2.5 Y 5/6) to grysh 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').
			2.00 /2.00	5930	11				
				5929	12				
			1.75 /2.00	5928	13				
				5927	14			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 thinly 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').
GH70-08ST			1.00 /2.00	5926	15				
				5925	16				
			2.00 /2.00	5924	17				
				5923	18				
			2.00 /2.00	5922	19				
				5921	20				Total Depth Drilled 20.00

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: D. L. RIGGR	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.

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
					5868	0			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').
	GH7041057			0.75 /2.00	5867	1				
					5866	2			CL:	All core used for samples. Field description follows: Clayey Silt with some gravel. Light brown. Gravel subangular (clasts to 2"). Dry.
	GH7041057			1.00 /2.00	5865	3			CL:	All core used for samples. Field description follows: Silty Clay with some gravel. Dark brown. Gravel fine, no gravel in tip of core. Trace of caliche. Dry. No recovery (3.0'-4.0').
					5864	4			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').
	GH7041157 GH7041257			1.25 /2.00	5863	5				
					5862	6				Total Depth Drilled: 6.00 Total Depth Casing: 6.00 Bottom of Filter Pack: 6.00
					5861	7				
					5860	8				
					5859	9				
						10				

STATE PLANE COORDINATE:		TOTAL DEPTH (FT): 18.00	GROUND ELEVATION (FT):	5871.20	PROJECT NUMBER:	007-RFI/RI	LOG OF BORING NUMBER:
NORTH:	75196	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. HIGGR	52994
EAST:	205085	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 BEDROCK 16.0'. CORE LOGGER: J.A. HIGGINS.

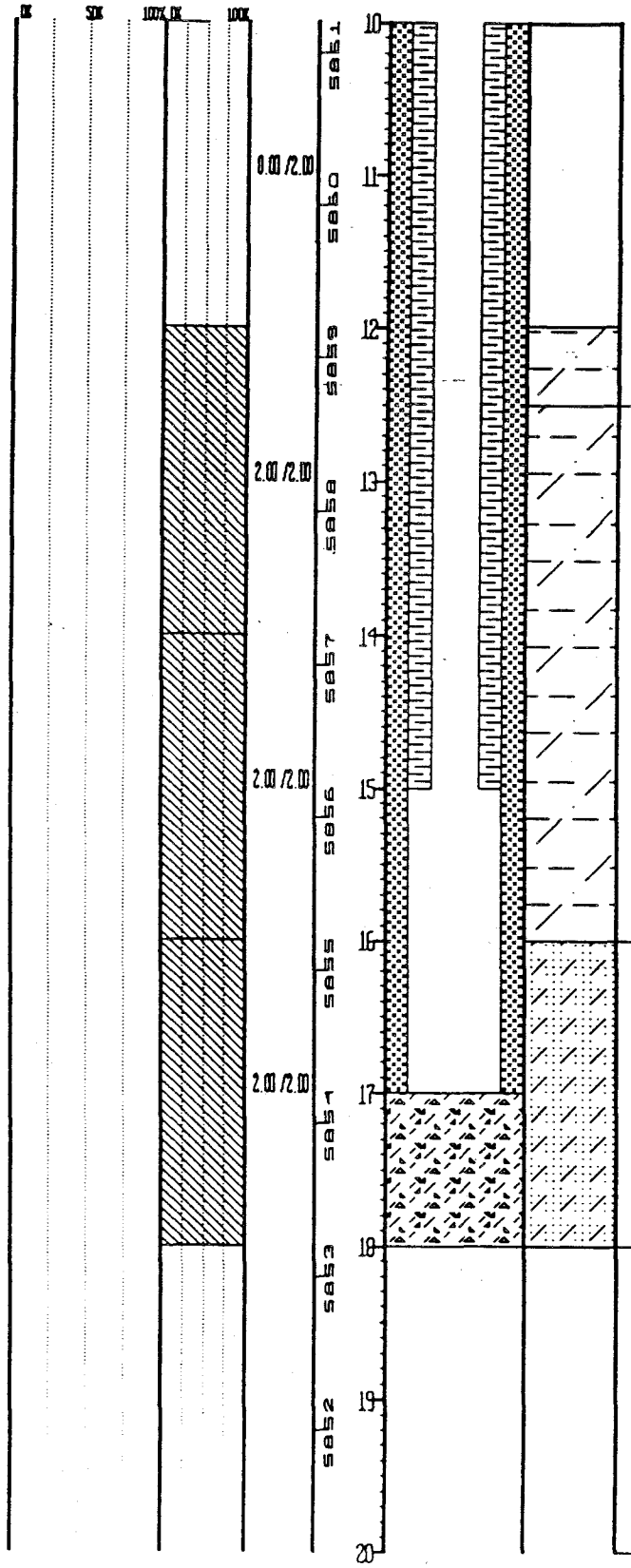
SAMPLE NUMBER	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
	0% 50% 100%	0% 100%							
			1.75 /2.00	5871 5870	0 1			CL:	Sandy Silt with trace of gravel. Dark grayish brown (2.5 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	5869 5868	2 3			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').
			0.00 /1.00	5867	4				
			1.00 /1.00	5866	5			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').
			0.00 /2.00	5865 5864	6 7				
			1.00 /2.00	5863 5862	8 9 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')

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 18.00	GROUND ELEVATION (FT):	5871.20	PROJECT NUMBER:	007-RFI/RI
NORTH: 753196	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. KIGER
EAST: 2085085	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	DATE DRILLED:	10/25/94

LOG OF BORING NUMBER: 52994

REMARKS: BEDROCK WELL INSTALLED. TOTAL DEPTH 18.0'. TOP OF BEDROCK 5.0'. TOP OF UNWEATHERED BEDRPCL 16.0'. 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: 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

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. RIGGS	53094
EAST:	2085095	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	DATE DRILLED:	10/19/94	

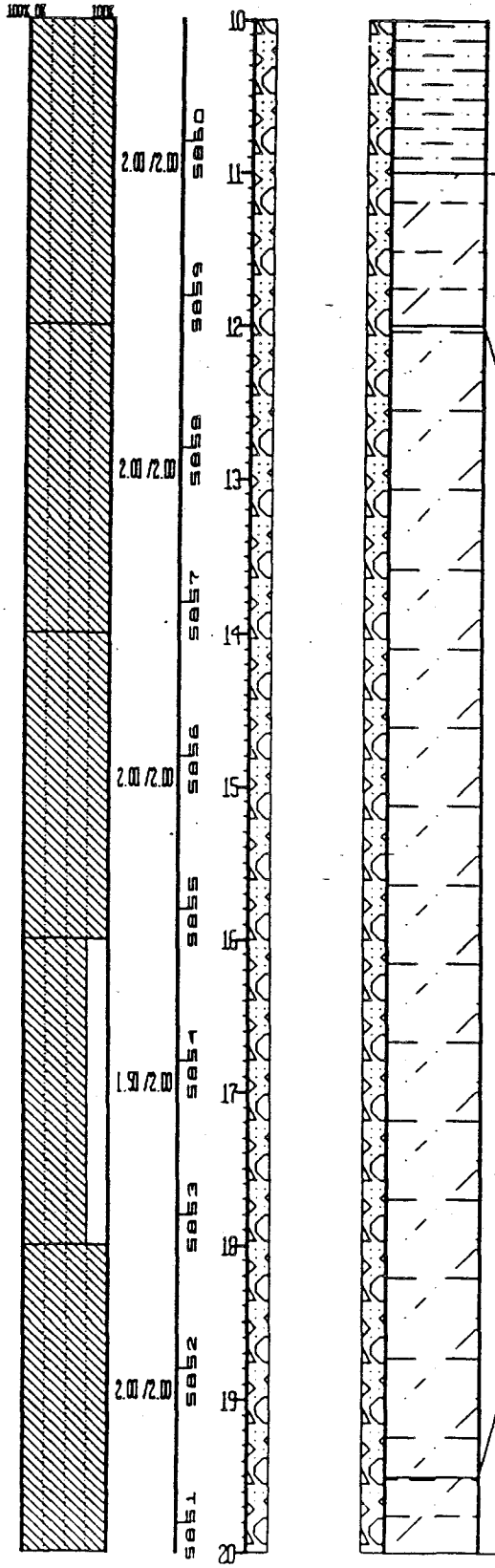
REMARKS: BEDROCK WELL INSTALLED TO 67.0'. TOTAL DEPTH DRILLED 90.0'. TOP OF BEDROCK 5.25'. TOP OF UNWEATHERED BEDROCK 19.0'. NO SAMPLES.
CORE LOGGER: J.A. HIGGINS.

SAMPLE GRADATION SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	SAMPLE NO.	DEPTH (FT)	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
0% 50%	100% 0% 100%	2.00/2.00	sab0	0		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.
			sab9	1			
				2			
		1.00/2.00	sab8	3		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')
			sab7	4			
		2.00/2.00	sab6	5		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.
			sab5	6			
		2.00/2.00	sab4	7		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.
		2.00/2.00	sab3	8		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.
		2.00/2.00	sab2	9			
			sab1	10			

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. KIGER	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. KIGGINS.

CHEMICAL SAMPLE DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRAIN SIZE (0% – 50%) | PERCENT RECOVERY (100% OK – 100%) | 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% Silghtly friable, laminar bedding marked by color bands. Few micro-fractures. Dry. Fe-oxide stained. 57% Clay, 25% silt, 18% sand.

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 90.00	GROUND ELEVATION (FT):	5870.80	PROJECT NUMBER:	007-RFI/RI
NORTH: 753198	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. RIGGS
EAST: 2085095	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	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.

SAMPLE NO	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
		0% 100%	1.25 /2.00	5850	20–21			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').
			2.00 /2.00	5849	22–23			SILTY CLAYSTONE	Silty Claystone with some sand. Olive brown (2.5 Y 4/4). Sand m-f. 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.
			2.00 /2.00	5848	23–24			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 m-f. 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.
			2.00 /2.00	5847	24–25				
			2.00 /2.00	5846	25–26				
			2.00 /2.00	5845	26–27			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.
			2.00 /2.00	5844	27–28			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.
			2.00 /2.00	5843	28–29				
			2.00 /2.00	5842	29–30				
				5841	30				

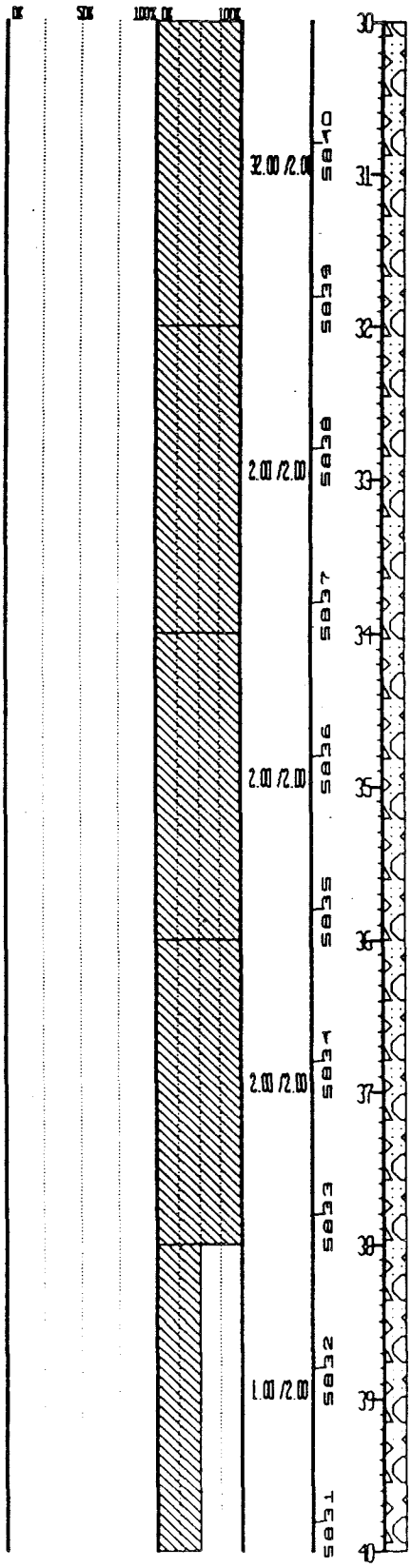
STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 90.00	GROUND ELEVATION (FT):	5870.80	PROJECT NUMBER:	007-RFI/RI
NORTH: 753198	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. RIGGS
EAST: 2085095	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	DATE DRILLED:	10/19/94

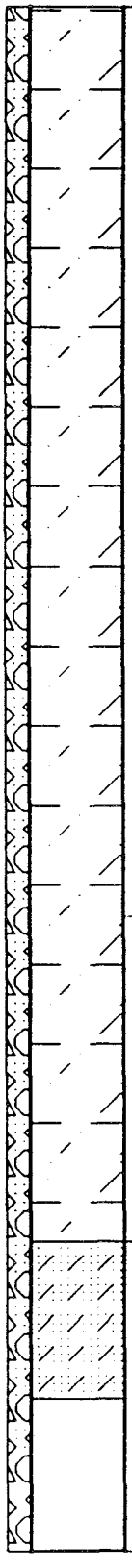
LOG OF BORING NUMBER: 53094

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 DEPTH | GRADATIONAL SAMPLE DEPTH | SAMPLE NUMBER | SAMPLE GRADE 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 mf, 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 mf. 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.

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. RIGGS	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. KIGGINS.

SAMPLE	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
OK	SIX	100% OK	100%						
			1.00 /2.00	5830	40				
				5829	41				
			1.00 /2.00	5828	42				
				5827	43				
			0.75 /2.00	5826	44				
				5825	45				
			2.00 /2.00	5824	46				
				5823	47				
			2.00 /2.00	5822	48				
				5821	49	10/27/94			
					50				

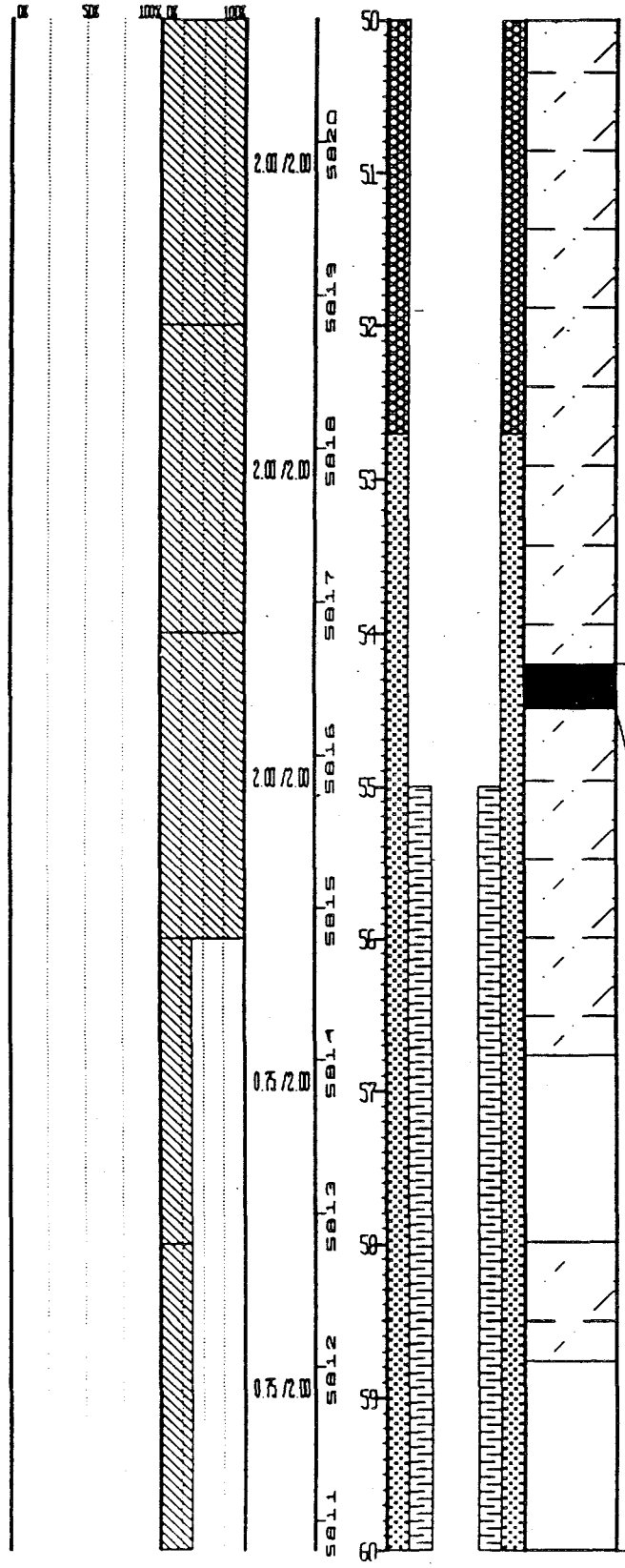
CLAYEY SILTSTONE: Clayey Siltstone with some sand. Color varies from gray (2.5 Y 5/1) to dark gray (2.5 Y 4/1) to very dark gray (2.5 Y 2.3/1) to black (2.5 Y 2.5/1). sand nf. Sand and silt subangular to subrounded, composed of quartz, and carbonaceous fragments. Poorly sorted. Highly friable in some 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.

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. RIGGR	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



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 appar-nt. 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:	TOTAL DEPTH (FT): 90.00	GROUND ELEVATION (FT): 5870.80	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:
NORTH: 53198	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN): 2.00	GEOLOGIST: D. L. HIGGR	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.

SAMPLE #	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
	DK SOK	100% DK 100%	0.25 /2.00	sab10	60			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 malleable. No bedding apparent. Wet. 53% Sand, 33% silt, 14% clay.
				sab9	61			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').
			1.25 /2.00	sab8	62			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').
				sab7	63				
			2.00 /2.00	sab6	64				
				sab5	65				
			2.00 /2.00	sab4	66				
				sab3	67				
			1.50 /2.00	sab2	68				
				sab1	69				
					70				

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 90.00	GROUND ELEVATION (FT):	5870.80	PROJECT NUMBER:	007-RFI/RI
NORTH: 753198	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. KIBOR
EAST: 2085095	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	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 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
			100% OK	1.25 /2.00	5800	70–71			SANDY SILTSTONE	Sandy Siltstone with some clay. Olive gray (5 Y 5/2) to gray (5 Y 5/1). Sand mf. 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').
				1.00 /2.00	5799	72–73				
				1.75 /2.00	5798	73–74				
				0.50 /2.00	5797	74–75				
				1.25 /2.00	5796	75–76				
					5795	76–77			SILTY CLAYSTONE	Silty Claystone with a trace of sand. Dark grayish brown (2.5 YR 4/2). Sand mf 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').
					5794	77–78				
					5793	78–79				
					5792	79–80				
					5791	80				

STATE PLANE COORDINATE:		TOTAL DEPTH (FT): 90.00	GROUND ELEVATION (FT):	5870.80	PROJECT NUMBER:	017-RFI/RI	LOG OF BORING NUMBER:
NORTH	753198	AREA: 017 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. RIGGS	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.

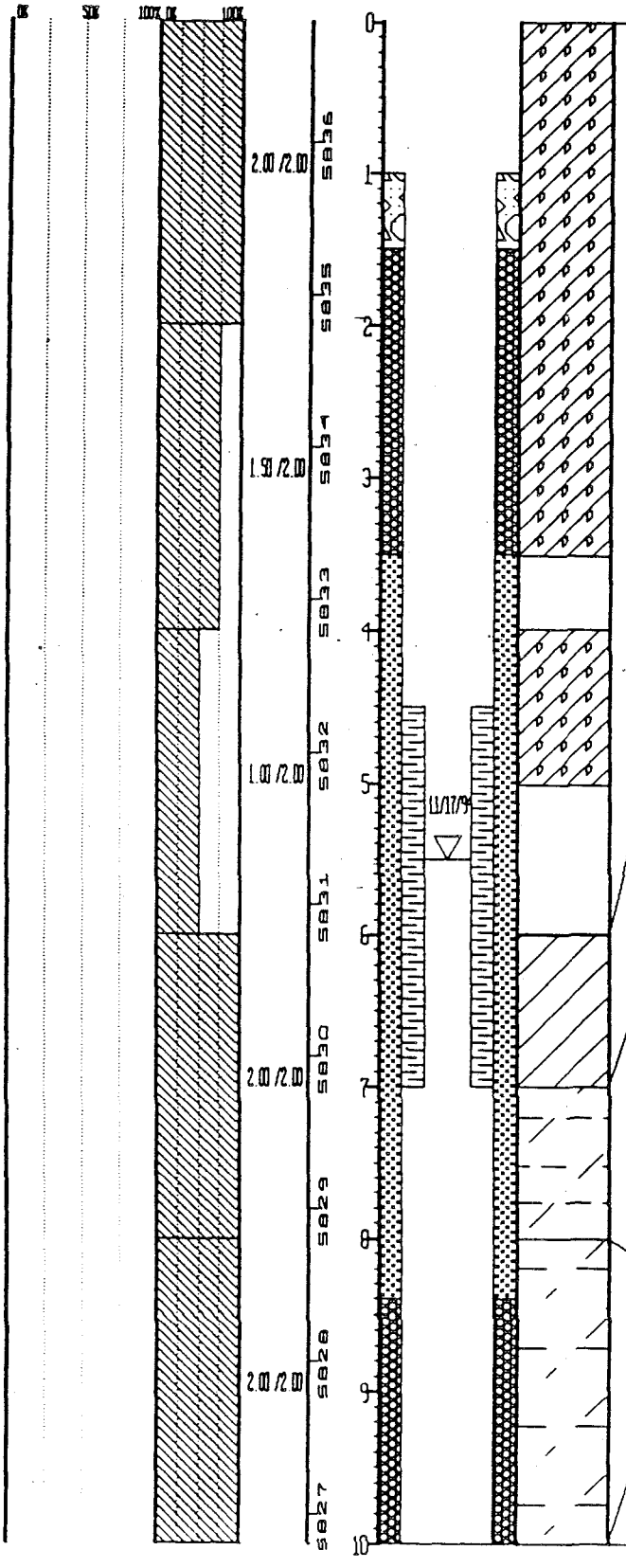
GRADATION	SAMPLE NUMBER	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
				0.00 /2.00	5790	80–81				SILTY CLAYSTONE: No recovery (80.0'-90.0').
				0.00 /2.00	5789	82–83				
				0.00 /2.00	5788	83–84				
				0.00 /2.00	5787	84–85	10/24/94 ▽			
				0.00 /2.00	5786	85–86				
				0.00 /2.00	5785	86–87				
				0.00 /2.00	5784	87–88				
				0.00 /2.00	5783	88–89				
				0.00 /2.00	5782	89–90				
					5781	90				

Total Depth Drilled: 90.00 Total Depth Casing: 67.00
Bottom of Filter Pack: 67.00

STATE PLANE COORDINATE:		TOTAL DEPTH (FT): 10.00	GROUND ELEVATION (FT):	5836.80	PROJECT NUMBER:	007-RFI/RI	LOG OF BORING NUMBER:
NORTH:	753434	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	2.00	GEOLOGIST:	D. L. RIGGR	53194
EAST:	2086037	LOCATOR NUMBER: 0	BOREHOLE DIAMETER (IN):	7.00	DATE DRILLED:	10/14/94	

REMARKS: ALLUVIAL WELL INSTALLED. TOTAL DEPTH 10.0'. TOP OF BEDROCK 7.0'. NO SAMPLES COLLECTED. 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



SC: Gravelly Clayey Sand with some silt. Brown (10 YR 5/3). Gravel fnc, (mainly f with clasts to 2" maximum diameter). Sand fnc (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

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 30.00	GROUND ELEVATION (FT): 5971.50	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:	
NORTH: 73291	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	GEOLOGIST: D. L. RIGGS	53494	
EAST: 2083637	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 12.6'. TOP OF UN WEATHERED BEDROCK 27.0'. GEOTECHNICAL SAMPLES ONLY. CORE LOGGER: J.A. HIGGINS.

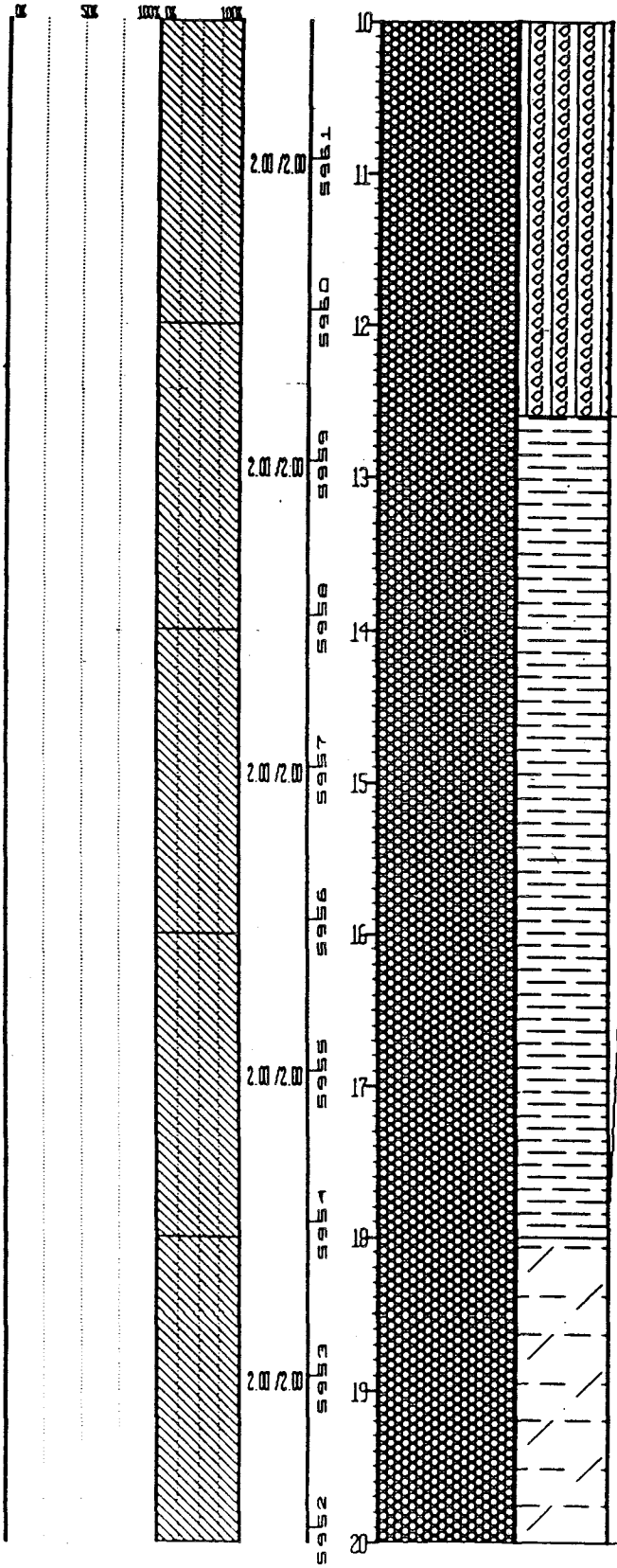
SAMPLE	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
	0% 50%	100% 0% 100%	1.75 /2.00	5971 5970	0 1 2			GM/gc	Sandy Gravel with some silt and clay. Matrix is yellowish red (5 YR 4/6). Gravel and sand fnc, 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').
			2.00 /2.00	5969	3			CL	Silty Clay with some sand and a trace of gravel. Yellowish red (5 YR 4/6). Sand cmf, quartz, subangular. Gravel f, quartzite, angular. Moderate plasticity. No bedding. Dry. 57% Clay, 25% silt, 15% sand, 3% gravel.
				5968	4			GM/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.
			2.00 /2.00	5967	5			SM/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 mf. Sand fnc. Gravel and sand rounded to subrounded. Gravel mainly metamorphic rock fragments; sand mainly quartz. No bedding apparent. Slightly moist to very moist becoming 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.)
				5966	6				
			2.00 /2.00	5965	7				
				5964	8				
			2.00 /2.00	5963	9				
				5962	10				

GRAPHLOGS1

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 30.00	GROUND ELEVATION (FT): 5971.90	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:	
NORTH: 753291	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	GEOLOGIST: D. L. RIGGR	53494	
EAST: 2083637	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 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 works thin fine sand and silt laminae as well as spotty carbonaceous material. Silghtly weathered.

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 30.00	GROUND ELEVATION (FT): 5971.90	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:
NORTH: 753291	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	GEOLOGIST: D. L. RIGGS	53494
EAST: 2083637	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 12.6'. TOP OF UN WEATHERED BEDROCK 27.0'. GEOTECHNICAL SAMPLES ONLY. CORE LOGGER: J.A. HIGGINS.

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
	DK SDK	100% DK 100%	2.00 /2.00	5951	20 21				
			2.00 /2.00	5950	22				
			2.00 /2.00	5949	23				
			2.00 /2.00	5948	24				
			2.00 /2.00	5947	25				
			2.00 /2.00	5946	26				
			2.00 /2.00	5945	27				
			2.00 /2.00	5944	28				
			2.00 /2.00	5943	29				
				5942	30				

Total Depth Drilled: 30.00

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. RIGGS	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 UNSE WEATHERED BEDROCK 28.1'. 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
		DK / SDX	100% DK / 100%	0.50 /2.00	5561	0			SW:	Gravelly Sand with some silt and a trace of clay. Matrix is brown (10 YR 5/3). Gravel fnc (mainly medium with clasts up to 2.0"), sand fnc (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').
				1.75 /2.00	5560	1				
					5559	2				
					5558	3				
				1.75 /2.00	5557	4			SM:	Silty Sand with trace of clay and gravel. Light yellowish brown (10 YR 6/4). Gravel f, sand fnc (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').
					5556	5				
					5555	6			SM:	Gravelly Sand with some silt and clay. Yellowish brown (10 YR 5/8). Gravel mf, sand fnc (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.
				2.00 /2.00	5554	7				
CH7D4CDST					5553	8			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 fnc (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.
				2.00 /2.00	5552	9				
						10				

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 30.00	GROUND ELEVATION (FT): 5961.20	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:
NORTH: 753360	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	GEOLOGIST: D. L. MIGOR	53594
EAST: 2084089	LOCATION 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 LNSE WEATHERED BEDROCK 28.1'.
GEOTECHNICAL SAMPLES ONLY. CORE LOGGER: J.A. HIGGINS.

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
			2.00 /2.00	5951	10–11			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 fmc. 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	12–13			SM:	Gravelly Sand with some silt and trace of clay. Dark yellowish brown (10 Y 3/6). Gravel fn. Sand cmf. 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	5946	15–16				
			1.00 /2.00	5944	16–17			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	5942	19–20				

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. HIGGIN	53594
EAST: 2084089	LOCATION 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 LIKE WEATHERED BEDROCK 28.1'. 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
		CL SIL	100% CL	100%		20				
				0.20 /2.00	5541	21				
					5540	22				
9/20/94				0.25 /2.00	5539	23				
					5538	24				
				0.00 /2.50	5537	25				
					5536	26				
				1.00 /1.50	5535	27				
					5534	28				
				1.50 /2.00	5533	29				
					5532	30				

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

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. RIGGS	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.

SAMPLE #	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
		100% OK		5939	0			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')
53694-001ST			1.50 /2.00	5938	1				
				5937	2			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.
53694-002ST			2.00 /2.00	5936	3				
				5935	4				
			1.75 /2.00	5934	5				
				5933	6				
			2.00 /2.00	5932	7				
				5931	8			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')
			2.00 /2.00	5930	9				
					10				

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 34.00	GROUND ELEVATION (FT):	5939.00	PROJECT NUMBER:	007-RFI/RI
NORTH: 753403	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):		GEOLOGIST:	D. L. RIGGS
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.

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
			2.00/2.00	5929	10				
				5928	11				
			2.00/2.00	5927	12				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.
			2.00/2.00	5926	13				
				5925	14				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).
			2.00/2.00	5924	15				
				5923	16				
			2.00/2.00	5922	17				
				5921	18				
			1.75/2.00	5920	19				
					20				

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. RIGGS	53694
EAST: 2084561	LOCATION 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.

SAMPLE NO.	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM(FT)	DEPTH(FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
			2.00/2.00	5919	20				
				5918	21				
				5917	22				
			2.00/2.00	5916	23				
				5915	24				
			2.00/2.00	5914	25				
				5913	26				
			1.75/2.00	5912	27				
				5911	28				
			2.00/2.00	5910	29				
					30				

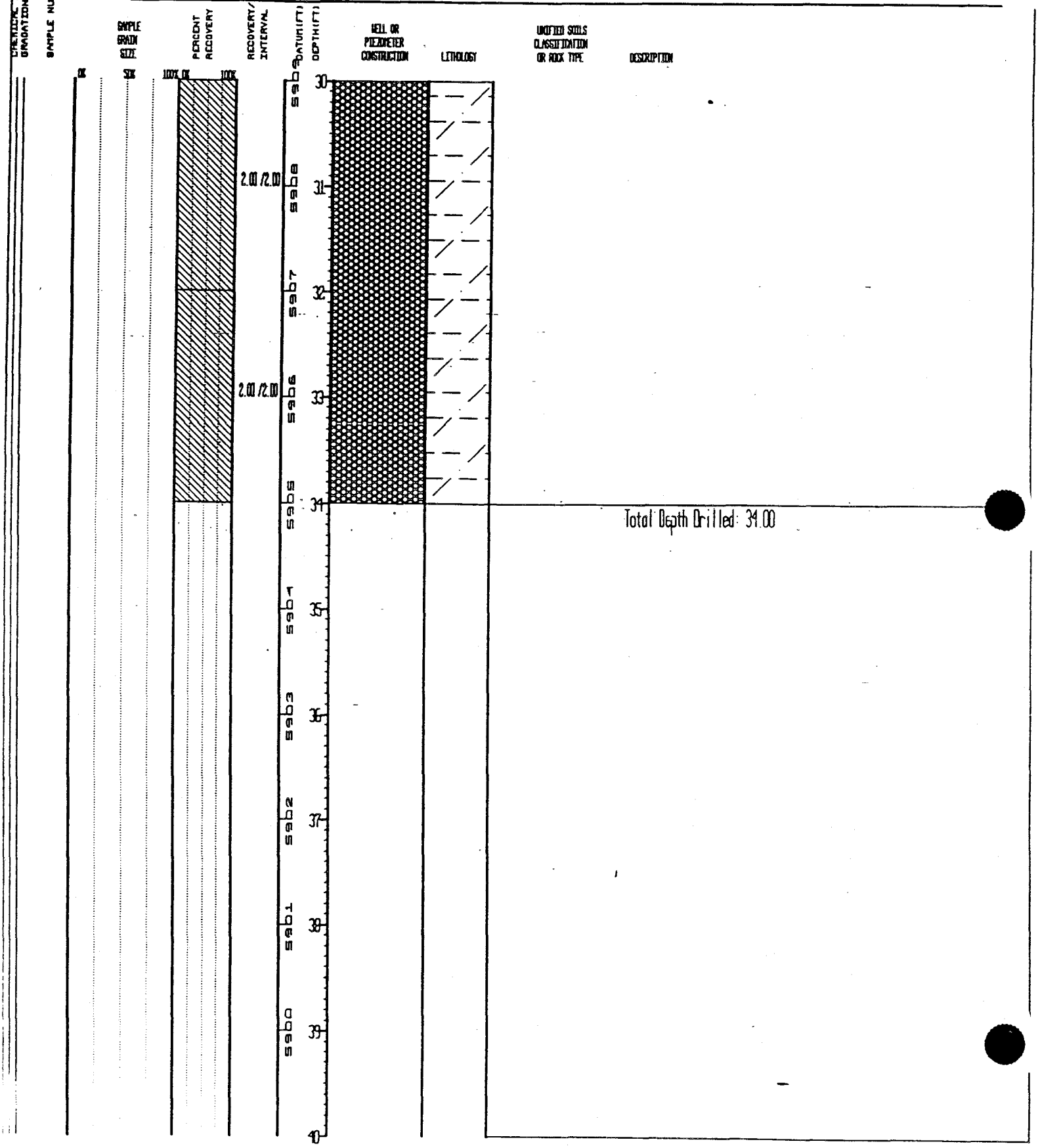
SILTY CLAYSTONE: Silty Claystone with some sand light yellowish brown (2.5 Y 6/4)' to grayish brown (2.5 Y 5/2)'. Sand fn, angular, quartz. Moderately sorted. Porosity=20%-30% Not cemented. Very friable. Thinly laminated, thin and horizontal. Micro-fractures horizontal, vertical, and at 45 degree angles. 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').

STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 34.00	GROUND ELEVATION (FT):	5939.00	PROJECT NUMBER:	007-RFI/RI
NORTH: 753403	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):		GEOLOGIST:	D. L. HIGGIN
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.



STATE PLANE COORDINATE:	TOTAL DEPTH (FT): 6.00	GROUND ELEVATION (FT): 5884.00	PROJECT NUMBER: 007-RFI/RI	LOG OF BORING NUMBER:
NORTH 753084	AREA: 007 PRESENT LANDFILL	CASING DIAMETER (IN):	GEOLOGIST: D. L. RIGGR	53794
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.

SAMPLE	SAMPLE GRAIN SIZE	PERCENT RECOVERY	RECOVERY/INTERVAL	DATUM (FT)	DEPTH (FT)	WELL OR PIEZOMETER CONSTRUCTION	LITHOLOGY	UNIFIED SOILS CLASSIFICATION OR ROCK TYPE	DESCRIPTION
		100%	2.00/2.00	5883	1			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.
				5882	2			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.
			2.00/2.00	5881	3			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.
			2.00/2.00	5879	5				
				5878	6				Total Depth Drilled: 6.00
				5877	7				
				5876	8				
				5875	9				
					10				

Table of Contents

B.1. DRAWDOWN RECOVERY TEST DATA AND ANALYTICAL SOLUTIONS B-1

B.2. REFERENCES B-1

Tables

Table B-1 Geometric Mean of Hydraulic Conductivity for OU 7 Surficial Materials (Alluvial and Artificial Fill)

Table B-2 Geometric Mean of Hydraulic Conductivity for OU 7 Artificial Fill

Table B-3 Geometric Mean of Hydraulic Conductivity for OU 7 Alluvial Materials

Table B-4 Geometric Mean of Hydraulic Conductivity for OU 7 Weathered Bedrock

Table B-5 Geometric Mean of Hydraulic Conductivity for OU 7 Unweathered Bedrock

Table B-6 Completion Information for Wells Downgradient of the Landfill

Figures

Figure B-1 AQTESOLV Solution for Well 53094x

Figure B-2 AQTESOLV Solution for Well 53194

Figure B-3 AQTESOLV Solution for Well B207089

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
s slug test

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	

Table B-6 Completion Information for Wells Downgradient of the Landfill

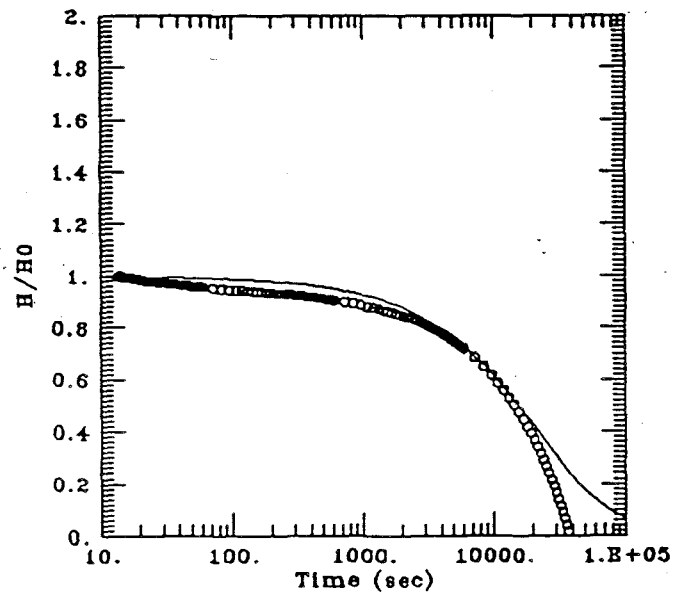
Location	Formation Completed	Screen Interval (feet bgs)	Hydrostratigraphic Unit	Date Completed
Wells in the Vicinity of the East Landfill Pond				
0786	Qc	3.00-5.74	UHSU	1986
0886	KaKlss(u)	59.08-63.79	LHSU	1986
B206789	KaKl(w)	9.80-19.28	UHSU	1989
B206889	KaKl(w)	8.00-17.45	UHSU	1989
Wells Downgradient 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 Laramie 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	lower hydrostratigraphic unit

Figure B-1
AQTESOLV Solution for Well 53094x

53094x



DATA SET:
53094x
01/06/93

AQUIFER TYPE:
Confined

SOLUTION METHOD:
Cooper et al.

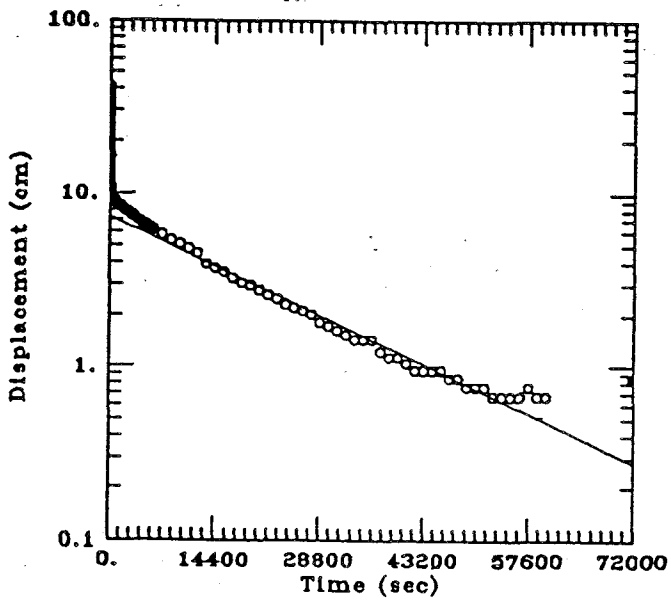
ESTIMATED PARAMETERS:
T = 0.0003287 cm^2/sec
S = 0.0001

TEST DATA:
H0 = 46.2 cm
rc = 2.54 cm
rw = 8.89 cm
b = 502.9 cm

K = T/b
K = 1.05×10^{-6} cm/sec

Figure B-2
AQTESOLV Solution for Well 53194

53194



DATA SET:
53194cm
01/08/95

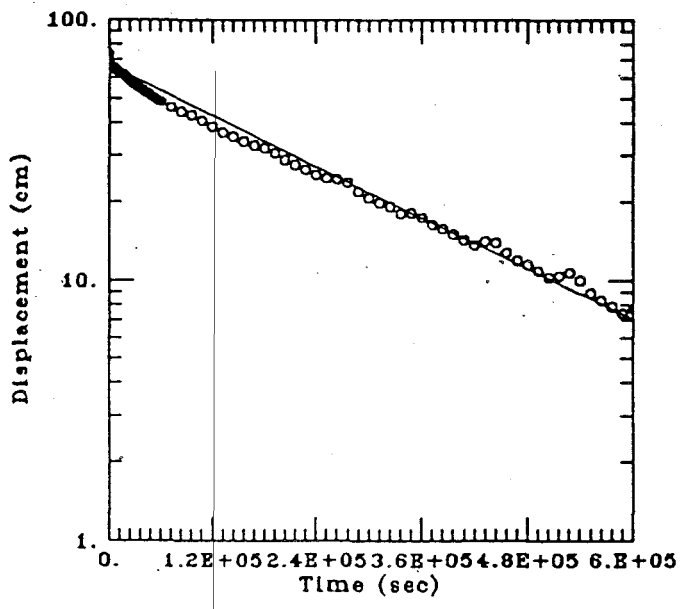
AQUIFER TYPE:
Unconfined
SOLUTION METHOD:
Bouwer-Rice

ESTIMATED PARAMETERS:
K = 2.1217E-05 cm/sec
y0 = 7.258 cm

TEST DATA:
H0 = 41.15 cm
rc = 5.882 cm
rw = 8.89 cm
L = 41.15 cm
b = 41.15 cm
H = 41.15 cm

Figure B-3
AQTESOLV Solution for Well B207089

B207089



DATA SET:
B207089
01/06/95

AQUIFER TYPE:
Unconfined
SOLUTION METHOD:
Bouwer-Rice

ESTIMATED PARAMETERS:
K = 5.4728E-08 cm/sec
y0 = 87.11 cm

TEST DATA:
H0 = 68.31 cm
rc = 2.54 cm
rw = 8.89 cm
L = 661.4 cm
b = 848.5 cm
H = 948.5 cm

Table of Contents

C.1. INTRODUCTION C-1

C.2. OBJECTIVES C-1

C.3. CONCEPTUAL MODEL C-1

C.4. MODEL SELECTION C-2

C.5. MODEL CONSTRUCTION C-2

C.5.1 SELECTION OF GRID EXTENT AND MODEL BOUNDARIES C-2

C.5.2 SELECTION OF GRID CELL SIZE C-3

C.5.3 TOPOGRAPHIC AND HYDRAULIC PARAMETER DATA C-3

C.6. CALIBRATION AND VERIFICATION C-3

C.6.1 CALIBRATION USING MARCH 1993 HEAD MEASUREMENTS C-4

C.6.2 VERIFICATION USING APRIL 1992 WELL HEAD MEASUREMENTS C-6

C.7. SENSITIVITY ANALYSIS C-6

C.8. PREDICTIVE SIMULATIONS C-7

C.8.1 WATER BALANCE CALCULATIONS FOR VARIOUS SCENARIOS C-7

C.8.2 PARTICLE TRACKING C-8

C.8.3 ESTIMATION OF FLOW TO SEEP AREA C-9

C.8.4 ESTIMATION OF TIME REQUIRED TO DEWATER LANDFILL MASS C-9

C.9. SUMMARY AND CONCLUSIONS C-10

C.10. REFERENCES C-10

C.11. SOFTWARE C-11

Tables

Table C-1 List of Model Boundaries for Layer 1

Table C-2 List of Model Boundaries for Layer 2

Table C-3 Model Parameters

Table C-4 CALSTATS Results for No-Action Scenario

Table C-5 Hydraulic Conductivity Values Corresponding to Hydraulic Conductivity Zones

Table C-6 CALSTATS Results for April 1992 Well Head Measurements

Table C-7 Summary of Flows for Three Scenarios

Table C-8 Cell-by-Cell Flows for the No-Action Scenario

Table C-9 Vertical Flows for the No-Action Scenario

Table C-10 Recharge for the No-Action Scenario

Table C-11 Water Balance for the No-Action Scenario

Table C-12 Cell-by-Cell Flows for the Cap-Only Scenario

Table C-13 Vertical Flows for the Cap-Only Scenario

Table C-14 Recharge for the Cap-Only Scenario

Table C-15 Water Balance for the Cap-Only Scenario

Table C-16 Cell-by-Cell Flows for the Cap and North Slurry Wall Scenario

Table C-17 Vertical Flows for the Cap and North Slurry Wall Scenario

Table C-18 Recharge for the Cap and North Slurry Wall Scenario

Table C-19 Water Balance for the Cap and North Slurry Wall Scenario

Figures

Figure C-1 Boundary Conditions for Layer 1

Figure C-2 Boundary Conditions for Layer 2

Figure C-3 Bottom Elevation of Layer 1

Figure C-4 Bottom Elevation of Layer 2

Figure C-5 Hydraulic Conductivity Distribution for Layer 1

Figure C-6 Hydraulic Conductivity Distribution for Layer 2

Figure C-7 Potentiometric Map of Surficial Material (March 1993)

Figure C-8 Saturated Thickness of Surficial Material (March 1993)

Figure C-9 Simulated Potentiometric Surface for the No-Action Scenario

Figure C-10 Water Balance for Landfill Mass

Figure C-11 MODFLOW Terminology for Flows Out of a Single Model Cell

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

Figure C-14 Comparison of Flows Out of East Boundary of Landfill Over Time

Figure C-15 Potentiometric Surface in Layer 1 at 0 Days for the Cap-Only Scenario

Figure C-16 Potentiometric Surface in Layer 1 at 1,000 Days for the Cap-Only Scenario

Figure C-17 Potentiometric Surface in Layer 1 at 2,000 Days for the Cap-Only Scenario

Figure C-18 Potentiometric Surface in Layer 1 at 3,000 Days for the Cap-Only Scenario

Figure C-19 Potentiometric Surface in Layer 1 at 4,000 Days for the Cap-Only Scenario

Figure C-20 Potentiometric Surface in Layer 1 at 5,000 Days for the Cap-Only Scenario

Figure C-21 Potentiometric Surface in Layer 1 at 6,000 Days for the Cap-Only Scenario

Figure C-22 Potentiometric Surface in Layer 1 at 7,000 Days for the Cap-Only Scenario

Figure C-23 Potentiometric Surface in Layer 1 at 8,000 Days for the Cap-Only Scenario

Figure C-24 Potentiometric Surface in Layer 1 at 9,000 Days for the Cap-Only Scenario

Figure C-25 Potentiometric Surface in Layer 1 at 10,000 Days for the Cap-Only Scenario

Figure C-26 Potentiometric Surface in Layer 1 at 0 Days for the Cap and North Slurry Wall Scenario

Figure C-27 Potentiometric Surface in Layer 1 at 1,000 Days for the Cap and North Slurry Wall Scenario

Figure C-28 Potentiometric Surface in Layer 1 at 2,000 Days for the Cap and North Slurry Wall Scenario

Figure C-29 Potentiometric Surface in Layer 1 at 3,000 Days for the Cap and North Slurry Wall Scenario

Figure C-30 Potentiometric Surface in Layer 1 at 4,000 Days for the Cap and North Slurry Wall Scenario

Figure C-31 Potentiometric Surface in Layer 1 at 5,000 Days for the Cap and North Slurry Wall Scenario

Figure C-32 Potentiometric Surface in Layer 1 at 6,000 Days for the Cap and North Slurry Wall Scenario

Figure C-33 Potentiometric Surface in Layer 1 at 7,000 Days for the Cap and North Slurry Wall Scenario

Figure C-34 Potentiometric Surface in Layer 1 at 8,000 Days for the Cap and North Slurry Wall Scenario

Figure C-35 Potentiometric Surface in Layer 1 at 9,000 Days for the Cap and North Slurry Wall Scenario

Figure C-36 Potentiometric Surface in Layer 1 at 10,000 Days for the Cap and North Slurry Wall Scenario

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 contaminants. 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 water-bearing data.

C.5.1 SELECTION OF GRID EXTENT AND MODEL BOUNDARIES

A model grid of 5,000 x 1,500 ft was selected. The selected area extends approximately 500 ft upgradient of the landfill mass to the west, 2,000 ft downgradient of the East Landfill Pond to the east, 200 ft south of the landfill to a groundwater divide, and 500 ft 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 were used to simulate the existing groundwater-intercept system. Drain cell elevations were set according to as-built drawings for the groundwater-intercept system. In some locations, these elevations are above the top of weathered bedrock, providing a potential pathway for groundwater flow. 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 drain 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 x 50 ft 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 geometric means of previous hydraulic conductivity measurements were used as initial values for hydraulic conductivity for the two layers. The range of measured 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-3.

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 collected 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 ft 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, 17 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-4.

The current model calibration uses recharge values ranging from 0.0002 ft/day (0.88 in./year) to 0.0004 ft/day (1.76 in./year). The larger of these two values is approximately 11 percent of the average annual precipitation at Rocky Flats. The values were 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 varied within the range of conductivities that had been exhibited for the layer in question. Hydraulic conductivity values for Layer 1 range from 0.042 to 7.2 ft/day, with 0.72 ft/day assigned to most cells. Most cells in Layer 2 are assigned a hydraulic conductivity value of 0.0022 ft/day, with certain cells assigned a value of 0.022 ft/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-5.

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, indicating a better calibration.

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-ft 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 ft. 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 may not be 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.

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 82 percent of the wells are simulated within plus or minus 3 ft. Three of 17 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 greater 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 assess 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-6.

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 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 3 ft) 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-7. For each scenario, outflow equals inflow. The model indicates 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 1.97 gallons per minute (gpm). Recharge or infiltration contributes approximately 1.19 gpm of that amount. Groundwater inflow contributes approximately 0.78 gpm. Outflow equals inflow.

2. Cap-Only Scenario. A single layer cap is simulated by reducing the recharge over the landfill mass by two orders of magnitude. Total flow into the landfill is 0.95 gpm. Recharge or infiltration contributes approximately 0.01 gpm of that amount. Groundwater inflow contributes approximately 0.94 gpm. Outflow equals inflow.

3. Cap and North Slurry Wall Scenario. This scenario assumes that the groundwater flow is altered by the addition of a 1 x 10E-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 0.38 gpm. Recharge or infiltration contributes approximately 0.01 gpm of that amount. Groundwater inflow contributes approximately 0.37 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-8). The flows across each segment of the boundary plane are tabulated in Table C-8 and presented in Figure C-10. The flowrates 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-9 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 flowrate of recharge is calculated using the recharge area and the recharge flux rate. (Table C-10).

5. A water balance is performed using the horizontal inflow, vertical inflow, recharge, and horizontal outflow (Table C-11).

6. Tables C-12 to C-15 provide detailed information on the water balance for the cap only alternative. Tables C-16 to C-19 provide detailed information on the water balance for the cap and north slurry wall 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 0.10 and retardation is set to 1.0. The speed of particle movement is extremely sensitive to the input values for effective porosity and retardation. The pathways taken by the particles are not affected by these values. Studies at Rocky Flats have produced an effective porosity value of approximately 0.10, which is an approximation of the specific yield for the subsurface media (Belcher 1995). By using a retardation factor of 1, the particle tracking velocities approximate the expected velocities for a tracer compound like chloride (i.e., they move at the same velocities as groundwater). Contaminants with a retardation factor greater than 1 will have expected velocities that equal the velocity of the tracer divided by the retardation factor (i.e., they move at velocities less than those of the groundwater).

The particle tracking illustrates the following points:

- Flows from the east end of the landfill converge 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 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.

- 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 2,000 days (over 5 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 5,000 days or over 13 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 467 ft^3/day, or 2.43 gpm. The flows into the one drain cell and the two constant head cells directly east of the drain cell total 328 ft^3/day, or 1.68 gpm. The drain cell could not lower the potentiometric surface down to the seep elevation (approximately 5,923 ft). 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 69 percent of the total flow to the pond and seep.

C.8.4 ESTIMATION OF TIME REQUIRED TO DEWATER LANDFILL MASS

Two simulations were run to evaluate the relative effectiveness of the cap alone and the cap and north slurry wall combined in dewatering the landfill mass. Low hydraulic conductivity cells were used to simulate the proposed north slurry wall, and recharge was set to 2E-06 ft/day (reduced by two orders of magnitude) over the landfill mass to simulate the proposed cap. A comparison of flows out of the landfill mass over the 10,000-day period for the no-action scenario, the cap-only scenario, and the cap and north slurry wall scenario are presented in Figure C-14. For the no-action scenario, the flow out of the landfill mass stays constant at 1.95 gpm. For the cap-only scenario, the flow out of the landfill decreases quickly and equilibrates at 0.97 gpm at 5,000 days. The flowrate remained steady after 5,000 days. This implies that equilibrium has been reached with the inflow to the landfill equaling the outflow. For the cap and north slurry wall scenario, the flow out of the landfill mass decreases more than the flow in the cap-only scenario and equilibrates at 0.39 gpm at 8,000 days. The potentiometric surfaces for Layer 1 for every 1,000 days of simulated time are presented in Figures C-15 through C-25 for the cap-only scenario and in Figures C-26 through C-36 for the cap and north slurry wall scenario. Areas of dewatering are shown by multiple potentiometric lines converging around an area. Figures C-15 and C-26 show

four areas of dewatering east of the dam at time zero in the simulation. Although no wells exist in the simulated dewatered areas, this is consistent with the observation that wells below the dam are often dry. For both the cap-only scenario and the cap and north slurry wall scenario, areas of dewatering appear by 3,000 days (Figures C-18 and C-29). At equilibrium, the areas of dewatering are more extensive for the cap and north slurry wall scenario (Figure C-36) than for the cap-only scenario (Figure C-25). In addition, the simulated saturated thickness at equilibrium (obtained by comparing the simulated potentiometric surface to layer bottom elevations) is approximately 4 ft for the cap and north slurry wall scenario and approximately 8 ft for the cap-only scenario. These saturated thicknesses are consistent with the simulated flow out of the landfill mass of 0.39 gpm for the cap and north slurry wall scenario and 0.97 gpm for the cap-only scenario.

Full dewatering of the landfill does not occur in either simulation. Two factors prevent full dewatering: (1) a small amount of horizontal and vertical 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 these simulations, 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 either the cap only or the cap and north slurry wall. The cap and north slurry wall combined are more effective in reducing the flow of contaminated water from the landfill, reducing the flowrate of clean water into the landfill mass, and reducing the saturated thickness within the landfill mass. The cap alone (without the slurry wall) would eliminate much of the seasonal variability of flows and would virtually eliminate vertical infiltration through waste above the water table. Both the cap and slurry wall and the cap alone should result in a decrease in contaminant loading to groundwater downgradient of the landfill.

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.

