Technical Memorandum

Revised Work Plan
Operable Unit No. 7 — Present Landfill (IHSS 114) and Inactive Hazardous Waste Storage Area (IHSS 203)

Volume I—Sections 1–8

Draft Report

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ADMIN RECORD

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The Adminstrative Record Staff

EXECUTIVE SUMMARY

This Operable Unit (OU) No 7 Revised Work Plan Technical Memorandum presents the findings of the Phase I Resource Conservation and Recovery Act (RCRA) facility investigation/remedial investigation (RFI/RI), the results of the data quality objectives (DQO) process, which identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7, and the sampling and analysis plan developed for the collection of these additional data These activities are pursuant to the Interagency Agreement (IAG) signed by the U S Department of Energy (DOE), the Colorado Department of Health (CDH), and the U S Environmental Protection Agency (EPA), which addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues CDH is the lead regulatory agency at OU 7

OU 7 is one of the 16 OUs at the Rocky Flats site in Jefferson County, Colorado Each OU is made up of a number of individual hazardous substance sites (IHSSs) OU 7 comprises the Present Landfill (IHSS 114), the Inactive Hazardous Waste Storage Area (IHSS 203), and the East Landfill Pond and adjacent spray evaporation areas

Operation of the Present Landfill (IHSS 114) for disposal of nonradioactive solid waste began in 1968 and will continue until the anticipated date of closure in 1997 Because records indicate that some hazardous waste was disposed in the landfill, it was designated as an interim status RCRA-regulated unit Tritium and strontium were detected in leachate draining from the landfill in 1973 Interim response activities included construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill (West Landfill Pond and East Landfill Pond), a subsurface intercept system for diverting groundwater around the landfill, and a subsurface leachate-collection system Spray evaporation of water from the East Landfill Pond is conducted to prevent overflow of the pond and release of water downstream and to protect surface water and groundwater in the vicinity of the landfill

The Inactive Hazardous Waste Storage Area (IHSS 203), located at the southwest corner of the Present Landfill, was used for storage of drummed liquids and solids in 1986 and 1987 It was also included as an interim status RCRA-regulated unit in the November 1986 RCRA Part B permit application for Rocky Flats Because it is located within the Present Landfill, it will be remediated to meet requirements for closure of the unit at the same time as the landfill

A presumptive remedy strategy for streamlined site characterization and site remediation has been adopted by DOE, CDH, and EPA for the Present Landfill Source containment is the designated presumptive remedy for municipal landfills and consists of the following elements institutional controls, a landfill cap, gas collection and treatment, leachate control, and leachate collection and treatment This streamlined approach, which is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements and is supported by guidance in the National Contingency Plan, eliminates the need for initial identification and screening of alternatives during the feasibility study and allows for acceleration of the schedule to implement remedial actions and achieve final closure Data needed for the design of the presumptive remedies, assessment of the nature and extent of groundwater contamination, and the risk assessment will be collected in accordance with the sampling and analysis plan included in this document

Data collected during the Phase I RFI/RI have undergone rigorous review and data-quality evaluation Approximately 87 percent of the records have been reviewed and evaluated in accordance with EPA procedures for the documentation and validation of Level IV and V data Less than 3 percent of these records have been rejected The valid data are considered usable for site characterization, human health and environmental risk assessments, remedial alternative evaluation, and engineering and remedial action design Historical data collected from 1990 through 1993 were not evaluated, their usability was determined from laboratory qualifiers and validation codes

The OU 7 Revised Work Plan Technical Memorandum describes the site physical features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology to characterize OU 7 within the Rocky Flats site framework Results of the Phase I RFI/RI show that leachate within the landfill is primarily recharged by precipitation through the interim soil cover material However, groundwater does flow under the intercept system on the north side of the landfill

Results of the Phase I RFI/RI were also used to characterize the primary sources of contamination at OU 7, which include landfilled wastes and associated leachate and gas The landfill covers an area of approximately 27 acres The total volume of landfilled material including soil cover is approximately 415,000 cubic yards, the volume of waste is 291,000 cubic yards Composition of landfill gas generated by waste degradation is typically 45 to 70 percent methane and 20 to 40 percent carbon dioxide indicating anaerobic conditions Concentrations of methane and carbon dioxide are highest in the eastern portion of the landfill where wastes are

thickest and youngest Approximately 96,000 cubic yards of landfill gas occupy the void and pore spaces in the landfill In general, landfill-generated gases appear to be contained within the existing intercept system Leachate is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through waste Approximately 5,756,000 gallons of leachate is present within the landfill Methane concentrations in leachate range from 0 003 to 31 4 milligrams per liter Concentrations of volatile organic compounds (VOCs) are variable throughout the landfill

Chemical concentration data from various environmental media sampled at OU 7 were evaluated with the following two distinct objectives to identify potential contaminants of concern (PCOCs) and to describe the nature and extent of contamination Data from OU 7 samples were compared to data from background samples for each media Statistical comparisons for PCOC identification consisted of the following steps (1) a hot-measurement test, (2) the Gehan Test, (3) the Quantile Test, (4) the Slippage Test, (5) the t-test, and (6) professional judgment Analytes having concentrations elevated relative to background concentrations, as indicated by any of the statistical tests, are considered PCOCs Histograms and box-and-whisker plots were generated for each analyte from each media type for both site and background data Isoconcentration maps were generated to evaluate the spatial distribution of contaminants

On the basis of statistical evaluations, the following PCOCs were identified in surface soils from IHSS 203 calcium, copper, radium-226, americium-241, and uranium-235 Americium-241 and uranium-235 activities exceeded the $UTL_{99/99}$ value, calcium, copper, and radium-226 were identified using the inferential statistical tests PCBs were detected at low concentrations in approximately 20 percent of the soil samples from IHSS 203 and are also considered PCOCs PCOCs identified in surface soils from IHSS 114 include calcium, copper, strontium-89,90, and gross beta

Calcium, strontium, and radium-226 were identified as PCOCs in surface soils from the East Landfill Pond based on results of the inferential statistical tests Arsenic, barium, calcium, lead, magnesium, selenium, sodium, vanadium, zinc, americium-241, radium-226, and nitrate/nitrite were identified as PCOCs based on $UTL_{99/99}$ comparisons These exceedances were generally in the range of 2 to 3 times the maximum background concentration However, the activity of one sample was 27 times the maximum background activity for americium-241 Radionuclides exceeded background activities only in the 0- to 2-inch soil horizon

Seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-228) were identified as PCOCs in surficial geologic materials upgradient of

OU 7, radium-226 was identified as a PCOC in upgradient bedrock material Cesium-137 and uranium-238 were identified as PCOCs in surficial deposits located near the north groundwater intercept system discharge point Uranium-238 was also identified as a PCOC in surface water from the intercept system discharge These data suggest that the north groundwater intercept system discharge water may be a source of uranium-238 to geologic materials downgradient of the landfill However, the ultimate source of uranium-238 may be located upgradient of the landfill, as indicated by the upgradient borehole data

Statistical comparisons of East Landfill Pond sediments to background stream sediments identified metal, radionuclide, and inorganic analytes at concentrations significantly elevated with respect to background concentrations In addition, 15 semivolatile organic compounds (SVOCs) were detected in East Landfill Pond sediments collected near the leachate seep Their presence indicates that SVOC contamination of East Landfill Pond sediments has probably occurred Cesium-137 was the only radionuclide found at activities higher than background The highest activities of cesium-137 and other radionuclides were present in the sample collected from the west end of the pond, closest to the leachate seep

VOCs and SVOCs were detected in surface-water samples from the leachate seep The VOCs include benzene, toluene, ethylbenzene, xylene (BTEX) and chlorinated hydrocarbons Tritium activities were elevated relative to background activities in water from the leachate seep, the East Landfill Pond, and the southern groundwater-intercept discharge Americium-241 was elevated above background in water from the East Landfill Pond, south groundwater-intercept discharge, and the north groundwater-intercept discharge Uranium-235 and uranium-238 were both elevated relative to background in water from the pond, and the north discharge point, only uranium-238 was elevated above background in water from the south discharge point As may be expected, water in the East Landfill Pond is similar in quality to water from the leachate seep and from the groundwater intercept system However, VOCs and SVOCs were detected more frequently in seep water

Groundwater in the UHSU at OU 7 contains metals, radionuclides, organic parameters, and nitrates at concentrations higher than background Sources of radionuclides and chlorinated hydrocarbon contamination to UHSU groundwater may be located upgradient of the landfill and within IHSS 166 1 (within OU 6) The landfill appears to be the primary source of metals and BTEX compounds PCOCs were identified in groundwater from the LHSU However, in LHSU groundwater collected downgradient of the landfill, radionuclide and VOC concentrations were not significantly higher than concentrations in LHSU groundwater from background wells

The DQO process presented in the Interim Final Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process (EPA 1993c) was used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7 For the purpose of streamlined site characterization and site remediation, OU 7 has been divided, roughly by media, into three decision-making areas East Landfill Pond sediments and soils in spray evaporation areas adjacent to the pond, groundwater and surface water, and the Present Landfill and IHSS 203

In order to determine whether or not remediation of East Landfill Pond sediments and adjacent soils is required, it is necessary to determine if concentrations of contaminants present risk to human health or the environment and, if so, the appropriate response action No additional data are needed to define the nature and extent of contamination in soils, but additional soil sampling and analysis will be required to support the risk assessment PCOCs were identified in soils based on statistical comparisons and the hot-measurement test UTL exceedances in soils were randomly distributed across the site Additional sampling and analysis is recommended to verify the UTL exceedances and to describe contaminant distribution around sample locations where PCOC concentrations exceeded an applicable or relevant and appropriate requirement (ARAR) or preliminary remediation goal (PRG) value No additional sampling of pond sediments is recommended because the available data already support a decision to take remedial actions

A response action for contaminated surface water in the East Landfill Pond has already been developed Under the presumptive-remedy strategy, the East Landfill Pond will undergo clean closure Surface water in the pond will have to meet requirements for delisting and will probably be pumped to a treatment facility at the site The surface-water data currently available are sufficient to determine whether or not surface-water quality meets requirements for delisting

The presumptive remedy does not address the long-term groundwater response action In order to fully describe impacts to groundwater resulting from contaminant releases from the landfill and to determine whether or not these impacts require a response action, the concentrations of PCOCs must be compared to ARARs Available data indicate that some PCOCs clearly exceed ARARs in groundwater from the upper hydrostratigraphic unit (UHSU) and remediation of groundwater will be required However, the full extent of groundwater contamination has not been described Therefore, the installation of additional wells at four locations is recommended to characterize potential contaminant migration pathways and improve descriptions of contaminant distribution

Presumptive remedies dictate the remedial actions that will be taken at the Present Landfill and IHSS 203 and additional chemical characterization of affected media in those areas is not needed to make decisions about remediation Other types of information will be required to design the landfill cap and the control systems for landfill-generated gas and leachate The collection of soil samples to characterize the physical properties of the interim soil cover material is recommended to provide the additional data needed

The specific objectives of the Phase II field investigation include the following

- Verify analyte concentrations in surface soils around the East Landfill Pond at locations where PCOC concentrations exceeded the $UTL_{99/99}$ value Collect samples from the 0- to 2-inch horizon at 34 locations and the 0- to 10-inch horizon at 10 locations Collect one sample per location

- Investigate the distribution of analytes in surface soils around the East Landfill Pond where analyte concentrations exceeded draft PRGs to delineate the area of soil contamination around each hotspot Collect samples from the 0- to 2-inch horizon at 10 locations and the 0- to 10-inch horizon at two locations Collect four samples per location Collect samples 25 feet from the original sample location where soils exceeded draft PRGs, one each to the north, south, east, and west of the original location

- Evaluate the effectiveness of the groundwater intercept system north of the landfill by installing two alluvial wells, one on each side of the system Measure water levels at each well Collect groundwater samples monthly for four months to characterize groundwater quality further

- Delineate the extent of UHSU groundwater contamination on the southeast side of the East Landfill Pond by installing one well in weathered bedrock Collect groundwater samples monthly for four months to characterize groundwater quality Perform a drawdown recovery test to estimate the hydraulic conductivity of the screened unit

- Delineate the extent of UHSU groundwater contamination on the north side of the East Landfill Pond downgradient of IHSS 167 1 by installing one well in alluvial materials Collect groundwater samples monthly for four months to characterize groundwater quality Perform a drawdown recovery test to estimate the hydraulic conductivity of the screened unit

- Delineate the extent of groundwater contamination in the UHSU, determine the presence or absence of contamination in the LHSU, and improve the monitoring network along No Name

Gulch by installing a group of three wells downgradient of the existing compliance wells and one well farther down No Name Gulch Screen the group of wells across valley-fill alluvium, weathered bedrock, and bedrock Screen the single well across valley-fill alluvium Collect groundwater samples monthly for four months to characterize groundwater quality Perform drawdown recovery tests to estimate the hydraulic conductivity of the screened units

- Characterize the interim soil cover material for use in landfill cap design Collect surface soil samples at 27 locations Measure physical properties of the soil, including standard proctor density, grain size, Atterberg limits, *in situ* moisture content, and unconfined compressive strength

Data collected during the Phase II investigation will be used to determine the contaminants in surface soils that present a risk to human health and the environment and the appropriate response action required to reduce those risks, describe the impacts to groundwater resulting from contaminant releases from the landfill and determine whether or not these impacts require a response action, support closure of the Present Landfill under CHWA and RCRA, design the landfill cap, leachate control system, leachate collection and treatment system, and gas collection and treatment system, and meet the IAG milestone of July 1997 for IM/IRA implementation

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ACRONYMS AND ABBREVIATIONS

af	artificial fill
ARARs	applicable or relevant and appropriate requirements
BAT®	Bengt-Arne Torstensson
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
BTOB	below top of bedrock
C	runoff coefficient
CAMU	Corrective Action Management Unit
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHWA	Colorado Hazardous Waste Act
CI	confidence interval
CLP	Contract Laboratory Program
cm/sec	centimeters per second
COC	contaminant of concern
CPT	cone penetration test
CRDL	contract-required detection limit
cu ft	cubic feet
cu yd	cubic yard
CV	coefficient of variation
cy	cubic yards
DCA	dichloroethane
DCE	dichloroethene
DIL	dilution
DOE	U S Department of Energy
DQO	data quality objective

EIS	environmental impact statement
EMD	Rocky Flats Environmental Management Department
EPA	U S Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low-Energy Radiation
ft	feet
ft^3	cubic feet
$ft^3/day/ft^2$	cubic feet per day per square feet
ft/ft	feet per feet
ft/yr	feet per year
FWHM	full width at half maximum
gal	gallon
gal/min	gallons per minute
gal/month	gallons per month
GC	gas chromatogram
GC/MS	gas chromatography/mass spectrometry
GFAA	graphic furnace atomic adsorption
gpm	gallons per minute
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
hr/day	hours per day
HSU	hydrostratigraphic unit
IAG	Interagency Agreement
IDL	instrument detection limit
IDM	investigative-derived materials
IHSS	individual hazardous substance site
IM/IRA	interim measure/interim remedial action
in Hg	inches of mercury
K	hydraulic conductivity
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone

ℓ	liter
lb	pound
LDRs	land disposal restrictions
LHSU	lower hydrostratigraphic unit
MDL	method detection limit
MG	million gallons
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MG/month	million gallons per month
min/hr	minutes per hour
mL	milliliter
mo	month
MS	matrix spike
MSD	matrix spike duplicate
NC	not calculated
NCP	National Contingency Plan
NDE	not deep enough
ND-GC	no data - gas chromatogram
NEPA	National Environmental Policy Act
NMOC	non-methane organic compound
NP	not performed
NP-ACC	not performed - access
NP-DRY	not performed - dry
NP-DUP	not performed - duplication of effort
NP-EQUIP	not performed - equipment
NP-REF	not performed - refusal
NPDES	National Pollutant Discharge Elimination System
NR-WP	not required - work plan
NS-DRY	not sampled - dry
NS-REF	not sampled - refusal
OU	operable unit

oz	ounce
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
ppm	parts per million
PRG	preliminary remediation goal
psi	pounds per square inch
PU&D	Property Utilization and Disposal
PVC	polyvinyl chloride
QA	quality assurance
QAA	quality assurance addendum
QAPjP	quality assurance project plan
Qc	colluvium
QC	quality control
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium
%R	percent recovery
RCRA	Resource Conservation and Recovery Act
REP	replicate
REX	re-extraction
RFD	reference dose
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA facility investigation/remedial investigation
RPD	relative percent difference
SAP	sampling and analysis plan
SOPs	standard operating procedures
SVOC	semivolatile organic compound
SWMU	solid waste management unit

TAL	target analyte list
TCA	trichloroethane
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TIC	tentatively identified compound
TOC	total organic carbon
TRG	target
TSS	total suspended solids
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
USCS	Unified Soil Classification System
UHSU	upper hydrostratigraphic unit
UTL	upper tolerance limit
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99-percent confidence level
VOA	volatile organic analysis
VOC	volatile organic compound
WABS	water level below bottom of screen
wk	week
WQCC	Water Quality Control Commission
WSIC	Waste Stream Identification and Characterization
WSRIC	Waste Stream Residue Identification and Characterization

1 INTRODUCTION

Operable Unit (OU) No 7 is one of 16 OUs at the Rocky Flats Site in Jefferson County, Colorado Each OU is made up of a number of individual hazardous substance sites (IHSSs) OU 7 comprises the Present Landfill (IHSS 114), the Inactive Hazardous Waste Storage Area (IHSS 203), and the East Landfill Pond and adjacent spray evaporation areas

As a result of the production of nuclear weapon components, processing of radioactive substances, and fabrication of metals, hazardous substances have been released at the Rocky Flats site A Phase I Resource Conservation and Recovery Act (RCRA) facility investigation/remedial investigation (RFI/RI) was conducted at OU 7 in 1992 and 1993 to characterize the site physical features, describe contaminant sources, and determine the nature and extent of contamination in soils resulting from such releases Data obtained during the Phase I RFI/RI, along with existing data, were to be used for developing and screening remedial alternatives and estimating the risks to human health and the environment posed by contaminant sources within OU 7 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 the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) dated January 22, 1991 (DOE 1991a) The IAG program developed by DOE, EPA, and CDH addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues that pertain to the site CDH is the lead regulatory agency at the site

Prior to completion of the Phase I RFI/RI and initiation of Phase II, the focus of investigations at OU 7 changed due to the adoption of a presumptive-remedy strategy for streamlined site characterization and site remediation by DOE, CDH, and EPA Source containment is the designated presumptive remedy for municipal landfills (EPA 1993a) The containment presumptive remedy consists of the following elements institutional controls, a landfill cap, landfill gas collection, source area groundwater control, and leachate collection and treatment, if necessary This streamlined approach, which is consistent with Colorado Hazardous Waste Act (CHWA) closure requirements

supported by guidance in the National Contingency Plan (NCP) and recent EPA guidance for landfills (EPA 1991a, EPA 1993a, EPA 1993b), eliminates the need for initial identification and screening of alternatives during the feasibility study and allows for acceleration of the schedule to implement remedial actions and achieve final closure As a result of this strategy, the Phase I RFI/RI report and comprehensive baseline risk assessment are no longer required Data needed for the design of the presumptive remedies, an assessment of the nature and extent of groundwater contamination, and a focused risk assessment will be collected in accordance with the sampling and analysis plan included in this document Fieldwork will be followed by preparation of an interim measure/interim remedial action (IM/IRA) decision document and finally, implementation of the IM/IRA

1 1 Purpose of Report

This OU 7 Revised Work Plan Technical Memorandum presents the findings of the Phase I investigation, the results of the data quality objective (DQO) process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7, and the sampling and analysis plan developed to collect these data

1 2 Organization of Report

This section presents background information regarding the locations and operational histories of the IHSSs and associated areas that make up OU 7 (Section 1 3) and discusses previous investigations at the site (Section 1 4) Section 2 presents the site characterization, including surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology Section 3 discusses data quality and usability Section 4 presents the process for identifying potential contaminants of concern (PCOCs), including the methodologies for aggregating data and comparing site data to background data, presents the PCOCs at OU 7 based on assessment of existing data, and discusses the nature and extent of contamination Section 5 discusses the DQOs for additional sampling Section 6 presents the sampling and analysis plan (SAP) Section 7 presents the quality assurance (QA) and quality control (QC) objectives for data collection, analysis, validation, and reporting Section 8 presents references cited in the report

Supporting data are included in the appendices to the report Appendix A presents tables listing hazardous and nonhazardous waste streams disposed in the landfill prior

to 1986 Appendix B contains selected as-built drawings of the groundwater intercept system Appendix C summarizes the Phase I RFI/RI field investigation Appendix D presents cone penetration test profiles and interpretations Appendix E presents borehole logs in LOGGER format Appendix F contains well construction diagrams Appendix G presents Phase I RFI/RI field data electronic format Appendix H presents drawdown recovery test data and analytical solutions in hard copy and electronic format Appendix I contains input data and calculations for the water balance Appendix J presents data-quality tables Appendix K contains box plots for each analyte by media Appendix L presents histograms for each analyte by media Appendix M presents the results of statistical analyses Appendix N presents OU 7 analytical data in electronic format

1 3 Background

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

Until January 1992, Rocky Flats was operated as a nuclear weapons research, development, and production plant Nuclear weapon components were fabricated from plutonium, uranium, beryllium, and stainless steel Parts made at the plant were shipped elsewhere for assembly Support activities conducted at the plant included chemical recovery and purification of recyclable transuranic radionuclides and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (Rockwell International 1987a) Both radioactive and nonradioactive wastes were generated in the production process and were either stored or disposed on the site

The Rocky Flats site is currently in transition from a defense production facility to a facility whose planned future missions include environmental restoration, waste management, maintaining production contingency, and eventual decontamination and decommissioning The preliminary assessment performed under the DOE Environmental Restoration program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination (DOE 1986)

Additional information regarding historical plant operations, production activities, past waste disposal practices at Rocky Flats, and previous investigations not directly related to OU 7 are provided in the OU 7 Phase I work plan (DOE 1991b)

This report addresses investigations at OU 7, which is located north of the plant complex on the western end of No Name Gulch (Figure 1-2) OU 7 encompasses approximately 44 acres (Figure 1-3) The Present Landfill and the Inactive Hazardous Waste Storage Area were assigned IHSS (formerly solid waste management unit [SWMU]) reference numbers by Rockwell International (1987a) and were grouped together and designated as OU 7 During 1991, the boundary of OU 7 was modified to include the East Landfill Pond and adjacent spray evaporation areas which were not included in OU 6 The locations of two of the spray fields in OU 6 (IHSSs 167 2 and 167 3) were changed based on historical research, including a review of files and photographs from the Rocky Flats site repository and employee interviews conducted for the historical release report, and now fall within the OU 7 boundary (DOE 1992a) The updated locations of IHSSs 167 2 and 167 3 directly overlie the area investigated during the Phase I RFI/RI for OU 7, and discussions of results relevant to these IHSSs are included in this report

Section 1 3 1 presents details of the IHSS locations and operations Section 1 3 2 summarizes the regulatory histories of these IHSSs Section 1 3 3 discusses physical features of the landfill and interim response actions for OU 7

1 3 1 Description and Operational History of OU 7

The background and physical setting of the Present Landfill, Inactive Hazardous Waste Storage Area, and East Landfill Pond and adjacent spray evaporation areas composing OU 7 are discussed below Also located within No Name Gulch are OU 6 IHSSs, including trenches A, B, and C (IHSSs 166 1, 166 2, and 166 3, respectively) 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 placed within this trench More information regarding the operational history of these IHSSs is presented in the Phase I RFI/RI Work Plan for Operable Unit 6 - Walnut Creek Priority Drainage (OU 6 work plan) (DOE 1992b)

1 3 1 1 Present Landfill (IHSS 114)

Operation of the Present Landfill began on August 14, 1968, and is expected to continue until the anticipated date of closure in 1997 A portion of the natural drainage was filled with soils from an onsite borrow area to a thickness of up to 5 feet to construct a surface on which to start landfilling Waste was then delivered to the landfill and spread across the work area Disposal procedures at the landfill have not changed significantly since the landfill went into operation (DOE 1991b) The landfill was originally constructed to provide for disposal of nonradioactive solid wastes However, the criteria used historically to define nonradioactive material is not known

In 1973, after tritium and strontium were detected in leachate draining from the landfill, Health Physics Operations initiated a radiation monitoring program to prevent further inadvertent disposal of radioactive material Prior to compaction and burial at the landfill, the waste material is screened with a Bicron Analyst FIDLER, which is a field instrument for detecting low-energy radiation Any radioactive items are returned to the building of origin for disposal (DOE 1992a) After radiation monitoring is completed, the waste layer is compacted and covered with 6 inches of soil from onsite stockpiles Waste disposal operations continue in this manner until the waste layer is within 3 feet of a predetermined elevation The lift is then completed with the addition of a 3-foot-thick layer of compacted soil Based on visual observation (Rockwell International 1988a), some areas of the landfill surface may not have received a full 3-foot layer of compacted soil

Other than monitoring for radioactivity, little testing was performed to characterize the landfilled wastes prior to 1986 In 1986, waste streams generated at the plant were characterized under the Waste Stream Identification and Characterization (WSIC) program (Rockwell International 1986a, 1986b, 1986c, 1986d, and 1987b) Beginning in 1989, waste streams generated at the plant were characterized under the Waste Stream Residue Identification and Characterization (WSRIC) program More detailed characterization and analytical testing of Rocky Flats waste streams are currently being performed under the WSRIC program Section 4 discusses further the composition of landfilled wastes

1 3 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 (Figure 1-3) This area was actively used between 1986 and 1987 as a hazardous waste storage area for both drummed liquids and solids (Rockwell International 1988b) Fifty-five-gallon drums containing liquids were stored in 14 cargo containers One additional container was used to store spill-control items such as oil sorbent and sorbent pillows

At maximum inventory, the hazardous waste area consisted of eight 20-foot-long cargo containers, each capable of holding 18 55-gallon drums, and six 40-foot-long cargo containers, each capable of holding 40 55-gallon drums Fifty-five-gallon drums were placed and conveyed within the cargo containers on rollers constructed of aluminum Two conveyors extended along the full length of the cargo container A 3-foot-wide aisle extended down the center of the cargo container to permit access and inspection The rollers elevated the drums approximately 2 inches above the catch-basin floor

The cargo containers were modified to meet the requirements for secondary containment in accordance with 6 Colorado Code of Regulations (CCR) 1007-3 Section 264 175 Containers were fitted with signs, air vents, electrical grounding, and locks A catch basin, constructed of 11-gauge steel with a welded steel rim and a minimum height of 6 inches, was placed within each cargo container to contain spills The basins, as designed, were capable of containing at least 10 percent of the total volume of hazardous waste stored within the cargo containers Drummed solids in 55-gallon containers were placed outside the cargo containers on the ground surface

Total liquid storage capacity for the 14 cargo containers was 21,120 gallons The maximum inventory recorded for all wastes, including solids, is not known Because wastes were transferred between drums for consolidation, small spills may have occurred, however, no spills of reportable quantities occurred in this area during transfer operations (Rockwell International 1988b)

RCRA-listed wastes were stored in 12 of the 14 cargo containers and included solvents, coolants, machining wastes, cuttings, lubricating oils, organics, and acids No information is available regarding the separation of waste types between the individual cargo containers Two of the 20-foot-long cargo containers also were used to store

polychlorinated biphenyl (PCB)-contaminated soil and debris, as well as PCB-contaminated oil from transformers taken out of service (Baker 1988)

During the first week of May 1987, all cargo containers were removed from the Inactive Hazardous Waste Storage Area Hazardous materials are no longer stored at the site

1 3 1 3 East Landfill Pond Spray Evaporation Areas

Spray evaporation of water from the East Landfill Pond along the north and south banks of the pond began in approximately May 1974 and continues as necessary Spray evaporation is conducted to prevent overflow of the pond and release of water downstream and to protect surface water and groundwater in the vicinity of the landfill (DOE 1992a)

Two discrete spray evaporation areas have been identified within OU 7 The Pond Area Spray Field (IHSS 167 2) and South Area Spray Field (IHSS 167 3) are located along the north and south banks of the East Landfill Pond immediately above the water line (DOE 1992a) and were investigated as part of the Phase I RFI/RI for OU 7 Dimensions of the spray fields are approximately 100 feet by 460 feet for IHSS 167 2 and 120 feet by 440 feet for IHSS 167 3

1 3 2 Regulatory History of OU 7

Since the landfill opened in 1968, operations have continuously evolved in response to state and federal regulations Prior to the IAG, both IHSS 114 and IHSS 203 were subject to RCRA regulations because of ongoing disposal and/or storage of hazardous wastes related to production operations For this reason, these units were included in the November 1986 RCRA Part B permit application for Rocky Flats With the signing of the IAG, IHSS 114 and IHSS 203 were incorporated into OU 7 The IAG integrates both RCRA and CHWA closure and corrective action obligations and CERCLA response obligations that apply to OU 7 Additional details of the regulatory history of IHSSs 114 and 203 are discussed below

1 3 2 1 Present Landfill (IHSS 114)

The landfill was originally constructed for disposal of noncontaminated solid wastes In October 1972, the policies concerning disposal of waste at the landfill were reviewed

and judged to be in accordance with applicable state and federal regulations (Rockwell International 1988a)

DOE issued additional guidelines in February 1973 to control burial of solid and liquid wastes in the landfill Detectable contaminant concentrations were established for specific radioactive materials, such as plutonium, in both solid and liquid phases In the fall of 1973, Health Physics Operations began its program of monitoring the waste for radiation in response to the DOE guidelines

In July 1977, DOE established guidelines and procedures for solid waste management, in accordance with 40 Code of Federal Regulations (CFR) 241 (Rockwell International 1988a) Guidelines for waste disposal were redefined to prevent disposal of waste material with detectable radioactivity Further guidelines were established to prohibit disposal of liquids, "special items," and "non-routine wastes" in the landfill, except by special permit The Waste Management Section and the Hazardous Materials Committee of Rockwell International issued the permits The solid waste management procedures were established in 1977 for both radiation monitoring and groundwater monitoring programs Radiation monitoring included measurements at the point of waste origination and at the landfill The groundwater monitoring program consisted of installing wells at the landfill site and sampling the wells once every five months Water samples were analyzed for plutonium, gross alpha, conductivity, pH, and nitrate

At the request of Rockwell International, CDH inspected the landfill in 1978 and 1979 CDH stated that the landfill appeared to comply with state and federal minimum standards and health department regulations (CDH 1979)

In 1986 and 1987, studies were conducted to identify waste streams generated at the plant (Rockwell International 1986a, 1986b, 1986c, and 1986d) These WSIC reports identified 338 waste streams being disposed in the landfill, including 241 waste streams identified as nonhazardous solid waste and 97 solid waste streams that contained hazardous waste or hazardous constituents As of November 1986, the waste streams identified as hazardous in the 1986 studies were no longer disposed in the landfill In 1987, recommendations that outlined how the waste streams identified at the plant should be disposed were made (Rockwell International 1987b) The report identified 144 waste streams that were recommended for continued landfill disposal

Because records indicate that some hazardous waste was disposed at the landfill, it was designated as an interim status RCRA-regulated unit and included in the RCRA Part B permit application for the plant (Rockwell International 1987b) The landfill currently accepts only nonhazardous solid waste and therefore will not be permitted as an operating RCRA unit In 1988, an alternate groundwater monitoring program was implemented at OU 7 in accordance with 6 CCR 1007-3 and 40 CFR 265 90 (d) for interim status RCRA units OU 7 will remain under interim status until closure A closure plan (Rockwell International 1988a) was prepared for OU 7 and submitted to CDH and EPA in July 1988 However, prior to approval, the closure plan was superseded by the IAG

The presumptive remedy outlined in EPA guidance documents (EPA 1993a and 1993b) addresses containment of the landfill mass and control of leachate–groundwater and landfill gas These activities will be implemented under the IM/IRA Post-closure inspection, maintenance, and monitoring of the landfill will be performed in accordance with 6 CCR 1007-3 Part 264 (40 CFR Part 264)

1 3 2 2 Inactive Hazardous Waste Storage Area (IHSS 203)

IHSS 203 was used between 1986 and 1987 as a hazardous waste storage area This IHSS was included in the November 1986 RCRA Part B permit application for Rocky Flats as an operating RCRA hazardous waste unit In that application, it was referred to as Unit #1 Cargo containers used to store drums of hazardous waste at this location were designed to meet the requirements for secondary containment in accordance with 6 CCR 1007-3 Section 264 175

Because IHSS 203 is located within the Present Landfill (IHSS 114), it will be contained along with the landfill mass for closure Post-closure inspection, maintenance, and monitoring of the landfill will be performed in accordance with 6 CCR 1007-3 Part 264 (40 CFR Part 264) These activities will be implemented under the IM/IRA, in accordance with the IAG

1 3 3 Landfill Structures and Interim Response Actions

As previously mentioned, in May 1973 tritium and strontium were detected in leachate draining from the landfill In response, an investigation was conducted to determine the location of the source Monitoring of waste prior to burial was initiated to prevent

further disposal of radioactive material, and interim response activities were undertaken to control the generation and migration of landfill leachate

Interim response activities included construction of a surface-water diversion ditch around the perimeter of the landfill, two detention ponds immediately east of the landfill, a subsurface intercept system for diverting groundwater around the landfill, and a subsurface leachate collection system Construction of the semi-permanent, engineered systems began in October 1974 and was completed in January 1975 These interim response action systems are discussed briefly below Figure 1-4 shows the locations of the landfill structures

1 3 3 1 Surface-Water Diversion System

The surface-water diversion ditch diverts surface runoff around the landfill (Figure 1-4) This system was designed to reduce the infiltration of surface water into the landfill, thereby reducing the volume of leachate draining from the landfill

1 3 3 2 Ponds

Two ponds were constructed as part of the interim response action to control leachate generated by the landfill (figures 1-3 and 1-4) These ponds were formed by constructing temporary berms across the drainage immediately downstream of the landfill Both ponds covered approximately ½ acre The West Landfill Pond (Pond #1) impounded leachate generated by the landfill The East Landfill Pond (initially called Pond #2) provided a back-up system for any overflow from the West Landfill Pond and was also used to collect intercepted groundwater, as needed The leachate collection system originally drained only to the West Landfill Pond Discharge of the intercepted groundwater could be directed (via a series of valves in the subsurface pipes) to either pond or to surface drainages downgradient of the ponds

In 1974, a more permanent embankment was constructed for the East Landfill Pond in approximately the same location as the original berm The new embankment was an engineered dam structure with a spillway, designed to retain the majority of the water in the channel A low-permeability clay core keyed into bedrock was constructed within the embankment to reduce seepage The remaining shell of the embankment was constructed of more permeable silty to clayey granular soils The East Landfill Pond covers approximately two and one-half acres