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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				
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
16	48	1	5920	NA
16	49	1	5920	NA
16	50	1	5920	NA
17	50	1	5920	NA
16	51	1	5920	NA
17	51	1	5920	NA
15	52	1	5920	NA
16	52	1	5920	NA
17	52	1	5920	NA
15	53	1	5920	NA
16	53	1	5920	NA
17	53	1	5920	NA
15	54	1	5920	NA
16	54	1	5920	NA
17	54	1	5920	NA
15	55	1	5920	NA
16	55	1	5920	NA
17	55	1	5920	NA
18	55	1	5920	NA
14	56	1	5920	NA
15	56	1	5920	NA
16	56	1	5920	NA
17	56	1	5920	NA
18	56	1	5920	NA
14	57	1	5920	NA
15	57	1	5920	NA
16	57	1	5920	NA
17	57	1	5920	NA
18	57	1	5920	NA
19	57	1	5920	NA
14	58	1	5920	NA
15	58	1	5920	NA

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
16	58	1	5920	NA
17	58	1	5920	NA
18	58	1	5920	NA
19	58	1	5920	NA
13	59	1	5920	NA
14	59	1	5920	NA
15	59	1	5920	NA
16	59	1	5920	NA
17	59	1	5920	NA
18	59	1	5920	NA
19	59	1	5920	NA
13	60	1	5920	NA
14	60	1	5920	NA
15	60	1	5920	NA
16	60	1	5920	NA
17	60	1	5920	NA
18	60	1	5920	NA
19	60	1	5920	NA
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
16	100	1	5827	NA
17	100	1	5825	NA
18	100	1	5825	NA
19	100	1	5825	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
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

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
		Drain Cells		
16	17	1	5972	1.68E+00
17	17	1	5972	1.68E+00
18	17	1	5973	1.68E+00
15	18	1	5970	1.68E+00
16	18	1	5971	1.68E+00
18	18	1	5971	1.68E+00
19	18	1	5971	1.68E+00
20	18	1	5966	1.68E+00
15	19	1	5970	1.68E+00
20	19	1	5964	1.68E+00
14	20	1	5970	1.68E+00
15	20	1	5970	1.68E+00
20	20	1	5964	1.68E+00
21	20	1	5964	1.68E+00
14	21	1	5970	1.68E+00
21	21	1	5964	1.68E+00
14	22	1	5970	1.68E+00
21	22	1	5964	1.68E+00
22	22	1	5964	1.68E+00
14	23	1	5969	1.68E+00
22	23	1	5964	1.68E+00
14	24	1	5969	1.68E+00
22	24	1	5964	1.68E+00
23	24	1	5964	1.68E+00
13	25	1	5968	1.68E+00
14	25	1	5968	1.68E+00
23	25	1	5962	1.68E+00
13	26	1	5968	1.68E+00
23	26	1	5962	1.68E+00
13	27	1	5968	1.68E+00
23	27	1	5962	1.68E+00
13	28	1	5967	1.68E+00
23	28	1	5962	1.68E+00
12	29	1	5967	1.68E+00
13	29	1	5967	1.68E+00
23	29	1	5962	1.68E+00
12	30	1	5966	1.68E+00
23	30	1	5964	1.68E+00
12	31	1	5966	1.68E+00
23	31	1	5962	1.68E+00
12	32	1	5965	1.68E+00
23	32	1	5962	1.68E+00
12	33	1	5964	1.68E+00
23	33	1	5962	1.68E+00
12	34	1	5963	1.68E+00
23	34	1	5960	1.68E+00
23	35	1	5960	1.68E+00
23	36	1	5960	1.68E+00
16	47	1	5922	5.00E+00

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
General Head Boundary Cells				
12	1	1	5990	1.00E+00
11	2	1	5989	1.00E+00
12	2	1	5990	1.00E+00
11	3	1	5989	1.00E+00
11	4	1	5989	1.00E+00
10	5	1	5988	1.00E+00
11	5	1	5989	1.00E+00
10	6	1	5988	1.00E+00
9	7	1	5988	1.00E+00
10	7	1	5988	1.00E+00
9	8	1	5987	1.00E+00
9	9	1	5987	1.00E+00
8	10	1	5987	1.00E+00
9	10	1	5987	1.00E+00
8	11	1	5986	1.00E+00
7	12	1	5986	1.00E+00
8	12	1	5986	1.00E+00
7	13	1	5985	1.00E+00
6	14	1	5980	1.00E+00
7	14	1	5985	1.00E+00
6	15	1	5980	1.00E+00
6	16	1	5979	1.00E+00
5	17	1	5979	1.00E+00
6	17	1	5979	1.00E+00
5	18	1	5979	1.00E+00
4	19	1	5978	1.00E+00
5	19	1	5978	1.00E+00
4	20	1	5978	1.00E+00
4	21	1	5977	1.00E+00
3	22	1	5980	1.00E+00
4	22	1	5977	1.00E+00
3	23	1	5980	1.00E+00
2	24	1	5979	1.00E+00
3	24	1	5979	1.00E+00
2	25	1	5979	1.00E+00
2	26	1	5978	1.00E+00
1	27	1	5978	1.00E+00
2	27	1	5978	1.00E+00
1	28	1	5978	1.00E+00
1	29	1	5977	1.00E+00
1	30	1	5976	1.00E+00
1	31	1	5976	1.00E+00
1	32	1	5975	1.00E+00
1	33	1	5974	1.00E+00
1	34	1	5973	1.00E+00
1	35	1	5971	1.00E+00
1	36	1	5970	1.00E+00
1	37	1	5969	1.00E+00
1	38	1	5968	1.00E+00

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
1	39	1	5967	1.00E+00
1	40	1	5966	1.00E+00
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	1.50E-01
1	57	1	5940	1.00E-01
2	57	1	5925	1.05E+00
1	58	1	5950	1.00E-01
3	58	1	5915	1.05E+00
1	59	1	5949	1.00E-01
3	59	1	5915	1.05E+00
1	60	1	5944	1.00E-01
4	60	1	5915	1.05E+00
1	61	1	5944	1.00E-01
4	61	1	5913	1.05E+00
1	62	1	5943	1.00E-01
4	62	1	5909	1.05E+00
16	62	1	5884	1.05E+00
1	63	1	5942	1.00E-01
4	63	1	5905	1.05E+00
16	63	1	5884	1.05E+00
1	64	1	5942	1.00E-01
5	64	1	5895	1.05E+00
16	64	1	5883	1.05E+00
1	65	1	5941	1 00E-01
5	65	1	5895	1.05E+00
16	65	1	5883	1.05E+00
1	66	1	5940	1.00E-01
6	66	1	5895	1.05E+00
16	66	1	5883	1.05E+00
1	67	1	5939	1.00E-01
7	67	1	5887	1.05E+00
16	67	1	5883	1.05E+00
1	68	1	5938	1.00E-01
8	68	1	5885	1.05E+00
16	68	1	5882	1.05E+00
1	69	1	5937	1.00E-01

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
9	69	1	5883	1.05E+00
16	69	1	5882	1.05E+00
1	70	1	5936	1.00E-01
9	70	1	5883	1.05E+00
16	70	1	5882	1.05E+00
1	71	1	5936	1.00E-01
10	71	1	5881	1.05E+00
16	71	1	5881	1.05E+00
1	72	1	5936	1.00E-01
11	72	1	5881	1.05E+00
12	72	1	5881	1.05E+00
16	72	1	5878	1.05E+00
1	73	1	5935	1.00E-01
13	73	1	5877	1.05E+00
16	73	1	5874	1.05E+00
1	74	1	5935	1.00E-01
14	74	1	5875	1.05E+00
15	74	1	5871	1.05E+00
16	74	1	5870	1.05E+00
1	75	1	5934	1.00E-01
16	75	1	5866	1.05E+00
1	76	1	5934	1.00E-01
16	76	1	5863	1.05E+00
1	77	1	5933	1.00E-01
16	77	1	5863	1.05E+00
1	78	1	5933	1.00E-01
16	78	1	5863	1.05E+00
1	79	1	5932	1.00E-01
16	79	1	5863	1.05E+00
1	80	1	5932	1.00E-01
16	80	1	5862	1.05E+00
1	81	1	5932	1.00E-01
16	81	1	5862	1.05E+00
1	82	1	5931	1.00E-01
16	82	1	5862	1.05E+00
1	83	1	5930	1.00E-01
16	83	1	5861	1.05E+00
1	84	1	5928	1.00E-01
16	84	1	5859	1.05E+00
1	85	1	5927	1.00E-01
16	85	1	5856	1.05E+00
1	86	1	5926	1.00E-01
16	86	1	5853	1.05E+00
1	87	1	5925	1.00E-01
16	87	1	5850	1.05E+00
1	88	1	5924	1.00E-01
16	88	1	5847	1.05E+00
1	89	1	5923	1.00E-01
16	89	1	5845	1.05E+00
1	90	1	5922	1.00E-01

Table C-1
List of Model Boundaries for Layer 1

Row	Column	Layer	Head	Conductance
16	90	1	5843	1.05E+00
1	91	1	5922	1.00E-01
16	91	1	5842	1.05E+00
1	92	1	5921	1.00E-01
16	92	1	5841	1.05E+00
1	93	1	5919	1.00E-01
16	93	1	5840	1.05E+00
1	94	1	5918	1.00E-01
16	94	1	5839	1.05E+00
1	95	1	5917	1.00E-01
16	95	1	5838	1.05E+00
1	96	1	5916	1.00E-01
16	96	1	5837	1.05E+00
1	97	1	5915	1.00E-01
16	97	1	5835	1.05E+00
1	98	1	5914	1.00E-01
16	98	1	5834	1.05E+00
1	99	1	5913	1.00E-01
16	99	1	5833	1.05E+00
1	100	1	5912	1.00E-01

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
Constant Head Cells				
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
16	50	2	5920	NA
15	51	2	5920	NA
16	51	2	5920	NA
17	51	2	5920	NA
15	52	2	5920	NA
16	52	2	5920	NA
17	52	2	5920	NA
15	53	2	5920	NA
16	53	2	5920	NA
17	53	2	5920	NA
15	54	2	5920	NA
16	54	2	5920	NA
17	54	2	5920	NA
15	55	2	5920	NA
16	55	2	5920	NA
17	55	2	5920	NA
15	56	2	5920	NA
16	56	2	5920	NA
17	56	2	5920	NA
18	56	2	5920	NA
14	57	2	5920	NA
15	57	2	5920	NA
16	57	2	5920	NA
17	57	2	5920	NA
18	57	2	5920	NA
19	57	2	5920	NA
14	58	2	5920	NA
15	58	2	5920	NA
16	58	2	5920	NA
17	58	2	5920	NA
18	58	2	5920	NA

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
19	58	2	5920	NA
14	59	2	5920	NA
15	59	2	5920	NA
16	59	2	5920	NA
17	59	2	5920	NA
18	59	2	5920	NA
19	59	2	5920	NA
14	60	2	5920	NA
15	60	2	5920	NA
16	60	2	5920	NA
17	60	2	5920	NA
18	60	2	5920	NA
19	60	2	5920	NA
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
General Head Boundary Cells				
11	1	2	5986	1.00E-01
10	2	2	5985	1.00E-01
11	2	2	5986	1.00E-01
10	3	2	5985	1.00E-01
10	4	2	5985	1.00E-01
9	5	2	5984	1.00E-01
10	5	2	5984	1.00E-01

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
9	6	2	5984	1.00E-01
8	7	2	5983	1.00E-01
9	7	2	5983	1.00E-01
8	8	2	5983	1.00E-01
8	9	2	5982	1.00E-01
7	10	2	5982	1.00E-01
8	10	2	5982	1.00E-01
7	11	2	5981	1.00E-01
6	12	2	5981	1.00E-01
7	12	2	5981	1.00E-01
6	13	2	5980	1.00E-01
6	14	2	5980	1.00E-01
5	15	2	5979	1.00E-01
6	15	2	5980	1.00E-01
5	16	2	5979	1.00E-01
5	17	2	5979	1.00E-01
4	18	2	5978	1.00E-01
5	18	2	5978	1.00E-01
4	19	2	5978	1.00E-01
3	20	2	5977	1.00E-01
4	20	2	5977	1.00E-01
3	21	2	5977	1.00E-01
3	22	2	5976	1.00E-01
2	23	2	5976	1.00E-01
3	23	2	5976	1.00E-01
2	24	2	5976	1.00E-01
2	25	2	5975	1.00E-01
1	26	2	5975	1.00E-01
2	26	2	5975	1.00E-01
1	27	2	5974	1.00E-01
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

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
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
2	57	2	5918	1.67E-02
1	58	2	5944	1.00E-01
3	58	2	5908	1.67E-02
1	59	2	5942	1.00E-01
3	59	2	5908	1.67E-02
1	60	2	5941	1.00E-01
4	60	2	5908	1.67E-02
1	61	2	5940	1.00E-01
4	61	2	5906	1.67E-02
1	62	2	5940	1.00E-01
4	62	2	5902	1.67E-02
16	62	2	5867	1.67E-02
1	63	2	5939	1.00E-01
4	63	2	5898	1.67E-02
16	63	2	5866	1.67E-02
1	64	2	5938	1.00E-01
5	64	2	5988	1.67E-02
16	64	2	5865	1.67E-02
1	65	2	5937	1.00E-01
6	65	2	5988	1.67E-02
16	65	2	5863	1.67E-02
1	66	2	5936	1.00E-01
6	66	2	5988	1.67E-02
16	66	2	5862	1.67E-02
1	67	2	5935	1.00E-01
7	67	2	5880	1.67E-02
16	67	2	5866	1.67E-02
1	68	2	5934	1.00E-01
8	68	2	5878	1.67E-02
16	68	2	5865	1.67E-02
1	69	2	5933	1.00E-01
9	69	2	5876	1.67E-02
16	69	2	5863	1.67E-02
1	70	2	5932	1.00E-01
9	70	2	5876	1.67E-02
16	70	2	5862	1.67E-02
1	71	2	5932	1.00E-01
10	71	2	5874	1.67E-02
16	71	2	5861	1.67E-02
1	72	2	5932	1.00E-01

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
11	72	2	5874	1.67E-02
12	72	2	5874	1.67E-02
16	72	2	5860	1.67E-02
1	73	2	5931	1.00E-01
13	73	2	5870	1.67E-02
16	73	2	5854	1.67E-02
1	74	2	5931	1.00E-01
14	74	2	5868	1.67E-02
15	74	2	5864	1.67E-02
16	74	2	5853	1.67E-02
1	75	2	5930	1.00E-01
16	75	2	5853	1.67E-02
1	76	2	5930	1.00E-01
16	76	2	5851	1.67E-02
1	77	2	5930	1.00E-01
16	77	2	5849	1.67E-02
1	78	2	5929	1.00E-01
16	78	2	5848	1.67E-02
1	79	2	5929	1.00E-01
16	79	2	5846	1.67E-02
1	80	2	5928	1.00E-01
16	80	2	5844	1.67E-02
1	81	2	5928	1.00E-01
16	81	2	5842	1.67E-02
1	82	2	5927	1.00E-01
16	82	2	5840	1.67E-02
1	83	2	5926	1.00E-01
16	83	2	5838	1.67E-02
1	84	2	5925	1.00E-01
16	84	2	5836	1.67E-02
1	85	2	5924	1.00E-01
16	85	2	5836	1.67E-02
1	86	2	5923	1.00E-01
16	86	2	5835	1.67E-02
1	87	2	5921	1.00E-01
16	87	2	5833	1.67E-02
1	88	2	5920	1.00E-01
16	88	2	5832	1.67E-02
1	89	2	5919	1.00E-01
16	89	2	5830	1.67E-02
1	90	2	5918	1.00E-01
16	90	2	5828	1.67E-02
1	91	2	5918	1.00E-01
16	91	2	5827	1.67E-02
1	92	2	5917	1.00E-01
16	92	2	5825	1.67E-02
1	93	2	5916	1.00E-01
16	93	2	5823	1.67E-02
1	94	2	5915	1.00E-01
16	94	2	5822	1.67E-02

Table C-2
List of Model Boundaries for Layer 2

Row	Column	Layer	Head	Conductance
1	95	2	5914	1.00E-01
16	95	2	5822	1.67E-02
1	96	2	5912	1.00E-01
16	96	2	5821	1.67E-02
1	97	2	5911	1.00E-01
16	97	2	5819	1.67E-02
1	98	2	5910	1.00E-01
16	98	2	5818	1.67E-02
1	99	2	5909	1.00E-01
16	99	2	5816	1.67E-02
1	100	2	5908	1.00E-01

Table C-3
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 1979
Effective Porosity	0.10	Telephone interview Wayne Belcher, EG&G Rocky Flats, May 11, 1995

Table C-4
CALSTATS Results for No-Action Scenario

Well Name	Target Head	Model Head	Residual
Layer 1			
1086	5984.28	5984.11	0.17
4087	5879.71	5885.93	-6.22
5887	5983.10	5981.75	1.35
6187	5972.48	5971.38	1.10
6487	5966.21	5967.94	-1.73
6687	5969.71	5968.44	1.27
6887	5960.25	5959.47	0.78
7187	5958.36	5954.67	3.69
70093	5978.48	5977.86	0.62
70393	5986.17	5985.97	0.20
70693	5972.53	5975.11	-2.58
71893	5970.36	5970.34	0.02
72293	5943.41	5943.73	-0.32
B206489	5965.20	5964.88	0.32
70193	5978.15	5977.86	0.29
71493	5970.14	5975.44	-5.30
72393	5971.03	5969.14	1.89
71193	5974.37	5975.60	-1.23

Summary Statistics for Entire Model

Residual Mean = -3.681604

Residual Standard Dev. = 6.984842

Residual Sum of Squares = 1620.897893

Absolute Residual Mean = 4.581294

Minimum Residual = -25.926758

Maximum Residual = 3.691055

Observed Range in Head = 126.170000

Res. Std. Dev./Range = 0.055361

Well Name	Target Head	Model Head	Residual
Layer 2			
70493	5965.66	5985.96	-20.30
B206189	5965.23	5966.89	-1.66
B206289	5953.07	5965.41	-12.34
B206589	5960.64	5962.24	-1.60
B206689	5941.46	5948.65	-7.19
B206789	5916.65	5925.54	-8.89
B206889	5900.12	5912.24	-12.12
B206989	5860.00	5885.93	-25.93

Statistics for Layer 1

Number of Targets = 17

Residual Mean = -0.351134

Residual Standard Dev. = 2.412037

Residual Sum of Squares = 101.000670

Absolute Residual Mean = 1.693227

Minimum Residual = -6.215293

Maximum Residual = 3.691055

Observed Range in Head = 106.460000

Res. Std. Dev./Range = 0.022657

Statistics for Layer 2

Res. Std. Dev./Range = 0.068420

Residual Mean = -9.972491

Residual Standard Dev. = 8.332280

Residual Sum of Squares = 1519.897223

Absolute Residual Mean = 10.036532

Minimum Residual = -25.926758

Maximum Residual = -0.288184

Observed Range in Head = 118.150000

Number of Targets = 9

Table C-5
Hydraulic Conductivity Values Corresponding to Hydraulic Conductivity Zones

Zone	K_x (ft/day)	K_y (ft/day)	K_z (ft/day)
1	7.2E-01	7.2E-01	7.2E-02
2	not used		
3	7.2E-01	7.2E-01	7.2E-02
4	4.2E-02	4.2E-02	4.2E-03
5	3.6E+00	3.6E+00	3.6E+00
6	7.2E-03	7.2E-03	7.2E-04
7	not used		
8	1.4E+00	1.4E+00	1.4E-01
9	not used		
10	7.2E-02	7.2E-02	7.2E-03
11	7.2E+00	7.2E+00	7.2E-01
12	4.7E-03	4.7E-03	4.7E-03

Table C-6
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	5965.23	5966.57	-9.14
B206289	5953.07	5965.25	-19.76
B206589	5960.64	5961.71	-0.18
B206689	5941.46	5948.64	-5.60
B206789	5916.65	5925.75	-15.06
B206889	5900.12	5912.24	-15.36
B206989	5860.00	5885.92	-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

Table C-7
Summary of Flows for Three Scenarios

Scenario	No Action		Cap Only		Cap and North Slurry Wall	
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		1.19		0.01		0.01
Horizontal Inflow (Individual segments directly below)		0.77		0.91		0.34
Inflow through or under North Slurry Wall	0.35		0.28		0.08	
Inflow through or under North Groundwater Intercept	0.43		0.54		0.13	
Inflow through or under West Groundwater Intercept	0.00		0.01		0.02	
Inflow through or under South Groundwater Intercept	-0.07		0.02		0.06	
Inflow through or under South Slurry Wall	0.06		0.05		0.05	
Vertical Inflow		0.02		0.04		0.03
Summary of Flows		1.97		0.95		0.38

Table C-8
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)
Cells on North, West, and South, from Northeast Corner going Counterclockwise										
North Slurry Wall										
1	9	48				2.1	1	2.1		
1	9	47				2.8	1	2.8		
1	9	46				3.3	1	3.3		
1	9	45				3.7	1	3.7		
1	9	44				4.2	1	4.2		
1	9	43				4.2	1	4.2		
1	9	42	-0.4	-1	0.4					
1	8	42				2.4	1	2.4		
1	8	41				5.2	1	5.2		
1	8	40				5.2	1	5.2		
1	8	39				5.5	1	5.5		
1	8	38				5.8	1	5.8		
1	8	37				6.7	1	6.7		
1	8	36				2.7	1	2.7		
1	9	35	2.8	1	2.8					
1	10	35	5.7	1	5.7					
1	11	35	4.4	1	4.4					
Summary (positive is into landfill) for north slurry wall					13.3			53.9	**67.12**	**0.35**

Table C-8
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	3.7	1	3.7					
1	13	35	21.9	1	21.9					
1	14	35	23.6	1	23.6	2.3	1	2.3		
1	14	34				4.1	1	4.1		
1	14	33				4.3	1	4.3		
1	14	32				3.7	1	3.7		
1	14	31				2.9	1	2.9		
1	14	30				2.0	1	2.0		
1	14	29				1.4	1	1.4		
1	14	28				1.1	1	1.1		
1	14	27				0.9	1	0.9		
1	14	26				0.2	1	0.2		
1	14	25				-1.5	1	-1.5		
1	15	24	5.3	1	5.3	-0.1	1	-0.1		
1	15	23				0.7	1	0.7		
1	15	22				2.4	1	2.4		
1	15	21				3.8	1	3.8		
Summary (positive is into landfill) for north intercept					54.6			28.3	**82.88**	**0.43**

Table C-8
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	0.6	1	0.6	0.7	1	0.7		
1	17	19	1.3	1	1.3					
1	18	19	0.4	1	0.4					
1	19	19	0.0	1	0.0					
1	19	20				2.2	-1	-2.2		
1	19	21				0.9	-1	-0.9		
1	20	21	-0.2	1	-0.2					
Summary (positive is into landfill) for west intercept					2.2			-2.4	**-0.29**	**0.00**

Table C-8
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				2.1	-1	-2.1		
1	20	23				0.9	-1	-0.9		
1	21	23	-0.1	1	-0.1					
1	21	24				1.6	-1	-1.6		
1	21	25				0.7	-1	-0.7		
1	22	25	0.0	1	0.0					
1	22	26				1.4	-1	-1.4		
1	22	27				1.5	-1	-1.5		
1	22	28				1.5	-1	-1.5		
1	22	29				1.3	-1	-1.3		
1	22	30				0.6	-1	-0.6		
1	22	31				1.0	-1	-1.0		
1	22	32				0.7	-1	-0.7		
1	22	33				0.4	-1	-0.4		
1	22	34				0.2	-1	-0.2		
1	22	35				-0.2	-1	0.2		
1	22	36				-1.0	-1	1.0		
1	23	36	-0.1	1	-0.1					
Summary (positive is into landfill) for south intercept					-0.2			-12.6	**-12.81**	**-0.07**

Table C-8
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				-0.9	-1	0.9		
1	23	38				-1.1	-1	1.1		
1	23	39				-1.2	-1	1.2		
1	23	40				-1.2	-1	1.2		
1	23	41				-0.7	-1	0.7		
1	23	42				-0.6	-1	0.6		
1	23	43				-0.5	-1	0.5		
1	23	44				-0.8	-1	0.8		
1	23	45				-0.7	-1	0.7		
1	23	46				-0.9	-1	0.9		
1	23	47				-1.1	-1	1.1		
1	23	48				-0.9	-1	0.9		
Summary (positive is into landfill) for south slurry wall					0.0			10.6	**10.59**	**0.06**
Total Flow into Landfill from North, West, South									**147.48**	**0.77**

Table C-8
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)
Cells on East Landfill Boundary										
1	10	48	-1.7	-1	1.7					
1	11	48	-0.5	-1	0.5					
1	12	48	0.1	-1	-0.1					
1	13	48	1.3	-1	-1.3					
1	14	48	1.3	-1	-1.3					
1	15	48	68.7	-1	-68.7					
1	16	48	0.0	-1	0.0					
1	17	48	93.8	-1	-93.8					
1	18	48	16.7	-1	-16.7					
1	19	48	5.4	-1	-5.4					
1	20	48	0.6	-1	-0.6					
1	21	48	0.0	-1	0.0					
	22	48	0.2	-1	-0.2					
1	23	48	0.5	-1	-0.5					
Drain Cell Flows										
1	16	47	-60.2	1	-60.2					
Constant Head Cell Flows										
1	16	48	-129.1	1	-129.1					
Summary (negative is flow out of landfill)					-375.6			0.0	**-375.58**	**-1.95**
	shaded cells define the boundary plane for the landfill mass.									

Table C-9
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	0.0
1	16-19	21	0.1
1	16-20	22	0.1
1	16-20	23	0.1
1	16-21	24	0.1
1	15-21	25	0.2
1	15-22	26	0.1
1	15-22	27	0.1
1	15-22	28	0.0
1	15-22	29	0.0
1	15-22	30	0.0
1	15-22	31	0.0
1	15-22	32	0.0
1	15-22	33	0.0
1	15-22	34	0.0
1	15-22	35	0.0
1	9-22	36	-0.7
1	9-23	37	-0.3
1	9-23	38	-0.2
1	9-23	39	-0.3
1	9-23	40	-0.4
1	9-23	41	-0.4
1	9-23	42	-0.2
1	10-23	43	-0.3
1	10-23	44	-0.5
1	10-23	45	-0.4
1	10-23	46	-0.5
1	10-23	47	-0.6
1	10-23	48	0.6
Summary (positive is flow out of landfill) (ft^3/day)			**-3.3**
Summary (positive is flow out of landfill) (gpm)			**0.0**

Table C-10
Recharge for the No-Action Scenario

Layer	Row	Columns		No. of Cells	No. of Dry Cells	No. of Cells with Recharge	Area of Recharge (ft^2)	Recharge Flux Rate (ft/day)	Recharge (ft^3/day)
		From	To						
1	9	36	42	7	0	7	17,500	4E-04	7.0
1	10	36	48	13	0	13	32,500	4E-04	13.0
1	11	36	40	5	0	5	12,500	4E-04	5.0
1	11	41	48	8	0	8	20,000	2E-04	4.0
1	12	36	40	5	0	5	12,500	4E-04	5.0
1	12	41	48	8	0	8	20,000	2E-04	4.0
1	13	36	40	5	0	5	12,500	4E-04	5.0
1	13	41	48	8	0	8	20,000	2E-04	4.0
1	14	36	40	5	0	5	12,500	4E-04	5.0
1	14	41	48	8	0	8	20,000	2E-04	4.0
1	15	25	40	16	0	16	40,000	4E-04	16.0
1	15	41	48	8	0	8	20,000	2E-04	4.0
1	16	21	40	20	0	20	50,000	4E-04	20.0
1	16	41	48	8	0	8	20,000	2E-04	4.0
1	17	20	40	21	0	21	52,500	4E-04	21.0
1	17	41	48	8	0	8	20,000	2E-04	4.0
1	18	20	40	21	0	21	52,500	4E-04	21.0
1	18	41	48	8	0	8	20,000	2E-04	4.0
1	19	20	40	21	0	21	52,500	4E-04	21.0
1	19	41	48	8	0	8	20,000	2E-04	4.0
1	20	22	40	19	0	19	47,500	4E-04	19.0
1	20	41	48	8	0	8	20,000	2E-04	4.0
1	21	24	48	25	0	25	62,500	2E-04	12.5
1	22	26	48	23	0	23	57,500	2E-04	11.5
1	23	37	48	12	0	12	30,000	2E-04	6.0
Totals					0	298	745,000		228.0
Recharge (ft^3/day)									**228.0**
Recharge (gpm)									**1.18**

Table C-11
Water Balance for the No-Action Scenario

Horizontal Flow In				
Total Flow into Landfill from North, West, South	147.5	ft^3/day	0.77	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	3.3	ft^3/day	0.02	gpm
Recharge into Landfill	228.0	ft^3/day	1.18	gpm
Flow In + Recharge	378.8	ft^3/day	1.97	gpm
Recharge as Percent of (Flow In + Recharge)	60.2	%		
Horizontal Flow In as Percent of (Flow In + Recharge)	38.9	%		
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	378.8	ft^3/day	1.97	gpm
Horizontal Flow Out of Landfill at East Boundary	-375.6	ft^3/day	-1.95	gpm
Percent Error	0.9	%	0.9	%

Table C-12
Cell-by-Cell Flows for the Cap-Only 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 North, West, and South, from Northeast Corner going Counterclockwise										
North Slurry Wall										
1	9	48				1.5	1	1.5		
1	9	47				2.0	1	2.0		
1	9	46				2.4	1	2.4		
1	9	45				2.7	1	2.7		
1	9	44				3.0	1	3.0		
1	9	43				3.0	1	3.0		
1	9	42	-0.5	-1	0.5					
1	8	42				2.1	1	2.1		
1	8	41				4.4	1	4.4		
1	8	40				4.4	1	4.4		
1	8	39				4.7	1	4.7		
1	8	38				5.1	1	5.1		
1	8	37				6.0	1	6.0		
1	8	36				2.5	1	2.5		
1	9	35	2.3	1	2.3					
1	10	35	4.5	1	4.5					
1	11	35	3.0	1	3.0					
Summary (positive is into landfill) for north slurry wall					10.4			43.7	**54.1**	**0.28**

Table C-12
Cell-by-Cell Flows for the Cap-Only 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	2.6	1	2.6					
1	13	35	16.0	1	16.0					
1	14	35	17.9	1	17.9	3.2	1	3.2		
1	14	34				5.1	1	5.1		
1	14	33				5.6	1	5.6		
1	14	32				5.2	1	5.2		
1	14	31				4.8	1	4.8		
1	14	30				4.1	1	4.1		
1	14	29				4.1	1	4.1		
1	14	28				3.6	1	3.6		
1	14	27				3.7	1	3.7		
1	14	26				3.1	1	3.1		
1	14	25				2.2	1	2.2		
1	15	24	4.8	1	4.8	2.4	1	2.4		
1	15	23				3.0	1	3.0		
1	15	22				5.3	1	5.3		
1	15	21				7.6	1	7.6		
Summary (positive is into landfill) for north intercept					41.3			63.0	**104.2**	**0.54**

Table C-12
Cell-by-Cell Flows for the Cap-Only 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	0.3	1	0.3	0.7	1	0.7		
1	17	19	0.9	1	0.9					
1	18	19	0.4	1	0.4					
1	19	19	0.2	1	0.2					
1	19	20				0.6	-1	-0.6		
1	19	21				0.2	-1	-0.2		
1	20	21	0.1	1	0.1					
Summary (positive is into landfill) for west intercept					2.0			0.0	**2.0**	**0.01**

Table C-12
Cell-by-Cell Flows for the Cap-Only 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				0.3	-1	-0.3		
1	20	23				0.1	-1	-0.1		
1	21	23	0.2	1	0.2					
1	21	24				0.1	-1	-0.1		
1	21	25				0.0	-1	0.0		
1	22	25	0.2	1	0.2					
1	22	26				0.0	-1	0.0		
1	22	27				0.1	-1	-0.1		
1	22	28				0.1	-1	-0.1		
1	22	29				0.0	-1	0.0		
1	22	30				0.0	-1	0.0		
1	22	31				-0.1	-1	0.1		
1	22	32				-0.2	-1	0.2		
1	22	33				-0.4	-1	0.4		
1	22	34				-0.7	-1	0.7		
1	22	35				-1.2	-1	1.2		
1	22	36				-1.9	-1	1.9		
1	23	36	0.2	1	0.2					
Summary (positive is into landfill) for south intercept					0.7			3.9	**4.6**	**0.02**

Table C-12
Cell-by-Cell Flows for the Cap-Only 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				-1.2	-1	1.2		
1	23	38				-1.0	-1	1.0		
1	23	39				-1.1	-1	1.1		
1	23	40				-1.2	-1	1.2		
1	23	41				-0.6	-1	0.6		
1	23	42				-0.6	-1	0.6		
1	23	43				-0.4	-1	0.4		
1	23	44				-0.8	-1	0.8		
1	23	45				-0.5	-1	0.5		
1	23	46				-0.8	-1	0.8		
1	23	47				-1.1	-1	1.1		
1	23	48				-0.9	-1	0.9		
Summary (positive is into landfill) for south slurry wall					0.0			10.2	**10.2**	**0.05**
Total Flow Into Landfill from North, West, South									**175.1**	**0.91**

Table C-12
Cell-by-Cell Flows for the Cap-Only 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	-2.1	-1	2.1					
1	11	48	-0.1	-1	0.1					
1	12	48	0.0	-1	0.0					
1	13	48	0.0	-1	0.0					
1	14	48		-1	0.0					
1	15	48	20.3	-1	-20.3					
1	16	48	47.6	-1	-47.6					
1	17	48	30.1	-1	-30.1					
1	18	48	4.2	-1	-4.2					
1	19	48	1.1	-1	-1.1					
1	20	48	0.4	-1	-0.4					
1	21	48	-0.1	-1	0.1					
	22	48	0.0	-1	0.0					
1	23	48	0.5	-1	-0.5					
General Head Boundary Flows										
1	16	47	-42.3	1	-42.3					
1	16	48	-41.5	1	-41.5					
Summary (negative is flow out of landfill)					-185.8			0	**-185.83**	**-0.97**
	shaded cells define the boundary plane for the landfill mass.									

Table C-13
Vertical Flows for the Cap-Only Scenario

All Landfill Cells, Lower Face, Flow Down into Layer 2			
Layer	Rows	Column	Lower Face Flow
1	17-19	20	-0.2
1	16-19	21	0.0
1	16-20	22	0.0
1	16-20	23	0.0
1	16-21	24	0.0
1	15-21	25	0.1
1	15-22	26	0.0
1	15-22	27	0.0
1	15-22	28	-0.1
1	15-22	29	-0.1
1	15-22	30	-0.1
1	15-22	31	0.0
1	15-22	32	0.0
1	15-22	33	0.0
1	15-22	34	-0.1
1	15-22	35	-0.1
1	9-22	36	-0.8
1	9-23	37	-0.4
1	9-23	38	-0.4
1	9-23	39	-0.5
1	9-23	40	-0.5
1	9-23	41	-0.4
1	9-23	42	-0.4
1	10-23	43	-0.4
1	10-23	44	-0.6
1	10-23	45	-0.4
1	10-23	46	-0.7
1	10-23	47	-0.4
1	10-23	48	-0.6
Summary (positive is flow out of landfill) (ft^3/day)			**-6.9**
Summary (positive is flow out of landfill) (gpm)			**-0.04**

Table C-14
Recharge for the Cap-Only Scenario

Layer	Row	Columns		No. of Cells	No. of Dry Cells	No. of Cells with Recharge	Area of Recharge (ft^2)	Recharge Flux Rate (ft/day)	Recharge (ft^3/day)
		From	To						
1	9	36	42	7	0	7	17,500	2E-06	0.0
1	10	36	48	13	0	13	32,500	2E-06	0.1
1	11	36	40	5	0	5	12,500	2E-06	0.0
1	11	41	48	8	0	8	20,000	2E-06	0.0
1	12	36	40	5	0	5	12,500	2E-06	0.0
1	12	41	48	8	3	5	12,500	2E-06	0.0
1	13	36	40	5	0	5	12,500	2E-06	0.0
1	13	41	48	8	1	7	17,500	2E-06	0.0
1	14	36	40	5	0	5	12,500	2E-06	0.0
1	14	41	48	8	0	8	20,000	2E-06	0.0
1	15	25	40	16	0	16	40,000	2E-06	0.1
1	15	41	48	8	0	8	20,000	2E-06	0.0
1	16	21	40	20	0	20	50,000	2E-06	0.1
1	16	41	48	8	0	8	20,000	2E-06	0.0
1	17	20	40	21	0	21	52,500	2E-06	0.1
1	17	41	48	8	1	7	17,500	2E-06	0.0
1	18	20	40	21	0	21	52,500	2E-06	0.1
1	18	41	48	8	0	8	20,000	2E-06	0.0
1	19	20	40	21	0	21	52,500	2E-06	0.1
1	19	41	48	8	0	8	20,000	2E-06	0.0
1	20	22	40	19	0	19	47,500	2E-06	0.1
1	20	41	48	8	0	8	20,000	2E-06	0.0
1	21	24	48	25	0	25	62,500	2E-06	0.1
1	22	26	48	23	0	23	57,500	2E-06	0.1
1	23	37	48	12	0	12	30,000	2E-06	0.1
Totals					5	293	732,500		1.5
Recharge (ft^3/day)									**1.5**
Recharge (gpm)									**0.01**

Table C-15
Water Balance for the Cap-Only Scenario

Horizontal Flow In				
Total Flow into Landfill from North, West, South	175.1	ft^3/day	0.91	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	6.9	ft^3/day	0.04	gpm
Recharge into Landfill	1.5	ft^3/day	0.01	gpm
Flow In + Recharge	183.5	ft^3/day	0.95	gpm
Recharge as Percent of (Flow In + Recharge)	0.8	%		
Horizontal Flow In as Percent of (Flow In + Recharge)	95.4	%		
Vertical Flow In as Percent of (Flow In + Recharge)	3.8	%		
Summary of Flows In (percent)	100.0	%		
Water Balance: Compare Inflow and Outflow				
Flow In + Recharge	183.5	ft^3/day	0.95	gpm
Horizontal Flow Out of Landfill at East Boundary	-185.8	ft^3/day	-0.97	gpm
Percent Error	1.3	%	1.3	%

Table C-16
Cell-by-Cell Flows for the Cap and 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)
Cells on North, West, and South, from Northeast Corner going Counterclockwise										
North Slurry Wall										
1	9	48				0.8	1	0.8		
1	9	47				0.7	1	0.7		
1	9	46				0.6	1	0.6		
1	9	45				0.6	1	0.6		
1	9	44				0.7	1	0.7		
1	9	43				0.6	1	0.6		
1	9	42	0.0	-1	0.0					
1	8	42				0.7	1	0.7		
1	8	41				1.2	1	1.2		
1	8	40				1.0	1	1.0		
1	8	39				1.1	1	1.1		
1	8	38				1.2	1	1.2		
1	8	37				1.8	1	1.8		
1	8	36				0.9	1	0.9		
1	9	35	1.0	1	1.0					
1	10	35	1.3	1	1.3					
1	11	35	0.6	1	0.6					
Summary (positive is into landfill) for north slurry wall					2.8			11.9	**14.7**	**0.08**

Table C-16
Cell-by-Cell Flows for the Cap and 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)
North Groundwater Intercept										
1	12	35	0.5	1	0.5					
1	13	35	3.0	1	3.0					
1	14	35	6.2	1	6.2	0.7	1	0.7		
1	14	34				1.2	1	1.2		
1	14	33				1.4	1	1.4		
1	14	32				1.1	1	1.1		
1	14	31				0.9	1	0.9		
1	14	30				0.4	1	0.4		
1	14	29				0.7	1	0.7		
1	14	28				0.7	1	0.7		
1	14	27				0.9	1	0.9		
1	14	26				0.6	1	0.6		
1	14	25				0.4	1	0.4		
1	15	24	2.1	1	2.1	0.2	1	0.2		
1	15	23				0.6	1	0.6		
1	15	22				1.8	1	1.8		
1	15	21				1.2	1	1.2		
Summary (positive is into landfill) for north intercept					11.8			12.8	**24.6**	**0.13**

Table C-16
Cell-by-Cell Flows for the Cap and 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	0.2	1	0.2	0.2	1	0.2		
1	17	19	0.4	1	0.4					
1	18	19	0.5	1	0.5					
1	19	19	0.4	1	0.4					
1	19	20				-0.8	-1	0.8		
1	19	21				-0.6	-1	0.6		
1	20	21	0.6	1	0.6					
Summary (positive is into landfill) for west intercept					2.1			1.5	**3.6**	**0.02**

Table C-16
Cell-by-Cell Flows for the Cap and 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 Groundwater Intercept										
1	20	22				-1.1	-1	1.1		
1	20	23				-0.7	-1	0.7		
1	21	23	0.5	1	0.5					
1	21	24				-1.0	-1	1.0		
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				-0.5	-1	0.5		
1	22	29				-0.5	-1	0.5		
1	22	30				0.0	-1	0.0		
1	22	31				-0.3	-1	0.3		
1	22	32				-0.3	-1	0.3		
1	22	33				-0.6	-1	0.6		
1	22	34				-0.8	-1	0.8		
1	22	35				-1.3	-1	1.3		
1	22	36				-2.0	-1	2.0		
1	23	36	0.2	1	0.2					
Summary (positive is into landfill) for south intercept					1.2			11.0	**12.2**	**0.06**

Table C-16
Cell-by-Cell Flows for the Cap and 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				-1.2	-1	1.2		
1	23	38				-1.0	-1	1.0		
1	23	39				-1.1	-1	1.1		
1	23	40				-1.2	-1	1.2		
1	23	41				-0.6	-1	0.6		
1	23	42				-0.6	-1	0.6		
1	23	43				-0.4	-1	0.4		
1	23	44				-0.8	-1	0.8		
1	23	45				-0.5	-1	0.5		
1	23	46				-0.8	-1	0.8		
1	23	47				-1.1	-1	1.1		
1	23	48				-0.9	-1	0.9		
Summary (positive is into landfill) for south slurry wall					0.0			10.2	**10.2**	**0.05**
Total Flow into Landfill from North, West, South									**65.3**	**0.34**

Table C-16
Cell-by-Cell Flows for the Cap and 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)
Cells on East Landfill Boundary										
1	10	48	-2.9	-1	2.9					
1	11	48	-0.6	-1	0.6					
1	12	48	0.0	-1	0.0					
1	13	48	0.0	-1	0.0					
1	14	48	0.0	-1	0.0					
1	15	48	0.8	-1	-0.8					
1	16	48	21.7	-1	-21.7					
1	17	48	7.1	-1	-7.1					
1	18	48	0.5	-1	-0.5					
1	19	48	2.0	-1	-2.0					
1	20	48	0.2	-1	-0.2					
1	21	48	-0.1	-1	0.1					
	22	48	0.0	-1	0.0					
1	23	48	0.5	-1	-0.5					
General Head Boundary Flows										
1	16	47	-23.7	1	-23.7					
1	16	48	-22.0	1	-22.0					
Summary (negative is flow out of landfill)					-75.0			0	**-74.96**	**-0.39**
	shaded cells define the boundary plane for the landfill mass.									

Table C-17
Vertical Flows for the Cap and North Slurry Wall Scenario

All Landfill Cells, Lower Face, Flow Down into Layer 2			
Layer	Rows	Column	Lower Face Flow
1	17-19	20	-0.2
1	16-19	21	-0.1
1	16-20	22	-0.1
1	16-20	23	0.0
1	16-21	24	0.0
1	15-21	25	0.0
1	15-22	26	0.0
1	15-22	27	0.0
1	15-22	28	-0.1
1	15-22	29	-0.1
1	15-22	30	-0.1
1	15-22	31	-0.1
1	15-22	32	0.0
1	15-22	33	0.0
1	15-22	34	-0.1
1	15-22	35	-0.1
1	9-22	36	-0.5
1	9-23	37	-0.2
1	9-23	38	-0.3
1	9-23	39	-0.5
1	9-23	40	-0.6
1	9-23	41	-0.4
1	9-23	42	-0.1
1	10-23	43	-0.3
1	10-23	44	-0.4
1	10-23	45	-0.5
1	10-23	46	-0.7
1	10-23	47	-0.1
1	10-23	48	-0.6
Summary (positive is flow out of landfill) (ft^3/day)			**-6.5**
Summary (positive is flow out of landfill) (gpm)			**-0.03**

Table C-18
Recharge for the Cap and North Slurry Wall Scenario

Layer	Row	Columns From	To	No. of Cells	No. of Dry Cells	No. of Cells with Recharge	Area of Recharge (ft^2)	Recharge Flux Rate (ft/day)	Recharge (ft^3/day)
1	9	36	42	7	0	7	17,500	2E-06	0.0
1	10	36	48	13	0	13	32,500	2E-06	0.1
1	11	36	40	5	0	5	12,500	2E-06	0.0
1	11	41	48	8	0	8	20,000	2E-06	0.0
1	12	36	40	5	0	5	12,500	2E-06	0.0
1	12	41	48	8	2	6	15,000	2E-06	0.0
1	13	36	40	5	0	5	12,500	2E-06	0.0
1	13	41	48	8	3	5	12,500	2E-06	0.0
1	14	36	40	5	0	5	12,500	2E-06	0.0
1	14	41	48	8	1	7	17,500	2E-06	0.0
1	15	25	40	16	0	16	40,000	2E-06	0.1
1	15	41	48	8	0	8	20,000	2E-06	0.0
1	16	21	40	20	0	20	50,000	2E-06	0.1
1	16	41	48	8	0	8	20,000	2E-06	0.0
1	17	20	40	21	0	21	52,500	2E-06	0.1
1	17	41	48	8	1	7	17,500	2E-06	0.0
1	18	20	40	21	0	21	52,500	2E-06	0.1
1	18	41	48	8	1	7	17,500	2E-06	0.0
1	19	20	40	21	0	21	52,500	2E-06	0.1
1	19	41	48	8	0	8	20,000	2E-06	0.0
1	20	22	40	19	0	19	47,500	2E-06	0.1
1	20	41	48	8	1	7	17,500	2E-06	0.0
1	21	24	48	25	0	25	62,500	2E-06	0.1
1	22	26	48	23	0	23	57,500	2E-06	0.1
1	23	37	48	12	0	12	30,000	2E-06	0.1
Totals					9	289	722,500		1.4
Recharge (ft^3/day)									**1.4**
Recharge (gpm)									**0.01**

Table C-19
Water Balance for the Cap and North Slurry Wall Scenario

Horizontal Flow In				
Total Flow into Landfill from North, West, South	65.3	ft^3/day	0.34	gpm
Vertical Flow In				
Flow into Landfill through Bottom Cell Faces	6.5	ft^3/day	0.03	gpm
Recharge into Landfill	1.4	ft^3/day	0.01	gpm
Flow In + Recharge	73.3	ft^3/day	0.38	gpm
Recharge as Percent of (Flow In + Recharge)	2.0	%		
Horizontal Flow In as Percent of (Flow In + Recharge)	89.1	%		
Vertical Flow In as Percent of (Flow In + Recharge)	8.9	%		
Summary of Flows In (percent)	100.0	%		
Water Balance: Compare Inflow and Outflow				
Flow In + Recharge	73.3	ft^3/day	0.38	gpm
Horizontal Flow Out of Landfill at East Boundary	-75.0	ft^3/day	-0.39	gpm
Percent Error	2.3	%	2.3	%

Figure C–1

Boundary Conditions for Layer 1

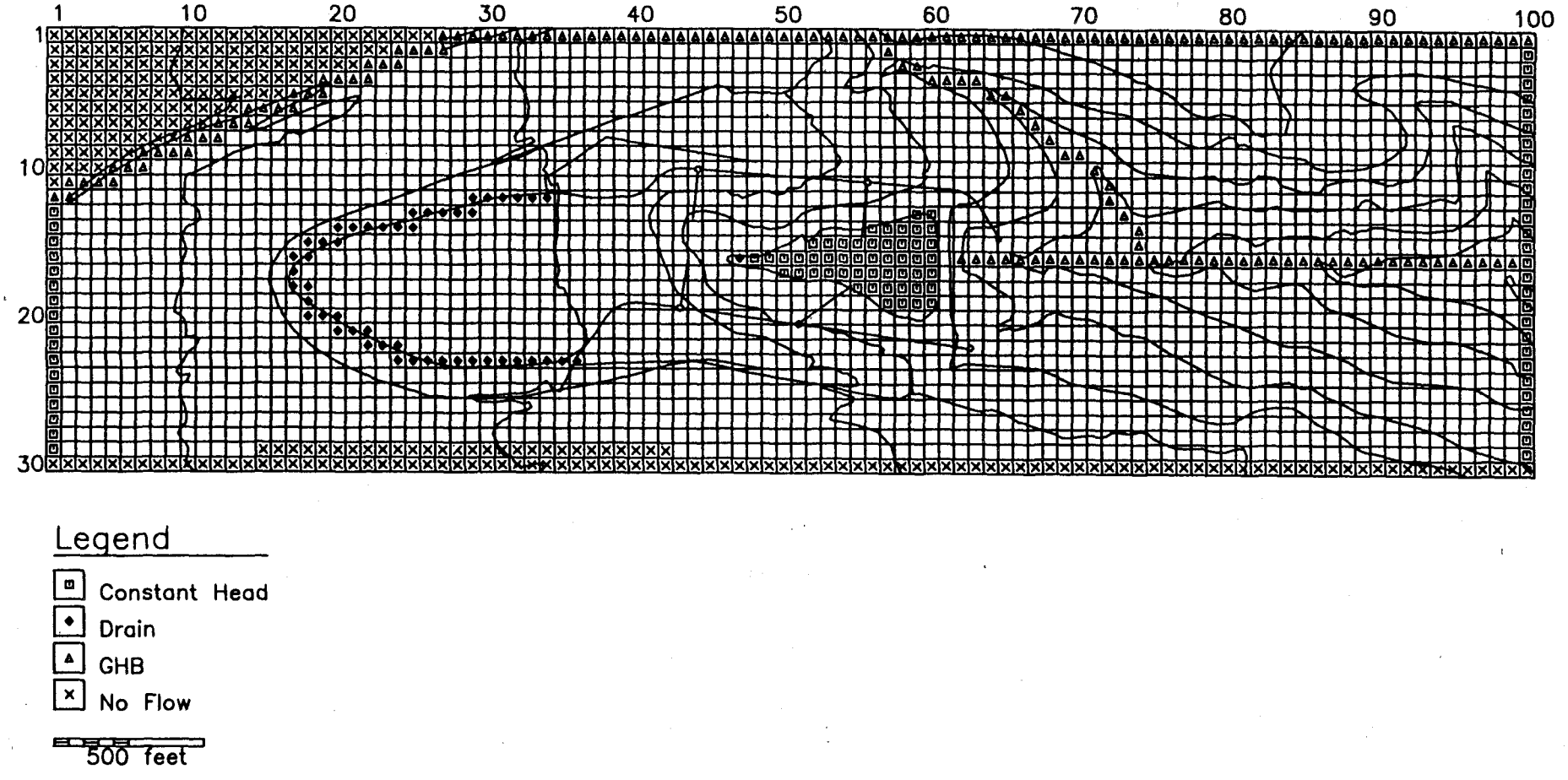
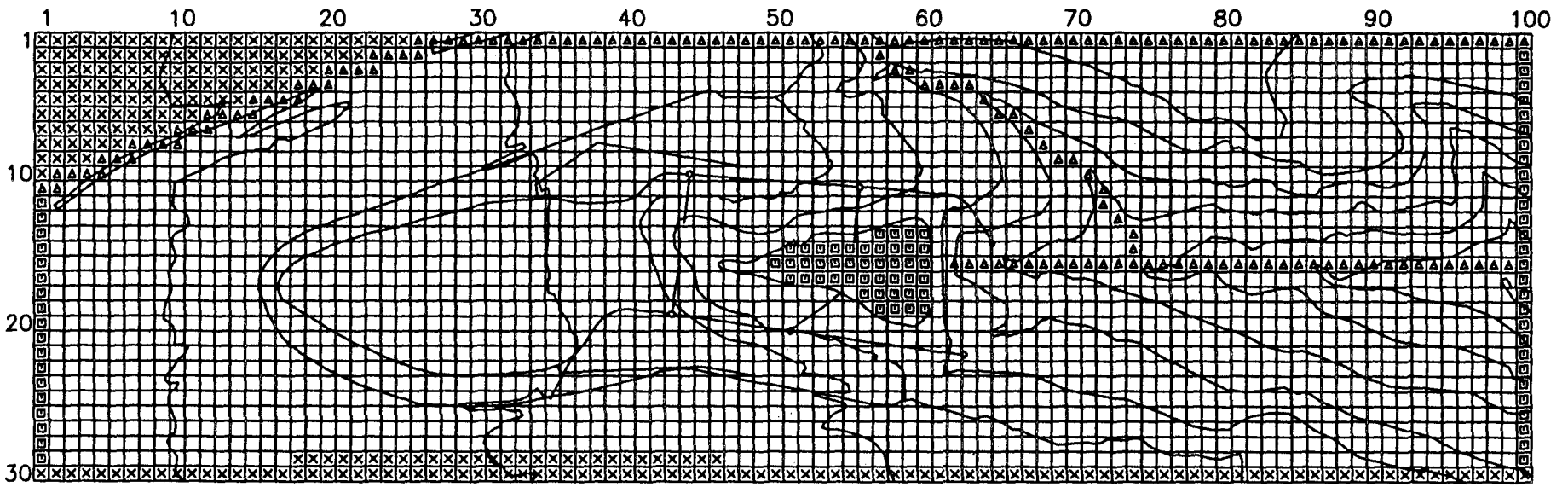


Figure C–2

Boundary Conditions for Layer 2



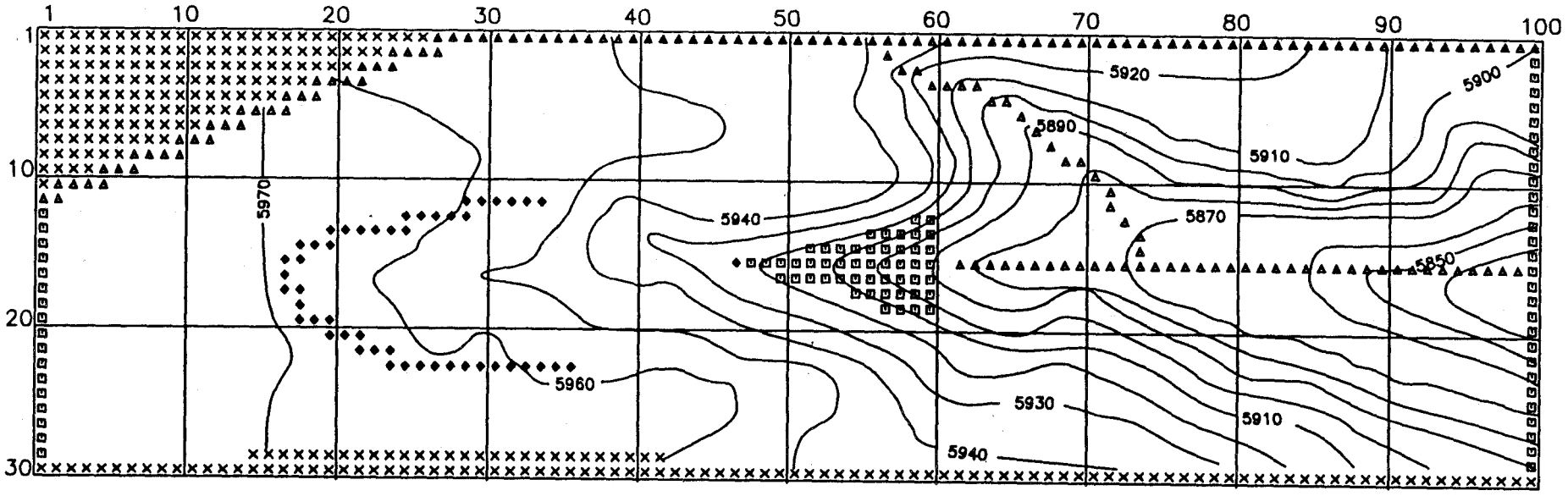
Legend

- Constant Head
- GHB
- No Flow

500 feet

Figure C-3

Bottom Elevation of Layer 1



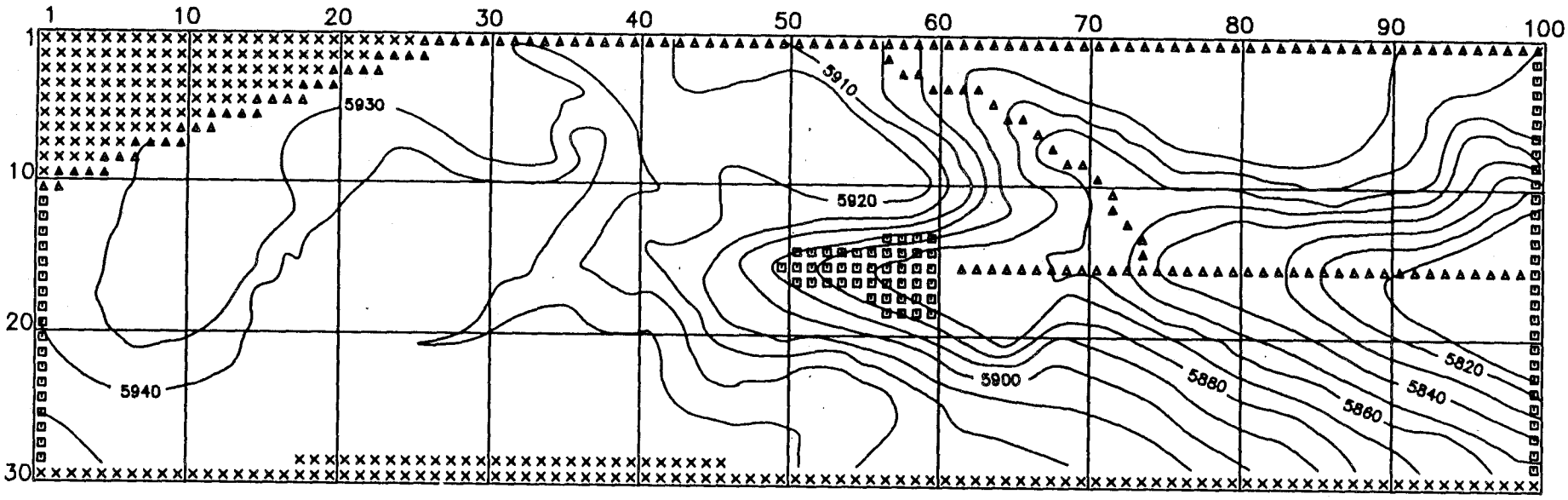
Legend

- Constant Head
- Drain
- GHB
- No Flow

500 feet

Figure C-4

Bottom Elevation of Layer 2



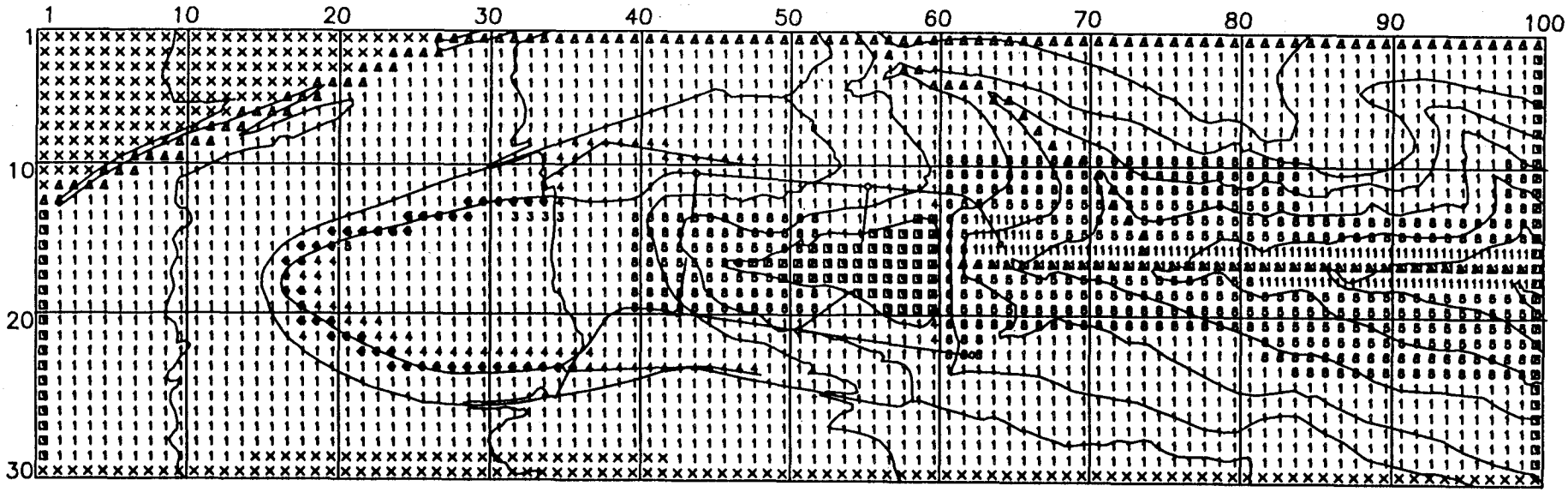
Legend

- Constant Head
- GHB
- No Flow

500 feet

Figure C-5

Hydraulic Conductivity Distribution for Layer 1



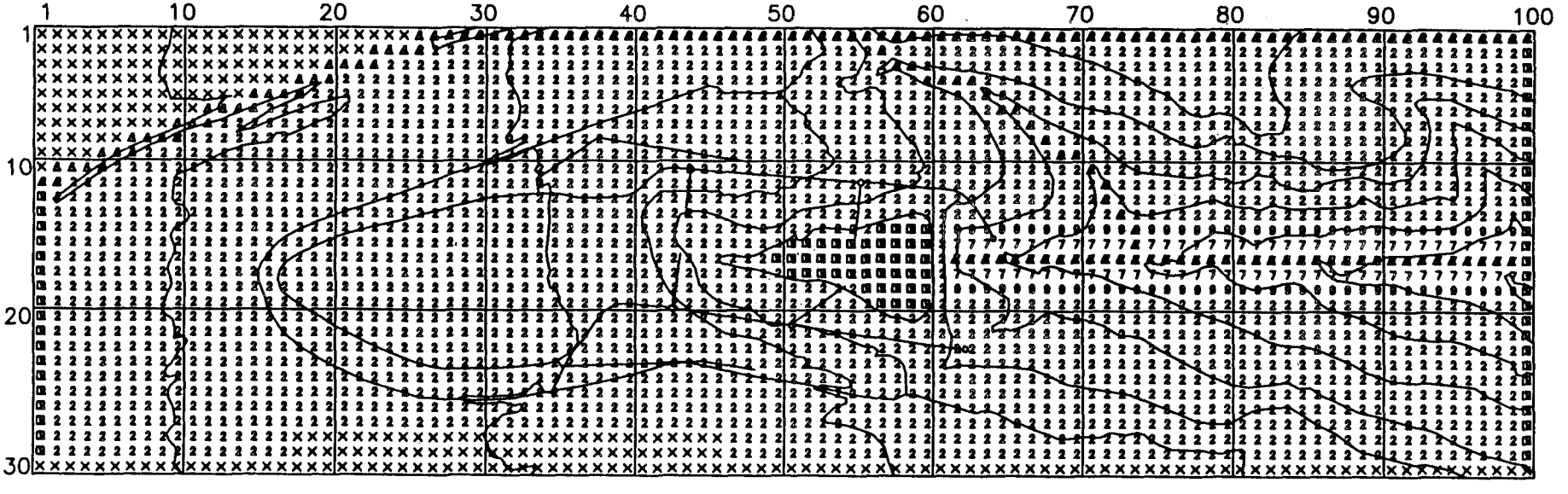
Legend

- Constant Head
- Drain
- GHB
- No Flow
- Transmissivity/K Zones

500 feet

Figure C–6

Hydraulic Conductivity Distribution for Layer 2



Legend

- Constant Head
- GHB
- No Flow
- Transmissivity/K Zones

500 feet

Figure C-9

Simulated Potentiometric Surface for the No-Action Scenario

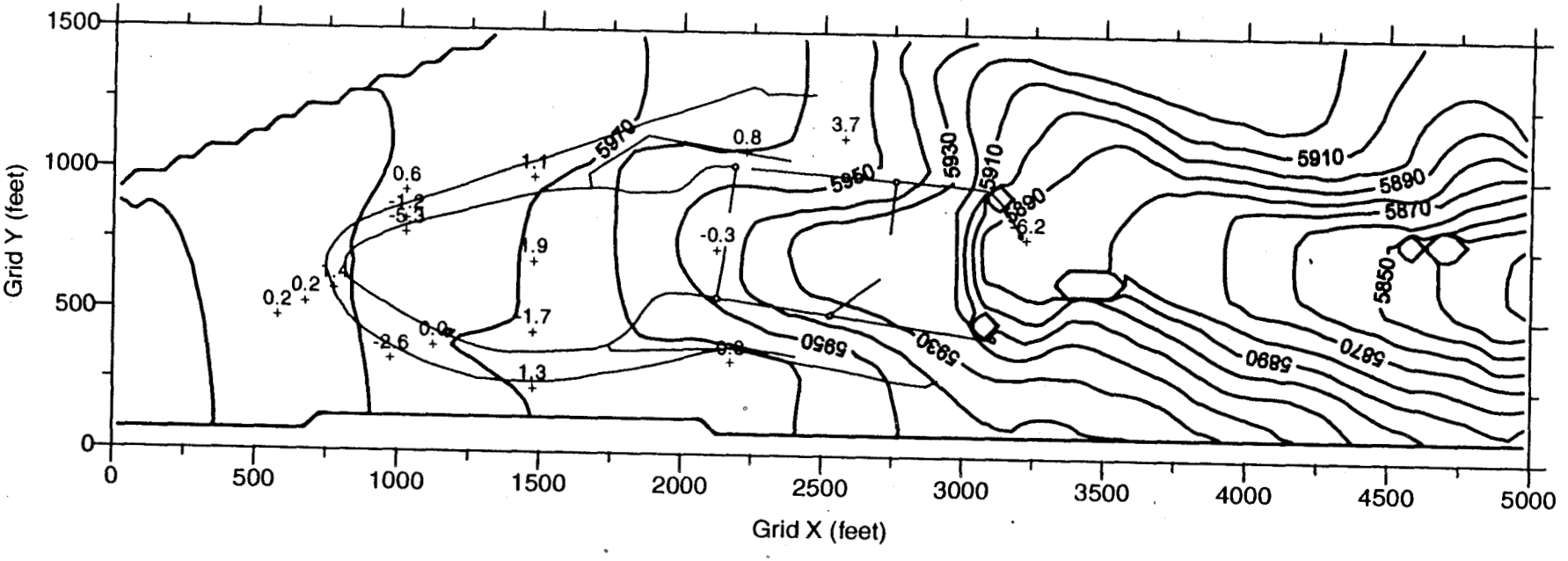


Figure C-11. MODFLOW Terminology for Flows Out of a Single Model Cell

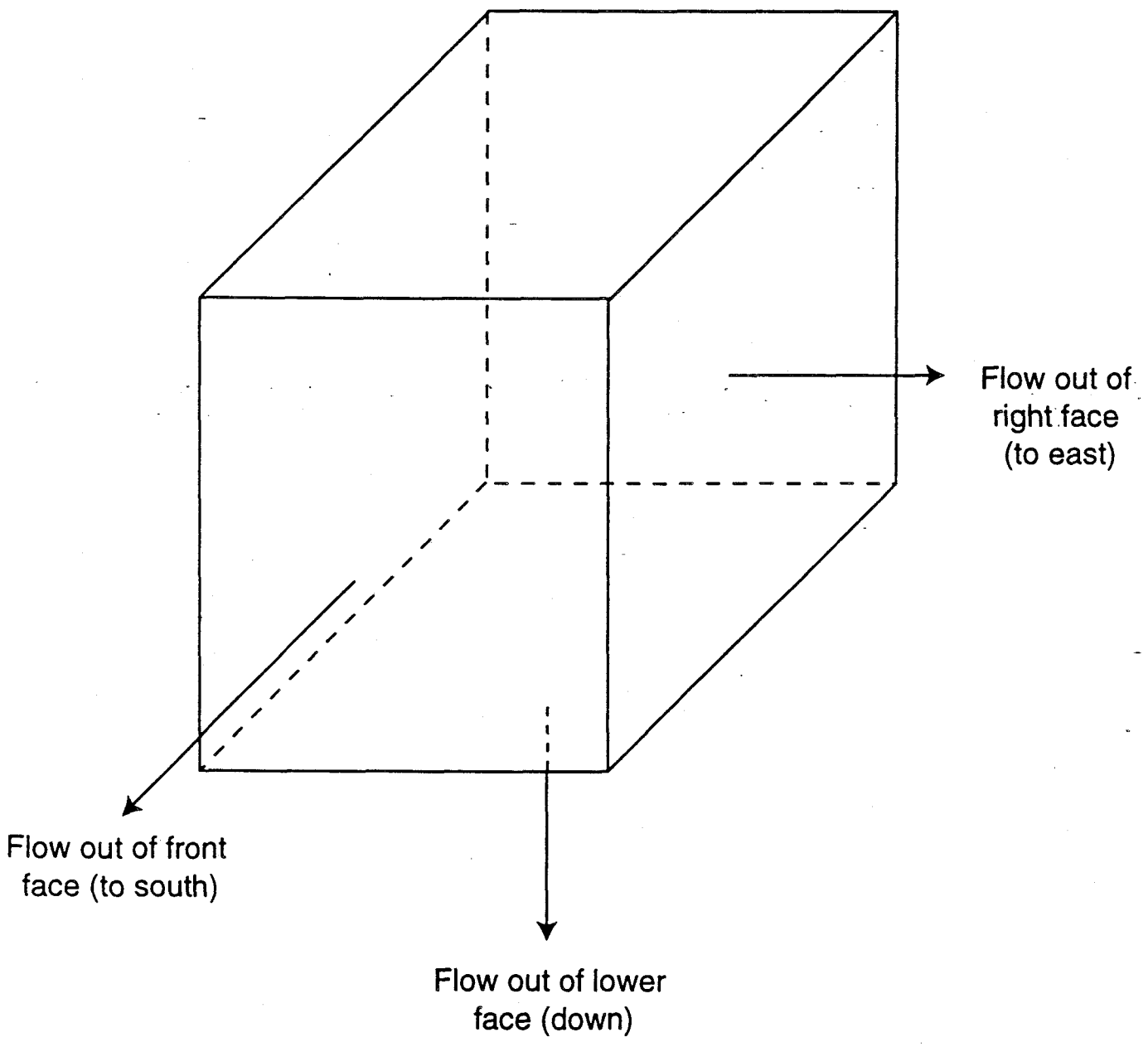


Figure C-12

Particle Tracking in Layer 1 for the No-Action Scenario

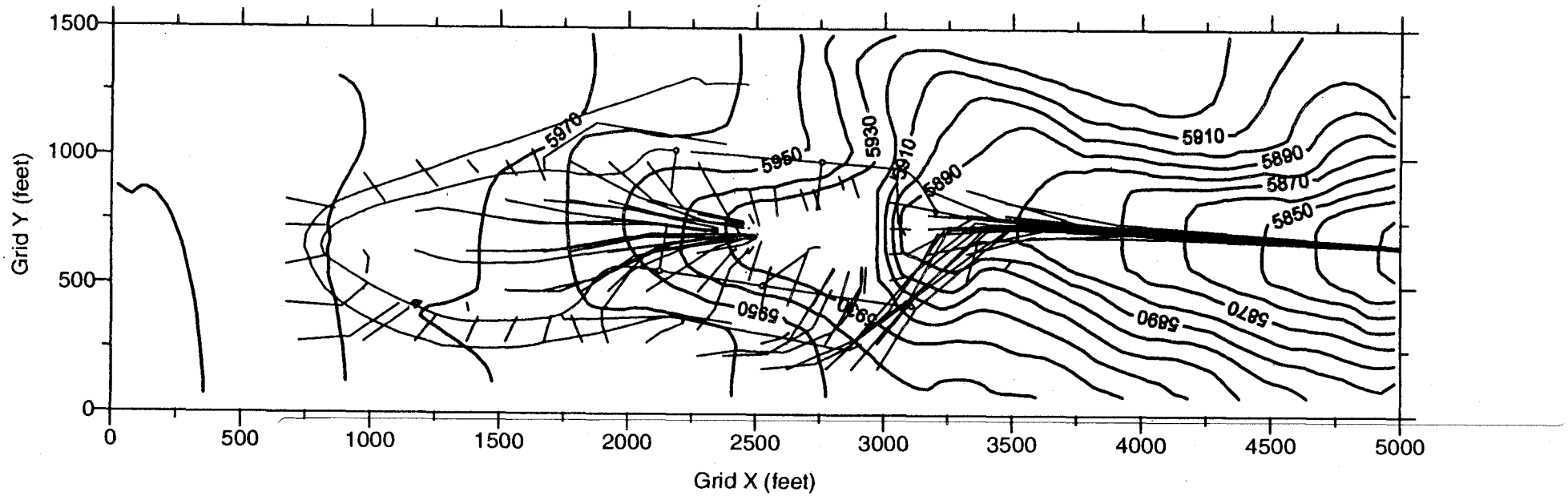


Figure C-13

Particle Tracking in Layer 2 for the No-Action Scenario

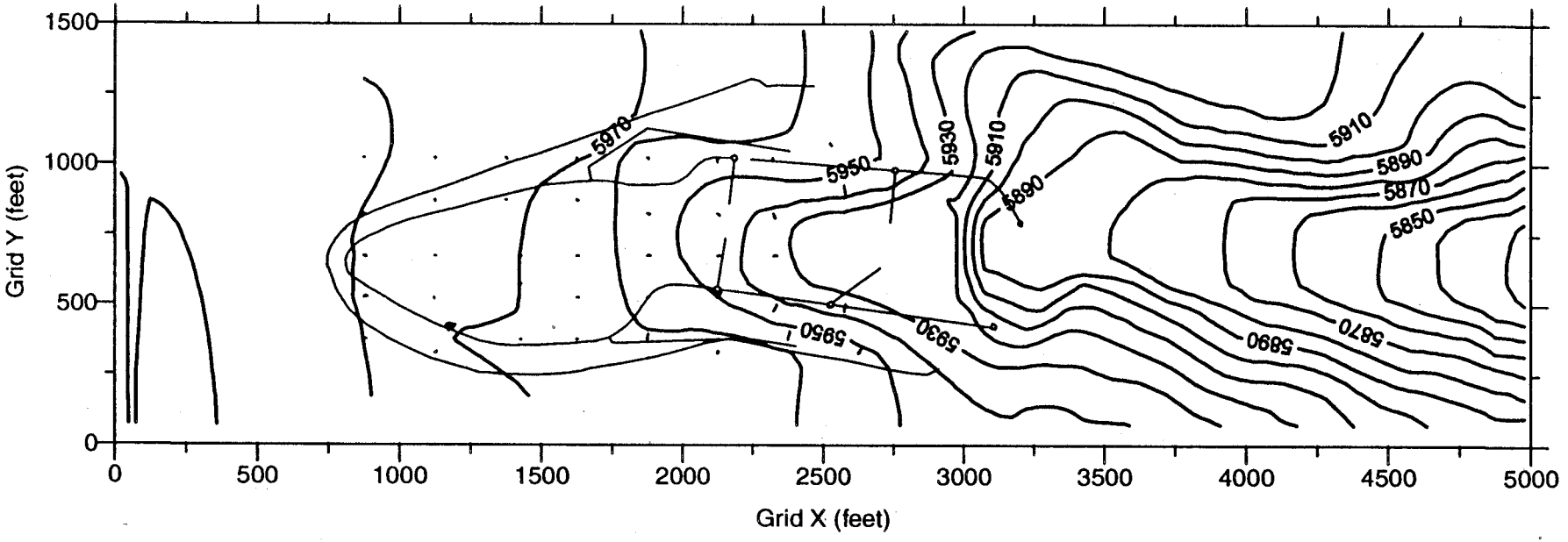


Figure C-14
Comparison of Flows Out of East Boundary of Landfill Over Time

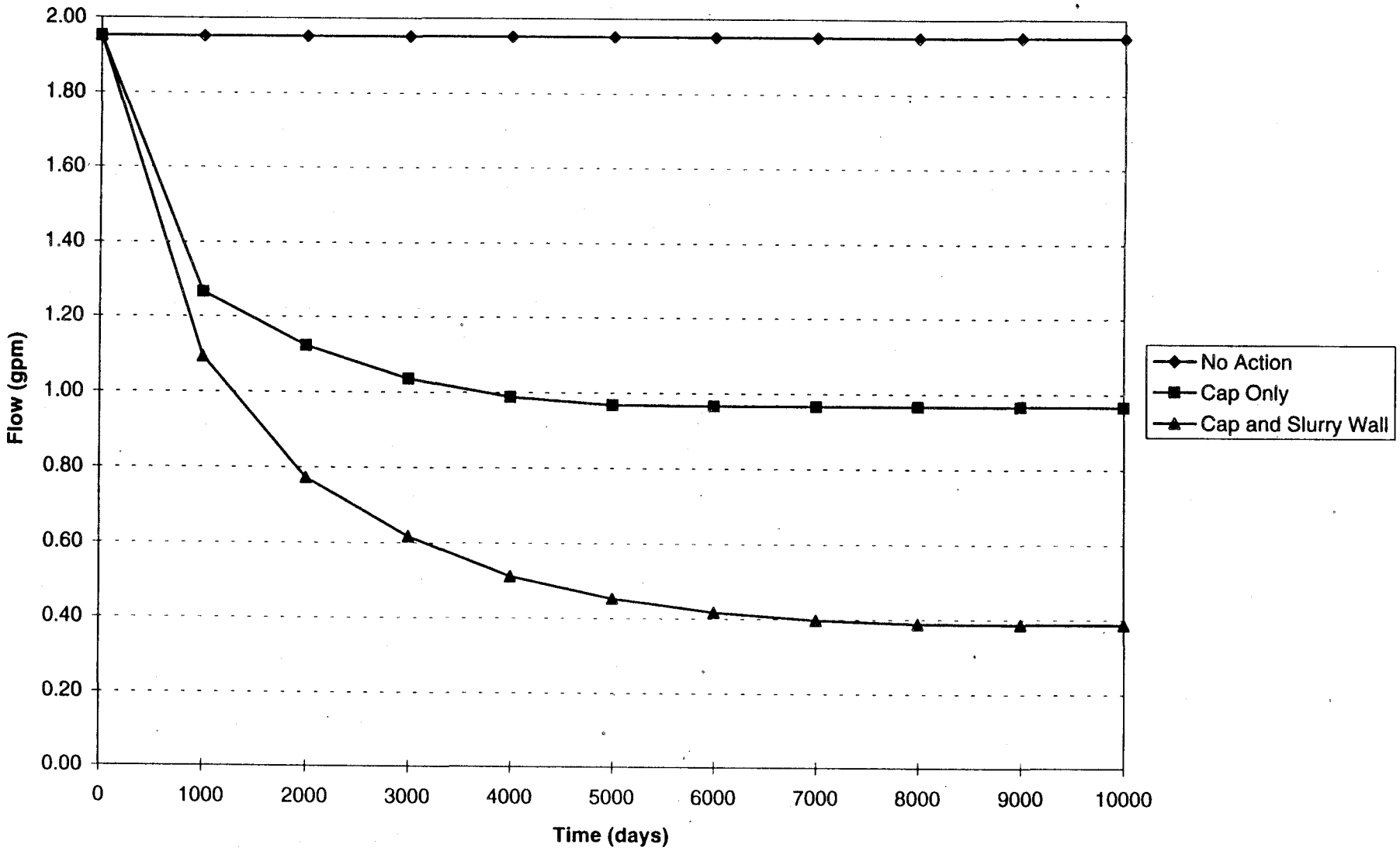


Figure C-15

Potentiometric Surface in Layer 1 at 0 Days for the Cap-Only Scenario

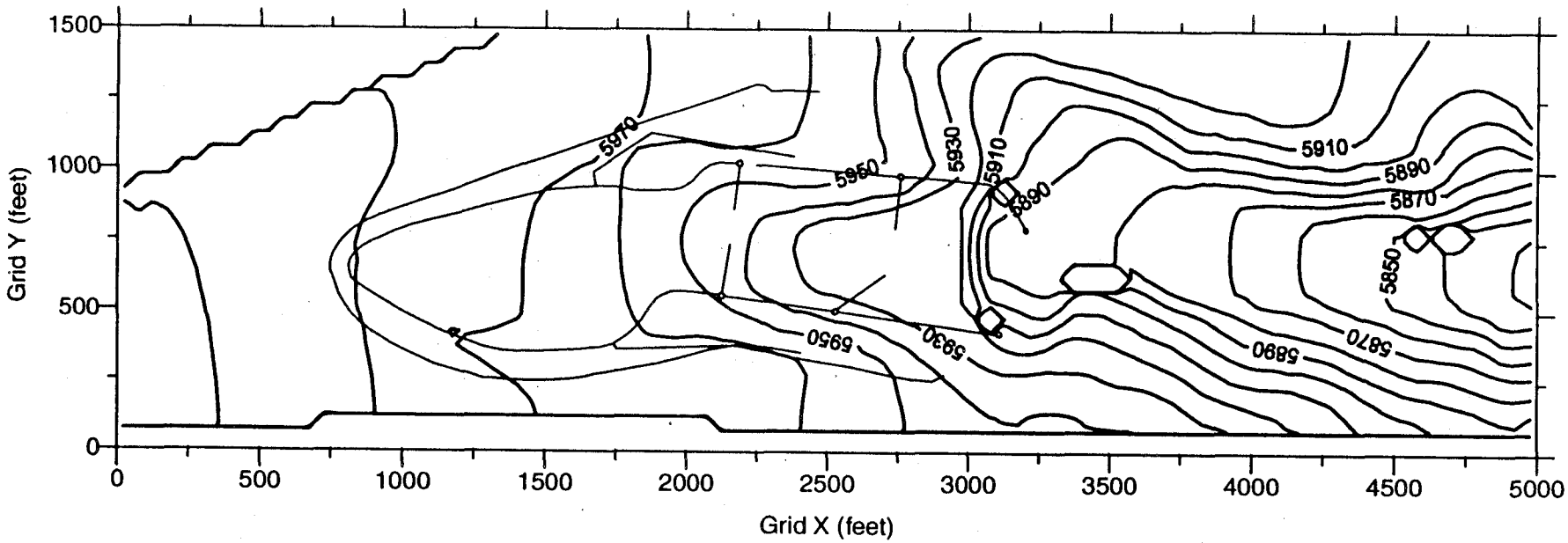


Figure C-16

Potentiometric Surface in Layer 1 at 1,000 Days for the Cap-Only Scenario

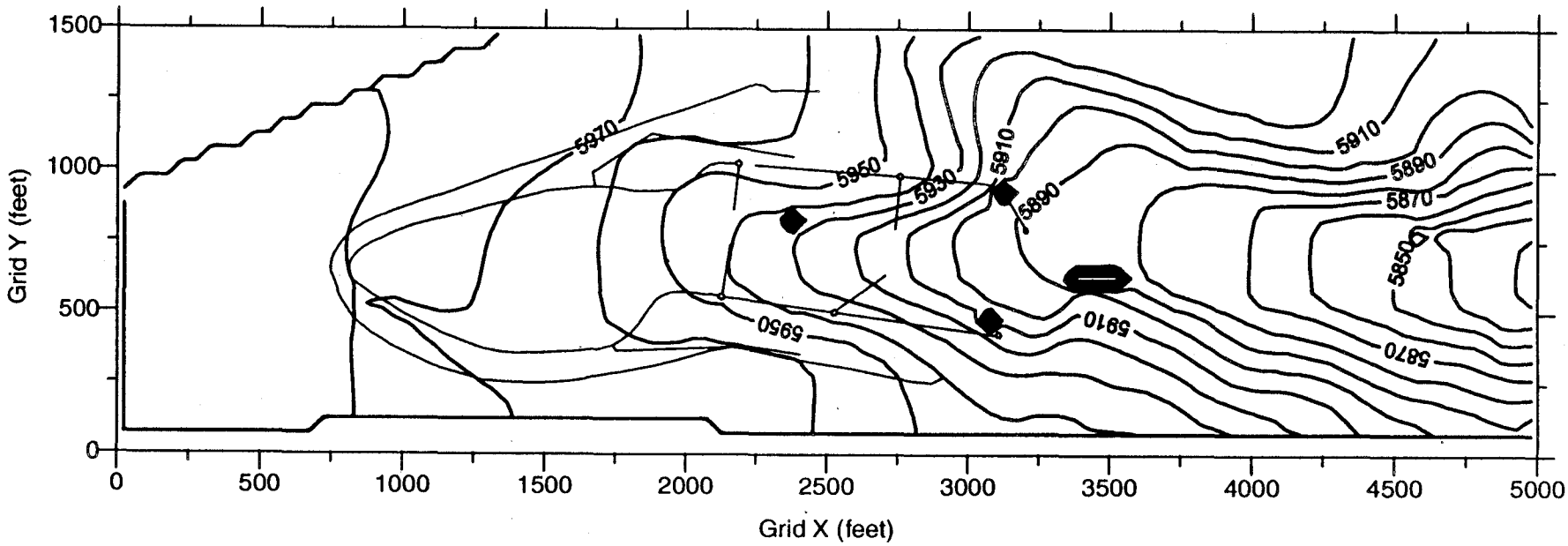


Figure C-17

Potentiometric Surface in Layer 1 at 2,000 Days for the Cap-Only Scenario

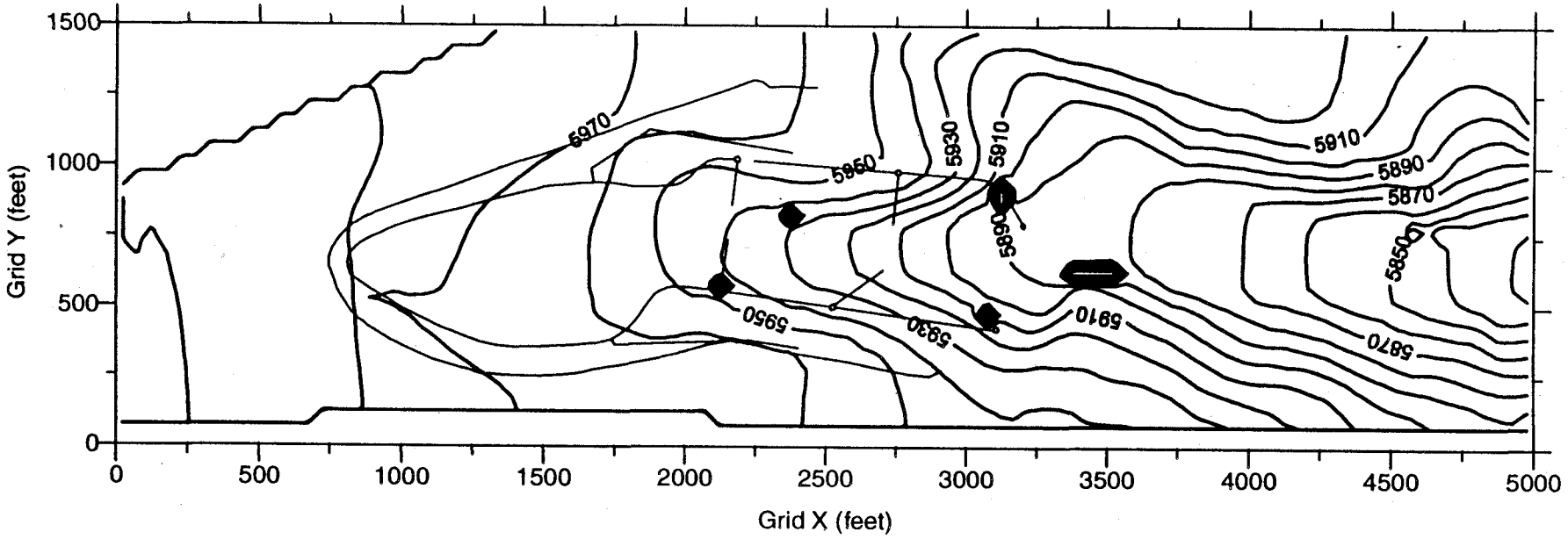


Figure C-18

Potentiometric Surface in Layer 1 at 3,000 Days for the Cap-Only Scenario

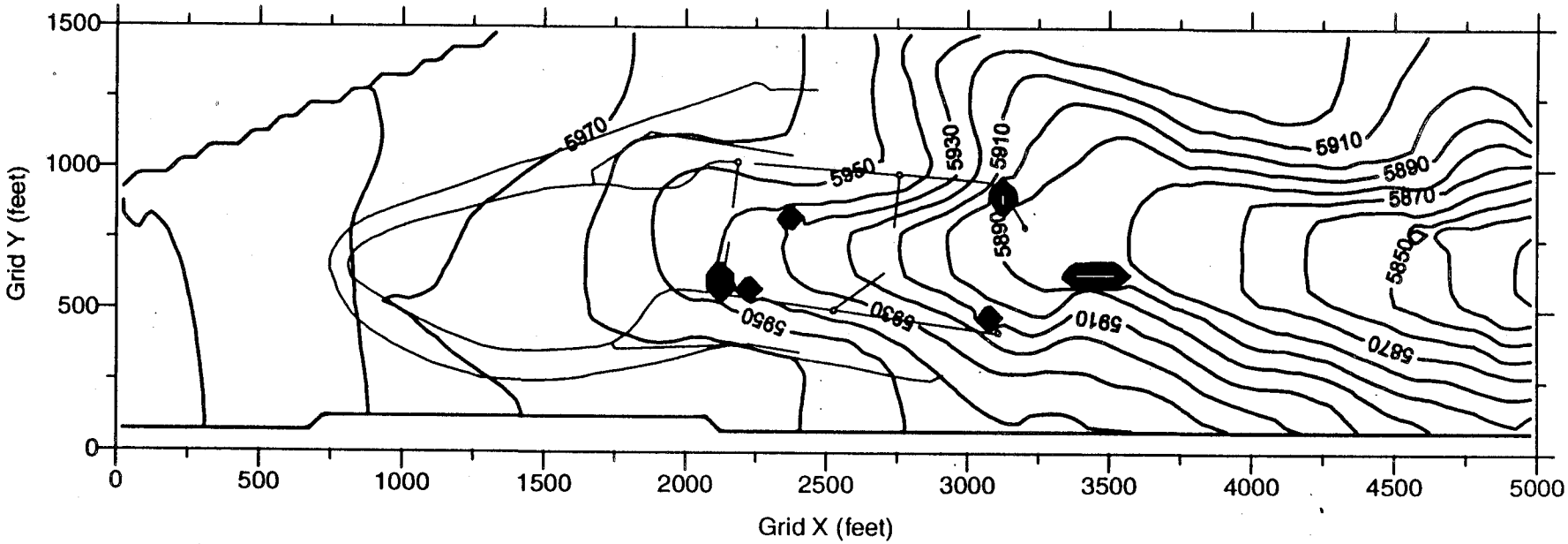


Figure C-19

Potentiometric Surface in Layer 1 at 4,000 Days for the Cap-Only Scenario

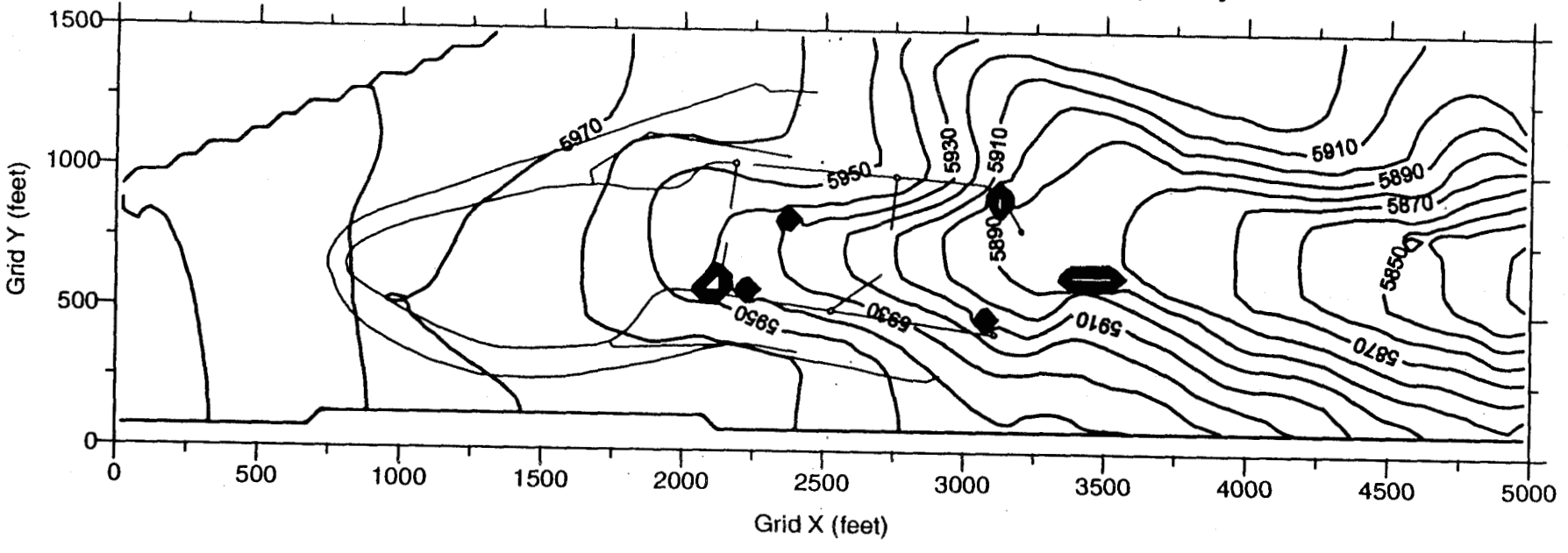


Figure C-20

Potentiometric Surface in Layer 1 at 5,000 Days for the Cap-Only Scenario

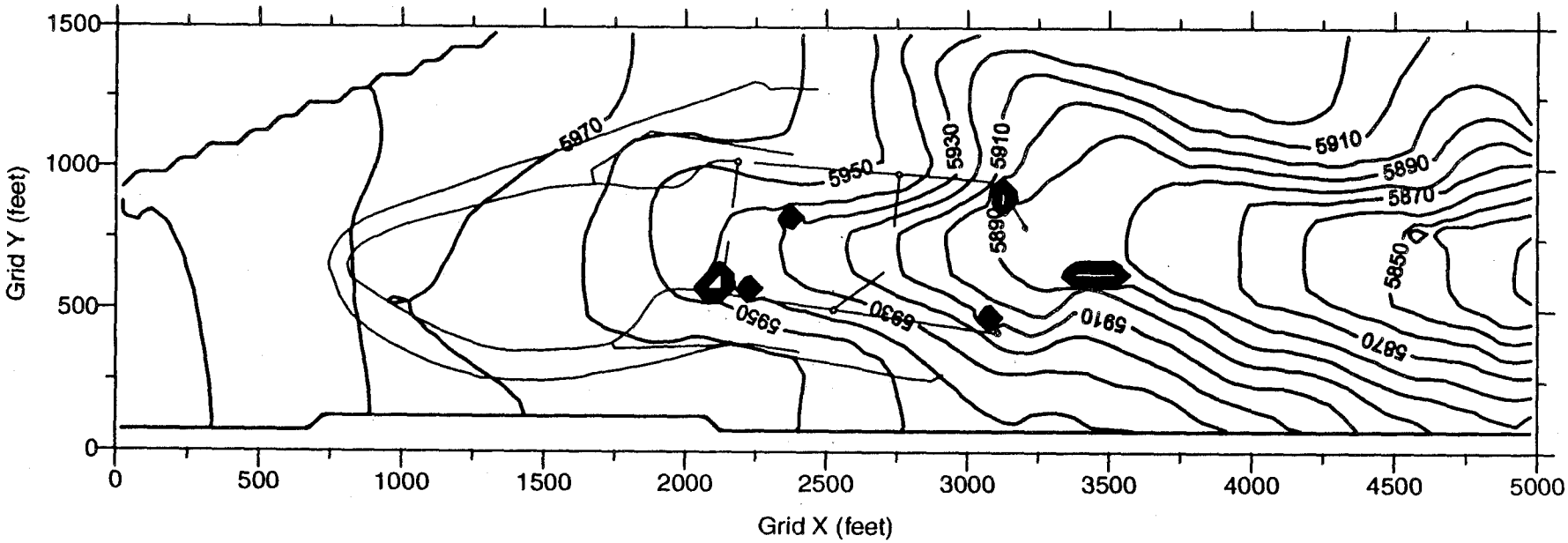


Figure C-21

Potentiometric Surface in Layer 1 at 6,000 Days for the Cap-Only Scenario

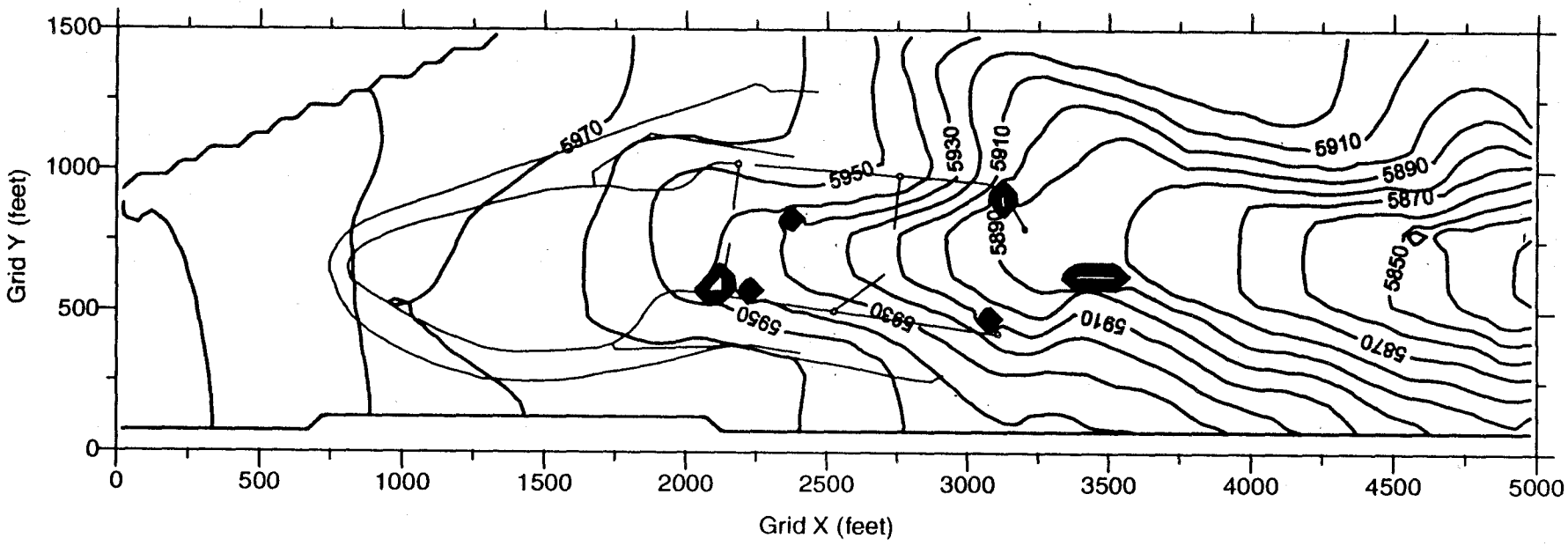


Figure C-22

Potentiometric Surface in Layer 1 at 7,000 Days for the Cap-Only Scenario

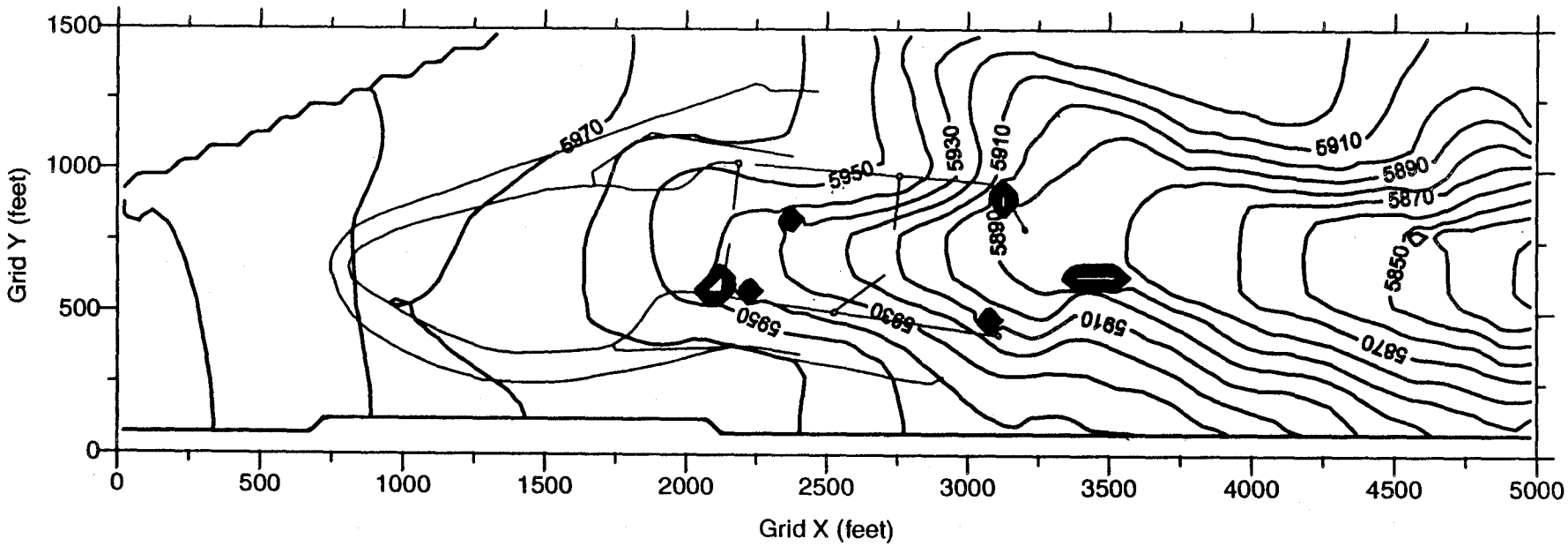


Figure C-23

Potentiometric Surface in Layer 1 at 8,000 Days for the Cap-Only Scenario

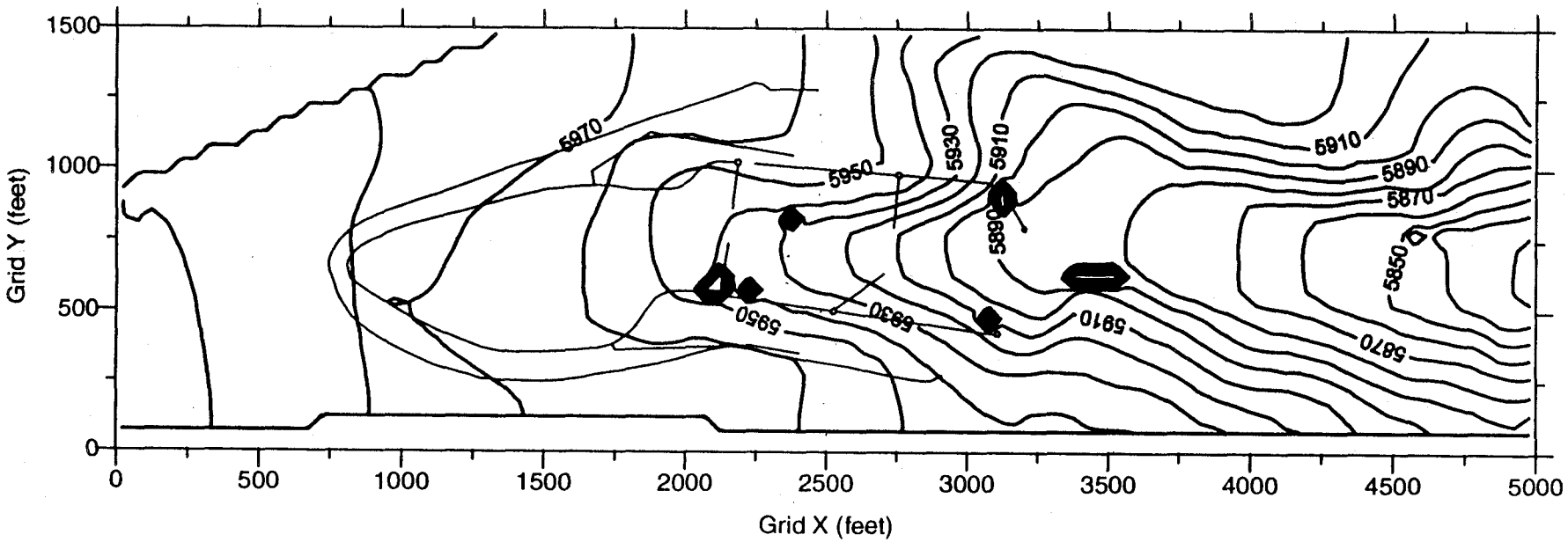


Figure C-24

Potentiometric Surface in Layer 1 at 9,000 Days for the Cap-Only Scenario

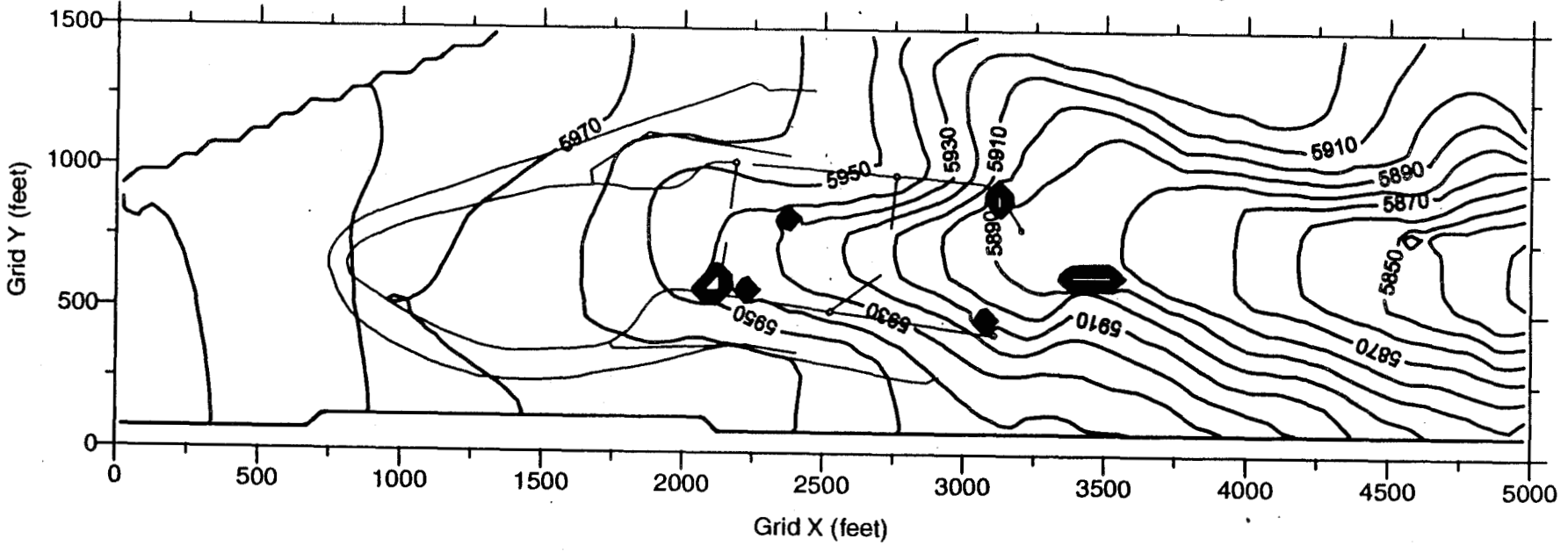


Figure C-25

Potentiometric Surface in Layer 1 at 10,000 Days for the Cap-Only Scenario

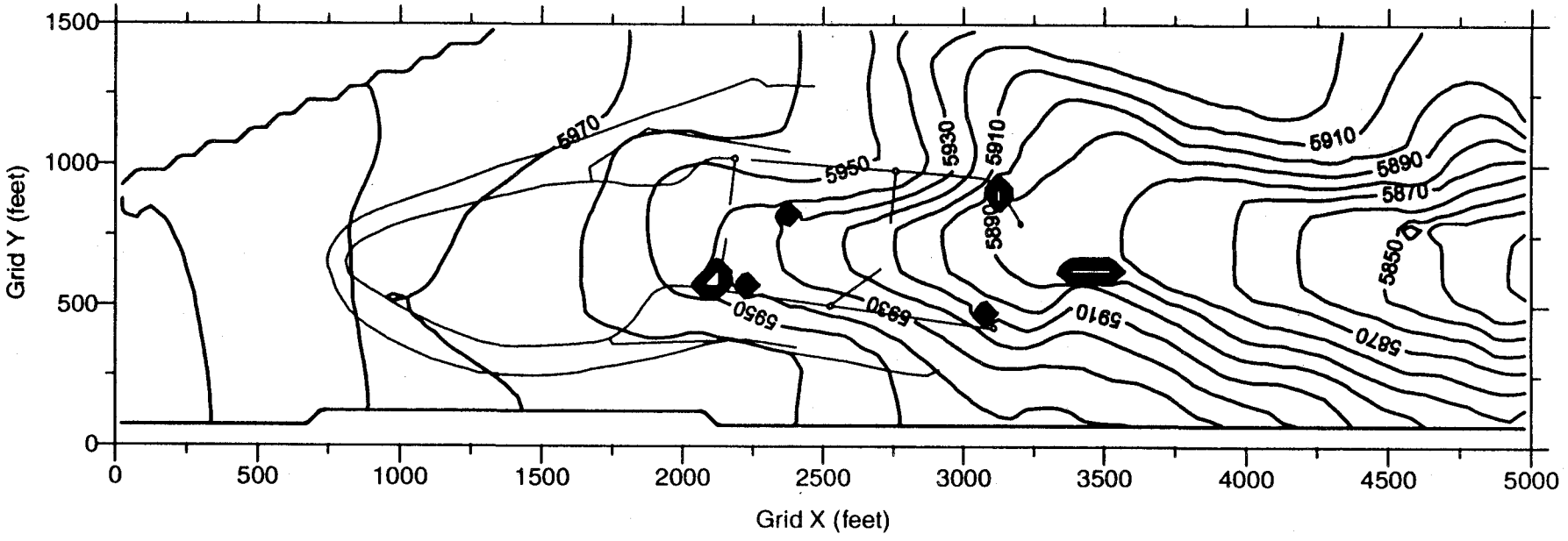


Figure C-26

Potentiometric Surface in Layer 1 at 0 Days for the Cap and North Slurry Wall Scenario

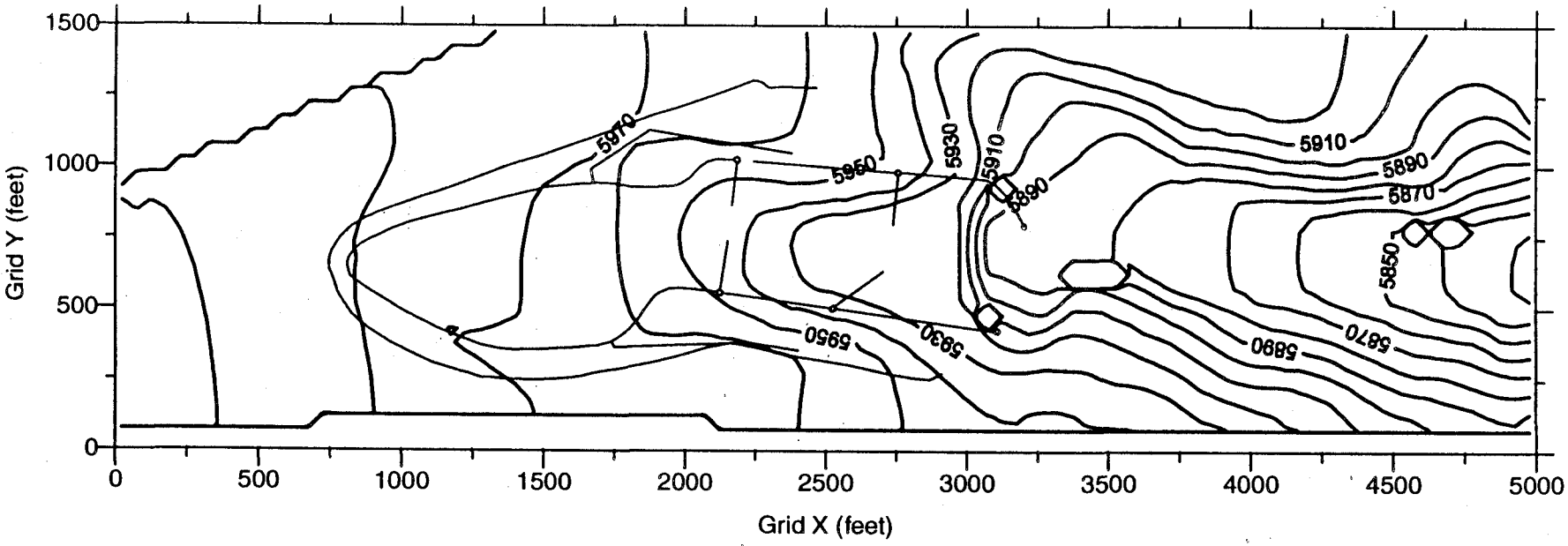


Figure C-27

Potentiometric Surface in Layer 1 at 1,000 Days for the Cap and North Slurry Wall Scenario

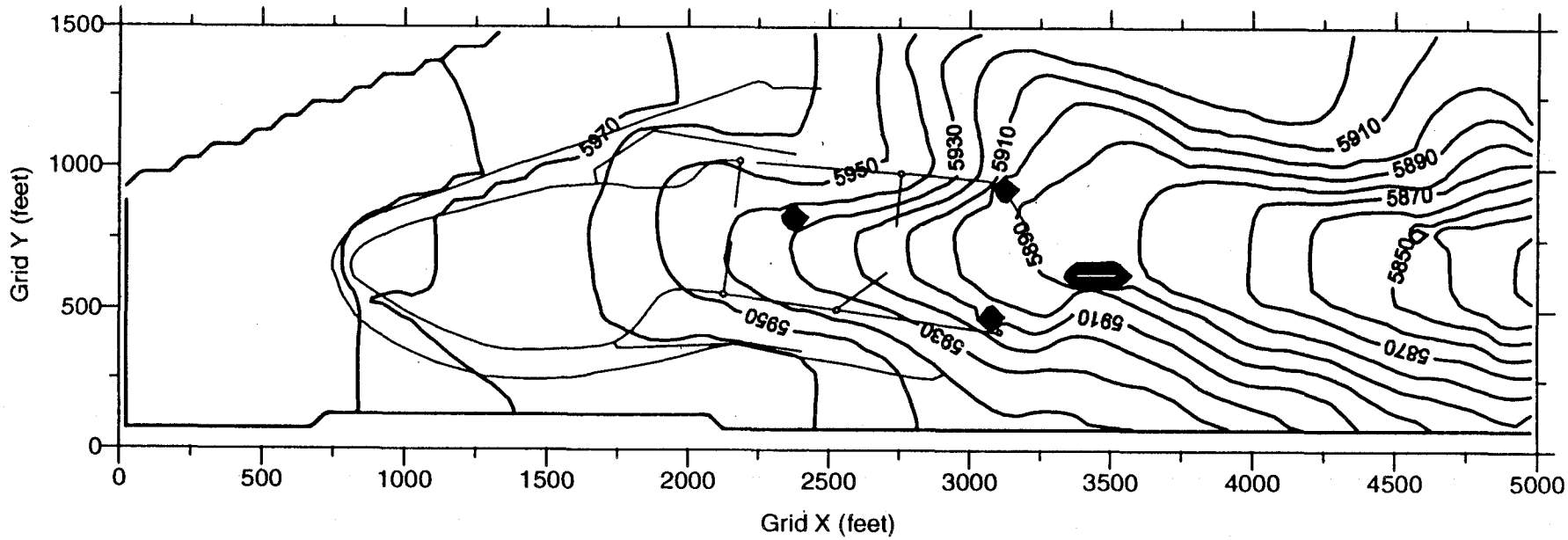


Figure C-28

Potentiometric Surface in Layer 1 at 2,000 Days for the Cap and North Slurry Wall Scenario

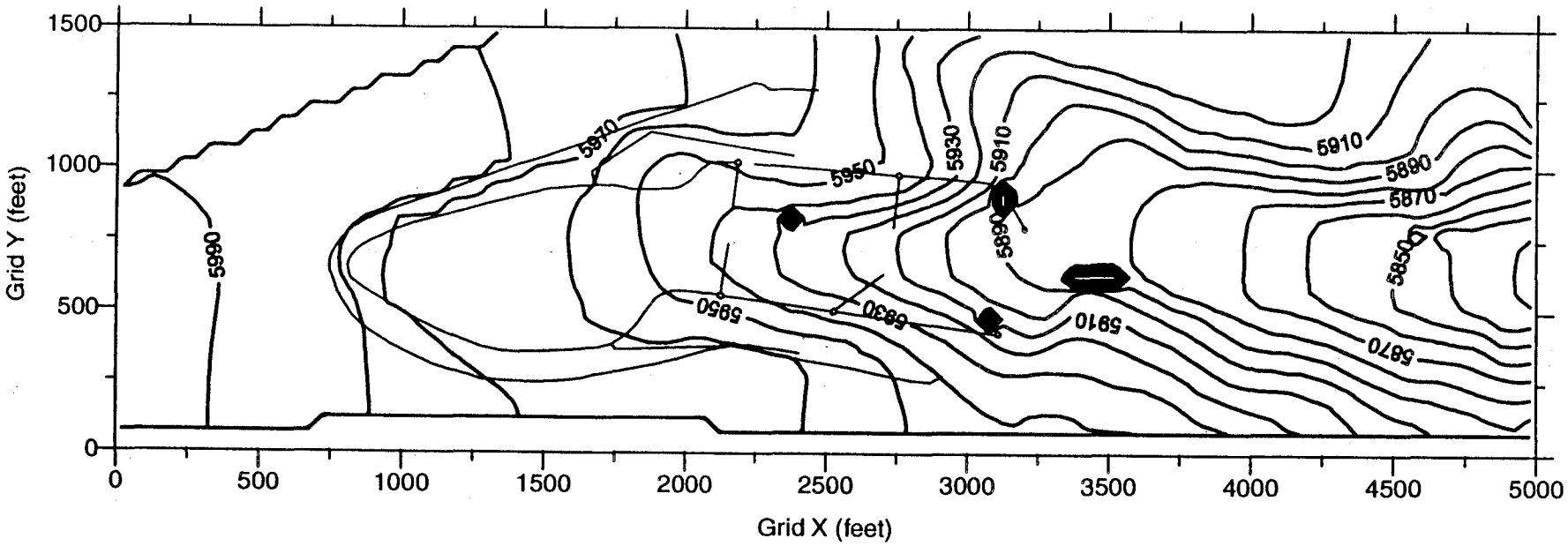


Figure C-29

Potentiometric Surface in Layer 1 at 3,000 Days for the Cap and North Slurry Wall Scenario

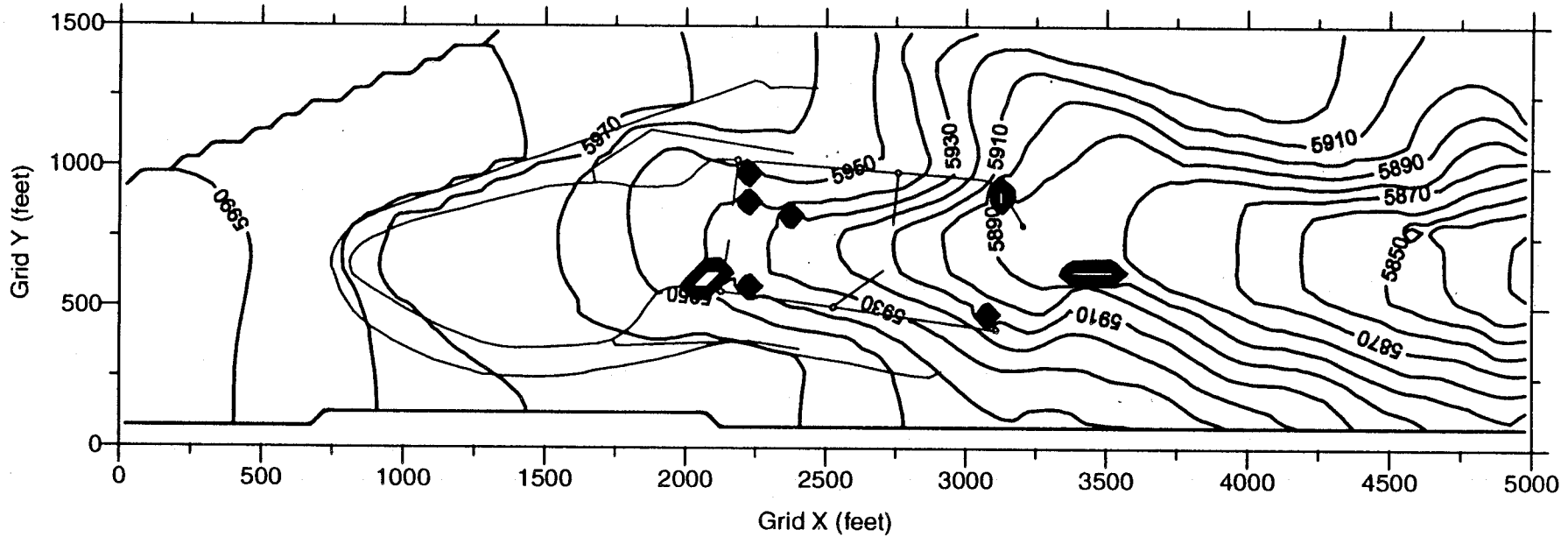


Figure C-30

Potentiometric Surface in Layer 1 at 4,000 Days for the Cap and North Slurry Wall Scenario

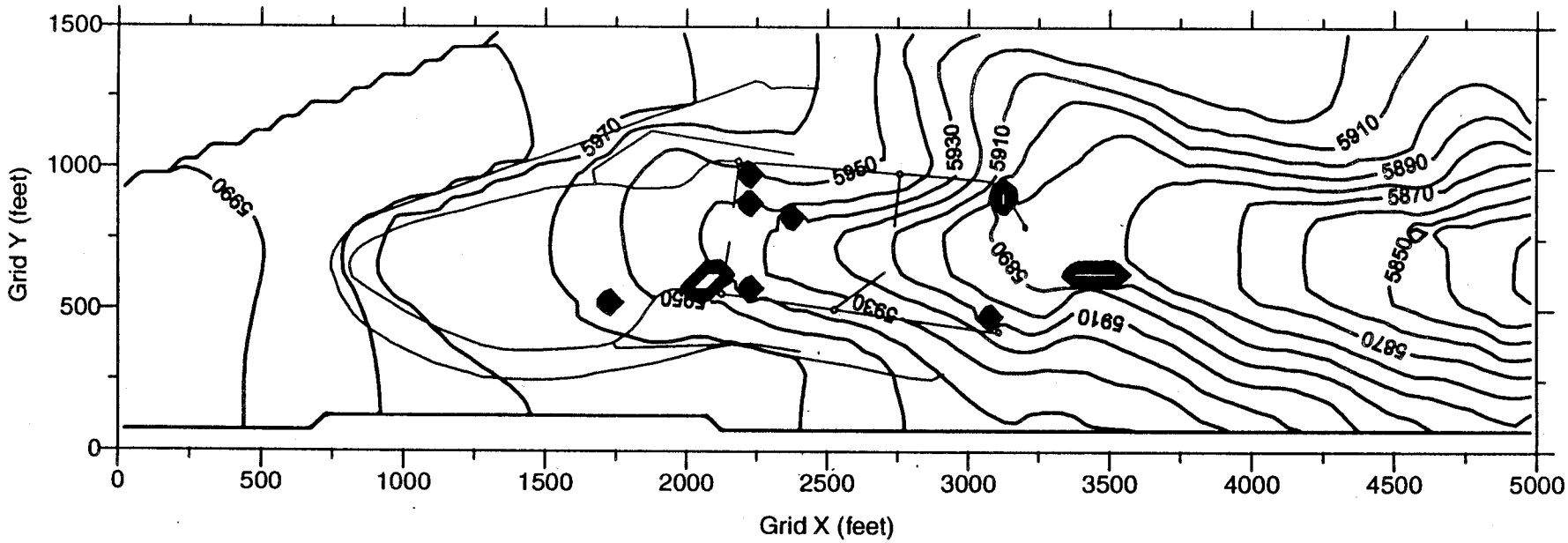


Figure C-31

Potentiometric Surface in Layer 1 at 5,000 Days for the Cap and North Slurry Wall Scenario

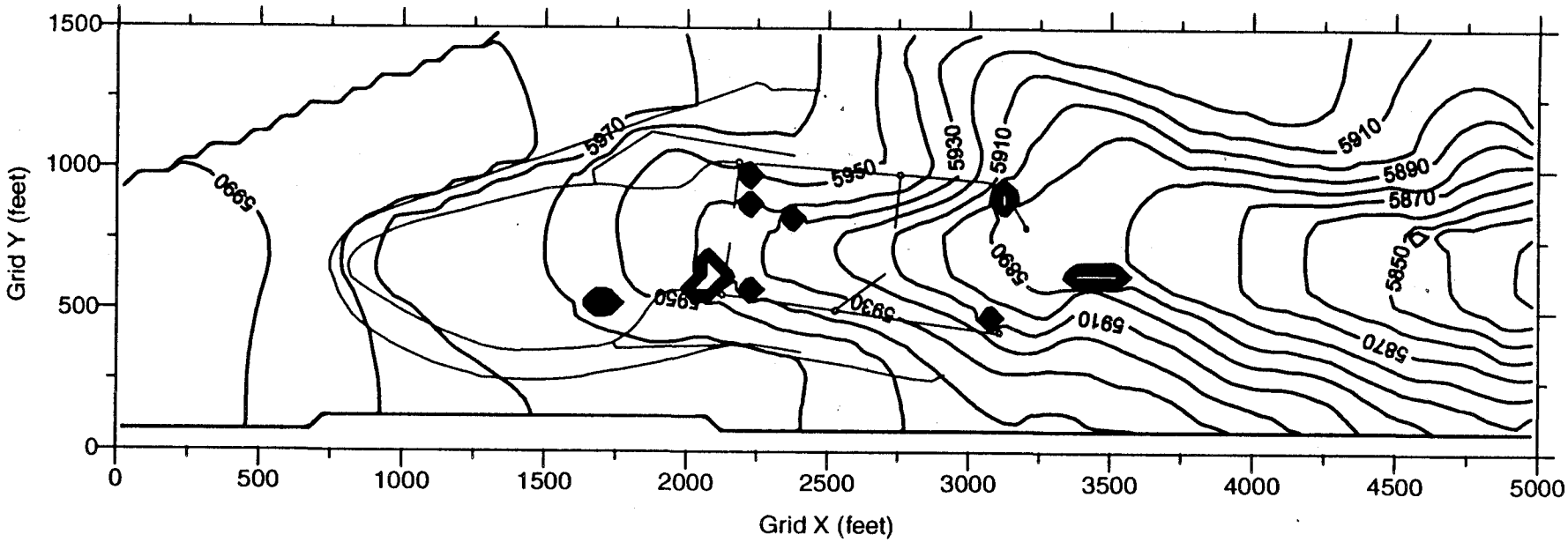


Figure C-32

Potentiometric Surface in Layer 1 at 6,000 Days for the Cap and North Slurry Wall Scenario

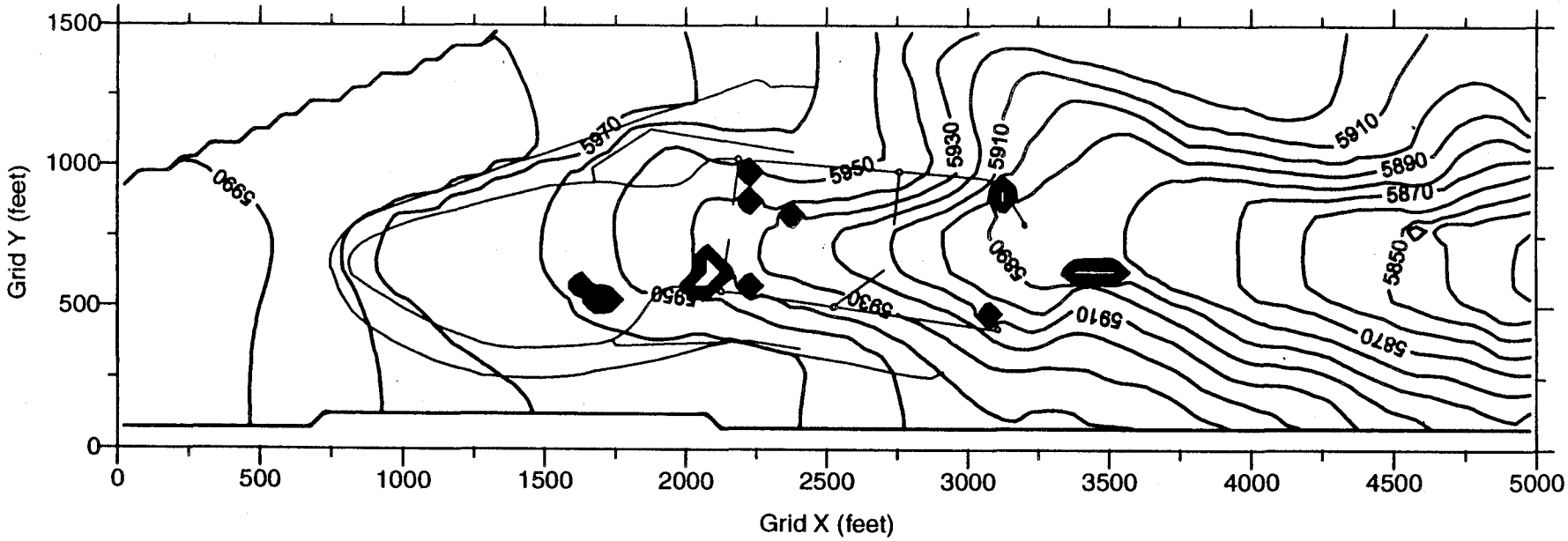


Figure C-33

Potentiometric Surface in Layer 1 at 7,000 Days for the Cap and North Slurry Wall Scenario

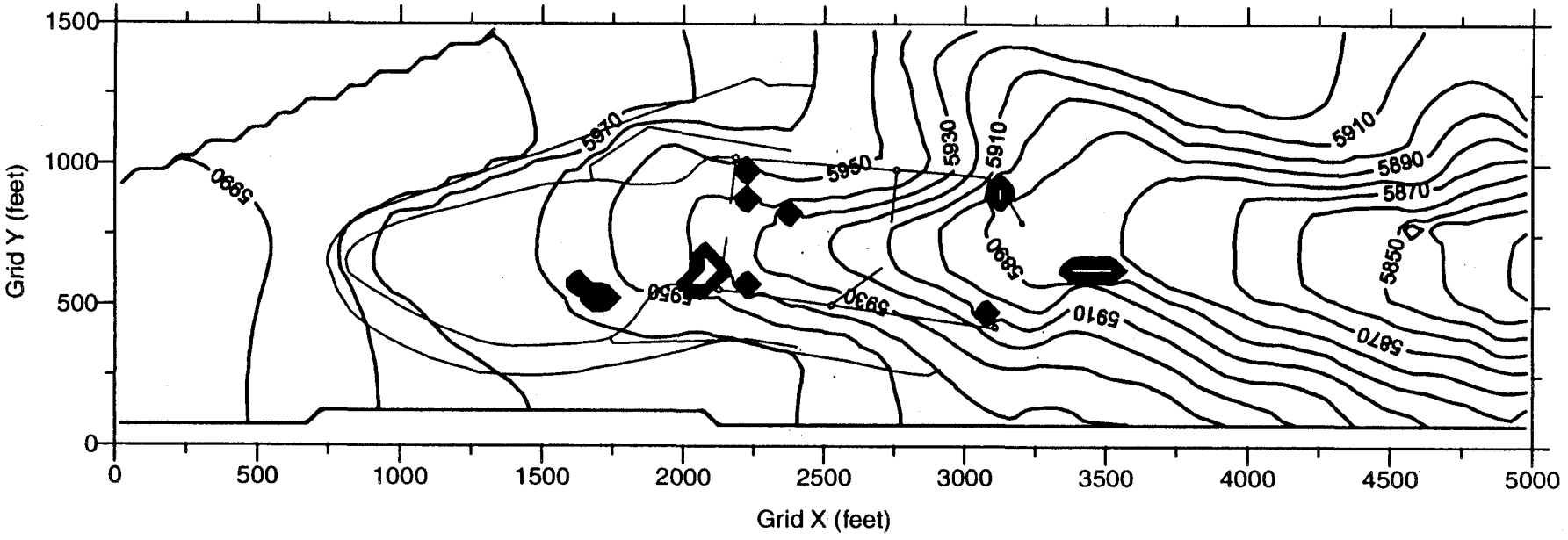


Figure C-34

Potentiometric Surface in Layer 1 at 8,000 Days for the Cap and North Slurry Wall Scenario

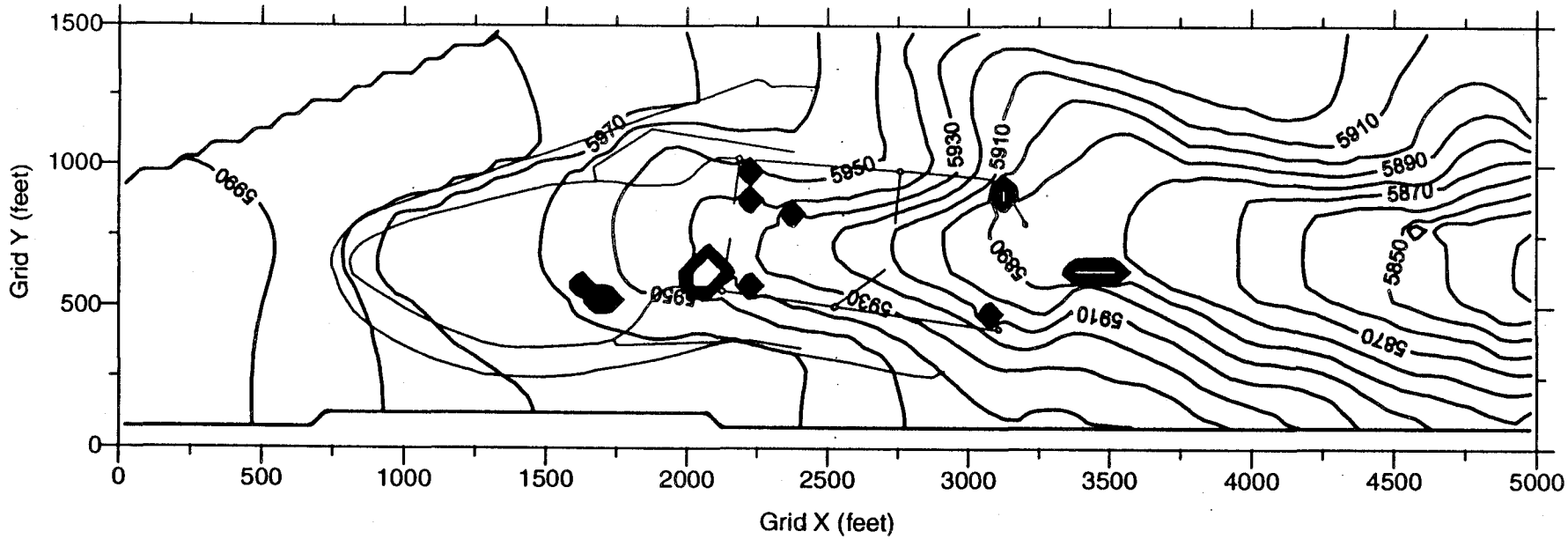


Figure C-35

Potentiometric Surface in Layer 1 at 9,000 Days for the Cap and North Slurry Wall Scenario

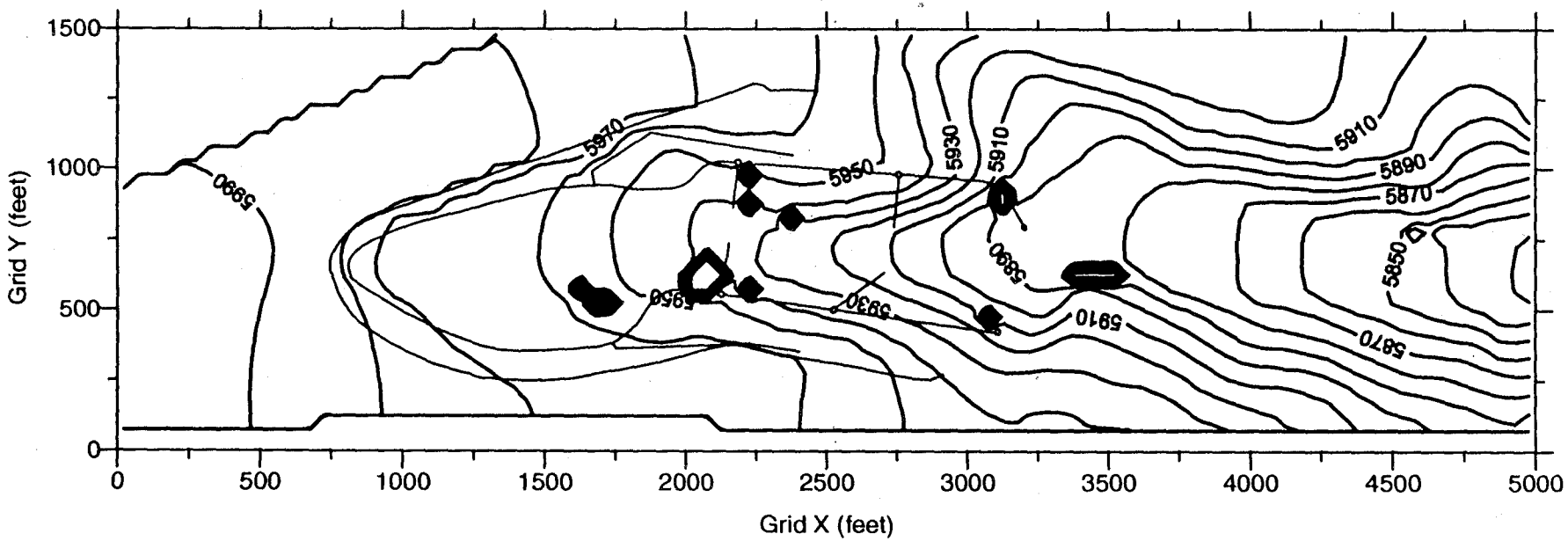


Figure C-36

Potentiometric Surface in Layer 1 at 10,000 Days for the Cap and North Slurry Wall Scenario

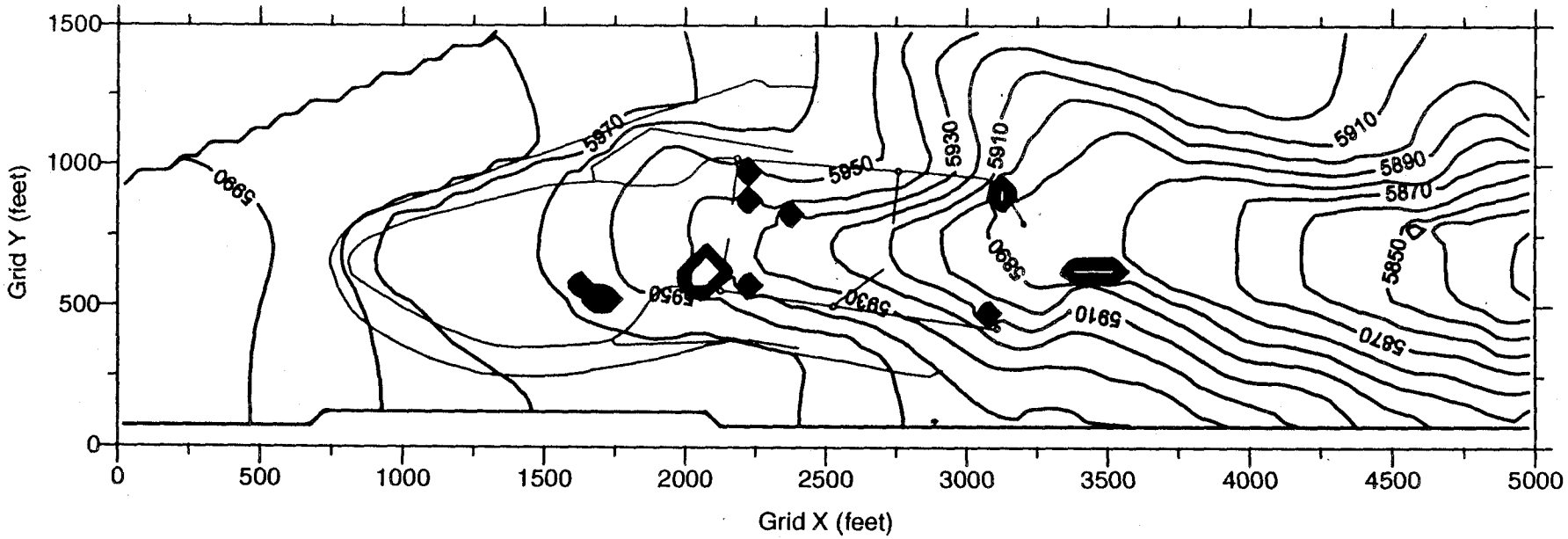


Table of Contents

D.1. GROUNDWATER CONTAMINANT TRANSPORT MODELING D-1

D.2. METHODOLOGY D-1

D.3. INPUT PARAMETERS D-3

D.3.1 SOURCE TERMS D-3

D.3.2 TRANSPORT PARAMETERS D-3

D.3.2.1 Organic Contaminants D-4

D.3.2.2 Inorganic Contaminants D-5

D.3.2.3 Retardation Coefficient D-5

D.3.3 HYDRAULIC PARAMETERS D-6

D.3.4 MODELING RESULTS: VALLEY FILL ALLUVIUM D-6

D.3.4.1 Inorganic Contaminants D-6

D.3.4.2 Organic Contaminants D-7

D.4. REFERENCES D-8

Tables

Table D-1 Fate and Transport Parameters for 30-Year Simulations

Table D-2 Groundwater Contaminant Transport Parameters and Simulated Results at the Compliance Boundary, 30-Year Continuous Source Simulation from the Landfill Source

Figures

Figure D-1 Mean Chloride Concentrations in UHSU Groundwater (mg/L)

Figure D-2 Predicted Manganese Concentrations, 30-Year Continuous Source Simulation

Figure D-3 Predicted Ammonia Concentrations, 30-Year Continuous Source Simulation

Figure D-4 Predicted Cadmium Concentrations, 30-Year Continuous Source Simulation

Figure D-5 Predicted Zinc Concentrations, 30-Year Continuous Source Simulation

Figure D-6 Predicted Arsenic Concentrations, 30-Year Continuous Source Simulation

Figure D-7 Predicted Selenium Concentrations, 30-Year Continuous Source Simulation

Figure D-8 Predicted Iron Concentrations, 30-Year Continuous Source Simulation

Figure D-9 Predicted Benzene Concentrations, 30-Year Continuous Source Simulation

Figure D-10 Predicted Bis(2-Ethylhexyl)Phthalate Concentrations, 30-Year Continuous Source Simulation

Figure D-11 Predicted Methylene Chloride Concentrations, 30-Year Continuous Source Simulation

Figure D-12 Predicted Trichloroethene Concentrations, 30-Year Continuous Source Simulation

Figure D-13 Predicted Vinyl Chloride Concentrations, 30-Year Continuous Source Simulation

Figure D-14 Predicted Naphthalene Concentrations, 30-Year Continuous Source Simulation

D.1. GROUNDWATER CONTAMINANT TRANSPORT MODELING

Modeling of groundwater contaminant migration from the Present Landfill was performed using a three-dimensional solute transport solution developed by Domenico and Robbins (1985) and refined by Domenico (1987). The proposed remedial actions for landfill closure that will have the greatest impact on groundwater flow include draining the East Landfill Pond and removing the dam. In addition, the landfill cap will significantly reduce precipitation and runoff infiltration, percolation, and generation of leachate, thereby reducing groundwater flow. As a result, the point of compliance might be located at the edge of the waste management area. Therefore, well 4087 has been proposed as the point of compliance. The objective of the modeling is to identify contaminants that exceed ARARs at the point of compliance thirty years after landfill closure. Transport modeling focuses on the valley fill alluvium within the upper hydrostratigraphic unit (UHSU), because source to receptor migration through the weathered and unweathered bedrock is unlikely because of extremely low hydraulic conductivity values.