To prevent the two ponds from overfilling and discharging into No Name Gulch, excess pond water was originally pumped to the Solar Evaporation Ponds (DOE 1992a) From January of 1974 to September of 1975, pond water was diverted to a manhole northwest of Building 990 and discharged to Pond B-2 (DOE 1992a) Beginning in September of 1975, pond water was sprayed on the ground surface to enhance evaporation Areas where spray evaporation operations historically occurred were designated as IHSSs and incorporated into OU 6 (Figure 1-3) Water that collected in the West Landfill Pond was sprayed on a 3 9-acre plot (designated IHSS 167 1) located approximately 800 feet northeast of the West Landfill Pond Two other spray fields (IHSSs 167 2 and 167 3) were located on the hillsides near the East Landfill Pond and were used for spray evaporation of water that collected in the East Landfill Pond Water from the East Landfill Pond is still sprayed on the hillside south of the pond After finalization of the OU 6 work plan (DOE 1992b) and implementation of OU 6 Phase I RFI/RI fieldwork, the correct locations of IHSSs 167 2 and 167 3 were identified based on a review of historical information (DOE 1992a) (Figure 1-3) Because the locations of these IHSSs now lie within the area investigated for OU 7, the two IHSSs are considered part of the OU 7 investigation and are addressed in this report

Between 1977 and 1981, landfill expansion covered the discharge points of the leachate collection system into the West Landfill Pond The West Landfill Pond was covered in May of 1981 during further eastward expansion of the landfill Apparently, the berm that created the West Landfill Pond was not removed, nor was the leachate collection system rerouted to drain into the East Landfill Pond Presumably, leachate collected by the subsurface control system still drains to the area of the former West Landfill Pond The East Landfill Pond now receives leachate draining from the face of the landfill

1 3 3 3 Subsurface Drainage Control System

A subsurface drainage control system was installed around the perimeter of the landfill in 1974 The subsurface drainage system included both a leachate collection system and a groundwater intercept system, constructed outside the perimeter of the landfilled wastes (Figure 1-5) The leachate collection system collects leachate generated from the landfill waste and discharges to the West Landfill Pond The groundwater intercept system was designed to intercept and divert groundwater flow around the landfill, thereby reducing the volume of leachate generated from the landfill waste

The two-part system was constructed by excavating around the perimeter of the landfilled wastes to depths of 10 to 25 feet below ground surface The excavation was 24-feet wide at the base Selected as-built drawings of the intercept system are presented in Appendix B of this report All as-built drawings of the intercept system are included in Appendix A of the OU 7 Phase I work plan (DOE 1991b)

The groundwater intercept portion of the system was installed on the outside of the excavation, away from the landfill waste (Figure 1-5) This system consisted of a 1-foot-thick sand and gravel filter blanket installed along the excavation face and covered by a 4 5-foot-thick clay barrier The filter blanket was designed to intercept groundwater and drain to a 6-inch-diameter perforated pipe installed at the bottom of the excavation (and outside of the clay barrier) The intercepted groundwater could then be discharged to either pond or to surface drainage The clay barrier was designed to prevent or reduce groundwater flow into the landfill The as-built sections and profile sheets (sheets 2 and 3 of 12, Sanitary Landfill Renovations, Appendix B) indicate that the bottom of the system may be above the bedrock surface approximately halfway between wells B106089 and 6587 (on the south side of the intercept system) and approximately halfway between wells B106089 and 6387 (on the north side of the intercept system)

The leachate collection system was constructed immediately inside of, and in the same trench as, the groundwater intercept system Although the design drawings specified a 6-inch-diameter perforated pipe for the leachate collection system, as-built drawings indicate that the leachate collection system consisted of a 5-foot-thick gravel backfill placed in the bottom of the trench on the landfill side The collected leachate was directed into the West Landfill Pond, which was intended to retain the leachate without discharging to the East Landfill Pond (Rockwell International 1988a)

Between 1977 and 1981, the leachate collection and groundwater intercept system was buried beneath waste during landfill expansion It has been speculated that lateral expansion of waste placement has resulted in wastes being located beyond the extent of the subsurface drains to the north and south (Rockwell International 1988a) Eastward expansion covered the points where the leachate collection system discharged into the West Landfill Pond

1 3 3 4 Slurry Walls

In 1982, two soil-bentonite slurry walls were constructed 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 (Figure 1-4)

Details of the connection in the design drawings indicate that the west end of each slurry wall intersects, but does not break, the groundwater intercept system At these intersections the existing drain pipe was replaced with ductile iron pipe, which was joined with the existing drain pipe using mechanical compression joints These sections of ductile iron pipe and the joints at each end were then encased with concrete poured against undisturbed bedrock at the bottom of the excavation This concrete block interrupted the hydraulic continuity of the sand and gravel filter blanket located outside of the clay barrier, and the only hydraulic connection of the groundwater diversion drain across the slurry trench was through the new segment of pipe As a result, there would be no outlet from the groundwater intercept system if these pipes were to be damaged or clogged The slurry walls extend eastward approximately 700 feet from these points of intersection Based on as-built drawings, the slurry walls vary in depth from 10 to 25 feet

1 4 Previous Investigations at OU 7

A number of previous investigations have been conducted at the site for the purpose of evaluating physical characteristics and potential contamination Previous investigation reports reviewed for this investigation include

- Present Landfill Closure Plan, Rocky Flats Plant (Rockwell International 1988a)
- RCRA Annual Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant (EG&G 1994a)
- Phase II Geologic Characterization Data Acquisition Surface Geologic Mapping of the Rocky Flats Plant and Vicinity (EG&G 1992a)
- Surface Water and Sediment Geochemical Characterization Reports, Rocky Flats Plant (EG&G 1991a and 1994b)

- Background Geochemical Characterization Reports, Rocky Flats Plant (EG&G 1992b and 1993a)
- Closure Plan, Inactive Interim Status Facilities, Hazardous Waste Storage Area, SWMU #203, Rocky Flats Plant (Rockwell International 1988b)
- Present Landfill Hydrogeologic Characterization Report, Rocky Flats Plant (Rockwell International 1988c)
- Phase I RFI/RI Work Plan for Operable Unit 6 - Walnut Creek Priority Drainage (DOE 1992b)
- Geotechnical Engineering Report for Geotechnical Analysis of Earthen Dams A-3, B-1, B-3, and Landfill Dam (EG&G 1993b)
- Final Historical Release Report for the Rocky Flats Plant (DOE 1992a)

Results of other unpublished or not widely available studies conducted at the Present Landfill are discussed below

1 4 1 Tritium Investigation

In May of 1973, tritium and strontium-89,90 were detected in leachate at a drainage seep from the landfill (Rockwell International 1987c) As a result, temporary berms were constructed across the drainage to halt the flow of leachate into No Name Gulch Monitoring wells were installed directly in the landfilled waste or directly below the saturated waste materials, and leachate–groundwater samples from wells were collected and analyzed to locate the source of the tritium and strontium (Woodward-Clevenger 1974) Elevated readings were followed by drilling more borings and wells until the general location of the source was identified (Rockwell International 1987c) The number of wells installed is referenced in previous reports and varies from 47 (Rockwell International 1987c) to 52 (DOE 1992a)

Of the samples of leachate–groundwater from boreholes in the landfill analyzed for strontium-89,90, the concentration in only one sample appeared elevated (7 picocuries per liter [pCi/L]) (Woodward-Clevenger 1974) All other samples of leachate-groundwater contained strontium-89,90 at concentrations of less than 1 pCi/L The method detection limit for strontium-89,90 at the time of analysis was 0 1 pCi/L

Strontium-89,90 concentrations were analyzed in samples collected from the landfill ponds, drainages, and the groundwater intercept system and were generally found at or below background levels

The concentrations of tritium detected in leachate–groundwater during 1973 are shown in Figure 1-6 The highest measured concentration of tritium was 301,609 pCi/L The depth of the tritium source, total activity, configuration, and source container, if any, were not determined The tritium source is located in an area of the landfill used during 1970 Concentrations of tritium in leachate seeping from the landfill decreased from a high in 1973 to substantially lower concentrations in 1980 (Figure 1-7) Concentrations of tritium during 1980 were approximately equal to the CDH Water Quality Control Commission (WQCC) surface-water standard of 500 pCi/L promulgated in April 1991 The wells near the eastern end of the landfill exhibited decreasing tritium concentrations between 1973 and 1981 No information is available regarding abandonment of the wells installed for the tritium investigation

1 4 2 Geotechnical Investigations

A geotechnical engineering study for landfill remediation was performed in 1974 (Zeff, Cogorno and Sealy, Inc 1974) Recommendations were made and plans were developed for a groundwater diversion and leachate collection system around the perimeter of the landfill (see Section 1 3 3)

Another geotechnical engineering study was performed to evaluate proposed landfill expansion (Lord 1977) The claystone bedrock beneath the landfill was judged adequate to serve as a subsurface hydraulic barrier, and the overburden soils were judged adequate for daily landfill cover (Rockwell International 1988a)

1 4 3 Soil-Gas Surveys

In 1986, Tracer Research conducted a sitewide soil-gas survey for chlorinated organic compounds Samples were analyzed for chloroform, 1,1,1-trichloroethane (1,1,1-TCA), trichloroethene (TCE), tetrachloroethene (PCE), and 1,1-dichloroethene (1,1-DCE) Only one sampling site was located at the landfill PCE was the only target analyte detected at this site

Another soil-gas survey using the Petrex method was initiated in 1987 in the landfill area, however, no actual data were obtained because the sampling points were improperly located

During 1987, a soil-gas survey was performed using portable gas chromatography methods to detect gases commonly generated by landfill wastes Results were reported by Rockwell International (1988a) and are presented in Appendix B of the OU 7 Phase I work plan (DOE 1991b) Methane was detected at 2 of the 20 sampling locations at concentrations less than 0 4 parts per million (ppm) Other compounds were detected but not identified in the landfill soil gas Hydrogen sulfide was not detected The sampling methodology used during the investigation was not documented in the report

Because of limited sampling and/or the lack of documentation of sampling methods, data from these investigations are of limited value

1 4 4 Geophysical Investigations

Geophysical surveys using ground-penetrating radar and electromagnetics were conducted at OU 7 during early 1991 Ground-penetrating radar was used in an attempt to delineate the individual components of the groundwater intercept system and the slurry walls (EG&G 1991b) Although clays and buried conductive materials (landfilled debris) presented difficulties in locating the groundwater intercept system, the inferred slurry wall locations approximated the as-built drawings The ground-penetrating radar data suggest that the intersection of the slurry wall with the groundwater intercept system on the north side is located further to the west than previously thought

The electromagnetic geophysical survey was performed to determine its effectiveness in mapping subsurface total dissolved solids (TDS) plumes (EG&G 1991c) Suspected areas of high TDS content were delineated by the survey, however, these potential plumes could also be interpreted as lenses of conductive clay The report concluded that additional characterization of the physical properties of alluvial and bedrock materials was required to delineate high TDS plumes from naturally occurring, conductive geologic material

1 4 5 Phase I RFI/RI Investigation

A Phase I RFI/RI investigation was conducted at OU 7 in 1992 and 1993 The 12 specific objectives of this investigation as detailed in the OU 7 Phase I work plan (DOE 1991b) are briefly described below

Characterize Site Physical Features

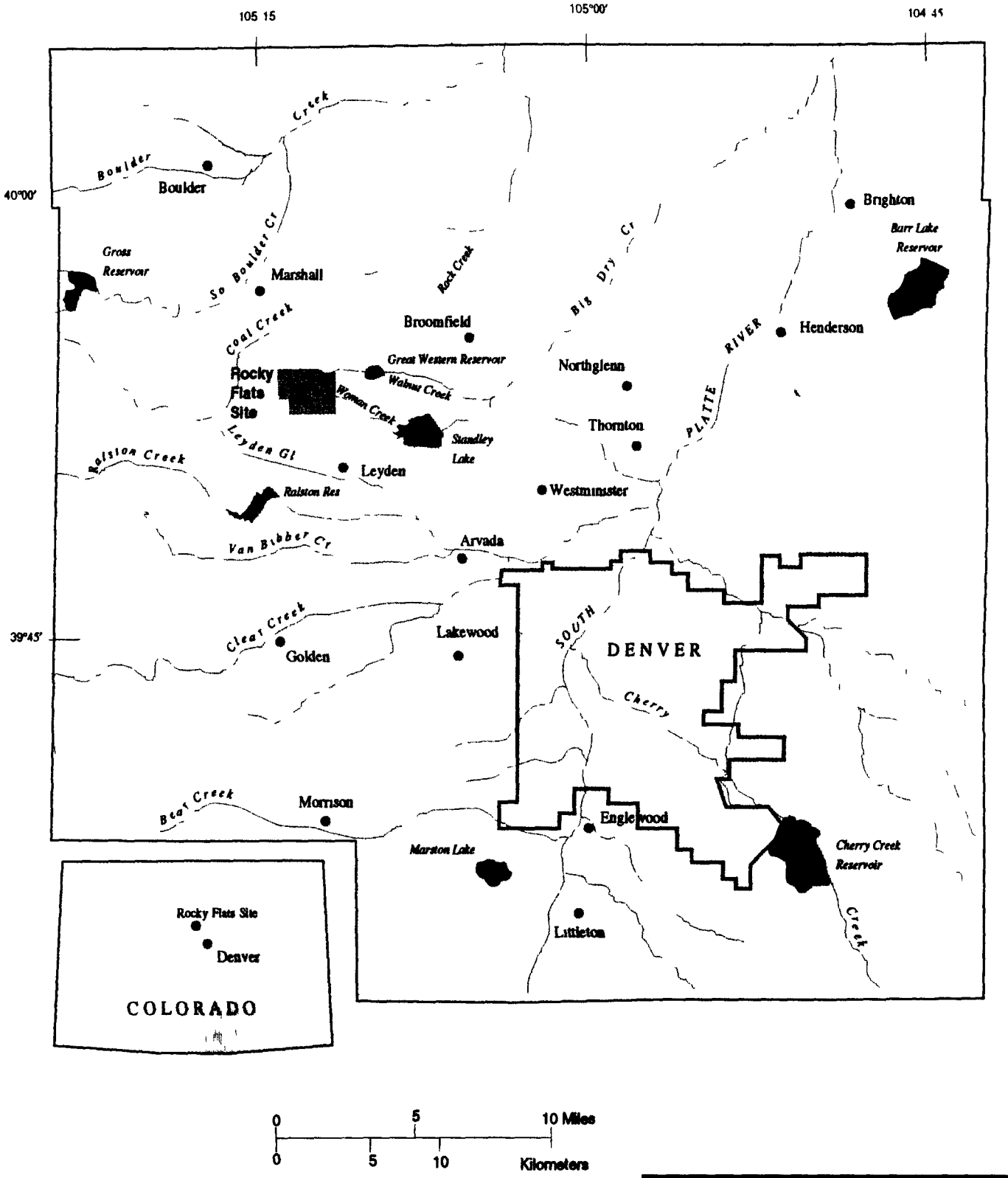
- Determine representative site-specific background concentrations of analytes in groundwater and subsurface materials
- Characterize the flow regime within and around OU 7 to evaluate the effects of the groundwater intercept system and slurry walls on leachate–groundwater movement
- Characterize surface-water and groundwater interactions
- Evaluate infiltration of precipitation through the existing soil cover material

Define Contaminant Sources

- Determine the presence or absence of soil contamination at IHSS 203
- Determine the presence or absence of contamination in soils where spray evaporation occurred
- Further characterize the waste streams disposed in the landfill, and evaluate the environmental fate and transport of the chemicals associated with the identified waste streams
- Determine the area and volume of landfill material
- Determine the volume and character of leachate
- Determine the character and volumes (gas production) of landfill-generated gases
- Characterize leachate-contaminated materials (including soils, bedrock, and former West Landfill Pond sediments) beneath the landfill
- Characterize contamination in surface water and sediments in the East Landfill Pond

Section 1

Figures



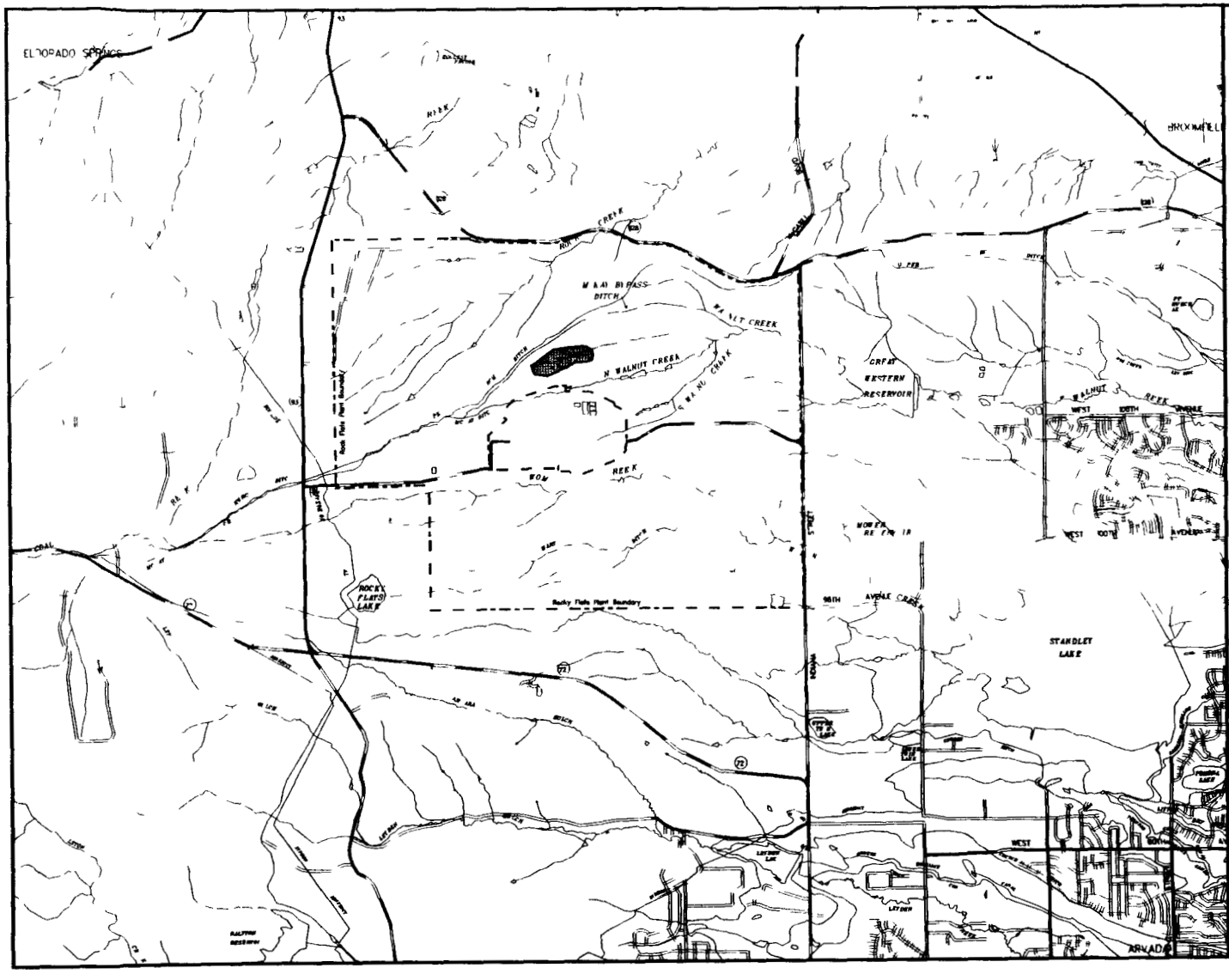
U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Location of Rocky Flats Site

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 1 1

MEB/RFP & Vicinity Map.ai\11 11-93



EXPLANATION

- Streams
- Rocky Flats Site Boundary
- Primary Roads
- Secondary Roads
- Light-Duty Roads
- OU 7

N

0 Miles 1 2

0 Feet 4500 9000

Scale 1 inch = 4500 feet

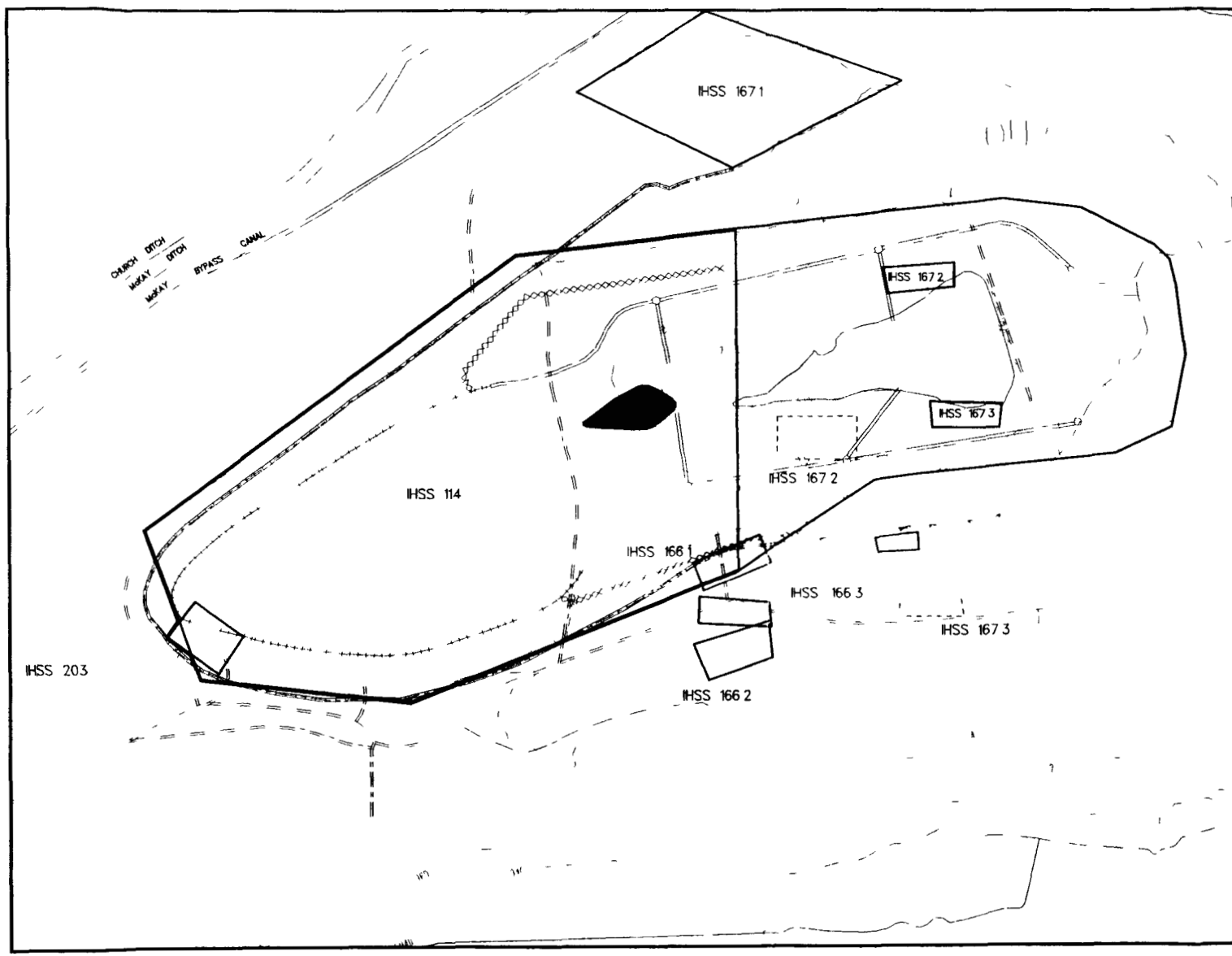
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Location Map of OU 7, Rocky Flats Site, and Vicinity

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-2

03/21/94 VICINITYMAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary
- OU 6 Historical IHSS Boundary
- East Landfill Pond
- Approximate Extent of West Landfill Pond
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System (perforated) (non-perforated)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

Locations of Individual Hazardous Substance Sites at OU 7

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-3

04/04/94 OU7HSS.MAP

NOTICE:

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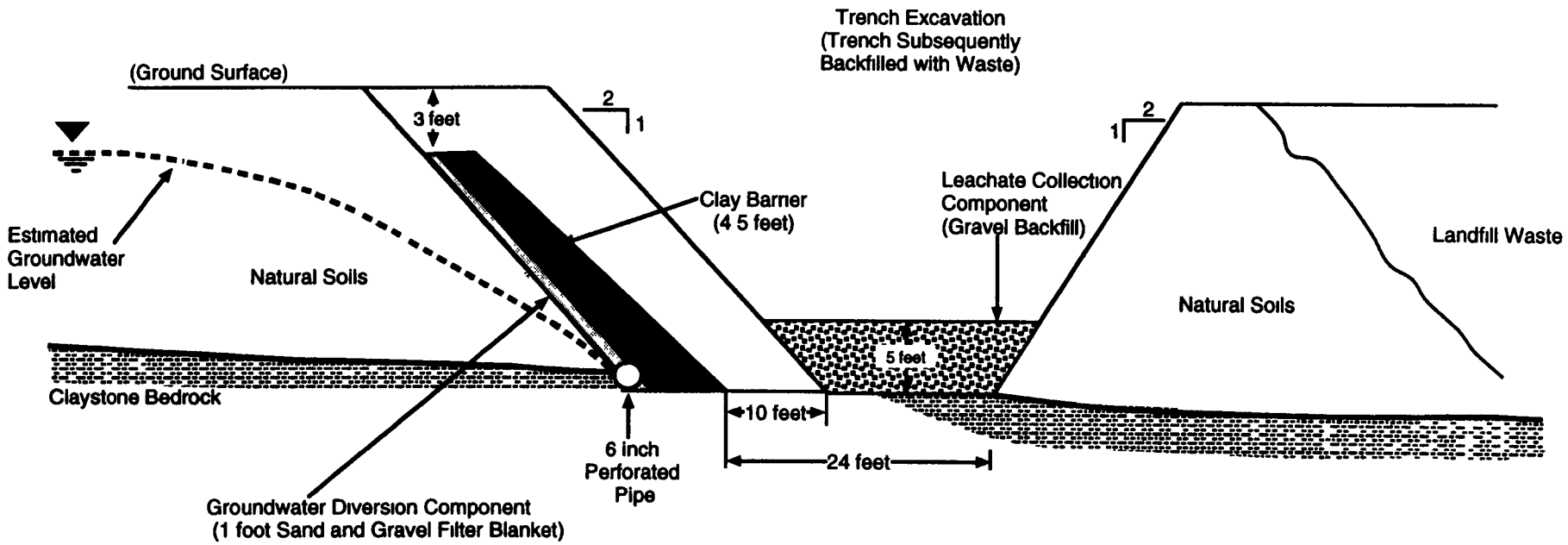
The Adminstrative Record Staff



Approximate Scale 1 inch = 20 feet

U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden Colorado

Design Section of Groundwater Intercept and Leachate Collection System

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 1 5

Source Rockwell International 1988b

M\ES\Leachate System mdw\7 26

EXPLANATION

Tritium Concentration Contour
(dashed where approximately located)
* Units in thousands of picocuries per liter

Tritium Sampling Location

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall Groundwater Intercept System
(perforated)
(non-perforated)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

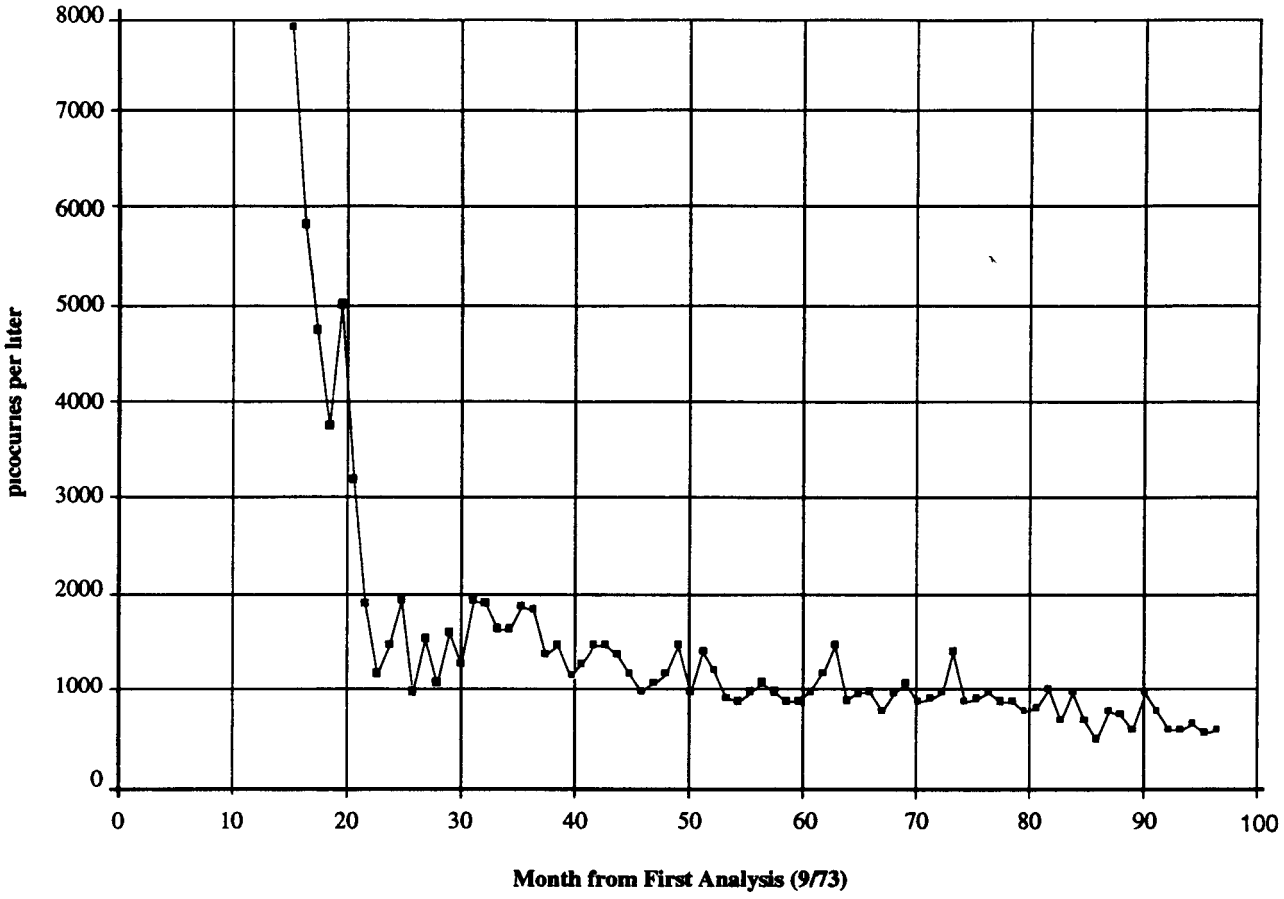
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Tritium in Landfill Leachate in 1973

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 1-6

03/21/94 TRITIUMMAP



U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Tritium in West Landfill Pond from 1973 to 1980

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 1-7

M\ES\Fig 1 5 Tritium Conc mdw\7 26

2. SITE CHARACTERIZATION

Section 2 fulfills the general objective of characterizing the physical and biological features of OU 7 and three of the four specific objectives of the Phase I RFI/RI site characterization as follows

- Characterize the flow regime within and around OU 7 to evaluate the effects of the groundwater intercept system and slurry walls on leachate–groundwater movement
- Evaluate infiltration of precipitation through the existing soil cover material
- Characterize surface water–groundwater interactions

The fourth specific objective, to determine representative site-specific background concentrations of analytes in groundwater and subsurface materials, is addressed in Section 4

Sections 2 1 through 2 7 describe surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology

2.1 Surface Features

OU 7 lies north of the industrial area on the western end of No Name Gulch OU 7 includes the Present Landfill (IHSS 114), the Inactive Hazardous Waste Storage Area (IHSS 203), and the East Landfill Pond and adjacent spray evaporation areas (IHSSs 167 2 and 167 3) In addition, a surface-water diversion system, a groundwater intercept system, and a leachate collection system lie within OU 7 (Figure 2-1) The physical setting and surface features for each of the IHSSs and other areas that constitute OU 7 are described in the following sections

2 1 1 Present Landfill (IHSS 114)

The Present Landfill (IHSS 114), is an operating landfill that covers an area of approximately 27 acres The actively operating area of the landfill is surrounded by a 3-foot-high, chain-link fence Access to the landfill is currently through the south gate, located in the center of the south edge of the landfill Two other gates have been used in the past, the west gate, east of IHSS 203, and the north gate, on the north side of the

landfill These gates remain locked except during the operating hours of the landfill when the south gate is open

A surface-water diversion ditch is located just outside the landfill fence and follows the fence perimeter on its north and south sides (Figure 2-1) The ditch was designed to divert surface runoff around the landfill 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 On the south side of the landfill, the ditch runs east above the East Landfill Pond and drops into the unnamed tributary to No Name Gulch below the East Landfill Pond` The ditch is 2- to 3-feet deep and 5-feet wide at the bottom and has a trapezoidal shape The slopes and floor of the ditch are composed of sparsely vegetated native soil material No waste disposal is known to have occurred outside of the surface-water diversion ditch

A gravel road, located outside of the fence and the surface-water diversion ditch, follows the perimeter of the landfill on its north, south, and west sides The road continues east, beyond the eastern limit of landfill operations, towards the East Landfill Pond The Property Utilization and Disposal (PU&D) yard lies southwest of the landfill along the south side of this road (Figure 2-1) The PU&D yard is surrounded by an eight-foot chain link fence, and access is controlled through locked gates This open storage area has been used by various groups at the Rocky Flats site for surplus storage since 1974 Currently the area is used by the carpentry, power, and trucking groups Historically, such items as surplus roofing tar and motor oil have been stored in the area but no documentation was found indicating any releases of hazardous materials to the environment (DOE 1992a) A power substation is located east of this open storage area and south of the landfill No documentation was found that detailed incidents of concern related to the power substation (DOE 1992a)

As discussed in Section 1 3 1 1, waste disposal procedures currently used at the landfill have not significantly changed since the landfill went into operation in 1968 (DOE 1991b) During the Phase I RFI/RI field investigation, active disposal operations took place in the western and central portions of the landfill Heavy equipment used to move waste and fill was stored within the landfill Temporary roads or access routes were routinely placed within the landfill for use by trucks carrying waste These temporary roads consisted of a 2- to 6-inch-thick, coarse gravel layer over clean fill

During the Phase I RFI/RI field investigation, a large volume of clean fill material was stockpiled in a number of 10- to 20-foot-tall mounds along the south and west margins of the landfill The stock piles of clean fill were used as the interim soil cover on waste material Excluding the areas of stockpiled clean fill, the ground surface of the landfill was irregular and hummocky during the fall and winter of 1992 Standing water collected in low areas and within small depressions during precipitation or snowmelt events Regrading of the landfill surface in the spring of 1993 eliminated the hummocky topography, and the ground surface slopes to the east at a 2 to 3 degree angle The landfill was reseeded in the fall of 1993