Under the current closure strategy, the eastern edge of the cap will be east of the landfill seep (SW097). The groundwater quality at well 72293 is assumed to be representative of the leachate near the edge of the landfill contaminant source and was chosen as a potential point source for the modeling simulations. Although the landfill seep is technically surface water, this location was also considered a potential point source because contaminated seep water may impact the shallow groundwater. Under the proposed grading plan, the seep will become buried under the cap by fill and flow will recur as groundwater. Chemicals of concern (identified as applicable or relevant and appropriate requirements [ARARs] exceedances at well 72293 and SW097) include benzene, naphthalene, vinyl chloride, bis(2-ethylhexyl)phthalate, methylene chloride, trichloroethene, ammonia, cadmium, arsenic, iron, manganese, selenium and zinc.

D.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. For this modeling effort, only longitudinal contaminant migration was examined. Because of this, only contaminant migration along the plume centerline was simulated. The source term is modeled as a continuous point source where the rate of injection is continuous for 30 years. Concentrations of chemicals remain constant at the source and do not decrease over time. Therefore, for non-reactive solutes, the maximum steady state concentration is maintained at all distances from the source (x) that equal the advective transport velocity (n) multiplied by the time duration of mass injection (t). This expression excludes transport in the transverse (y) and vertical (z) directions. Although simplified, the one-dimensional centerline solution provides a reasonable estimate given that groundwater flow is restricted along the narrow drainage within the East Landfill Pond area and the upper reaches of No Name Gulch. In addition, the

centerline solution provides a more conservative estimate at the compliance boundary because traverse and vertical dispersion is neglected.

Modeling assumptions include homogeneous and isotropic flow conditions and a constant seepage velocity in the x (downgradient) direction. 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

$$C(x,0,0,t) = (C_o/2)\exp(-kt')\,\mathrm{erfc}[(x-vt)/2(D_x t)^{1/2}]\,\{\mathrm{erf}[Y/4\,(D_y x/v)^{1/2}]\,\mathrm{erf}[Z/4\,(D_z x/v)^{1/2}]\} \qquad \text{(D-1)}$$

where

x	=	Linear distance in the direction of groundwater flow from the source [L]
Y	=	Source width [L]
v	=	Advective transport velocity (average linear velocity of groundwater) in the x direction (isotropic) [L/T]
t	=	Duration (time) of contaminant mass injection [T]
t'	=	Travel time (x/v) [T]
D_x	=	Coefficient of longitudinal hydrodynamic dispersion $[L^2/T] = \alpha_x v_x + D_m$
α_x	=	Longitudinal dispersivity [L]
D_m	=	Molecular diffusion along x axis $[L^2/T]$
D_y	=	Coefficient of transverse hydrodynamic dispersion $[L^2/T] = \alpha_y v_y + D_m$
α_y	=	Transverse dispersivity [L]
Z	=	Source width in the vertical plane [L]
D_z	=	Coefficient of vertical hydrodynamic dispersion $[L^2/T] = \alpha_z v_z + D_m$
α_z	=	Vertical dispersivity [L]

exp = Exponent

erf = Error function

erfc = Complimentary error function

C = Contaminant concentration as a function of x [M/L^3]

C_o = Contaminant concentration at the source [M/L^3]

k = First order decay constant; set equal to zero if no decay [T^{-1}]

D.3. INPUT PARAMETERS

Input parameters and initial boundary conditions are based on observed field conditions. Hydraulic and transport parameters are also based on OU 7 site-specific data (DOE 1994) as well as information provided in the Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site (EG&G 1995). Input parameters and the values used for the modeling simulations are presented in Tables D-1 and D-2.

D.3.1 SOURCE TERMS

Modeled source concentrations for chemicals (that exceed ARARs) are based on maximum and mean (iron only) concentrations for all chemicals (except for zinc, iron, and methylene chloride) at monitoring well 72293. Source concentrations for zinc, iron and methylene chloride are based on maximum and mean (iron only) concentrations at the seep (SW097). Simulated results are predicted at the top of the saturated zone for valley fill alluvium deposits. With the exception of zinc, iron, and methylene chloride, point source concentrations originate at monitoring well 72293. The landfill seep (SW097) may serve as a potential point source of zinc, iron and methylene chloride contamination because the concentrations of these compounds at the seep exceed the corresponding ARARs for groundwater. For this reason the landfill seep was designated as a point source of zinc, iron, and methylene chloride contamination Depending on the point source (72293 or SW097), simulated concentrations were modeled at two lateral distances from the source: (1) a lateral distance of 1073 ft from well 72293 to the compliance point (well 4087) and (2) a lateral distance of 914 ft from SW097 to well 4087.

D.3.2 TRANSPORT PARAMETERS

The lateral dispersivity (α_L) value is based on the chloride plume geometry presented in Figure D-1. Field measured values of α_L presented in the literature suggest that αL can be estimated at one-tenth

of the flow length (Gelhar 1986, Fetter 1993). Therefore, based on the observed flow length of 375 ft (Figure D-1), α_L is estimated at 37.5 ft (0.1 x 375 ft). The transverse dispersivity (α_T) is typically one-tenth to one twentieth the longitudinal dispersivity (Fetter 1993). A more conservative αT value of 1.9 ft (one-twentieth of α_L) was used in the modeling simulations. The vertical (α_Z) dispersivity was excluded from the simulations by setting this value to zero. This provides a conservative concentration estimate at the compliance boundary. The effective diffusion term was obtained by multiplying the diffusion coefficient (1 x 10E-9 m^2/sec) with the tortuosity coefficient (0.5 m^2/sec) parameter. The tortuosity coefficient is related to the shape of the flowpath of water molecules that flow through porous media. The diffusion and tortuosity coefficients are typical values reported in the literature (Fetter 1993).

D.3.2.1 Organic Contaminants

Most organic compounds have 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 solute per unit mass 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):

$$K_d = Koc \times foc \qquad \text{(D-2)}$$

where

K_d = 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 foc value of 0.0135 for valley-fill alluvium (DOE 1994) and K_{oc} values obtained from the literature (Knox et al. 1993), the K_d value may be estimated from the above expression. These adsorption parameters are presented in Table D-1.

Other processes that may attenuate organic compounds in groundwater include hydrolysis, oxidation, volatilization, and biodegradation. Howard et al. (1991) reports groundwater half-lives for most organic compounds. The most conservative half-lives for groundwater were used for the modeling simulations (Table D-1).

D.3.2.2 Inorganic Contaminants

The transport of metals (arsenic, cadmium, iron, manganese, and zinc) in groundwater is generally controlled by the redox conditions within the landfill. The groundwater redox zones within and near municipal landfills are generally characterized by three types of zones: (1) an anaerobic zone within the landfill; (2) a zone where the oxidized native groundwater dilutes the landfill leachate, and (3) a transition zone between the anaerobic and oxidized groundwater. Dissolved oxygen concentrations measured from 1990 through 1993 confirm these redox conditions at OU 7. Mean dissolved oxygen concentrations increase in the downgradient direction from 1.63 mg/L at well 72293 to 6.98 mg/L at well 4087. However, pH appears to be a non factor of contaminant mobility given the range of neutral pH values (6.96 at well 72293 to 6.84 at well 4087) measured from 1990 through 1993 (DOE 1994). For the purpose of the modeling it is assumed that these conditions exist and that as the groundwater containing leachate migrates from the landfill it becomes enriched in oxygen.

Arsenic tends to be mobile under reducing conditions, however as the groundwater becomes oxidized the compound becomes attenuated by adsorption to the aquifer matrix. Cadmium under normal redox conditions has a low solubility and has a tendency to adsorb to the aquifer matrix. Although ammonia is typically transformed to nitrate through oxidation, it also has a slight tendency to adsorb to solids. Zinc, although highly soluble, may also absorb to the aquifer matrix under normal redox conditions. As a result, soil-water distribution coefficients (Kd) of 5, 6.5, 1.25 and 0.1 for arsenic, cadmium, ammonia and zinc, respectively, were used as adsorptive parameters in the modeling simulations (DOE 1992; EPA 1978; DOE 1984). The most conservative of the reported distribution coefficients were used.

Iron, selenium and manganese are highly soluble and although may become reactive under oxidizing conditions were modeled as non-reactive ions. Therefore, selenium, iron and manganese were modeled with a conservative retardation coefficient of 1. All metals and inorganic ions were modeled with a decay coefficient of zero. Transport parameters are presented in Table D-1.

D.3.2.3 Retardation Coefficient

Once determined, the K value can be used to calculate the retardation coefficient (R) from the following equation:

$$R = 1 + \rho K_d/h \qquad \text{(D-3)}$$

where

ρ = Soil density (g/cm^3)

h = Effective porosity (dimensionless)

As the result of adsorption processes, contaminant movement through the aquifer is significantly less than the rate of groundwater movement. For example, using an average soil density of 1.77 g/cm^3 for unconsolidated surficial deposits (DOE 1993), a K_d value of 1.44, and an effective porosity value of 0.1, and substituting into the above equation results in R of 26.57 for trichloroethene. In general, the computed retardation coefficient predicts contaminant movement at 1/26th of the seepage velocity, assuming chemical equilibrium between the liquid and solid phase (n of contaminant = n of water/R).

D.3.3 HYDRAULIC PARAMETERS

The geometric mean of site-wide hydraulic conductivity values (7.3 ft/day) is used as a representative value for the valley fill alluvium (EG&G 1995). The seepage velocity is based on the observed hydraulic gradient of 0.05 along the east-west axis of the East Landfill Pond area and the upper reaches of No Name Gulch (DOE 1995) and an estimated effective porosity value of 0.1 for the valley fill alluvium (Hurr 1976). The hydraulic and modeling parameters are summarized in Table D-2.

D.3.4 MODELING RESULTS: VALLEY FILL ALLUVIUM

Transport simulations were performed for benzene, vinyl chloride, bis(2-ethylhexyl)phthalate, methylene chloride, naphthalene, trichloroethene, manganese, iron, arsenic, cadmium, ammonia, selenium, and zinc. The results (summarized in Table D-2) of these simulations predict chemical concentrations at the proposed compliance points 30 years after landfill closure. Figures D-2 through D-14 illustrate contaminant concentrations as a function of distance from the source.

D.3.4.1 Inorganic Contaminants

The modeling results indicate that the inorganic compounds (manganese, iron, arsenic, cadmium, ammonia, selenium and zinc) show significantly greater migration than the organic contaminants. This is primarily due to the greater persistence (no degradation) of the metals and inorganics in groundwater. Despite the relatively greater mobility of the metals and inorganics, only the predicted iron concentration exceeds the corresponding ARAR at the proposed compliance point. The following summarizes the results of the 30-year contaminant transport modeling:

The simulated manganese concentration of 172 mg/L at the compliance point is slightly less than the ARAR (200 mg/L) (Figure D-2). However this result may be overly conservative because the source concentration is based on the maximum manganese value at well 72293.

The predicted ammonia concentrations (60 mg/L) is slightly less than the ARAR of 100 mg/L at the proposed compliance point (Figure D-3).

The predicted cadmium concentration (<0.01 mg/L) at the compliance point is significantly less than the ARAR of 3.1 mg/L (Figure D-4).

Figure D-5 shows that the predicted zinc concentration (59 mg/L) is significantly less than the ARAR (2000 mg/L) at the compliance point.

The predicted arsenic concentration (< 0.1 mg/L) is significantly less than the corresponding ARAR of 50 mg/L at the proposed compliance point (Figure D-6).

The simulated selenium concentration (0.47 mg/L) is significantly less than the corresponding ARAR (20 mg/L) at the compliance point (Figure D-7).

The simulated iron concentration (1771 mg/L) at the compliance point exceeds the ARAR (1000 mg/L) (Figure D-8). However, this simulation may be overly conservative because iron was modeled as a non-reactive solute.

Perhaps an alternative concentration limit could be proposed for iron in groundwater. This limit could be based on the distance from the landfill to the sight boundary and the distance from the site boundary to an exposure point for potential receptors. Another alternative concentration limit is the background Upper Tolerance Limit ($UTL_{99/99}$) (DOE 1994). Figure D-8 shows that despite exceeding the ARAR (1000 mg/L), the predicted iron concentration at the compliance point is significantly less than the site-wide background $UTL_{99/99}$ of 32,398 mg/L or even the background mean concentration of 3,722 mg/L (DOE 1994).

D.3.4.2 Organic Contaminants

The 30-year contaminant transport modeling indicates insignificant movement of the organic contaminants, as simulated concentrations of the analytes are orders of magnitude less than the corresponding ARARs at the proposed compliance point (Figures D-9 through D-14; Table D-2). These results appear to be reasonable, given the current spatial distribution of the organic contaminants. With the exception of vinyl chloride, detections of the modeled contaminants downgradient of the landfill are infrequent and show no definitive spatial trends. Among the organic compounds, vinyl chloride is the most ubiquitous in nature and has the greatest persistence and mobility of the modeled contaminants due to the relatively long half life of this chemical (69,000 hours). Despite having the highest simulated concentration at the proposed compliance point (0.2 mg/L), the simulated 30-year vinyl chloride concentration is less than the corresponding ARAR (2 mg/L).

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Table D-1 Fate and Transport Parameters for 30-Year Simulations

Analyte	K_{oc} (ml/g)	f_{oc}	k_d (ml/g)	ρ_b (g/cm3)	η	R	half lives hrs	k hrs^{-1}
Benzene	87.1	0.0135	1.18	1.77	0.1	21.81	17280	4.01E-05
Bis(2-Ethylhexyl)Phthalate	100000	0.0135	1350.00	1.77	0.1	23896.00	9336	7.42E-05
Methylene Chloride	8.71	0.0135	0.12	1.77	0.1	3.08	1344	5.16E-04
Naphthalene	1288	0.0135	17.39	1.77	0.1	308.77	6192	1.12E-04
Trichloroethene	107	0.0135	1.44	1.77	0.1	26.57	39672	1.75E-05
Vinyl Chloride	2.45	0.0135	0.03	1.77	0.1	1.59	69000	1.00E-05
Ammonia	nd	0.0135	1.25[c]	1.77	0.1	23.13	nd	nd
Arsenic	nd	0.0135	5[a]	1.77	0.1	89.50	nd	nd
Cadmum	nd	0.0135	6.5[a]	1.77	0.1	116.05	nd	nd
Iron	nd	0.0135	nd	1.77	0.1	1.00	nd	nd
Manganese	nd	0.0135	nd	1.77	0.1	1.00	nd	nd
Selenium	nd	0.0135	nd	1.77	0.1	1.00	nd	nd
Zinc	nd	0.0135	0.1[b]	1.77	0.1	2.77	nd	nd

Notes

K_{oc} Organic carbon coefficient (Knox et al. 1993)

f_{oc} Fraction of organic carbon in the soil matrix (DOE 1994)

k_d Soil-water distribution coefficient

η Effective porosity (DOE 1995)

R Retardation coefficient

k First Order Decay Coefficient (Howard et al. 1991)

nd No data

a EPA 1978; DOE 1992

b DOE 1984; DOE 1992

Table D-2
Groundwater Contaminant Transport Parameters and Simulated Results at the Compliance Boundary
30-Year Continuous Source Simulation from the Landfill Source

Analyte	v ft/day	α_L (ft)	α_T (ft)	Molecular Diffusivity (m2/sec)	ω	k hrs-1	R	x[1] (feet)	Source Concentration[2] (µg/L)	Predicted Concentration (µg/L) at the Compliance Point	ARAR (ug/L)
Benzene	3.65	60	1.9	1.00E-09	0.05	4.01E-05	21.81	1073	5	<0.01	1
Vinyl Chloride	3.65	60	1.9	1.00E-09	0.05	1.00E-05	1.59	1073	10	0.2	2
Bis(2-Ethylhexyl)Phthalate	3.65	60	1.9	1.00E-09	0.05	7.42E-05	23896.00	1073	11	<0.01	10
Naphthalene	3.65	60	1.9	1.00E-09	0.05	1.12E-04	308.77	1073	31	<0.01	10
Methylene Chloride	3.65	60	1.9	1.00E-09	0.05	1.43E-07	3.08	914	6	<0.01	4.7
Trichloroethene	3.65	60	1.9	1.00E-09	0.05	1.75E-05	26.57	1073	5	<0.01	3
Manganese (dissolved)	3.65	60	1.9	1.00E-09	0.05	nd	1	1073	8320	172	200
Iron (total)	3.65	60	1.9	1.00E-09	0.05	nd	1	914	85722	1917	1000
Ammonia (total)	3.65	60	1.9	1.00E-09	0.05	nd	23.3	1073	NA	60	100
Arsenic (total)	3.65	60	1.9	1.00E-09	0.05	nd	1	1073	74.7	<0.01	50
Cadmium (dissolved)	3.65	60	1.9	1.00E-09	0.05	nd	116	1073	NA	<0.01	3.1
Selenium (dissolved)	3.65	60	1.9	1.00E-09	0.05	nd	1	1073	22.7	0.47	20
Zinc (total)	3.65	60	1.9	1.00E-09	0.05	nd	2.77	914	2630	59	2000

Notes

v Seepage Velocity; Based on site specific hydraulic conductivity (7.3 ft/day) , hydrailic gradient (0.05) and effective porsity (0.01) values

α_L Longitudinal dispersivity

ω Tortuosity coefficient

k First order decay coefficient (Howard et al. 1991)

R Retardation coefficient

ARAR Applicable or relevant and appropriate requirements

NA Not applicable

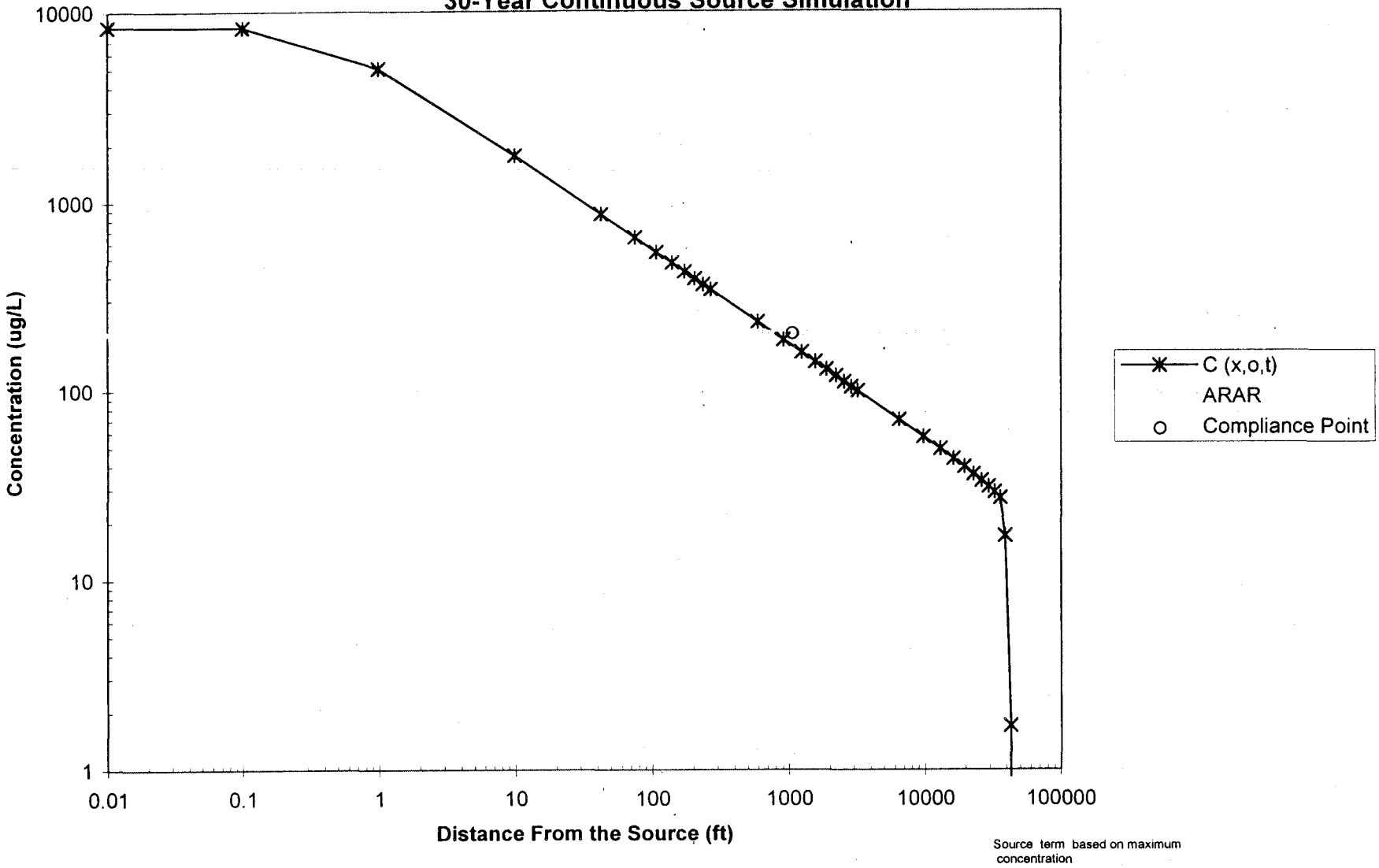
1 Transport distance (x) measured from the source to the compliance point

2 Source concentrations based on mean and maximum values at monitoring well 72293 or SW097;iron source concentration based on mean value at SW097

Source width boundaries: X=Y=Z=1

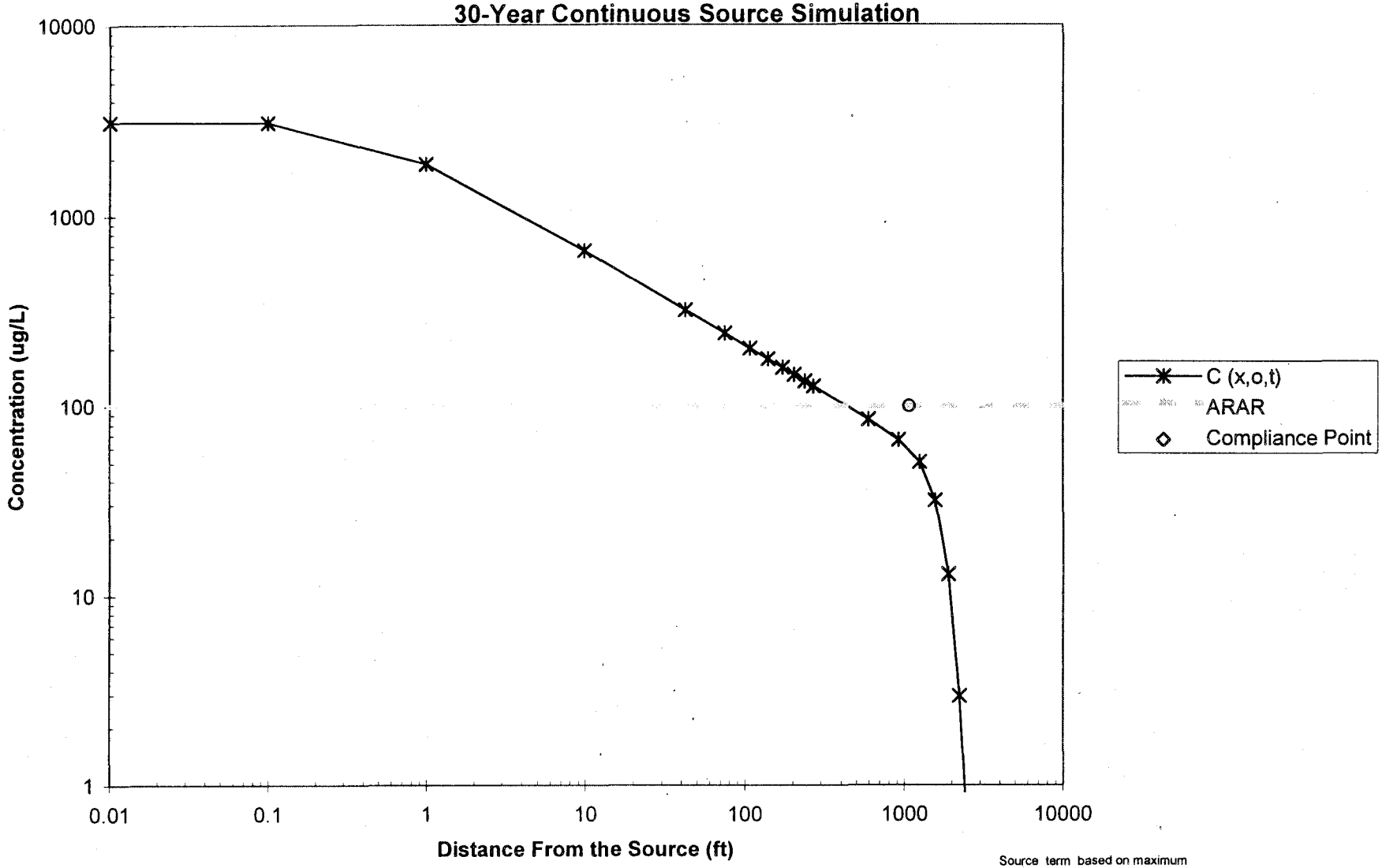
Shading indicates chemical exceeds ARAR at the compliance boundary

Figure D-2
Predicted Manganese Concentrations
30-Year Continuous Source Simulation



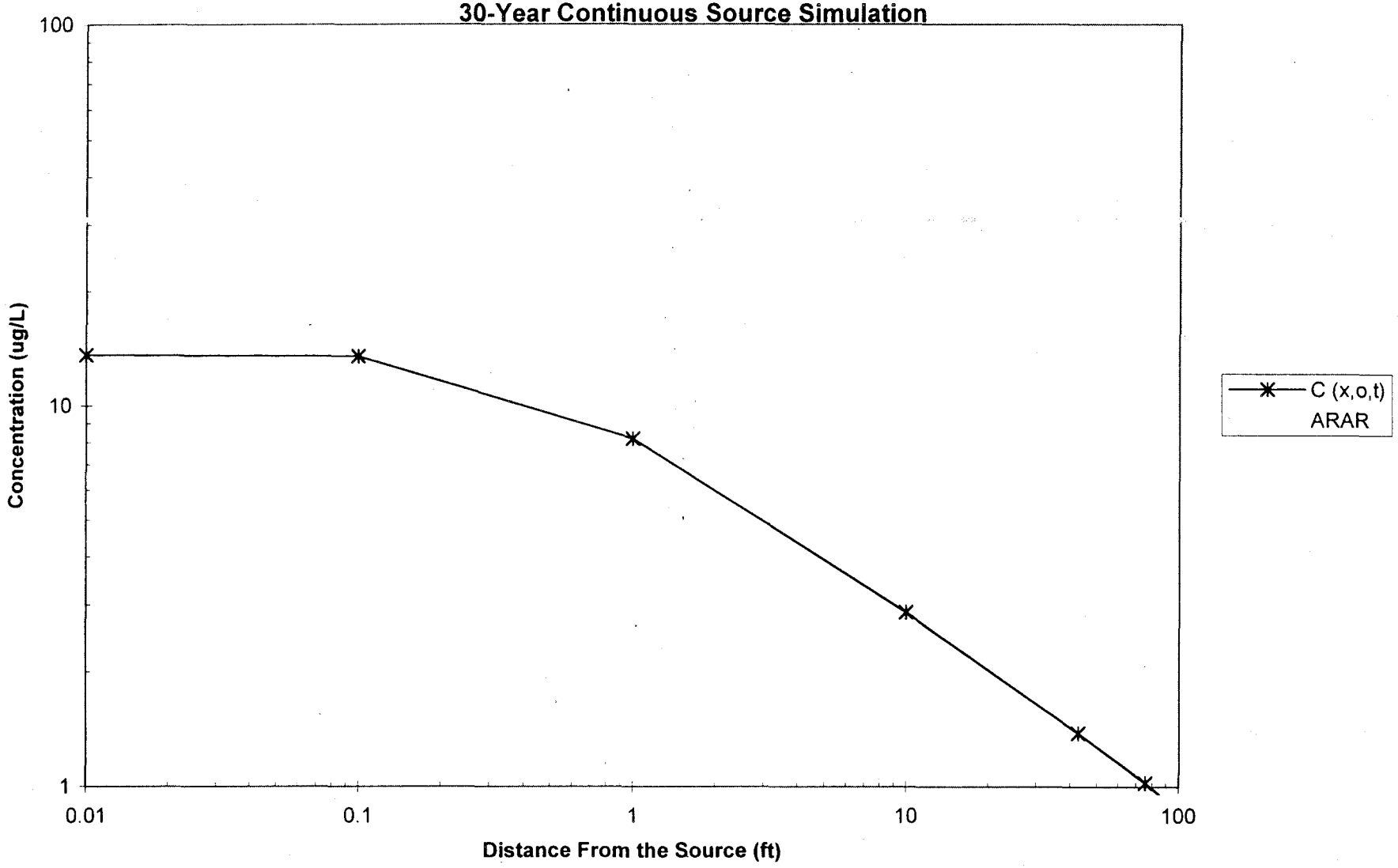
Source term based on maximum concentration

Figure D-3
Predicted Ammonia Concentrations
30-Year Continuous Source Simulation



Source term based on maximum concentration

Figure D-4
Predicted Cadmium Concentrations
30-Year Continuous Source Simulation



Source term based on maximum

Figure D-5
Predicted Zinc Concentrations
30-Year Continuous Source Simulation

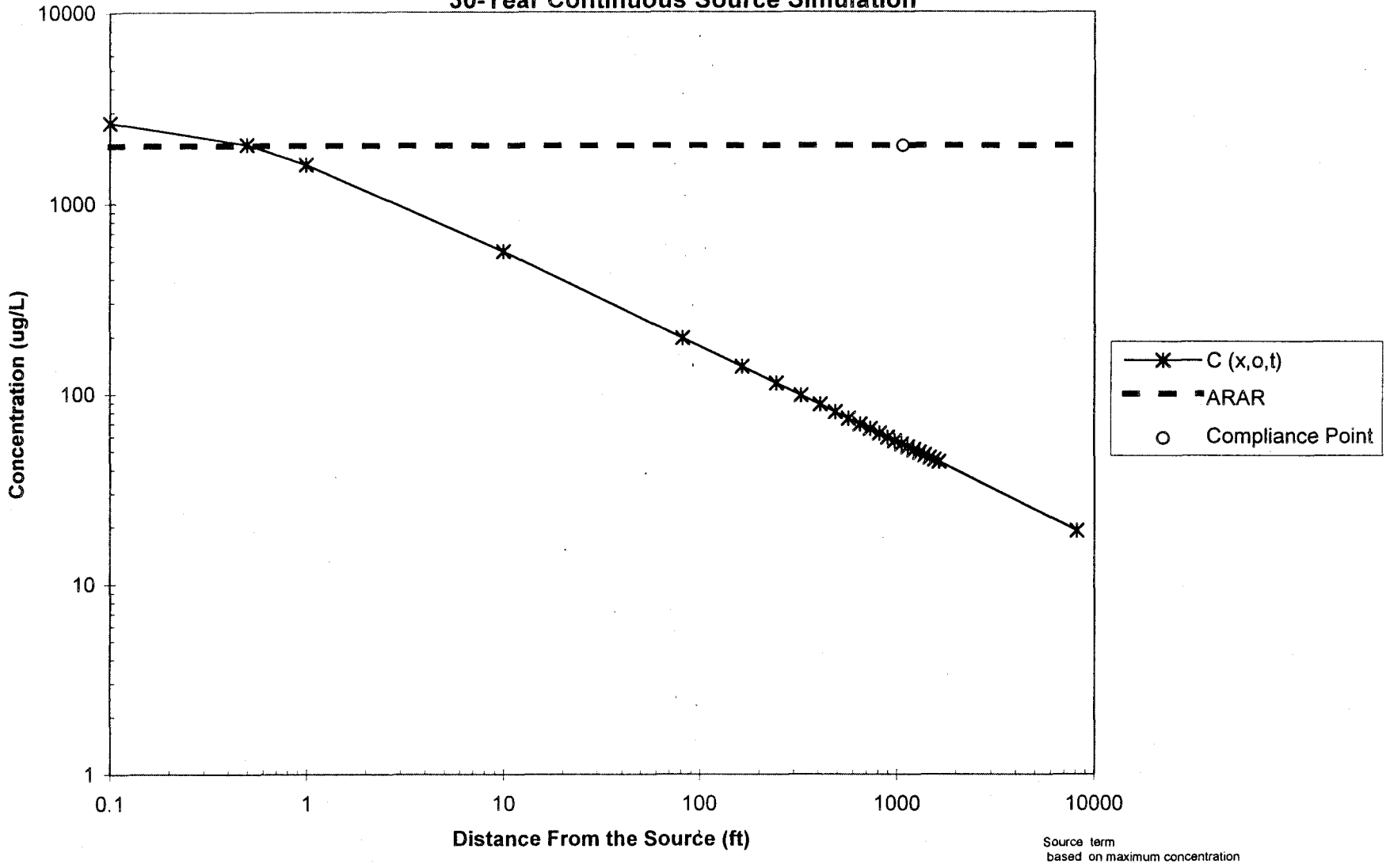
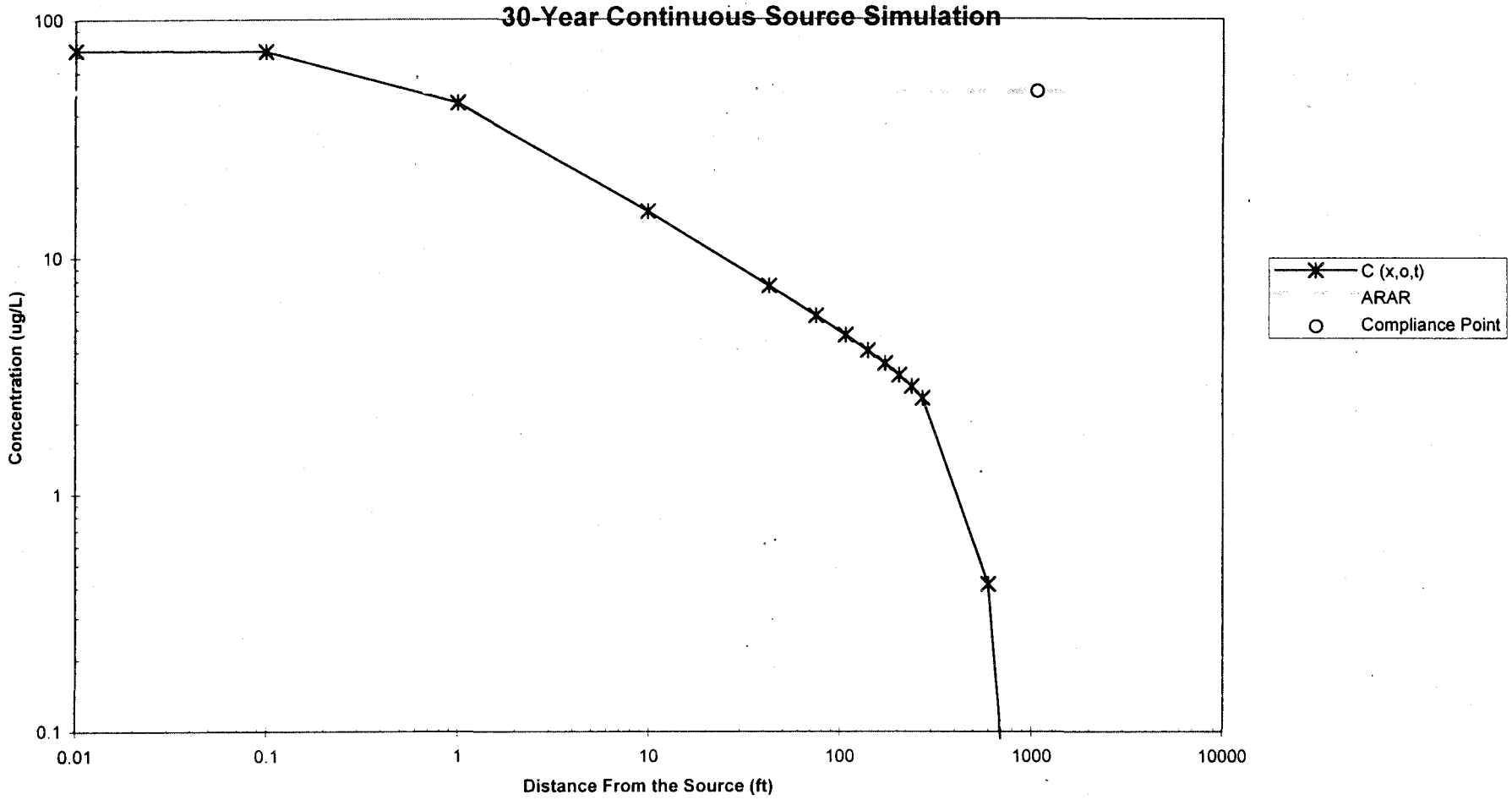
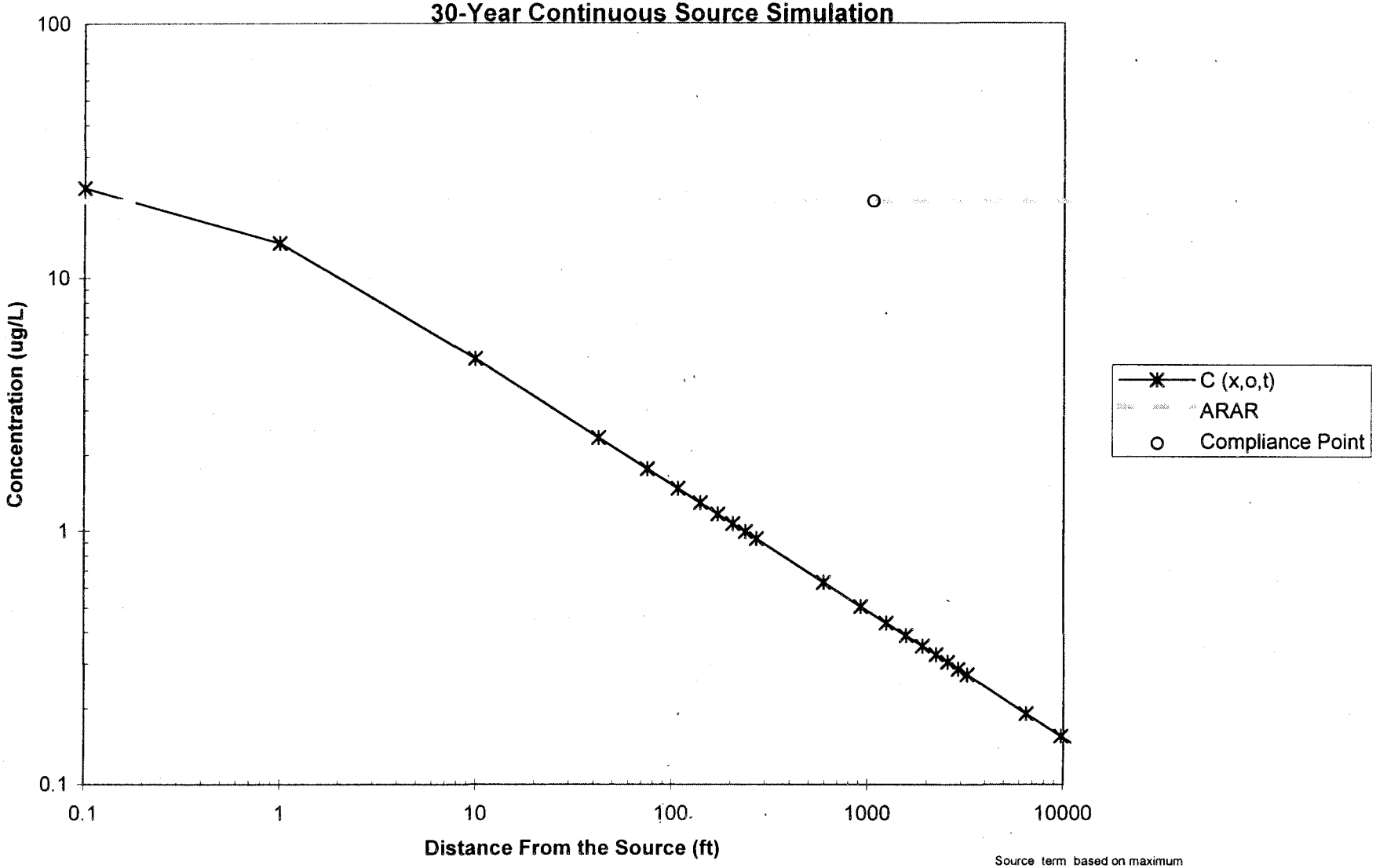


Figure D-6
Predicted Arsenic Concentrations
30-Year Continuous Source Simulation



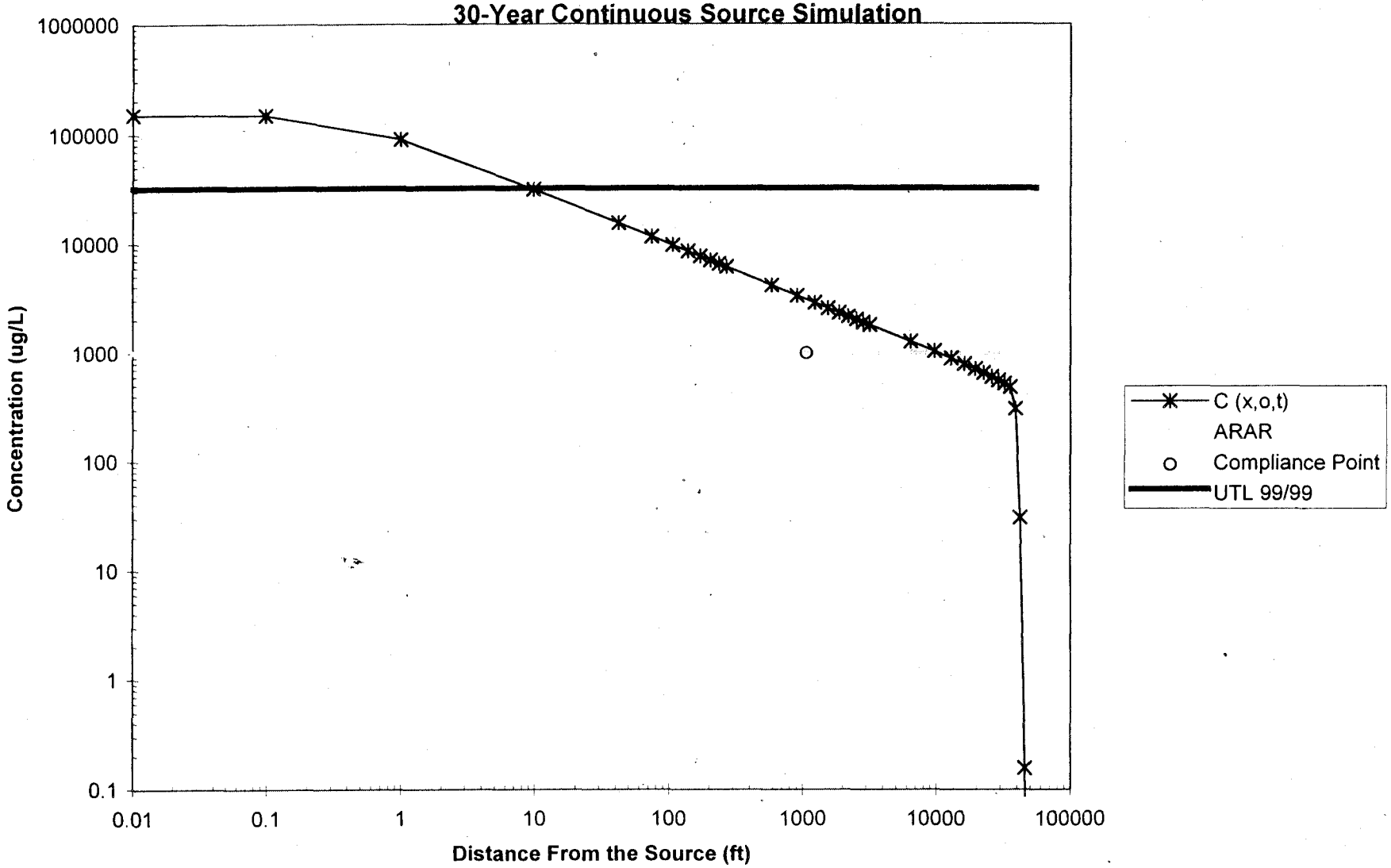
Source term based on maximum concentration

Figure D-7
Predicted Selenium Concentrations
30-Year Continuous Source Simulation



Source term based on maximum concentration

Figure D-8
Predicted Iron Concentrations
30-Year Continuous Source Simulation



Source term based on mean concentration

Figure D-9
Predicted Benzene Concentrations
30-Year Continuous Source Simulation

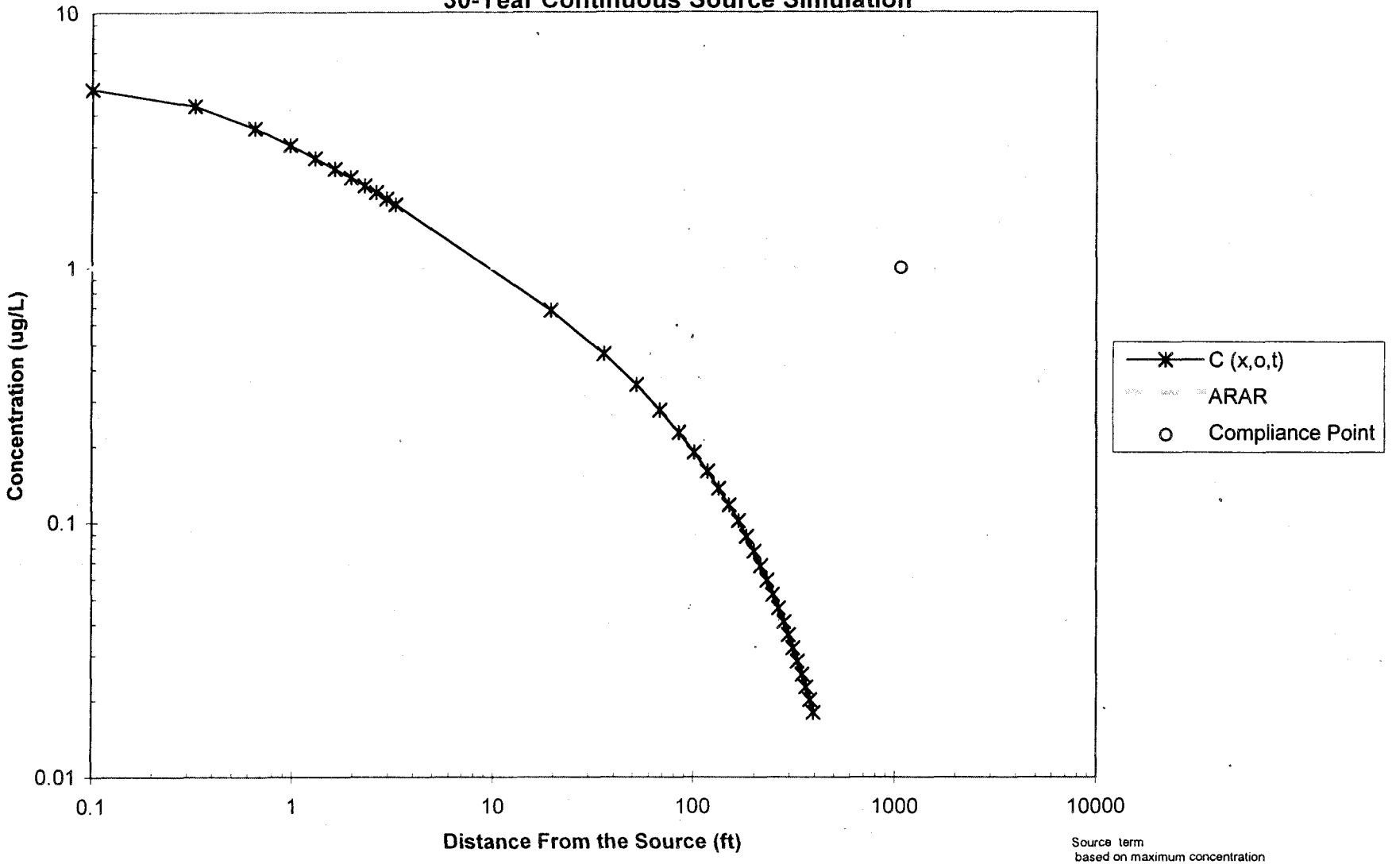
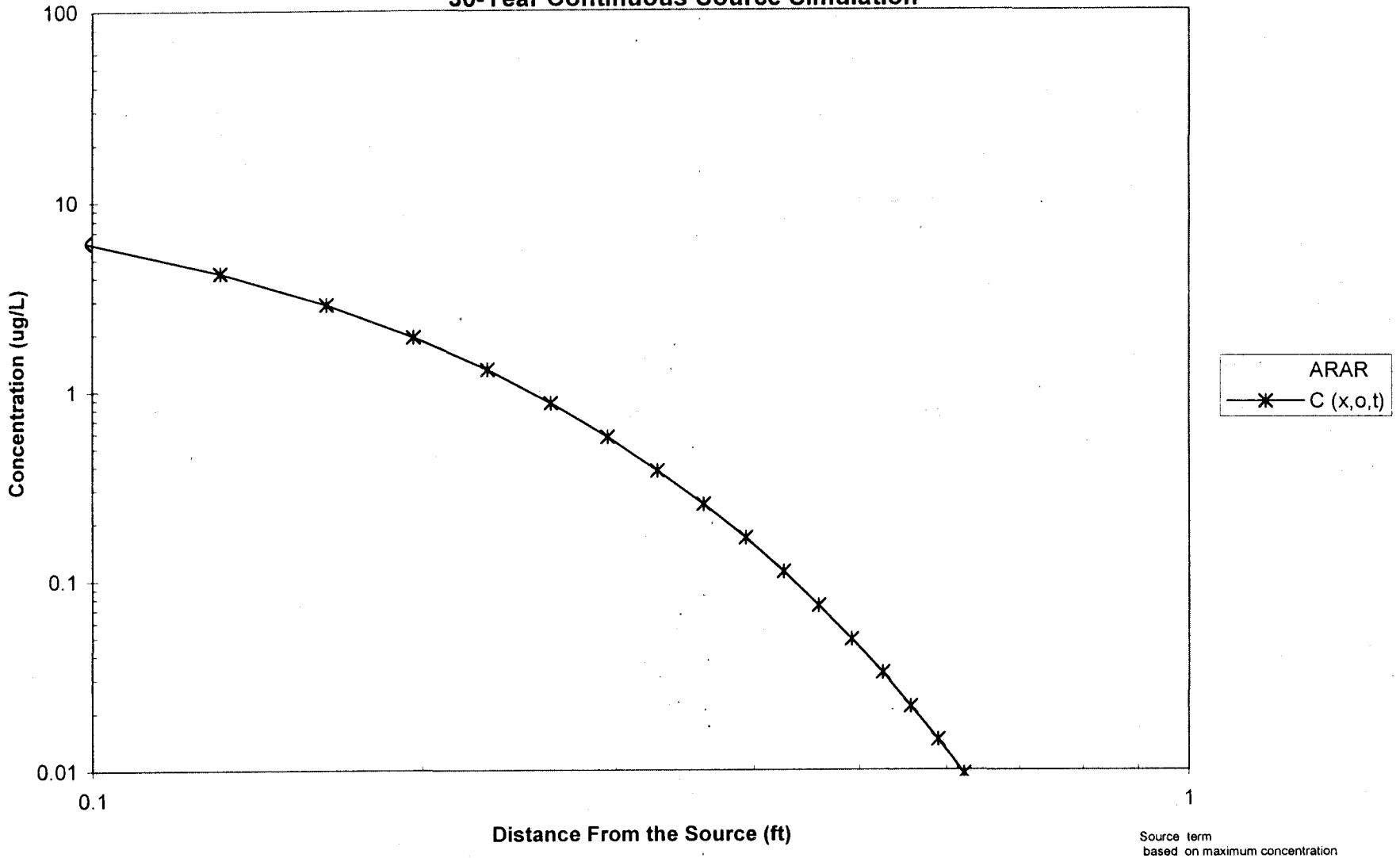


Figure D-10
Predicted Bis(2-Ethylhexyl)Phthalate Concentrations
30-Year Continuous Source Simulation



Source term
based on maximum concentration

Figure D-11
Predicted Methylene Chloride Concentrations
30-Year Continuous Source Simulation

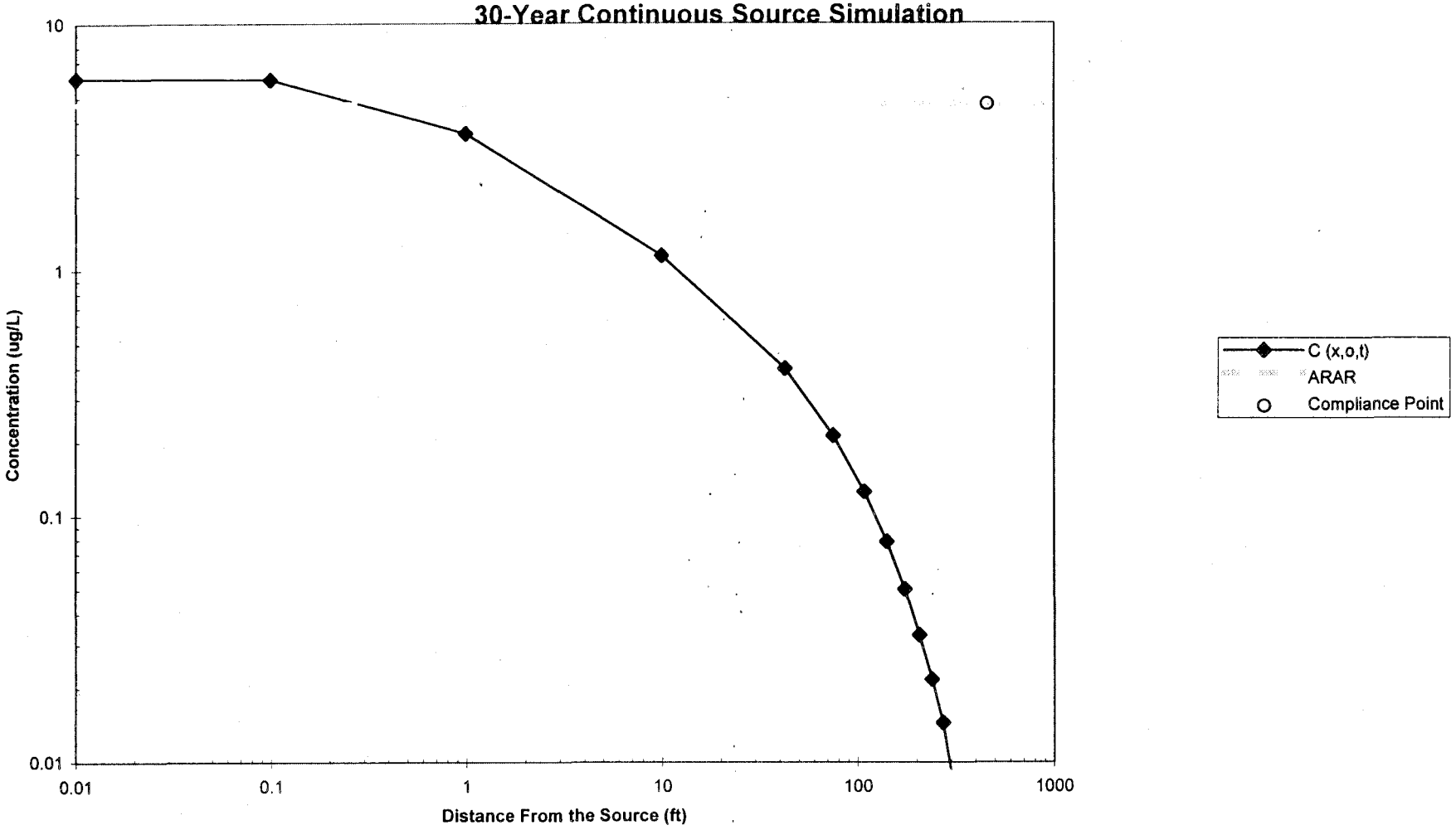
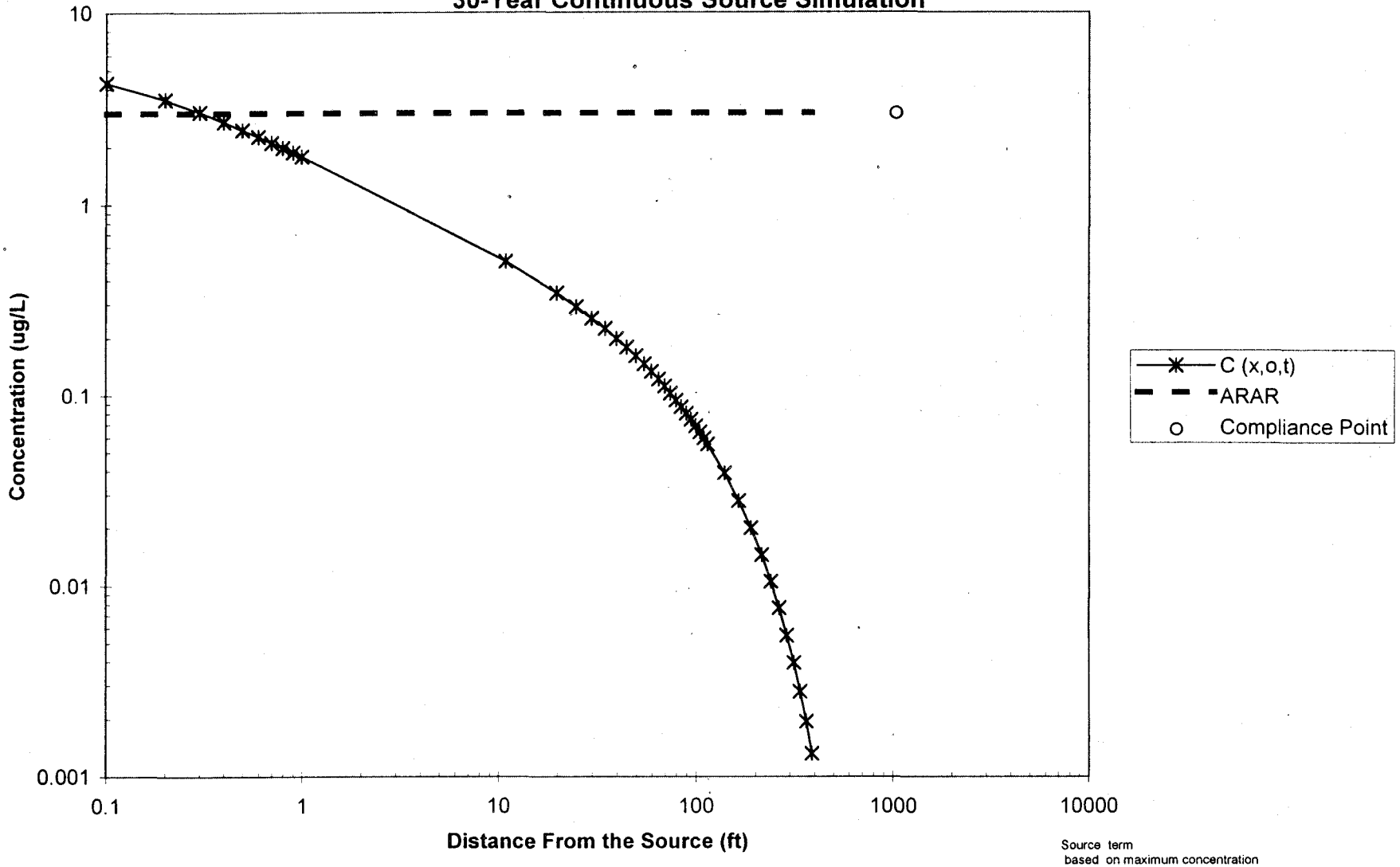


Figure D-12
Predicted Trichloroethene Concentrations
30-Year Continuous Source Simulation



Source term
based on maximum concentration

Figure D-13
Predicted Vinyl Chloride Concentrations
30-Year Continuous Source Simulation

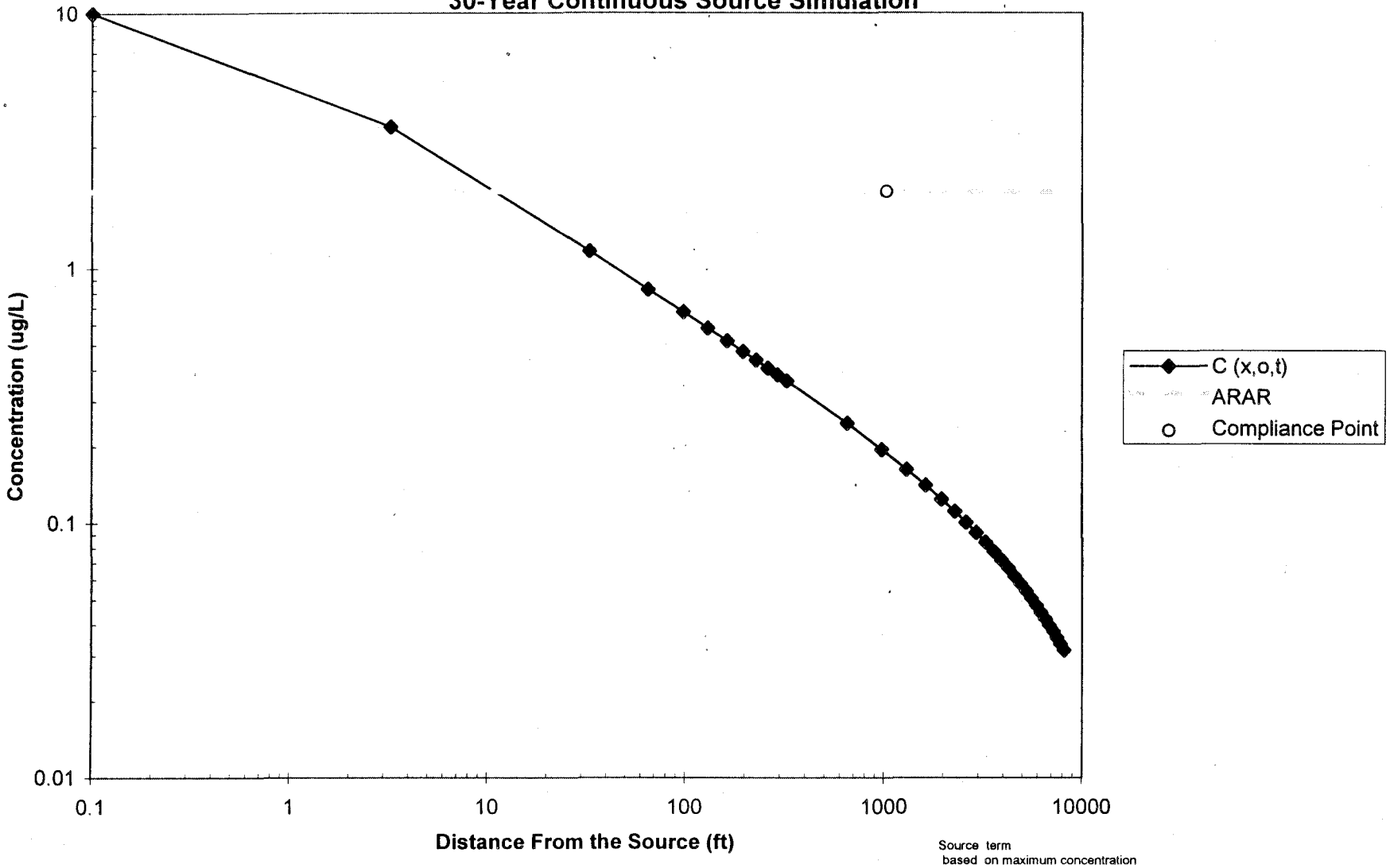
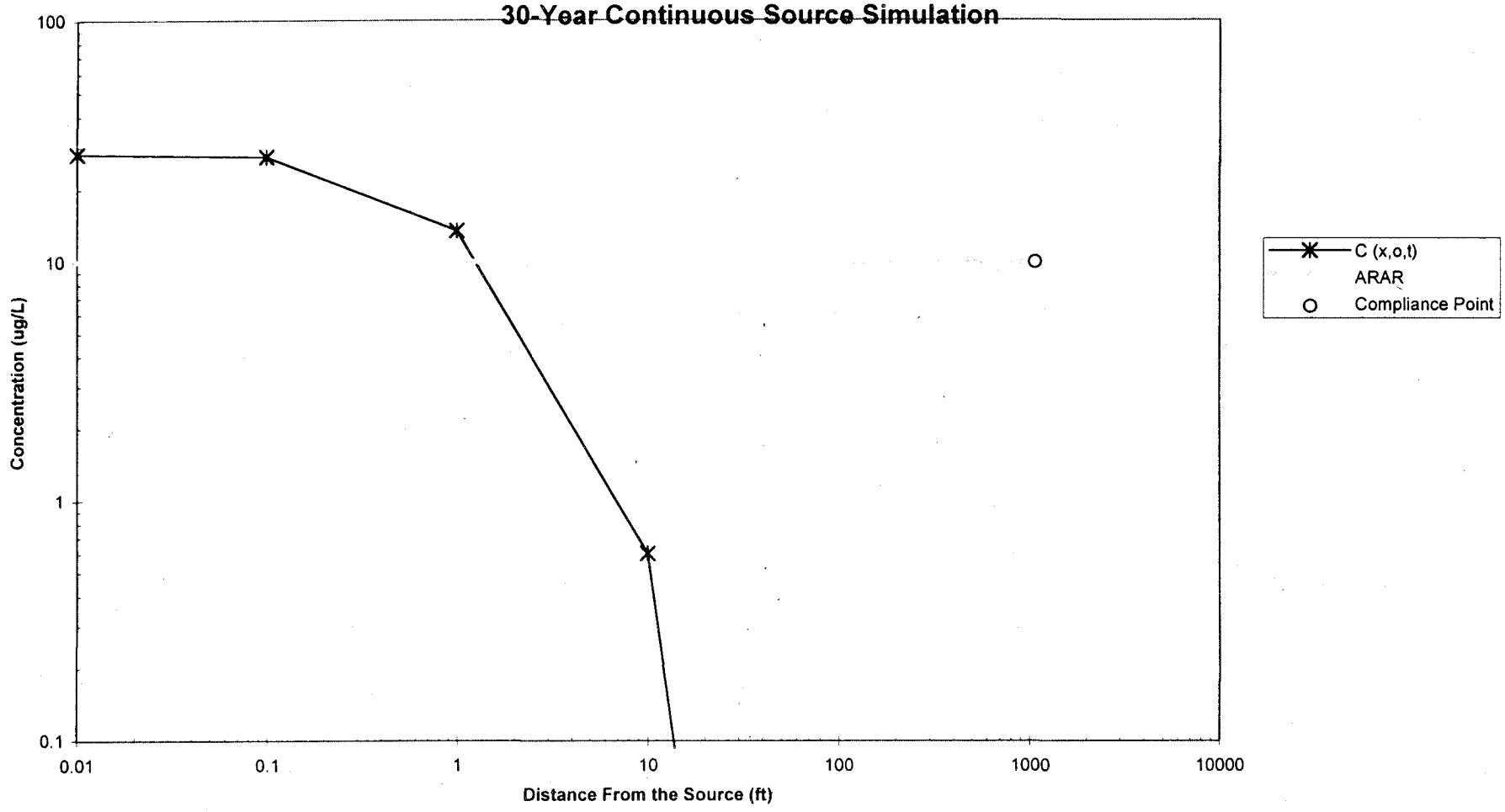


Figure D-14
Predicted Naphthalene Concentrations
30-Year Continuous Source Simulation



Source term based on maximum concentration

Table of Contents

E.1. PURPOSE OF THE ANALYSIS E-1

E.2. DESCRIPTION OF GRADING PLAN E-1

E.2.1 LANDFILL SETTLEMENT E-1

E.2.2 DIFFERENCES BETWEEN TYPICAL MUNICIPAL SOLID WASTE AND OU 7 WASTE E-1

E.3. METHODOLOGY E-2

E.3.1 PERCENT SETTLEMENT: E-3

E.3.2 SOWERS METHOD E-3

E.3.3 GIBSON AND LO MODEL E-4

E.3.4 POWER CREEP LAW E-5

E.4. RESULTS E-5

E.5. REFERENCES E-6

Tables

Table E-1 Settlement Method and Comparison

E.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.