The location of the old landfill pond, also known as the West Landfill Pond or Pond #1, is no longer evident at the ground surface because of continuing eastward expansion of the landfill The current eastern extent of landfill operations is marked by a steep face that descends approximately 50 feet to the edge of the East Landfill Pond This face was advanced further eastward and regraded in late spring 1993 The face is now covered with clean fill and has approximately a 40 percent slope During the Phase I RFI/RI field investigation large pieces of asphalt were piled along the top of the east face of the landfill When the landfill was advanced eastward in spring 1993 the asphalt was moved east and down the slope, then covered with clean fill

In the northeast and southeast corners of the landfill old asbestos disposal areas are marked by several large warning signs Asbestos had been buried in several pits within these posted areas There is no surface expression of these disposal areas, and the ground surface appears undisturbed The areal extents of these disposal areas cannot be delineated by an inspection of surface features

Five gas vents are present within the operating landfill These vents are constructed of polyvinyl chloride (PVC) and project above the ground surface approximately 5 feet Each vent is protected from heavy equipment by four, 15-foot-high steel posts Numerous monitoring wells are also present within the landfill The construction and location of these wells are discussed in Appendix C

2 1 2 *Inactive Hazardous Waste Storage Area (IHSS 203)*

The Inactive Hazardous Waste Storage Area (IHSS 203) is located at the southwest corner of the landfill and covers less than one-half acre (Figure 2-1) This area was actively used between 1986 and 1987 for the storage of drummed liquid and solid

hazardous wastes (Rockwell International 1988b) The IHSS is unfenced and the boundaries, as shown on maps, are not marked by any distinctive surface features No visible evidence for past usage of this area remains except for sparse remnants of an asphalt-paved surface just east of the IHSS and some red gravel fill within the IHSS The ground surface is generally flat within IHSS 203 The IHSS is bounded along its western edge by the surface-water diversion ditch that runs adjacent to the IHSS 114 boundary (Figure 2-1)

A power line runs east-west just south of IHSS 203 At the southwest corner of the IHSS the power line joins a tall wooden pole (telephone pole) Power was available at this pole by a hook-up to the line during the Phase I RFI/RI field investigation A small wooden guard house was also present at this location There was no power available to this structure and the structure was removed in the spring of 1993

2 1 3 *East Landfill Pond and Spray Evaporation Areas (IHSSs 167 2 and 167 3)*

The East Landfill Pond covers an area of approximately two and one-half acres and fills the center of the valley downgradient from the operating landfill The pond receives landfill leachate and surface runoff from the landfill area and also collects groundwater flowing from the groundwater intercept system Pond water is retained by an engineered embankment on the pond's east side that rises approximately 45 feet above the valley floor The embankment slopes on the west side, facing the pond, are covered with well-graded, angular to subrounded, bouldery riprap The embankment slopes on the east side are covered with herbaceous vegetation A gravel road follows along the top of the pond embankment and crosses the valley occupied by the pond Gravel-surfaced pullouts are present west of the road on both the south and north sides of the pond embankment The gravel extends down into the water and is used as a boat ramp A gravel road descends below the pond embankment on the north side of the pond and provides vehicle access to groundwater monitoring wells and surface-water discharge points in the valley bottom The gravel pullouts and monitor well access road are not shown in Figure 2-1 but do appear in a recent photograph of the East Landfill Pond (Figure 2-2)

An emergency spillway is located on the south side of the pond embankment The spillway is a trapezoidal, earth-cut spillway that is 6-feet deep and 10-feet wide at the bottom A 6-foot by 8-foot concrete box culvert carries spillway discharge under the access and into the drainage below the embankment There is a weir on the upstream

side of the box culvert Water from the East Landfill Pond can spill over into this structure when the pond surface elevation exceeds 5921 feet The pond surface elevation was measured at 5919 5 feet above mean sea level in June 1993 The pond embankment has an elevation of 5926 3 feet

The outlet works for the pond consist of a 10-inch iron pipe, equipped with an upstream butterfly valve There is also a gate valve and concrete stilling basin located at the downstream toe of the landfill dam There is a large area of riprap downstream of the stilling basin The outlet works are currently non-operational because the East Landfill Pond is not a permitted discharge point (EG&G 1993b)

To prevent the pond from overfilling and spilling into the drainage, water is periodically sprayed onto the ground surface adjacent to the landfill to enhance evaporation IHSSs 167 2 and 167 3 were used for spray evaporation of water from the pond and are located along its north and south banks Recent spray evaporation from the pond continues in these areas as shown in Figure 2-2 A generator and pump are present on the south side of the pond adjacent to the road that follows the top of the pond embankment The pump lifts water from the pond to plastic (PVC) pipes that lie on the south slope of the pond The pipes extend west from the pump approximately 50 yards Remnants of an earlier spray or water diversion system are present on the north and south slopes along the pond Six-inch diameter, solid-walled pipes are present on the ground surface in these areas Slotted metal pipe is also present on the north side of the pond Excess pond water has also been pumped from the pond to holding ponds in the Walnut Creek drainage Metal piping leading south from the East Landfill Pond toward the A-series ponds is present on the south slope of the pond and can be seen in Figure 2-2

The ground on the north and south sides of the East Landfill Pond is sloped and covered with native herbaceous and shrubby vegetation The slopes on either side of the pond are dissected by a generally north-south trending fence that marks the eastern extent of the fence line surrounding the landfill The 3-foot-tall chain-link fence extends to the shoreline of the pond on both sides On the east side of this fence the slopes appear undisturbed by landfill and construction activities On the north slope west of the fence, the ground surface was hummocky and showed evidence of recent slumping Intermittent seepage may occur in an area on the north slope of the pond where plants indicative of wet conditions are present (cattails and small cottonwood

trees) No seepage was observed in this area during the Phase I RFI/RI field investigation (November 1992 through April 1993) The slopes west of the fence line were recently regraded and reseeded A temporary road constructed of coarse gravel leads from the southeast corner of the landfill to the monitoring wells and leachate seep at the western edge of the pond

2.2 Meteorology and Climate

The area surrounding the Rocky Flats site has a continental, semiarid climate characteristic of the Southern Rocky Mountain region Temperatures at the site exhibit large seasonal variations and, occasionally, dramatic short-term temperature changes Summer high temperatures are typically in the mid-80°F range during the days with lows below 60°F at night During the winter months temperatures are relatively mild, ranging from 40 to 45°F during the day and 15 to 25°F at night Periods of extremely hot or cold weather are usually brief and do not occur every year Temperature extremes recorded at the plant range from 102°F on July 12, 1971, to -26°F on January 12, 1963 (DOE 1980) Figure 2-3 summarizes average, monthly temperature ranges

Mean annual precipitation at the Rocky Flats site, including rainfall and snowmelt, is nearly 16 inches Approximately 40 percent of the annual precipitation falls during the months of April, May, and June Summer thunderstorms (July and August) account for an additional 30 percent of the annual precipitation Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively Snowfall averages 85 inches per year, occurring generally from October through May Heaviest snowfall occurs in March Snowfall provides approximately half of the total moisture for the year The average relative humidity is 46 percent (DOE 1980) Figure 2-3 summarizes average, monthly precipitation totals

The Rocky Flats site is noted for its strong, gusty winds, which frequently occur with thunderstorms and passage of weather fronts The windstorm season extends from late November into April, and the height of the season occurs in January The highest wind speeds occur during this season as westerly windstorms known as chinooks Wind speeds typically exceed 75 miles per hour, and gusts may exceed 100 miles per hour However, northwesterly wind directions and wind speeds under 15 miles per hour are the predominant wind conditions at the Rocky Flats site Moderately strong northerly or southerly winds are common in winter and summer, respectively, and easterly winds ("upslopes") may be associated with snowfall The steep-sided canyons along the

Front Range tend to channel the airflow during both upslope and downslope conditions (DOE 1980)

Meteorology at the site is strongly influenced by the diurnal cycle of mountain and valley breezes Two dominant flow patterns exist, one during daytime conditions and one at night During daytime hours, as the earth heats, air tends to flow toward the higher elevations (upslope) The general airflow pattern during upslope conditions for the Denver area is typically north to south, with flow moving up the South Platte River Valley and then entering the canyons into the Front Range After sunset, the air against the mountain sides is cooled and begins to flow toward the lower elevations (downslope) During downslope conditions, air flows down the canyons of the Front Range onto the plains This flow converges with the South Platte River Valley flow moving toward the north-northeast (Hodgin 1983, Hodgin 1984, and DOE 1986) A summary of 1992 wind direction and speed is illustrated in Figure 2-4 in the form of wind-rose diagrams The diurnal pattern of wind directions is evident on these diagrams

2 3 Soils

The surface soils at OU 7 are predominantly deep, well-drained loams, clay loams, and very cobbly sandy loams with slow permeability Table 2-1 presents a brief description of soil types Figure 2-5 shows the distribution of soil types in the vicinity of OU 7

Soils around the East Landfill Pond consist of clay loams from the Denver-Kutch-Midway series These soils are medium to very dark brown, fine, montmorillonitic, mesic Torrertic Argiustolls that formed in calcareous, clayey material derived from undifferentiated Arapahoe and Laramie Formation claystones Soils on the pediment surrounding the landfill are from the Flatiron series These soils are grayish brown to reddish or yellowish brown, clayey, montmorillonitic, mesic Aridic Paleustolls that formed in non-calcareous, cobbly, stony, gravely, and loamy material of the Rocky Flats Alluvium Soils on the edge of the pediment are from the Nederland series These soils are medium to dark brown, loamy, mixed, mesic Aridic Argiustolls that formed in cobbly, gravely, and loamy alluvium derived from mixed sources (Rocky Flats Alluvium and undifferentiated Arapahoe and Laramie Formation claystones) Soils in the valley bottoms are from the Haverson series These soils are fine, loamy, mixed, mesic Ustic Torrifluvents formed in stratified, loamy alluvium of mixed origin adjacent to intermittent streams (Price and Amen 1980)

Interim soil cover material currently stockpiled and used at the landfill was obtained from the Rocky Flats Alluvium at a location outside OU 7 Historical analytical data characterizing the daily soil cover and fill material underlying the interim soil cover were presented in the OU 7 work plan (DOE 1991b) These data are limited to borehole samples collected during drilling of groundwater monitoring wells B106089, B206189, and B206389 Interim soil cover material was described during surface-soil sampling activities at the landfill These soils are reddish brown to dark brown, clayey sands and poorly graded, clayey gravels The gravel component was 30 to 40 percent in the eastern (older) part of the landfill and greater than 50 percent in the active landfill area in March 1993 The landfill has since been regraded, and a new layer of soil cover material was placed on top Because the soil cover material was recently placed on the landfill surface, vertical stratification into soil horizons has not yet taken place Analytical data characterizing the interim soil cover material and soils around the East Landfill Pond are discussed in Section 4 3 and presented in Appendix N

During the Phase I RFI/RI soil sampling program, general descriptions of soil texture and color were recorded at each sample location Within the 0- to 2-inch soil horizon at IHSS 203, three general soil types were identified A dark brown, very gravely loam covered the northern half of the sample grid The south-central portion of the grid was composed of non-native red gravel fill, and two sample locations at the far western corner of the grid consisted of a very gravely, sandy clay loam Within the 2- to 10-inch soil horizon the majority of the grid consisted of a dark brown, very gravely loam Two sample locations in the northwestern portion of the grid consisted of a yellow-brown clay Two sample locations in the southeastern portion of the grid consisted of non-native red gravel fill

Soil in the 0- to 2-inch horizon within the spray evaporation areas on the northern and southern edges of the East Landfill Pond and the sample area east of the dam generally consisted of loam and clay loam with small isolated areas of gravely loam Soils on the western edge and the northwestern corner of the sample grid contained more gravel and sand Soil on the dam itself consisted of a gravely loam At a soil depth of 2 to 10 inches the majority of the East Landfill Pond sample area consisted of clay and clay loam A small area in the north-central portion of the grid and the dam itself consisted of gravely clay

2 4 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 1988c, DOE 1991b), existing geologic characterization reports (EG&G 1991d, EG&G 1992a), U S Geological Survey publications (Spencer 1961, Van Horn 1972), Colorado School of Mines reports (Weimer 1976), and the borehole drilling, monitoring well installation, and cone penetration test (CPT) tasks of the Phase I RFI/RI field investigation A description of the general geologic framework and specific descriptions of surficial and bedrock geologic units are presented in the following sections Geologic interpretations of CPT profiles are included in Appendix D and geologic borehole logs are presented in Appendix E

2 4 1 General Geologic Framework

The Rocky Flats site is located on a broad, eastward sloping plain just east of the Colorado Front Range The surface cover is composed of a series of coalescing alluvial fans that were developed along the Front Range during the Pleistocene The alluvial fans extend eastward approximately 5 miles from their origin near the mouth of Coal Creek Canyon The industrial area and the Present Landfill are located near the eastern extent of the alluvial-fan deposits The alluvial fans were deposited on a broad, gently sloping erosional surface, or pediment

The pediment at the Rocky Flats site is underlain by more than 10,000 feet of gently dipping (less than 2 degrees) Pennsylvanian to Upper Cretaceous sedimentary rocks in the Denver Basin West of the site these strata are abruptly upturned and form hogback ridges parallel to the Front Range uplift The slope of the pediment at the Rocky Flats site (approximately 6 degrees) is steeper than the dip of the underlying sedimentary rocks (approximately 1 to 2 degrees) As a result, shallow Upper Cretaceous strata pinch out to the east against the erosion surface rather than plunging down into the subsurface toward the center of the Denver Basin

Dissection of the gravel-capped pediment has occurred by headward erosion and planation along several eastward-flowing streams and their tributaries, including Rock Creek, Walnut Creek, and Woman Creek Fluvial processes have formed moderately steep hill slopes 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 6000 feet Waste material is confined laterally by the surface-water diversion ditch and by the bedrock slopes of the valley Thickness of the artificial fill, which includes waste and interim soil cover material, ranges from approximately 5 to 45 feet Artificial fill is thickest near the centerline of the valley and thinnest around the perimeter of the landfill, inside the surface-water diversion ditch

Figure 2-6 presents a generalized stratigraphic section for the Rocky Flats site that shows the vertical sequence of surficial deposits and bedrock Surficial and bedrock geologic units that influence groundwater flow include the Rocky Flats Alluvium and the underlying Arapahoe and Laramie Formations Also important is the artificial fill material of the landfill, which is not shown on the figure The Fox Hills Sandstone occurs at a depth of approximately 700 to 800 feet, which is too deep to be affected by the landfill As such, it is not described

Figure 2-7 shows the lateral distribution of surficial geologic material at OU 7 Eight cross-sections were constructed to illustrate the lateral and vertical relationships of surficial and bedrock units The base of waste material, alluvium–weathered bedrock contact, weathered bedrock–unweathered bedrock contact, and potentiometric surfaces shown in the cross-sections were drawn using borehole, monitoring well, and CPT data and extrapolated in between data points Tables 2-2 and 2-3 present the depths and elevations of the alluvium–weathered bedrock contact and weathered bedrock–unweathered bedrock contact from CPT profiles and boreholes and wells, respectively The location and dimensions of the groundwater intercept system were obtained from as-built drawings Figure 2-8 is an index map that shows where the eight cross-section lines are located Figures 2-9 through 2-16 present geologic cross sections A-A' through H-H' Horizontal and vertical scales of the cross sections are 1 inch equals 50 feet so there is no vertical exaggeration Cross-sections A-A', B-B', C-C', D-D', and H-H' show the shape of the buried valley and the distribution of surficial materials along north-south profiles from the western end of the landfill to the slope below the East Landfill Pond embankment Cross sections E-E', F-F', and G-G' trend west-east along

the centerline of the valley from the upgradient wells through the landfill and the East Landfill Pond to the downgradient wells below the embankment

2 4 2 *Surficial Geology*

Surficial material consists of Quaternary alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, alluvial deposits of the valley-fill alluvium, and artificial fill (Figure 2-7) The Rocky Flats Alluvium caps the divides north and south of No Name Gulch Colluvium covers the hillsides down to the drainage or to the East Landfill Pond Valley-fill alluvium is present along the channel of No Name Gulch downstream of the East Landfill Pond Artificial fill and disturbed surficial material is present within the boundaries of the landfill, at IHSS 203, and along the surface-water diversion ditch, Upper Church Ditch, and McKay Ditch All surficial deposits are part of the upper hydrostratigraphic unit at the Rocky Flats site, which is discussed in more detail in Section 2 5 1

2 4 2 1 Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at Rocky Flats (Scott 1965) The alluvium ranges from 0 to 100 feet in thickness It is thickest west of the Rocky Flats site near the apex of the fans and thinnest just east of the Rocky Flats site near the depositional limit of the fans (EG&G 1992a) The Rocky Flats Alluvium consists of yellowish brown to reddish brown, poorly sorted, coarse bouldery gravel in a silt and clay matrix, with lenses of clay, silt, and sand, and varying amounts of caliche Generally, the gravels are coarsest grained west of Rocky Flats and become finer grained toward the east Pebbles, cobbles, and boulders are composed primarily of quartzite, but include lesser amounts of schist, gneiss, granite, pegmatite, sandstone, and siltstone (EG&G 1992a)

Thirteen wells (1086, 5887, 6087, 6687, 7087, 7187, 7287, 76792, 76992, 77392, 70093, 70393, and 70693) located around the perimeter of the landfill are completed in the Rocky Flats Alluvium (Figure 2-7 and Table 2-4) Thickness of the alluvium is 25 to 30 feet in wells on the north, west, and south sides of the landfill west of the south gate (figures 2-9, 2-10, 2-11, 2-12, and 2-13, Cross sections A-A', B-B', C-C', D-D', and E-E'), and 10 to 15 feet thick on the divides north and south of the East Landfill Pond east of the south gate (Figure 2-12, Cross section D-D') The Rocky Flats Alluvium is composed of unconsolidated, yellowish brown to grayish orange, angular

to subrounded, poorly sorted, coarse gravel in a clayey sand matrix, with interbeds or lenses of sand, silt, and clay Pebbles and cobbles are composed of quartzite, granite, and gneiss Maximum pebble size ranges from 1 to 3 inches in diameter Caliche was described in drill cores from the ground surface down to the alluvium–bedrock contact at approximately 8 feet near the eastern limit of the Rocky Flats Alluvium on the divides north and south of the East Landfill Pond (wells 7187 and 7287) The caliche occurs in the matrix of gravel-rich zones and in pockets in clay-rich zones These zones may be discharge points for alluvial groundwater along the hillside above the East Landfill Pond

2 4 2 2 Colluvium

Quaternary colluvium covers the valley slopes between the pediment on which the Rocky Flats Alluvium is deposited and the No Name Gulch drainage or the East Landfill Pond (Figure 2-7) Colluvial materials have been deposited by slope wash and downward creep of alluvial material and bedrock Three wells (0586, 0686, and 0786) are completed in the colluvial material, and several wells (0886, B206789, B206889, and B207289) were drilled through colluvium into the underlying bedrock The colluvium is 1 to 5 feet thick on the slopes around the East Landfill Pond and below the dam (Figure 2-16, Cross-section H H') The colluvium consists of unconsolidated, moderate to dark brown, structureless clay with some sand and a trace gravel Soil development has occurred and roots are present down to depths of 3 feet

2 4 2 3 Valley-Fill Alluvium

Quaternary valley-fill alluvium has been deposited in the No Name Gulch drainage downstream of the East Landfill Pond (Figure 2-7) The alluvium is derived from reworked alluvial material and bedrock Two wells (4087 and 4287) are completed in valley-fill alluvium, and several wells (4187, B206989, B207089, and B207189) were drilled through valley-fill alluvium into the underlying bedrock (Figure 2-15, Cross section G-G') The alluvium is 3- to 8-feet thick in the OU 7 area and becomes thicker downstream to the east (12 feet in well 0486) The alluvium consists of unconsolidated, dusky brown, laminated to structureless clay with lenses of gravel Gravels have a sandy- to clayey-silt matrix that is often iron stained

2 4 2 4 Artificial Fill

Three types of artificial fill are present in the vicinity of the landfill excavated gravels, construction materials, and landfill waste The first type of artificial fill was derived from excavation of Upper Church Ditch and McKay Ditch and consists of stockpiles of gravel northwest of the landfill (Figure 2-7) This material is presumably disturbed Rocky Flats Alluvium

The second type of artificial fill consists of materials used to construct the groundwater intercept system, the leachate collection system, and the embankment of the East Landfill Pond Most of this material is below the ground surface and is not shown on the surficial geology map (Figure 2-7) Clay, coarse sand, and gravel were encountered during drilling of upgradient well B106089 (DOE 1991b) Disturbed claystone, sand, and gravel were encountered during drilling of well 71193 (Figure 2-10, Cross section B-B') The occurrence of this material is inconsistent with bedding of native materials and has been interpreted as construction material for the groundwater intercept system Material used to construct the East Landfill Pond embankment was encountered in test holes TH047292 and TH047492 (Figure 2-15, Cross section G-G') The embankment consists of a clay core that is 40-feet thick surrounded by a clayey sand to gravel shell Coarse, bouldery riprap covers the embankment slopes on the west side

The third type of artificial fill consists of waste and daily soil cover material at the landfill The fill is described in Phase I drill cores as a mixture of clay, sand, and gravel containing asphalt, concrete, insulated wire, wood, paper, plastic, rubber, metal, construction ribbon, surgical gloves, saranex suits, and other materials associated with landfilling activities

Sixteen wells (6187, 6287, 6487, 6587, 6887, B106089, 71193, 71493, 71693, 71893 72093, 72293, 72393, 72493, 00393, and 00493) located within the landfill are completed in the artificial fill Five other wells (5987, 6387, 6787, B206189, and B206389) were originally completed in artificial fill but have since been replaced or abandoned Waste material interlayered with daily soil cover was encountered in 32 CPTs (CPT00293 through CPT01593, CPT01993, CPT02093, and CPT02293 through CPT03793) Thickness of the artificial fill ranges from approximately 4 feet at well 6287 to 35 feet at well 72093 and is up to 45 feet at CPT01393 near the centerline of the valley (Figure 2-14, Cross section F-F') In some cases waste material is encountered throughout the borehole or CPT profile, and in other cases there is some

clay, sand, and gravel fill material beneath the waste The base of the waste material is delineated on each cross section

2 4 3 Bedrock Geology

Bedrock unconformably underlies the surficial deposits and consists of claystones, siltstones, and sandstones of the Upper Cretaceous Arapahoe and Laramie Formations

2 4 3 1 Arapahoe Formation

The Upper Cretaceous Arapahoe Formation, as defined in the Phase I geologic characterization report (EG&G 1991d), is approximately 150-feet thick beneath the middle portion of the Rocky Flats site It contains at least five separate, discontinuous, but mappable sandstone units, designed as the No 1 through No 5 sandstones More recent work, based on field mapping (EG&G 1992a), indicates that the Arapahoe Formation is less than 50-feet thick in the middle portion of the site The basal Arapahoe sandstone, as defined in the Phase II geologic characterization surface geologic mapping report (EG&G 1992a), is stratigraphically equivalent to the uppermost, or No 1, sandstone of the Phase I geologic characterization report Attempts to resolve this controversy are in progress Regardless of the thickness described for the Arapahoe Formation at the Rocky Flats site, the No 1 sandstone is the uppermost sandstone unit of significant lateral extent, and it is of concern as a potential migration pathway

The No 1 sandstone is a yellowish-gray to dark yellowish-orange, fine-to medium-grained, locally conglomeratic, subangular to subrounded, moderately to poorly sorted, planar-laminated to trough cross-bedded sandstone, with an abundance of grains of well-rounded quartz sand Conglomeratic sandstone lenses at the base of the unit contain pebbles of chert, ironstone, and rock fragments (EG&G 1992a, Van Horn 1972, and Weimer 1976)

2 4 3 2 Laramie Formation

The Upper Cretaceous Laramie Formation unconformably underlies the Arapahoe Formation and is approximately 600 to 800 feet thick The Laramie Formation is informally subdivided into two members, the upper member is generally much finer grained than the lower member

The upper member of the Laramie Formation is approximately 300 to 500 feet thick and consists primarily of olive-gray and yellowish-orange claystones Four sandstone units (designed 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 in the Arapahoe Formation, as defined in the Phase I geologic characterization report or in the Laramie Formation, as defined in the Phase II geologic characterization report and shown in this report (Figure 2-6) Deep boreholes, drilled during the 1991–1992 sitewide geologic-characterization program and targeting these sandstones, encountered siltstone more often than sandstone Where present the sandstones are olive gray, very fine-grained, subangular, well-sorted, platy-laminated to ripple-laminated, locally calcareous, silty, and clayey Because they lie within claystones and they are not in hydraulic connection with either the No 1 sandstone or the surficial deposits, the No 2 through No 5 sandstones are probably not significant migration pathways for potential contaminants to groundwater

The lower member of the Laramie Formation is 300-feet thick and is composed of sandstones, claystones, and coal beds The sandstones are yellowish gray, very fine- to medium-grained, subangular to subrounded, moderately sorted, thin- to thick-bedded, ripple-laminated to trough cross-bedded and contain abundant plant remains These sandstone beds are more laterally extensive than sandstone beds in the upper Laramie Formation Claystones present within the lower Laramie Formation are generally kaolinitic

2 4 3 3 Undifferentiated Arapahoe and Laramie Formations

In general, the base of the Arapahoe Formation is marked by the presence of medium-grained to conglomeratic sandstones composed of well-rounded, frosted quartz sand grains with pebbles of chert, rock fragments, and ironstone The lowermost 20 feet of the Arapahoe Formation is shown underlying the Rocky Flats Alluvium on the divides north and south of the unnamed tributary to No Name Gulch in the Phase II geologic characterization report (EG&G 1992a) However, sandstones exhibiting the distinctive characteristics of the basal Arapahoe Formation or No 1 sandstone 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

Figure 2-17 shows the topography of the bedrock surface, which has been scoured and shaped by various alluvial and fluvial processes Features most apparent on the map are the west-trending channel of No Name Gulch, which extends from the present valley below the East Landfill Pond embankment under the pond and landfill to the upgradient wells near the west edge of the map area, and the two smaller northwest- and southwest-trending tributaries Bedrock highs are evident between the main channel and the smaller tributaries Weathering of bedrock is dependent on factors such as the abundance of fractures, presence of root zones, elevation relative to the water table, and proximity to drainages and appears most extensively along the drainages

Weathering is evident in drill cores by color mottling and by the abundance of iron-oxide staining Weathered and unweathered bedrock are discussed separately because weathered bedrock is considered part of the upper hydrostratigraphic unit (UHSU) at the Rocky Flats site, along with surficial materials Unweathered bedrock comprises the lower hydrostratigraphic unit (LHSU) The upper and lower hydrostratigraphic units are discussed in more detail in Section 2 5 1

Weathered Bedrock

Ten wells (B206289, B206589, B206689, B206789, B206889, B206989, B207089, B207289, 70193, and 70493) at OU 7 are completed in weathered bedrock Thickness of weathered bedrock ranges from 0 feet at well 70893, which is located on the pediment along the southwest edge of the landfill, to 57 feet at CPT00793, which is located near the center of the channel beneath the landfill Weathered bedrock is thickest in the valley bottom where surface water intermittently flowed down No Name Gulch before it was diverted around the landfill The lateral and vertical distribution of weathered bedrock is shown in the geologic cross sections (figures 2-9 through 2-16)

The weathered bedrock is composed primarily of gray to yellowish brown, mottled, structureless claystones and silty claystones containing a trace of carbonaceous material and occasional thin interbeds of siltstone and, less frequently, fine-grained sandstone Vertical to subvertical fractures are occasionally observed in drill cores Iron-oxide staining is common In general, sandstone and siltstone interbeds encountered are less than 10-feet thick Sandstones are composed of gray to yellowish brown, very fine- to fine-grained, subangular to subrounded, well sorted, friable, quartzose sand

In the landfill closure plan (Rockwell International 1988a), subcropping sandstones directly underlying the unconsolidated surficial material were described at well locations 6487, 6587, 7087, and 7287 on the south side of the landfill and the East Landfill Pond Plate 4-3 of the landfill closure plan shows the estimated areal extent of subcropping sandstones based on the thickness in wells 7087 and 7287 and a regional dip of 7 degrees east A 7-degree dip was also used in proposing that the uppermost sandstone in well 4187 would subcrop underneath the East Landfill Pond In the OU 7 Phase I work plan (DOE 1991b), subcropping sandstones were described at locations mentioned above and at well B206489 Shallow sandstones within 15 feet of the alluvial–bedrock contact were described in wells B206589 and B206789 Recent sitewide investigations were cited to explain the change in interpretation of regional dip from 7 degrees to 2 degrees east (EG&G 1992a)

Since the landfill closure plan and OU 7 Phase I work plan were completed, drill cores from 1986, 1987, and 1989 wells were relogged using grain-size analysis procedures in Geotechnical SOP GT 1 (EG&G 1992c) as part of the Phase I geologic characterization program (EG&G 1991d) Units that were originally described as sandstones are now described as siltstones and silty claystones Because the original borehole logs were used for the landfill closure plan and the OU 7 Phase I work plan and the revised borehole logs were used for this report, the presence of interpreted subcropping sandstones has changed

Based on the revised borehole logs, fine-grained silty sandstones subcrop beneath the alluvium only at well location B207089, which is downgradient of the East Landfill Pond The subcropping sandstone at well B207089 is laminated, pale yellowish brown to dark yellowish orange, very fine- to fine-grained, moderately to well sorted, silty to clayey sandstone, interbedded with silty claystone and is less than 4-feet thick This sandstone pinches out approximately 500 feet downstream and is not present at well 4287 Shallow sandstones (present within 15 feet of the contact between alluvium and bedrock) were encountered in wells 6487 (24 5- to at least 28 0-feet deep — total depth not encountered), located within the landfill on the south side, and B206789 (8 0 to 8 3 feet), located on the southwest shore of the pond Based on a 2-degree regional dip, these shallow sandstones will not subcrop in the OU 7 area

Unweathered Bedrock

Six wells (0886, 0986, 4187, 70293, 70593, and 70893) at OU 7 are completed in unweathered bedrock The lateral and vertical distribution of unweathered bedrock is shown in the geologic cross sections (figures 2-9 through 2-16)

Unweathered bedrock is composed primarily of dark to very dark gray, laminated to structureless claystones and silty claystones with scattered fragments and stringers of carbonaceous material Claystones contain occasional thin interbeds of siltstone and sandstone Sandstones are composed of laminated to cross-laminated, gray to olive gray, very fine- to fine-grained, subangular to subrounded, well-sorted quartzose sands with a trace of mafic minerals and disseminated sulfides Porosity ranges from 5 to 20 percent and averages approximately 10 percent Calcite occasionally occurs as a pore-filling cement in thin sandstone beds

2 4 4 Structural Features

The folded structure of bedrock strata immediately west of the Rocky Flats site results in steeply eastward-dipping exposures of the Laramie Formation and underlying units These units receive recharge from precipitation along the exposed hogbacks northwest and southwest of the site Other large-scale features that may significantly affect the direction and rate of groundwater flow are currently under investigation

Small-scale structural features, such as joints and fractures, are present in bedrock units Surfaces of joints and fractures are commonly coated with secondary oxide and hydroxide minerals in the weathered portion of bedrock units Slickensides are also present on some fracture surfaces The presence of such features increases secondary porosity and permeability and may facilitate groundwater transport through bedrock units by providing preferential flow paths in low-permeability claystones

2 5 Hydrogeology

The hydrogeology 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 1991b), sitewide groundwater monitoring, assessment, and protection plans and reports (EG&G 1990a, EG&G 1990b, EG&G 1991e, EG&G 1993c, DOE 1992b, and DOE 1993a), and water-level

measurement and hydraulic conductivity test activities of the Phase I RFI/RI field investigation

Site characterization of the landfill began in 1986 Two well pairs, each consisting of an alluvial and a bedrock well, were installed to characterize the hydrogeology in the vicinity of the landfill (Rockwell International 1988a) One well pair was installed upgradient (0986 and 1086) and the other downgradient (0786 and 0886) of the landfill

In 1987, 17 additional monitoring wells, 16 alluvial wells, and 1 bedrock well were installed to characterize the site and determine the effectiveness of the groundwater intercept system Well 5887 was installed upgradient immediately west of the landfill Eight wells (5987, 6087, 6187, 6287, 6387, 6487, 6587, and 6687) were installed across the groundwater intercept system on the west, north, and south sides Five wells (6787, 6887, 7087, 7187, and 7287) were installed to evaluate the north and south slurry walls Three wells (4087, 4187, and 4287), two alluvial and one bedrock, were installed downgradient of the East Landfill Pond embankment to monitor groundwater leaving the landfill Well 4287 is located downstream of well 4087, just east of the OU 7 map coverage

In 1989, 13 monitoring wells were installed Well B106089 replaced well 5987, which was drilled into the clay seal of the groundwater intercept system Six wells (B206189, B206289, B206589, B206689, B206789, and B207289) were drilled to locate and monitor potential subcropping sandstones around the East Landfill Pond Two wells (B206389 and B206489) were installed to evaluate the effectiveness of the slurry walls Two wells (B206889 and B206989) were installed to monitor groundwater in the vicinity of the discharge points for the groundwater intercept system, and two wells (B207089 and B207189) were installed to monitor bedrock sandstones encountered in wells 0886 and 4187

In 1992 and 1993, 11 boreholes were drilled and 16 monitoring wells were installed as part of the Phase I RFI/RI field investigation for OU 7 (Appendix C) Thirty-six CPTs were also performed Site characterization was performed using data from 1986 through 1993 wells and boreholes

Descriptions of the groundwater flow system, drawdown recovery test-data analyses and results, groundwater flow directions and velocities, and the effectiveness of landfill structures are presented in the following sections Descriptions of Phase I RFI/RI field activities including monitoring well installation, water-level measuring, well development, and drawdown recovery tests are presented in Appendix C Water-level data are presented in Appendix G Drawdown recovery test data are presented in Appendix H Water balance data and calculations are presented in Appendix I

2 5 1 Groundwater Flow System

The UHSU, which corresponds to the uppermost aquifer of the groundwater assessment plan (DOE 1993a), is unconfined and consists of saturated, unconsolidated surficial materials and weathered bedrock As discussed in Sections 2 4 2 and 2 4 3, surficial materials include the Rocky Flats Alluvium, colluvium, valley-fill alluvium, and artificial fill Weathered bedrock is composed of undifferentiated Arapahoe and Laramie Formation sandstones and claystones