E.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 ft 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.

E.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).

E.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 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 ft 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.

E.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 use change in overburden pressure, time of load application, and compressibility factors instead of change in void ratio in the general consolidation theory equation.

E.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.

E.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

$$S_s = H\, C_\alpha /(1+ e_0)\log(t_2/ t_1) \qquad \text{(E-1)}$$

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

$$C_{\alpha m} = C_\alpha/(1+e_0) \qquad \text{(E-2)}$$

Using this term, the Sowers equation then becomes

$$S_s = H\, C_{\alpha m}\log(t_2/t_1) \qquad \text{(E-3)}$$

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 ft 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 timeframe considered for secondary waste settlement is 30 years.

E.3.3 GIBSON AND LO MODEL

The Gibson and Lo model for refuse is as follows (Sharma and Lewis 1994)

$$S(t) = H\,\Delta\sigma\,\{a + b[1-\exp(-\lambda/b)]\} \qquad \text{(E-4)}$$

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, $\Delta\sigma$. Because 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:

$$\mathrm{Ln}(a) = -\,0.03442\,(\Delta\sigma) - 7.155 \qquad \text{(E-5)}$$

$$\mathrm{Ln}(b) = -\,0.01386\,(\Delta\sigma) - 4.8283 \qquad \text{(E-6)}$$

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.

E.3.4 POWER CREEP LAW

The power creep law presented is expressed in the following form (Sharma and Lewis 1994)

$$S(t) = H\,\Delta\sigma\,m\,(t_r/t\}^n \qquad \text{(E-7)}$$

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

$$m = 3.4 \times 10^{-5}\ (1/\text{kPa}) \qquad \text{(E-8)}$$

$$n = 0.65 \qquad \text{(E-9)}$$

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.

E.4. RESULTS

Table E-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 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 ft (percent method) to 2.19 ft (Sowers method). If the 5.5 ft 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).

E.5. REFERENCES

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Table E-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%
5'-5	1	7	1.05	15.00%	0.41	5.91%	0.19	2.65%	0.32	4.54%

Table E-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
(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 (Fesset *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) - 4.8283) (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^{-3} (1/kPa)
- Use: n = 0.65: average value (Edil 1990)

Table of Contents

F.1. ENGINEERED COVER PERFORMANCE MODELING F-1

F.1.1 SOIL INPUT F-2

F.1.2 SITE-SPECIFIC SOIL CHARACTERISTICS F-3

F.1.3 COVER DESIGN INPUT DATA F-5

F.1.4 CLIMATE-RELATED INPUT PARAMETERS F-5

F.1.5 PRECIPITATION INPUT F-5

F.1.6 GROWING SEASON F-5

F.1.7 EVAPOTRANSPIRATION INPUT F-6

F.1.7.1 Evaporative Zone Depth F-6

F.1.7.2 Maximum Leaf Area Index F-6

F.1.8 LATITUDE F-7

F.1.9 SUMMARY F-7

F.2. REFERENCES F-7

Tables

Table F-1 Summary of HELP Input Data - OU 7 Cover Sections

Table F-2 Installation Defects

Table F-3 Leakage Rates vs. Defects

Table F-4 Temperature Data Summary

Table F-5 Precipitation Data

Table F-6 Summary of HELP Modeling Results

Figures

Figure F-1 Schematic Profile View of a Typical Hazardous Waste Landfill

Figure F-2 OU 7 Cover Options Analyzed with the HELP Model

List of Attachments
Help Output Files

F1 - Final HELP Output Files for Cover Sections 1–9

Figure 1 HELP Run - Cover Alternative 1 & 2 Input Summary

Figure 2 HELP Run - Cover Alternative 3 Input Summary

Figure 3 HELP Run - Cover Alternative 4 Input Summary

Figure 4 HELP Run - Cover Alternative 5 Input Summary

Figure 5 HELP Run - Cover Alternative 6 Input Summary

Figure 6 HELP Run - Cover Alternative 7 Input Summary

Figure 7 HELP Run - Cover Alternative 8 Input Summary

Figure 8 HELP Run - Cover Alternative 9 Input Summary

F2 - HELP Output Files for Cover Section 3, Drainage Layer Slope Sensitivity

F3 - HELP Output Files for Cover Section 1, Evaporative Depth Sensitivity Study

F4 - HELP Output Files for Cover Section 2, Evaporative Depth Sensitivity Study

F5 - HELP Output Files for Cover Section 3, Evaporative Depth Sensitivity Study

F6 - HELP Output Files for Cover Section 2, Leaf Area Index Sensitivity

F7 - HELP Output Files for Cover Section 3, Leaf Area Index Sensitivity

F.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 F-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 F-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 F1.

F.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

F.1.1.1 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.

1. The user can enter the CN directly

2. The user can enter the CN for a soil type and have HELP modify it for a given slope and slope length

3. 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 F2.

F.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 F-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 in.) 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 F-2.

There are six options in the HELP model to describe the contact between the geomembrane and the underlying soil.

- 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 F-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 ft, 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.

F.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 ft

F.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 F-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.

F.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 F-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.

F.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)

F.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.

F.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 in. (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 in. and 14 in. 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 in. was used to simulate fair vegetation. A sensitivity analysis of the effects of evaporative zone depth was performed and is presented in Attachments F5, F6, and F7. The results of this analysis show that an evaporative zone depth of 28 in. is reasonable in that it does not allow excess percolation of water through the vegetative layer nor does it restrict percolation to a minimum.

F.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 as follows:

- 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 F2 and F3. 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.

F.1.8 LATITUDE

The latitude used for solar radiation data generation for normal conditions is 39.77 degrees North, the latitude of Denver, Colorado.

F.1.9 SUMMARY

Results of the HELP modeling runs for each cover section option are summarized in Table F-6.

F.2. REFERENCES

ASI (Advanced Sciences, Inc.), 1991, *Stormwater Runoff Quantity for Various Design Events*, Rocky Flats Plant, January.

EG&G Rocky Flats, Inc., 1992, *Rocky Flats Plant Site Environmental Report for 1992.*

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.

Schroeder, P. R., T. S. Dozier, P. A. Zappi, B. M. McEnroe, J. W. Sjostrom, and R. L. Peyton, 1994a, *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3 EPA/600/R-94/168b*, September 1994, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, Ohio.

Schroeder, P. R., N. M. Aziz, C. M. Lloyd, and P. A. Zappi, 1994b, *The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3, EPA/600/R-94/168a*, September 1994, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, Ohio.

Table F-1 Summary of HELP Input Data - OU 7 Cover Sections

Layer Description	HELP Default Soil Number	Thickness (in.)	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
3 Soil layer permeability modified to 1x10-5 cm/sec

Definitions

cm/sec centimeter per second
GCL geosynthetic clay liner
FMC flexible membrane cover

Table F-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 F-3 Leakage Rates vs. Defects

HDPE Liner Installation Defects per Acre	Leakage Rate (cubic ft/acre/year) Corresponding With Different Underlying Soils			
	$3x10^{-9}$ cm/sec GCL	$1x10^{-7}$ cm/sec Clay Soil	$1x10^{-4}$ cm/sec Clay Soil	FMC with no underlying soil
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	68.077	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

Table F-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 F-5 Precipitation Data

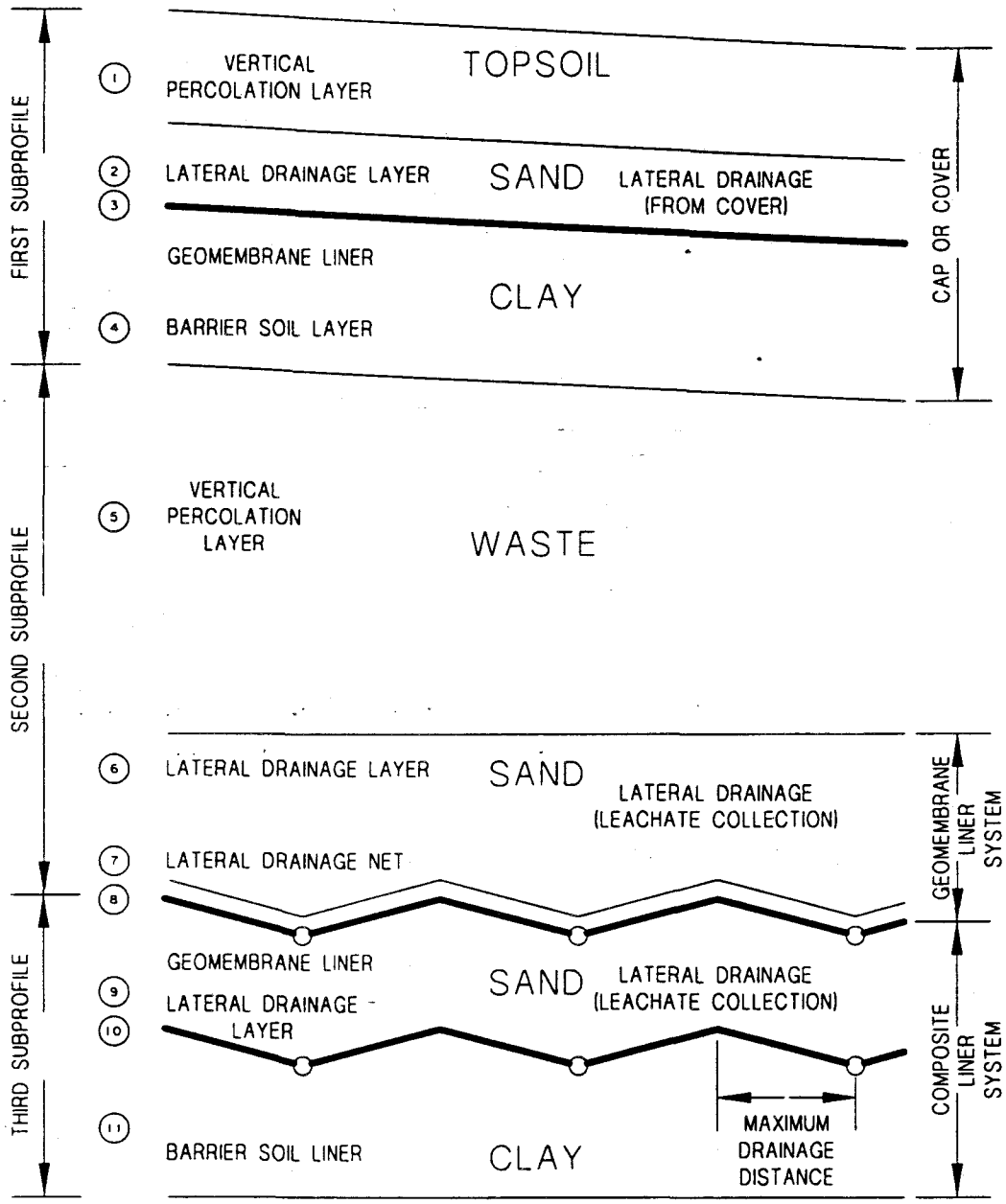
Month	Normal (Mean) Monthly Precipitation at Rocky Flats (in.)	Average Monthly Precipitation Input into HELP (in.)	Synthetically Generated Average (30 year) Monthly Precipitation Output from HELP (in.)
JAN	0.46	0.60	0.46
FEB	0.48	0.43	0.48
MARCH	1.22	1.33	1.22
APRIL	1.13	1.80	1.13
MAY	2.74	3.32	2.75
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**

Table F-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	5.848	5.849	5.849
Leakage[1]	1.4×10^{-0}	1.1×10^{-0}	1.0×10^{-0}	2.1×10^{-2}	3.5×10^{-2}	1.6×10^{-4}	2.0×10^{-8}	1×10^{-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 (in.)



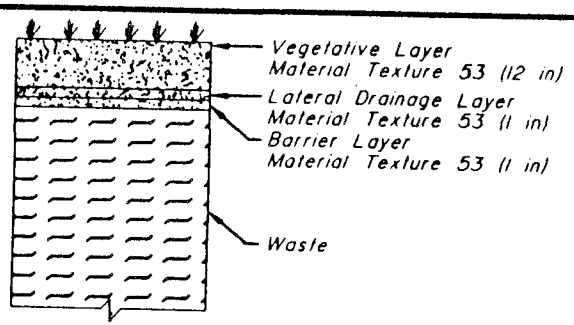
Project No	Design By:	Scale:
601	P. Corser	NA
File	Drawn By:	Date
Fig1.DWG	W. Parker	April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road P.O. Box 774018
Steamboat Springs, Colorado 80477

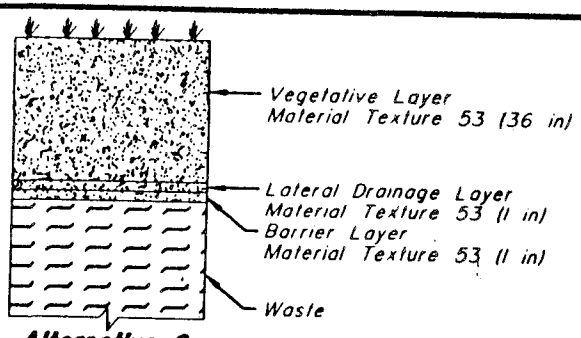
Figure F-1

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

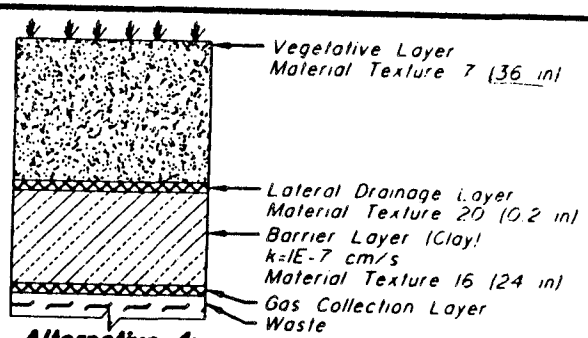
Schematic Profile View of a Typical Hazardous Waste Landfill



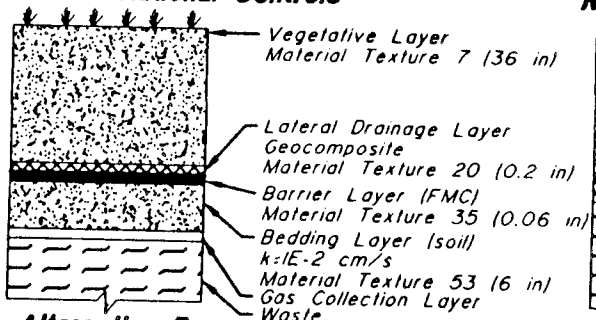
Alternative 1: No Action
Alternative 2: Institutional Controls



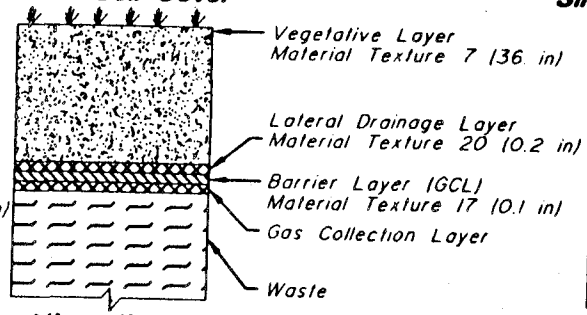
Alternative 3: Native Soil Cover



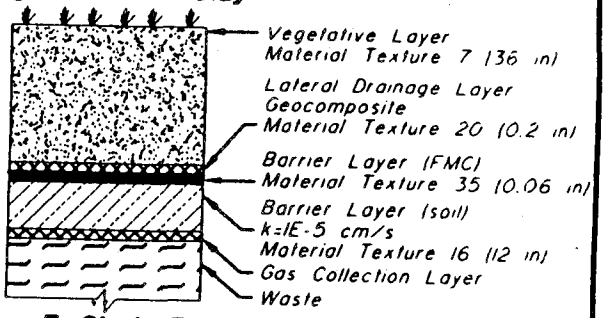
Alternative 4: Single Barrier - Clay



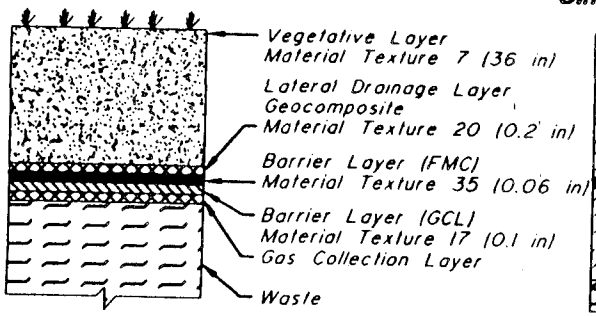
Alternative 5: Single Barrier FMC



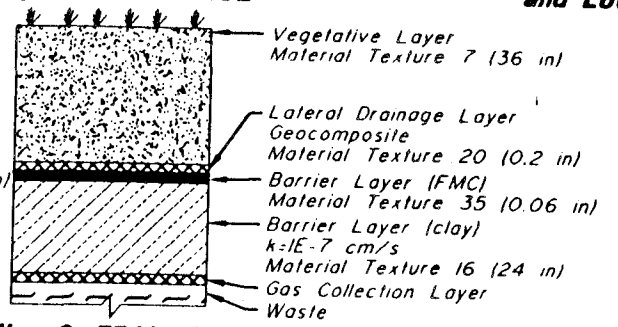
Alternative 6: Single Barrier - GCL



Alternative 7: Single Barrier-FMC and Low Permeability Soil



Alternative 8: Composite Barrier - FMC and GCL



Alternative 9: EPA's Composite Barrier - FMC and Clay

Project No.: 601	Design By: P. Corser	Scale: NA
File: COVERS.DWG	Drawn By: P. Pellicer	Date: April 19, 1995

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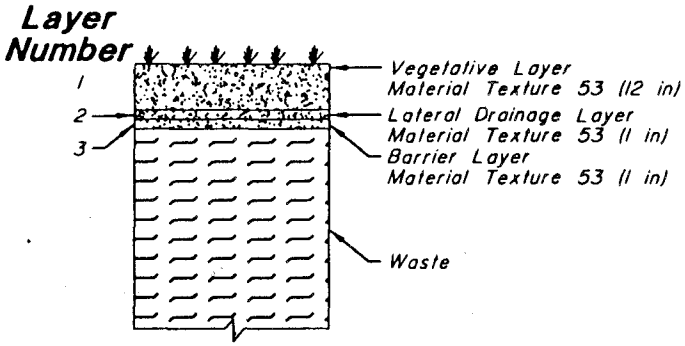
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure F-2

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

OU7 Cover Options Analyzed With The HELP Model



Cover Alternative 1 & 2 (Existing Conditions & Institutional Controls)

Input Parameters

- ☒ 1. Vegetative Cover Soil, Texture 53, k=1E-2 cm/s
- ☒ 2. Lateral Drainage Layer, Texture 53, k=1E-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=1E-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:	0.033	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	Design By	Scale
601	P. Corser	NA
File	Drawn By	Date
COVER1.DWG	P. Pellicer	April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 1

U.S. 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              **
******************************************************************************
******************************************************************************

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
```

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)

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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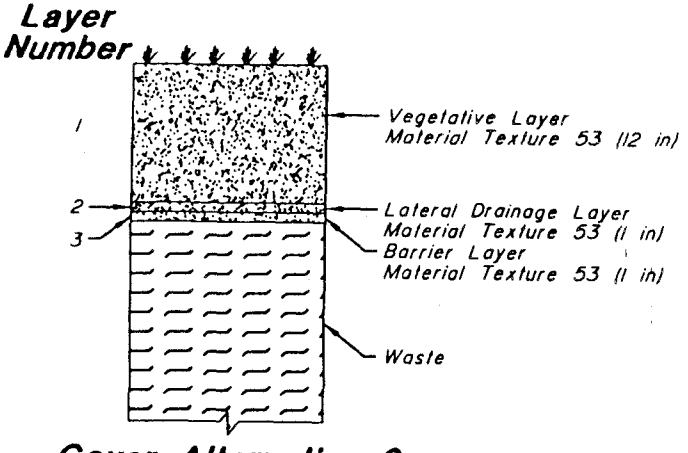
FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	0.3314	0.0276
2	0.0240	0.0240
3	0.4370	0.4370
SNOW WATER	0.000	

****
****



Cover Alternative 3
Native Soil Cover

Input Parameters

- ☒ 1. Vegetative Cover Soil, Texture 53, k=1E-2 cm/s
- ☒ 2. Lateral Drainage Layer, Texture 53, k=1E-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=1E-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.	Design By	Scale
601	P. Corser	NA
File	Drawn By	Date
COVER9.DWG	P. Pellicer	April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 2

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

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
```

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

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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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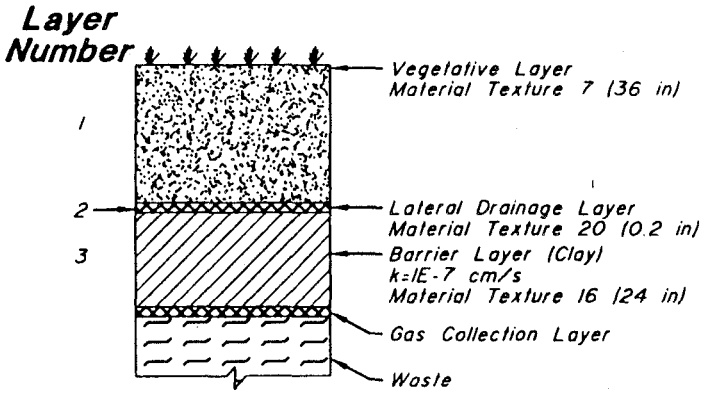
****



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=1E+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=1E-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:	4.809	0.294
Leakage:	1.0398 [3774.7]	0.0034 [12.41]
Head on Barrier Layer:	0.006	0.13

Project No.	Design By	Scale
601	P. Corser	NA
File	Drawn By	Date
COVER4.DWG	P. Pellicer	April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 3

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

HELP Run - Cover Alternative 4 Input Summary

```
******************************************************************************
******************************************************************************
**              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

****

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

****

****

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	

****
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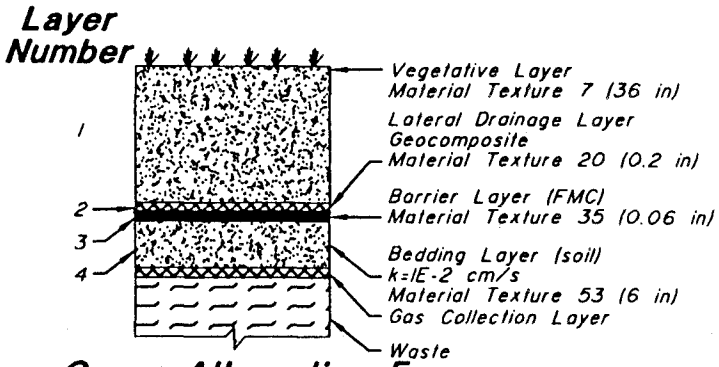

Cover Alternative 5
Single Barrier - FMC

Input Parameters

- ☒ 1. Vegetative Cover Soil, Texture 7, k=5E-4 cm/s
- ☒ 2. Lateral Drainage Layer, Texture 20, k=1E+1 cm/s
  Slope=2%, Length=500 ft
- ☒ 3. FMC, Texture 35, k=1E-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=1E-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) (ft^3)	Peak Daily (in) (ft^3)
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. 601	Design By P. Corser	Scale NA
File COVER5.DWG	Drawn By P. Pellicer	Date April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 4

U.S. 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
```

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

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

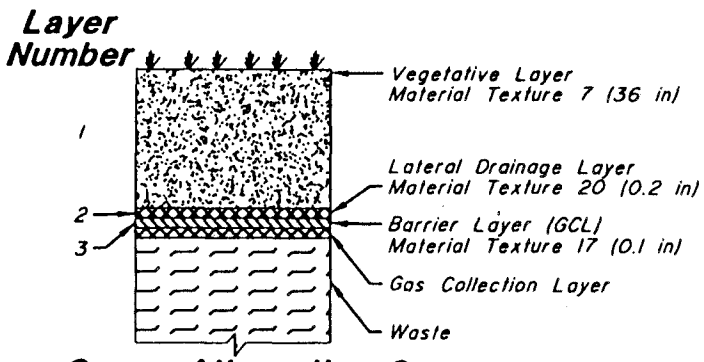
****

****

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	

****



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=1E+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 (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.: 601	Design By: P. Corser	Scale: NA
File: COVER6.DWG	Drawn By: P. Pellicer	Date: April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 5

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

HELP Run - Cover Alternative 6 Input Summary

```
******************************************************************************
******************************************************************************
**              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
```

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

****

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

****
****

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

****

****

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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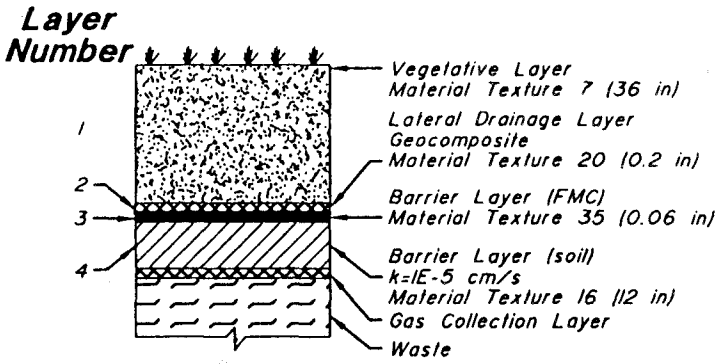

Cover Alternative 7
Single Barrier - FMC
and Low Permeability Soil

Input Parameters

- ☒ 1. Vegetative Cover Soil, Texture 7, k=5E-4 cm/s
- ☒ 2. Lateral Drainage Layer, Texture 20, k=1E+1 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=1E-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) (ft^3)	Peak Daily (in) (ft^3)
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
File: COVER7.DWG	Drawn By: P. Pellicer	Date: April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 6

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

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
```

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	1.73	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 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

****
****

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

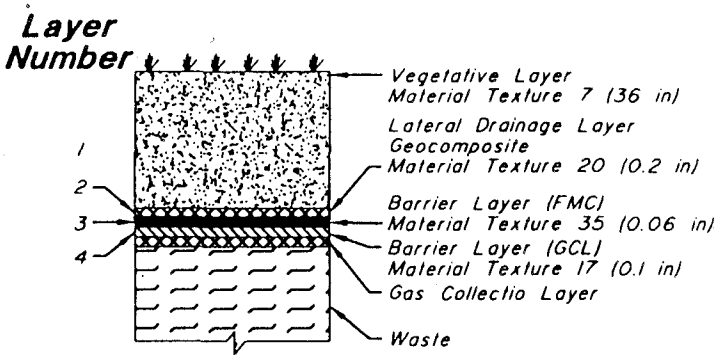
****

****

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	

****
****



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=1E+1 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

Project No.: 601	Design By: P. Corser	Scale: NA
File: COVER68.DWG	Drawn By: P. Pellicer	Date: April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 7

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

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
```

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	=	4.040	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

****

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	974.4993
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)	0.2542
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	0.1500	0.7500
SNOW WATER	0.000	

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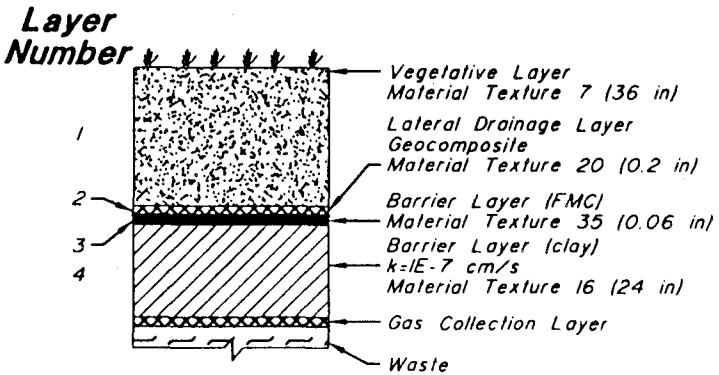

Cover Alternative 9
EPA's Composite Barrier
FMC and Clay

Input Parameters

- ☒ 1. Vegetative Cover Soil, Texture 7, k=5E-4 cm/s
- ☒ 2. Lateral Drainage Layer, Texture 20, k=1E+1 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=1E-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 No: 601	Design By: P. Corser	Scale: NA
File: COVER9.DWG	Drawn By: P. Pellicer	Date: April 19, 1995

TerraMatrix
Engineering & Environmental Services
1475 Pine Grove Road, P.O. Box 774018
Steamboat Springs, Colorado 80477

Figure 8

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

HELP Run - Cover Alternative 9 Input Summary

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******************************************************************************
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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
```

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

****

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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	(1.23904)	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

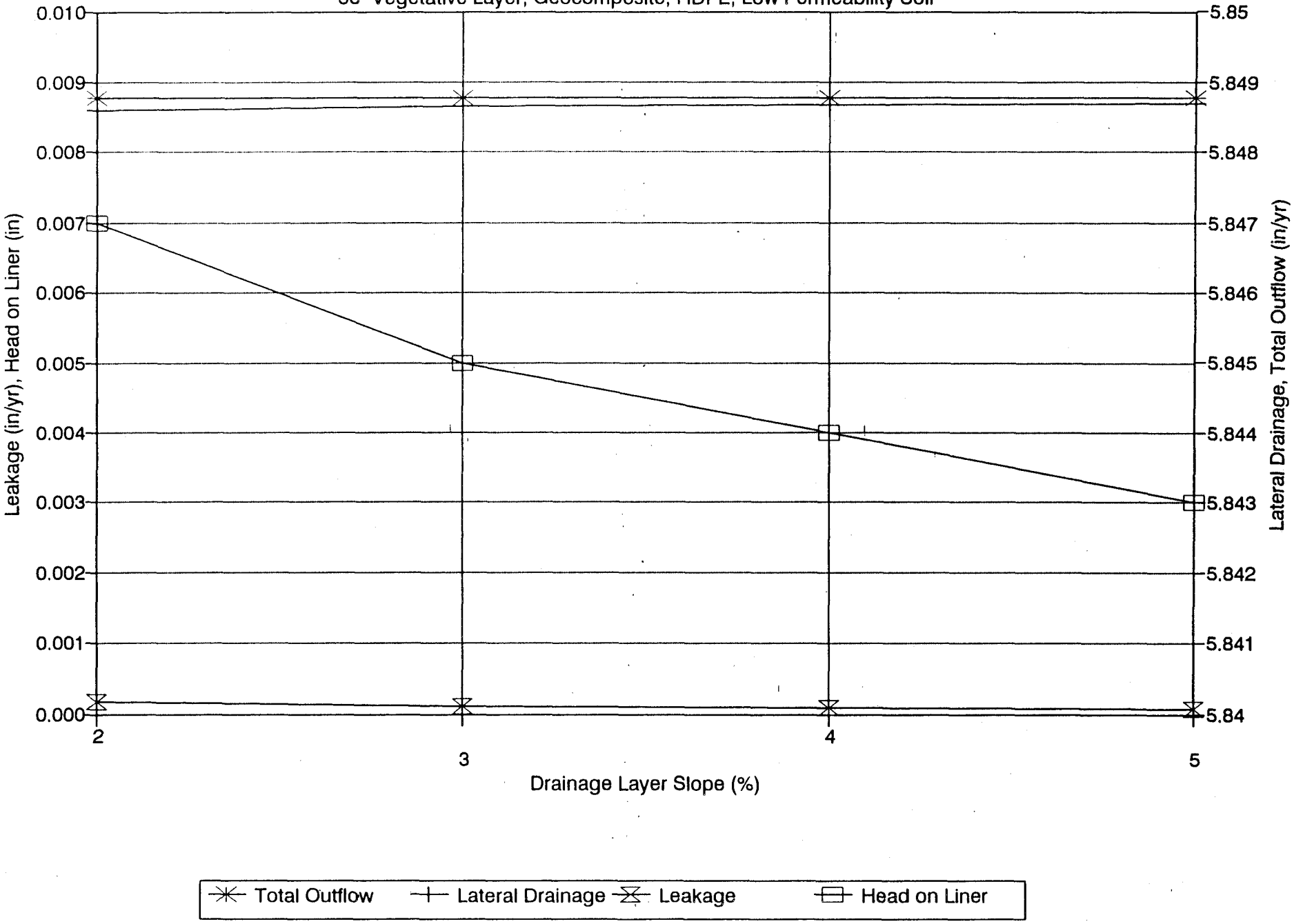
LAYER	(INCHES)	(VOL/VOL)
1	5.4640	0.1518
2	0.0060	0.0302
3	0.0000	0.0000
4	10.2480	0.4270
SNOW WATER	0.000	

****
****

Attachment F2
HELP Output Files for Cover Section 3
Drainage Layer Slope Sensitivity

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

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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              **
******************************************************************************
******************************************************************************

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


******************************************************************************

     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.	=	0.9999999975000E-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

****

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)

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

****

****

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              **
******************************************************************************
******************************************************************************

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

******************************************************************************

     TITLE:  LDL SLOPE SENSITIVIY ANALYSIS SEC3  FILE:  SSEC3_4

******************************************************************************

     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
```

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)

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 SENSITIVIY 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

****

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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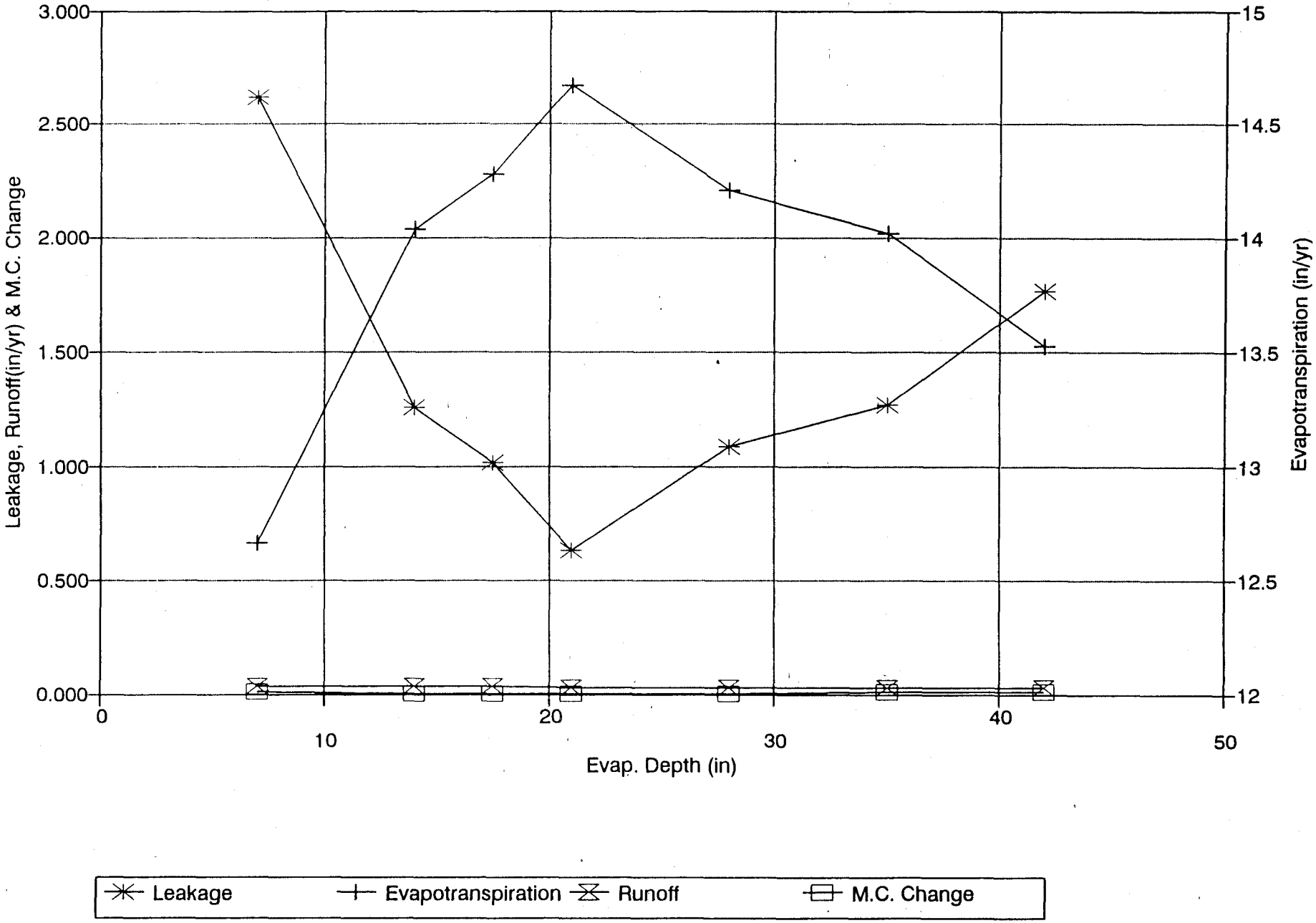
Attachment F3
HELP Output Files for Cover Section 1
Evaporative Depth Sensitivity Study

SECTION 1 EVAP. DEPTH SENSITIVITY

42" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer



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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:  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   =      0.0765 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

****

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	0.0468	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


******************************************************************************

     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)

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
	0.83	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	0.065	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
```

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	0.003
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	0.0304	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)

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)

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
```

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

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	0.1426
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

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              **
******************************************************************************
******************************************************************************

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

******************************************************************************

     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
```

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)

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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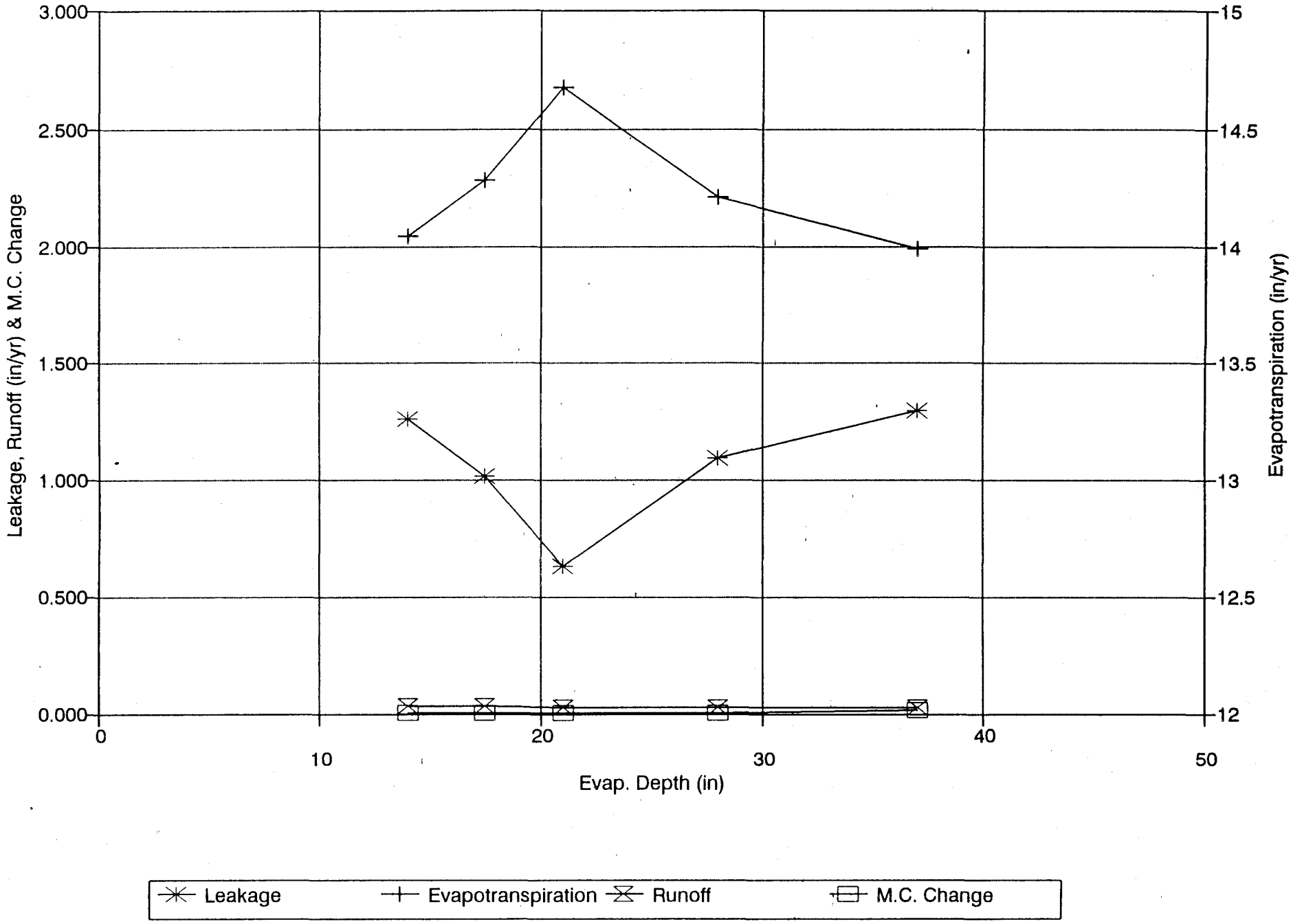
Attachment F4
HELP Output Files for Cover Section 2
Evaporative Depth Sensitivity Study

SECTION 2 EVAP. DEPTH SENSITIVITY

36" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer



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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\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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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

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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	0.202	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

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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)	0.001	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

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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	0.00302
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

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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              **
******************************************************************************
******************************************************************************

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


******************************************************************************

     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
```

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

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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	0.0366	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

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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\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


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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 =      0.0295 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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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

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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	0.000
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)

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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**              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)

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              **
******************************************************************************
******************************************************************************

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:  OU7 EVAP. DEPTH SENSITIVETY ANALYSIS  FILE: SEC2

******************************************************************************

    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
```

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
	1.517	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	0.0328	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)

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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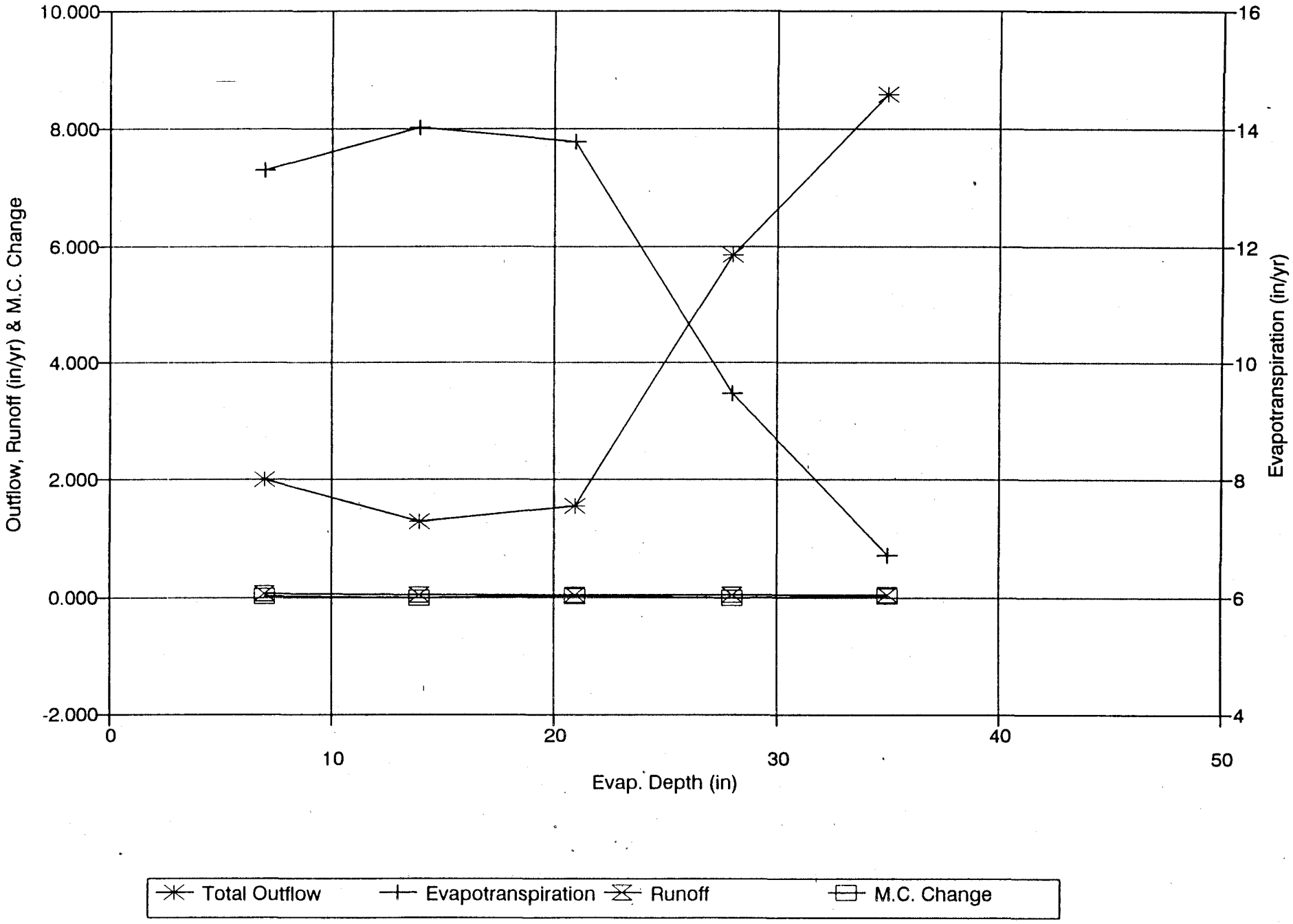
Attachment F5
HELP Output Files for Cover Section 3
Evaporative Depth Sensitivity Study

SECTION 3 EVAP. DEPTH SENSITIVITY

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             **
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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
```

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

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	0.008	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)

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              **
******************************************************************************
******************************************************************************

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
```

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

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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 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 =      0.1532 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

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	0.023	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	0.0667	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)

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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**              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

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	0.017	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)

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

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	0.014	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	0.2100	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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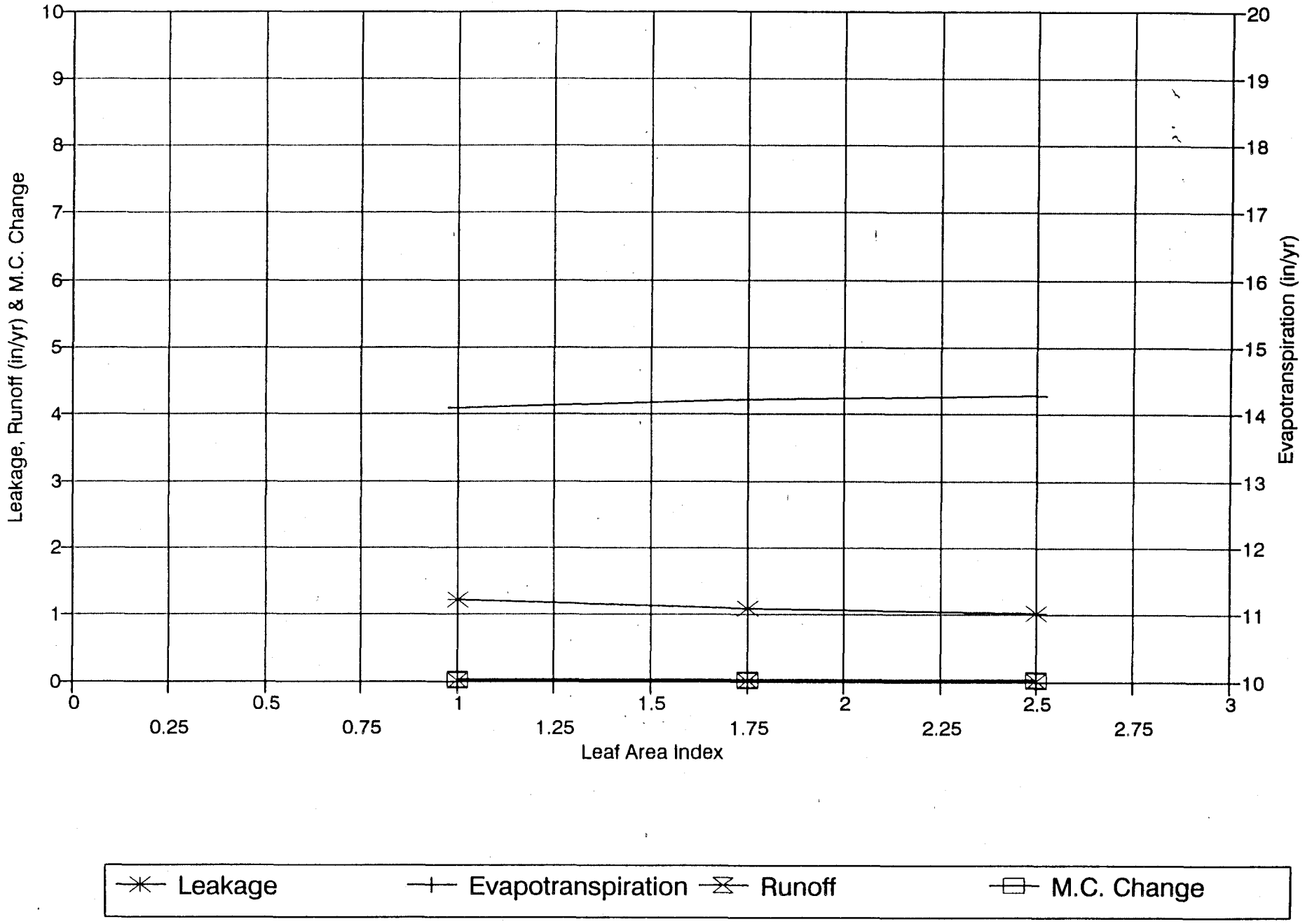
Attachment F6
HELP Output Files for Cover Section 2
Leaf Area Index Sensitivity

SECTION 2 LEAF AREA INDEX SENSITIVITY

36" Vegetative Layer, 1" Lateral Drainage Layer, 1" Barrier Soil Layer



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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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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

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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	0.0366	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

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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
```

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

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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	0.913	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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**              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\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

******************************************************************************

     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 =      0.0481 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)

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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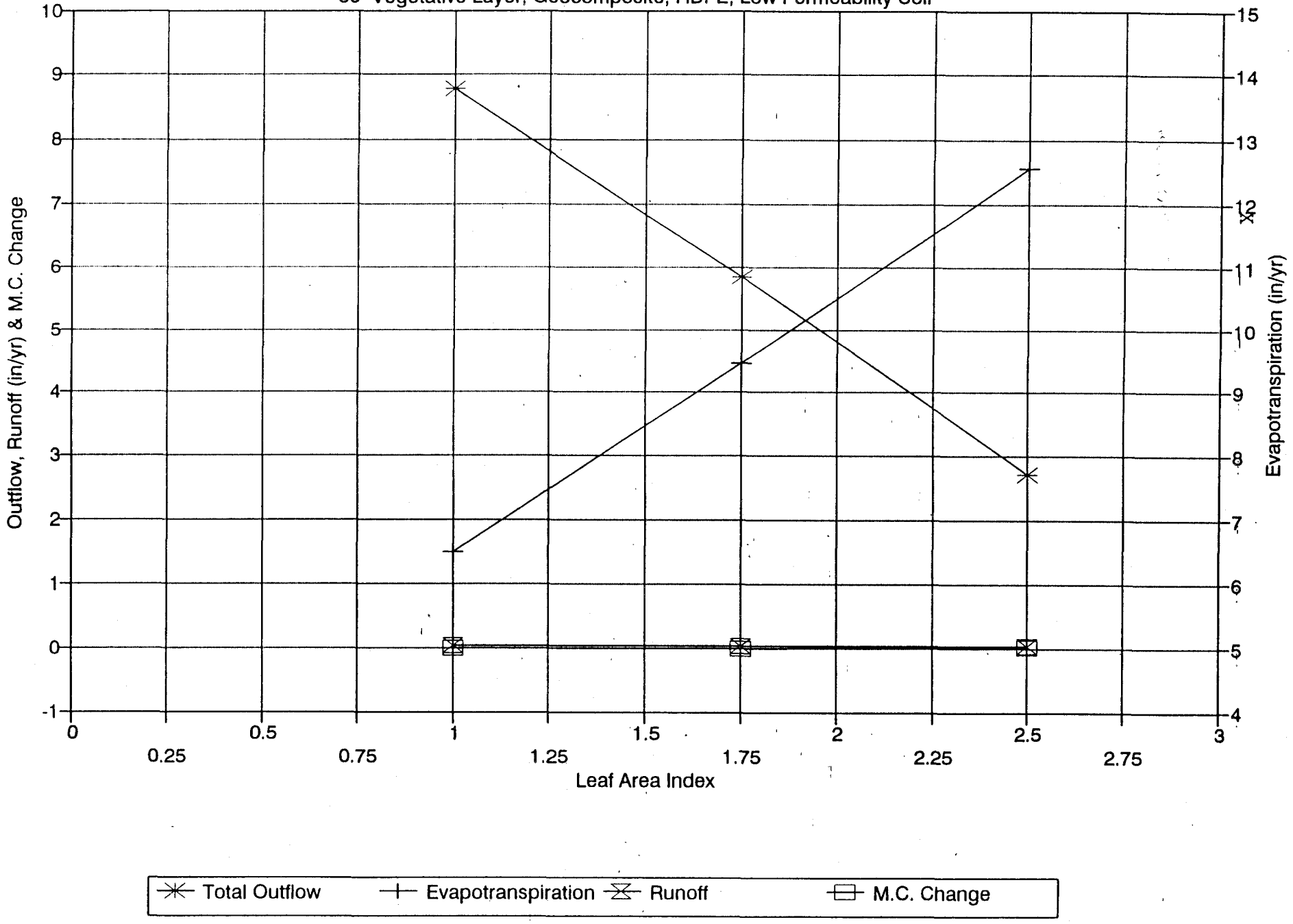
Attachment F7
HELP Output Files for Cover Section 3
Leaf Area Index Sensitivity

SECTION 3 LEAF AREA INDEX SENSITIVITY

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\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.

******************************************************************************

     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

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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              **
******************************************************************************
******************************************************************************

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

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	0.008	0.000
	0.000	0.000	0.000	0.000	0.000	0.001
STD. DEVIATIONS	0.008	0.023	0.073	0.000	0.042	0.000
	0.000	0.000	0.000	0.000	0.000	0.003
EVAPOTRANSPIRATION						
TOTALS	0.332	0.398	0.603	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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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             **
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******************************************************************************

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

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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 =      0.1472 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

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	0.009	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)

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

****

****

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

****

****

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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Table of Contents

G.1. LANDFILL CLOSURE COST ESTIMATION REQUIREMENTS G-1

G.2. COST ESTIMATE SOURCES G-1

G.3. ASSUMPTIONS AND CALCULATIONS G-1

G.3.1 CLOSURE PERIOD G-1

G.3.1.1 Mobilization/Demobilization G-1

G.3.1.2 Wetland Mitigation G-2

G.3.1.3 Groundwater Monitoring Wells G-2

G.3.1.4 Reroute South Surface-Water Drainage Ditch G-2

G.3.1.5 Landfill Cover G-2

G.3.1.6 Landfill Gas-Collection System G-3

G.3.1.7 Security G-3

G.3.1.8 Notation on Property Deed G-3

G.3.1.9 Miscellaneous Cost Items G-4

G.3.1.10 Indirect Costs G-4

G.3.2 POSTCLOSURE CARE PERIOD G-5

G.3.2.1 Present Worth G-5

G.3.2.2 Landfill Gas Monitoring G-5

G.3.2.3 Groundwater Monitoring Wells G-5

G.3.2.4 Landfill Cap Maintenance G-6

G.3.2.5 Drainage Ditch Clean Out G-6

G.3.2.6 Fence Maintenance G-6

G.3.2.7 5-Year Review G-6

G.3.2.8 Certification of Postclosure G-6

G.3.2.9 Indirect Costs G-7

G.4. REFERENCES G-7

Tables

Table G-1 Units Costs for Cover System Components

Table G-2 Institutional Controls - Conceptual Cost Estimate

Table G-2a O&M Conceptual Cost Estimate - Institutional Controls

Table G-3 Capping Option A - Conceptual Cost Estimate
Table G-4 Capping Option B - Conceptual Cost Estimate
Table G-5 Capping Option C - Conceptual Cost Estimate
Table G-6 Capping Option D - Conceptual Cost Estimate
Table G-7 Capping Option E - Conceptual Cost Estimate
Table G-8 Capping Option F - Conceptual Cost Estimate
Table G-8 Capping Option G - Conceptual Cost Estimate
Table G-10 O&M Conceptual Cost Estimate For All Capping Options
Table G-11 Onsite Conventional Groundwater Treatment - Conceptual Cost Estimate
Table G-11a Conventional Treatment System O&M Conceptual Cost Estimate
Table G-12 Passive Treatment Wall-Conceptual Cost Estimate
Table G-12a Passive Treatment Wall System O&M Conceptual Cost Estimate
Table G-13 Capital Cost Seepwater Discharge Treatment at OU1
Table G-13a Treatment at OU1 O&M Conceptual Cost Estimate
Table G-14 Passive Wetlands Treatment Conceptual Cost Estimate
Table G-14a Wetlands Treatment System O&M Conceptual Cost Estimate
Table G-15 Forager Wall Treatment System-Conceptual Cost Estimate
Table G-16 Surface Water Discharge System - Conceptual Cost Estimate
Table G-17 Groundwater Discharge - Conceptual Cost Estimate
Table G-18 Surface and Subsurface Water Discharge Systems Conceptual O&M Cost Estimate
Table G-19 Groundwater Collection System - Conceptual Cost Estimate
Table G-19a Groundwater Collection System - Conceptual O&M Cost Estimate
Table G-20 Gravel Blanket Collection System - Conceptual Cost Estimate
Table G-20a Gravel Blanket Collection System - Conceptual O&M Cost Estimate
Table G-21 Slurry Wall - Conceptual Cost Estimate
Table G-22 Alternative 2 - Capital Cost Cap, Discharge to Groundwater
Table G-23 Alternative 3 - Capital Cost Cap, Slurry Wall, Discharge to Groundwater
Table G-24 O&M Costs for Alternatives 2 and 3 Detailed Cost Estimate
Table G-25 Alternative 4 - Capital Cost Passive Wetlands Groundwater Treatment from Seepwater
Table G-25a Detailed O&M Cost Estimate Alternative 4: with Wetlands Treatment System
Table G-26 Risk Analysis Assessment Form for Conceptual Cost Estimate
Table G-27 Risk Analysis and Assessment Form for Detailed Cost Estimate

G.1. LANDFILL CLOSURE COST ESTIMATION REQUIREMENTS

A detailed cost estimate for landfill closure and for the 30-year postclosure 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.

G.2. COST ESTIMATE SOURCES

The cost estimate presented in this section is based on the following sources.

- Guidance Manual: Cost Estimates for Closure and Postclosure 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, landfill cover installation, gas monitoring, and groundwater monitoring. Detailed units and frequencies are obtained from vendors, operator experience, and previous closure plans.

G.3. ASSUMPTIONS AND CALCULATIONS

Assumptions and calculations are described for the closure period and the 30-year postclosure care period by unit. Unit costs for components of all cover systems are provided in Table G-1. Conceptual cost estimates for the remediation options are provided in Tables G-2 through G-19. Detailed cost estimates for Alternatives 2, 3, and 4 are provided in Tables G-20 through G-22.

G.3.1 CLOSURE PERIOD

Assume 6 months for completion and 21 working days in a month.

G.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.

G.3.1.2 Wetland Mitigation

The landfill cap covers approximately 0.8 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.

Total wetland acreage required to be built is as follows:

3 x 0.8 acres + 10% = 2.64 acres

G.3.1.3 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 G.3.2).

G.3.1.4 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 ft of the diversion ditch will be rerouted at $8 per ft. This construction cost is for an unlined, 12-ft-wide by 3-ft-deep trapezoidal ditch. Design of the ditch will be undertaken during the final design.

G.3.1.5 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.

G.3.1.5.1 Vegetative Layer

- The fill material will be obtained onsite or from a nearby offsite source. The net fill material required varies from 62,200 yd^3 to 68,200 yd^3, depending on the grading fill plan, and the total surface area is 1,296,900 square ft (29.8 acres) with varying depths across the landfill. It is assumed that special preparation of this material is not required.
- The 36-in. vegetative cover consists of 6 in. of soil on top of 36 in. of soil.

G.3.1.5.2 Lateral-Drainage/Biotic Barrier 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/biotic barrier layer.

G.3.1.5.3 Barrier Layer

- The FMC layer made from a 30-mil PVC is 0.06-in. thick.
- GCL is bentonite between two layers of geotextiles and is 0.1-in. thick.
- FMC/GCL layer is a bonded composite of both the FMC and the GCL and is 0.16-in. thick.
- The soil bedding layer is 6 in. of soil. It is assumed that special preparation of this material is not required.
- The low-permeability soil layer is 12-in. thick and requires wet table conditioning and compaction.
- The 24-in. compacted clay layer requires bentonite additive followed by wet and dry table conditionings and compaction.

The RCRA cover area is 919,150 ft^2 (21.1 acres). The cost per square ft for each cover layer is summarized in Table G-1.

The itemized costs include landfill waste grading and trim, procurement, and installation of each component. These costs are based on previous experience.

G.3.1.6 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.

G.3.1.7 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-ft-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 ft. Additionally, a 6-ft-high by 3-ft-wide galvanized-steel gate will be installed, and reflectorized signs will be placed every 500 ft.

G.3.1.8 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.

G.3.1.9 Miscellaneous Cost Items

As part of the closure plan, the East Landfill Pond, pond sediments, and dam are to be removed. Materials from the dam and sediments will be placed in the landfill under the cap. The pond will be dewatered prior to sediment or dam removal.

The estimated volumes for the above are:

Sediments	4,000 yd^3
Dam materials	18,900 yd^3

G.3.1.10 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.

G.3.2 POSTCLOSURE CARE PERIOD

G.3.2.1 Present Worth

The present worth for each cost component is determined using the following formula. The postclosure period is assumed to be 30 years; however, at any time the postclosure 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

$$PW = DC \times \sum \frac{DC_t}{(1+i)^t} \qquad \text{(G-1)}$$

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).

G.3.2.2 Landfill Gas Monitoring

Quarterly samples will be taken from the landfill gas monitoring vents costing $300/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 postclosure period.

G.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 postclosure period.

G.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.

G.3.2.5 Drainage Ditch Clean Out

Assume annual clearing of drainage ditch debris is adequate maintenance to keep it operable for 30 years.

G.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.

G.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.

G.3.2.8 Certification of Postclosure

Assume during the postclosure 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.

G.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)

G.4. REFERENCES

DOE, 1994, *Rocky Flats Plant Environmental Restoration Management Cost Estimating Handbook*, 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 G-1 Units Costs for Cover System Components

Cover Component	Unit Cost Per Square Ft
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 G-2
Institutional Controls - Conceptual 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	$13	$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 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

Table G-2a
O&M Conceptual Cost Estimate
Institutional Controls

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
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	N/A
TOTAL DIRECT ANNUAL COSTS:					$29,100			
ANNUALIZED PERIODIC COSTS:					$2,300			
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/Periodic Costs)								
ADMINISTRATION (10%)		ANNUAL			$3,200	30	$62,800	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)		ANNUAL			$7,900	30	$154,900	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:								**$217,700**
TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:								**$832,600**

* dollar values rounded up to the nearest $100

Table G-3
Capping Option A - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Native Soil Cover (Option A)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$2,212,800**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$2,214,200**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$44,300
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$442,600
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$553,200
CQA (15% of construction costs)	LS			$332,000
HEALTH & SAFETY (5% of total direct costs)	LS			$110,800
ADMINISTRATIVE (10% of total direct costs)	LS			$221,500
CONTINGENCY (25% of total direct costs)	LS			$553,600
TOTAL INDIRECT CAPITAL COSTS				**$2,213,700**
PROJECT TOTALS				**$4,427,900**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs are not included.