Sources of groundwater recharge to the UHSU include infiltration of precipitation, snowmelt, storm runoff, and seepage from ditches, drainages, and the East Landfill Pond Discharge occurs through evaporation, evapotranspiration, and seepage where the water table intersects the ground surface or surface-water features such as streams, ditches, and ponds 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, but is diverted around the landfill by way of the groundwater intercept system and discharged to the East Landfill Pond In the incised stream valley, groundwater flows toward the drainage or the East Landfill Pond, following the topography Groundwater in No Name Gulch flows to the east in the valley fill materials and intermittently discharges as subsurface flow across the eastern boundary of the Rocky Flats site

The LHSU is generally confined and consists primarily of unweathered bedrock claystone with isolated sandstone units Each sandstone bed in the LHSU could be considered a separate hydrostratigraphic unit

Sources of groundwater recharge to the LHSU include infiltration of precipitation in outcrop areas, leakage from alluvial gravels of the UHSU in subcrop areas west of the landfill, and possibly seepage from weathered bedrock of the UHSU Discharge may occur where sandstone units intersect incised stream valleys Groundwater in the LHSU generally flows to the east, from recharge areas west of OU 7 toward discharge areas along incised stream valleys

2 5 2 *Drawdown Recovery Test Data Analysis and Results*

Drawdown recovery test data were analyzed with AQTESOLV software (Geraghty and Miller 1991) using the Bouwer and Rice (1976) and Bouwer (1989) solution method for unconfined aquifers and the Cooper et al (1967) solution method for confined aquifers Well 70593, which is completed in a confined aquifer, was analyzed using both methods to compare and verify the results Hydraulic conductivity estimates for well 70593 are within an order of magnitude for both methods Hydraulic conductivities were calculated for surficial materials of the UHSU and for several sandstone and siltstone beds of the LHSU Time-drawdown plots for each test, with best-fit lines used to estimate hydraulic conductivity, are presented in Appendix H Appendix H also presents tables that compare parameter terminology for the Bouwer and Rice and Cooper et al methods (Table H-1), list input parameters for each test (Table H-2), and list test-data file names (Table H-3) The test-data files are presented in digital format

2 5 2 1 The Bouwer and Rice Method

The Bouwer and Rice method was developed specifically for the analysis of drawdown recovery tests and provides order of magnitude estimates of hydraulic conductivity (Bouwer and Rice 1976, Bouwer 1989) For the purpose of calculating hydraulic conductivity, the AQTESOLV program allows the user to choose among two curve matching techniques (1) automated curve matching generated by iterative nonlinear least-squares numerical methods and (2) visual curve matching The visual curve matching technique was the preferred method of analysis because it allows the user to neglect the data points representing pore drainage from within the filter pack (initial steep curve on the time-drawdown plot) (Bouwer 1989) Data points representing radial flow through void spaces in the landfill were also neglected (initial steep curve on the time-drawdown plot) Type curves for the Bouwer and Rice method are

presented in Appendix H (Figure H-1) The Bouwer and Rice equation, which was developed from the Thiem equation to solve for hydraulic conductivity (K), is as follows

$$K = \frac{r_c^2 \ell n (R_e / r_w)}{2 L_e} \frac{1}{t} \ell n \ (y_0 / y_t)$$

where

K = hydraulic conductivity [L/T]

r_c = radius of casing or riser pipe where the head is rising (or falling) [L]

R_e = effective radial distance over which the head is dissipated [L]

r_w = horizontal distance to the undisturbed aquifer (borehole radius) [L]

L_e = length of open section (screen) [L]

t = time

y_0 = head at time t_0 (start of test) [L]

y_t = head at time t ($t>t_0$) [L]

[ ] = units in which terms are expressed, L = length, T = time

The parameters r_w, L_e, and r_c were determined from the well construction geometry (reported in Table 2-4 and shown in well construction diagrams presented in Appendix F) The radius of the well (r_w) was considered as the radius of the borehole reported on the well construction logs L_e was considered to be the vertical length between the top and bottom of the slotted-screen section of the well for wells in which the screened section was fully saturated before the slug was introduced For wells in which the depth to water was within the screened interval, L_e was calculated as the length of the saturated screen interval In general, the parameter r_c was taken as the radius of the well casing when the static water level was above the screened section However, when the water level was within the screened interval, an adjustment was made to the casing radius (r_c) value to compensate for the thickness and high porosity of the sand pack around the well screen This adjustment was made because the sand pack normally drains at a quicker rate than the surrounding aquifer when the screened interval is not fully saturated

2 5 2 2 The Cooper Method

The Cooper method (Cooper et al 1967) mathematically defines the hydraulic properties of the surrounding saturated formation after a known volume of water is instantaneously injected or withdrawn from a well of finite diameter Observed hydraulic head displacement versus time plots are compared to a set of type curves for the determination of transmissivity (T) and storativity (S) (Appendix H, Figure H-2) Hydraulic conductivity was calculated from the transmissivity and storativity values Visual curve matching was used and data points representing pore drainage from within the filter pack were neglected The Cooper method is based on the following equation

$$H/H_0 = \frac{8\alpha}{\pi^2} \int_0^\infty \frac{e^{-\beta u^2/\alpha}}{u\,\{[uJ_0(u) - 2\alpha J_1(u)]^2 + [uY_0 - 2\alpha Y_1(u)]^2\}}\,du$$

Laplace solution for response in well

$$\bar{h} = \frac{T_w\, S\, H_0\, K_0(rq)}{T\, q\, [r_w q\, K_0(r_w q) + 2\alpha\, K_1(r_w q)]}$$

$$q = (pS/T)^{1/2}$$

p = Laplace transform variable

where

H = head in well at time t [L]

H_0 = initial head in well due to slug injection or withdrawal [L]

a = $r_w^2 S/r_c^2$ [dimensionless]

r_w = effective radius of well [L]

r_c = internal radius of well casing [L]

β = Tt/r_c^2

J_0 = Bessel function of first kind, zero order

J_1 = Bessel function of first kind, first order

Y_0 = Bessel function of second kind, zero order

Y_1 = Bessel function of second kind, first order

K_0 = modified Bessel function of second kind, zero order

K_1 = modified Bessel function of second kind, first order

[ ] = units in which terms are expressed, L = length

2 5 2 3 Drawdown Recovery Test Results

Table 2-5 presents the drawdown recovery test results from the Phase I RFI/RI The drawdown recovery tests give adequate spatial approximations of hydraulic conductivity, however, there are limitations associated with the tests Water levels may not have stabilized before the tests were performed due to slow recharge rates in bedrock wells in the LHSU, such as wells 70593 and 70893 Estimated hydraulic conductivities are only representative of the material a few radial feet around the borehole because of the small radius of influence induced by the drawdown stress Test results obtained from partially penetrating wells may not be representative of the entire saturated thickness of the formation because of the heterogeneity of the geologic material

Hydraulic conductivity estimates for surficial materials in the UHSU range from 4 05 x 10^{-4} to 2 99 x 10^{5} centimeters per second (cm/sec) for the Rocky Flats Alluvium, 6 20 x 10^{5} to 5 90 x 10^{-6} cm/sec for artificial fill without waste material, 1 35 x 10^{-4} to 9 62 x 10^{-6} cm/sec for artificial fill with waste material, and 1 29 x 10^{-6} to 1 48 x 10^{7} cm/sec for weathered bedrock The high hydraulic conductivities for artificial fill with waste material indicate the presence of void spaces within the landfill debris The low hydraulic conductivities for weathered bedrock reflect its composition (clayey siltstone and claystone) Hydraulic conductivity estimates for unweathered bedrock in the lower hydrostratigraphic unit range from 4 73 x 10^{7} cm/sec for fine-grained sandstones to 5 90 x 10^{-7} cm/sec for siltstones

Table 2-6 compares hydraulic conductivity values calculated for the Phase I RFI/RI at OU 7 to hydraulic conductivity values obtained from previous investigations at the landfill and values in the literature There are fewer significant figures for the values in this table than in Table 2-5 because of the uncertainty of the methodologies used to analyze historical aquifer test data Phase I RFI/RI hydraulic conductivities estimates

for surficial materials and bedrock are within an order of magnitude of values obtained from previous investigations and values in the literature

Figures 2-18, 2-19, and 2-20 present the areal distribution of hydraulic conductivity values for surficial materials, weathered bedrock, and unweathered bedrock, respectively, using data from the Phase I RFI/RI and previous investigations The figures also show whether values were obtained from drawdown recovery tests or slug tests No distinct trends are apparent on any of the maps, however, the range of hydraulic conductivity values varies by an order of magnitude on each map Hydraulic conductivity ranges from 10^{3} to 10^{-6} cm/sec for surficial materials, 10^{-6} to 10^{7} for weathered bedrock, and 10^{7} to 10^{-8} cm/sec for unweathered bedrock The large range for surficial materials is a result of the high variability of constituent materials, which include clay, silt, sand, gravel, and waste material

2 5 3 *Groundwater Flow*

Groundwater elevation data from 34 monitoring wells were used to construct potentiometric maps of saturated surficial materials for the months of December 1992, January 1993, February 1993, and March 1993 (figures 2-21 through 2-24) Groundwater elevation data from 12 monitoring wells were used to construct potentiometric maps of weathered bedrock for the same four months (figures 2-25 through 2-28) These maps show that the configuration of the potentiometric surfaces and hydraulic gradients changed little during that four-month period Historical groundwater elevation data indicate that water levels are generally lower from December through March Groundwater elevations are presented in Table 2-7 and well construction details are summarized in Table 2-4

Groundwater elevations from several monitoring wells were below the reported elevation of the bottom of the well screen and/or the top of weathered bedrock (Table 2-8) The surficial materials or weathered bedrock at most of these monitoring well locations was assumed to be unsaturated for the purpose of constructing potentiometric maps Surficial materials at well B206389 were not considered unsaturated because measured water levels were below the screened section but above the weathered bedrock contact

The groundwater flow observations discussed in this section are based on the configuration of the potentiometric and isopach map surfaces presented in figures 2-21

through 2-28 and figures 2-29 and 2-30, respectively Hydraulic gradients were determined by calculating the change in hydraulic head along the flowpath distance between two points Three flow paths were chosen to account for the observed change in hydraulic gradient from the main landfill area to the East Landfill Pond drainage area Well pair 5887/72293 was selected for measuring the flow path distance in the main landfill area, well pair B206389/0786 was selected for the flow path distance in the East Landfill Pond drainage area, and piezometer–well pair TH047492/4187 was selected for the flow path distance along the East Landfill Pond embankment Hydraulic head differences were determined from the potentiometric surfaces (figures 2-21 through 2-28)

The potentiometric maps show that surficial groundwater within the Present Landfill generally flows to the east along the buried drainage The isopach maps confirm that areas of greatest saturated thickness occur along this buried drainage The vertical hydraulic gradients between surficial and weathered bedrock groundwater generally show a downward component of flow This suggests that contaminated surficial leachate–groundwater may be affecting the groundwater quality in weathered bedrock

2 5 3 1 Groundwater Flow in Surficial Materials

Based on the potentiometric maps, the U-shaped patterns of the equipotential lines indicate that groundwater flow inside the intercept system is directed toward the center of the landfill However, the major component of flow is to the east (figures 2-21 through 2-24) The mean hydraulic gradient computed from the monthly potentiometric maps is 0 030 (Table 2-9) Groundwater flow in the East Landfill Pond drainage and east of the pond embankment appears to be topographically controlled, with flow from the west, north, and south directed toward the East Landfill Pond or No Name Gulch The mean hydraulic gradient is 0 128 for the East Landfill Pond drainage and 0 16 for the East Landfill Pond embankment

The saturated thickness maps show three areas where surficial materials are unsaturated (figures 2-29 and 2-30) One consistently unsaturated area is located on the ridge south of the East Landfill Pond, a second is located at the southwest end of the landfill at well 71693, and the third is located in No Name Gulch east of the East Landfill Pond embankment

The saturated thickness of surficial materials is greatest near the center of the landfill in the vicinity of wells 72093 and 72293 (figures 2-29 and 2-30) The concentric patterns of the isopach lines in this area suggest that recharge may be occurring by groundwater flow under or through the north groundwater intercept system The geologic cross section presented in Figure 2-11 shows that this area is coincident with a depression in the weathered bedrock surface Groundwater inflow may occur in this area where the groundwater intercept system is not keyed into bedrock

2 5 3 2 Groundwater Flow in Weathered Bedrock

Similar to flow in surficial materials, groundwater in weathered bedrock generally flows to the east (figures 2-25 through 2-28) The mean hydraulic gradient computed from potentiometric maps is 0 030 (Table 2-9) Groundwater flow in the East Landfill Pond drainage and east of the pond embankment is topographically controlled and flows from the west, north, and south toward the pond The mean hydraulic gradient is 0 103 for the East Landfill Pond drainage and 0 254 along the East Landfill Pond embankment Weathered bedrock on the ridge south of the pond was unsaturated from December 1992 through March 1993 Weathered bedrock beneath No Name Gulch was unsaturated in February and March 1993

2 5 3 3 Vertical Hydraulic Gradients

Vertical hydraulic gradients were calculated using groundwater elevations from four well pairs (Table 2-10) A well pair consists of two wells, one screened across surficial materials and the other screened across weathered bedrock The vertical hydraulic gradients vary from December 1992 through March 1993 because of monthly changes in groundwater elevations Vertical hydraulic gradients were calculated using methods in the 1992 annual RCRA groundwater monitoring report (EG&G 1993c) These calculations were based on the assumption that the measured hydraulic head values were obtained from homogeneous and isotropic groundwater flow systems The method used to calculate vertical hydraulic gradients is explained in Table 2-10

The vertical hydraulic gradients calculated range from 0 070 to 0 561 for well pair 6487/B206189, 0 388 to 0 599 for well pair 4087/B207089, and 0 098 to 1 103 for well pair 70393/70493 The vertical gradients generally indicate a downward component of flow The vertical hydraulic gradient calculated for well pair 70093/70193 ranges from

-0 057 to 0 024 The negative vertical gradient during January 1993 at this well pair indicates an upward component of flow

Vertical hydraulic gradients were also calculated for well pair 72393/72093 Both of these monitoring wells are completed in artificial fill but are screened across separate intervals Well 72393 is screened across the upper 7 feet of saturated material, and well 72093 is screened across the bottom 5 feet of saturated material The calculated vertical hydraulic gradients range from 0 005 to 0 003 at this well pair (Table 2-10) The low vertical gradient indicates a relatively slow downward component of flow through artificial fill at this location

2 5 3 4 Groundwater Flow Velocities

Groundwater flow velocities calculated for saturated surficial materials and weathered bedrock approximate advective transport rates for dissolved constituents In the 1992 annual RCRA groundwater monitoring report (EG&G 1993c), an assumed effective porosity of 0 1 had been used to calculate groundwater flow velocities within the Present Landfill area However, estimated porosity values reported on the borehole logs are often greater than 0 1 for weathered bedrock (Appendix E) In addition, the effective porosity of surficial materials within the landfill may be slightly higher than 0 10 as a result of the presence of void spaces Because of the uncertainty of the actual effective porosity values, an assumed range of effective porosity values (0 1 to 0 2) was used to calculate the groundwater flow velocities presented in Table 2-11

Horizontal Groundwater Flow Velocities in Surficial Materials

Average linear groundwater flow velocities for surficial materials within the Present Landfill were calculated along three flow paths to account for the steeper gradients in the East Landfill Pond drainage area and the East Landfill Pond embankment (Table 2-11) Input parameters for the calculation include geometric mean hydraulic conductivity values, effective porosity (0 1 to 0 2), and mean hydraulic gradients for well pairs along the flow paths Geometric mean hydraulic conductivity values for artificial fill (2 99 x 10^{5} cm/sec) and colluvium (1 59 x 10^{4} cm/sec) were estimated using drawdown recovery test data for wells 71193, 71493, 71893, 72093, 72293, and 72393 (Table 2-6) The geometric mean hydraulic conductivity value (1 59 x 10^{4} cm/sec) for the Rocky Flats Alluvium, estimated using drawdown recovery test data for wells 70093, 70393, and 70693, was used for colluvium within the East Landfill Pond

drainage area A hydraulic conductivity value of 1 27 x 10^{7} cm/sec, measured at piezometer TH0474492 (EG&G 1993e), was used for the East Landfill Pond embankment The average linear groundwater flow velocity in the landfill ranges from 9 28 feet per year (ft/yr) to 4 64 ft/yr (well pair 5887/72293) The average linear groundwater flow velocity in the colluvial material in the East Landfill Pond drainage area ranges from 210 57 ft/yr to 105 29 ft/yr (well pair B206389/0786) Average linear groundwater flow velocities through the East Landfill Pond embankment are greatly retarded as a result of the clay core and range from 0 21 ft/yr to 0 10 ft/yr (piezometer–well pair TH047492/4187)

Groundwater Flow Velocities in Weathered Bedrock

Average linear groundwater flow velocities for weathered bedrock were calculated along three flow paths (Table 2-11) Input parameters for the calculation include a geometric mean hydraulic conductivity value of 4 37 x 10^{7} cm/sec estimated using drawdown recovery test data for wells 70193 and 70493, assumed effective porosity values ranging from 0 1 to 0 2, and mean hydraulic gradients for well pairs along the flow paths Average linear groundwater flow velocities range from 0 14 ft/yr to 0 07 ft/yr in the landfill area (well pair 5887/72293) Average linear groundwater flow velocities in the East Landfill Pond drainage range from 0 47 ft/yr to 0 23 ft/yr (well pair B206389/0786) Average linear groundwater flow velocities through the East Landfill Pond embankment range from 1 15 ft/yr to 0 57 ft/yr (piezometer–well pair TH047492/4187) In general, the groundwater flow velocities in weathered bedrock are one to three orders of magnitude lower than the groundwater flow velocities in surficial materials

2 5 4 *Effectiveness of Landfill Structures*

The effectiveness of landfill structures can be evaluated using historical groundwater elevation data and TDS data

2 5 4 1 Well Hydrograph Comparison

Well hydrographs were constructed for 25 monitoring wells completed in surficial materials to compare water levels upgradient and downgradient of the landfill structures These wells are located along five north-south transects (AA-AA', BB-BB', CC-CC', DD-DD', and EE-EE') and one east-west transect (FF-FF') (Figure 2-31) The

well hydrographs, presented in figures 2-32 through 2-37, are used in conjunction with the potentiometric (figures 2-21 through 2-28) and isopach (figures 2-29 and 2-30) maps to assess the effectiveness of landfill structures

Transect AA-AA' Evaluation of the North and South Sides of the Groundwater Intercept System

The well hydrograph presented in Figure 2-32 shows that water levels within the groundwater intercept system are lower than water levels upgradient or outside the system Well 71693, located within the groundwater intercept system, was consistently dry while the saturated thickness on the upgradient side approaches 9 feet at well 71893 (Figure 2-32) The tightly spaced configuration of the isopach lines between wells 71893 and 71693 (figures 2-29 and 2-30) indicate that groundwater is being drawn toward the groundwater intercept system in this area The isopach lines upgradient of the north side of the groundwater intercept system (between wells 70093 and 71193) also indicate that groundwater is being drawn toward the intercept system The hydrograph for well 71493 shows that water levels have remained constant and suggests that the leachate collection system is working properly, assuming there is a line sink controlling head in the vicinity, or that well 71493 is actually situated outside of the intercept system near the perforated drain

Transect BB-BB'. Evaluation of the North Side of the Groundwater Intercept System

The well hydrograph presented in Figure 2-33 shows that the water levels within the intercept system are generally lower than the water levels outside of the system Well 6287 is situated upgradient of the intercept system near the drain (refer to cross section C-C', Figure 2-11) If the drain was working properly, the induced drawdown would have a noticeable impact on the water levels at well 6287 However, the water levels at this monitoring well show seasonal fluctuations similar to those observed in wells 6087 and 6187, situated upgradient of the influence of the drain, which suggests that the perforated drain near this location is not working properly The configuration of the isopach (figures 2-29 and 2-30) and potentiometric (figures 2-21 through 2-24) maps indicate a source of recharge to the center part of the landfill The recharge may occur by groundwater flow under or through the north intercept system The potential cause of failure in the groundwater intercept system is illustrated in geologic cross section C-C' (Figure 2-11) and shows that the intercept system is not keyed into bedrock,

indicating that groundwater may be flowing underneath the system Groundwater inflow may also be occurring through a breach in the clay barrier

Transect CC-CC': Evaluation of the South Side of the Groundwater Intercept System

Figure 2-34 shows that water levels outside or upgradient of the intercept system are higher than water levels within the system Seasonal water-level fluctuations in wells 6587 and 6687 (located outside of the intercept system) are similar in magnitude to fluctuations observed in well 6487 (located inside of the system) Apparently these wells are situated beyond the extent of the drawdown influence induced by the groundwater intercept system The isopach maps (figures 2-29 and 2-30) indicate that the groundwater intercept system is effectively diverting groundwater in this area The difference in saturated thicknesses (Figure 2-29) between wells 6587 (8 03 feet) and 6487 (3 1 feet) confirm the effectiveness of the intercept system along transect CC-CC'

Transect DD-DD': Evaluation of the North Slurry Wall

The well hydrograph presented in Figure 2-35 allows a comparison of the groundwater elevation data from a well pair (6787/6887) that straddles the north slurry wall The hydrograph shows that water levels in these two wells are generally within two tenths of a foot of one another The isopach maps (figures 2-29 and 2-30) show that the saturated thicknesses at wells 6787 and 6887 are nearly identical (within a hundredth of a foot) Based on the well hydrograph and isopach maps, groundwater appears to be flowing over and/or through the slurry wall However, it is possible that the well pair was not properly positioned on either side of the slurry wall or that the slurry wall does not extend this far to the east

Transect EE-EE': Evaluation of the South Slurry Wall

The well hydrograph used to evaluate the effectiveness of the south slurry wall is presented in Figure 2-36 Generally, water levels inside of the slurry wall are lower (2 to 6 feet at well B206389) than water levels measured outside of the slurry wall The potentiometric (figures 2-21 through 2-24) and isopach (figures 2-29 and 2-30) maps indicate that groundwater flow is being diverted away from the landfill in this area The isopach maps also show that saturated surficial materials are slightly thicker on the

upgradient side of the south slurry wall, confirming the effectiveness of the system at this location

Transect FF-FF': Evaluation of the West Side of the Groundwater Intercept System

The well hydrograph presented in Figure 2-37 shows seasonal water-level fluctuations of 3 to 5 feet in well B106089 compared to fluctuations of approximately 10 feet observed in wells located farther way from the intercept system This suggests that drawdown induced by the drain is affecting seasonal water-level fluctuations at well B106089 Based on these observations it appears that the perforated drain (refer to cross section E-E', Figure 2-13) is working properly in this area Water levels outside of the system are consistently lower in wells situated near the groundwater intercept system suggesting a downward gradient toward the drain The potentiometric (figures 2-21 through 2-24) and isopach (figures 2-29 and 2-30) maps also indicate that groundwater is being drawn toward the intercept system Figure 2-30 shows that the saturated surficial materials are thicker on the upgradient side of the intercept system (9 71 feet at well 0986), verifying that groundwater is being diverted around the landfill in this area

Evaluation of the Leachate Collection System

As discussed in Section 1 3 3, the leachate collection system drains to the buried West Landfill Pond, located in the vicinity of wells 72293 and 72493 Geologic cross section D-D' (Figure 2-12) illustrates the location of these wells with respect to the bottom of the buried drainage and the West Landfill Pond The saturated thickness of landfill material at well 72293 is only 2 41 feet (figures 2-29 and 2-30), which suggests that there is no recharge to this area Therefore, the leachate collection system is not discharging groundwater and/or leachate to the buried West Landfill Pond

2 5 4 2 Groundwater Quality Comparison

The distribution of TDS was used to evaluate the effectiveness of landfill structures Comparison of groundwater quality data, for the purpose of evaluating the effectiveness of the groundwater intercept system, is based on the null hypothesis that TDS concentrations in groundwater outside of the intercept system are statistically different than TDS concentrations in groundwater inside of the intercept system

The confidence interval width about the mean was calculated using observations from each monitoring well location (Figure 2-38) to test the previously stated null hypothesis The following equation (Sanders et al 1983), based on the assumption that the observations are normally distributed and are independent of each other, was used to calculate the confidence interval (CI)

$$CI = \bar{X} \pm t_{\alpha/2} (s/\sqrt{n})$$

where

$\bar{X}$ = mean

$t_{\alpha/2}$ = tabulated "t" value at a specified level of significance

s = standard deviation

n = number of observations

CI = confidence interval width about the mean

In practice, the normal distribution assumption may be validated by the Central Limit Theorem, which applies to sample populations where the number of observations approach 10, regardless of the underlying distribution (Sanders et al 1983) Therefore, the normal distribution assumption is justified for the data sets used to calculate TDS confidence interval widths because the number of samples in each data set are either greater than or approach 10 observations (Table 2-12) In addition, quarterly and/or monthly sampling rounds ensure that observations are independent The confidence interval widths were computed using a confidence level of 90 percent with a two-tailed level of significance $\alpha/2$ The "t" constant value is a function of degrees of freedom and probability of nonexceedance and was obtained from tabulated values presented by Sanders et al (1983) Input parameters and computed confidence interval widths are summarized in Table 2-12 Confidence interval widths were not calculated for wells with a limited number of observations, instead the range and mean were used to compare TDS concentrations

The spatial distribution of TDS concentrations in surficial groundwater within the Present Landfill area are presented in Figure 2-38 The map shows that TDS concentrations in general are significantly greater in the landfill within the groundwater intercept system However, groundwater quality outside of the intercept system may

be affected by upgradient contaminant sources or by waste material disposed beyond the perforated drain

TDS concentrations in wells located along Transect AA-AA' (Figure 2-31) [wells 70093 (170 milligrams per liter [mg/L]), 71193 (170 mg/L to 280 mg/L), and 71493 (170 mg/L to 270 mg/L)] are similar Although wells 70093 and 71193 are upgradient of the system and well 71493 is supposed to be downgradient, this similarity of TDS concentrations suggests that well 71493 may be situated upgradient of the intercept system near the drain The well hydrograph presented in Figure 2-32 also indicates that well 71493 may be upgradient The TDS concentrations at these locations are also significantly lower than TDS concentrations observed in nearby wells 72393 (1300 mg/L) and 72093 (1200 mg/L) in the landfill indicating that waste material is probably not buried beyond the intercept system in this area

TDS concentrations within the intercept system are significantly greater than concentrations outside of the intercept system for wells located along Transect BB-BB' (Figure 2-31) Groundwater quality does not appear to be affected by waste material outside the intercept system in this area Groundwater flow under the north side of the groundwater intercept system may be diluting TDS concentrations in wells 6387 (CI = 556 mg/L to 502 mg/L), 72393 (1300 mg/L), and 72093 (1200 mg/L) because the concentrations are much lower than elsewhere in the landfill (well 72293, 1700 mg/L)

In reference to the wells located along Transect CC-CC' (Figure 2-31), TDS concentrations in well 6487 (CI = 380 mg/L to 298 mg/L), located within the intercept system, are significantly greater than TDS concentrations in well 6587 (CI = 249 mg/L to 215 mg/L), located outside the system This indicates that the south side of the groundwater intercept system is diverting groundwater around the landfill Well hydrograph (Figure 2-34) and isopach maps (figures 2-29 and 2-30) confirm this interpretation However, elevated TDS concentrations in well 6687 (CI = 441 mg/L to 242 mg/L) imply that waste material or an upgradient contaminant source may have an impact on groundwater quality in this area

TDS concentrations in wells 6787 (CI = 191 mg/L to 160 mg/L) and 6887 (CI = 216 mg/L to 176 mg/L) located along Transect DD-DD' (Figure 2-31) are similar to TDS concentrations in upgradient wells 70093 (170 mg/L) and 70393 (190 mg/L) The TDS concentrations in wells 6787 and 6887 suggest that buried waste material does not extend this far to the north and that the well pair does not straddle the north slurry wall

The north slurry wall may actually be located further to the south or may not extend this far to the east

In reference to the wells located along Transect EE-EE' (Figure 2-31), the TDS concentrations in well B206389 (CI = 726 mg/L to 619 mg/L), located downgradient of the south slurry wall, are significantly greater than the TDS concentrations in wells 7287 (CI = 372 mg/L to 321 mg/L) and B206489 (405 mg/L to 359 mg/L), located upgradient of the south slurry wall The distribution of TDS concentrations along the EE-EE' transect suggest that groundwater is diverted away from the south slurry wall, which is supported by the well hydrograph (Figure 2-36) and isopach maps (figures 2-29 and 2-30) However, TDS concentrations in wells 7287 and B206489 are significantly higher than TDS concentrations in upgradient wells 70093 (170 mg/L) and 70393 (190 mg/L) suggesting that the groundwater quality in this area may be affected by contaminant sources in IHSSs 166 1, 166 2, and 166 3

TDS concentrations in well B106089 (CI = 406 mg/L to 301 mg/L), located close to the groundwater intercept system, are significantly greater than the TDS concentrations in wells 5887 (CI = 182 mg/L to 154 mg/L), 1086 (CI = 147 mg/L to 125 mg/L), and 70393 (190 mg/L), which are located farther away The elevated TDS concentrations in well B106089 indicate that groundwater quality may be affected by contaminant sources in IHSS 203 or by waste material buried beyond the intercept system (Transect FF-FF' [Figure 2-31])

2 5 4 3 Significance of Comparisons

The groundwater elevation data (potentiometric maps, isopach maps, and well hydrographs) indicate that the groundwater intercept system is functioning effectively except on the north side between Transects AA-AA' and BB-BB' The isopach maps show that groundwater flow is occurring under and/or through the groundwater intercept system in this area There is also compelling evidence based on the groundwater elevation data that the south slurry wall is effectively diverting groundwater around from the landfill Based on supporting evidence from the TDS distribution map, it is apparent that well pair 6787/6887 does not straddle the north slurry wall Therefore, an adequate assessment of the effectiveness of the north slurry wall cannot be made

The TDS distribution map shows that maximum TDS concentrations in surficial materials occur within the groundwater intercept system, with the highest concentrations in the center of the landfill Elevated TDS concentrations are observed in wells located beyond the limit of the groundwater intercept system and slurry walls along the western and southern perimeter of the landfill The groundwater quality outside of the south slurry wall may be affected by contaminant sources in the PU&D yard and in IHSSs 166 1, 166 2, and 166 3 Waste material buried beyond the limit of the intercept system may be affecting groundwater quality along the western and southwestern perimeter of the landfill

2.6 Surface-Water Hydrology

Surface-water hydrology at OU 7 is controlled by natural drainages, ditches, a surface-water diversion system, a subsurface drainage control system, a detention pond, a spray evaporation system, and surface-water runoff Hydrologic data used to characterize OU 7 were compiled from previous landfill investigations (DOE 1991b and EG&G 1991f), sitewide drainage and flood-control reports (EG&G 1992d and 1992e), precipitation data (Pamp 1993), and pond water elevation measurements, flow rate measurements, and pond sediment coring activities of the Phase I RFI/RI Descriptions of the landfill structures and interim response actions are included in Section 1 3 3 Descriptions of natural surface-water features, surface-water runoff, infiltration through the existing soil cover material, and groundwater–surface water interactions are presented in the following sections Water balance data are presented in Appendix I Inflows and outflows to the OU 7 watershed are quantified, and a water balance is presented The water balance calculates the change in storage and determines the resultant surface-water elevations of the East Landfill Pond

2 6 1 Drainages and Ditches

The Rocky Flats site is drained by three intermittent streams and their tributaries Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2) Flow is generally from west to east and occurs mainly after precipitation events or during spring snowmelt

The Walnut Creek drainage basin occupies approximately 3,110 acres from the base of the foothills near the mouth of Coal Creek Canyon, through the Rocky Flats site, to Great Western Reservoir Walnut Creek is comprised of three tributaries No Name Gulch, North Walnut Creek, and South Walnut Creek These tributaries drain the

central and northeastern area of the Rocky Flats site, including the northernmost portion of the industrial area The three tributaries converge in the northeast buffer zone west of Indiana Street From this confluence, the Walnut Creek drainage extends approximately 1 mile east to Great Western Reservoir Just east of the plant boundary, water from Walnut Creek is diverted around Great Western Reservoir to Big Dry Creek via the Broomfield Diversion Canal, which is an offsite canal operated by the city of Broomfield

There are seven water supply ditches that occur in the Rocky Flats drainage system Two ditches, McKay Ditch and Upper Church Ditch, are located just north of OU 7 in the Walnut Creek drainage basin (Figure 2-1) McKay Ditch conveys water from Coal Creek to Great Western Reservoir via Walnut Creek Upper Church Ditch conveys water from Coal Creek directly to Great Western Reservoir for storage purposes These ditches have not diverted water since 1989 (Weatherbee 1993)

Surface-water flow to the landfill is controlled by a diversion ditch constructed around the north, west, and south perimeter of the landfill The north and south branches of the ditch discharge into small natural drainages that flow to points downslope of the East Landfill Pond embankment in No Name Gulch Standing water may be observed in sections of the ditch after a significant storm event or snowmelt

2 6 2 *Landfill Seep*

Surface-water sampling station SW097 is located at the base of the east face of the landfill where leachate seeps from the landfill into the East Landfill Pond During field activities for the Phase I RFI/RI field investigation at OU 7, leachate flow rates were estimated between 0 01 and 0 02 cubic feet per second (cfs) Table 2-13 shows historical flow rates measured at station SW097 These data are incomplete and not consistent with other discharge monitoring efforts In August 1990, landfill leachate discharge was measured using a temporarily installed 8-inch Palmer-Bowlus flume The flow rate was measured at 0 015 cfs (EG&G 1991f)

2 6 3 *Intercept System Discharge Points*

Surface-water sampling stations SW099 and SW100, located downslope in No Name Gulch, are discharge points A series of valves control the discharge points of the groundwater intercept system During the four-month Phase I field investigation at OU

7, intercepted groundwater was presumably discharged into the East Landfill Pond rather than No Name Gulch No flows were observed at station SW100, the southern groundwater intercept discharge point Flow was observed once, in March 1993, at station SW099, the northern groundwater intercept discharge point Discharge was measured at a flow rate of 0 003 cfs The water in the concrete weir may have originated from snowmelt or precipitation instead of being discharged from the groundwater intercept system

2 6 4 *East Landfill Pond and Spray Evaporation System*

The East Landfill Pond and surrounding slopes are considered a subbasin within the OU 7 watershed and are referred to as the East Landfill Pond drainage basin The pond is recharged by groundwater, leachate, and surface-water runoff from the landfill and surrounding slopes Surface-water sampling station SW098 is located in the central east section of the pond adjacent to the dam Water surface elevations are recorded at this site during sampling events Historical water surface elevations for station SW098 range from 5,919 0 to 5,920 5 feet

Water loss from the pond consists of natural and controlled evaporation The pond water volumes fluctuate seasonally On average, the volume occupies 2 5 surface area acres An emergency spillway, located at the southeast corner of the pond (Figure 2-1), is at an elevation of approximately 5,921 feet Pond water levels are controlled by spray evaporation to prevent overflow into the spillway draining to No Name Gulch The spray evaporation system operates six months per year Ideally, the spray evaporation system reduces East Landfill Pond water volumes to 75 percent capacity (5 65 million gallons) When water levels approach the spillway elevation and spray evaporation does not significantly reduce the pond volume, water is diverted to Pond A-1 or A-2 This emergency response to elevated water levels rarely occurs and was last known to have occurred in March 1992

Sediment in the East Landfill Pond ranges from 0 5- to 0 8-feet thick and consists of clay, silt, and organic matter The upper 0 2 to 0 5 feet consists of black silt and clay with very fine roots occurring in either thin mats or scattered throughout the core No bedding or lamination were visible The remaining 0 3 to 0 4 feet of core consists of very dark gray clay with some silt Very fine roots were observed but they decreased with depth Olive gray claystone was present at the bottom of core SED70193 The moisture content of the cores ranged from 40 to 50 percent

2 6 5 *Surface-Water Runoff*

The relationship between precipitation and the resulting runoff in the OU 7 drainage basin was examined Many factors affect this relationship, such as the topography, geology, soil types, and physical characteristics of the basin The OU 7 drainage basin characteristics were delineated in the Rocky Flats drainage and flood control master plan (EG&G 1992d) The average slope of the basin is estimated at 0 037 feet per feet (ft/ft) Six percent of the drainage basin area is designated as impervious to infiltration Impervious retention (the retention of rainfall in depressions such as road ways or parking lots that does not contribute to runoff or infiltration) is expressed as an equivalent depth of rainfall and is estimated at 0 10 inches Conversely, pervious retention (the retention of rainfall in depressions or on vegetation that does not contribute to runoff but can infiltrate) is assumed to be 0 5 inches (EG&G 1992d)

2 6 6 *Infiltration*

Infiltration is the process by which precipitation moves downward into the soil Surface effects between the soil particles and the water exert tension that draws moisture downward into the soil through capillary passages Factors influencing rates of infiltration include soil type, soil cover, slope, precipitation intensity, antecedent moisture content of the soil, and water quality Infiltration rates are quantified using Horton's equation (EG&G 1992d) as follows

$$F = F_o + (F_i - F_o)e^{at}$$

where

F = infiltration rate (inches per hour)

F_i = initial infiltration rate (inches per hour)

F_o = final infiltration rate (inches per hour)

a = decay coefficient

t = time (seconds)

Site-specific coefficients and input parameters used to calculate the infiltration rate for the OU 7 drainage basin are F_i = 3 5 (inches per hour), F_o = 0 55 (inches per hour), and

a = 0 0013 (EG&G 1992d) The infiltration rate is initially 3 5 inches per hour but decreases exponentially to 0 5 inches per hour in the first hour The potential infiltration rate is highest at the beginning of a precipitation event As infiltration continues, the wetted zone in the soil expands downward and the infiltration rate decreases in an exponential manner until the soil reaches field capacity At field capacity the soil is holding all of the water that it can under the pull of gravity Precipitation greater than the amount of water infiltrated results in surface-water runoff

2 6 7 *Water Balance*

Water-balance calculations for the Present Landfill area, presented in the groundwater–surface-water collection study (EG&G 1991f), accounting for precipitation, evapotranspiration, and soil-water storage resulted in zero recharge to the surficial groundwater system due to the high evapotranspiration rate An alternative method accounting only for runoff assumed that 75 percent of the incident precipitation infiltrated through the soil cover to recharge the surficial groundwater This method most likely overestimates recharge from precipitation because soil evaporation loss was neglected In semiarid regions where the duration of storm events is low to moderate, the soil evaporation loss is a major component in the water-balance calculations

The Phase I RFI/RI water balance for the OU 7 watershed is confined to the drainage boundary of the Present Landfill within the surface-water diversion ditch and the East Landfill Pond drainage basin The inflows and outflows for the water balance are illustrated schematically in Figure 2-39 and are quantified for a typical year in Table 2-14 The storage volume of the East Landfill Pond is calculated by adding the inflows and subtracting the outflows using the following equation

Δ East Landfill Pond Storage = Inflows - Outflows

Inflows = precipitation + infiltration + groundwater inflow + groundwater base flow + surface runoff + discharge from the groundwater intercept system + runoff from spray evaporation

Outflows = evaporation from the landfill surface + downward seepage + pond evaporation + evapotranspiration

Each of the components of the water balance on Table 2-14 are described below

2 6 7 1 Column A, Month

All rows of the water balance table are entered monthly, starting with January and ending in December

2 6 7 2 Column B, Precipitation

Precipitation is reported as average monthly rainfall Precipitation data were obtained from the Rocky Flats meteorological station (Figure 2-3)

2 6 7 3 Column C, Pan Evaporation

Pan evaporation data were taken directly from meteorological station monthly pan evaporation data for the period October 1991 to September 1992 (Appendix I) Collection of pan evaporation data was discontinued after September 1992 The evaporation pan is assumed to be the standard Weather Bureau Class A pan The pan is screened and is estimated at 3 to 4 feet in diameter and 10 inches in depth Pan evaporation data were used to calculate evaporation from the East Landfill Pond (Column L)

2 6 7 4 Column D, Infiltration

Infiltration of precipitation into the surficial material covering the landfill surface was estimated at 5 percent of the total monthly precipitation, based on evaporation of 75 percent (see Column E) and a runoff coefficient of 20 percent (see Column I)

2 6 7 5 Column E, Evaporation from the Landfill Surface

Evaporation of incident precipitation from the surface of the landfill was estimated at 75 percent of the total monthly precipitation (Brady 1974)

2 6 7 6 Column F, Groundwater Inflow Under the Groundwater Intercept System

The monthly volume of groundwater inflow under the north groundwater intercept system into the landfill was estimated using the following equation based on Darcy's Law and the Dupuit-Forchheimer assumptions (McWhorter and Sunada 1977)

$$Q = Kh \, {}^{dh}\!/_{dx}$$

where

Q = volumetric flow [L^3/T]

K = hydraulic conductivity [L/T]

h = thickness of flow and hydraulic head [L]

dh/dx = hydraulic gradient [dimensionless]

Assumptions used in the calculations include homogeneous and isotropic flow conditions, steady one-dimensional flow, the cross-sectional area of flow decreases along the flow path as the saturated thickness decreases, flow is normal to the intercept system, and inflow occurs through a 444-foot-long section where it is presumed that the intercept system is failing The input parameters include a hydraulic conductivity value of 2 99 x 10^5 cm/sec (geometric mean value for artificial fill, Table 2-5), a hydraulic gradient of 0 01 obtained from well pair 6187/6287, and saturated thicknesses along the 444-foot-long stretch of the intercept system were determined from the isopach maps (figures 2-29 and 2-30) The groundwater inflow calculations and relevant parameters are summarized in Appendix I

2 6 7 7 Column G, Downward Seepage from the Landfill

The volume of groundwater seeping from the landfill down into weathered bedrock, vertical flow (Q), was estimated from Darcy's Law by multiplying the vertical Darcy flux (q_z) by the cross sectional area (A), where $Q = q_zA$ Assumptions inherent in the estimate include homogeneous and isotropic flow conditions, steady one-dimensional flow, vertical flow normal to the weathered bedrock surface, and vertical flow through fully saturated units The input parameters used to estimate vertical seepage include a hydraulic conductivity value of 4 37 x 10^7 cm/sec (geometric mean value for weathered bedrock groundwater, Table 2-5), a vertical hydraulic gradient of 0 054 (geometric mean value, Table 2-10) for the December 1992 flux calculations, a vertical hydraulic gradient value of 0 080 (geometric mean value, Table 2-10) for the March 1993 flux calculations, and a seepage area of 714,375 square feet (see Appendix I) The vertical hydraulic gradient value for the December flux calculations was obtained from February 1993 groundwater elevation data because it is assumed to be more representative of the actual flow conditions The geometric mean value of 0 483 for December 1992 was obtained from only two observations and would greatly

overestimate the volume flux The well hydrographs (figures 2-32 through 2-37) verify that surficial groundwater conditions in December 1992 are similar to conditions in February 1993

2 6 7 8 Column H, Groundwater Base Flow

As stated earlier, it is assumed that groundwater within the surficial material of the landfill is isolated from the underlying unweathered bedrock Although a deeper groundwater system within the bedrock exists, it is assumed that the gradient between these two groundwater systems is negligible in comparison to the gradient of flow to the East Landfill Pond A constant base flow to the pond is assumed (see potentiometric maps, figures 2-21 through 2-24) The magnitude of groundwater base flow is based on Darcy's Law, as follows

$$Q = KIA$$

where

Q = groundwater flow

K = hydraulic conductivity

I = hydraulic gradient

A = cross-sectional area of flow

As described in Section 2 5, the average hydraulic conductivity of landfill material is $2\ 99 \times 10^{5}$ cm/sec The average hydraulic conductivity of colluvium is $1\ 59 \times 10^{4}$ cm/sec The area surrounding most of the East Landfill Pond is assumed to have the same average hydraulic conductivity as the colluvium ($1\ 59 \times 10^{4}$ cm/sec) Based on data from December 1992 to March 1993, the groundwater hydraulic gradient within the vicinity of the East Landfill Pond is equal to an average of 0 128 ft/ft Finally, to calculate the rate of groundwater base flow to the East Landfill Pond a cross-sectional area of flow must be estimated Because most of the East Landfill Pond bottom is underlain by unweathered bedrock, the cross-sectional area of flow is defined by the depth of groundwater at the pond shoreline This groundwater depth can be defined by existing seeps and is estimated at a depth of 5 feet (see geologic cross section G-G', Figure 2-15) The cross-sectional area of flow is estimated by multiplying the depth of flow (5 feet) by the length of the pond shoreline (approximately 1,500 feet) The area

is approximately 7,500 square feet Substituting the above values into the Darcy's Law equation gives a monthly average groundwater infiltration rate of approximately 0 097 or 0 10 milligrams per month

The monthly volume of groundwater flowing laterally through the system was estimated from the Dupuit-Forchheimer equation (see Column F description) The following assumptions were used to estimate the lateral outflow the cross-sectional area of lateral flow decreases along the flow path as the saturated thickness decreases, isotropic and homogeneous flow conditions exist, steady one-dimensional flow exists, and lateral flow is normal to the eastern boundary of the landfill (Figure 2-40) The input parameters for lateral flow include a hydraulic conductivity value of 2 99 x 10^{5} cm/sec and lateral hydraulic gradients of 0 129 for December 1992 and 0 128 for March 1993 (hydraulic gradients for the East Landfill Pond drainage area were used, Appendix I) The isopach maps (figures 2-29 and 2-30) were used to determine the saturated thicknesses along the eastern boundary

2 6 7 9 Column I, Runoff

The OU 7 watershed is located in the drainage area of No Name Gulch and occupies approximately 37 acres The watershed has been divided into four subareas (Figure 2-41), each having different runoff characteristics Area I incorporates the Present Landfill and contains 22 3 acres Area II is an engineered slope just below the landfill and above the East Landfill Pond This subarea has light vegetation and occupies 2 5 acres Area III consists of highly vegetated steep slopes on the north and south sides of the East Landfill Pond and contains 9 3 acres Area IV is the East Landfill Pond, which covers 2 4 to 2 7 acres

The monthly surface runoff is estimated using the runoff coefficient (C) of the Rational Method formula (Appendix I) The runoff volume for each subarea is estimated as a fraction of the total precipitation by multiplying the total rainfall volume by the subarea runoff coefficient The magnitude of the runoff coefficient is dependent upon surface slope, permeability, vegetation, and roughness (Appendix I) The estimated areas and runoff coefficients of each subarea are as follows

- Area I — 22 3 acres, flat, no vegetation C = 0 20
- Area II — 2 5 acres, steep, light vegetation C = 0 50

- Area III — 9 3 acres, steep, heavy vegetation C = 0 40
- Area IV — 2 5 acres, leachate pond surface C = 1 00

As shown above, a runoff coefficient of 1 00 is delineated for the leachate pond surface to simulate the direct storage of rainfall in the pond Total monthly landfill runoff is estimated with the following formula

$$\text{Runoff} = (\text{precip})(\text{Area I})(0\ 2) + (\text{precip})(\text{Area II})(0\ 5) + (\text{precip})(\text{Area III})(0\ 4) + (\text{precip})(\text{Area IV})$$

2 6 7 10 Column J, Discharge to Pond from the Groundwater Intercept System

The volume of water discharging to the East Landfill Pond via the groundwater intercept system was calculated for high and low flow periods using Darcy's Law and the Dupuit-Forchheimer assumptions (Appendix I) The Dupuit-Forchheimer assumptions include isotropic and homogeneous flow, steady state flow, horizontal flow, a hydrostatic pressure head distribution along all vertical planes, flow normal to the drain, and a horizontal, impermeable weathered bedrock surface (McWhorter and Sunada 1977)

The well hydrograph presented in Figure 2-37 indicates a sloping water table toward the perforated drain, verifying the Dupuit-Forchheimer assumptions The near-constant head conditions observed in well B106089 confirm the proximity of that well to the perforated drain The problem is simplified by assuming that the observed hydraulic head in well B106089 represents the hydraulic head in the filter pack that surrounds the perforated pipe Based on this assumption, groundwater elevation data obtained from wells 5887 and B106089 were chosen to satisfy the h_x, h_l and L boundary conditions in the following equation

$$Q = K / 2L\,(h_x^{\,2} - h_l^{\,2})$$

where

Q = volumetric flow rate into drain [L^3/T]

K = hydraulic conductivity [L/T]

h_x = thickness of flow and head potential at a distance [L] from the drain {1}

h_l = thickness of flow and head potential at the drain [L]

L = distance between h_x and h_l ([L]

A hydraulic conductivity value of 2 99 x 10^{-5} cm/sec (8 46 x 10^{-2} ft/day) was used to solve for the volumetric flow rate (Q) The resulting flow rate across the seepage face at well B106089 is assumed to be intercepted by the drain and diverted to the East Landfill Pond Calculations and relevant input parameters used to solve the equation are presented in Appendix I The volumetric flow rate per unit area was multiplied by the length of the drain (1,748 feet) that is effectively intercepting groundwater This value was obtained by subtracting the length of the north groundwater intercept system that is presumed to be failing (444 feet) from the total length of the drain (2,192 feet) Solving for Q in the equation yields a monthly volume of flow that is intercepted by the drain and diverted to the East Landfill Pond (Appendix I)

The volumetric flow rate into the drain per unit area ranges from 4 32 x 10^{-2} cubic feet per day per square feet ($ft^3/day/ft^2$) in December to 4 26 x 10^{2} $ft^3/day/ft^2$ in March The monthly volume of intercepted groundwater diverted to the East Landfill Pond ranges from 2,341 cubic feet (ft^3) in December to 2,308 ft^3 feet in March The flow rates computed for December 1992 (low flow period) are unexpectedly higher than the computed flow rates for March 1993 (high flow period) However, the Dupuit-Forchheimer discharge equation is limited by many simplifying assumptions Violation of the homogeneous and isotropic assumptions may have slightly overestimated the December 1992 flow rate and/or slightly underestimated the March 1993 flow rate Despite these differences, the computed flow rates for December 1992 and March 1993 vary only slightly suggesting that the flow rate into the drain remains relatively constant The monthly volume of intercepted groundwater for March 1993 was used in the water balance

2 6 7 11 Column K, Downward Seepage from the East Landfill Pond

The volume of groundwater seeping from the East Landfill Pond down into weathered bedrock, vertical flow (Q), was estimated from Darcy's Law by multiplying the vertical Darcy flux (q_z) by the cross-sectional area (A), where $Q = q_z A$ Assumptions inherent in the estimate include homogeneous and isotropic flow conditions, steady one-dimensional flow, vertical flow normal to the weathered bedrock surface, and vertical

flow through fully saturated units The input parameters used to estimate vertical seepage are the same as the input parameters listed in Column G

2 6 7 12 Column L, East Landfill Pond Evaporation

Reservoir and pond evaporation are commonly estimated as a fraction of the pan evaporation rate For Weather Bureau Class A pans, pond evaporation is typically calculated as approximately 70 percent of the pan evaporation rate (Linslay et al 1975) Assuming this 70 percent reduction, the monthly pond evaporation volume is estimated by the following formula

Pond evaporation = (-pan evap)(0 7)(pond surface area)

As shown in Table 2-14, pond evaporation rates for December, January, and February are zero because the East Landfill Pond is typically covered with ice

2 6 7 13 Column M, Total Volume of Spray Evaporation

Total spray evaporation represents the total volume of water sprayed on the grassy slopes around the pond for a given month Because historical data on actual spray volumes are minimal, the estimated volume is based on typical operation procedures during the spray evaporation season (Andrews and Murray 1993)

The approximate spray evaporation pump rate is 700 gallons per minute Spray evaporation is generally conducted from May to October Spray evaporation does not take place on days when it is raining or there is significant cloud cover For the purpose of the water balance, an average of 22 spray evaporation days per month was assumed Spray evaporation pumps are generally turned on at 8 00 or 9 00 a m and turned off at 4 30 or 5 00 p m For the purposes of the water balances, an average of 7 hours of pump operation per day were assumed Based on the operational parameters and assumptions, an average monthly total spray evaporation is estimated as follows

Total flow = (700 gal/min)(60 min/hr)(7 hr/day)(22 day/month)
= 6,468,000 gal/month
= 6 47 MG/month

where

gal/min	=	gallons per minute
min/hr	=	minutes per hour
hr/day	=	hours per day
gal/month	=	gallons per month
MG/month	=	million gallons per month

2 6 7 14 Column N, Runoff From Spray Evaporation

Approximately 90 percent of the total volume of water pumped through the spray evaporation system runs back into the leachate pond (Andrews and Murray 1993) and therefore spray evaporation runoff is estimated as 90 percent of the total spray volume

2 6 7 15 Column O, Grass Area Evapotranspiration

As stated above, approximately 90 percent of the total volume of water pumped through the spray evaporation system runs back into the leachate pond It is assumed that no infiltration occurs and the remaining 10 percent of the total volume pumped undergoes evapotranspiration

2 6 7 16 Column P, East Landfill Pond Storage

The monthly pond storage is equal to the sum of the previous month storage, Column H (Groundwater Base Flow), Column I (Surface Runoff), Column L (Landfill Pond Evaporation), and Column O (Grass Area Evapotranspiration) Based on historical data, a starting storage volume of 6 0 million gallons (MG) in January is assumed

2 6 7 17 Column Q, Pond Water Surface Elevation

The pond surface water elevation is estimated with the East Landfill Pond capacity chart (Appendix I) The curve was generated from a detailed survey of the pond

2 6 8 Groundwater–Surface-Water Interactions

As shown by the water balance presented in Table 2-14, the reduction or increase in leachate pond volume is primarily determined by the magnitude of monthly rainfall runoff, spray evaporation, and direct pond evaporation Ideally, the spray evaporation system is operated with the intent of reducing the pond volume to 75 percent capacity or 5 65 MG by the end of the spray season in October As shown in the water balance, under normal rainfall and spray evaporation conditions, the pond volume can be reduced to 5 43 MG by the end of October Although a reduction under 75 percent capacity is achieved, it is interesting to note that the peak surface-water elevation in May reached a level of approximately 5,921 feet, the approximate spill elevation

The hydrographs presented in figures 2-32 through 2-37 show seasonal water-level fluctuations at most of the monitoring well locations These water-level fluctuations are compared to monthly precipitation data acquired from the Rocky Flats meteorological station (Pamp 1993) The precipitation hydrographs presented in figures 2-32 through 2-37 show that seasonal groundwater elevations roughly coincide with monthly precipitation although some lag is apparent This suggests that surficial groundwater and/or leachate is recharged from precipitation that infiltrates through the soil cover The infiltration rate through the soil cover varies from 3 5 inches/hour to 0 55 inches/hour

The East Landfill Pond is the major surface-water feature within OU 7 The East Landfill Pond impounds groundwater–leachate generated by the landfill The majority of the surface-water inflow to the East Landfill Pond occurs as runoff from spray evaporation and drainage from the seep located near the west end of the pond Groundwater from the groundwater intercept system can be discharged into the pond at two outfall points located along the northern and southern shoreline Pond water evaporates directly to the atmosphere or via spray irrigation onto the hillsides adjacent to the pond

Water elevations in surficial groundwater and surface-water elevations at the East Landfill Pond have similar seasonal trends, which suggests that surficial groundwater and surface water in the pond are hydraulically connected The water levels in well 0786, screened in surficial materials, are consistently greater than the East Landfill Pond water levels, suggesting that surficial groundwater is continuously recharging the pond Water levels in weathered bedrock well (B206789) show extreme water-level

fluctuations, possibly the result of quarterly sampling events As a result, seasonal trends are not apparent and correlation of weathered bedrock groundwater with pond surface elevations is not possible The hydrograph data are inconclusive regarding a hydraulic connection between the weathered bedrock and the pond However, observed water levels in well B206789 are consistently lower than the pond water elevations indicating that the East Landfill Pond may be recharging the weathered bedrock near the shoreline Estimated vertical hydraulic gradients between the East Landfill Pond and the weathered bedrock groundwater system are presented in Appendix I Based on these vertical gradients and a hydraulic conductivity value of $4\ 37 \times 10^{-7}$ cm/sec, and assuming homogeneous, isotropic, steady state, one-dimensional flow, the vertical Darcy flux (geometric mean) through the pond–weathered bedrock interface is $8\ 55 \times 10^{8}$ cm/sec

The configuration of the potentiometric maps (figures 2-21 through 2-24) suggest that water is seeping through the East Landfill Pond embankment The equipotential lines of the surficial and weathered bedrock groundwater systems are tightly spaced along the embankment indicating a steep gradient toward No Name Gulch The volume of water seeping through the embankment is probably minimal as indicated by the isopach maps (figures 2-29 and 2-30) which show a saturated thickness of less than 2 5 feet in this area Based on the hydraulic conductivity value of $1\ 27 \times 10^{-7}$ cm/sec measured at piezometer TH047292 (EG&G 1993b) and a mean hydraulic gradient of 0 16, the lateral Darcy flux through the embankment is $2\ 03 \times 10^{-8}$ cm/sec, assuming homogeneous, isotropic, steady-state, one-dimensional flow conditions

Conclusions from the water-balance calculations include the following (1) leachate–groundwater is primarily recharged by precipitation through the interim soil cover, (2) groundwater flow under the failed intercept system contributes less than 10 percent of the total inflow, and (3) leachate–groundwater outflow primarily occurs as downward seepage into weathered bedrock beneath the landfill

Conclusions based on the water-elevation data include the following (1) cyclic trends in groundwater elevations coincide with precipitation events, (2) surficial groundwater appears to be continuously recharging the East Landfill Pond, (3) downward seepage appears to be recharging the weathered bedrock beneath the East Landfill Pond, and (4) seepage through the East Landfill Pond embankment appears to be minimal, as

indicated by the calculated Darcy flux of 2 03 x 10^{-8} cm/sec and saturated thickness of less then 2 5 feet below the embankment

2 7 Ecology

The buffer zone surrounding the industrial area of the Rocky Flats site 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 disturbance associated with the landfill operations and construction of the East Landfill Pond and groundwater intercept system

2 7 1 Vegetation

The Rocky Flats site is located between Boulder and Golden, Colorado, in a transitional zone known as the Colorado Piedmont The Colorado Piedmont is an area of dissected topography containing floristic features from the Great Plains prairie and the Rocky Mountain foothills The present-day vegetation of Rocky Flats is dominated by mesic mixed grassland with integrated tall- and short-grass prairie community features Grasses prevalent on upland sites are western wheatgrass, blue grama, sideoats grama, Canada bluegrass, Kentucky bluegrass, and prairie junegrass Mesic sites support tall-grass and mixed-grass prairie species such as big bluestem, little bluestem, green needlegrass, and switchgrass More xeric sites are dominated by short-grass species, including buffalograss, needle-and-thread, red three-awn, ring muhly, and mountain muhly Dominant forbs were hairy gold-aster, Louisiana sage, western ragweed, broom snakeweed, and slimflower scurfpea Riparian and wetland vegetation occupy the seeps and valley floors with rushes, bulrushes, sedges, cattails, willows, and cottonwoods Weedy species such as cheatgrass, Japanese brome, diffuse knapweed, and klamath weed predominate on disturbed sites Reclaimed sites are dominated by smooth brome, crested wheatgrass, and intermediate wheatgrass Specific plant communities present in the OU 7 study area are described in the following subsections (Figure 2-42)

2 7 1 1 Mesic Mixed Grassland

Mesic mixed grassland is the most prevalent native habitat type at OU 7 This diverse plant community occurs in a wide variety of topographies, including broad flat uplands, valley floors, and hillsides Differences in slope, aspect, soil type, disturbance, and land use history are reflected in differences in dominance of the various grasses and forbs

characterizing the mesic grassland Species richness was sampled along 2 meter by 50 meter belt transects within the mesic mixed grassland Of the one hundred and six species identified, 34 were graminoids, 63 forbs, 5 shrubs, and 4 cacti Of the identified species within the OU 7 study area, 67 9 percent were native perennial species, suggesting a possible trend toward a native grassland climax community Dominant graminoids are western wheatgrass, Canada bluegrass, prairie junegrass and big bluestem Kentucky bluegrass, western wheatgrass, little bluestem, crested wheatgrass, sand dropseed, blue grama, and needle-and-thread were also present The most dominant forbs were diffuse knapweed, Louisiana sage, and Canada thistle Secondary forbs present included 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

2 7 1 2 Disturbed Community

A large portion of the industrial complex at the Rocky Flats site has been severely disturbed and currently supports primarily weedy species The majority of disturbance at OU 7 is attributable to surficial soil disturbance by heavy equipment used in landfill activities

A belt transect sampled within the disturbed community contained 27 species 7 grasses, 18 forbs, and 2 subshrubs The dominant graminoids were big bluestem and blue grama, followed by narrow-leaf sedge, Canada bluegrass, and mountain muhly The dominant forb was diffuse knapweed which is a highly competitive, introduced plant that infests roadsides, waste areas, and dry rangelands Other forbs present included Louisiana sage, hairy gold-aster, blazing star, western ragweed, klamath weed, and fringed sage The only shrub present was wild tarragon Native perennial species constituted 70 3 percent of the community, 68 4 percent of these plants were forbs or subshrubs Non-native plants accounted for the balance of the total species richness

2 7 1 3 Bare Ground

A large section of OU 7 was bare ground due to continuous earthmoving at the landfill Plants have little opportunity to germinate, grow, or establish in bare areas Most of the original topsoil has either been lost through wind and water erosion or buried in the landfill

2 7 1 4 Marshland

Tall and short marsh occur in the area around the East Landfill Pond Tall marsh occurs at the pond margins and is comprised of a near monoculture of broad-leaved cattail, which probably impacts establishment and growth of other hydrophytic plants The static water level in the pond probably promotes the persistence of the cattails The short marsh type occurs in the sprayed areas north and south of the pond where intermittent spray operations cause 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

2 7 2 Wildlife

The Rocky Flats site supports a wide variety of wildlife, large and small mammals, birds, reptiles, amphibians, aquatic macroinvertebrates, and fish This relatively rich animal community is, in part, due to the isolation of the site from the increasing human activity in the surrounding areas

The most abundant large mammal is the mule deer, population estimates exceed 100 animals White-tailed deer have also been infrequently observed Large carnivores present at Rocky Flats are coyotes, red foxes, gray foxes, striped skunks, long-tailed weasels, badgers, bobcats, and raccoons Eastern cottontails and white-tailed jack rabbits are also present Black-tailed prairie dogs occur in flat, upland areas in the northeastern corner of the buffer zone Some ponds support muskrats

The Rocky Flats environmental impact statement (EIS) (DOE 1980) reported that eight species of small mammals were captured during a live-trapping program in 1975 harvest mice, deer mice, meadow voles, thirteen-lined ground squirrels, hispid pocket mice, silky pocket mice, pocket gopher, and house mouse More recent studies have documented the occurrence of Mexican woodrats, plains and western harvest mice, prairie voles, and both western and meadow jumping mice

The varied habitats at the Rocky Flats site support many bird species Common grassland birds include western meadowlarks, horned larks, vesper sparrows, grasshopper sparrows, western kingbirds, and eastern kingbirds Riparian areas dominated by cottonwoods support black-billed magpies, northern orioles, yellow warblers, warbling

vireos, American robins, indigo buntings, blue grosbeaks, and lesser and American goldfinches MacGillivray's warblers, yellow-breasted chats, black-headed grosbeaks, green-tailed and rufous-sided towhees, and lazuli buntings occur in other wooded areas Marshlands support song sparrows, common yellowthroats, red-winged blackbirds, common snipe, and sora rails Common birds of prey occurring at the Rocky Flats site include American kestrels, northern harriers, red-tailed hawks, Swainson's hawks, great horned owls, and long-eared owls Occasionally, golden eagles, prairie falcons, rough-legged hawks, and short-eared owls are observed Bald eagles are noted visitors during the winter Open water areas, including ponds and intermittent creeks, attract water birds such as mallards, gadwall, green-winged teal, blue-winged teal, pied-billed grebes, spotted sandpipers, killdeer, great blue herons, black-crowned night-herons, and double-crested cormorants Migrating sandhill cranes have also been observed at the site

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 plains leopard frogs, Woodhouse's toads, northern chorus frogs, and tiger salamanders

Surface waters at Rocky Flats support a variety of aquatic macroinvertebrates, including snails and several orders of insects and crustaceans Oligochaeta, Amphipoda, Decapoda, Hydracarina, Plecoptera, Ephemeroptera, Odonata, Trichoptera, Coleoptera, Diptera, Gastropoda, and Pelecypoda. Some ponds and creeks are inhabited by fathead minnows, common carp, white suckers, creek chubs, golden shiners, and green sunfish Largemouth bass have been found in Ponds C-1, A-2, and Lindsay Pond However, the East Landfill Pond supports no fish and only a depauperate benthic macroinvertebrate community

Surveys for terrestrial arthropods, large mammals, birds, reptiles, and amphibians specifically on OU 7 were not performed due to its small area. No fish were collected during surveys conducted in the landfill pond

2 7 3 *Sensitive Habitats and Endangered Species*

Several wetlands identified at the Rocky Flats site come under the protection of state and federal wetland laws Wetlands at the Rocky Flats site were identified in conjunction with the National Wetlands Inventory (see FWS 1979) and field checked to verify their jurisdictional status by U S Army Corps of Engineers personnel These wetlands consist

of emergent, intermittently flooded stream channels and artificial, semipermanent ponds (wetland types PEMW and POWKF, respectively) (FWS 1979) At this time, the East Landfill Pond is classified as a RCRA management unit, although several wetland species grow in and around the pond

Three federally listed endangered wildlife species potentially occur at Rocky Flats These are the black-footed ferret, peregrine falcon, and bald eagle (ASI 1991) Black-footed ferrets require habitat in and around prairie dog colonies Although several prairie dog colonies exist at the Rocky Flats site, there are none in the immediate vicinity of OU 7 Black-footed ferrets are not known to occur in the vicinity Though bald eagles are seen during winter months, no roost areas or nest sites have been located on the Rocky Flats site Peregrine falcons may be periodic migrants in this area. In 1991, a peregrine falcon pair nested approximately 10 kilometers northwest of the Rocky Flats site It is possible that the hunting territory of such nesting peregrines could include Rocky Flats, although suitable habitat occurs closer to the known nest area Small size and lack of an appropriate prey base precludes OU 7 as an important habitat for these federally listed species

Potential habitat for several Colorado "Category 2" wildlife species occurs at Rocky Flats site Ferruginous hawks have been observed throughout the year and appear to be vagrants This species may nest near the Rocky Flats site and use the site for hunting Preble's meadow jumping mice were captured in small numbers along Woman Creek in 1991, and one individual was captured in reclaimed grassland within the OU 1 study area As a result, an intense survey was conducted in 1992 The 1992 program resulted in live captures of 10 Preble's meadow jumping mice, including 2 along Woman Creek below Pond C-1 Animals were captured in hydrophytic shrublands dominated by sandbar willow and leadplant, with relatively lush understory grasses and forbs Other Category 2 wildlife species potentially occurring, but not documented, at the Rocky Flats site include the white-faced ibis, mountain plover, long-billed curlew, and swift fox (ASI 1991) Again, the small size of OU 7, and inappropriate habitat, limits the value of OU 7 for these sensitive species

ASI (1991) reported four plant species of special concern potentially present at the Rocky Flats site These plants include one federally-listed threatened species, Ute lady's tresses, one Category 2 species, Colorado butterfly plant, and two species of concern in Colorado, forktip three-awn and toothcup Ute lady's tresses has been reported near Clear Creek to

the south of the Rocky Flats site and near South Boulder Creek to the north of the Rocky Flats site (ASI 1991), and suitable habitat does occur at the Rocky Flats site Colorado butterfly plant has not been reported near the Rocky Flats site, but wetlands along the major creeks represent suitable habitat for this species Neither species was found during surveys conducted 1992 (EG&G 1992f) Forktip three-awn was reported along Woman Creek in 1973 and was documented in the same area during intensive vegetation investigations of OU 5 in 1991 Toothcup has been reported in a temporary pool about 4 miles east of Boulder

Table 2-1
Description of Soil Types

Series[1]	Family	Phase	Minimum-Maximum Slope (%)	Infiltration Rate	Soil Type[1]
Denver-Kutch-Midway	Torrertic Argiustolls	clay loam	9-25	slow	31
Flatirons	Aridic Paleustolls	very cobbly sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	slow	60
Nederland	Aridic Argiustolls	very cobbly sandy loam	15-50	moderate	100
Gravel/Disturbed Ground/Interim Soil Cover	—	—	varies	moderate to rapid	111

[1] After Price and Amen 1980 (See Figure 2-5 for the distribution of soil types at OU 7)