Table G-4
Capping Option B - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Single-Barrier Clay (Option B)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. Clay Barrier Procure & Install	SF	919,150	$1.65	$1,516,600
E. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
F. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$4,683,200**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$4,684,600**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$93,700
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$936,700
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,170,800
CQA (15% of construction costs)	LS			$702,500
HEALTH & SAFETY (5% of total direct costs)	LS			$234,300
ADMINISTRATIVE (10% of total direct costs)	LS			$468,500
CONTINGENCY (25% of total direct costs)	LS			$1,171,200
TOTAL INDIRECT CAPITAL COSTS				**$4,684,000**
PROJECT TOTALS				**$9,368,600**

NOTE

* dollar values rounded up to the nearest $100

Engineering design costs are not included.

Table G-5
Capping Option C - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Single-Barrier FMC (Option C)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC Procure & Install	SF	919,150	$0.28	$257,400
E. Soil Bedding Layer Procure & Install	SF	919,150	$0.10	$92,000
F. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$3,516,000**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$3,517,400**

INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$70,400
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$703,200
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$879,000
CQA (15% of construction costs)	LS			$527,400
HEALTH & SAFETY (5% of total direct costs)	LS			$175,900
ADMINISTRATIVE (10% of total direct costs)	LS			$351,800
CONTINGENCY (25% of total direct costs)	LS			$879,400
TOTAL INDIRECT CAPITAL COSTS				**$3,516,700**

PROJECT TOTALS	**$7,034,100**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs are not included.

Table G-6
Capping Option D - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Single-Barrier GCL (Option D)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. GCL Procure & Install	SF	919,150	$0.65	$597,500
E. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
F. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$3,764,100**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$3,765,500**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$75,300
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$752,900
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$941,100
CQA (15% of construction costs)	LS			$564,700
HEALTH & SAFETY (5% of total direct costs)	LS			$188,300
ADMINISTRATIVE (10% of total direct costs)	LS			$376,600
CONTINGENCY (25% of total direct costs)	LS			$941,400
TOTAL INDIRECT CAPITAL COSTS				**$3,765,000**
PROJECT TOTALS				**$7,530,500**

NOTE

* dollar values rounded up to the nearest $100

Engineering design costs are not included.

Table G-7
Capping Option E - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Single-Barrier FMC with Low Permeability Soil (Option E)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC Procure & Install	SF	919,150	$0.28	$257,400
E. Low Permeability General Fill	SF	919,150	$0.50	$459,600
F. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$3,883,600**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$3,885,000**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$77,700
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$776,800
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$970,900
CQA (15% of construction costs)	LS			$582,600
HEALTH & SAFETY (5% of total direct costs)	LS			$194,300
ADMINISTRATIVE (10% of total direct costs)	LS			$388,500
CONTINGENCY (25% of total direct costs)	LS			$971,300
TOTAL INDIRECT CAPITAL COSTS				**$3,884,400**
PROJECT TOTALS				**$7,769,400**

NOTE

* dollar values rounded up to the nearest $100

Engineering design costs are not included.

Table G-8
Capping Option F - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: Composite-Barrier FMC/GCL (Option F)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC/GCL Composite Procure & Install	SF	919,150	$0.95	$873,200
E. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
F. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$4,039,800**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous*				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$4,041,200**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$80,800
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$808,000
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,010,000
CQA (15% of construction costs)	LS			$606,000
HEALTH & SAFETY (5% of total direct costs)	LS			$202,100
ADMINISTRATIVE (10% of total direct costs)	LS			$404,200
CONTINGENCY (25% of total direct costs)	LS			$1,010,300
TOTAL INDIRECT CAPITAL COSTS				**$4,040,600**
PROJECT TOTALS				**$8,081,800**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs are not included.

Table G-9
Capping Option G - Conceptual Cost Estimate

Cost Component	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS: EPA's Composite-Barrier FMC & Clay (Option G)				
Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC Procure & Install	SF	919,150	$0.28	$257,400
E. Clay Barrier Procure & Install	SF	919,150	$1.65	$1,516,600
F. Geocomposite Procure & Install (Drainage/Biotic & Gas Collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$4,940,600**
Miscellaneous				
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
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$1,400**
TOTAL DIRECT CAPITAL COSTS				**$4,942,000**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$98,900
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$988,200
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,235,200
CQA (15% of construction costs)	LS			$741,100
HEALTH & SAFETY (5% of total direct costs)	LS			$247,100
ADMINISTRATIVE (10% of total direct costs)	LS			$494,200
CONTINGENCY (25% of total direct costs)	LS			$1,235,500
TOTAL INDIRECT CAPITAL COSTS				**$4,941,300**
PROJECT TOTALS				**$9,883,300**

NOTE

* dollar values rounded up to the nearest $100

Engineering design costs are not included.

Table G-10
O&M Conceptual Cost Estimate
For All Capping Options

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
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 MONITORING	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			
ANNUALIZED PERIODIC COSTS:					$2,300			
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/Periodic Costs)						
ADMINISTRATION (10%)	ANNUAL	$3,900	30	$76,500	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$9,700	30	$190,200	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$266,700**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$1,026,700**

* dollar values rounded up to the nearest $100

Table G-11
Onsite Conventional Groundwater Treatment - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
LEACHATE STORAGE TANKS	LS	1	$77,900	$77,900
ELECTRICAL CONTROLS	LS	1	$40,000	$40,000
POWER SUPPLY	LS	1	$150,000	$150,000
ON-SITE GROUNDWATER TREATMENT SYSTEM	EA	1	$137,800	$137,800
HOUSING FOR TREATMENT SYSTEM	EA	1	$11,043	$11,100
TOTAL DIRECT CAPITAL COSTS				**$416,800**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$83,400
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$104,200
CQA (15%)	LS			$62,600
NPDES Permit Application (5%)	LS			$20,900
HEALTH & SAFETY (5%)	LS			$20,900
ADMINISTRATIVE (10%)	LS			$41,700
CONTINGENCY (25%)	LS			$104,200
TOTAL INDIRECT CAPITAL COSTS				**$437,900**
PROJECT TOTALS				**$854,700**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-11a
Conventional Treatment System
O&M Conceptual Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
ON-SITE GROUNDWATER TREATMENT								
A CHEMICALS & ELECTRICITY	GAL	ANNUALLY	1261440	$ 0.0004	$600	30	$11,800	N/A
B CARBON REPLACEMENT	DRUM	ANNUALLY	6	$600	$3,600	30	$70,600	N/A
C LABOR	HR	ANNUALLY	352	$95	$33,500	30	$656,700	N/A
D DISPOSAL	CF	ANNUALLY	134	$41	$5,500	30	$107,900	N/A
TOTAL DIRECT ANNUAL COSTS:					$43,200			
ANNUALIZED PERIODIC COSTS:					$0			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$847,000	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$847,000**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)						
ADMINISTRATION (10%)	ANNUAL	$4,400	30	$86,300	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$10,800	30	$211,700	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$298,000**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$1,145,000**

* dollar values rounded up to the nearest $100

Table G-12
Passive Treatment Wall - Conceptual Cost Estimate

PASSIVE TREATMENT PERMEABLE WALL - EnviroMetal Process	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
PHASE I AND II STUDY BY ENVIROMETAL	LS	1	$35,500.00	$35,500
Treatment Media - 20' by 1' by 200' long =4000 cf x 0.1 tons/cf = 400 tons	tons	400	$500	$200,000
SITE PREP, PERMITTING, ETC.	SY	1,500	$2.00	$3,000
Continuous Trenching Technology - 200 ft by 20 ft.	SF	4,000	$62.50	$250,000
LICENSE FEE	LS	1	$67,950.00	$68,000
TOTAL DIRECT CAPITAL COSTS				**$556,500**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$111,300
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$139,200
CQA (15%)	LS			$83,500
HEALTH & SAFETY (5%)	LS			$27,900
ADMINISTRATIVE (10%)	LS			$55,700
CONTINGENCY (25%)	LS			$139,200
TOTAL INDIRECT CAPITAL COSTS				**$556,800**
PROJECT TOTALS				**$1,113,300**

* dollar values rounded up to the nearest $100

Table G-12a
Passive Treatment Wall System
O&M Conceptual Cost Estimate

DIRECT CAPITAL COSTS: Single Barrier FMC (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
ON-SITE GROUNDWATER TREATMENT								
A WALL MEDIA FLUSH EVERY 5 YEARS	EA	AT YEAR 5	1	$ 15,000	N/A	5	N/A	$12,939
	EA	AT YEAR 10	1	$ 15,000	N/A	5	N/A	$11,162
	EA	AT YEAR 15	1	$ 15,000	N/A	5	N/A	$9,629
	EA	AT YEAR 20	1	$ 15,000	N/A	5	N/A	$8,306
	EA	AT YEAR 25	1	$ 15,000	N/A	5	N/A	$7,164
TOTAL DIRECT ANNUAL COSTS:					$0			
ANNUALIZED PERIODIC COSTS:					$2,600			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$0	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$49,199
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$49,199**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)					
ADMINISTRATION (10%)	ANNUAL	$300	30	$5,900	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$700	30	$13,800	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$19,700**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$68,900**

* dollar values rounded up to the nearest $100

Table G-13
Conceptual Cost Estimate
Seepwater Discharge Treatment at OU1

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
LEACHATE STORAGE TANKS	LS	1	$77,900	$77,900
ELECTRICAL CONTROLS	LS	1	$40,000	$40,000
POWER SUPPLY	LS	1	$150,000	$150,000
GROUNDWATER TREATMENT AT OU1 (Truck)	EA	1	$70,000	$70,000
TOTAL DIRECT CAPITAL COSTS				**$337,900**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$67,600
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$84,500
CQA (15%)	LS			$50,700
HEALTH & SAFETY (5%)	LS			$16,900
ADMINISTRATIVE (10%)	LS			$33,800
CONTINGENCY (25%)	LS			$84,500
TOTAL INDIRECT CAPITAL COSTS				**$338,000**
PROJECT TOTALS				**$675,900**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-13a
Treatment at OU1
O&M Conceptual Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
GROUNDWATER TREATMENT AT OU 1								
A. TRANSPORTATION TO OU 1	GAL	ANNUALLY	1051200	$0.05	$52,600	30	$1,031,000	N/A
B. TREATMENT AT OU 1	GAL	ANNUALLY	1051200	$0.41	$431,000	30	$8,447,800	N/A
C. TRUCK MAINTENANCE	EA	ANNUALLY	1	$7,000	$7,000	30	$137,300	N/A
TOTAL DIRECT ANNUAL COSTS:					$490,600			
ANNUALIZED PERIODIC COSTS:					$0			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$9,616,100	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$9,616,100**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)					
ADMINISTRATION (10%)	ANNUAL	$49,100	30	$962,400	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$122,700	30	$2,405,000	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$3,367,400**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$12,983,500**

* dollar values rounded up to the nearest $100

Table G-14
Passive Wetlands Treatment - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
ON-SITE WETLANDS PASSIVE GROUNDWATER TREATMENT SYSTEM	LS	1	$500,000	$500,000
TOTAL DIRECT CAPITAL COSTS				**$500,000**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$100,000
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$125,000
CQA (15%)	LS			$75,000
HEALTH & SAFETY (5%)	LS			$25,000
NPDES Permit Application (5%)	LS		$500,000	$25,000
ADMINISTRATIVE (10%)	LS			$50,000
CONTINGENCY (25%)	LS			$125,000
TOTAL INDIRECT CAPITAL COSTS				**$525,000**
PROJECT TOTALS				**$1,025,000**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-14a
Wetlands Treatment System
O&M Conceptual Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
ON-SITE WETLANDS TREATMENT A. ANNUAL MAINTENANCE	EA	ANNUALLY	1	$25,000	$25,000	30	$490,100	N/A
TOTAL DIRECT ANNUAL COSTS:					$25,000			
ANNUALIZED PERIODIC COSTS:					$0			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$490,100	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$490,100**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)*						
ADMINISTRATION (10%)	ANNUAL	$2,500	30	$49,100	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$6,300	30	$123,500	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$172,600**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$662,700**

* dollar values rounded up to the nearest $100

Table G-15
Forager Wall Treatment System - Conceptual Cost Estimate
and O&M (Regeneration) Conceptual Costs

	Direct Capital Cost* ($)	Indirect Capital Costs ($)	Changeout Cost** ($)	Time between Changeouts (days)	Frequency (times/ year)	Direct Annual O&M Cost ($/ year)	Present Value O&M Cost ($)	Present Value Total Cost ($)
Remove all analytes up to Iron	$ 211,500	$ 215,730	$ 5,875	17	21.5	$ 126,140	$ 2,472,400	$ 2,899,630
Remove all analytes up to Zinc	$ 211,500	$ 215,730	$ 5,875	365	1.0	$ 5,875	$ 115,200	$ 542,430
Remove all analytes up to Manganese	$ 211,500	$ 215,730	$ 5,875	365	1.0	$ 5,875	$ 115,200	$ 542,430
Remove all analytes up to Nickel	$ 211,500	$ 215,730	$ 5,875	365	1.0	$ 5,875	$ 115,200	$ 542,430

NOTE: Maximum time between changeout is 365 days.
* Capital Cost = $200,000 for funnel and installation of well casings and 100 c.f. x $115/c.f. for FORAGER (TM) Sponge
** Assumes changeout cost is 25% of cost of sponge plus $3,000 labor

O&M Cost based on	30	year life
Discount rate	3	%

Table G-16
Surface Water Discharge System - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
SURFACE SEEP DISCHARGE				
A. Seep Gravel Drain	CY	2,130	$15.00	$31,950
B. Seep Flow Area Gravel Fill	CY	12,800	$15.00	$192,000
TOTAL DIRECT CAPITAL COSTS				**$223,950**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$44,800
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$56,000
CQA (15%)	LS			$33,600
HEALTH & SAFETY (5%)	LS			$11,200
NPDES Permit Application (5%)	LS			$11,200
ADMINISTRATIVE (10%)	LS			$22,400
CONTINGENCY (25%)	LS			$56,000
TOTAL INDIRECT CAPITAL COSTS				**$235,200**

PROJECT TOTALS	**$459,150**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-17
Groundwater Discharge - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
SUBSURFACE SEEP DISCHARGE				
A. Seep Gravel Drain	CY	2,130	$15.00	$31,950
B. Seep Flow Area Engineered Fill	CY	34,000	$20.00	$680,000
TOTAL DIRECT CAPITAL COSTS				**$711,950**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$142,400
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$178,000
CQA (15%)	LS			$106,800
HEALTH & SAFETY (5%)	LS			$35,600
NPDES Permit Application (5%)	LS			$35,600
ADMINISTRATIVE (10%)	LS			$71,200
CONTINGENCY (25%)	LS			$178,000
TOTAL INDIRECT CAPITAL COSTS				**$747,600**

PROJECT TOTALS	**$1,459,550**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-18
Surface & Subsurface Water Discharge System
Conceptual O&M Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
DISCHARGE SYSTEM								
A. MONTHLY MAINTENANCE	4 HR	MONTH	48	$100	$4,800	30	$94,100	N/A
TOTAL DIRECT ANNUAL COSTS:					$4,800			
ANNUALIZED PERIODIC COSTS:					$0			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$94,100	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$94,100**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)					
ADMINISTRATION (10%)	ANNUAL	$500	30	$9,900	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$1,200	30	$23,600	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$33,500**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$127,600**

* dollar values rounded up to the nearest $100

Table G-19
Groundwater Collection System - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
EXCAVATE AND REMOVE EXISTING DRAIN	LS	1	$5,000	$5,000
EXCAVATE AND MOVE SUMP	LS	1	$5,000	$5,000
GROUNDWATER COLLECTION SYSTEM (Above Dam)				
A. GRAVEL BLANKET AND FUNNEL	LS	1	$13,700	$13,700
A. COLLECTION SUMP WITH PUMP	EA	1	$10,000	$10,000
B. PIPELINE SYSTEM	LS	1	$46,800	$46,800
TOTAL DIRECT CAPITAL COSTS				**$80,500**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$16,100
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$20,200
CQA (15%)	LS			$12,100
HEALTH & SAFETY (5%)	LS			$4,100
ADMINISTRATIVE (10%)	LS			$8,100
CONTINGENCY (25%)	LS			$20,200
TOTAL INDIRECT CAPITAL COSTS				**$80,800**
PROJECT TOTALS				**$161,300**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-19a
Groundwater Collection System - Conceptual O&M Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
GROUNDWATER COLLECTION SYSTEM								
A. WEEKLY INSPECTION	HR	WEEK	52	$100	$5,200	30	$102,000	N/A
B. MONTHLY MAINTENANCE	4 HR	MONTH	48	$100	$4,800	30	$94,100	N/A
C. MAINTENANCE MATERIALS (YR 1-30)	EA	YEAR	1	$600	$600	30	$11,800	N/A
D. ADDITIONAL MATERIAL REQUIREMENTS (YR 1-3)	EA	YEAR	1	$600	$600	3	$1,700	N/A
E. ELECTRICAL COSTS	LS	DAILY	365	$1.64	$600	30	$11,800	N/A
F. PUMP REPLACEMENT	EA	EVERY 15 YRS	N/A	$650	N/A	15	N/A	700
TOTAL DIRECT ANNUAL COSTS:					$11,800			
ANNUALIZED PERIODIC COSTS:					$100			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$221,400	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$700
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$222,100**

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)						
ADMINISTRATION (10%)	ANNUAL	$1,200	30	$23,600	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)	ANNUAL	$3,000	30	$58,900	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:					**$82,500**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$304,600**

* dollar values rounded up to the nearest $100

Table G-20
Gravel Blanket Collection System - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
EXCAVATE AND REMOVE EXISTING DRAIN	LS	1	$5,000	$5,000
EXCAVATE AND MOVE SUMP	LS	1	$5,000	$5,000
GRAVEL BLANKET COLLECTION AND STORAGE SYSTEM	CY	600	$15	$9,000
TOTAL DIRECT CAPITAL COSTS				**$19,000**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$3,800
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$4,800
CQA (15%)	LS			$2,900
HEALTH & SAFETY (5%)	LS			$1,000
ADMINISTRATIVE (10%)	LS			$1,900
CONTINGENCY (25%)	LS			$4,800
TOTAL INDIRECT CAPITAL COSTS				**$19,200**
PROJECT TOTALS				**$38,200**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-20a
Gravel Blanket Collection System - Conceptual O&M Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
DISCHARGE SYSTEM A. MONTHLY MAINTENANCE	4 HR	MONTH	48	$100	$4,800	30	$94,100	N/A
TOTAL DIRECT ANNUAL COSTS:					$4,800			
ANNUALIZED PERIODIC COSTS:					$0			
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:							$94,100	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								**$94,100**
INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)								
ADMINISTRATION (10%)		ANNUAL			$500	30	$9,900	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)		ANNUAL			$1,200	30	$23,600	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:								**$33,500**
TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:								**$127,600**

* dollar values rounded up to the nearest $100

Table G-21
Slurry Wall - Conceptual Cost Estimate

	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
SLURRY WALL	SF	46,405	$13	$603,300
TOTAL DIRECT CAPITAL COSTS				**$603,300**
INDIRECT CAPITAL COSTS				
PROJECT / CONSTRUCTION MANAGEMENT (20%)	LS			$120,700
CONTRACTOR OVERHEAD & PROFIT (25%)	LS			$150,900
CQA (15%)	LS			$90,500
HEALTH & SAFETY (5%)	LS			$30,200
ADMINISTRATIVE (10%)	LS			$60,400
CONTINGENCY (25%)	LS			$150,900
TOTAL INDIRECT CAPITAL COSTS				**$603,600**
PROJECT TOTALS				**$1,206,900**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-22
ALTERNATIVE 2 - Capital Cost
Cap, Discharge to Groundwater

SINGLE BARRIER - FMC WITH LP SOIL LAYER	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
SUBSURFACE SEEP DISCHARGE				
A. Seep Gravel Drain	CY	2,130	$15.00	$31,950
B. Seep Flow Area Engineered Fill	CY	34,000	$20.00	$680,000
DEWATER POND	LS	1	$28,410.00	$28,410
CONSOLIDATE SEDIMENTS	CY	4,000	$6.92	$27,700
REMOVE EMBANKMENT	CY	18,900	$5.87	$111,000
WETLAND MITIGATION	AC	2.64	$40,000	$105,600
REROUTE SOUTH DIVERSION DITCH	LF	1,300	$8	$10,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC PROCURE & INSTALL	SF	919,150	$0.28	$257,400
E. LOW PERMEABILITY GENERAL FILL	SF	919,150	$0.50	$459,600
F. GEOCOMPOSITE PROCURE & INSTALL (drainage & gas collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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	$13	$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 - Construction				**$4,878,660**
DIRECT CAPITAL COSTS - Miscellaneous				
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
NOTATION ON PROPERTY DEED - FINAL CLOSURE	LS	1	$1,000	$1,000
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$2,400**
TOTAL DIRECT CAPITAL COSTS				**$4,881,060**

INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$97,600
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$975,800
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,219,700
CQA (15% of construction costs)	LS			$731,800
HEALTH & SAFETY (5% of all direct capital costs)	LS			$244,100
ADMINISTRATIVE (10% of all direct capital costs)	LS			$488,200
CONTINGENCY (15% of all direct capital costs)	LS			$732,200
TOTAL INDIRECT CAPITAL COSTS				**$4,489,400**

PROJECT TOTALS	**$9,370,460**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-23
ALTERNATIVE 3 - Capital Cost
Cap, Slurry Wall, Discharge to Groundwater

SINGLE BARRIER - FMC WITH LP SOIL LAYER	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
SUBSURFACE SEEP DISCHARGE				
A. Seep Gravel Drain	CY	2,130	$15.00	$31,950
B. Seep Flow Area Engineered Fill	CY	34,000	$20.00	$680,000
SLURRY WALL	SF	46,405	$13.00	$603,300
DEWATER POND	LS	1	$28,410	$28,410
CONSOLIDATE SEDIMENTS	CY	4,000	$6.92	$27,700
REMOVE EMBANKMENT	CY	18,900	$5.87	$111,000
WETLAND MITIGATION	AC	2.64	$40,000	$105,600
REROUTE SOUTH DIVERSION DITCH	LF	1,300	$8	$10,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	62,200	$6.00	$373,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	62,200	$2.00	$124,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC PROCURE & INSTALL	SF	919,150	$0.28	$257,400
E. LOW PERMEABILITY GENERAL FILL	SF	919,150	$0.50	$459,600
F. GEOCOMPOSITE PROCURE & INSTALL (drainage & gas collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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	$13	$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 - Construction				$5,481,960
DIRECT CAPITAL COSTS - Miscellaneous				
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
NOTATION ON PROPERTY DEED - FINAL CLOSURE	LS	1	$1,000	$1,000
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				$2,400
TOTAL DIRECT CAPITAL COSTS				$5,484,360
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$109,700
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$1,096,400
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,370,500
CQA (15% of construction costs)	LS			$822,300
HEALTH & SAFETY (5% of all direct capital costs)	LS			$274,300
ADMINISTRATIVE (10% of all direct capital costs)	LS			$548,500
CONTINGENCY (15% of all direct capital costs)	LS			$822,700
TOTAL INDIRECT CAPITAL COSTS				$5,044,400
PROJECT TOTALS				$10,528,760

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-24
O&M Costs for Alternatives 2 and 3
Detailed Cost Estimate

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
GROUNDWATER MONITORING (4 WELLS)								
A. SAMPLING	EA	BI-ANNUALLY	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	BI-ANNUALLY	2	$240	$500	30	$9,900	N/A
III. VALIDATION	EA	BI-ANNUALLY	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	BI-ANNUALLY	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
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 YRS	1	$25,000	N/A	5	N/A	$92,300
CERTIFICATION OF POST-CLOSURE								
A. INSPECTION (YEARLY)	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			
ANNUALIZED PERIODIC COSTS:					$7,700			
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/Periodic Costs)								
ADMINISTRATION (10%)		ANNUAL			$4,600	30	$90,200	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (25%)		ANNUAL			$11,400	30	$223,500	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:								**$313,700**

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	**$1,206,400**

* dollar values rounded up to the nearest $100

Table G-25
Alternative 4 - Capital Cost
Passive Wetlands Groundwater Treatment from Seepwater Discharge

SINGLE BARRIER - FMC WITH LP SOIL LAYER	UNIT	QUANTITY	UNIT COST	TOTAL COST*
DIRECT CAPITAL COSTS - Construction				
MOBILIZATION / DEMOBILIZATION (LUMP SUM)	LS	1	$250,000	$250,000
SITE PREP, ROAD CONSTRUCTION, ETC.	SY	133,400	$1.00	$133,400
DEWATER POND	LS	1	$28,410	$28,410
CONSOLIDATE SEDIMENTS	CY	4,000	$6.92	$27,700
REMOVE EMBANKMENT	CY	26,200	$5.87	$153,800
WETLAND MITIGATION	AC	2.64	$40,000	$105,600
SURFACE SEEP DISCHARGE TO COLLECTION SYSTEM				
A. Seep Gravel Drain	CY	2,130	$15.00	$31,950
B. Seep Flow Area Gravel Fill	CY	12,800	$10.00	$128,000
ON-SITE WETLANDS PASSIVE GROUNDWATER TREATMENT SYSTE	LS	1	$500,000	$500,000
REROUTE SOUTH DIVERSION DITCH	LF	1,300	$8	$10,400
LANDFILL SURFACE GRADING AND TRIM	SY	102,100	$1.00	$102,100
LANDFILL CAP				
A. PROCURE & PREPARATION				
I. FILL MATERIAL	CY	68,200	$6.00	$409,200
II. VEGETATIVE MATERIAL	CY	85,100	$4.00	$340,400
III. TOP SOIL	CY	17,000	$10.00	$170,000
B. PLACEMENT				
I. FILL LAYER PLACEMENT	CY	68,200	$2.00	$136,400
II. VEGETATIVE LAYER	CY	85,100	$2.00	$170,200
III. TOP SOIL	CY	17,000	$2.00	$34,000
C. TRIM				
I. FILL LAYER SURFACE	SY	144,100	$1.00	$144,100
II. VEGETATIVE LAYER SURFACE	SY	102,100	$1.00	$102,100
III. TOP SOIL	SY	102,100	$1.00	$102,100
D. FMC PROCURE & INSTALL	SF	919,150	$0.28	$257,400
E. LOW PERMEABILITY GENERAL FILL	SF	919,150	$0.50	$459,600
F. GEOCOMPOSITE PROCURE & INSTALL (drainage & gas collection)	SF	1,838,300	$0.41	$753,800
G. VEGETATION	SF	1,296,900	$0.07	$90,800
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 - Construction				**$4,917,460**
DIRECT CAPITAL COSTS - Miscellaneous				
GROUNDWATER 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
NOTATION ON PROPERTY DEED - FINAL CLOSURE	LS	1	$1,000	$1,000
TOTAL DIRECT CAPITAL COSTS - Miscellaneous				**$2,400**
TOTAL DIRECT CAPITAL COSTS				**$4,919,860**
INDIRECT CAPITAL COSTS				
CERTIFICATION / SURVEY PLAT / SURVEYING (2% of const. costs)	LS			$98,400
PROJECT / CONSTRUCTION MANAGEMENT (20% of const. costs)	LS			$983,500
CONTRACTOR OVERHEAD & PROFIT (25% of construction costs)	LS			$1,229,400
CQA (15% of construction costs)	LS			$737,700
HEALTH & SAFETY (5% of all direct capital costs)	LS			$246,000
NPDES Permit Application (5% of Treatment System)	LS		$500,000	$25,000
ADMINISTRATIVE (10% of all direct capital costs)	LS			$492,000
CONTINGENCY (15% of all direct capital costs)	LS			$738,000
TOTAL INDIRECT CAPITAL COSTS				**$4,550,000**
PROJECT TOTALS				**$9,469,860**

NOTE
* dollar values rounded up to the nearest $100
Engineering design costs not included.

Table G-25a
Detailed O&M Cost Estimate
Alternative 4: with Wetlands Treatment System

DIRECT ANNUAL/PERIODIC COSTS (3% DISCOUNT RATE) COST COMPONENT	UNIT	FREQUENCY	QUANTITY (#/YEAR)	UNIT COST	DIRECT ANNUAL COST*	LIFE OF ITEM (YEARS)	PRESENT WORTH ANNUAL COSTS*	PRESENT WORTH PERIODIC COSTS*
GROUNDWATER COLLECTION SYSTEM								
A. WEEKLY INSPECTION	HR	WEEK	52	$100	$5,200	30	$102,000	N/A
B. MONTHLY MAINTENANCE	4 HR	MONTH	48	$100	$4,800	30	$94,100	N/A
C. MAINTENANCE MATERIALS (YR 1-30)	EA	YEAR	1	$600	$600	30	$11,800	N/A
D. ADDITIONAL MATERIAL REQUIREMENTS (YR 1-3)	EA	YEAR	1	$600	$600	3	$1,700	N/A
ON-SITE WETLANDS TREATMENT								
A. ANNUAL MAINTENANCE	EA	ANNUALLY	1	$25,000	$25,000	30	$490,100	N/A
GROUNDWATER MONITORING (4 WELLS)								
A. SAMPLING	EA	BI-ANNUALLY	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	BI-ANNUALLY	2	$240	$500	30	$9,900	N/A
III. VALIDATION	EA	BI-ANNUALLY	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	BI-ANNUALLY	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
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 YRS	1	$25,000	N/A	6	N/A	$92,300
CERTIFICATION OF POST-CLOSURE								
A. INSPECTION (YEARLY)	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:					$74,000		
ANNUALIZED PERIODIC COSTS:					$7,700		
TOTAL PRESENT WORTH OF DIRECT ANNUAL COSTS:						$1,441,900	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:							$150,500
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:							$1,592,400

INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual/Periodic Costs)							
ADMINISTRATION (10%)		ANNUAL			$8,200	30	$160,800	N/A
MAINTENANCE RESERVE & CONTINGENCY COSTS (15%)		ANNUAL			$12,300	30	$241,100	N/A
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:								$401,900

TOTAL PRESENT WORTH OF DIRECT AND INDIRECT ANNUAL/PERIODIC COSTS:	$1,994,300

* dollar values rounded up to the nearest $100

Table G-26
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.
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
Public Involvement	0.3	7.0	2.1	10.0	

Table G-26
Risk Analysis Assessment Form for Conceptual Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Total Possible	Comments
Management Constraints					
Funding	0.6	7.0	4.2	10.0	2-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		

Table G-27
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.
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	2-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

Table G-27
Risk Analysis and Assessment Form for Detailed Cost Estimate

Risk Event or Condition	Probability Score	Cost Impact Score	Weighted Cost Score	Comments
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	

Table of Contents

H.1. INTRODUCTION H-1

H.2. AIR POLLUTION CONTROL AND PERMITTING H-1

H.2.1 CONSTRUCTION PROJECT REQUIREMENTS H-1

H.2.2 AIR POLLUTION EMISSION NOTICES AND PERMITS H-1

H.3. APPLICABILITY AT OU 7 ..... H-2

H.3.1 SPECIFIC LANDFILL STANDARDS H-2

H.3.2 CRITERIA POLLUTANTS H-3

H.3.2.1 EPA Proposed Standards H-3

H.3.2.2 NMOC Emission Calculations H-3

H.3.3 HAZARDOUS AIR POLLUTANTS H-5

H.3.4 POLLUTION CONTROL REQUIREMENTS H-6

H.4. SUMMARY H-6

Tables

Table H-1 Estimated NMOC Emissions from the Present Landfill

Table H-2 HAP *De Minimis* Levels

Table H-3 Estimated Flow Rates Required to Exceed HAP *De Minimis* Levels

H.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.

H.2. AIR POLLUTION CONTROL AND PERMITTING

H.2.1 CONSTRUCTION PROJECT REQUIREMENTS

Colorado Air Regulation No. 1 requires new construction projects on sites over 1 acre in a nonattainment 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.

H.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 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.

H.3. APPLICABILITY AT OU 7

H.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. However, there are no specific provisions in the RCRA treatment, storage, and disposal facility (TSDF) regulations for air pollution controls.

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

H.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.

H.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.

H.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:

$$Q_T = \sum_{I=1}^{n} 2\, k\, L_o\, M_i\, (e^{-kt_i})\, (C_{NMOC})\, (3.595 \times 10^{-9}) \qquad \text{(H-1)}$$

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 ith section of landfill, yrs
C_{NMOC}	=	Concentration of NMOC, ppmv as hexane
3.595×10^{-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:

$$M_{NMOC} = 2\ L_o\ R\ (1 - e^{-kt})\ (C_{NMOC})\ (3.595 \times 10^{-9}) \qquad \text{(H-2)}$$

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
3.595×10^{-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 H-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.

H.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 H-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 H-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 regulations, and thereby trigger Colorado air permitting requirements, are also included in Table H-3.

Many of the highest sampled concentrations shown in Table H-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 H-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.

H.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.

H.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 nonmethane organic compounds.

Table H-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[2]	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[2]	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]	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

1. Based on 20 yd^3 received per day for 365 days/year from 1968 to 1978 (OU 7 Final Work Plan p. 4-7 DOE 1994)
2. Based on total 160,000 yd^3 averaged annually from 1974 to 1986 (OU 7 Final Work Plan p. 4-7 DOE 1994)
3. Based on EG&G monitoring from November 1992 to April 1993 -- 1,000 yd^3 per month (OU 7 Final Work Plan p. 4-8)
4. Based on one ton/cubic yard; 898 Megagrams/ton
5. Based on annual loadings calculated
6. Based on total volume of material expected in landfill at closure, including fill (OU 7 Final Work Plan p. 4-8 DOE 1994)
7. Formula (a)(1)(i) from 56 Fed. Reg. 24503
8. Formula (a)(1)(ii) from 56 Fed. Reg. 24503

Table H-2 HAP *De Minimis* Levels

Chemical	CAS No.	Reporting Bin	Scenario 3 *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

Table H-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

Appendix I
Annual Soil-Loss Calculations, Methodologies, and Assumptions

Table of Contents

I.1. SEDCAD+ SEDIMENTATION COMPUTER MODEL I-1

I.1.1 RUNOFF VOLUME, V, AND PEAK DISCHARGE, Q I-2

I.1.2 SOIL ERODIBILITY FACTOR, K I-2

I.1.3 REPRESENTATIVE SLOPE LENGTH, λ I-2

I.1.4 AVERAGE SLOPE I-2

I.1.5 CONTROL PRACTICE FACTOR, CP I-3

I.1.5.1 ANNUAL SEDIMENT YIELD, V_{ANNUAL} I-3

I.1.6 RESULTS I-3

Tables

Table I-1 Runoff Volume and Peak Discharge for the OU 7 Cover

Table I-2 Results of Soil-Loss Calculations

Attachments

Attachment I1 Rocky Flats OU 7: Soil Loss 6H:1V Slopes

Attachment I2 Rocky Flats OU 7: Soil Loss 7 Slopes

I.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

$$Y = 95 \times (V \times Q_p)^{0.56} \times K \times LS \times CP \qquad \text{(I-1)}$$

where

Y	=	Sediment yield (tons)
V	=	Runoff volume (acre-ft)
Q_p	=	Peak discharge (cubic ft 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:

$$LS = \frac{\lambda^m}{72.6} \times \text{(slope factor)} \qquad \text{(I-2)}$$

where

λ	=	Representative slope length (ft)
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

I.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 I-1.

I.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

I.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 I1).

I.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 I1).

I.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

I.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

$$V_{annual} = \frac{R_{annual}}{R_{storm}} x Y \qquad \text{(I-3)}$$

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:

$$R_{annual} = 27 \times (P_{2,6})^{2.2} \qquad \text{(I-4)}$$

where

$P_{2,6}$ = 2-year, 6-hour precipitation =1.6 in.

$$R_{storm} = \frac{19.25}{D^{0.4672}} \times (P_{10,24})^{2.2} \qquad \text{(I-5)}$$

where

$P_{10,24}$ = 10-year, 24-hour precipitation = 3.2 in.
D = Storm Duration = 24 hours

I.1.6 RESULTS

Soil loss analyses were conducted for both slope areas (Table I-2). The following are the results:

Table I-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 I-2 Results of Soil-Loss Calculations

Item	6H:1V Slope Area	7 Percent Slope Area
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

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 ft	7 percent
6H:1V		
S-61	500 ft	7 percent
S-62	400 ft	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 = $27\,(P_{2,6})^{2.2} = 27\,(1.6)^{2.2} = 75.9$

Civil Software Design -- SEDCAD+ Version 3.1
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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	18.95

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

Civil Software Design -- SEDCAD+ Version 3.1
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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

Appendix J
Responses to U.S. Environmental Protection Agency and Colorado Department of Public Health and Environment Comments on Operable Unit 7 Draft IM/IRA Decision Document

EPA/PRC ENVIRONMENTAL MANAGEMENT, INC. TECHNICAL REVIEW OF PHASE I IM/IRA DECISION DOCUMENT FOR OPERABLE UNIT 7

SEPTEMBER 18, 1995

EXECUTIVE SUMMARY

The Interim Measures/Interim Remedial Action (IM/IRA) decision document for Operable Unit (OU) 7 (OU 7 DD) provides the basis for closing a portion of OU 7 under the presumptive remedy approach. Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation (EPA 1993). The objective of the presumptive remedy approach is to streamline the site investigation and remedial action selection for sites that fit these categories. The OU 7 DD concludes that the presumptive remedy for landfills—containment—will address all pathways with the exception of surface water and sediment in the East Landfill Pond and surface soils in the spray evaporation areas. The OU 7 DD presents a focused risk assessment for these pathways and concludes that there is no risk above acceptable range associated with these pathways. The most serious deficiencies identified in the OU 7 DD are with the methodology and conclusions of the focused risk assessment. These deficiencies can be grouped as follows:

Comment 1

Methodologies to evaluate both human health and ecological risks are unacceptable. Several complete exposure pathways were not considered in the human health risk assessment in the OU 7 DD. In addition, many human health risk assessment methods do not conform to EPA guidance (EPA 1989, 1991a). In particular, the use of invalidated data and comparison of mean chemical concentrations to applicable or relevant and appropriate requirements (ARARs). Unless these deficiencies are corrected, risk to human receptors may be significantly underestimated. The conclusion that there is no risk to wildlife at the East Landfill Pond surface water and sediments was arbitrary in that it contradicted the results of the focused risk assessment for these media, and it was based on incorrect water quality standards.

Response

For the revised document, human health risks have been evaluated only for the open-space exposure scenario because this is the anticipated future land use for the area surrounding the landfill as recommended by the Future Land-Use Working Group (DOE 1995). Exposure pathways for occupational scenarios are incomplete because industrial development at OU 7 will not be possible due to land-use restrictions (deed restrictions and/or state orders) after construction of the landfill cap. The ecological worker scenario was not evaluated because the open-space scenario is more conservative.

Risks will be recalculated using validated data only (i.e., eliminating 1990 data). Mean chemical concentrations, as well as maximum values and 95 percent upper confidence limits on the means (UCL_{95}), will be compared to applicable or relevant and appropriate requirements (ARARs) in the Draft Final IM/IRA DD. If the maximum or UCL_{95} is above an ARAR but the mean is not, outlier testing and professional judgment will be used to determine contaminants of concern (COCs).

Comment 2

The OU 7 DD does not discuss where leachate will discharge after construction of the cap and whether it will continue to be treated. A project is currently underway to install a passive seep collection and treatment system. The treatment system will be dismantled prior to cap construction. The document asserts that capping the landfill will cover the landfill seep (where leachate that has been identified as Resource Conservation and Recovery Act [RCRA]-listed F039 waste discharges) thus eliminating exposure to the seep. The document states that a gravel blanket or French drain beneath the general fill layer will prevent the leachate from building up and creating a new seep. However, the OU 7 DD does not specify where the new discharge point will be located. Instead, the document emphasizes that the landfill cap and slurry wall will diminish flow into the landfill to the point where the seep will eventually dry up. Groundwater modeling results provided with the document suggest that leachate will continue to discharge in excess of 1 gallon per minute (gpm) for approximately 5 years after the cap is constructed and will be flowing at a rate of 0.4 gpm 24 years after the cap is constructed.

Response

The revised Interim Measure/Interim Remedial Action Decision Document evaluated several groundwater/leachate control mechanisms. The groundwater/leachate control alternatives that underwent a detailed analysis consisted of: (1) natural attenuation and seep water discharge to groundwater, (2) slurry wall with seep water discharge to groundwater, and (3) engineered wetlands with seep water discharge to surface water.

From the detailed analysis and the comparative analysis, the preferred option for groundwater/leachate control is natural attenuation and seep water discharge to groundwater. The existing seep area would be covered with fill and included inside the area of the capped landfill. A gravel drainage layer will be constructed under the cap from the seep downgradient to the east just past the extent of the cap. This will allow leachate at the seep to drain and discharge to the fill down the valley. The East Landfill Pond will be filled with up to 20 ft of engineered fill that will serve as a conduit for seep water to percolate to groundwater. The engineered fill will generally consist of granular fill with a permeability of approximately of 1 x 10^{-2} cm/sec. The fill can be augmented with organic material such as peat, to promote natural attenuation.

Comment 3

The status of the East Landfill Pond is unclear. The pond has received a RCRA-listed F039 waste in the past and apparently will continue to do so for some time into the future. Groundwater modeling results suggest that the landfill will still be discharging leachate 24 years into the future. Because of deficiencies in the focused risk assessment approach, it is premature to assume that the RCRA-listed F039 waste can be delisted in the near future. Therefore, it appears that the East Landfill Pond will have to be managed as an active RCRA surface impoundment, at least in the near future.

Response

Based on agreements between DOE, EPA, and CDPHE, the Revised Draft IM/IRA DD will recommend complete removal of the East Landfill Pond. With implementation of the Proposed Action Memorandum, the FO39 contained in groundwater emanating from the seep will be collected and treated to remove the RCRA FO39 waste from the water and reduce contaminant loading to the East Landfill Pond.

J.1 INTRODUCTION

At the request of the U.S. Environmental Protection Agency (EPA), PRC Environmental Management, Inc. (PRC) has conducted a technical review of the Phase I Interim Measures/Interim Remedial Action (IM/IRA) Decision Document for Operable Unit 7 (OU 7) at the U.S. Department of Energy (DOE) Rocky Flats Environmental Technology Site (RFETS). OU 7 comprises the following Individual Hazardous Substance Sites (IHSSs): the Present Landfill (IHSS 114); the Inactive Hazardous Waste Storage Area (IHSS 203); the Pond Area Spray Field (IHSS 167.2); and the South Area Spray Field (IHSS 167.3). The IM/IRA Decision Document for OU 7 (OU 7 DD) was submitted by Kaiser-Hill on behalf of DOE on August 24, 1995. General comments are presented in Section 2.0. General Comments pertain to the document as a whole or to multiple sections of the document. Specific comments are presented in Section 3.0. Specific comments are keyed to a particular page, paragraph, table or figure. Where PRC found similar problems in several sections of the report, a general comment was provided to avoid redundancy. Typographical and editorial errors within the OU 7 work plan have not been addressed.

J.2 GENERAL COMMENTS

This section presents general comments on the human health risk assessment (HHRA), the ecological risk assessment, the landfill design, groundwater modeling, and applicable or relevant and appropriate requirements (ARARs).

J.2.1 Human Health Risk Assessment

Comment 1

Several parameters used in the exposure calculations should be eliminated because there is insufficient supporting information, and they could cause the estimated intakes of chemicals of concern (COCs) to be significantly underestimated. Exposure parameters that should not be used include the matrix effect (ME), respirable fraction (RF), and respiratory deposition factor (DF). The ME was used to account for decreased absorption of COCs in the gastrointestinal (GI) tract due to decreased bioavailability. In addition, no explanation is provided to support the ME value which is used to estimate intake. ME factors depend on the specific soil type in the OU. At a minimum, the soil type on which the ME is based should be compared to site-specific soil conditions. If soil types are dissimilar, then the ME cannot be used in estimating intakes. EPA has previously requested that ME factors be submitted for approval prior to use in the risk assessment. Until there is EPA concurrence, the ME factor should not be used in the exposure equation to estimate risk.

The RF value is used to estimate respirable particles (PM-10) in the air due to fugitive dust emissions from surficial soils. This relationship, however, is accounted for in the particulate emission factor (PEF), which was used in the exposure equation. The RF parameter should be eliminated from the intake factor equation. Use of the RF value inappropriately decreases exposure concentrations.

The DF variable accounts for the fraction of inhaled particulates retained in the lung. This parameter adjusts the chronic daily intake (CDI) in such a manner that only 85 percent of inhaled particulates are accounted for in the exposure estimates. The assessment implies that the remaining particulates are cleared through mucociliary transport or moved to the oral cavity and swallowed (Cassarett and Doull 1986). If only 85 percent of inhaled particles are deposited in the lungs, the remaining 15 percent must be expectorated or swallowed. If a deposition factor is used, then the ingestion intake equation should be revised to reflect the increase in contaminant intake from particulates not deposited in the lungs, but ingested. It would be more appropriate, however,

to eliminate this factor from the reasonable maximum exposure (RME) inhalation equation for all receptors, as was stated by EPA in the April 11, 1995 letter to DOE regarding exposure parameters and in previous discussions between EPA and DOE.

Response

Use of chemical-specific matrix effects (MEs) was approved by EPA as an RFETS-specific exposure parameter and will remain in exposure calculations for the Revised Draft IM/IRA DD. A discussion will be included in the text to outline the rationale for using specific ME values for soils. This rationale is conservative in that all ME factors are high based on findings in the literature. This conservative approach accounts for different soil types.

The respirable fraction (RF) will be eliminated from intake factor equations because this parameter is accounted for in the particulate emission factor (PEF).

The respiratory deposition factor (DF) will be eliminated from exposure calculations in the Revised Draft IM/IRA DD as agreed.

Comment 2

Mean chemical concentrations in surface water and groundwater were compared to chemical-specific ARARs. This is incorrect. To be protective of adverse human health effects and allow an adequate margin of safety, the maximum detected concentration should be compared to maximum contaminant levels (MCLs) for groundwater and ambient water quality criteria for surface water, unless otherwise required by law. The 95th percentile upper confidence limit (95 UCL) or maximum concentration, whichever is highest, should be used for comparison to risk-based standards.

Response

Mean chemical concentrations, as well as maximum values and 95 percent upper confidence limits on the means (UCL_{95}), will be compared to applicable or relevant and appropriate requirements (ARARs) in the Revised Draft IM/IRA DD. If the maximum or UCL_{95} is above an ARAR but the mean is not, outlier testing and professional judgment will be used to determine COCs.

Comment 3

The focused risk assessment presented in the OU 7 DD includes a complete evaluation of an open-space scenario. The construction worker and office worker scenarios, however, exclude several potentially complete exposure pathways. For example, in addition to groundwater ingestion, office workers may be exposed to surface soils through ingestion, inhalation of particulates, and dermal contact. Tracer element studies have shown that soil ingestion occurs equally from indoor dust and outdoor soil. It has also been shown that chemical concentrations in indoor dust are approximately equal to that in outdoor soil. Soil exposure pathways should be evaluated for occupational receptors. Inhalation of volatile organic compounds (VOCs) migrating through subflooring by office workers is also a potential exposure pathway that should be considered.

For the construction worker scenario, exposure to subsurface soil is evaluated. Surface soils, however, must be contacted in order for subsurface contact to occur. Therefore, exposure to surface soil through inhalation of particulates, ingestion, and dermal contact should be included in the evaluation of the construction worker scenario. A mixing model can be used to combine surface and subsurface soils. Exposure point concentrations for construction workers should be estimated from data aggregated from 0 to 12 ft below ground surface (bgs). In addition, dermal

contact and ingestion of seep water are complete pathways for construction workers during construction of a drain connecting the leachate seep to the pond. These pathways should also be included in the quantitative risk assessment.

In the spray evaporation areas, receptors who use the open space are the only potential human receptors considered. If occupational development in these areas is possible, risks to occupational workers and construction workers should be evaluated. If these receptors are not considered, reasons for excluding these scenarios should be discussed.

Response

Construction worker and office worker exposure scenarios will not be evaluated in the Revised Draft IM/IRA DD because these scenarios are not applicable for this area.

Inhalation of volatile organic compounds (VOCs) was considered in the open-space scenario. However, exposure of human receptors in the open-space scenario to subsurface soils is an incomplete pathway.

The previous use of the office worker scenario in estimating human health risk from exposure to groundwater was inappropriate. After the initial OU 7 risks had already been computed, a new approach was taken (during IHSS prioritization) to address groundwater contaminant concerns in a more reasonable fashion. Under currently expected land uses and agreed-upon exposure scenarios, there are no exposures to groundwater unless it surfaces in seeps, streams, or ponds. The open-space scenario which are consistent with recommendations from the Future Site Use Working Group (DOE 1995) and ASAP (Kaiser-Hill 1996) represents the most probable future exposures in the buffer zone. Therefore, the open-space exposure scenario was chosen in order to conservatively estimate potential risks to the public from groundwater. For this evaluation, it is assumed that maximum concentrations of chemicals found in groundwater represent the highest potential concentrations to which an open-space user might be exposed at a seep or other surface water location. For the Revised Draft IM/IRA DD, therefore, groundwater risks will be estimated using the maximum groundwater concentration in the surface water exposure intake equations for the open-space receptor. The unnamed tributary of Walnut Creek (No Name Gulch) is a losing stream year-round (see response to comment 2 for Executive Summary).

Risks to construction workers involved in remediation activities do not need to be evaluated because a site-specific health and safety plan in conjunction with the activity hazard analysis would include information about site contaminants and specific procedures for personal protective equipment and monitoring required for construction of the response action.

Comment 4

Chemical data from landfill leachate are not validated in this document. The appropriate data validator or laboratory personnel should be contacted if it is unclear whether the data have been validated (EPA 1989a). Qualifiers are assigned to data by the laboratory conducting the analyses and the person performing the data validation. The "B" qualifier attached to the data cannot be assumed to represent chemicals present in laboratory blank samples if the data have not been validated. For example, a "B" qualifier attached to organic chemical data by laboratory personnel indicates that the analyte was found in the associated blank as well as in the sample. The data validator would then determine whether the chemical concentration in the site sample was above 10 times the blank concentration (and, therefore, a detect) or below that level (and, therefore, a nondetect value). Until data are validated, the attached qualifiers cannot be assumed correct.

In addition, several chemicals were detected infrequently but at concentrations exceeding ARARs. These detections were assumed to be outliers and were eliminated from further consideration. This should be supported with rationale for assuming that the detect is an outlier.

Response

None of the 1990 chemical data are validated. Data with "B" qualifiers referenced in the comment are from 1990. The 1990 data were used in the nature and extent of contamination discussion in the Technical Memorandum, Revised Work Plan for Operable Unit 7, September 2, 1995, and for comparability, the same data set was used for the IM/IRA DD. The 1990 data will not be used for the focused human health risk assessments and ARARs comparisons in the Revised Draft IM/IRA DD.

Approximately 92 percent of the 1991 through 1993 chemical data are validated (subsurface soil 96 percent, biota 100 percent, groundwater 73 percent, sediment 98 percent, soil gas 100 percent, surface soil 88 percent, leachate/surface water 89 percent). Most data used for the Phase I IM/IRA DD were evaluated for data quality (precision, accuracy, representativeness, completeness, and comparability [PARCC]) and usability in the Final Work Plan Technical Memorandum (September 1994). Approximately 67 percent of the total results for surface water, which include leachate, pond water, and groundwater intercept discharge, are valid and fully usable. Approximately 18 percent of the total results are estimated results that are fully usable. Approximately 9 percent of the total results are not validated and were used in the IM/IRA DD. Only 6 percent of the total results for surface water were rejected or otherwise determined unusable. The rejected results are not used in the Revised Draft IM/IRA DD.

Chemicals detected infrequently but at concentrations exceeding ARARs were considered "outliers" in the Draft IM/IRA DD if the chemical was detected in less than 5 percent of the samples collected. Following the procedures outlined in Statistical Comparisons of Site-to-Background Data in Support of RFI/RI Investigations (EG&G 1994), professional judgment was used as the final step in the identification of potential contaminants of concern (PCOCs). Professional judgment follows the statistical comparison steps and includes a review of test results and graphic compilations of the data. The professional judgment of the reviewer is required to consider factors not apparent from the statistical comparisons, such as spatial and temporal distribution of analytes; historic information regarding past site operations; inter-element correlations; mass-balance calculations; and knowledge of the hydrology, geochemistry, and geology of the site. This final step is used to identify "outliers" or other occurrences that may otherwise be erroneously included in the final PCOC list.

An outlier is defined as "an observation that does not conform to the pattern established by other observations in the data set" (Gilbert 1987). As used in the OU 7 IM/IRA document, this included primarily single detections (temporally non-recurrent or non-reproducible) and spatially isolated occurrences. It should also be noted that with large data sets such as these (greater than 50 samples), occasional UTL exceedances are expected because the Upper Tolerance Limits (UTL) value includes only the 99th percentile of the background data. Thus, isolated samples may be reflective of the statistical methodology, laboratory error or a sampling anomaly. The word "anomaly" in the PCOC discussion may be more concise than "outlier."

In the Revised Draft IM/IRA DD, the rationale for the elimination of any PCOCs through outlier testing or professional judgment shall be provided.

J.2.2 Ecological Risk Assessment

Comment 1

The ecological risk assessment repeatedly states that the existing seep will be covered by the presumptive remedy and, therefore, will not be a point of exposure to contaminants for ecological receptors in the future. It is not clear, however, where leachate that currently is released at the seep will go. It appears that it may be collected by a drain system and discharged to the East Landfill Pond. If this is not the case, it is not clear how this would reduce the likelihood of an organism's exposure to the contaminants. Although the volume of leachate discharged from the landfill is expected to attenuate over time, initial discharges would probably be similar to current volumes, but to a smaller receiving body. Conditions at the discharge point would therefore be expected to be similar to the current situation and overall pond water quality would be expected to be worse. The OU 7 DD should evaluate the effects of movement of the leachate discharge point rather than assuming burial of the seep will eliminate leachate discharge. Ecological risk should be reassessed and all discussions related to discharges of seep and pond waters should be reassessed.

Response

As described in the response to comment 2 of the Executive Summary, the preferred alternative for groundwater/leachate control is natural attenuation and seep water discharge to groundwater. Extensive modeling has been conducted that demonstrates that seep water will not surface and no new ARARs will be exceeded at the Point of Compliance during the 30-year postclosure care period. Currently, alluvial aquifer concentrations of iron, chromium, and lead exceed ARARs. Dissolved chromium and total recoverable lead exhibited one exceedance of the corresponding ARARs. The standards are based on acute and chronic criteria for aquatic life. In addition, the mean values for iron are less than the mean for background, and the maximum values are also less than the background maximum.

Comment 2

The OU 7 DD states that receptors were assumed to use OU 7 100 percent of the time in order to develop a conservative estimate of risks. At the end of the risk assessment, however, it was determined that this approach was too conservative and the calculated risk was reduced. In order to be a usable tool, a risk assessment should reflect the most likely site conditions. The revision of basic exposure parameters after the compilation of risk calculations has the appearance of an arbitrary change designed to reduce risk. Actual assessment parameters should be defined from the beginning.

Response

Exposure parameters were not arbitrarily altered to reduce the level of apparent risk. Rather, risks associated with the "worst case" scenario were clearly presented, and the implications of relaxing conservative assumptions were discussed.

The ecological portion of the focused risk assessment was intended to be a screening-level evaluation of risk. The use of conservative assumptions regarding exposure parameters is appropriate when conducting a screening-level evaluation (EPA 1994). Conservatism was adopted wherever assumptions were needed so that all assumptions would tend to bias results in the same direction (EPA 1994). As a result, the qualitative interpretation of the results tended to focus on the potential effects of relaxing the conservatism in assumptions about factors such as site use, bioavailability, or the number of organisms affected.

Comment 3

All identified uncertainties relate to overestimation of ecological risk. Others are noticeably absent, such as the lack of organism-specific or chemical-specific toxicity information. All types of potential uncertainties should be identified rather than just those resulting in overestimated risk.

Response

See response to comment 2 for Ecological Risk Assessment.

Comment 4

It appears that potential chemicals of concern (PCOCs) were eliminated from further consideration if no ecological effects information have been developed for them. The rationale to support this approach should be provided. The conservative standard procedure is to retain PCOCs for which there are no effects data.

Response

If no ecological effects information has been developed for a PCOC, there is no meaningful way to assess the risk from that compound. For this reason, PCOCs without ecological effects information were omitted from further consideration.

Comment 5

The development of a no observed adverse effects level (NOAEL) cannot be based on a single study that tested a single dose of concentration that resulted in an observed effect. One observation does not allow distinction of a range of effects. The analyses of NOAELs should be re-evaluated.

Response

The statement that a formal NOAEL cannot be derived from a single dose is accurate. However, formally derived toxicity constants are often not available for a specific chemical/species combination. All of the benchmarks used in the document were derived from toxicological literature according to a review procedure designed by DOE contractors at Oak Ridge National Laboratory. The process for deriving benchmarks has been approved by EPA Region VIII ecotoxicologists for use in screening-level risk assessments at RFETS.

Comment 6

Throughout the OU 7 DD, the need to mitigate the loss of wetlands during the construction of the landfill is identified, with the potential for use of wetlands banked during construction of the Standley Lake diversion project to compensate for the lost wetlands. It is not clear that wetlands will be created beyond those required to mitigate wetland losses from construction of that project. More specificity should be provided regarding the potential loss of wetlands during construction of the landfill cap.

Response

Mitigation of the OU 7 wetlands is included in the "Memorandum of Agreement for the Administration of a Wetlands Bank at Rocky Flats"(DOE 1995), which has been approved by EPA and is presently being reviewed by COE and USFW.

Comment 7

Much of the ecological risk assessment is based on incorrect water quality standards and the assumption that covering the seep will eliminate the release of leachate. These factors underestimate the ecological risk associated with OU 7. Ecological risk should be reassessed for all media, receptors, and PCOCs.

Response

Only correct state water quality standards will be used in the revised document. Stream segment-specific state water quality standards for radionuclides were developed for protection of human health and are not applicable to aquatic life. Therefore, benchmarks developed specifically for RFETS by scientists at Argonne National Laboratory and Oregon State University were used to evaluate the potential for toxic exposure of aquatic life.

See response to comment 2 for Ecological Risk Assessment.

Comment 8

Risk to aquatic life in the East Landfill Pond appears to be minimal, based on toxicity studies and the presence of organisms that are moderately tolerant of pollution. However, the species list is not very diverse and is largely composed of species that are highly tolerant of polluted environments. The basis for determination of tolerance should be explained, including whether it is related to sewage-related compounds or metals and nonsewage organic compounds. Tolerance of an organism to pollutants is not consistent across the range of pollutants. Rationale should be provided regarding the apparent paucity of species in a 20-year-old pond with an apparently consistent water supply.

Response

As noted previously, the recommended alternative in the Revised Draft IM/IRA DD will include elimination of the East Landfill Pond and moving the sediments under the landfill cap. Therefore, the potential limitations on the aquatic community due to sediment contaminants in the East Landfill Pond are not an issue.

Comment 9

Ecological effects of contaminated surface and subsoils were not evaluated. The effects of contaminants on plants and burrowing animals should be evaluated.

Response

The revised IM/IRA DD will evaluate ecological effects of contaminated surface and subsurface soils.

Comment 10

The process used to identify PCOCs is not described beyond saying a standard set of criteria, including professional judgment were used. Rationale should be provided for eliminating contaminants.

Response

See response to comment 4 for Ecological Risk. The exposure and risk screens described in Appendix D were conducted for all PCOCs identified leachate at the seep (SW097) and surface soil, subsurface soils, and groundwater downgradient of the landfill. Selection of PCOCs was not conducted as part of the ERA. The methodology for identifying PCOCs is specified in Section 2 of the IM/IRA. Metals, radionuclides, and indicator parameters with 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. No PCOCs were eliminated before the performance of the ERA.

J.2.3 Landfill Design

This technical review also identifies several landfill design issues. These comments highlight aspects of design that PRC believes should be reconsidered or closely examined as the presumptive remedy moves into the design stage.

Comment 1

The OU 7 DD evaluates three cover systems to cap the OU 7 landfill. The only difference among the three alternatives is the design of the low-permeability layer(s). All three alternatives include a flexible membrane cover (FMC). Underlying the FMC, Alternative A (previously Alternative 5) includes soil bedding material, Alternative E (previously Alternative 7) includes 12 in. of low-permeability (1E-05 centimeters per second [cm/sec]) soil, and Alternative G (previously Alternative 9) includes 24 in. of clay (1E-07 cm/sec). According to the document, Alternative E is the recommended alternative. Compared to Alternative G, Alternative E has greater long-term effectiveness, is easier to implement, has lower costs, and has greater short-term effectiveness. The conclusion that Alternative E has greater long-term effectiveness should be further supported for several reasons. The reasons are enumerated below

- According to the report, Alternative E has greater long-term effectiveness because the clay layer in Alternative G is subject to desiccation cracking and is therefore more prone to leakage if the FMC ruptures. The report states that covers constructed with clay materials at high moisture contents may be subject to more desiccation than covers constructed of soil materials at a lower moisture content. This statement requires further rational, as it contradicts landfill closure regulations, standard accepted practices, and EPA guidance (EPA 1985, 1989b, 1991b). Furthermore, if water is percolating through a ruptured FMC, it seems that any underlying desiccated clay will rehydrate and function as intended.

Response

Seven cover systems were evaluated in the revised OU 7 Decision Document.

In general, factors that influence clay layer desiccation include the clay mineralogy, plasticity, sand content, initial moisture content, temperature variations, nature of the clay's contact with overlying geomembrane or underlying surface, and overburden pressures. These factors have been investigated by several researchers, and it has been suggested that a clay layer having a lower swelling potential, lower plasticity index, lower initial moisture content, and a thicker vegetative soil cover which provides sufficient temperature insulation and overburden pressure to maintain a tight contact between the clay and the overlying geomembrane will be less likely to desiccate than a clay layer that does not have these characteristics.

The low-permeability soil layer proposed for Alternative E is intended to incorporate many of the factors identified above to reduce the potential for clay desiccation compared to the clay layer proposed in Alternative G.

Clay healing generally applies to clay liner systems that will be subjected to high overburden pressures from overlying waste fills. In cases of very large landfills, the clay can be become highly compressed causing a redistribution of the clay to close cracks and voids. These high overburden pressures are typically not present in cover systems.

The ability of a clay to rehydrate after cracking is very dependent on the characteristic of the clay. A pure bentonitic clay such as GCL will hydrate and achieve a permeability similar to a pre-drying condition; however, normal compacted clay covers would not have the potential to totally rehydrate and achieve a permeability equal to the pre-drying permeability.

Comment 2

According to EPA guidance (1989b), a dual-component barrier system is desirable because the layers complement each other. The FMC will tend to roof over the inconsistencies in the underlying compacted soils, while the compacted soil will tend to significantly impede the flow of any leakage through a hole in the overlying FMC (EPA 1989b). In addition, placing an FMC above a moist clay layer tends to protect the clay from desiccation. Finally, each component tends to back up the other in the event of a failure of either component (EPA 1989b). If there is leakage through a hole in the FMC or if the FMC significantly ruptures, 24 in. of clay with a hydraulic conductivity of 1E-07 cm/sec (Alternative G) will be more effective than a 12-in. soil layer with a hydraulic conductivity 100 times larger (Alternative E). The Hydrologic Evaluation of Landfill Performance (HELP) model should be rerun to determine how well the two soil layers "back up" the FMC in the event of failure or slight leakage.

Response

We concur with the EPA guidance documents that recommended a dual-component barrier system. A composite system is the basis for the proposed Alternative (Alternative E) which includes an FMC over a low-permeability soil. However, we are concerned that in the long run a highly plastic, high moisture content clay (Alternative 9) will eventually dry and crack. The cracks will form soil irregularities and stress concentrations in the FMC that may result in defects in the FMC. Holes in the FMC directly above desiccation cracks may result in infiltrating water having a direct conduit to the waste. Although this cannot be accurately modeled, this condition is considered to be worse than an intact FMC overlying a low-permeability soil ($1x10^{-5}$ - $1x10^{-7}$ cm/sec) that is not cracked.

The HELP analyses that were conducted in support of the selection of Alternative 7 evaluated the impacts of expected defects in the FMC for both Alternatives 7 and 9. Recommended defect rates were included in the HELP analyses for both alternatives, and the results indicated leakage rates of $1.6x10^{-4}$ in. (average annual totals) for Alternative 7 and $1x10^{-5}$ in. for Alternative 9. This corresponds to 0.001 percent of rainfall for Alternative 7 and 0.00007 of rainfall for Alternative 9. This is not considered to be a large difference.

We concur that if a large defect occurs in the FMC that a $1\ x10^{-5}$ cm/sec clay will allow considerably more water to infiltrate than a $1\ x\ 10^{-7}$ cm/sec clay. However, large defects or ruptures in the cover should not occur if a proper construction quality assurance (CQA) program (as recommended by the EPA) is implemented during construction. Large defects and/or ruptures that may occur after construction should be observable from the surface during normal inspections and could be repaired.

Comment 3

Landfill closure regulations typically require final covers to have hydraulic conductivities less than or equal to the hydraulic conductivity of the underlying soils. The OU 7 DD assumes the hydraulic conductivity of the weathered bedrock below the landfill to be approximately 1E-07 cm/sec. If there is leakage through a hole in the FMC or if the FMC significantly ruptures, the 12- in. soil layer's hydraulic conductivity of 1E-05 cm/sec is not less than the underlying soils, as required. Therefore, leakage into the landfill could exceed seepage out, resulting in the "bathtub" effect. This effect is undesirable because waste can become saturated and produce highly concentrated leachate. In addition, leachate hydraulic heads will increase within the landfill, which can increase leakage rates out.

Response

In comparing the permeability of the cover system with the permeability of the subsurface, we have utilized the permeability values for the subsurface that were based on field scale tests and the composite permeability of the FMC and the low-permeability soil. We do not believe that it is appropriate to compare the permeability of the low-permeability soil directly below a small defect (1 cm in diameter considered typical for a good CQA program) and the field-scale permeability values. As stated above, large ruptures during construction should be located and repaired as part of the CQA program. Large ruptures after construction should be noted during regular inspections and could be repaired.

Comment 4

FMC rupture could be caused by differential settlement. Any differential settlement will also affect the soil layer below. Alternative G may be less susceptible to settlement effects as compared to Alternative E. The compacted clay component can deform somewhat more without rupturing because it is thicker and because clay has "self healing" properties as a result of the clay's shrink and swell characteristics. The text states that the potential for differential settlement is limited. However, the landfill is generating gases and decomposing. Therefore, settlement is likely to occur following cap construction. The advantages of the self-healing properties of clay and the potential for differential settlement have not been given adequate consideration in the IM/IRA.