Table 2-2
Depth to Bedrock at CPT Locations

CPT Location	Depth to KaKI(w) (feet bgs)	Elevation Top of KaKI(w) (feet)	Thickness of KaKI(w) (feet)	Depth to KaKI(u) (feet bgs)	Elevation Top of KaKI(u) (feet)
CPT00193	NDE	NDE	NDE	NDE	NDE
CPT00293	NDE	NDE	NDE	NDE	NDE
CPT00393	21 0	5971 5	23 0	44 0	5948 5
CPT00493	22 0	5968 6	18 0	40 0	5950 6
CPT00593	32 0	5958 3	13 0	45 0	5945 3
CPT00693	25 0	5964 9	11 0	36 0	5953 9
CPT00793	28 0	5957 7	57 0	85 0	5900 7
CPT00893	29 0	5956 6	39 0	68 0	5917 6
CPT00993	36 5	5950 1	8 5	45 0	5941 6
CPT01093	37 0	5951 9	10 0	47 0	5941 9
CPT01193	45 0	5936 9	9 0	54 0	5927 9
CPT01293	41 5	5940 0	7 5	49 0	5932 5
CPT01393	42 0	5934 8	15 0	57 0	5919 8
CPT01493	45 0	5929 6	12 0	57 0	5917 6
CPT01593	40 0	5933 4	18 0	58 0	5915 4
CPT01693	NP	NP	NP	NP	NP
CPT01793	NDE	NDE	NDE	NDE	NDE
CPT01893	14 0	5955 0	42 0	56 0	5913 0
CPT01993	12 0	5953 9	NDE	NDE	NDE
CPT02093	18 0	5945 1	21 0	39 0	5924 1
CPT02193	NP	NP	NP	NP	NP
CPT02293	42 0	5930 1	16 0	58 0	5914 1
CPT02393	32 0	5941 2	18 0	50 0	5923 2
CPT02493	NDE	NDE	NDE	NDE	NDE
CPT02593	15 0	5955 2	24 0	39 0	5931 2
CPT02693	26 0	5960 4	14 0	40 0	5946 4
CPT02793	24 0	5960 7	18 0	42 0	5942 7
CPT02893	38 5	5956 4	15 5	54 0	5940 9
CPT02993	24 0	5961 0	10 0	34 0	5951 0
CPT03093	NDE	NDE	NDE	NDE	NDE
CPT03193	NDE	NDE	NDE	NDE	NDE
CPT03293	25 0	5959 0	10 0	35 0	5949 0
CPT03393	NDE	NDE	NDE	NDE	NDE
CPT03493	23 0	5966 3	12 0	35 0	5954 3
CPT03593	NDE	NDE	NDE	NDE	NDE
CPT03693	28 0	5961 1	9 0	37 0	5952 1
CPT03793	25 0	5962 1	9 0	34 0	5953 1
CPT03893	NDE	NDE	NDE	NDE	NDE

Definitions

bgs	below ground surface
CPT	cone penetration test
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
NDE	not deep enough
NP	not performed

Table 2-3
Depth to Bedrock at Borehole and Well Locations

Borehole or Well Location	Elevation of Ground Surface (feet)	Depth to Top of KaKl(w) (feet bgs)	Elevation of Top of KaKl(w) (feet)	Depth to Top of KaKl(u) (feet bgs)	Elevation of Top of KaKl(u) (feet)	Thickness of KaKl(w) (feet)
0586	5724 38	9 00	5715 38	NDE	NDE	ND
0686	5814 68	10 50	5804 18	NDE	NDE	ND
0786	5924 94	5 00	5919 94	NDE	NDE	ND
0886	5925 60	1 00	5924 60	15 60	5910 00	14 60
0986	5996 39	30 30	5966 09	NDE	NDE	ND
1086	5996 62	23 00	5973 62	NDE	NDE	ND
4087	5883 00	5 80	5877 20	NDE	NDE	ND
4187	5882 95	3 50	5879 45	25 45	5857 50	21 95
4287	5854 34	6 10	5848 24	NDE	NDE	ND
5887	5995 46	22 00	5973 46	NDE	NDE	ND
5987	5992 90	20 50	5972 40	NDE	NDE	ND
6087	5984 44	27 00	5957 44	NDE	NDE	ND
6187	5984 42	28 00	5956 42	NDE	NDE	ND
6287	5984 54	26 30	5958 24	NDE	NDE	ND
6387	5985 63	25 00	5960 63	NDE	NDE	ND
6487	5986 09	22 00	5964 09	NDE	NDE	ND
6587	5983 48	21 00	5962 48	NDE	NDE	ND
6687	5982 26	15 30	5966 96	NDE	NDE	ND
6787	5970 00	16 40	5953 60	NDE	NDE	ND
6887	5968 91	15 50	5953 41	NDE	NDE	ND
7087	5966 71	12 00	5954 71	NDE	NDE	ND
7187	5963 89	14 00	5949 89	NDE	NDE	ND
7287	5969 60	8 00	5961 60	NDE	NDE	ND
B106089	5993 30	22 50	5970 80	NDE	NDE	ND
B206189	5984 50	20 90	5963 60	NDE	NDE	ND
B206289	5977 59	15 00	5962 59	31 50	5964 09	16 50
B206389	5969 70	13 30	5956 40	31 50	5964 09	16 50
B206489	5969 14	7 30	5961 84	NDE	NDE	ND
B206589	5967 80	7 50	5960 30	36 80	5931 00	29 30
B206689	5959 31	3 70	5955 61	36 80	5931 00	29 30
B206789	5927 90	4 80	5923 10	36 80	5931 00	29 30
B206889	5917 09	3 00	5914 09	36 80	5931 00	29 30
B206989	5882 42	6 00	5876 42	36 80	5931 00	29 30
B207089	5883 07	6 00	5877 07	31 50	5851 57	25 50
B207189	5884 80	5 50	5879 30	30 42	5854 38	24 92
B207289	5948 27	0 20	5948 07	30 42	5854 38	24 92
76792	ND	ND	ND	30 42	5854 38	24 92
76992	ND	ND	ND	30 42	5854 38	24 92
77392	ND	ND	ND	30 42	5854 38	24 92

Borehole or Well Location	Elevation of Ground Surface (feet)	Depth to Top of KaKl(w) (feet bgs)	Elevation of Top of KaKl(w) (feet)	Depth to Top of KaKl(u) (feet bgs)	Elevation of Top of KaKl(u) (feet)	Thickness of KaKl(w) (feet)
70093	5990 90	22 30	5968 60	30 42	5854 38	24 92
70193	5990 30	19 50	5970 80	30 42	5854 38	24 92
70293	5990 70	21 50	5969 20	45 07	5945 63	23 57
70393	5997 90	22 80	5975 10	NDE	NDE	ND
70493	5998 00	21 30	5976 70	NDE	NDE	ND
70593	5998 00	22 00	5976 00	54 25	5943 75	32 25
70693	5991 20	28 50	5962 70	NDE	NDE	ND
70893	5991 20	26 30	5964 90	31 20	5960 00	4 90
70993	5884 40	7 20	5877 20	28 00	5856 40	20 80
71093	5908 40	8 40	5900 00	32 70	5875 70	24 30
71193	5989 30	20 20	5969 10	NDE	NDE	ND
71393	5989 90	21 80	5968 10	38 00	5951 90	16 20
71493	5990 40	24 00	5966 40	NDE	NDE	ND
71593	5988 30	27 00	5961 30	37 00	5951 30	10 00
71693	5988 30	26 50	5961 80	NDE	NDE	ND
71793	5987 27	25 60	5961 67	31 80	5955 47	6 20
71893	5987 70	26 00	5961 70	NDE	NDE	ND
71993	5986 20	36 40	5949 80	42 50	5943 70	6 10
72093	5986 00	35 40	5950 60	NDE	NDE	ND
72193	5973 16	39 60	5933 56	58 20	5914 96	18 60
72293	5973 70	32 70	5941 00	NDE	NDE	ND
TH047292	5926 68	45 50	5881 18	NDE	NDE	ND
TH047492	5891 75	12 50	5879 25	NDE	NDE	ND
70993	5884 40	7 20	5877 20	26 27	5858 13	19 07
71093	5908 40	8 10	5900 30	33 40	5875 00	25 30
65792	5937 80	0 00	5937 80	NDE	NDE	ND
62792	5953 20	3 10	5950 10	NDE	NDE	ND
61992	5944 30	1 80	5942 50	NDE	NDE	ND
71593	5988 30	27 00	5961 30	NDE	NDE	ND
71793	5987 27	25 50	5961 77	NDE	NDE	ND
71393	5989 90	21 90	5968 00	NDE	NDE	ND
72393	5985 20	35 40	5949 80	NDE	NDE	ND
72493	5973 70	32 70	5941 00	NDE	NDE	ND

Definitions

bgs	below ground surface
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
ND	no data
NDE	not deep enough

Table 2-4
Well Construction Details

Location	Ground Surface Elevation (feet)	Top of Casing Elevation (feet)	Formation Completed	Well Casing and Screen Diameter (inches)	Depth to Top of Screen (feet bgs)	Depth to Bottom of Screen (feet bgs)	Depth to Bottom of Well (feet toc)	Bottom of Well Elevation (feet)
0586	5724 38	5726 37	Qc	2 00	4 40	9 76	12 34	5714 03
0686	5814 68	5816 72	Qc	2 00	3 28	8 88	11 47	5805 25
0786	5924 94	5926 54	Qc	2 00	3 00	5 74	7 70	5918 84
0886	5925 60	5926 90	KaKlss(u)	2 00	59 08	63 79	65 50	5861 40
0986	5996 39	5998 23	KaKlss(u)	2 00	122 57	135 35	144 22	5854 01
1086	5996 62	5998 19	Qrf	2 00	3 29	23 78	25 82	5972 37
4087	5883 00	5884 61	Qvf	2 00	3 50	6 46	8 70	5875 91
4187	5882 95	5884 49	KaKlss(u)	2 00	81 21	93 79	96 19	5788 30
4287	5854 34	5855 87	Qvf	2 00	3 00	6 36	7 68	5848 19
5887	5995 46	5996 77	Qrf	2 00	3 50	22 26	24 44	5972 33
5987	5992 90	5994 67	af		3 50	20 75	abandoned	
6087	5984 44	5985 96	Qrf	2 00	3 50	27 47	30 30	5955 66
6187	5984 42	5985 77	af	2 00	3 50	28 24	30 35	5955 42
6287	5984 54	5986 37	af	2 00	3 50	26 56	29 50	5956 87
6387	5985 63	5987 01	af		3 50	25 40	abandoned	
6487	5986 09	5987 34	af	2 00	13 00	23 33	26 11	5961 23
6587	5983 48	5984 99	af	2 00	10 70	23 96	25 67	5959 32
6687	5982 26	5983 67	Qrf	2 00	3 40	17 96	22 59	5961 08
6787	5970 00	5971 76	af		11 72	16 46	abandoned	5952 83
6887	5968 91	5970 32	af	2 00	11 15	15 75	17 02	5953 30
7087	5966 71	5968 38	Qrf	2 00	3 50	16 26	18 96	5949 42
7187	5963 89	5965 49	Qrf	2 00	3 50	13 51	16 25	5949 24
7287	5969 60	5971 25	Qrf	2 00	3 50	6 76	6 52	5964 73
B106089	5993 30	5995 35	af	4 00	3 70	22 40	26 46	5968 89
B206189	5984 50	5986 57	KaKl(w)	4 00	25 90	35 36	abandoned	5947 73
B206289	5977 59	5979 49	KaKl(w)	4 00	32 37	41 82	44 91	5934 58
B206389	5969 70	5971 56	af	4 00	4 00	9 50	abandoned	5954 85
B206489	5969 14	5971 46	KaKl(w)	4 00	3 25	10 00	13 31	5958 15
B206589	5967 80	5969 72	KaKl(w)	4 00	23 50	35 10	37 82	5931 90
B206689	5959 31	5961 20	KaKl(w)	4 00	8 70	18 17	21 56	5939 64
B206789	5927 90	5930 19	KaKl(w)	4 00	9 80	19 28	22 50	5907 69
B206889	5917 09	5919 15	KaKl(w)	4 00	8 00	17 45	20 20	5898 95
B206989	5882 42	5884 32	KaKl(w)	4 00	11 80	21 30	24 29	5860 03
B207089	5883 07	5884 95	KaKlss(w)	4 00	31 32	52 98	56 52	5828 43
B207189	5884 80	5886 72	KaKlss(u)		70 98	75 43	abandoned	5811 03
B207289	5948 27	5950 49	KaKl(w)	4 00	5 20	14 65	17 84	5932 65
76792	RFEDS	5945 37	Qrf	4 00	ND	ND	10 30	5935 07
76992	RFEDS	5957 99	Qrf	4 00	ND	ND	14 41	5943 58
77392	RFEDS	5965 46	Qrf	4 00	ND	ND	12 05	5953 41

Location	Ground Surface Elevation (feet)	Top of Casing Elevation (feet)	Formation Completed	Well Casing and Screen Diameter (inches)	Depth to Top of Screen (feet bgs)	Depth to Bottom of Screen (feet bgs)	Depth to Bottom of Well (feet toc)	Bottom of Well Elevation (feet)
70093	5990 90	5992 91	Qrf	2 00	7 00	22 00	27 00	5965 91
70193	5990 30	5992 36	KaKl(w)	2 00	22 30	37 30	41 41	5950 95
70293	5990 70	5992 71	KaKlss(u)	2 00	52 10	67 10	70 80	5921 91
70393	5997 90	6000 01	Qrf	2 00	7 80	22 80	27 01	5973 00
70493	5998 00	5999 98	KaKl(w)	2 00	24 00	44 00	48 04	5951 94
70593	5998 00	5999 84	KaKlss(u)	2 00	121 00	136 00	140 07	5859 77
70693	5991 20	5992 71	Qrf	2 00	8 40	28 40	31 61	5961 10
70893	5991 20	5993 06	KaKlss(u)	2 00	51 00	66 00	70 02	5923 04
71193	5989 30	5991 11	af	2 00	18 00	20 00	24 01	5967 10
71493	5990 40	5992 43	af	2 00	18 80	22 80	27 03	5965 40
71693	5988 30	5990 22	af	2 00	16 30	26 30	30 20	5960 02
71893	5987 70	5989 67	af	2 00	10 70	25 70	30 33	5959 34
72093	5986 00	5988 32	af	2 00	30 40	35 40	39 31	5949 01
72293	5973 70	5975 94	af	2 00	27 60	32 60	37 32	5938 62
72393	5985 20	5987 52	af	2 00	12 00	22 00	25 86	5961 66
72493	5973 70	5975 88	af	2 00	17 90	27 90	32 01	5943 87

Definitions

af	artificial fill
bgs	below ground surface
KaKl(u)	unweathered undifferentiated Arapahoe and Laramie Formation
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone
ND	no data
Qc	colluvium
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium
RFEDS	Rocky Flats Environmental Database System
toc	top of casing

Table 2-5
Drawdown Recovery Test Data and Results

Well Location	Test Date	Geologic Unit	Lithology	Potentiometric Surface	Test Analysis Method	T (Cooper Only) (ft/day)	S (Cooper Only) (dimensionless)	Estimated K (cm/sec)
70093	04/06/93	Qrf	sandy gravel	Unconfined	Bouwer & Rice	NA	NA	4.05×10^{-4}
70193	04/12/93	KaKl(w)	clayey, siltstone	Unconfined	Bouwer & Rice	NA	NA	1.29×10^{-6}
70293	04/08/93	KaKlss(u)	sandstone, siltsone	Confined	Cooper et al	0.01207	0.0001	4.73×10^{7}
70393	04/05/93	Qrf	gravelly sand	Unconfined	Bouwer & Rice	NA	NA	2.99×10^{-5}
70493	04/12/93	KaKl(w)	claystone	Unconfined	Bouwer & Rice	NA	NA	1.48×10^{7}
70593	04/16/93	KaKlss(u)	siltstone	Confined	Bouwer & Rice	NA	NA	5.60×10^{7}
70593	04/16/93	KaKlss(u)	siltstone	Confined	Cooper et al	0.04333	0.0001	5.92×10^{7}
70693	04/05/93	Qrf	clayey sand	Unconfined	Bouwer & Rice	NA	NA	3.37×10^{-4}
70893	04/20/93	KaKlss(u)	siltstone	Unconfined	Bouwer & Rice	NA	NA	5.90×10^{7}
71193	04/08/93	af	silty sand	Unconfined	Bouwer & Rice	NA	NA	5.90×10^{-6}
71493	04/06/93	af	trash, gravelly sand	Unconfined	Bouwer & Rice	NA	NA	9.62×10^{-6}
71693	NT-Dry	af	trash, silty sand	Unconfined	NT-Dry	NA	NA	NA
71893	04/06/93	af	sand clay	Unconfined	Bouwer & Rice	NA	NA	6.20×10^{5}
72093	04/07/93	af	trash silty clay	Unconfined	Bouwer & Rice	NA	NA	2.32×10^{5}
72293	04/07/93	af	trash, sandy silt	Unconfined	Bouwer & Rice	NA	NA	6.48×10^{5}
72393	04/07/93	af	trash, gravelly sand	Unconfined	Bouwer & Rice	NA	NA	1.35×10^{-4}
72493	NT-Dry	af	trash, clayey sand	Unconfined	NT-Dry	NA	NA	NA

Definitions

af	artificial fill	Qrf	Rocky Flats Alluvium
ft	Feet	S	storage coefficient
K	hydraulic conductivity	T	transmissivity

KaKl(w) weathered undifferentiated Arapahoe and Laramie Formation

KaKlss(u) unweathered undifferentiated Arapahoe and Laramie Formation sandstone or siltstone

NA not applicable

NT not tested

Table 2-6
Hydraulic Conductivity Comparison

Saturated Material	K Values Obtained from the OU 7 Phase I RFI/RI (cm/sec)	K Values Obtained from Previous Investigations (cm/sec)	K Values from Freeze & Cherry (1979) (cm/sec)	K Values from Fetter (1980) (cm/sec)	K Geometric Mean OU 7 Phase I RFI/RI (cm/sec)
Rocky Flats Alluvium (Qrf)	3.37×10^{-4} - 2.99×10^{-5}	10^{3} - 10^{5} (d)	10^{3} - 10^{5} (silty sand)	10^{-4} - 10^{-6} (clayey sand)	1.59×10^{-4}
Weathered Bedrock KaKl(w)	1.29×10^{-6} - 1.48×10^{7}	10^{7} - 10^{-8}(b) 10^{-6} - 10^{7} (d)	NA	NA	4.37×10^{7}
Unweathered Bedrock KaKlss(u)	4.73×10^{7} - 5.92×10^{7}	10^{-6} - 10^{-8}(a) 10^{7} - 10^{-8}(d)	10^{-4} - 10^{-8} (sandstone)	NA	5.41×10^{7}
Disturbed Alluvium & Fill Material (af)	6.20×10^{5} - 5.90×10^{-6}	NA 10^{-4} - 10^{5}(d) 1.27×10^{7} cm/sec (e)	NA	NA	4.37
Landfill Debris (af)	1.35×10^{-4} - 2.32×10^{5}	3.1×10^{-4} (c) 6.7×10^{-4} (d)	NA	NA	

Definitions

af	artificial fill
cm/sec	centimeters per second
K	hydraulic conductivity
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	unweathered undifferentiated Arapahoe and Laramie Formation sandstone
NA	not available
RFI/RI	RCRA facility investigation/remedial investigation

Sources

(a) DOE 1991c
(b) EG&G 1991e
(c) EG&G 1990a
(d) DOE 1991b
(e) EG&G 1993b

Table 2-7
Groundwater Elevations and Saturated Thickness of Surficial Materials

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
0586	Qrf	5726 37	11 00	11 96	11 25	11 09	5715 37	5714 41	5715 12	5715 28	BTOB	BTOB	BTOB	BTOB
0686	Qrf	5816 72	11 16	dry	dry	dry	5805 56	dry	dry	dry	1 38	BTOB	BTOB	BTOB
0786	Qrf	5926 54	5 43	5 41	5 37	5 28	5921 11	5921 13	5921 17	5921 26	1 17	1 19	1 23	1 32
0886	KaKlss(u)	5926 90	41 81	34 24	57 90	49 62	5885 09	5892 66	5869 00	5877 28	NA	NA	NA	NA
0986	KaKlss(u)	5998 23	32 89	31 39	61 51	36 04	5965 34	5966 84	5936 72	5962 19	NA	NA	NA	NA
1086	Qrf	5998 19	13 90	14 43	14 57	13 91	5984 29	5983 76	5983 62	5984 28	10 67	10 14	10 00	10 66
4087	Qvf	5884 61	dry	dry	5 13	4 90	dry	dry	5879 48	5879 71	BTOB	BTOB	2 28	2 51
4187	KaKlss(u)	5884 49	46 40	38 47	34 48	70 13	5838 09	5846 02	5850 01	5814 36	NA	NA	NA	NA
4287	Qvf	5855 87	3 39	3 10	3 29	3 32	5852 48	5852 77	5852 58	5852 55	4 24	4 53	4 34	4 31
5887	Qrf	5996 77	13 60	14 15	14 29	13 67	5983 17	5982 62	5982 48	5983 10	9 71	9 16	9 02	9 64
5987	Qrf	5994 67	abandoned											
6087	Qrf	5985 96	13 28	13 66	13 55	13 18	5972 68	5972 30	5972 41	5972 78	15 24	14 86	14 96	15 34
6187	af/Qrf	5985 77	13 25	13 59	13 53	13 29	5972 52	5972 18	59/2 24	5972 48	16 10	15 76	15 82	16 06
6287	af/Qrf	5986 37	14 50	14 75	14 74	14 58	5971 87	5971 62	5971 63	5971 79	13 63	13 38	13 39	13 55
6387	af/Qrf	5987 01	abandoned											
6487	af/Qrf	5987 34	20 15	20 62	21 02	21 13	5967 19	5966 72	5966 32	5966 21	3 10	2 63	2 23	2 12
6587	Qrf	5984 99	14 48	15 17	15 55	15 25	5970 51	5969 82	5969 44	5969 74	8 03	7 34	6 96	7 26
6687	Qrf	5983 67	13 20	13 85	14 22	13 96	5970 47	5969 82	5969 45	5969 71	3 51	2 86	2 49	2 75
6787	Qrf	5971 76	11 51	11 65	11 61	11 33	5960 25	5960 11	5960 15	5960 43	6 65	6 51	6 55	6 83
6887	Qrf	5970 32	10 24	10 39	10 33	10 07	5960 08	5959 93	5959 99	5960 25	6 67	6 52	6 58	6 84
7087	Qrf	5968 38	16 57	16 40	18 13	17 91	5951 81	5951 98	5950 25	5950 47	BTOB	BTOB	BTOB	BTOB
7187	Qrf	5965 49	7 58	7 57	7 40	7 13	5957 91	5957 92	5958 09	5958 36	8 02	8 03	8 20	8 47
7287	Qrf	5971 25	5 92	6 15	6 38	5 92	5965 33	5965 10	5964 87	5965 33	3 73	3 50	3 27	3 73
B106089	af/Qrf	5995 35	22 31	22 30	22 30	22 35	5973 04	5973 05	5973 05	5973 00	2 24	2 25	2 25	2 20
B206189	KaKl(w)	5986 57	27 27	23 48	21 91	21 34	5959 30	5963 09	5964 66	5965 23	NA	NA	NA	NA

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
B206289	KaKl(w)	5979 49	22 93	19 38	34 10	26 42	5956 56	5960 11	5945 39	5953 07	NA	NA	NA	NA
B206389	af/Qrf	5971 56	11 88	11 82	11 97	11 99	5959 68	5959 74	5959 59	5959 57	3 28	3 34	3 19	3 17
B206489	Qrf/KaKl(w)	5971 46	6 50	6 55	6 71	6 26	5964 96	5964 91	5964 75	5965 20	3 12	3 07	2 91	3 36
B206589	KaKlss(w)	5969 72	8 80	8 87	9 26	9 08	5960 92	5960 85	5960 46	5960 64	NA	NA	NA	NA
B206689	KaKl(w)	5961 20	18 38	17 56	20 60	19 74	5942 82	5943 64	5940 60	5941 46	NA	NA	NA	NA
B206789	KaKl(w)	5930 19	12 51	11 49	17 02	13 54	5917 68	5918 70	5913 17	5916 65	NA	NA	NA	NA
B206889	KaKl(w)	5919 15	18 55	18 08	19 44	19 03	5900 60	5901 07	5899 71	5900 12	NA	NA	NA	NA
B206989	KaKl(w)	5884 32	21 90	21 35	23 81	23 43	5862 42	5862 97	5860 51	5860 89	NA	NA	NA	NA
B207089	KaKlss(w)	5884 95	24 40	23 42	22 86	27 41	5860 55	5861 53	5862 09	5857 54	NA	NA	NA	NA
B207189	KaKlss(u)	5886 72	28 01	27 65	27 33	27 53	5858 71	5859 07	5859 39	5859 19	NA	NA	NA	NA
B207289	KaKl(w)	5950 49	dry	dry	dry	dry	dry	dry	dry	dry	NA	NA	NA	NA
76792	Qrf	5945 37	NA	NA	dry	dry	NA	NA	dry	dry	NA	NA	NA	BTOB
76992	Qrf	5957 99	NA	NA	dry	dry	NA	NA	dry	dry	NA	NA	NA	BTOB
77392	Qrf	5965 46	10 00	10 12	10 21	10 27	5955 46	5955 34	5955 25	5955 19	BTOB	BTOB	BTOB	BTOB
70093	Qrf	5992 91	NA	15 75	14 75	14 43	NA	5977 16	5978 16	5978 48	NA	NA	8 75	9 07
70193	KaKl(w)	5992 36	NA	14 41	14 43	14 21	NA	5977 95	5977 93	5978 15	NA	NA	NA	NA
70293	KaKlss(u)	5992 71	NA	21 85	18 94	51 00	NA	NA	5973 77	5941 71	NA	NA	NA	NA
70393	Qrf	6000 01	NA	NA	14 23	13 84	NA	NA	5985 78	5986 17	NA	NA	10 68	11 07
70493	KaKl(w)	5999 98	NA	NA	16 03	34 32	NA	NA	5983 95	5965 66	NA	NA	NA	NA
70593	KaKlss(u)	5999 84	NA	NA	45 26	102 96	NA	NA	5954 58	5896 88	NA	NA	NA	NA
70693	Qrf	5992 71	19 35	20 45	20 87	20 18	5973 36	5972 26	5971 84	5972 53	10 66	9 56	9 14	9 83
70893	KaKlss(u)	5993 06	NA	57 69	46 94	62 42	NA	5935 37	5946 12	5930 64	NA	NA	NA	NA
71193	Qrf/af	5991 11	NA	NA	16 47	16 74	NA	NA	5974 64	5974 37	NA	NA	5 54	5 27
71493	af	5992 43	NA	NA	22 58	22 29	NA	NA	5969 85	5970 14	NA	NA	3 45	3 74
71693	Qrf/af	5990 22	NA	NA	NA	dry	NA	NA	NA	dry	NA	NA	NA	BTOB
71893	af	5989 67	NA	NA	NA	19 31	NA	NA	NA	5970 36	NA	NA	NA	8 66

Location	Screened Unit	Top of Casing Elevation (feet)	Depth to Water (feet bgs)				Water-Level Elevation (feet)				Saturated Thickness (feet) (alluvial wells only)			
			12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93	12/22/93	1/26/93	2/26/93	3/22/93
72093	af	5988 32	NA	NA	17 24	17 33	NA	NA	5971 08	5970 99	NA	NA	20 48	20 39
72293	af	5975 94	NA	NA	NA	32 53	NA	NA	NA	5943 41	NA	NA	NA	2 41
72393	af	5987 52	NA	NA	16 36	16 49	NA	NA	5971 16	5971 03	NA	NA	21 36	21 23
72493	af	5975 88	NA	NA	NA	dry	NA	NA	NA	dry	NA	NA	NA	BTOB

Definitions

af	artificial fill
bgs	below ground surface
BTOB	below top of bedrock
KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
KaKlss(u)	undifferentiated Arapahoe and Laramie Formation sandstone
KaKlss(w)	weathered undifferentiated Arapahoe and Laramie Formation sandstone
NA	not available
Qrf	Rocky Flats Alluvium
Qvf	valley-fill alluvium

Table 2-8
Wells with Measured Water Levels Below Screened Section and/or Below Top of Bedrock

Well Location[1]	Bottom of Well Screen Elevation	Top of Bedrock Elevation	December 1992 Water Level	January 1993 Water Level	February 1993 Water Level	March 1993 Water Level
4087	5876 54	5877 20	Dry	Dry	WABS	WABS
7087	5950 09	5954 71	5951 81	5951 98	5950 25	5950 47
77392	5956 56	5956 46	5955 46	5955 34	5955 25	5955 19
B206389	5960 20	5956 40	5959 68	5959 74	5959 59	5959 57
B206689	5941 14	NA	WABS	WABS	5940 60	WABS
B206989	5861 12	NA	WABS	WABS	5860 51	5860 89
B207289	5933 62	NA	Dry	Dry	Dry	Dry

[1] Wells completed in surficial materials - 4087, 7087, 77392 B206389 Wells completed in weathered bedrock - B206689 B206989 and B207289

Definitions

NA not applicable

WABS water level above bottom of screen

Table 2-9
Summary of Lateral Hydraulic Gradients[1]

Month	Surficial Materials			Weathered Bedrock		
	Main Landfill Area[2]	East Landfill Pond Drainage Area[3]	East Landfill Pond Embankment[4]	Main Landfill Area[2]	East Landfill Pond Drainage Area[3]	East Landfill Pond Embankment
December	0 031	0 129	0 160	0 031	0 100	0 241
January	0 031	0 129	0 160	0 030	0 100	0 267
February	0 031	0 128	0 160	0 033	0 113	0 267
March	0 029	0 128	0 160	0 026	0 100	0 241
Mean	0 030	0 128	0 160	0 030	0 103	0 254

1 Hydraulic gradients are dimensionless parameters

2 Hydraulic gradients for the main landfill area were calculated using well pair 5887 and 72293

3 Hydraulic gradients for the East Landfill Pond drainage area were calculated using well pair 0786 and B206389

4 Hydraulic gradients for the East Landfill Pond embankment were calculated using piezometer/well pair TH047492/4187

Table 2-10
Summary of Vertical Hydraulic Gradients[1]

Month	Well Pairs Used to Calculate Vertical Hydraulic Gradients				
	70093/70193	70393/70493	72393/72093	4087/B207089	6487/B206189
December	ND	ND	ND	0 415	0 561
January	-0 057	ND	ND	0 388	0 258
February	0 017	0 098	0 005	0 469	0 118
March	0 024	1 103	0 003	0 599	0 070

[1] The vertical hydraulic gradient was calculated as the quotient of the difference between elevations in water levels divided by the vertical distance between the screened intervals Specifically, the divisor was the difference between the elevation at the center of the screened interval for the well completed in the surficial materials and the elevation of the screened interval completed in the weathered bedrock Hydraulic head potentials and vertical distances between the screened intervals were based on the data presented in tables 2-4 and 2-7, respectively Vertical hydraulic gradients are dimensionless parameters

Definition

ND no data

Table 2-11
Summary of Groundwater Flow Parameters and Rates

Geologic Material	Drainage Area	Geometric Mean Hydraulic Conductivity (cm/sec)	Mean Hydraulic Gradient[1]	Range of Effective Porosity	Range for Average Linear Groundwater Flow Velocity[2] (ft/yr)
af	Main Landfill	2.99×10^{5}	0.030	0.1 - 0.2	9.28 - 4.64
Qc	East Landfill Pond Drainage Area	1.59×10^{-4}	0.128	0.1 - 0.2	210.57 - 105.29
KaKl(w)	Main Landfill	4.37×10^{7}	0.030	0.1 - 0.2	0.14 - 0.07
KaKl(w)	East Landfill Pond Drainage Area	4.37×10^{7}	0.103	0.1 - 0.2	0.47 - 0.23
af	East Landfill Pond Embankment	1.27×10^{7}[3]	0.160	0.1 - 0.2	0.21 - 0.10
KaKl(w)	East Landfill Pond Embankment	4.37×10^{7}	0.254	0.1 - 0.2	1.15 - 0.57

[1] Hydraulic gradient values based on data presented in Table 2-6

$$dh/dx = \frac{H_1 - H_2}{X_1 - X_2} = \text{Hydraulic Gradient, which is a dimensionless parameter}$$

[2] The average linear groundwater flow velocity is calculated as follows

$$q = K\frac{dh}{dx}$$

$$\upsilon = \frac{q}{n} = \frac{K}{n}\frac{dh}{dl}$$

where

- υ average linear groundwater flow velocity
- q Darcy flux (discharge per unit area)
- n effective porosity
- K hydraulic conductivity

[3] Hydraulic conductivity (K) value based on one observation (EG&G 1993b)

Definitions

- af artificial fill
- cm/sec centimeters per second
- ft/yr feet per year
- KaKl(w) weathered undifferentiated Arapahoe and Laramie Formation
- Qc colluvium

Table 2-12
Computed Confidence Interval Widths for Total Dissolved Solids

Well Location	CV	s	n	α/2	t	Mean (mg/L)	CI (mg/L)
70093	NA	NA	1	NA	NA	170[1]	NA
71193	NA	NA	2	NA	NA	218	170-280[2]
71493	NA	NA	2	NA	NA	214	170-270[2]
71693	ND	ND	ND	ND	ND	ND	ND
71893	NA	NA	1	NA	NA	280[1]	NA
6087	0 424	109	18	0 05	1 74	257	301-212
6187	0 158	23	18	0 05	1 74	147	156-137
6287	0 208	36	13	0 05	1 78	174	192-157
6387	0 094	50	11	0 05	1 81	529	556-502
72393	NA	NA	1	NA	NA	1300[1]	NA
72093	NA	NA	1	NA	NA	1200[1]	NA
6487	0 255	86	14	0 05	1 77	339	380-298
6587	0 14	32	12	0 05	1 80	232	249-215
6687	0 667	228	16	0 05	1 75	342	441-242
6787	0 143	25	9	0 05	1 86	176	191-160
6887	0 248	49	18	0 05	1 74	196	216-176
72293	NA	NA	1	NA	NA	1700	NA
72493	ND	ND	ND	ND	ND	ND	ND
B206389	0 118	79	8	0 05	1 90	673	726-619
7287	0 148	51	13	0 05	1 78	346	372-321
B206489	0 121	46	13	0 05	1 78	382	405-359
70393	NA	NA	1	NA	NA	190[1]	NA
1086	0 195	26	17	0 05	1 75	136	147-125
5887	0 197	33	17	0 05	1 75	168	182-154
5987	ND	ND	ND	ND	ND	ND	ND
B106089	1 86	85	9	0 05	1 86	353	406-301

[1] Mean not computed, single observation reported
[2] CI not computed, range of values reported

Definitions

α level of significance
CI confidence interval width
CV coefficient of variation
mg/L milligrams per liter
n number of observations
NA not applicable
ND no data
s standard deviation
t tabulates t" value (Sanders et al 1983)

Table 2-13
Landfill Leachate Flow Rates (SW097)

Date of Measurement	Flow Rate (gpm)	Flow Rate (cfs)
06/16/88	2 2	0 005
04/06/89	26 9[1]	0 06[1]
05/19/89	0 0	0 0
06/20/89	0 0	0 0
07/07/89	3 6	0 008
08/02/89	4 0	0 009
09/06/89	2 2	0 005
10/09/89	24 7[1]	0 05[1]
11/07/89	1 8	0 004
12/05/89	1 8	0 004
08/29/90	6 7	0 015[2]

[1] Believed to be an erroneous flow measurement
[2] Measured using a Palmer-Bowlus flume

Definitions

cfs cubic feet per second
gpm gallons per minute

Source

EG&G 1991f

Table 2-14
Water Balance for the OU 7 Drainage Basin

Month	Average Precipitation (inches)	Pan Evaporation (inches)	Infiltration through Landfill Surface (MG)	Evaporation from Landfill Surface (MG)	GW Inflow Under North GW Intercept System (MG)	Downward Seepage from Landfill into Weathered Bedrock (MG)	Ground-water Base Flow to Landfill Pond (MG)	Surface Runoff (MG)	Discharge to Landfill Pond from GW Intercept System (MG)	Downward Seepage from Landfill Pond into Weathered Bedrock (MG)	Landfill Pond Evaporation (MG)	Volume of Spray Evaporation (MG)	Runoff from Spray Evaporation (MG)	Grass Area Evapo-transpiration (MG)	Landfill Pond Storage (MG)	Pond Water Surface Elevation (feet)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Jan	0 46	-1 24	0 014	-0 205	0 0009	-0 0165	0 000	0 15	0 0173	-0 002	0 00	0 00	0 00	0 00	6 17	5919 7
Feb	0 48	-2 68	0 015	-0 213	0 0009	-0 0165	0 000	0 16	0 0173	-0 002	0 00	0 00	0 00	0 00	6 34	5919 9
Mar	1 22	-3 05	0 038	-0 541	0 0009	-0 0165	0 022	0 40	0 0173	-0 002	-0 15	0 00	0 00	0 00	6 62	5920 2
Apr	1 73	-4 48	0 054	-0 768	0 0009	-0 0165	0 038	0 56	0 0173	-0 002	-0 22	0 00	0 00	0 00	7 02	5920 6
May	2 74	-5 85	0 085	-1 217	0 0009	-0 0165	0 069	0 89	0 0173	-0 002	-0.29	6 47	5 82	-0 65	7 06	5920 7
Jun	1 85	-5 80	0 057	-0 822	0 0009	-0 0165	0 042	0 60	0 0173	-0 002	-0 29	6 47	5 82	-0 65	6 78	5920 4
Jul	1 49	-6 40	0 046	-0 661	0 0009	-0 0165	0 031	0 49	0 0173	-0 002	-0 32	6 47	5 82	-0 65	6 35	5919 9
Aug	1 52	-5 95	0 047	-0 674	0 0009	-0 0165	0 032	0 50	0 0173	-0 002	-0 29	6 47	5 82	-0 65	5 95	5919 4
Sep	1 49	-6 76	0 046	-0 661	0 0009	-0 0165	0 031	0 49	0 0173	-0 002	-0 33	6 47	5 82	-0 65	5 50	5918 8
Oct	0 92	-4 06	0 029	-0 408	0 0009	-0 0165	0 013	0 30	0 0173	-0 002	-0 20	6 47	5 82	-0 65	4 97	5918 0
Nov	0 79	-1 44	0 025	-0 351	0 0009	-0 0165	0 009	0 28	0 0173	-0 002	-0 07	0 00	0 00	0 00	5 18	5918 3
Dec	0 64	-1 24	0 020	-0 284	0 0009	-0 0165	0 004	0 21	0 0173	-0 002	0 00	0 00	0 00	0 00	5 41	5918 7

Change in Storage (ΔP) = Inflows Outflows = (B + D + F + H + I + J + N) (E + G + K + L + O)
Assumed Starting Landfill Pond Storage Volume, Jan 1 1993 = 6 00 million gallons (MG)
Landfill Pond Spillway Elevation = 5921 feet

Definition.

GW groundwater
MG million gallons

Columns

A Month

B Average Precipitation = average rainfall at the Rocky Flats meteorological station

C Pan Evaporation = historical 1991 & 1992 data from the Rocky Flats meteorological station

D Infiltration through Landfill Surface, estimated at 5% of precipitation

E Evaporation from Landfill Surface, estimated at 65% of precipitation

F Groundwater Inflow Under North Groundwater (GW) Intercept System, estimated with actual well pair data and assumed constant

G Downward Seepage from Landfill into Weathered Bedrock, estimated with actual well pair data and assumed constant

H Groundwater Base Flow to Landfill Pond, estimated as sum of columns D F and G see Section 2 6 7 for description

I Surface Runoff = (precip)(Area I)(Runoff Coeff) + + (precip)(Area III)(Runoff Coeff), see Section 2 6 7 for description

J Discharge to Landfill Pond from Groundwater Intercept System, estimated with actual well pair data and assumed constant

K Downward Seepage from Landfill Pond into Weathered Bedrock, estimated with actual well pair data and assumed constant

L Landfill Pond Evaporation = (0 70)(Pan Evap)(water surface area), see Section 2 6 7 for description

M Volume of Spray Evaporation, based on 700 gallons per minute flow rate, 7 hours per day 22 days per month, from May to October

N Runoff from Spray Evaporation, 10% efficiency 90% of spray runs off back to leachate pond

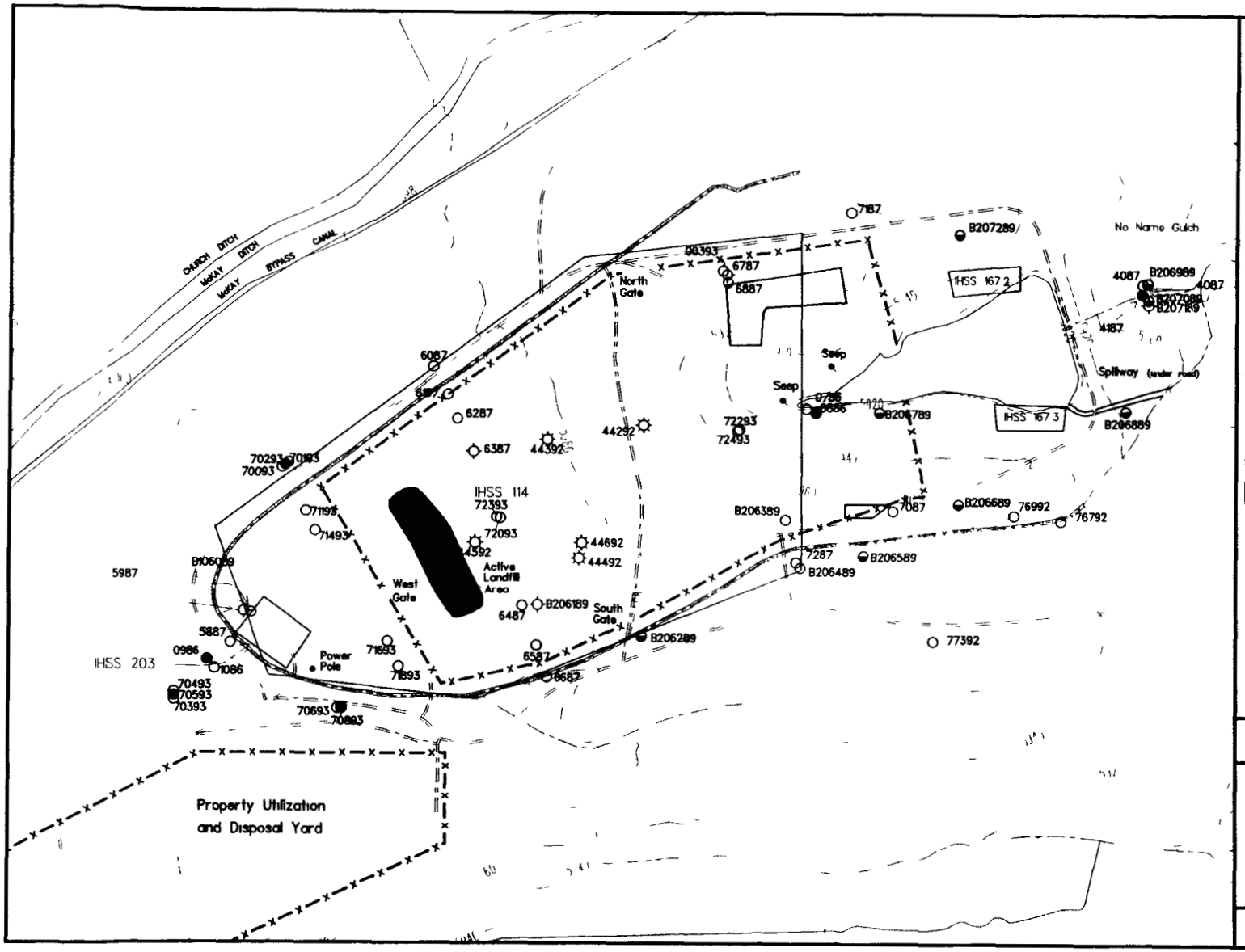
O Grass Area Evapotranspiration, 10% of total spray volume

P Landfill Pond Storage = volume of previous month + H + I + J + K + L + O

Q Pond Water Surface Elevation (see Appendix I)

Section 2

Figures



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Gas Venting Well
- OU7 IHSS Boundary
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Fence
- Asbestos Disposal Area

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

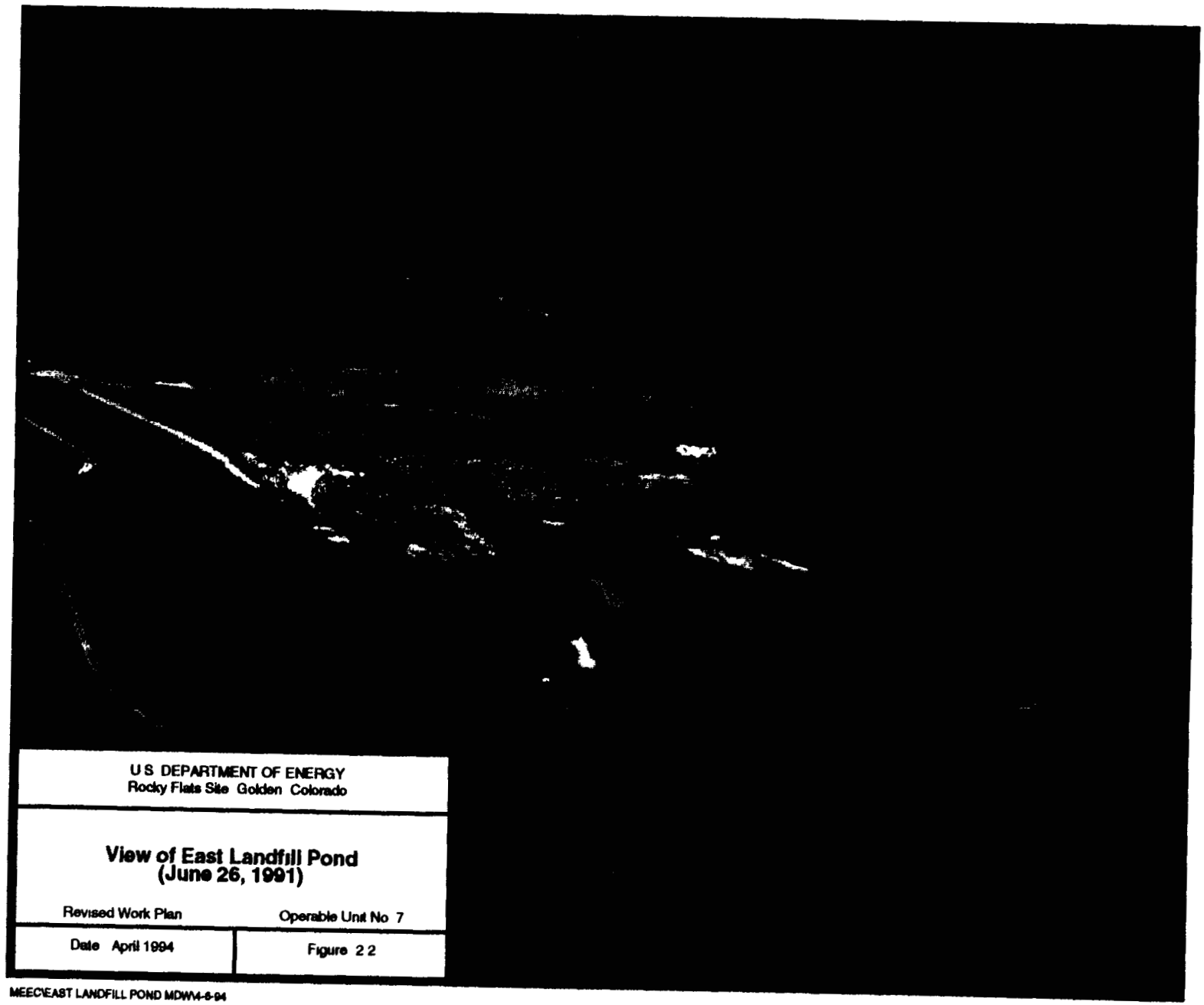
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surface Features at OU 7

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-1

04/04/94 FEATURES.MAP



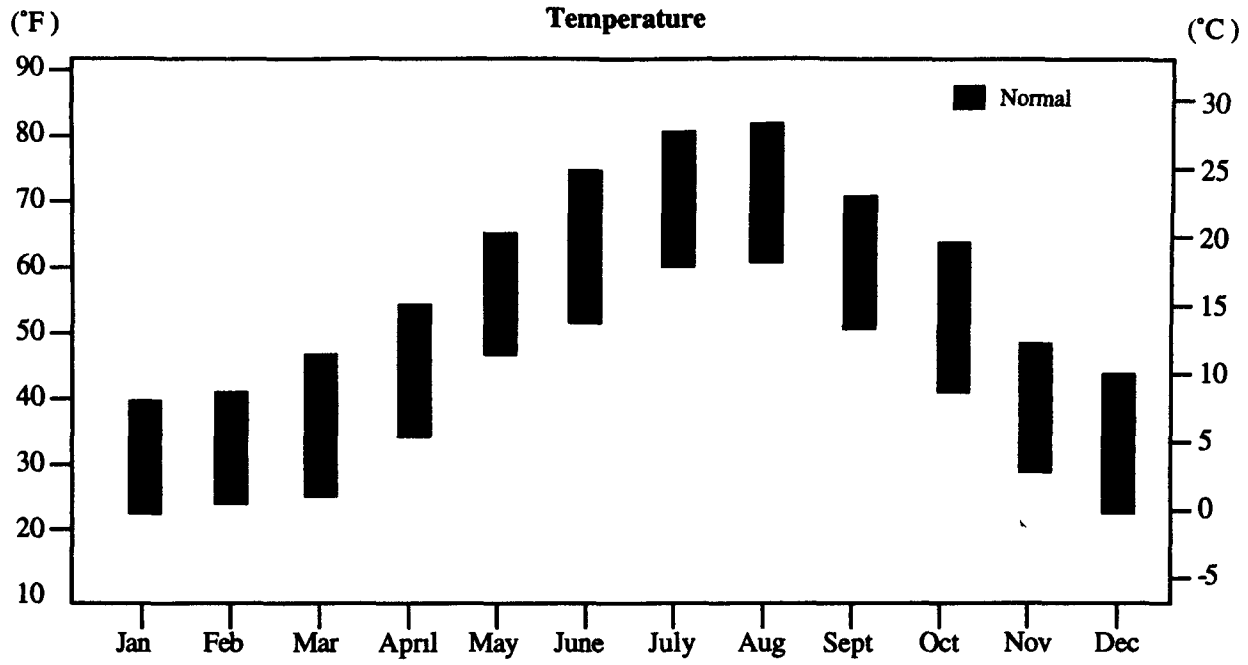
U S DEPARTMENT OF ENERGY
Rocky Flats Site Golden Colorado

View of East Landfill Pond (June 26, 1991)

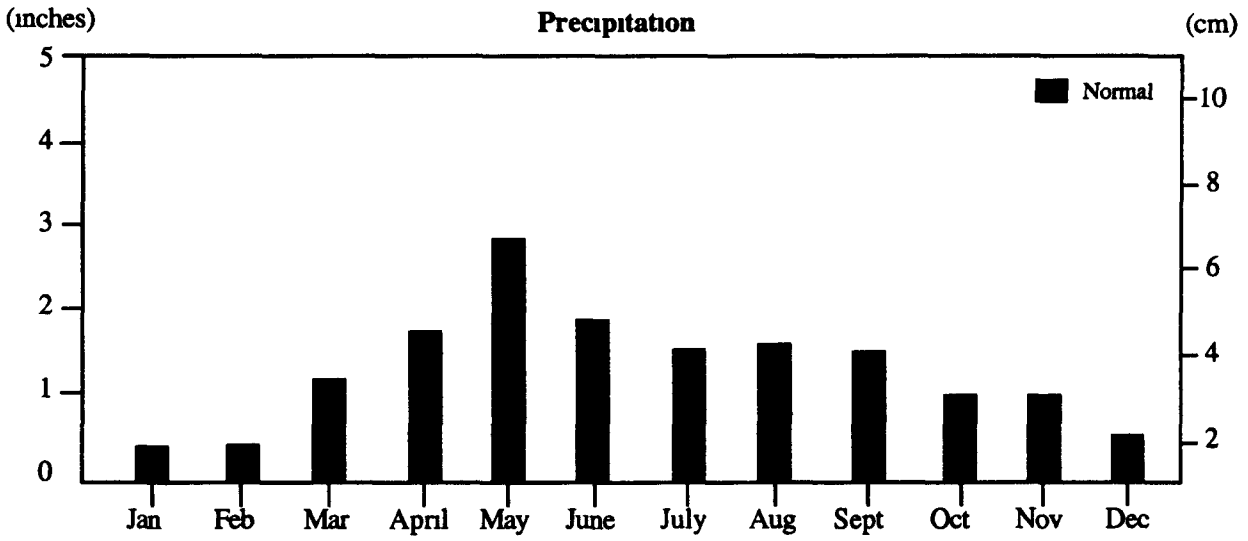
Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 2 2

MEEC\EAST LANDFILL POND MDW\4-6-94



Rocky Flats Plant Average Monthly Temperature Ranges



Rocky Flats Plant Average Monthly Precipitation

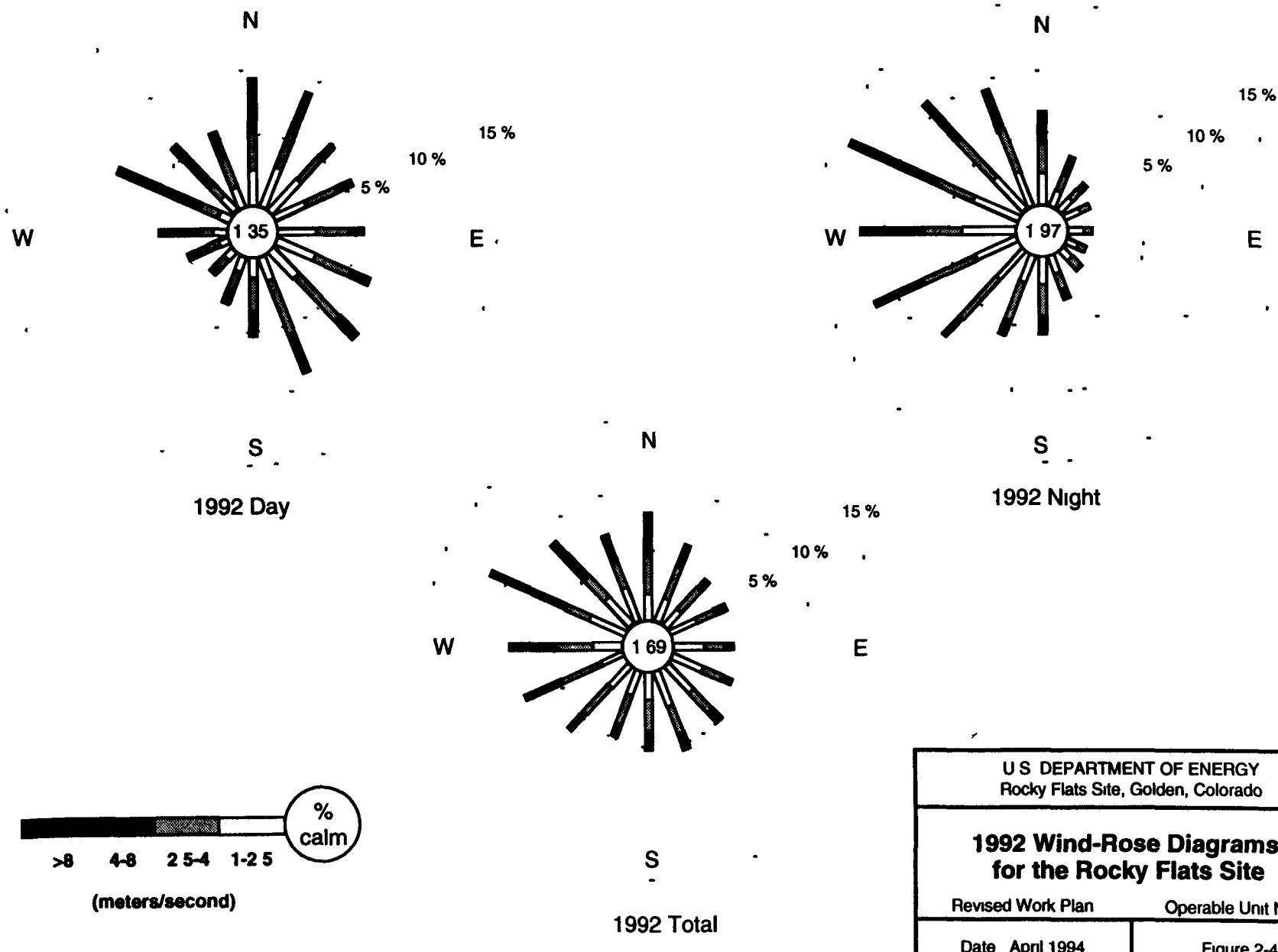
U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Average Monthly Temperature Range and Precipitation

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 2-3

m\ee\precip graph.mdw/4-5-94



U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

1992 Wind-Rose Diagrams for the Rocky Flats Site

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 2-4

MES\wind rose mdw\4-5-94

EXPLANATION

- Denver–Kutch–Midway (31)
- Flatirons (45)
- Haverson (60)
- Nederland (100)
- Gravel/Disturbed Ground/ Interim Soil Cover (111)

NOTE: Additional areas of disturbed ground may result from ongoing landfill activities

Modified from Price and Amen, (1980) (See Table 3–1 for a description of soil types)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

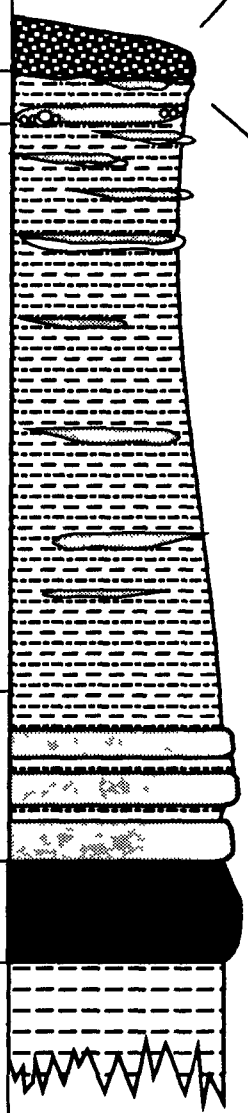
Distribution of Soil Types

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2–5

04/04/94 SOILSMAP

Age	Formation	Thickness (feet)
Quaternary	Rocky Flats Alluvium/ Colluvium	0-100
Cretaceous	Arapahoe Formation	0-50
	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)

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 intervals

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

U S DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Generalized Stratigraphic Section for the Rocky Flats Site

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 2-6

Reference Phase II Geologic Characterization
Surface Geologic Mapping Report, March 1992

M/ES/gen strat mdw/4-5-94

EXPLANATION

Artificial fill

Quaternary

Landslide (Qls)

Colluvium (Qc)

Valley–Fill Alluvium (Qvf)

Rocky Flats Alluvium (Qrf)

Cretaceous

Undifferentiated Arapahoe/ Laramie Formation (KaKl) (Claystone)

Geologic Contact, (dashed where inferred)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

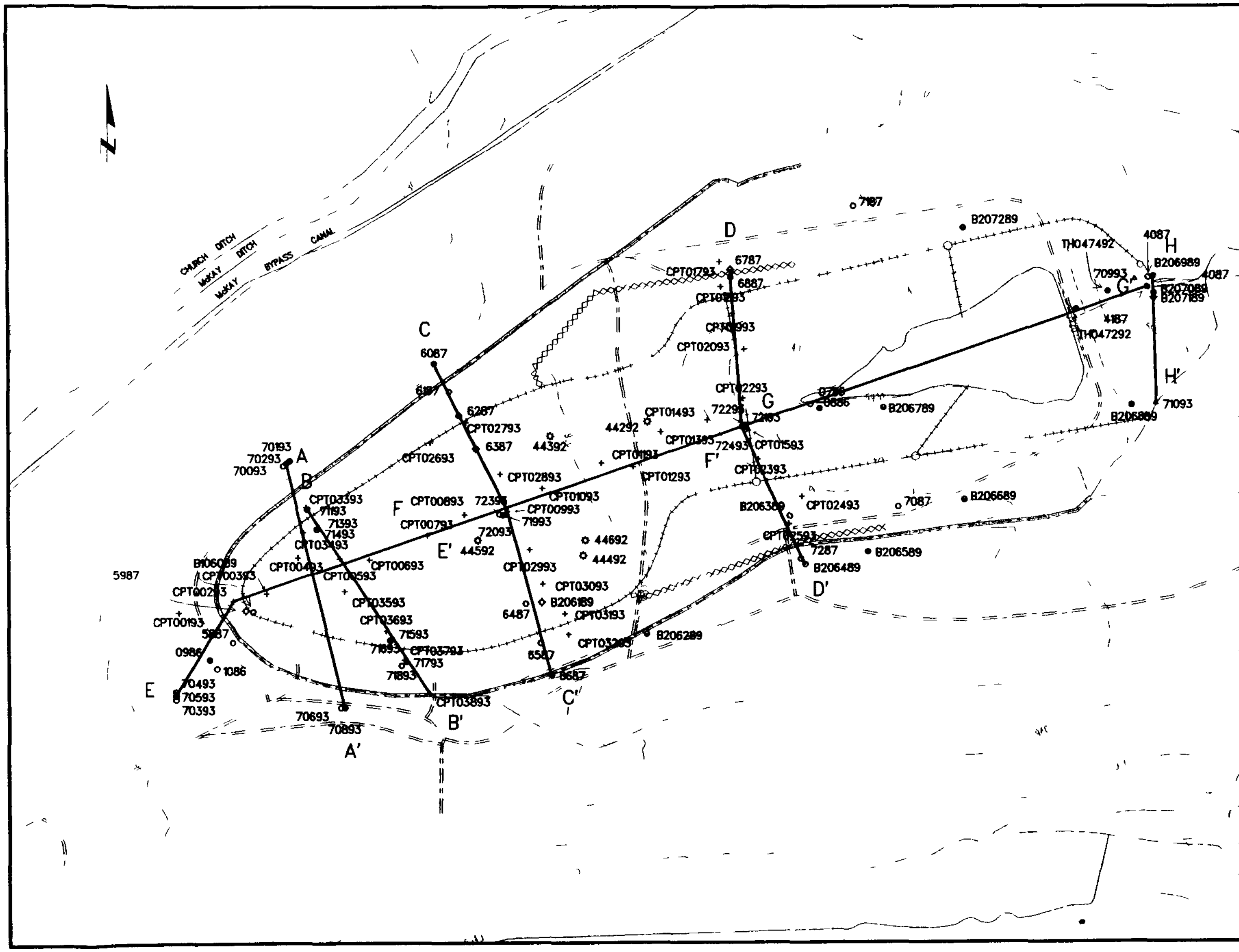
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Map of Surficial Materials

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2–7

04/04/94 GEOLOGY.MAP



EXPLANATION

- ○ Alluvial Well
- ◒ Weathered Bedrock Well
- ● Unweathered Bedrock Well
- ◇ Abandoned Well
- △ Borehole
- ☼ Gas Venting Well
- \+ CPT Location
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Geologic Cross-Section

0 Feet 250 500

Topographic Contour Interval = 20 Feet

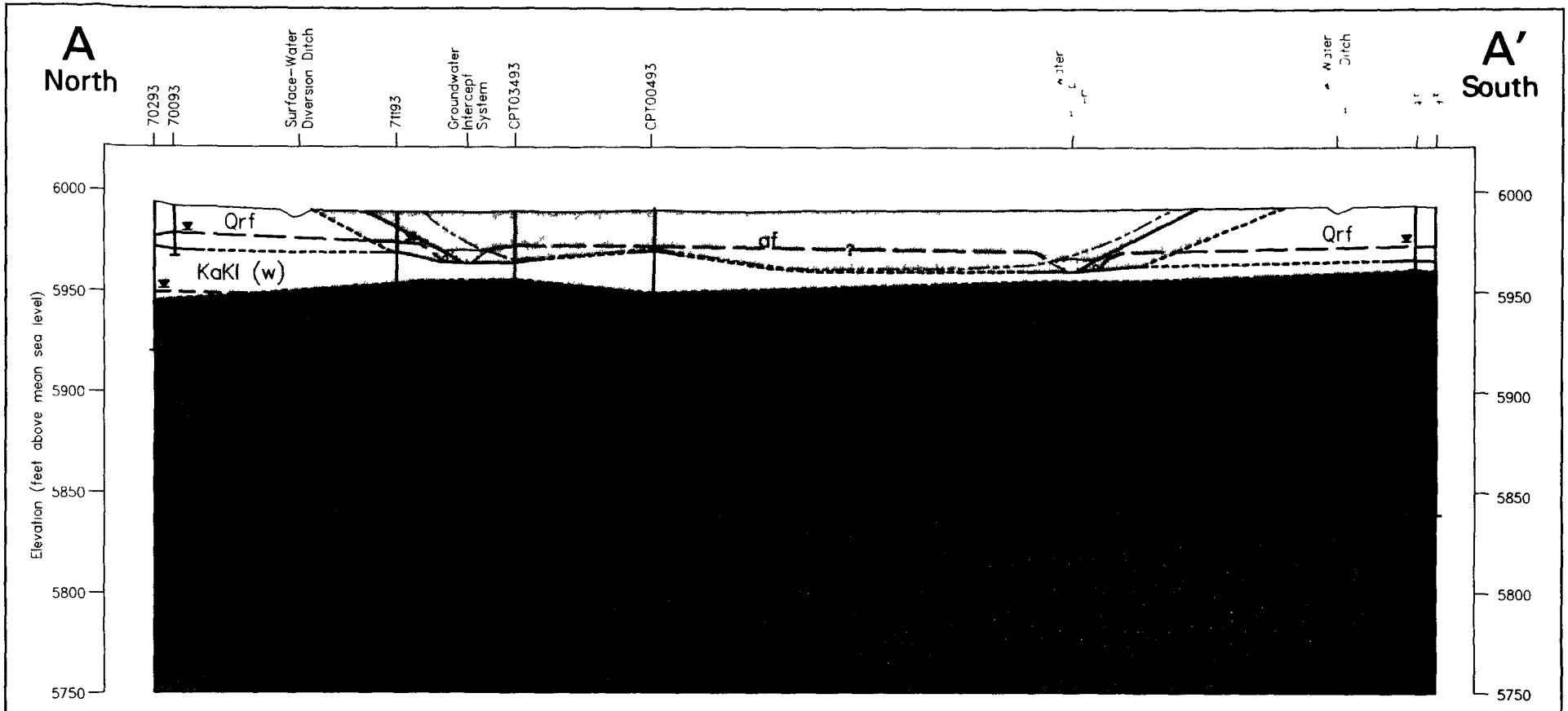
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Geologic Cross-Section Location Map

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-8

04/04/94 GEOPROFLE.MAP



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

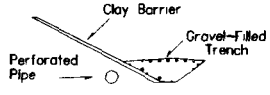
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit) (Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

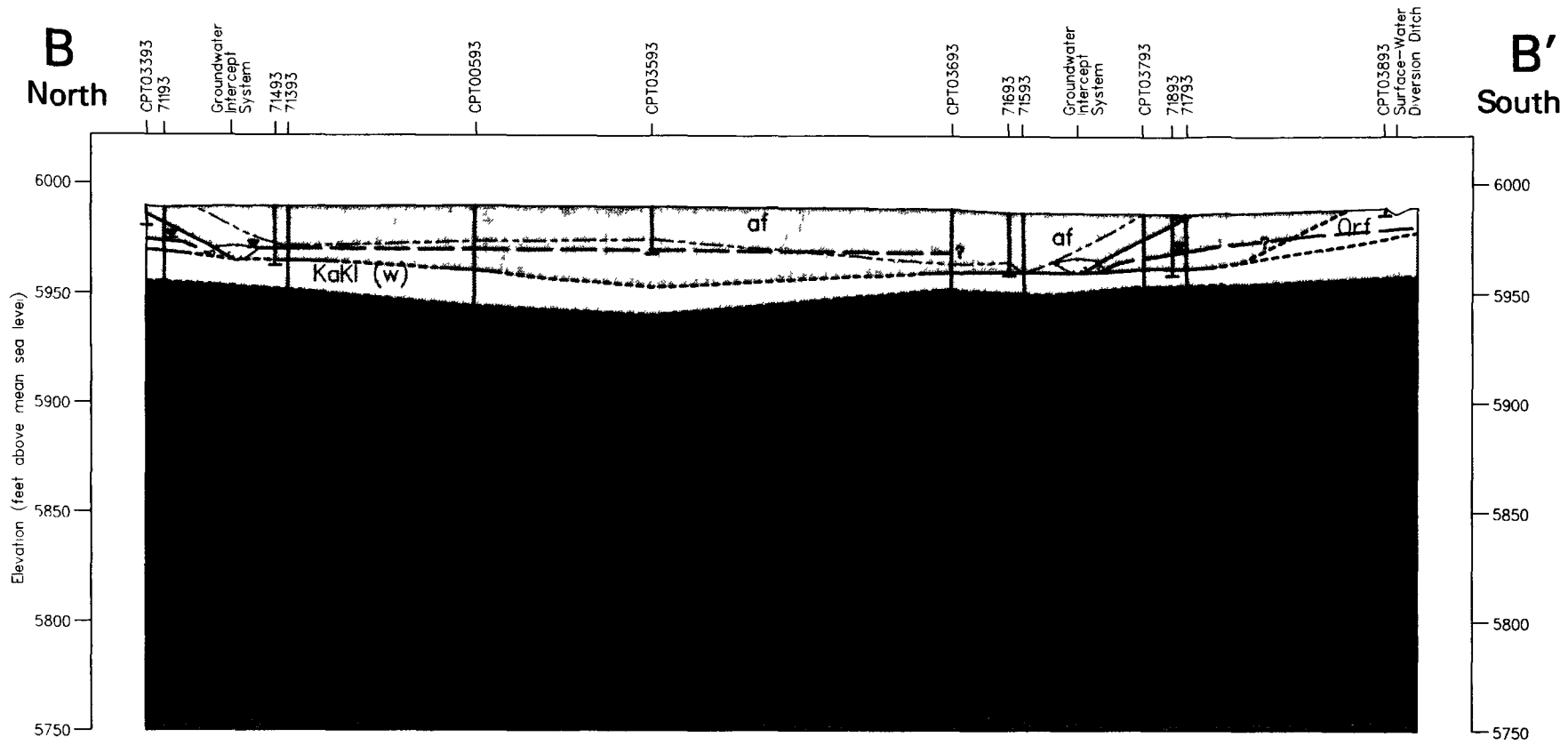
Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section A - A′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-9



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

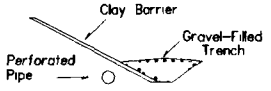
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section B - B′

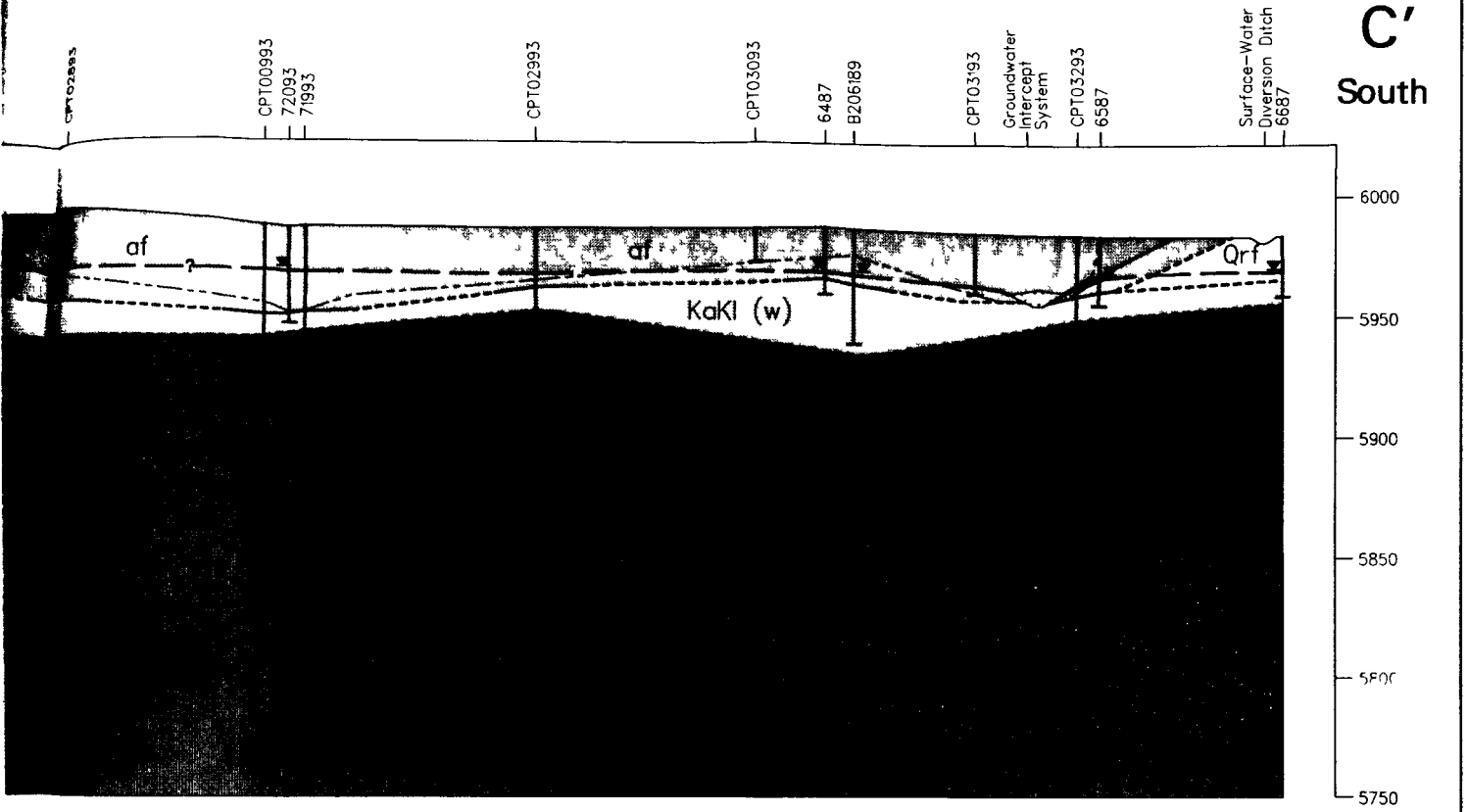
Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-10

NOTICE:

Figure 2-11 through figure 2-15 have been divided into two parts but only the first page lists the figure number.