Response

We concur that differential settlement can occur at the OU 7 landfill as a result of waste settlement. However, the grading plan for the landfill requires the placement of up to 15 ft of fill to achieve surface water drainage. This fill will be placed prior to cover construction and will act to minimize localized differential settlement. Only long-term regional settlements will put the liner components into compression, minimizing the potential for cracking.

The self-healing aspects of a clay layer are discussed above.

Comment 5

Based on the above comments, it may be useful to consider an alternative that uses a 12-in. layer of clay beneath the FMC. This alternative will be less costly than Alternative G, easier to implement, have greater short-term effectiveness, and still provide all the advantages associated with constructing the barrier layer with low-permeability clay.

Response

A reduction of the clay layer thickness from 24 in. to 12 in. only intensifies the clay desiccation issue in that a 12-in.-thick clay layer will be more sensitive to changes in permeability due to desiccation than a 24-in.-thick clay layer. See response to comment 1 for Landfill Design, bullets 1 and 2 above.

Comment 6

It is not clear why the evaluated alternatives do not include a biotic barrier in the cap. A biotic barrier protects the integrity of the low-permeability layer by preventing burrowing animals and plant roots from puncturing the layer. A biotic barrier also prevents plant and animals from being exposed to landfill contents. The text does state that the 36-in. vegetation layer will prevent burrowing animals from reaching the low-permeability layer, but it is not clear how this layer will achieve these results. The text should support the conclusions regarding burrowing animals and plant root depths, or else provide a biotic barrier in the caps.

Response

A review of site-specific biologic conditions at OU 7 indicates that a biotic barrier is necessary; however the geosynthetic in the lateral drainage layer will serve this purpose. The cover dimensions are preliminary. They will be further refined during Title II design.

Comment 7

Alternative G includes a gas collection layer directly below the clay layer. This configuration may result in desiccation of the clay layer. The Alternative G design should consider a layer placed above the gas vent to prevent gases from desiccating the overlying clay.

Response

The gas-collection layers shown in Alternative E and Alternative G are both located below the soil barrier component of the cap. This is an EPA-recommended standard design feature. Additionally, it is believed that the gas emitted from the waste will have a high moisture content and will not significantly promote desiccation in either design.

Comment 8

The three capping alternatives include a 36-in. vegetation layer. The rationale for the 36-in. thickness should be provided. The thickness should be based on factors such as frost depth, evaporative zone depth, expected burrow depth, and expected plant root depth.

Response

The dimensions given on the cover alternatives are preliminary. Further refinement of the design layer thickness will occur during the final design effort where issues such as frost burial depth, evaporative zone depth, burrowing animal depth, and plant root depth will specifically be addressed.

Comment 9

The report states that no-action alternative will not meet chemical-specific ARARs because leachate at the seep exceeds four Colorado water quality (CWQ) standards, one MCL and two practical quantitation limits (PQLs). For the two capping alternatives, the only chemical-specific

ARAR exceedances mentioned are associated with surface water (one CWQ standard) and groundwater (one MCL, one CWQ, and one PQL). The leachate exceedances are not discussed. Presumably, under the capping alternatives, the blanket drain will discharge leachate at the pond or at some other downgradient location. Therefore, exceedances in ARARs may occur at the seep discharge location under Alternatives E and G. The IM/IRA should address this potential noncompliance with ARARs.

Response

Based on agreements between DOE, EPA, and CDPHE, the Draft Final IM/IRA DD will recommend complete removal of the East Landfill Pond. Various alternatives will be analyzed to address the leachate at the seep. Options examined in Chapter 5 include active and passive treatment and discharge to surface water and groundwater. Based on this evaluation, it is determined that leachate must be treated prior to a surface water discharge. Leachate discharged to groundwater will meet ARARs at the Point of Compliance without treatment. In addition, under currently expected land uses and agreed-upon exposure scenarios, there are no exposures to groundwater unless it surfaces in seeps, streams, or ponds. The East Landfill Pond will be removed and the drainage regraded to prevent seeps. No Name Gulch is a losing stream year-round, so groundwater is not expected to surface in the stream (see response to comment 2 for Executive Summary). In addition, future development of groundwater will be prohibited by institutional controls.

J.2.4 Groundwater Modeling

Comment 1

The groundwater intercept system is not correctly represented in the MODFLOW groundwater flow model. The text states, and Figure C-1 shows, the groundwater intercept system is represented by drain cells which surround the northern, western, and southern sides of the landfill. The drain cell requires that the user specify a drain elevation (which does not have to coincide with the bottom of the cell) and a conductance. The drain cell withdraws water from the model at a rate determined by the drain conductance and difference between the head in the cell and the drain elevation, but only when the head in the cell exceeds the drain elevation. Figure C-1 shows, however, a gap in this boundary corresponding to the section of the intercept system that is believed to be ineffective. A previous document (DOE 1994) included a detailed evaluation of the effectiveness of the groundwater intercept system and concluded that the system did not function properly on the northern side of the landfill because the drain was not keyed into the bedrock, allowing water to flow underneath the drain and into the landfill. Therefore, the groundwater model would represent the groundwater system more accurately if a continuous boundary of drain cells surrounded the landfill area on the north, west, and south sides. Groundwater could still bypass the intercept system on the north side where the drain cell elevations are greater than the elevations of the bottoms of layer 1 drain cells. This configuration should provide a more accurate estimate of groundwater that enters the landfill from the north. Correctly representing this boundary condition should affect model calibration and require the model to be recalibrated.

Response

In the Draft IM/IRA DD model configuration, some drain cells were removed on the north side of the landfill, and the remaining drain cells on the north side were reduced in conductance from the values used for the south side drain cells (see Table C-1). This configuration is correct if the groundwater intercept system is partially to fully blocked on the north side. The potential for blockage exists from construction activities associated with the tie-in of the small slurry wall on the north side of the landfill. Other possible causes of blockage include activities during the construction of the intercept system and silting in of the drainage layer.

Whether the north drain is functioning is uncertain. Modeling of the drain as described in the comment has been performed. The fit of simulated heads to measured heads is acceptable, but not as good as the fit presented in Appendix C (as measured by residual sum of squares). Because the fit is acceptable and the blockage of the north drain has not been proven, the modeling will be performed as suggested in the comment.

Comment 2

Calibration of the model is inadequate because the modeled seep flow at the beginning of the no action scenario simulation (1.88 gpm) is one-half of the average observed seep flow (3.61 gpm) that was presented in the Modified Final Proposed Action Memorandum for Passive Seep Collection and Treatment at Operable Unit No. 7 (Kaiser-Hill 1995). Section C.6 of the text does not indicate that seep flow rate was included as a calibration target. It is generally recommended to use estimates of flow as calibration values in addition to heads in order to increase the likelihood of achieving a unique calibration (Anderson and Woessner 1992). This is particularly critical when the model is used to predict changes in flow rates in response to changes in the flow system, as is the case with this model. Therefore, the model should include the average seep flow as a calibration target. The model should also be recalibrated to achieve a better match between predicted and observed flow rates under the no-action scenario.

Response

The comment asserts that the groundwater flow model should be calibrated to the average flow at the seep. This assertion is incorrect: the groundwater flow model is calibrated not to "average" conditions, but to the conditions at one specific time, March 1993.

The seep flow measurements as reported have a high margin of error. All measurements of the seep flow, with one exception, are visual estimates only. Accurate flow measurement is difficult if not impossible because the seep location contains landfill debris, weeds, and multiple seepage points. Estimates made during multiple site visits during 1994 and 1995 ranged from 1 gpm to 5 gpm, with the majority of the estimates being between 1 and 2 gpm. During an extremely wet period in April 1995, near the 100-year high, flows were estimated at 5 gpm.

Well hydrographs in the landfill vicinity show that high water elevations occur in the spring, usually in April. These increased flows are due to increased infiltration following spring precipitation events. Elevations before and after the peak fluctuate rapidly and low to moderate flow conditions exist during the majority of the year. The model is calibrated to water elevations measured in March 1993, which more closely represent low to moderate flow conditions during the majority of the year, rather than to the high flow condition which occurs for only a short time period.

In summary, the seep flow was used in the calibration of the model. The model was calibrated using well head elevations, and the reasonableness of the simulated flow at the seep was used as a check. Adjustments to hydraulic conductivities and recharge were made during the calibration to adjust the simulated flow at the seep. A simulated flow of 1.88 gpm is reasonable for March 1993 flow conditions.

J.2.5 Applicable or Relevant and Appropriate Comments

Comment 1

Discussions regarding ARARs will require revision when other sections are revised.

Response

Descriptions of ARARs throughout the report will be revised as necessary.

Comment 2

Responsibility for determining compliance with the substantive requirements for permits is not clear. DOE does not discuss interactions with responsible agencies. The determining agency should be specified for all actions that will provide substantive efforts in lieu of formal administrative requirements.

Response

OU 7 remediation and closure activities will be conducted in accordance with the Interagency Agreement (IAG). Part 18 of the IAG states that response actions conducted entirely on site are exempted from the procedural requirements to obtain permits. However, these actions must satisfy applicable or relevant and appropriate federal and state standards, requirements, criteria, or limitations that would have been included in such permits. In accordance with the IAG, EPA, after consultation with the State, will determine the ARARs applied at the Site. Substantive requirements for permits should be identified as part of the ARARs process and determined in the final IM/IRA DD or CAD/ROD; therefore, EPA will have final determination over whether compliance with the substantive requirements for permits are achieved.

J.3. SPECIFIC COMMENTS

Comment 1

Executive Summary—The Executive Summary states that the presumptive remedy of containment addresses all potential pathways except surface water and sediment in the East Landfill Pond and surface soils in the spray evaporation areas. However, the presumptive remedy also does not address pathways associated with existing groundwater contamination outside landfill boundaries. Therefore, the document should clarify whether or not groundwater will be addressed along with surface water, sediment, and surface soils, if appropriate.

Response

The executive summary will be clarified. Groundwater downgradient of the source area will be addressed along with surface and subsurface soils downgradient of the landfill soils in the revised document.

Comment 2

Page 7-2. Third Paragraph. This paragraph states that the landfill cap will cover the existing leachate seep, thereby eliminating exposure to the seep. The text then states that a gravel blanket will drain seep water so the water will not build up and create a seep onto the new cap. It is not clear whether this gravel drainage blanket will daylight or where it will discharge. This location should be clarified. Exposure pathways could exist at the point of gravel drain discharge.

Response

As described in the response to comment 2 of the Executive Summary, the preferred alternative for groundwater/leachate control is natural attenuation and seep water discharge to groundwater.

Comment 3

Section 3. Page 3-3, 3rd paragraph. This paragraph discusses the potential exposure pathways associated with OU 7. It is unclear whether "ingestion and dermal contact with waste materials" includes direct contact with chemicals or dermal contact with contaminated soil. The text should be revised to clarify whether both pathways will be evaluated.

Response

The text will be revised to clarify that the exposure pathways are ingestion and dermal contact with contaminated soil.

Comment 4

Section 3.3.6. Page 3-9. This section concludes that the preliminary remediation goal (PRG) screen conducted on three East Landfill Pond sediment samples indicated that all 20 of the identified PCOCs for the East Landfill Pond sediments were found not to exceed the PRGs for an open space user, and therefore, there is no risk to human health from the East Landfill Pond sediments. The final work plan for OU 7 (DOE 1994) detailed the seven-step data quality objective (DQO) process that has guided decisions on data collection at OU 7. The outcome of the DQO analysis concluded that 400 additional sediment samples would be needed to determine whether five of the PCOCs identified for East Landfill Pond sediments exceed PRGs. However, the decision was made not to collect these 400 sediment samples. The text explains that "for these five PCOCs, the sample means exceeded the guidance or recommendation to be considered (TBC) or PRG by at least one order of magnitude. Given the magnitude of these exceedances, it is not likely that additional data will affect the decision to remediate these sediments." The text also states "the available data already strongly support a decision to take remedial actions." Therefore, according to the seven-step DQO decision-making tool developed by DOE for OU 7, 400 additional sediment samples still need to be collected in order to determine whether PCOCs for the East Landfill Pond exceed PRGs. The text should be revised accordingly.

Response

Four hundred additional sediment samples are not required to determine whether PCOCs for the East Landfill Pond Exceed PRGs. The sample number requirements developed by the seven-step data quality objectives were based on determining a PRG exceedance for a residential scenario, not an open-space recreational scenario. The recommended alternative in the Revised Draft IM/IRA DD will include complete elimination of the East Landfill Pond and moving sediments under the landfill cap.

Comment 5

Section 3. Page 3-35. Table 3-6. Although the reference for the particulate emission factor (PEF) value correctly cited as "EPA Guidance for Superfund Volume I, Human Health Evaluation Manual, Part B (1991)," the PEF value as listed in Table 3-6 is incorrect. A PEF of 4.63E9 cubic meters per kilogram (m^3/kg) is the default value provided in EPA guidance (1991a) and should be used in the calculation of particulate inhalation of surface soil. The table currently lists a value of 4.63E10 m^3/kg.

Response

The value for the particulate emission factor (PEF) in Table 3-6 will be corrected to 4.63E9 m^3/kg, the default value provided in EPA Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part B (1991).

Comment 6

Section 3. Figure 3-8. The conceptual site model for surface soils in spray evaporation areas should be revised to include office workers and construction workers who may also be exposed to surface soils through ingestion, dermal contact, external radiation, or inhalation of particulates. If construction or industrial activities could occur in these areas, then it is necessary to evaluate exposure via these pathways.

Response

The conceptual site model for surface soils downgradient of the landfill will not be revised to include office and construction workers. Exposure pathways for these scenarios are inappropriate because neither construction nor industrial activities will occur in these areas, based on recommendations of the Future Site Use Working Group (DOE 1995) and ASAP (Kaiser-Hill 1996).

Comment 7

Section 3. Figure 3-6. The conceptual site model for landfill leachate at the seep should be revised to include construction workers who may also be exposed to seep water through dermal contact and ingestion during construction of a drain connecting leachate seep to the pond. If this activity is expected to occur, then it is necessary to quantitatively evaluate exposure via these pathways.

Response

The conceptual site model for landfill leachate at the seep will not be revised to include construction workers involved in remediation activities because exposures from remediation activities would be precluded by site-specific health and safety requirements for personal protective equipment and monitoring.

Comment 8

Page 3-34. Table 3-5. Table 3-5 presents the site-specific exposure parameters for assessing risks to open-space users from soil ingestion. The values listed are acceptable for estimating intakes from nonradiological analytes, but are not appropriate for radionuclide risk estimates. Specifically, the soil ingestion rate for this receptor should be age- and weight-adjusted when used in radionuclide risk estimates. As stated in EPA guidance (1991a), soil ingestion rates differ for children and adults; therefore, age-adjusted ingestion rate factors are used in the soil pathway equation when assessing risks from radionuclide exposure. The soil ingestion rate must be adjusted because the radionuclide intake equation does not include body weight or averaging time, which are important when considering the difference in soil ingestion rates between adults and children. Children ingest more soil and weigh less than adults, but the increased soil ingestion rate is assumed to occur for only 6 years. EPA guidance (1991a) presents an equation for calculating the adjusted soil ingestion rate; it should be used for estimating the soil ingestion rate of open-space users at OU 7 for the radionuclide risk assessment.

Response

The soil ingestion rate for carcinogenic risk estimates will be age-averaged in the Revised Draft IM/IRA DD.

Comment 9

Page 7-2. Paragraph 2. The text implies that leachate exposure pathways will be interrupted by capping the landfill and providing a gravel blanket or French drain beneath the landfill to prevent leachate from building up beneath the landfill. The text does not specify where the gravel blanket or French drain will terminate, but suggests that it will discharge to groundwater and "the groundwater pathway is already incomplete." Because of the landfill's topographic position above the East Landfill Pond, leachate may still discharge to surface water in the East Landfill Pond, thereby allowing continued contamination of the east landfill pond and surrounding sediments. The discharge point for the French drain should be specified.

Response

As described in the response to comment 2 of the Executive Summary, the preferred alternative for groundwater/leachate control is natural attenuation and seep water discharge to groundwater.

Comment 10

Page 7-4. Paragraph 1. The text states that cap will be graded in such a way as to force surface water to the perimeter of the landfill, where it will accumulate in a surface water collection ditch and routed around the East Landfill Pond. Figures 7-3 and 7-5 show that the eastern face of the landfill will consist of two relatively steep slopes (20 percent) that slope toward each other, forming a valley in which a large volume of landfill runoff may collect.

The figures do not depict any structures or ditches that would prevent this flow from entering the East Landfill Pond. Because the pond is in direct contact with the landfill, this would increase the saturation of the landfill mass. Measures to stabilize erosion from the steep eastern slopes and to divert runoff from the pond should be discussed in the text.

Response

The recommended alternative for the Revised Draft IM/IRA DD will include complete elimination of the East Landfill Pond. Erosion control measures along the steeper eastern slopes of the landfill will be considered during the Title II design effort when slope angles in this area are finalized.

Comment 11

Page C-5. Paragraph 4. The text states that the model-generated potentiometric map supports the conclusion that the groundwater intercept system is failing on the northern side of the landfill. The groundwater intercept system was not correctly modeled on the northern side and was, in fact, left out of the model. Therefore, the model should not be cited to support this conclusion.

Response

In the model configuration presented in the Draft IM/IRA DD, some drain cells were removed on the north side of the landfill, and the remaining drain cells on the north side were input with lower conductance values than the conductance values used for the south side drain cells (see Table C-1). This configuration is correct if the groundwater intercept system is partially to fully blocked on the north side. The potential for blockage exists from construction activities associated with the tie-in of the small slurry wall on the north side of the landfill. Other possible causes of blockage include activities during the construction of the intercept system and silting in of the drainage layer.

Whether the north drain is functioning is uncertain. Modeling of the drain as described in the comment has been performed. The fit of simulated heads to measured heads is acceptable but not as good as the fit presented in Appendix C (as measured by residual sum of squares). Because the fit is acceptable and the blockage of the north drain has not been proven, the model configuration in the Revised Draft IM/IRA DD will include drain cells as suggested by the reviewer.

Comment 12

Page 3-15. Paragraph 1. The text asserts that ARARs are used to create a framework for determining the health- and risk-based limits for remedial actions and to develop remedial alternatives. This statement is incorrect. The human health and ecological risk assessments create the framework for determining health and risk-based limits and the resulting values may not be the same as ARARs. The text should be revised.

Response

The text will be revised accordingly.

Comment 13

Page 3-19. Section 3.4.2.1. This section states that minimization of the destruction, loss, or degradation of wetlands is required by Title 40 of the Code Federal Regulations (CFR) § 6.302(a). This section of regulations, however, pertains specifically to implementing Council of Environmental Quality regulations relative to the National Environmental Policy Act (NEPA), which is not pertinent to the discussion as cited. Loss of wetlands is governed by the Clean Water Act (CEWA) § 404 and the associated Corps of Engineers and EPA regulations, Executive Order 11990, and 10 CFR 1022. The text should be corrected.

Response

The text will be corrected.

Comment 14

Pages 3-23 and 3-24. Section 3.4.3.3. DOE proposed to delist the leachate from the landfill as a hazardous waste. Several problems have been identified relative to this proposal. The assumption that covering the seep with the landfill cap will remove the leachate source is not realistic because the preliminary design discussions indicate leachate will be collected in a drain for discharge to the East Landfill Pond. Although the flow of leachate is expected to attenuate to a steady rate over 10 years, it would be expected that initial flows would be similar to those currently observed. Current water quality at the seep exceeds CWQ standards for several constituents. Constituents should not be considered absent above maximum allowed concentrations (MACs) when the analytical detection limits exceed the MACs. DOE asserts that only the substantive requirements of 40 CFR 260.20 and 260.22 must be met for the leachate to be delisted. However, it falls under EPA's jurisdiction to determine whether those substantive requirements are met, not DOE. The text should be corrected.

Response

Delisting of the leachate will not be proposed in the Revised Draft IM/IRA.

J.4. REFERENCES

Andersen, M. P. and W. W. Woessner, 1992, *Applied Groundwater Modeling: Simulation Flow and Advective Transport*, Academic Press, Inc.

Cassarett, L. J. and J. Doull, 1986, *Cassarett and Doull's Toxicology: The Basic Science of Poisons* , C. D. Klaassen, M. O. Amdur and J. Doull (eds.), Third Edition, Macmillan Publishing Co., New York.

DOE, 1995, J. Robertson, DOE, to S. Stiger, EG&G, Personal Communication, Subject: "Exposure Factors and Exposure Scenarios," April 13.

EPA, 1985, *Covers for Uncontrolled Hazardous Waste Sites*, EPA/540/2-85/002, September.

EPA, 1989b, *Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments*, EPA/530-SW-89-047, July.

EPA, 1991a, *Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals*, Office of Solid Waste and Emergency Response, OSWER Directive 9285.7-01B.

EPA, 1991b, *Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites*, EPA/540/P-91/001, OSWER Directive 9355.3-11, February.

EPA, 1993, *Presumptive Remedy for CERCLA Municipal Landfill Sites*, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Directive No. 9355.0-49FS, September.

Kaiser-Hill, 1995, *Modified Proposed Action Memorandum, Passive Seep Collection and Treatment, Operable Unit No. 7*, Final, July.

Kaiser-Hill, 1996, *Accelerated Site Action Project*, Phase II Predecisional Draft, January 9.

U.S. Environmental Protection Agency, 1989a, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)*, Interim Final, September.

U.S. Department of Energy, 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.

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION COMMENTS ON DRAFT PHASE I IM/IRA DECISION DOCUMENT FOR OPERABLE UNIT 7

AUGUST 24, 1995

Comment 1

Section 1.3 (Page 1-4). Returning investigation-derived materials to the present landfill has been approved by the Division and EPA. This action should be mentioned in this document, either in this section or elsewhere.

Response

Returning investigation-derived material from the Phase I and supplemental field investigations to the landfill before closure will be mentioned in the Revised Draft IM/IRA DD.

Comment 2

Section 2.1.1 (Page 2-2). The specific solvents and degreasing agents that were disposed in the landfill should be identified along with any associated hazardous waste codes. The Work Plan mentions "97 solid waste streams that contained hazardous waste or hazardous constituents."

Response

Historical waste disposal records are not specific enough to identify the types of spent solvents and degreasing agents that were disposed. None of the wastes disposed were recorded as "listed" hazardous wastes. Appendix A of the Final Work Plan Technical Memorandum (DOE 1994) contains available information on hazardous and nonhazardous waste streams disposed from 1968 to 1986. Appendix A is reproduced here as Attachment 1.

Comment 3

Section 2.5.3 (Page 2-26). Methylene chloride in the leachate samples was detected at nearly twice the rate as in background samples and the maximum detection was five times the maximum background detection. These data do not support the contention that these detections are due only to laboratory contamination.

Response

For the Revised Draft IM/IRA DD, site data from 1990 will be omitted because these data are not validated. At the seep, methylene chloride is detected in 4 of 11 samples, or 36 percent of the samples. The maximum detection is 6 µg/L. Methylene chloride was detected in 26 of 100 samples, or 26 percent, in the background data set. The maximum detection in the background data set is 31 µg/L, with 5 detections equaling 20 µg/L or greater. This data comparison supports the contention that methylene chloride detected at the seep is a laboratory contaminant.

Comment 4

Section 2.5.4 (Page 2-27). The sentence that begins at the top of this page is unclear and may need to be re-written.

Response

The text will be revised.

Comment 5

Table 2-2 (Page 2-34). The units on this page of the table should be µg/L.

Response

The typographical error will be corrected.

Comment 6

Section 3.3.1 (Page 3-4). All regulatory references should be to the appropriate section of the Colorado Hazardous Waste Regulations (6 CCR 1007-). References to Subpart C wastes do not apply to F039 leachate and should be deleted.

It is more correct to state that leachate exists by application of the regulatory definition of leachate (6 CCR 1007-3 §260.10 and §261.31); it is not merely determined by the "derived from" rule.

Response

All regulatory references will be changed to the appropriate section of the Colorado Hazardous Waste Regulations. References to Subpart C waste will be deleted.

The text will be revised.

Comment 7

Section 3.3.1 (Page 3-5). Ingestion by future onsite workers is the only pathway which evaluates groundwater. It has been demonstrated that ingestion of contaminants in groundwater contributes only about a third of the total risk, and inhalation of VOCs from non-ingestion and non-showering uses each contribute approximately one third of the total risk from exposure to groundwater during domestic water use (Supplemental Guidance to RAGS: Region IV Bulletin, "Exposure to VOCs during Domestic Water Use: Contributions from Ingestion, Showering, and Other Uses"). Therefore, DOE's limitation of the calculations to a single pathway may significantly underestimate the risk from groundwater exposure In addition, DOE also did not calculate the possible exposure to contaminated basement air resulting from infiltration of groundwater VOCs through basement walls. Therefore, risk is also underestimated because of the omission of this pathway.

Response

The previous use of the office worker scenario in estimating human health risk from exposure to groundwater was inappropriate because occupational scenarios are not applicable for this area. After the initial OU 7 risks had already been computed, a new approach was taken (during IHSS prioritization) to address groundwater contaminant concerns in a more reasonable fashion. Under currently expected land uses and exposure scenarios agreed upon by the Future Land-Use Working Group (DOE 1995) and ASAP (Kaiser-Hill 1996), there are no exposures to groundwater unless it surfaces in seeps, streams, or ponds. The open-space scenario represents the most probable future exposures in the buffer zone. Therefore, the open-space exposure scenario was chosen in order to conservatively estimate potential risks to the public from

conservatively estimate potential risks to the public from groundwater. For this evaluation, it is assumed that maximum concentrations of chemicals found in groundwater represent the highest potential concentrations to which an open-space user might be exposed at a seep or other surface water location. For the Revised Draft IM/IRA DD, therefore, groundwater risks will be estimated using the maximum groundwater concentration in the surface water exposure intake equations for the open-space receptor. Inhalation of VOCs is an incomplete pathway and was not considered in the open-space scenario.

Comment 8

Section 3.3.4, 3.3.5, 3.3.6, 3.3.8 (Pages 3-7, 3-8, 3-9, 3-12). What is the basis for the statement that, "there is no risk to human health from inhalation or incidental ingestion of, or dermal exposure to leachate at the seep?" A number of semivolatile and volatile organics were detected in the leachate and a qualitative evaluation regarding the possible dermal toxicity of these chemicals is not presented here. The statement quoted above needs to be qualified with the phrase, "for this open space receptor." Otherwise, the statement could be construed as being true for unrestricted use, which is not the case. This also applies to similar statements on the other pages noted above.

Response

The statement, "there is no risk to human health from inhalation or incidental ingestion of or dermal contact with leachate at the seep," is based on results of the PRG screen that indicate that contaminant concentrations at the seep do not exceed risk-based concentrations for an open-space receptor.

Comment 9

Section 3.3.7 (Page 3-10). Compositing of soils is not an appropriate way to assess risk for an open space receptor, since such a receptor is more likely to be exposed to just the upper surficial soils. Compositing soils down to 10 in. also has the effect of diluting the exposure concentrations.

Response

Risk to an open-space receptor will be revised to include exposure to upper surficial soils (0 to 2 in.) only.

Comment 10

Section 3.3.7 (Page 3-11). The matrix effect for GI tract absorption has not been approved by either agency. Its inclusion in these calculations, however, does not have any effect because it is set to 1. However, it should be deleted from the equations.

Response

Use of chemical-specific matrix effects (MEs) was approved by EPA as an RFETS-specific exposure parameter and will remain in exposure calculations for the Revised Draft IM/IRA DD. A discussion will be included in the text to outline the rationale for using specific ME values for soils. This rationale is conservative in that all ME factors are high based on findings in the literature. This conservative approach accounts for different soil types.

Comment 11

Section 3.3.9 (Page 3-14). The argument at the end of this section that the exposure pathway for ingestion of groundwater downgradient of the landfill is incomplete is weak. There may be a combination of reasons to eliminate consideration of this pathway, but the fact that there are currently no plans to develop water wells is inadequate.

Response

The exposure pathway for ingestion of groundwater downgradient of the landfill was included in the focused risk assessment. In addition, discussion regarding No Name Gulch as a losing stream is included.

Comment 12

Section 3.4 (Page 3-15). Contrary to the statement in the top paragraph on this page, both the substantive aspects and the administrative requirements of ARARs, including those of RCRA/CHWA, apply to the Present Landfill. This comment will not apply once the single-regulatory agency concept ("carve-out") is implemented, presumably in the near future.

Response

The "carve-out" has been implemented so that EPA is now the lead regulatory agency. Therefore, only the substantive aspects of RCRA/CHWA apply.

Comment 13

Section 3.4.3.3 (Page 3-23). The delisting procedure described in the text is not the most effective method to deal with the landfill leachate. Environmental media which contained one or more hazardous waste must be managed as a hazardous waste until it is determined that the media no longer contains enough hazardous waste to present a threat to human health or the environment.

1. Risk to human health is evaluated by determining if the media:

   a) presents an excess risk of cancer greater than 1×10^{-6}, or

   b) constitutes a Hazard Index greater than 1.0.

2. If the media contains hazardous constituents that do not exceed human health risk levels, continuing management as a nonhazardous waste material may be necessary. Management action is required if environmental receptors (groundwater, surface water, ecological receptors, etc.) can potentially be damaged by the uncontrolled release of the contaminated media.

   a) Surface water or groundwater containing hazardous constituents are compared to water quality standard attached to the applicable water use classifications (currently Aquatic Life-Warm 2, Recreation 2, Agricultural and Water Supply for surface water; Domestic Use, Agricultural Use and Surface Water Protection for groundwater).

   b) Soils and sediments containing hazardous constituents which may leach into surface water or groundwater at levels above the standard described above must be managed or treated appropriately.

Leachate will likely continue to contaminate various environmental media after the actions prescribed in this document have been implemented. Until the surface water/groundwater, for instance, no longer contains F039 waste at levels which present risks as described above, a leachate treatment system will be required. This will likely be beyond the life of the treatment system established by the Seep Collection and Treatment PAM, and therefore, this document needs to address such a system. This issue will also require reviewing plans for the landfill dam.

Response

Based on the future land-use scenario (open-space), the leachate contained-in groundwater neither presents an excess human health risk of cancer greater than 1E-06 nor does it constitute a Hazard Index greater than 1. In addition, although leachate will continue to drain from the landfill mass for several years, there will be no exposure pathway for an open-space recreational user because the leachate will remain in the subsurface and will not be discharged to surface water unless it is treated.

Comment 14

Section 3.4.3.4 (page 3-24). This section mentions that a contingency plan will be developed to address leachate and groundwater that do not meet MACs. This contingency plan should be developed within this decision document.

Response

The reference to a contingency plan will be removed because leachate treatment will be evaluated explicitly in the revised IM/IRA DD.

Comment 15

Section 3.5.1.1 (Page 3-26). Because the landfill is an interim status closure unit, the requirements in 6 CCR 1007-3, §265.110 apply. The closure performance standard requires that the post-closure escape of leachate be controlled, minimized or eliminated.

Response

The referenced standard states that "the owner must close the facility in a manner that:...controls, minimizes or eliminates, to the extent necessary to protect human health and the environment , post-closure escape of... leachate." A focused risk assessment for the leachate showed no risk to human health. An ecological risk assessment indicated unacceptable risk for direct contact. Therefore, in the IM/IRA DD, alternatives were developed that control, minimize, or eliminate the post-closure escape of leachate. Alternatives include cap, slurry wall, treatment of the leachate and elimination of the exposure pathway.

Comment 16

Table 3-8 (Page 3-37). The combined adult and child exposure to surface soil by incidental ingestion has not been age-averaged over 30 years. Rather, the children's and adult's risks have been calculated separately. EPA guidance (RAGS) recommends age-averaging, even though children's risks are then lower. This is because of long latencies of some chemical effects such as carcinogenicity.

Response

The soil ingestion rate for carcinogenic risk estimates will be age-averaged in the Revised Draft IM/IRA DD.

Comment 17

Tables 3-15, 3-16, and 3-17 (Pages 43-53). How were the potential ARARs shown in these tables selected?

Response

In the original document, potential chemical-specific ARARs for OU 7 were developed using the Rocky Flats Draft Master List of Potential ARARs (February 1995), which includes Safe Drinking Water Act maximum contaminant levels (MCLs) (40 CFR 141), state MCLs (5 CCR 1003-1), RCRA MCLs (40 CFR 264.94), state water quality standards (5 CCR 1002-8, 3.1.11), and state basic standards for groundwater (5 CCR 1002-8, 3.11). For both groundwater and surface water, the most stringent standard was chosen for each chemical and compared to the practical quantitation limit (PQL) for that chemical. The higher value of the two was selected as the ARAR. This approach has been modified for the Revised Draft IM/IRA DD to be consistent with the Action Level Framework for surface water, groundwater, and soils.

The text in Section 3 will be revised to clarify how ARARs were selected.

Comment 18

Table 3-21 (Page 3-63). The Colorado Hazardous Waste Act in 6 CCR 1003-7 should be included as an applicable ARAR.

Response

The interim status regulations and standards of the Colorado Hazardous Waste Act have been added to the table.

Comment 19

Section 4.2.3 (Page 4-2). The institutional controls mentioned here may need to be strengthened with a compliance order. It is also unclear here in the text and in Table 4-2 exactly how water use will be controlled.

Response

The text will be modified to include a compliance order. A more detailed discussion of institutional controls is in Section 5.

Comment 20

Section 4.2.5, Section 7.3.5 and Section 8.2.3.1 (Pages 4-3, 7-13 and 8-9). How many gas vents will be installed and how was this number determined? Will a gas collection system require any piping in which condensate may collect?

Response

The number of gas vents will be determined during the final design effort. The rationale for the number of vents and the handling of condensate in the gas pipes will be provided at that time.

Comment 21

Section 4.2.6 (Page 4-4). This section states that vent pipes or gravel columns will extend through the cover and will be logical points for monitoring emissions from landfill. Geonets are normally used for liquid drainage applications and are only on the order of about 4 to 8 millimeters. The manner in which the vent pipes or gravel columns are attached to the gas collection geonet and then extended through the cover system should be addressed. Also explain how the gravel columns will be prevented from acting as conduits for liquids.

Response

The gas generated in the waste mass will generally consist of methane which will flow upward along pathways of least resistance until it reaches the gas collection layer where it will be channeled through the cover system by gas collection pipes. These gas collection pipes will be placed at high points in the cover system.

Geonets and geotextiles suggested for the gas collection layer are more permeable than the overlying soil and FMC barrier layers. Some infiltration of gas into the soil layer will occur but the majority of the gas will flow through the openings in the geonet and the geotextile. The thickness of the geonet layer within the geotextile/geonet/geotextile geocomposite does not greatly affect the composite's ability to transmit gas.

Richardson and Koerner (1987) list geonets and geotextiles suitable for use in gas venting systems.

The connection between the vent pipes/gravel columns and the geonet will be addressed in the Title II design document.

It is anticipated that the majority of precipitation falling onto the landfill cover will either run off the gentle slopes, evaporate from the top soil and vegetative layers, or drain through the geocomposite drainage layer on top of the FMC. Alternatives 5, 7, and 9 are identical with respect to the drainage features above the FMC, and HELP modeling indicates that the majority of the precipitation will be removed by these layers. Of the moisture that penetrates these drainage and barrier layers and enters the gas collection geocomposite, a small portion will likely drain downslope in the geonet layer; however, a larger portion of this moisture will drain through the geonet into the underlying geotextile and soak into the general fill layer.

Currently, there are no plans to prevent moisture from entering the gravel columns; however, since the cross-sectional area of these columns will be small in comparison to the area of the general fill, the likelihood of moisture reaching the columns and the impact it will have on the overall water balance is reduced. Once surface water has migrated through the cover section, it will ultimately migrate into the waste, regardless of whether it flows in the gravel columns or directly through the general fill placed to achieve the design surface grades. The only impact of the gravel columns will be to decrease the time for that water to reach the waste. However, in large areas of the landfill, the grading fill will be of limited thickness and therefore will not impede the rate of migration.

Comment 22

Sections 5.1.2, 6.2.2.2, 8.17, 9.2.2 (Pages 5-2, 6-10, 8-5, 9-8). Before this decision document can commit to draw on the wetlands mitigation bank, the managers of that project must be advised and provide assurances that sufficient acreage is available.

Response

OU 7 is eligible for inclusion in the wetland bank as described in the "Memorandum of Agreement for the Administration of a Wetland Bank at Rocky Flats" (DOE 1995), which has been approved by EPA and is presently being reviewed by COE and USFW. The text will be updated with the most recent status of the wetlands bank at the time of printing.

Comment 23

Sections 5.1.2 and 9.2.1.3 (Pages 5-2 and 9-7). Mitigation of sensitive habitat is discussed, but the text does not say what criteria should trigger an action nor what potential mitigating actions might be taken.

Response

Since the submittal of the draft IM/IRA DD, a trapping program was conducted at OU 7 and no Preble's meadow jumping mice were found after 400 trap nights. In addition, the potential habitat area at OU 7 is relatively small (less than 1 acre) and isolated from other Preble's populations. Additional potential habitat area will be regraded but in the long-term will be revegetated to restore or enhance the potential habitat. Therefore, detailed discussion of mitigation of Preble's habitat is no longer necessary.

Comment 24

Section 5.1.3 (Page 5-2). An appropriate slope stability analysis which supports the grading plan presented in this section should be included in the Title II design document.

Response

A slope stability analysis will be included in the Title II design document.

Comment 25

Section 5.1.5.1 (Page 5-4). A 36-in. vegetative-soil layer does not allow for a factor of safety for barrier layer protection in case depth of frost penetration is greater than 3 ft. It is recommended that a ft-thick biota layer consisting primarily of cobble-size material be incorporated into the cover design. A biota layer would provide the dual benefits of cover protection from burrowing animals as well as increasing the thickness of soils above the barrier layer materials, resulting in additional frost protection. The top soil and vegetative soil layer specifications must be addressed in the Title II design document.

Response

The frost depth in the area of OU 7 is 3 ft. Therefore, the existing design will provide adequate frost protection. A review of site-specific biologic conditions at OU 7 indicates that a biotic barrier is necessary. However, the geosynthetic drainage layer also serves this purpose. The cover dimensions are preliminary. They will be further refined during Title II design.

The top soil and vegetative soil layer specifications will be included in the Title II design document.

Comment 26

Section 5.1.5.4 (Page 5-6). Geocomposites are a combination of geonet and geotextile and are not normally considered appropriate for gas collection. Please see comment #21 above.

Response

Richardson and Koerner (1987) list geonets and geotextiles suitable for use in gas venting systems.

Comment 27

Section 5.1.5.4 (Page 5-7). It is our understanding that the design which facilitates gas treatment will be addressed in the Title II design document.

Response

Design of components of the gas-collection layer that will facilitate future gas treatment will be included in the Title II design document.

Comment 28

Section 5.1.5.5 (Page 5-7). This section states that, "the general fill material can consist of almost any natural soil material." General fill specifications must be addressed in the Title II design document.

Response

General fill specifications will be addressed in the Title II design document.

Comment 29

Figure 5-1. This illustration indicates that part of OU 6's IHSS 166.1 will fall under the "Extent of Landfill Cap." The text in Section 2.1.6 (Page 2-6) should clarify if this is in agreement with the investigations and decisions at OU 6.

Response

IHSS 166.1 is covered by the OU 7 cap only incidentally. The subsurface soil in this IHSS has been recommended for no further action. Groundwater will be addressed in the Groundwater Sitewide Strategy. The text will be clarified.

Comment 30

Section 5.2.7 (Page 5-11). This section states advantages of the Alternative 7 soil cover: "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 em/sec. The gas-collection system is designed to facilitate gas treatment if needed."

Calling a soil with a permeability of 1E-05 cm/sec a "low-permeability" soil is a misnomer. Permeabilities of this magnitude are associated with clayey sand and silty sand soils. These soil types are primarily coarse-grained and tend to have significantly higher permeabilities than fine-grained soil types.

Page G-4 of the appendices states that the results of this [sensitivity] analysis show that the permeability of the soil underlying the FMC has significant effect on leakage rates through defects in the FMC. The decreased protectiveness of substituting the "low-permeability" soil in place of clay below the FMC should be compensated for by the addition of a GCL (or equivalent) component to the barrier layer.

Page G-3 of the appendices states that the FMC 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 in.) was used. The proposed FMC to be used in the cover should be consistent with the 60-mil FMC used in the HELP model.

Response

The permeability of soils can range from 1E+2 to 1E-9 cm/sec (Cedergren 1977). A soil with a permeability of 1E-5 cm/sec is on the lower end of this range and is indicated as a "poor drainage" material. Therefore, a soil with a permeability of 1E-5 cm/sec can be classified as "low permeability." However, we do realize that there are soils with lower permeabilities.

As indicated in Cedergren (1977), soils with permeabilities in the range of 1E-5 cm/sec consist of very fine sands; organic and inorganic silts; mixtures of sand, silt, and clay; glacial till; stratified clay deposits; and "impervious" soils that have been modified by the effects of weathering (freezing and drying). We have selected a low-permeability soil with a permeability classification of 1E-5 to 1E-9 cm/sec because that is a realistic permeability value that any soil could achieve in the long run in a cover application where it is exposed to the effects of weathering.

The state has suggested the use of a GCL on top of the low-permeability soil to improve the performance of the cover section. We have considered the use of a GCL in the cover section and have evaluated the performance with the HELP model. The results are presented in the text and indicate that the performance of a cover section with a GCL or a low-permeability soil are similar.

The proposed FMC material type and thickness will be determined in the final design. However, the HELP runs that have been completed are considered appropriate even if the selected FMC material is not a 60-mil material because the major component impacting the leakage rate of FMCs is the defect rate and not the material thickness.

Comment 31

Section 6.0. A comprehensive QA/QC plan should be developed for the Low Permeability Soil Layer and all geomembranes. See EPA's "Technical Guidance Document: QA and QC for Waste Containment Facilities," EPA/600/R-93/182.

Response

A comprehensive QA/QC plan will be prepared as part of the final design and specification package. This plan will include sections specifically addressing the low-permeability soil layer and all geomembrane layers and, at a minimum, will conform to EPA's "Technical Guidance for QA and QC for Waste Containment Facilities" (EPA/600/R-93/182).

Comment 32

Section 6.2 (Pages 6-12, 6-16, 6-19, 6-21). Evaluations of short-term effectiveness mention that risks to workers due to exposure to contamination should be minimal. Will risks to workers be further evaluated and have all appropriate exposure pathways been considered? Will a health and safety plan be developed for construction workers, beyond the plans described for decontamination activities on page 6-8?

Response

Risks to workers involved in remediation activities do not need to be evaluated in the IM/IRA DD because the site-specific health and safety plan in conjunction with an activity hazard analysis will include information about site contaminants and specific procedures for personal protective equipment and monitoring required for remedial construction.

Comment 33

The potential for dust generation, erosion, etc. during the construction mentioned under Short-Term Effectiveness seem to be serious enough to warrant a greater weighting factor when evaluating comparative risks (Table 6-4).

Response

All nine CERCLA criteria are considered important. The weighting factor attempts to take into account relative importance in order to compare the alternatives and choose the preferred alternative. For example, is short-term effectiveness equally as important as long-term effectiveness?

As stated in Section 6.3.2, the primary concerns were dust generation and potential for erosion and subsequent sediment loading during construction. The lower weighting factor for short-term effectiveness reflects that both of these concerns can be readily mitigated using standard construction techniques for dust suppression (such as watering) and erosion control (such as sedimentation basins).

Due to the number of comments on this table, it will be deleted.

Comment 34

Section 6.2.2.2 (Page 6-13). It is debatable whether the vegetative soil layer prevents punctures of the FMC by plant roots and burrowing animals. Please see comment #25 above.

Response

The dimensions given on the cover alternates are preliminary. Further refinement for the design layer thicknesses will occur during the Title II design where issues such as frost burial depth, evaporation zone depth, burrowing animal depth, and plant root depth will be specifically addressed.

Comment 35

Section 6.2.3.1 (Page 6-13). It is debatable whether the installation requirements for the "low-permeability" soil would be less rigorous than those of a full clay liner.

The 1-ft lift thickness mentioned in this section may not provide sufficient cushion to prevent geonet damage or eliminate intrusion of adjacent materials into the geonet apertures during lift placement. All soil layer material specifications must be addressed in the Title II design document.

Response

Placement of soil materials over geosynthetics can be performed without damage to the geosynthetics with good construction quality assurance (CQA) monitoring and control.

Intrusion of adjacent materials into geonet apertures in a geocomposite is affected by the type of overlying geotextile and the amount of soil overburden placed on top of the geocomposite. We concur that all soil layer material specifications must be addressed in the Title II design document. In addition, geosynthetic material specifications and CQA plan must also consider compatibility of soil materials and placement practices with the geosynthetics.

Comment 36

Section 6.2.3.2 (Page 6-14). Specify the ways in which Alternative 7 does not comply with EPA guidance cited, and then explain how this alternative is nevertheless equally protective.

Response

The regulatory criteria for the barrier layer soil component is described as having a 2-ft barrier with saturated conductivity of less than or equal to 1E-07 cm/sec. Alternative design for this component is 1-ft thick with a hydraulic conductivity of 1E-05 cm/sec. This is the only component in the cover system that deviates from the EPA guidance documents. The barrier soil component proposed in Alternative 7 will be a low-plasticity soil that will be less susceptible to desiccation cracking than a high-plasticity clay layer of the type typically installed in conformance with EPA guidance. The leakage rate for the Alternative 7 cover is greater than the Alternative 9 cover; however, when both leakage rates are compared as a percent of the average annual rainfall they both perform at a similar level.

Comment 37

Section 6.3.1 (Page 6-21). This section states that the low-permeability soil layer may be less permeable than the clay barrier layer due to its resistance to desiccation. However, clay is the standard soil material used for landfill covers. Desiccation will be minimized since the clay will be buried at depth and not subject to surficial drying. It is debatable that Alternative E (previously Alternative 7) affords the highest degree of long-term effectiveness and permanence. This point is the major basis for giving Alternative 7 a higher score in Long-Term Effectiveness and Permanence.

Response

In general, factors that influence clay layer desiccation include the clay mineralogy, plasticity, sand content, initial moisture content, temperature variations, nature of the clay's contact with overlying geomembrane or underlying surface, and overburden pressures. These factors have been investigated by several researchers, and it has been suggested that a clay layer having a lower swelling potential, lower plasticity index, lower initial moisture content, and a thicker vegetative soil cover that provides sufficient temperature insulation and overburden pressure to maintain a tight contact between the clay and the overlying geomembrane will be less likely to desiccate than a clay layer that does not have these characteristics. The ability of a clay to rehydrate after cracking is very dependent on the characteristic of the clay. A pure bentonitic clay

such as GCL will hydrate and achieve a permeability similar to a pre-drying condition; however, normal compacted clay covers may not have the potential to totally rehydrate and achieve a permeability equal to the pre-drying permeability.

The low-permeability soil layer proposed for Alternative E is intended to incorporate many of the factors identified above to reduce the potential for clay desiccation compared to the clay layer proposed in Alternative G (previously Alternative 9).

Comment 38

Section 6.3.3.1 (Page 6-21). This section states that if "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." However, the clay layer is proposed to be placed above the landfill waste so chemical compatibility should not be a concern. Even so, if chemical compatibility testing is to be performed, it would have to be performed on the low permeability soil also.

Response

Compatibility testing for a new clay material to be used for clay layer repairs may not be a major concern due to the fact that the clay layer is placed above the waste layer.

Comment 39

Section 6.3.3.1 (Page 6-21). The text states that; "the clay barrier in Alternative G 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 low-permeability soil layer would also be subject to moisture conditioning and maintenance during construction.

Response

The low-permeability soil will require moisture conditioning during placement. This is expected to reduce the potential for desiccation cracking and associated repair during construction. Both of these factors are expected to facilitate placement, compaction, trimming, and CQA monitoring activities (see response to comment 35).

Comment 40

Section 6.4 and Table 6-4, (Pages 6-23 and 6-28). Consideration of the previous two comments may have an effect in the comparative risk evaluation.

Response

Due to the number of comments on this table, it will be deleted. However, comparative risks will be reevaluated to reflect comments and changes in the design, as appropriate.

Comment 41

Section 7.1 (Page 7-2). Where will the seep water be directed once it is collected by the gravel blanket or French drain mentioned in the second paragraph on this page?

Response

As described in the response to Comment 2 of the Executive Summary, the preferred alternative for groundwater/leachate control is natural attenuation and seep water discharge to groundwater.

Comment 42

Section 7.1 (Page 7-2). Leachate control does not exceed regulatory requirements despite the contrary statement on the fourth paragraph on this page. Because the landfill is an interim status closure unit, the requirements in 6 CCR 1007-3, §265.110 apply. The closure performance standard requires that the post-closure escape of leachate be controlled, minimized or eliminated.

Response

The referenced standard states that "the owner must close the facility in a manner that:...controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of... leachate." A focused risk assessment for the leachate showed no risk to human health. An ecological risk assessment indicated unacceptable risk for direct contact. Therefore, in the IM/IRA DD, alternatives were developed that control, minimize, or eliminate the post-closure escape of leachate. Alternatives include cap, slurry wall, treatment of the leachate and elimination of the exposure pathway.

Comment 43

Section 7.1 (Page 7-2). There will be no potential exposure to groundwater not "because there are no plans for future development of groundwater" as stated in the sixth paragraph, but rather because institutional controls will prohibit it.

Response

The text will be revised.

Comment 44

Section 7.2.1 and Section 8.1.12 (Pages 7-3 and 8-6). The deed notation mentioned here may not be an adequate institutional control to limit future development. The State may issue an order to limit future development.

Response

The text will be revised to include other institutional controls to limit future development, such as a compliance order.

Comment 45

Section 7.2.2.3 (Page 7-7). The text states: "The permeability of the FMC barrier is 1E-13 cm/sec, which is less than the permeability of natural subsoils at the landfill (1E-06 to 1E-07 cm/sec)." However, this thin flexible membrane is subject to damage from construction equipment and from differential settlement which could significantly increase its permeability.

Response

In our assessment of the permeability of the cover section compared to the foundation soils, we have evaluated the overall permeability of the cover system compared to the overall permeability

of the foundation soils. The calculation for the overall permeability of the cover section includes the combined effect of the FMC and the low-permeability soil (composite cover section). The composite cover section (even with a normally accepted number of defects) is considered much less permeable than a native soil with a permeability of 1E-7 cm/sec.

As a point of reference, we analyzed the leakage rate for the cover section for Alternative D, which consisted of a single clay barrier layer with a permeability of 1E-7 cm/sec (this could be considered comparable to the foundation soil with a permeability of 1E-7 cm/sec). The leakage rate was determined to be approximately 1 in./yr. This is compared to the leakage rate for the cover section for Alternative E (FMC [with defects]) over a low-permeability soil at approximately 2E-4 in./yr. This indicates that the composite cover system has a much lower net permeability than a single soil layer.

Comment 46

Section 7.2.2.3 and Section 8.2.3.3 (Pages 7-8 and 8-10). The selection of groundwater monitoring wells should be reviewed with RCRA Monitoring Program personnel. This program recently proposed eliminating some wells from its sampling schedule or sampling on a less frequent schedule. The proposed upgradient monitoring well, 70393, apparently receives contamination from a further upgradient source.

Response

The monitoring wells selected for post-closure groundwater monitoring will be reviewed and revised, if necessary, for the Revised Draft IM/IRA DD. Well 70093 is a more appropriate upgradient well. There are no organic compounds detected in well 70093.

Comment 47

Section 7.2.2.3 (Page 7-9). See comment #13 above.

Response

See response to comment 13.

Comment 48

Section 7.3.1.1 (Page 7-10). This section says that maximum settlements may range from 2.9 to 5.5 ft. Localized ponding of water on top of the cover will not be permitted. Also see comment #45 above.

Response

In general, settlement is a function of waste thickness and waste type. Several methods were used to estimate the amount of settlement at various points in the landfill cover. Based on these evaluations and allowing for worst case settlements, the cover system will have post settlement slopes between 3 and 5 percent.

We concur there is a possibility of local settlement that might result in localized ponding but we feel that this is remote due to the thickness of the general fill, which will further consolidate the waste, and components of the waste that reduce settlement potential, such as the construction debris component and the daily cover soil component. Localized settlement generally occurs when biodegradable materials or containers located near the upper surface of the waste fill deteriorate and collapse resulting in depressions at the surface. However, these localized

settlements are observable on the surface and are relatively easy to repair. Any localized settlement will be repaired as described in the Postclosure Plan.

Comment 49

Section 7.3.1.3 (Page 7-10). Little detail is provided on establishing a vegetative cover. Revegetation efforts both onsite and offsite have essentially failed and the lack of a plan that improves on past efforts may be a critical deficiency.

Response

Revegetation of the final contoured cap of the landfill is an important component for the success of this project. A revegetation plan that addresses the problems encountered at other OUs will be included in the Title II design document.

Once the source of the topsoil for the landfill cap has been determined and the soil characteristics can be evaluated, ecologists will establish an appropriate seed mixture for the final vegetative cover. Soil characteristics and the need for shallow-rooted species that provide good erosion control will be taken into account during the selection of a revegetation seed mixture.

Revegetation success will be evaluated annually during the 30-year postclosure period for sufficient ground cover and noxious weed presence. Re-application of seed will be undertaken and active weed control will be used if revegetation success is not acceptable.

Comment 50

Section 7.3.1.3 (Page 7-10). This text says that the northeast slope of the landfill will be reduced to 20%. This amount is at variance with the 6H:1V slope shown on Figure 7-3. What erosion protection measures will be necessary on this slope before vegetation is established?

Response

We concur the northeast slope is reduced from 33% to a 6H:1V which corresponds to a 16.7% slope, not a 20% slope as indicated in the text. This will be clarified to indicate a 6H:1V slope in all cases. However, these slope angles have only been estimated at this time for comparison of alternatives. Final slopes will be determined during the Title II design.

Erosion control measures for the eastern slope area will be considered during the Title II design.

Comment 51

Section 7.3.3 (Page 7-12). A manufacturer's QA report should be provided with any type of FML and geocomposite.

Response

Manufacturer's material specification and quality assurance test data are typically provided to customers upon request. In addition, it is common to obtain samples of this material when it arrives on site and to perform conformance tests to ensure that the material meets specifications. The manufacturer's product data, conformance sampling protocols, sample frequency, and types of tests to be performed will be called out in the Title II design specifications and construction quality assurance plan.

Comment 52

Section 7.3.4 (Page 7-13). Where will the seep water collected by the gravel blanket or French drain be directed?

Response

As described in the response to Comment 2 of the Executive Summary, the preferred alternative for groundwater/leachate control is natural attenuation and seep water discharge to groundwater.

Comment 53

Section 7.5 (Page 7-15). Slurry walls are problematic as evidenced by the need for further maintenance action on the present slurry wall. To imply that all of the subsurface flow will be "addressed by the proposed slurry wall" is probably overstating its capabilities.

Response

The text was not intended to suggest that 100% of the subsurface flow would be deflected by the slurry wall. The text will be modified to clarify this point.

It should be noted that the slurry wall primarily addresses flows due to the failure of the existing leachate-collection system trench as discussed in Section 2. Modeling shows that there may be some flow at the slurry wall; however, based on as-built drawings, this is probably due to the fact that the wall was not consistently keyed into the bedrock. Slurry walls are an EPA-approved method of controlling groundwater, and any slurry wall at OU 7 would be installed under a rigorous QA/QC program.

Comment 54

Section 8 (Page 8-1). If the single-regulatory agency concept ("carve-out') is implemented, then the substantive requirements of RCRA will still apply, but the administrative requirements will not. This distinction may change how the closure plan and post-closure plan are administered.

If this document is to serve as the Closure Plan for all of OU 7, then a discussion of how closure requirements will be met for IHSSs 203, 167.2, and 167.3 must also be included. A rationale for no action at these IHSSs should be included in previous sections.

Response

The "carve-out" has been implemented, and the document will be revised accordingly.

A discussion of how closure requirement are met for IHSSs 203, 167.2, 167.3 and the rationale for no action at these IHSSs will be included.

Comment 55

Because leachate collection and slurry wall maintenance are considered essential to closure of the landfill and are elements of the presumptive remedy strategy, these actions should be included with the recommended landfill cover alternative in any discussion of activities related to or required for closure. The sections of this document would be enhanced by including more detail about these two actions.

Response

The Revised Draft IM/IRA DD will not assume that the slurry wall and leachate collection and treatment are performed outside of the scope of the IM/IRA. Alternatives that incorporate the slurry wall and leachate treatment will be evaluated, and the best alternative will be chosen. The recommended alternative will include all the necessary components for its implementation.

Comment 56

Section 8.1.1 (Page 8-3). The discussion of the leachate in the third paragraph in this section should be modified to be consistent with comment 13 above.

Response

The discussion will be modified to be consistent with the response to Comment 13.

Comment 57

Section 8.2.3 (Page 8-8). Because the landfill is an interim status closure unit, the requirements in 6 CCR 1007-3 §265.110 apply. The closure performance standard requires that the post-closure escape of leachate be controlled, minimized or eliminated. Monitoring of the effectiveness of the slurry wall should be considered. Although the repairs to the slurry wall will be done as a separate maintenance action, its effectiveness is important in minimizing leachate as required by the closure performance standard and in providing long-term minimization of migration of liquids through the closed landfill (6 CCR 1007-3, §265.310).

Response

The referenced standard states that "the owner must close the facility in a manner that:...controls, minimizes or eliminates, to the extent necessary to protect human health and the environment , post-closure escape of... leachate." A focused risk assessment for the leachate showed no risk to human health. An ecological risk assessment indicated unacceptable risk for direct contact. Therefore, in the IM/IRA DD, alternatives were developed that control, minimize, or eliminate the post-closure escape of leachate. Alternatives include cap, slurry wall, treatment of the leachate and elimination of the exposure pathway.

Comment 58

Section 8.2.3.2 (Page 8-10). This text states that "groundwater will not be used as a source of drinking water." What specific controls will be in place to preclude using groundwater as a drinking source? The test also concludes that no exposure to groundwater is possible because groundwater does not discharge to surface water in No Name Gulch. Is No Name Gulch a losing stream year-round?

Response

Under currently expected land uses and exposure scenarios agreed upon by the Future Land-Use Working Group (DOE 1995), there are no exposures to groundwater unless it surfaces in seeps, streams, or ponds. The unnamed tributary of Walnut Creek (No Name Gulch) is a losing stream year-round (see response to comment 7).

The text will be revised to state that there will be no potential exposure to groundwater because deed restrictions and/or state orders will prohibit potential exposure. However, screening-level risk evaluations will be included in the revision.

Comment 59

Section 8.2.3.2 (Page 8-10). The wells proposed here as points of compliance may need to be adjusted to be able to effectively serve that purpose given that a leachate treatment system may need to be installed as part of this IM/IRA document.

There will be no potential exposure to groundwater not "because there are no plans for future development of groundwater," but rather because deed restrictions and/or state orders will prohibit it.

Response

The revised Draft IM/IRA DD will propose points of compliance that are appropriate for the recommended alternative.

The text will be revised to state that there will be no potential exposure to groundwater because deed restrictions and/or state orders will prohibit potential exposure.

Comment 60

Section 9.2.1.1 (Page 9-6). Lack of an improved revegetation plan (see comment #31) may mean that habitat loss will more than temporary as stated in the fourth paragraph of this section.

Response

As discussed in the response to comment 49, a revegetation plan will be submitted as part of the Title II design document. This plan will take into consideration revegetation problems experienced at other OUs.

REFERENCES

Cedergren, H. R., 1977, *Seepage, Drainage, and Flow Nets*, Second Edition, John Wiley & Sons, New York.

Richardson, G. N. and R. M. Koerner, 1987, *Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments*, Hazardous Waste Engineering Research Laboratory, U.S. EPA, Cincinnati, OH, December.

DOE (U.S. Department of Energy), 1995, J. Roberson, DOE, to S. Stiger, EG&G Rocky Flats, Personal Communication, Subject: "Changes to the Site-Wide Exposure Factors and Exposure Scenarios," April 13.

Kaiser-Hill, 1996, *Accelerated Site Action Project*, Phase II Predecisional Draft, January 9.

K.1. PROJECT DESCRIPTION

The Department of Energy proposes a construction project that would take place in wetlands at the Rocky Flats Environmental Technology Site, located north of Golden, Colorado. The project requires construction of a landfill cap and a natural attenuation system for seep discharge to groundwater at Operable Unit Seven. The objective of this Interim Measure/Interim Response Action is to meet the Colorado Hazardous Waste Act requirements for landfill closure [6 CCR 1007-3 Part 265.310] which are 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

Four alternatives were subjected to detailed and comparative analyses. The preferred alternative consists of a single-barrier cover, a passive gas collection system, and institutional controls. The membrane liner material has a permeability of 1E-15 cm/sec and is underlain by a 12-in. low-permeability soil layer (permeability of 1E-5 to 1E-7 cm/sec) and a geocomposite gas collection layer. The cover is overlain by a geocomposite lateral drainage/biotic barrier layer and a 3-ft vegetative cover. As agreed to by DOE, EPA, and CDPHE, the East Landfill Pond will be removed and the dam and pond sediments will be removed and consolidated in the landfill under the cap prior to closure. A gravel layer for discharge of the leachate from the seep would be installed under the cap at the seep location. This layer would allow the water to flow from under the cap and discharge to fill and then alluvial groundwater at a location downgradient from the cap.

The East Landfill Pond and some areas along the pond edge exhibit typical wetland characteristics. The landfill cap and natural attenuation system for seep discharge must be located in the wetland surrounding the pond. Because of this requirement, Title 10, Part 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements" has been identified as a potential ARAR.

K.2. WETLANDS EFFECTS

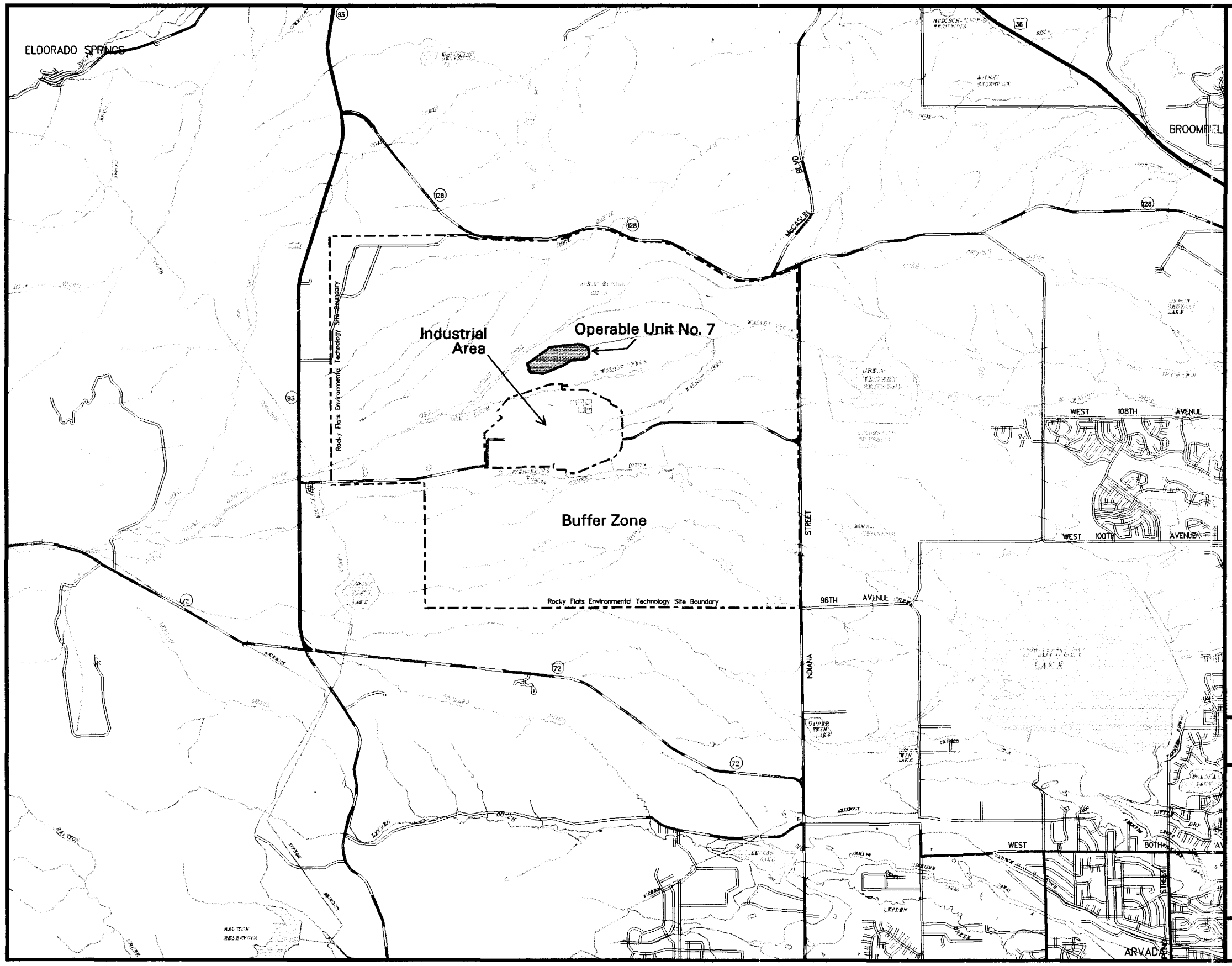
Construction of the landfill cap and natural attenuation system for seep discharge to groundwater will require the complete removal of 0.8 acres of palustrine emergent wetlands at the pond margin and 2.3 acres of deepwater habitat (lacustrine, unconsolidated bottom, permanently flooded) in the pond itself.

K.3 ALTERNATIVES

Four alternatives were evaluated as described in detail in the Interim Measure/Interim Response Action Decision Document, including the no action alternative. The no action alternative would not comply with the requirements for landfill closure [6 CCR 1007-3 Part 265.310].

Because the Present Landfill is considered an inactive hazardous waste site it must undergo a closure that is protective of human health and the environment following the provision of the Colorado Hazardous Waste Act. It is necessary to cover the East Landfill Pond and consolidate the pond sediments under the landfill cap prior to closure in order to meet requirements. Wetland impacts cannot be avoided.

Appropriate and practicable compensatory mitigation will be provided for the unavoidable impacts to wetlands. Compensatory mitigation for closure activities at Operable Unit Seven will be included in the wetland bank as described in "Memorandum of Agreement for the Administration of a Wetland Bank at Rocky Flats."



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

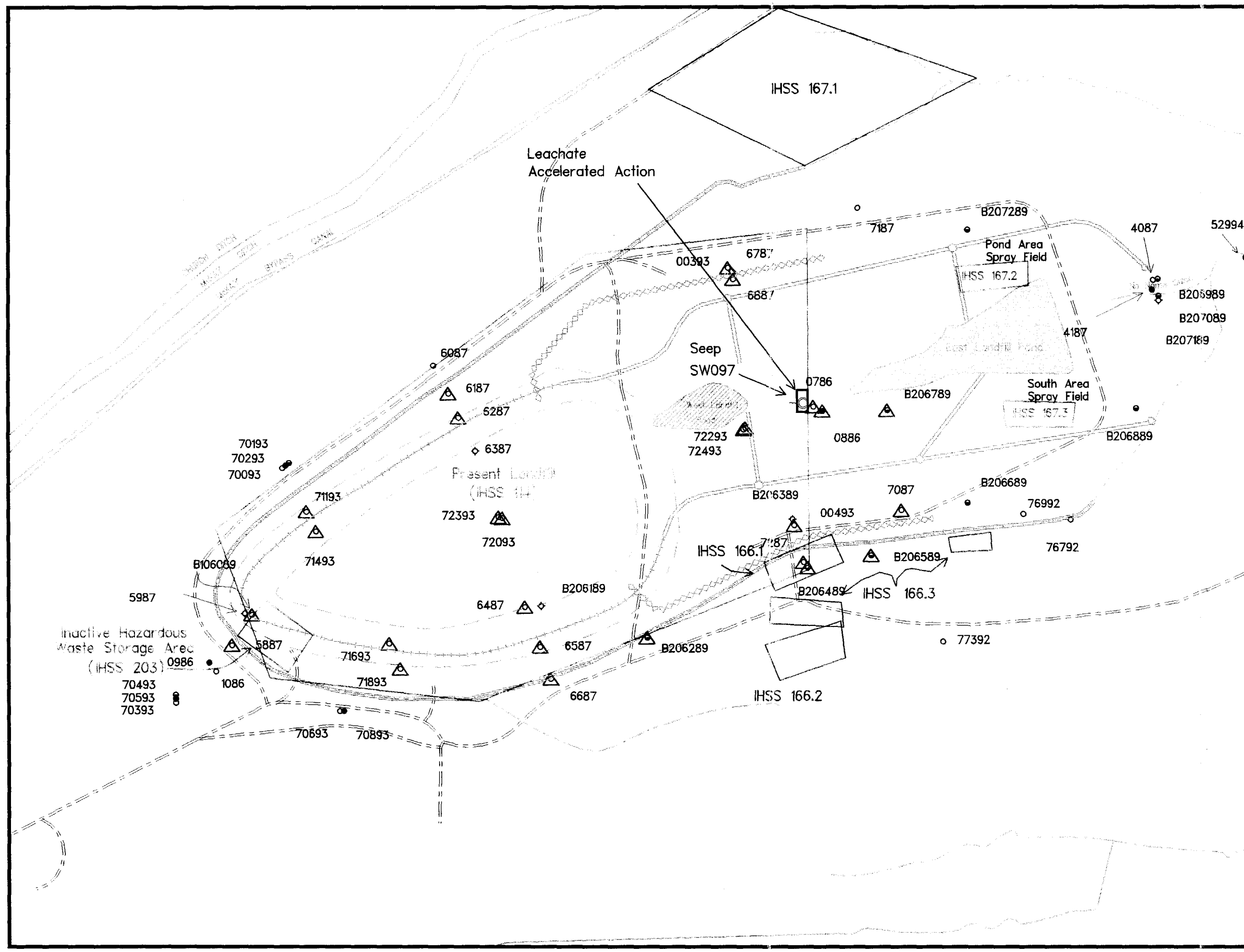
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 1-2

02/12/96 VICNITY.AML



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
- Wells to be Abandoned

N

0 Feet 250 500

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Location of Other Maintenance and Remedial Actions

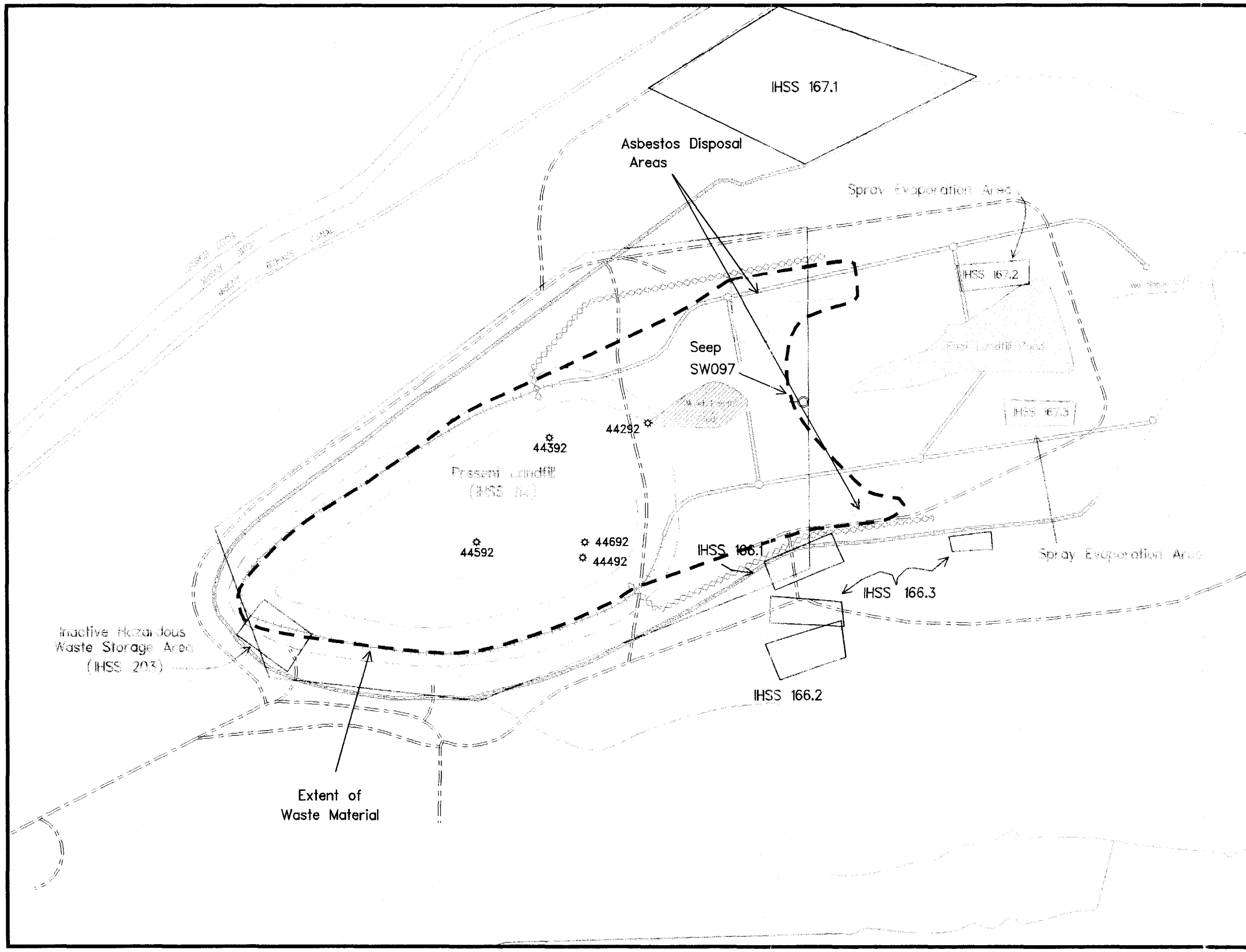
IM/IRA DD
and Closure Plan

Operable Unit No. 7

March 1996

Figure 1-4

02/12/96 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
- Gas-Venting Well

N

0 Feet 250 500

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Locations of IHSSs and Historical Interim Response Actions

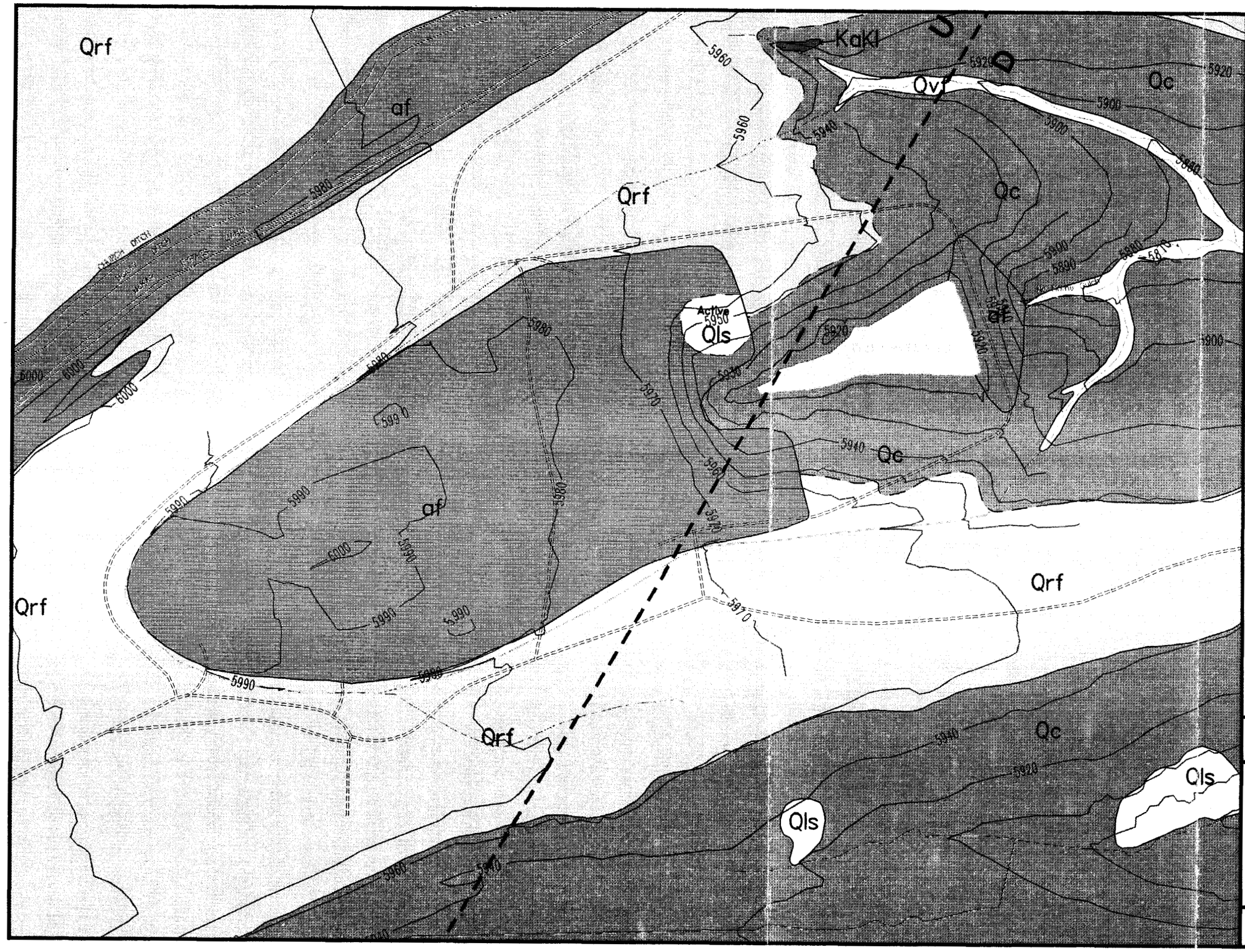
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2-1

02/12/96 IHSS.MAP



EXPLANATION

Artificial fill

Quaternary

Landslide (Qls)

Colluvium (Qc)

Valley–Fill Alluvium (Qvf)

Rocky Flats Alluvium (Qrf)

Cretaceous

Undifferentiated Arapahoe/ Laramie Formation (KaKl) (Claystone)

Fault

Geologic Contact, (dashed where inferred)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site, Golden, Colorado

Geologic Map of Surficial Materials

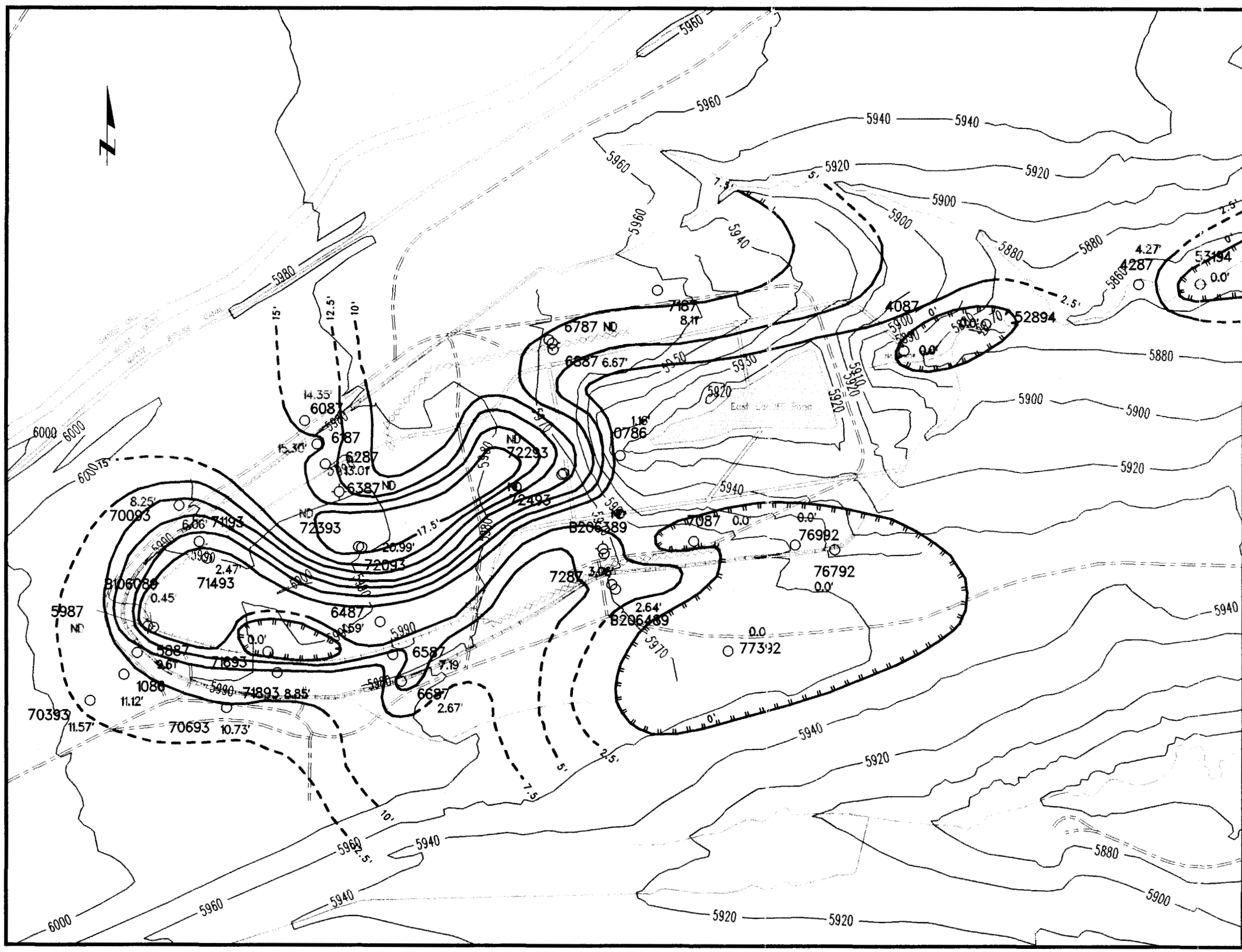
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2–4

02/12/96 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)

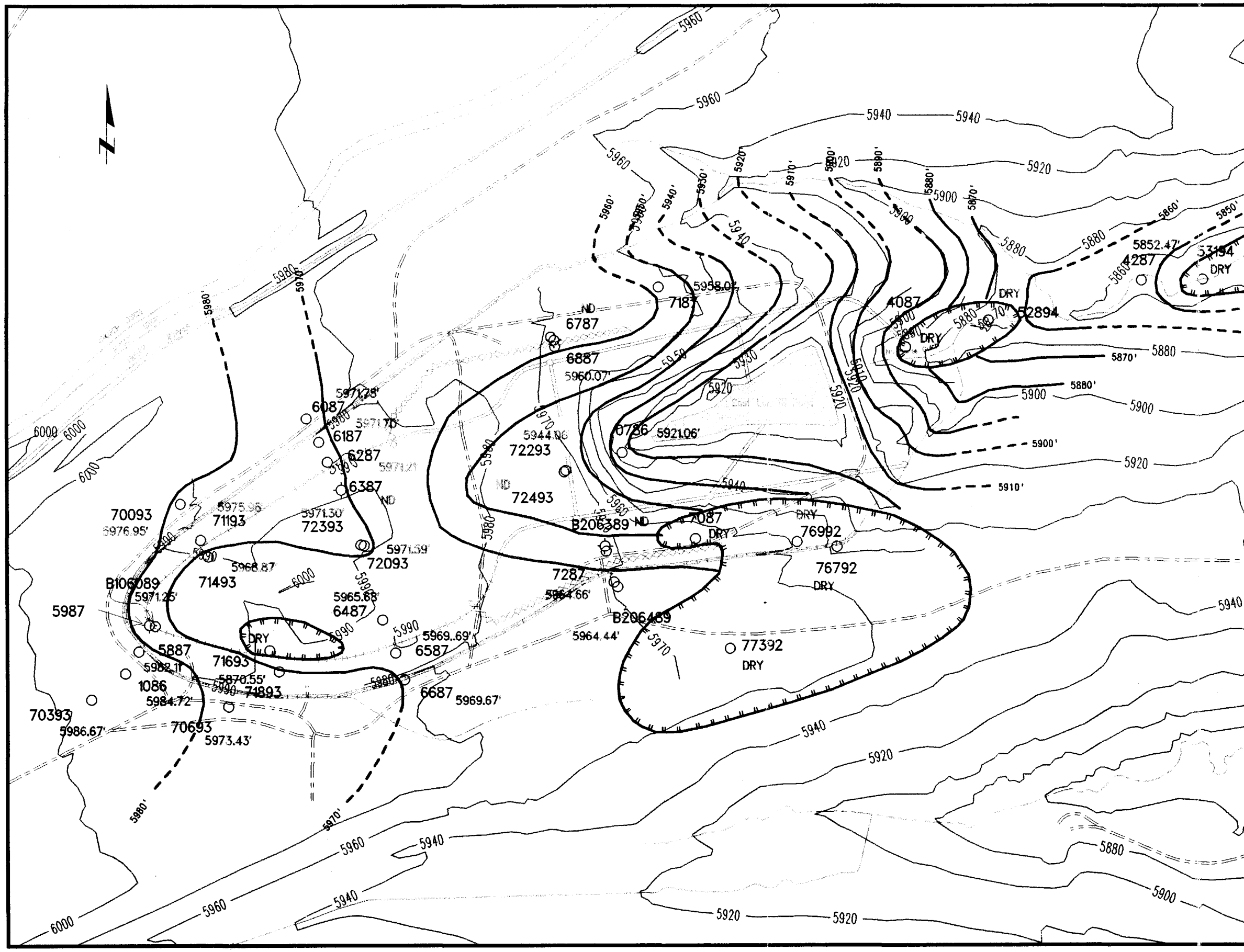
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2–6

02/12/96 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)

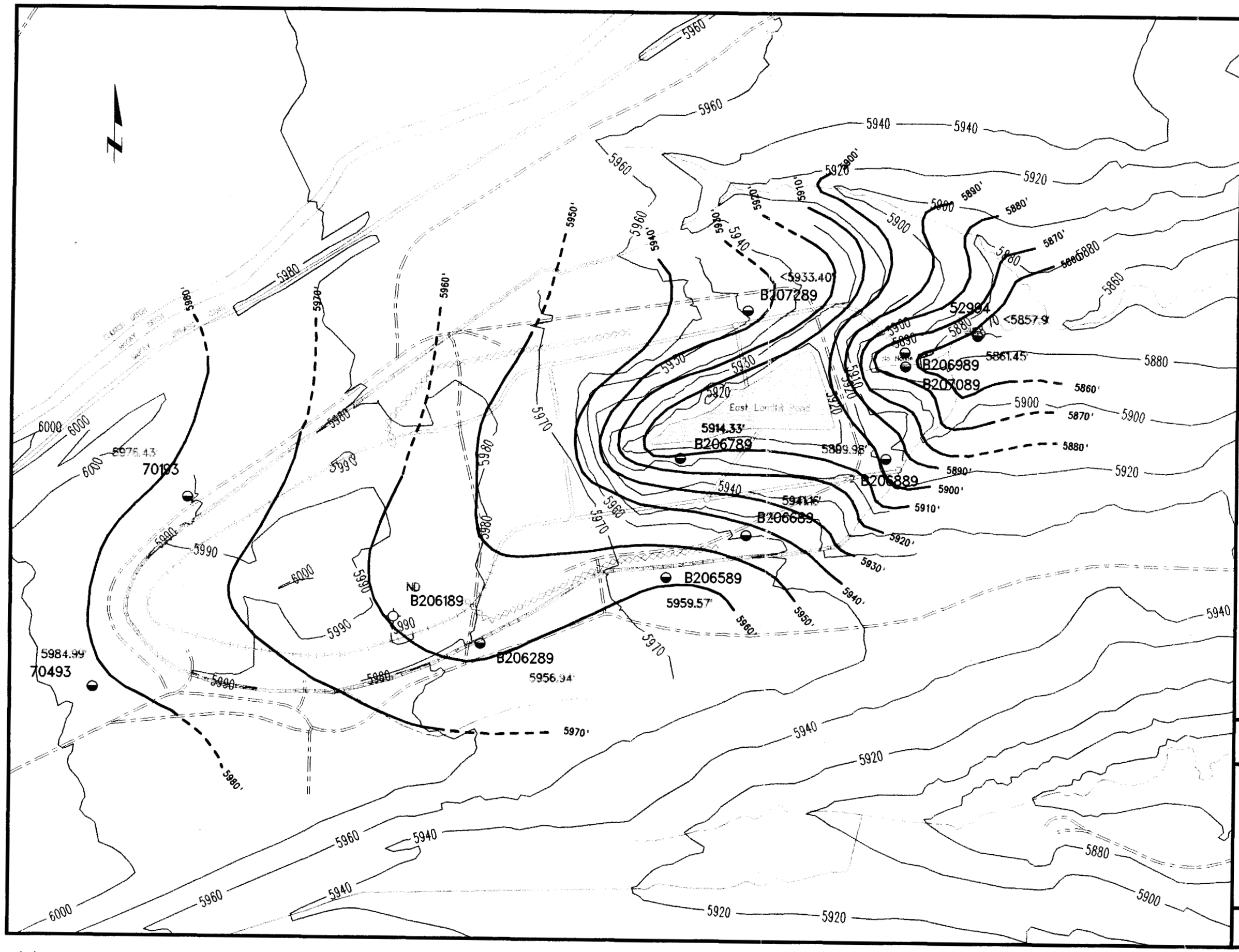
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2-9

02/12/96 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

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock Groundwater (2nd Quarter 1995)

IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2–10

02/12/96 Q295WEB.MAP

Distribution of Habitat Types
IM/IRA DD and Closure Plan

Operable Unit 7

EXPLANATION

- Xeric Mixed Grassland
- Disturbed Area - Developed Areas
- Disturbed Area - Disturbed/Barren Land
- Mesic Mixed Grassland
- Short Marsh
- Tall Marsh
- Short Upland Shrub
- Annual Grass Forb
- Open Water
- Riparian Shrubland - Willow
- Wet Meadow
- Reclaimed Mixed Grassland

Standard Map Features

- Fences
- Contours (20' Intervals)
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, roads, and fences provided by Facilities Engr., EG&G Rocky Flats, Inc. - 1991.
Hydrology provided by USGS - (date unknown)
Vegetation data Provided by Ebasco Inc. - 1993

N

Scale = 1 : 2880
1 inch represents 240 feet

100 0 200 400ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

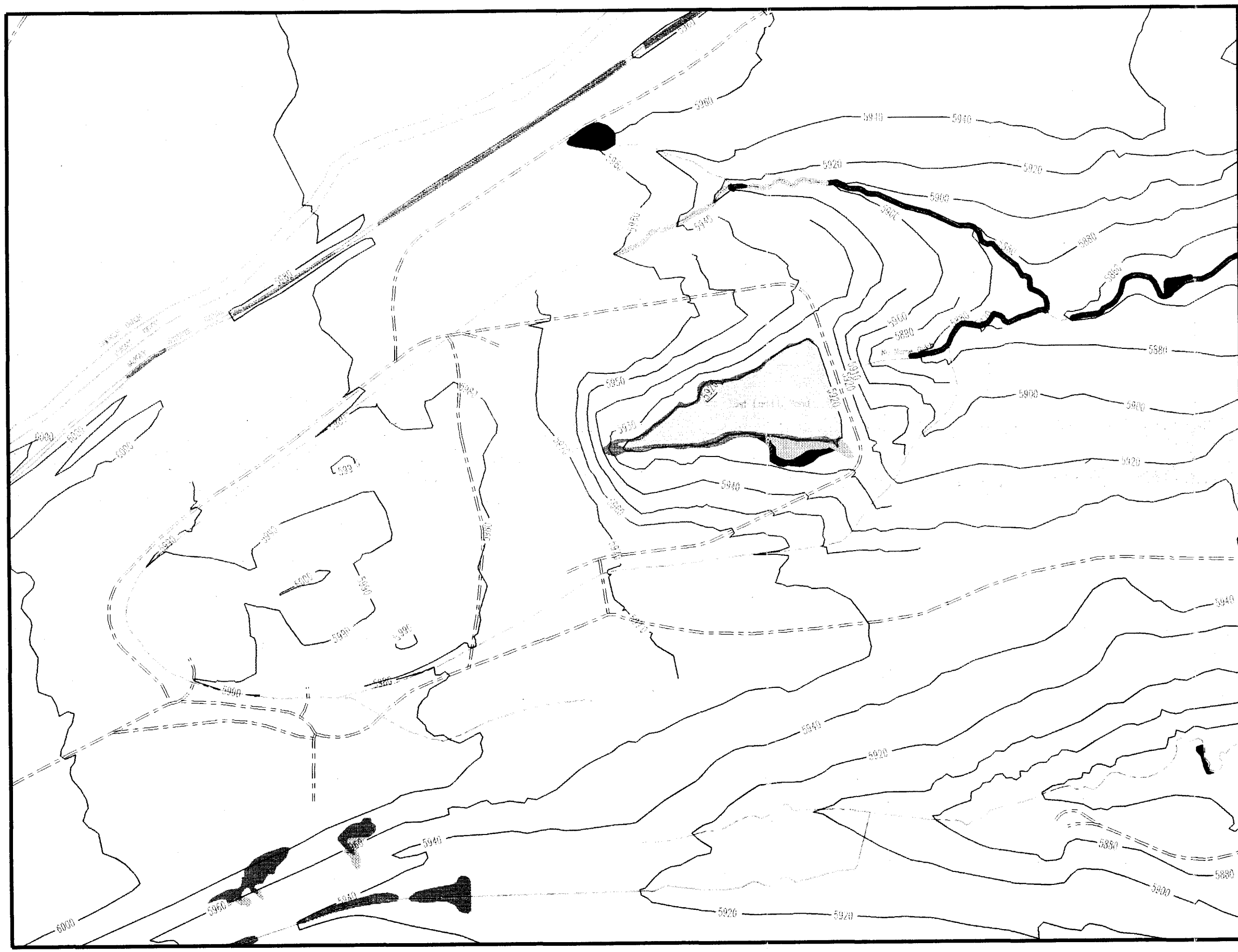
Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

MAP ID: ***Draft***

February 28, 1996

/home/s/51512/projects/rmrs-eco/ou7-im-irmap-1.aml



EXPLANATION

Ditch

Intermittent Stream

Dirt Road

WETLANDS/DEEP WATER HABITATS

PEMA (Palustrine Emergent, Temporarily Flooded)

PEMB (Palustrine Emergent, Saturated)

PEMC (Palustrine Emergent, Seasonally Flooded)

L1UBH (Lacustrine Limnetic, Unconsolidated Bottom, Permanently Flooded)

N

0 Feet 300 600

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site, Golden, Colorado

Wetland Areas

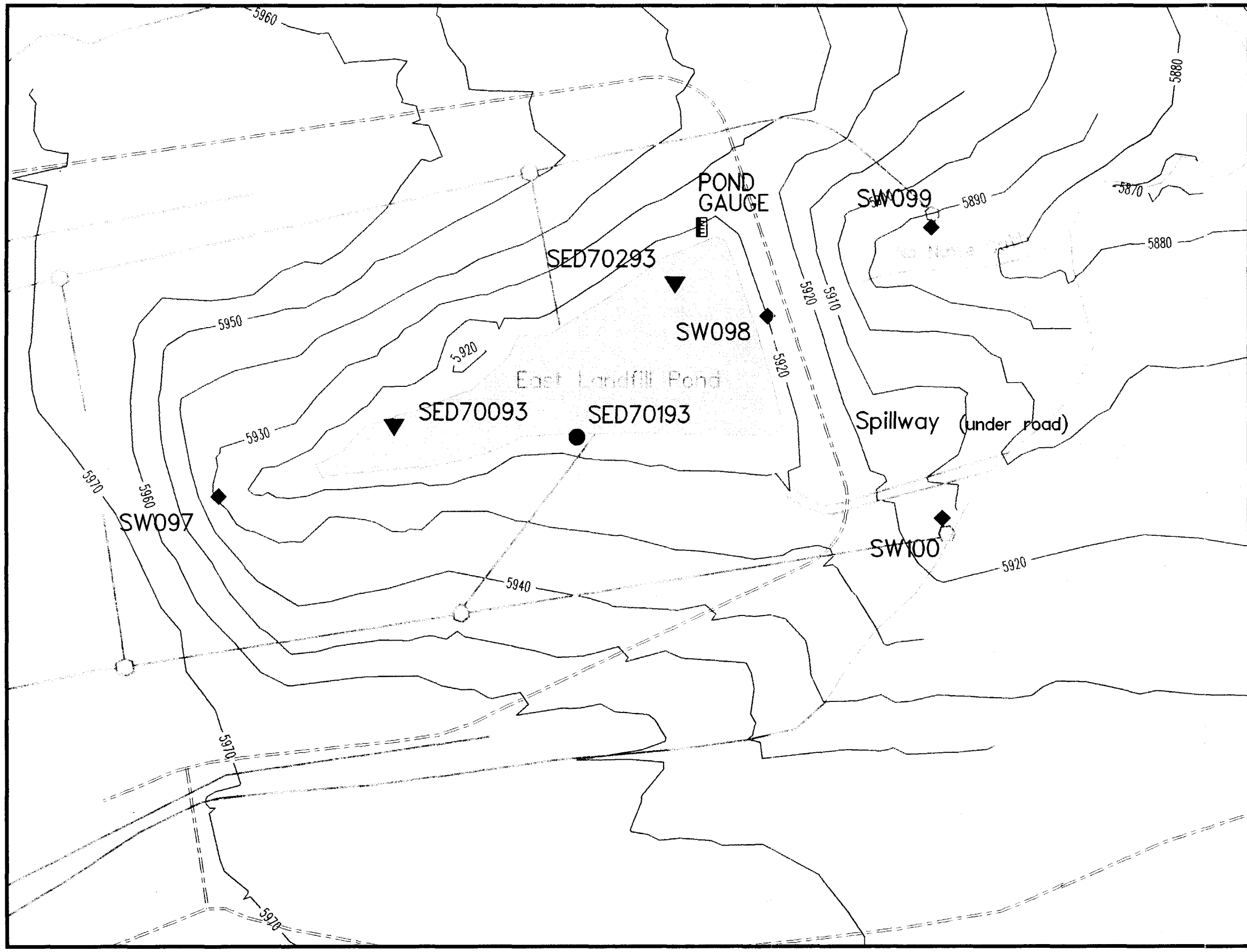
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2-12

02/12/96 WETLAND.MAP



EXPLANATION

- ● Sediment–Sampling Location
- ◆ Surface–Water Sampling Location
- ▼ Acute Toxicity Water and Sediment Sampling Location

Intermittent Stream

Dirt Road

Landfill Structures

N

0 Feet 120 240

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Surface-Water and Sediment Sampling Locations

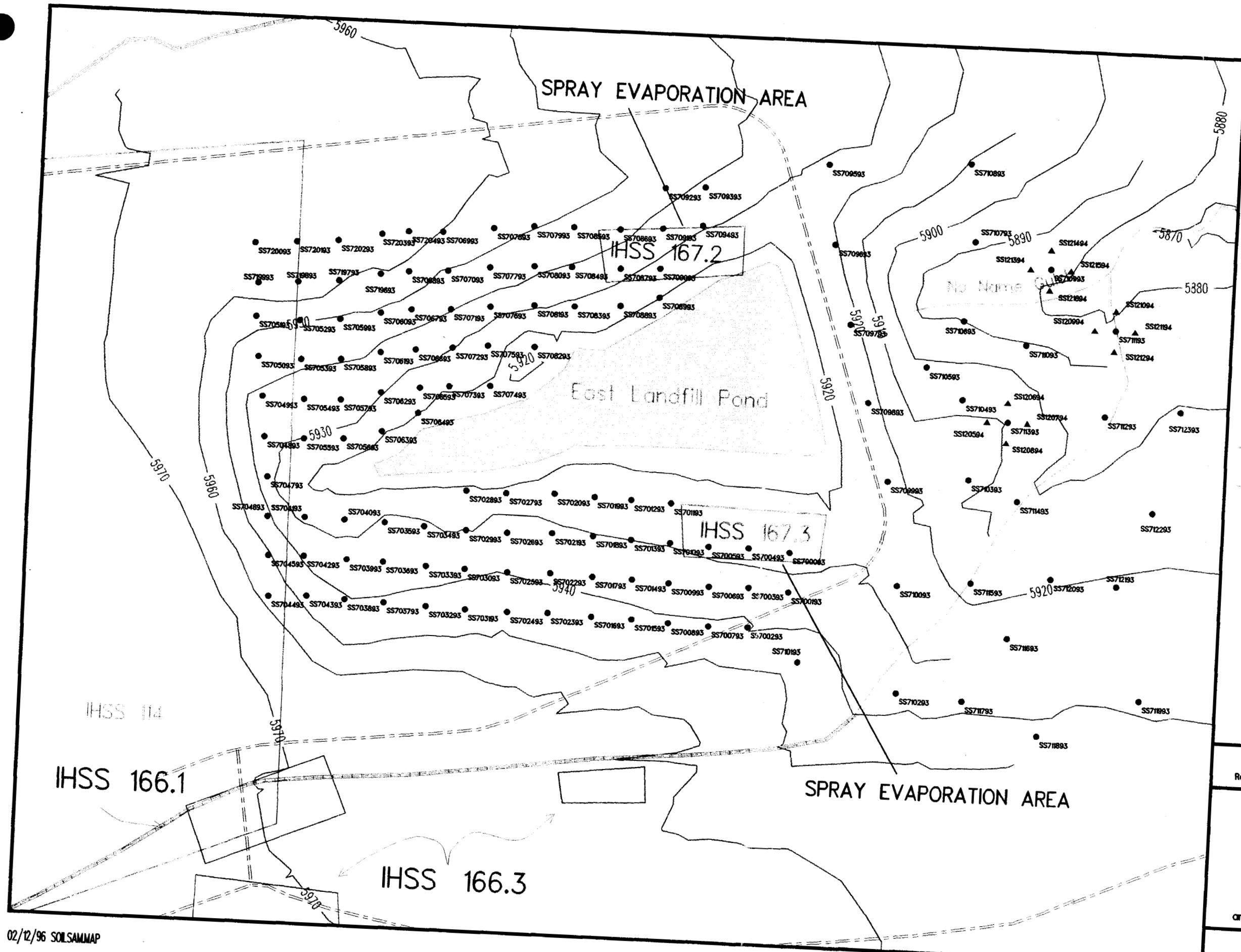
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2–13

02/12/96 SWSED.MAP



EXPLANATION

- Phase I Surface-Soil Sampling Location
- Additional Surface-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

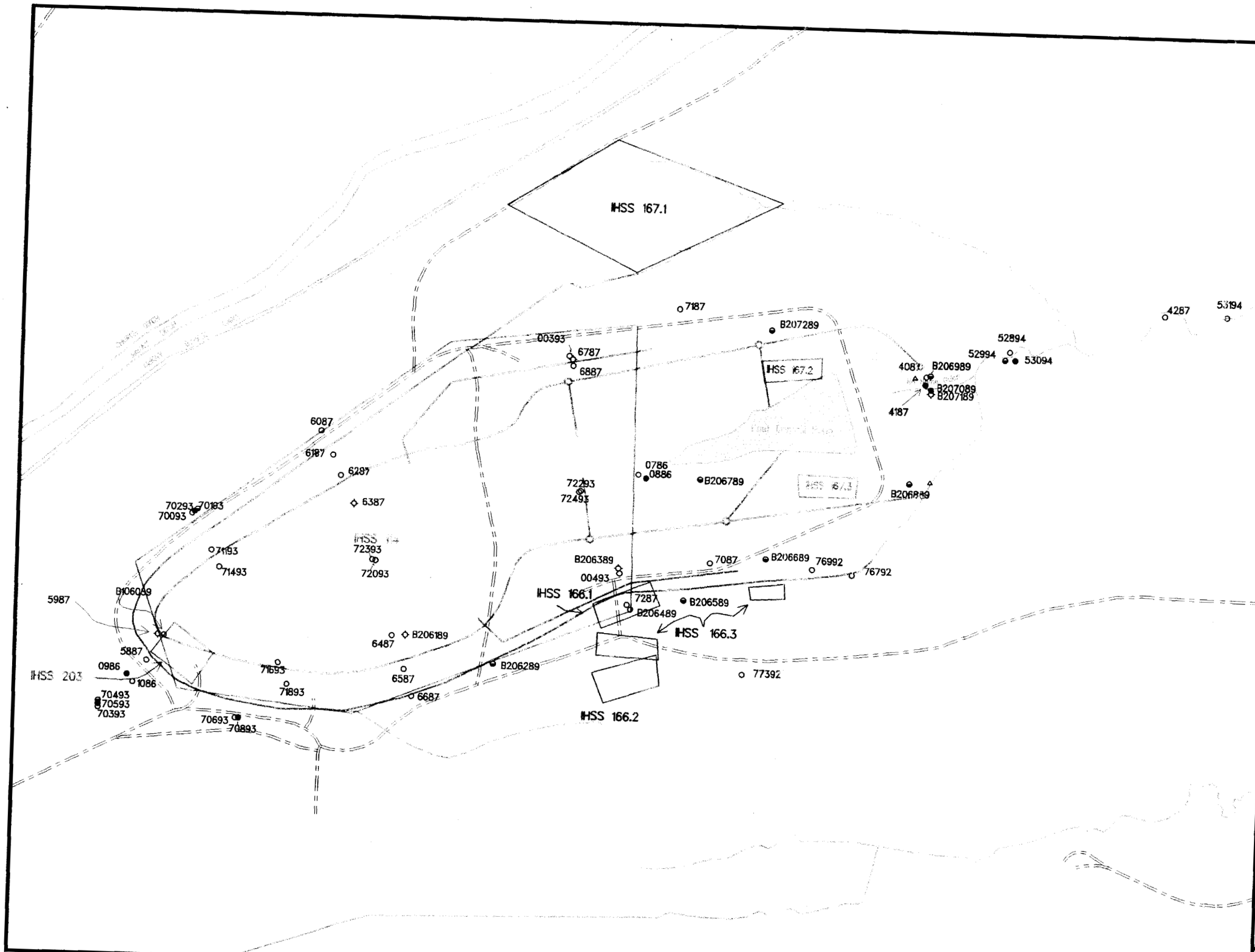
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 2-14

02/12/96 SOILSAMMAP



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
- Boreholes Sampled
- 52894 Downgradient Wells Sampled

0 Feet 300 600

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Downgradient Subsurface Geologic Materials and Groundwater Sampling Locations

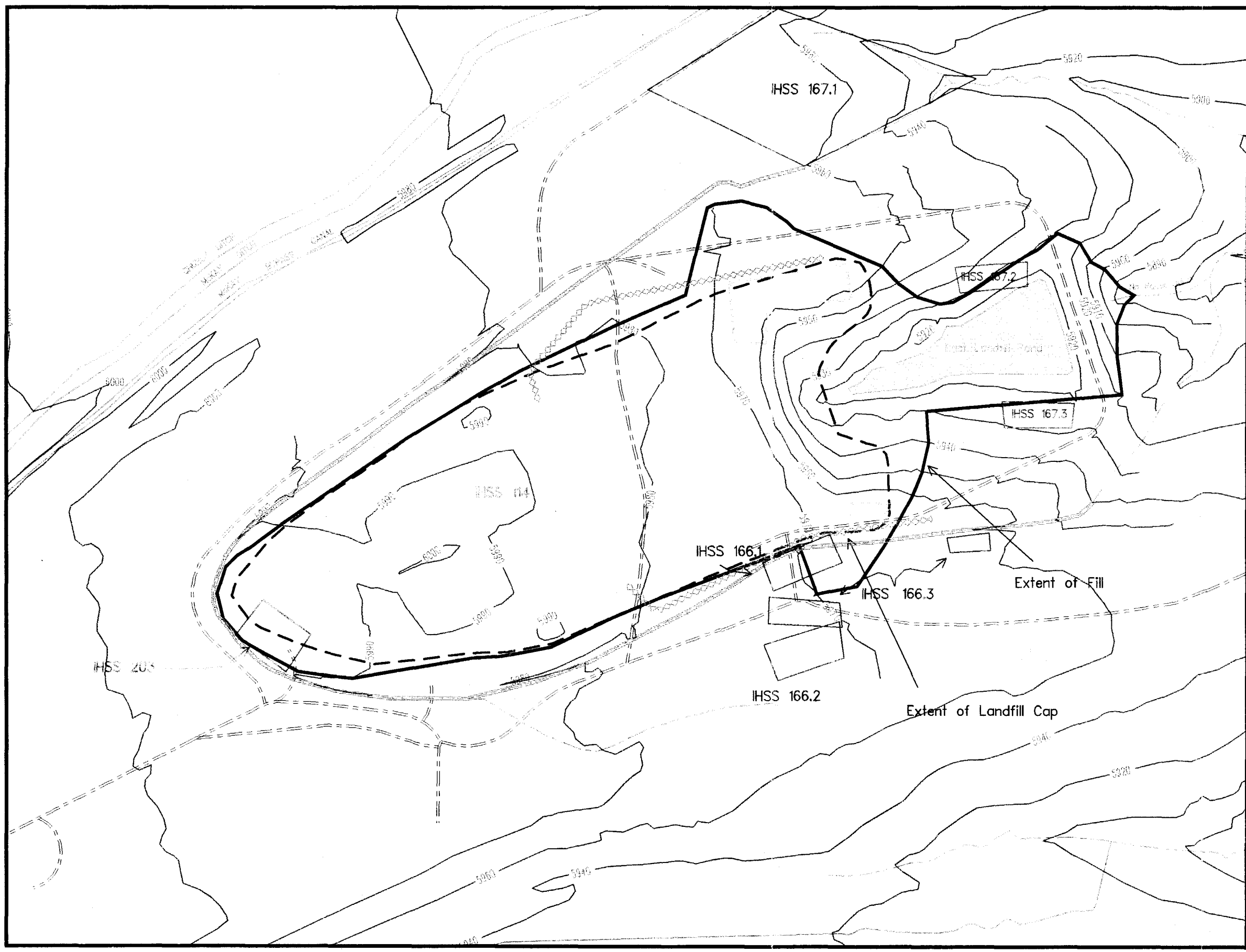
IM/IRA DD
and Closure Plan

Operable Unit No. 7

March 1996

Figure 2-15

02/12/96 STATWATER.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
- Approximate Extent of Asbestos Disposal
- Extent of Fill
- 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 and Fill

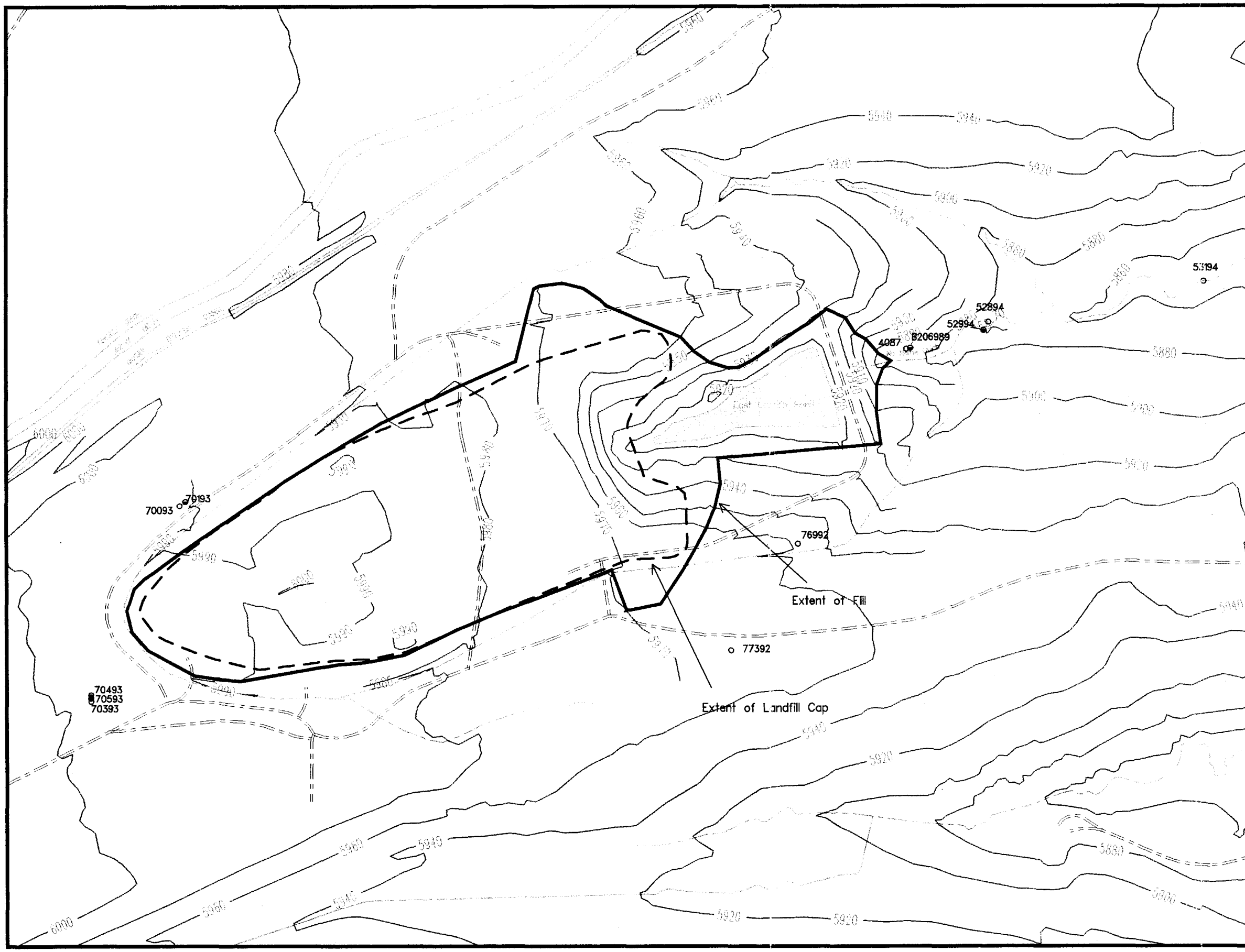
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 5-1

02/12/96 CAP.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well

Ditch

Intermittent Stream

Dirt Road

Extent of Fill

Extent of Landfill Cap

0 Feet 300 600

Topographic Contour Interval = 20 Feet

U.S. DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site, Golden, Colorado

Groundwater Monitoring Wells Remaining During Landfill Closure

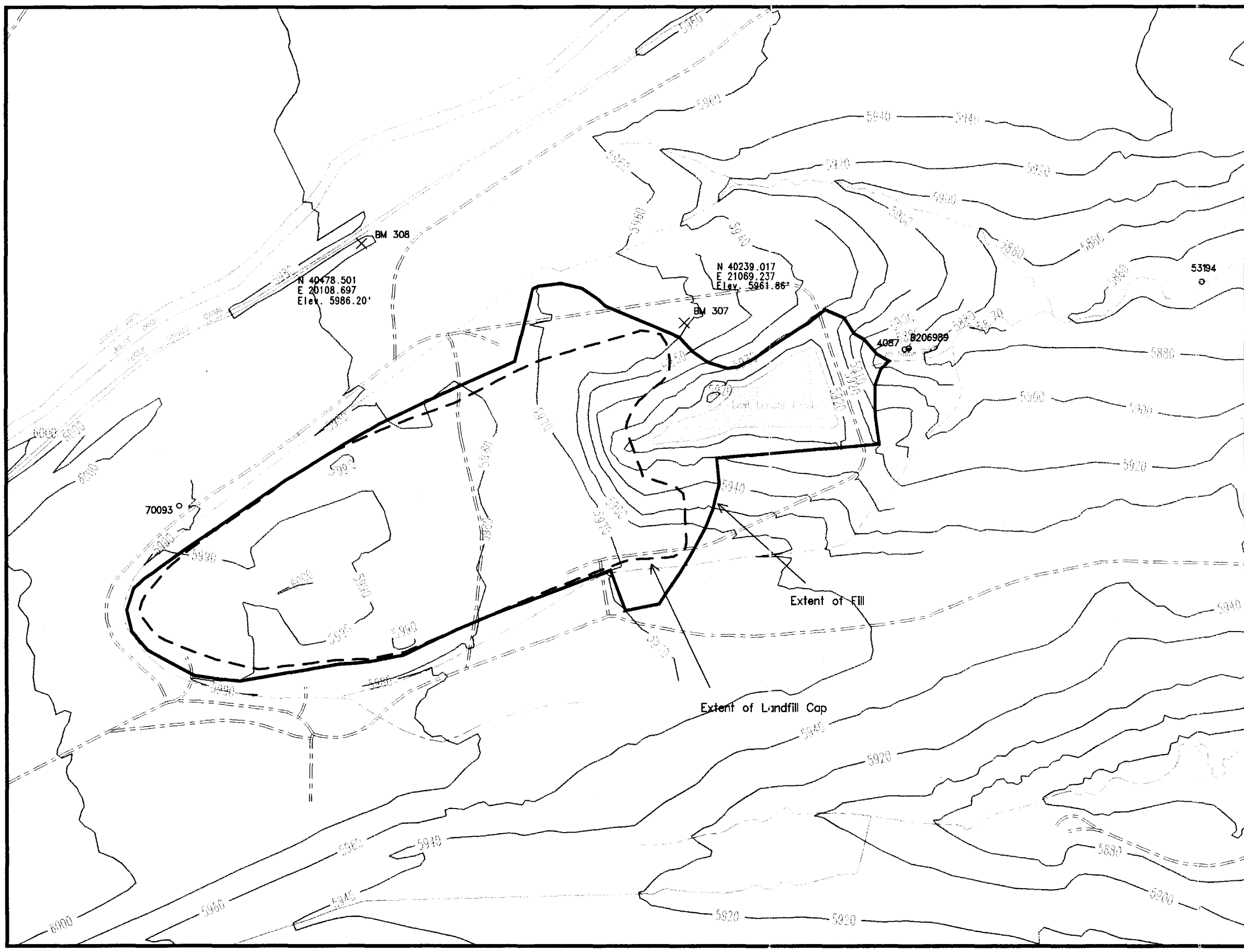
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 8-1

02/12/96 MONITORING_96.MAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Ditch
- Intermittent Stream
- Dirt Road
- Extent of Fill
- Extent of Landfill Cap
- BM Temporary Benchmark

*Note: Coordinates are listed in Rocky Flats local coordinate system.

N

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

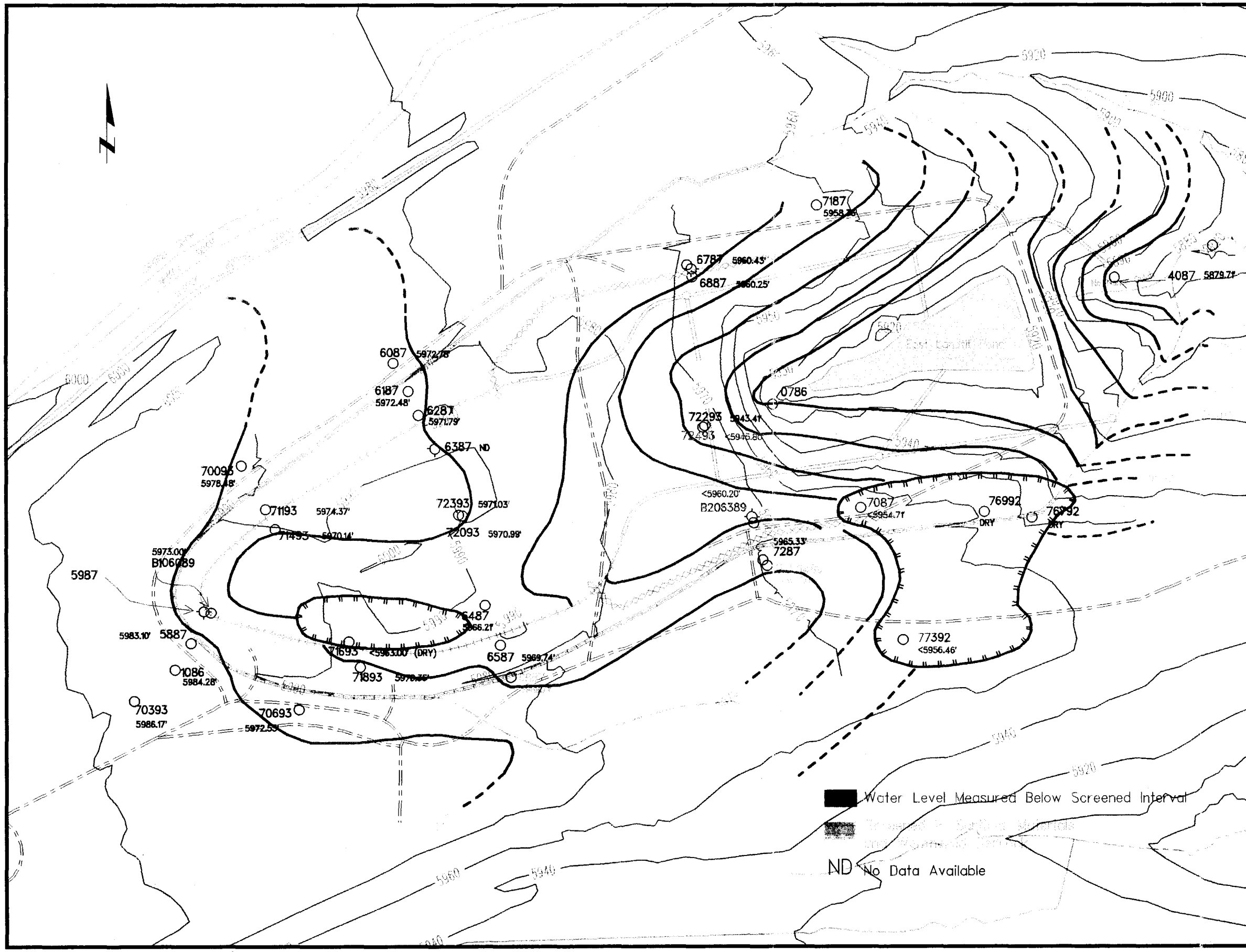
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure 8-2

02/12/96 POSTMON_96.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)

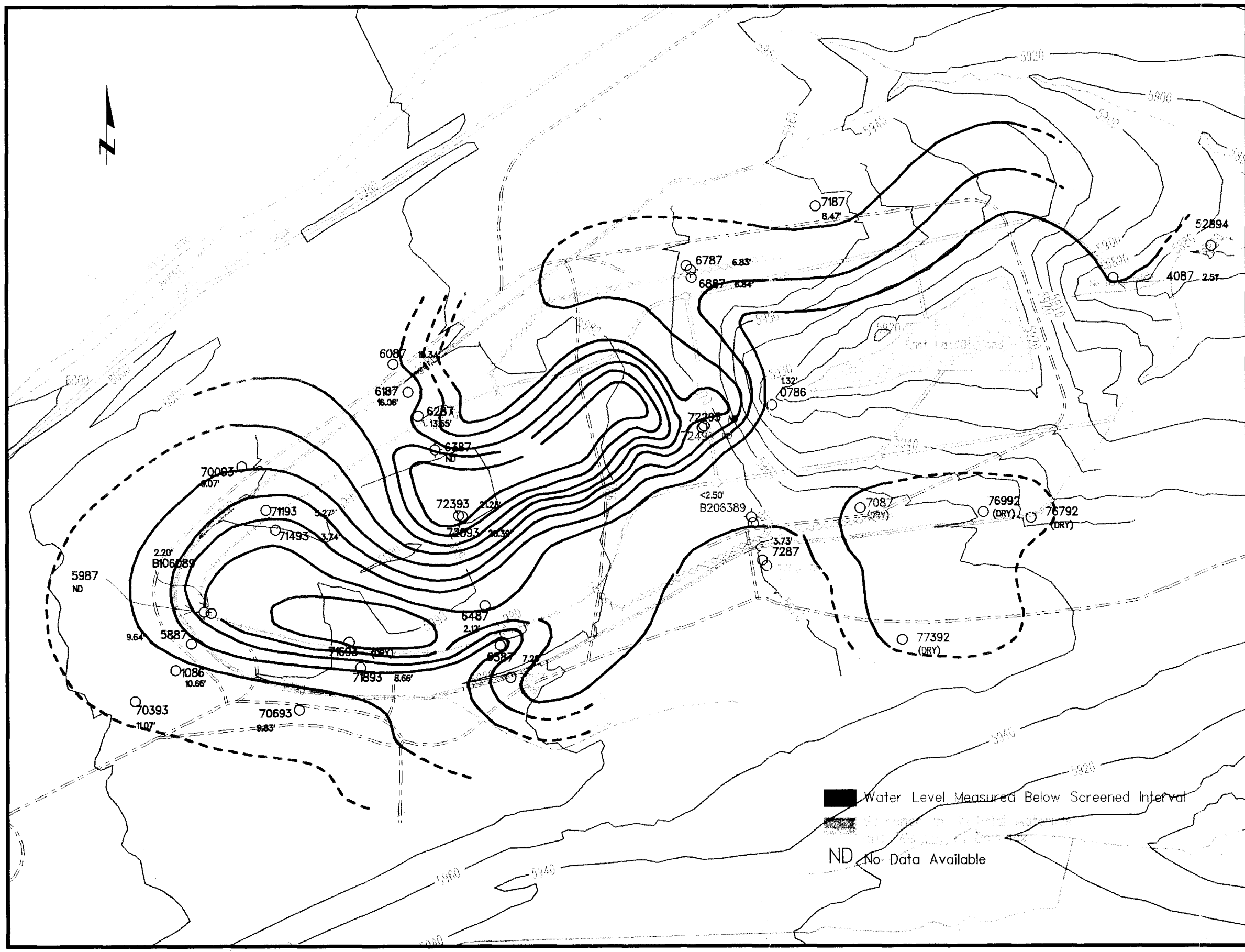
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure C-7

02/12/96 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)

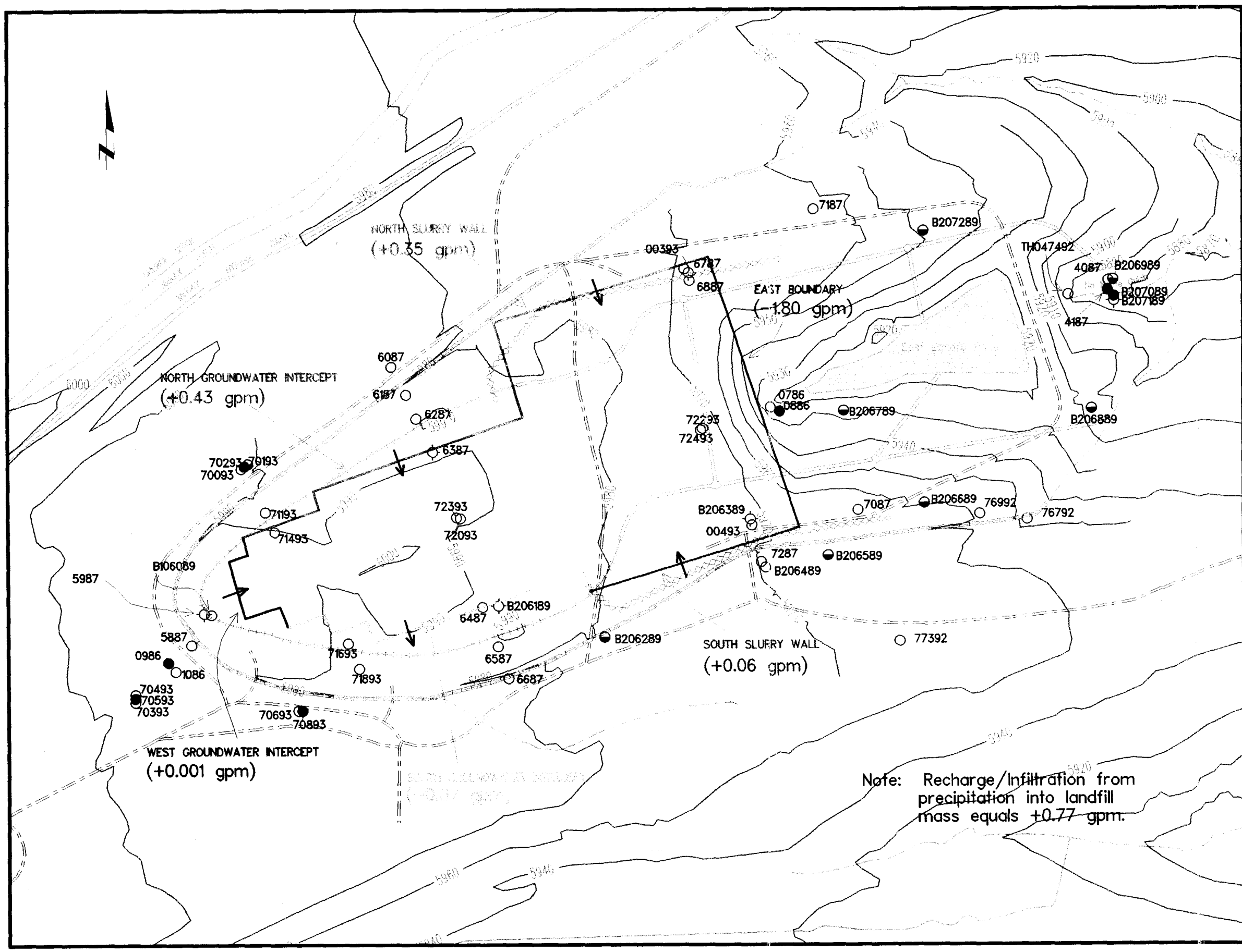
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure C-8

02/12/96 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

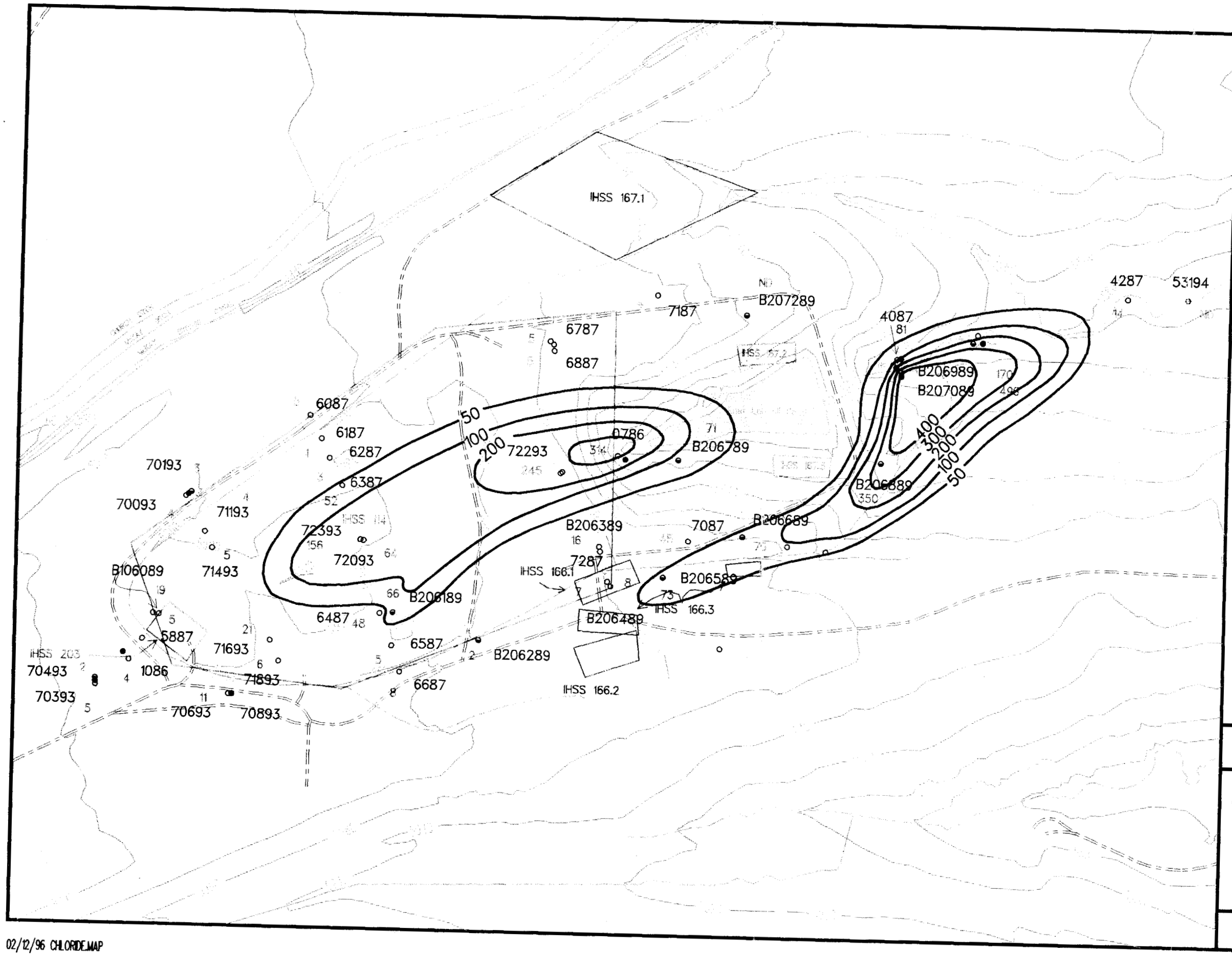
IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure C-10

02/12/96 WATERBALANCE.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

N

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)

IM/IRA DD and Closure Plan

Operable Unit No. 7

March 1996

Figure D-1

02/12/96 CHLORIDE.MAP