The Administrative Record Staff



Clay Barrier

Gravel-Filled Trench

Perforated Pipe

Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

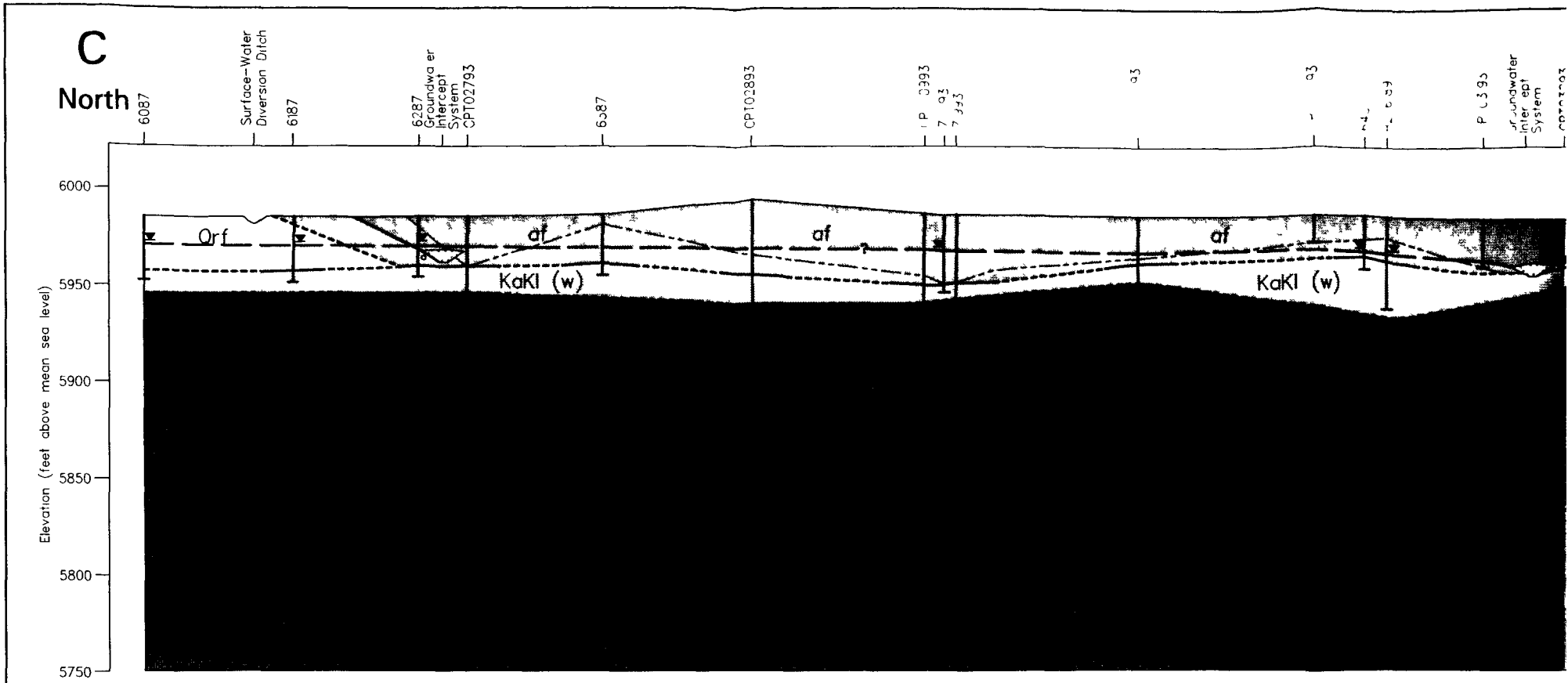
Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section C - C′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-11



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

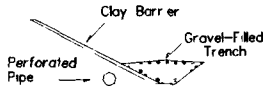
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af – Artificial Fill

Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

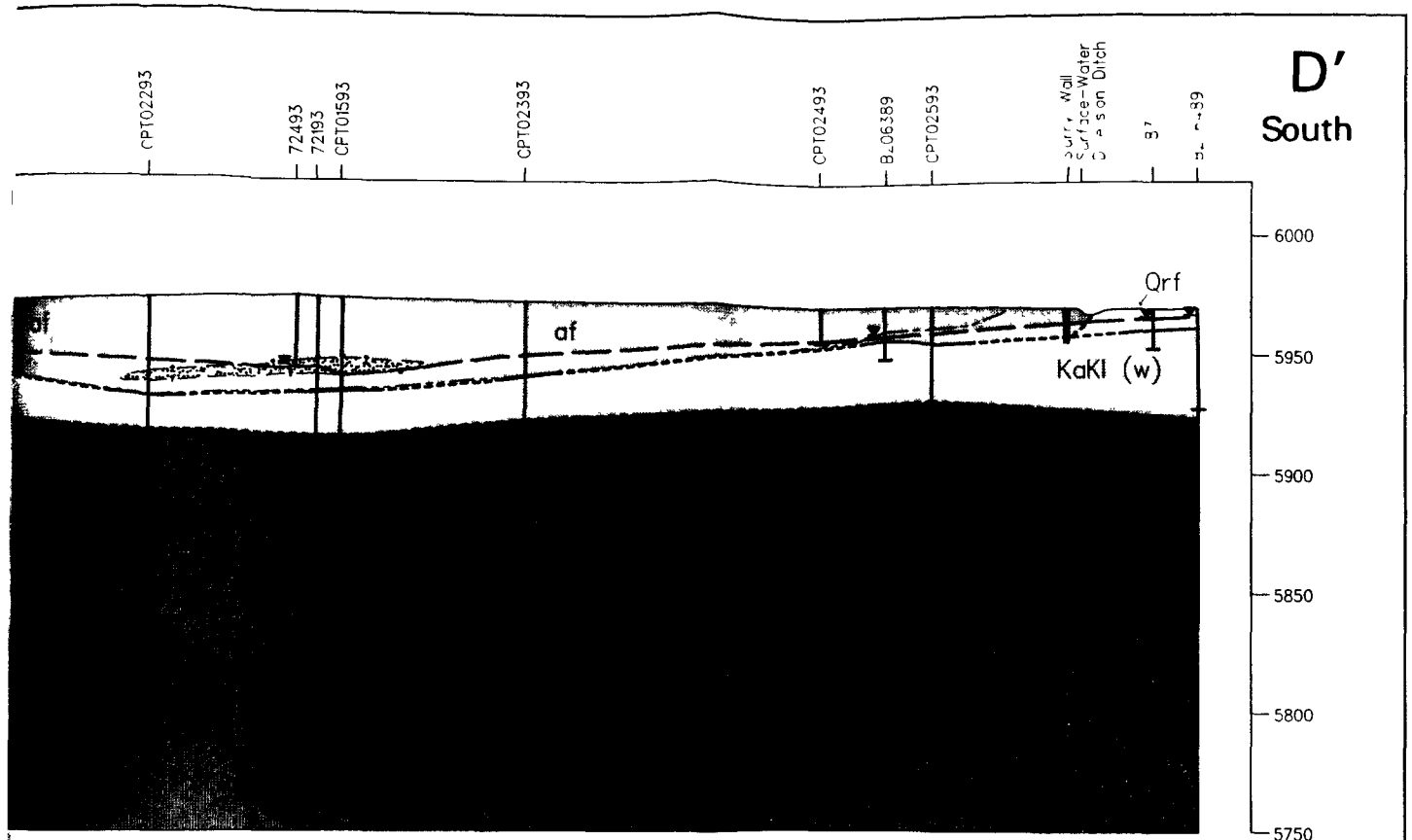
KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet



Clay Barrier

Gravel-Filled Trench

Perforated Pipe

Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

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Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet

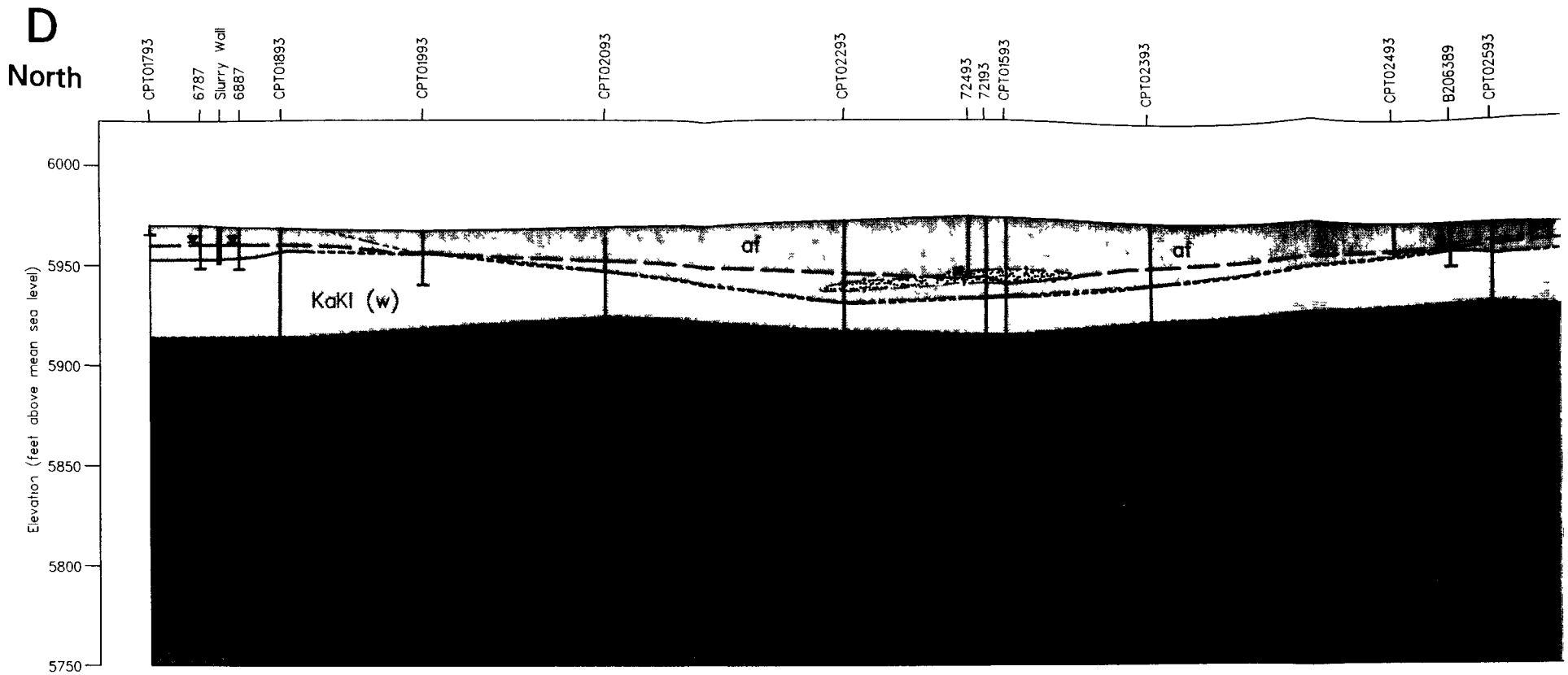
Buried West Landfill Pond Sediments

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

Geologic Cross-Section D - D'

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-12



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

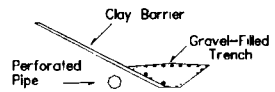
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit) (Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

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Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

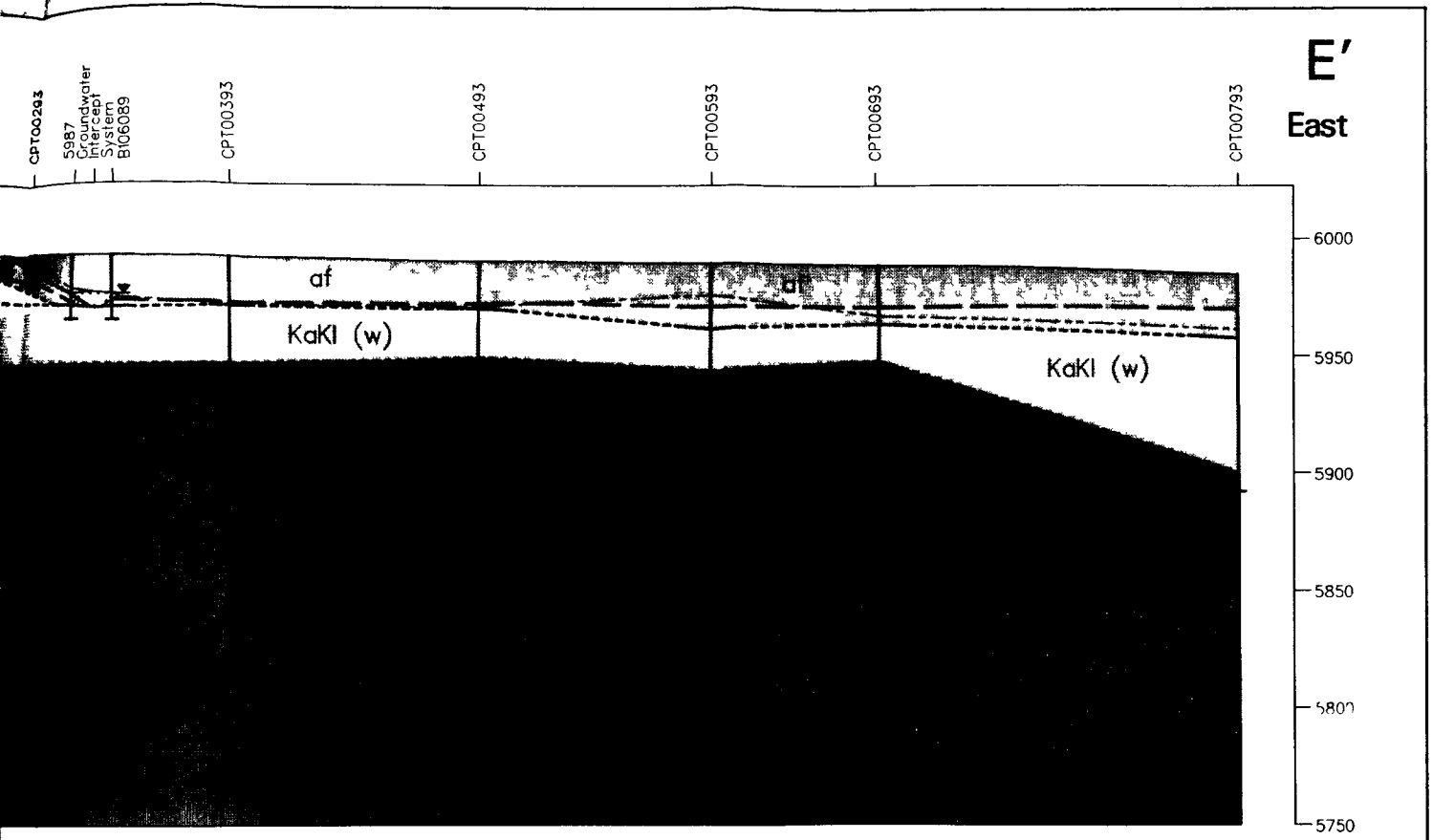
(w) – Weathered

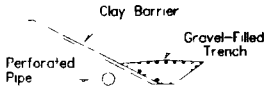
(u) – Unweathered

Buried West Landfill Pond Sediments

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet





Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

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Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

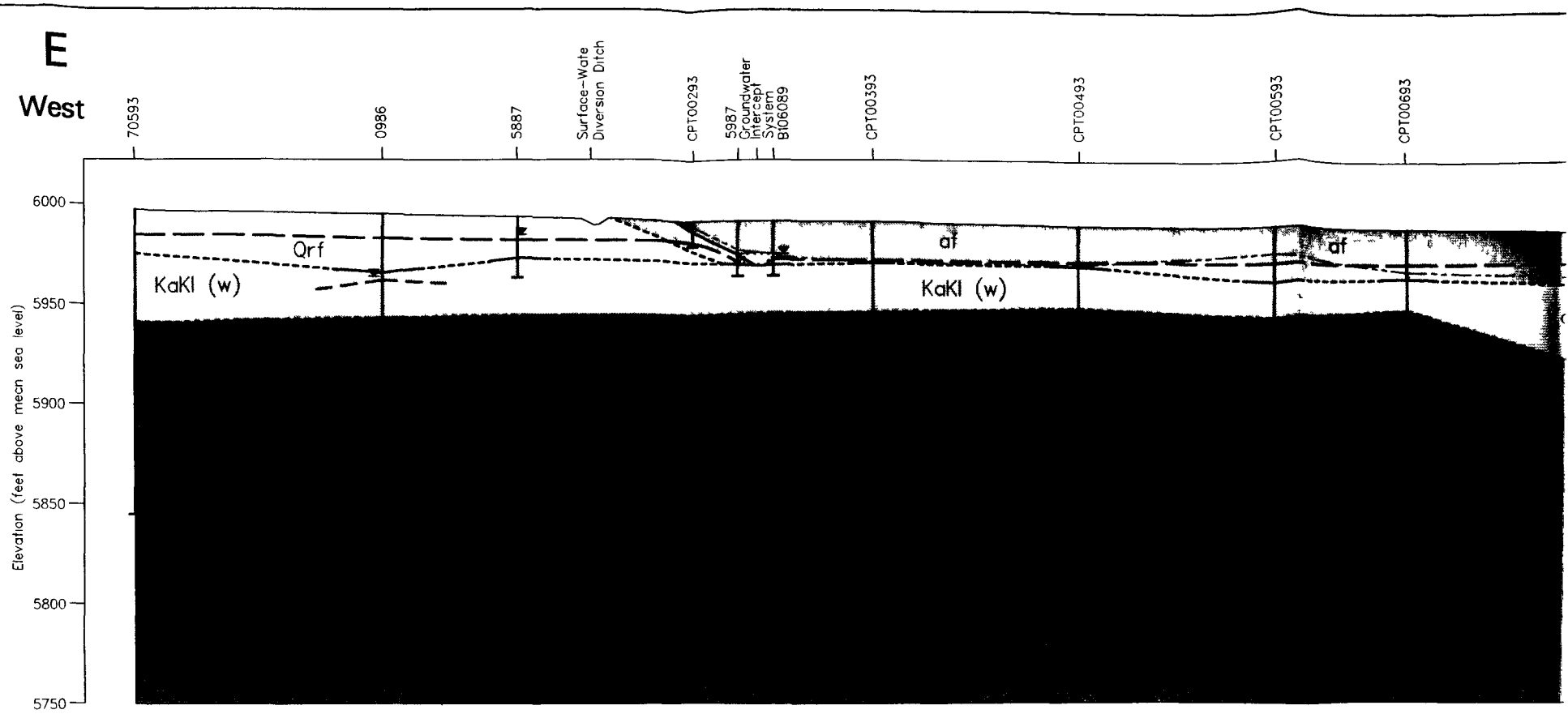
Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section E - E'

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-13



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

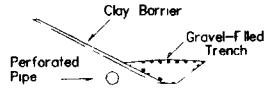
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

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Quaternary

Qrf – Rocky Flats Alluvium

Cretaceous

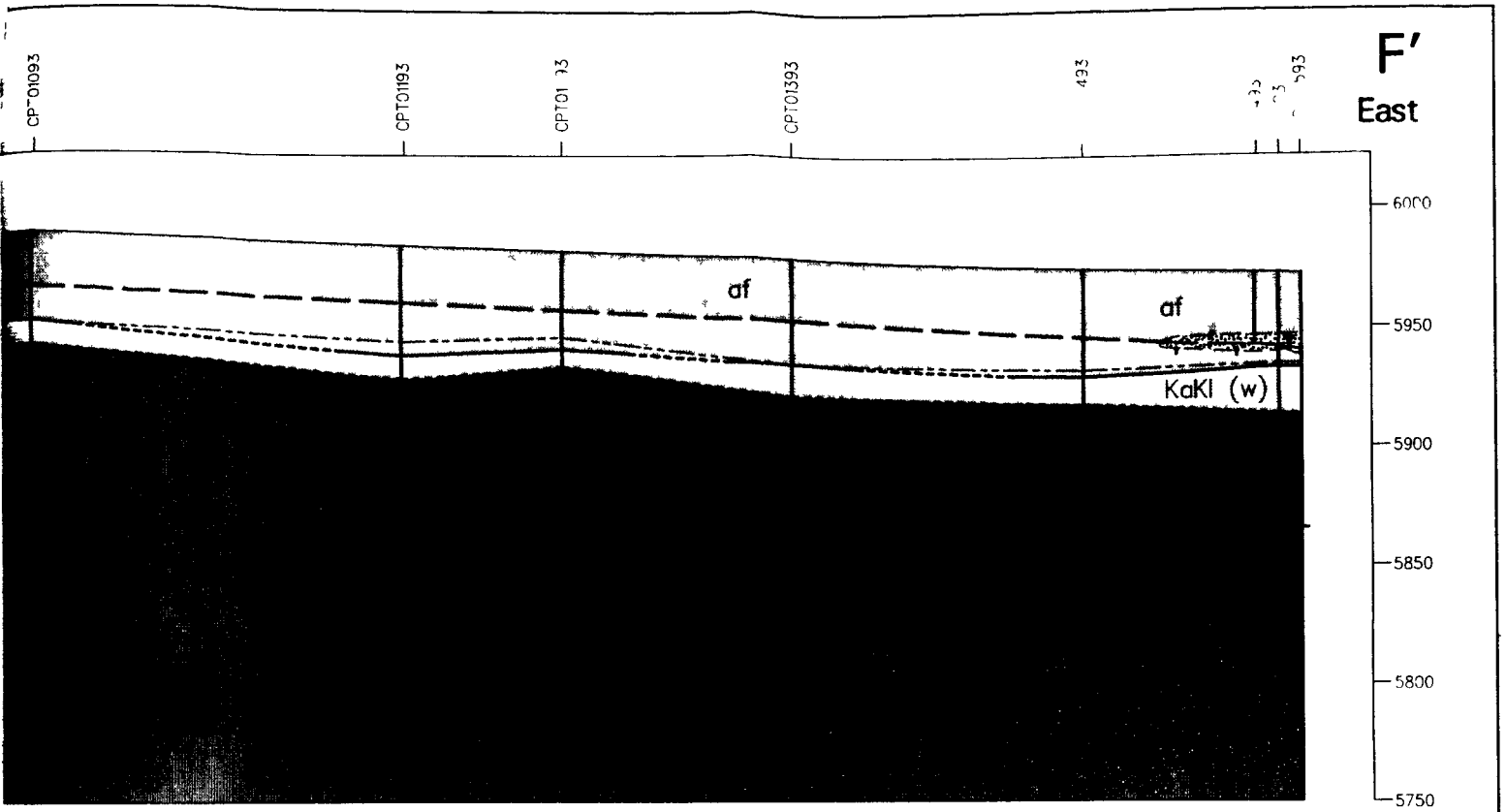
KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet



Clay Barrier

Gravel-Filled Trench

Perforated Pipe

Groundwater Intercept System

af – Artificial Fill

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Buried West Landfill Pond Sediments

Notes 1) Refer to borehole logs (Appendi E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

Horizontal Scale 1 inch = 50 feet

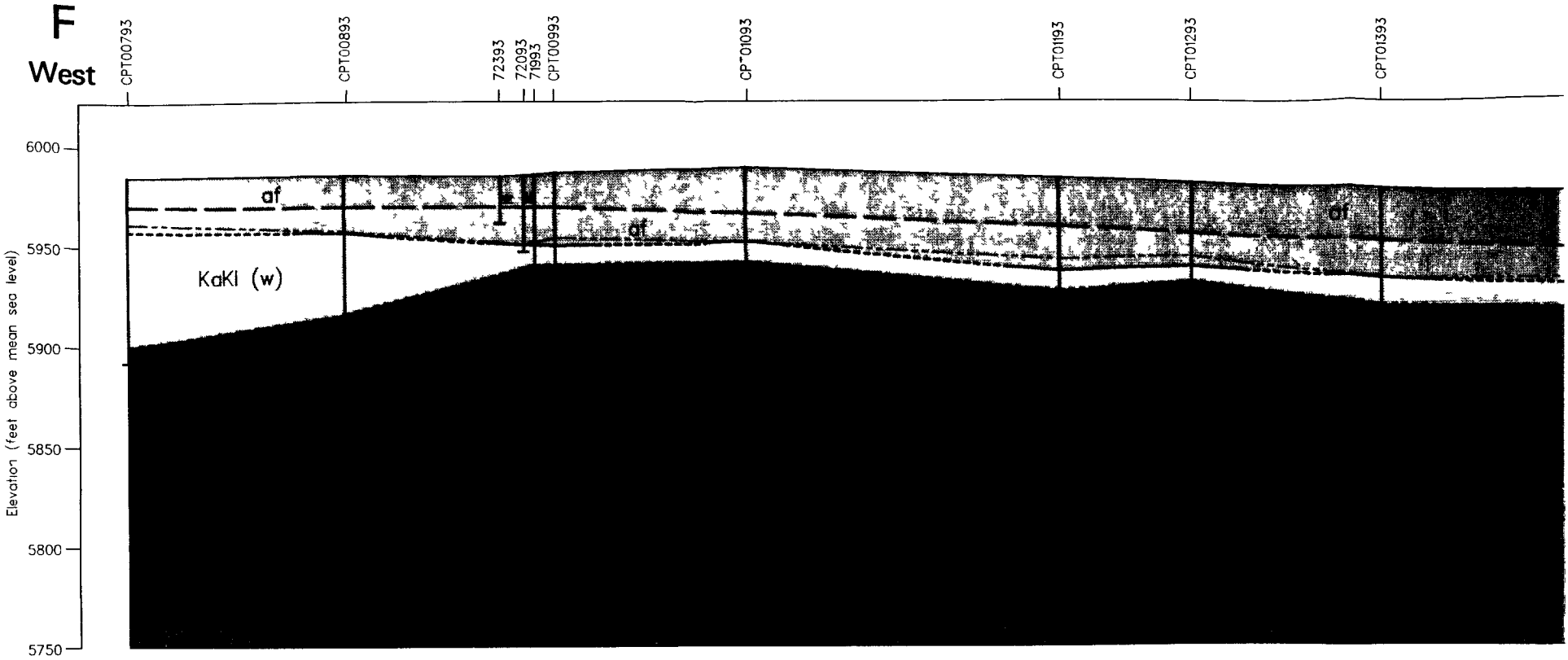
Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section F - F'

Revised Work Plan | Operable Unit No. 7

Date April 1994 | Figure 2-14



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

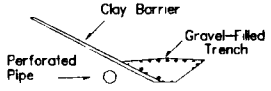
Geologic Contact (dashed where inferred)

Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit) (Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af - Artificial Fill

Cretaceous

KaKl - Undifferentiated Arapahoe and Laramie Formations

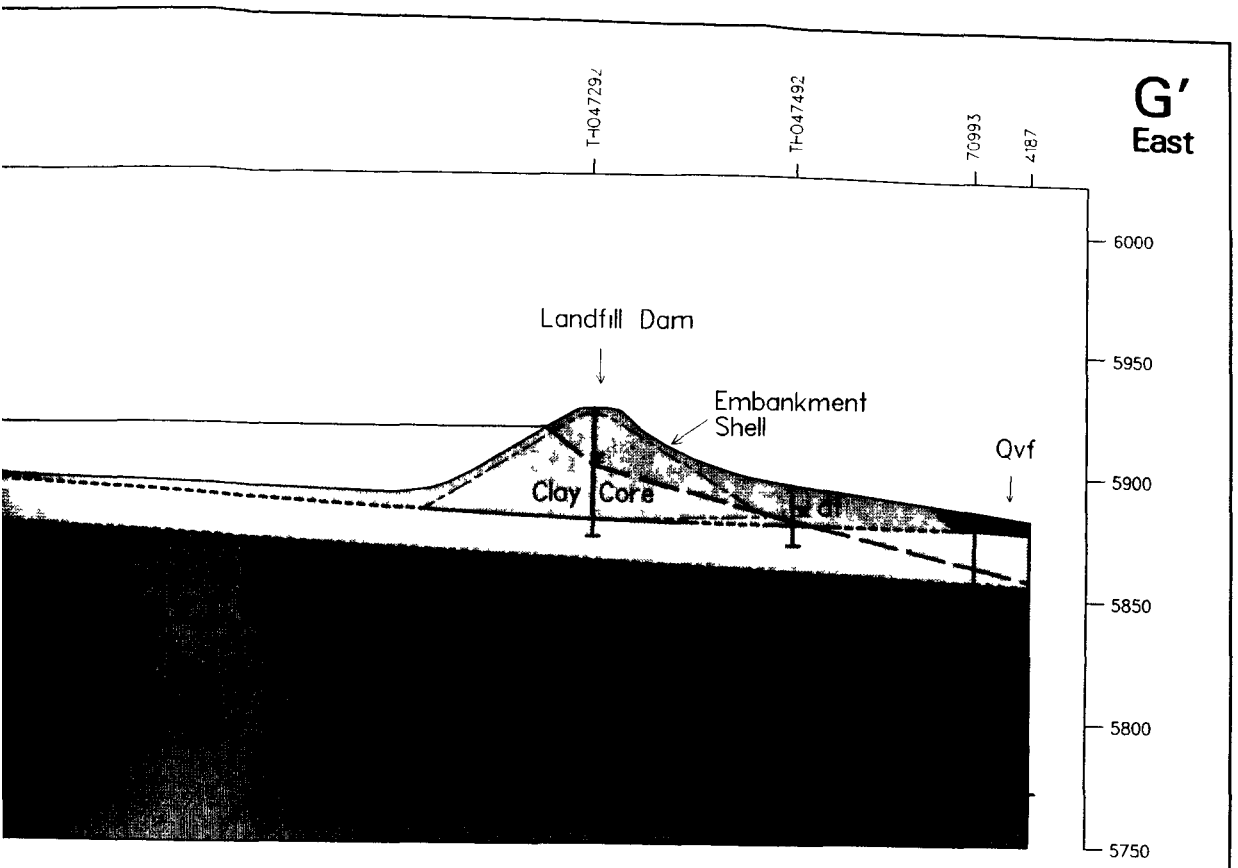
(w) - Weathered

(u) - Unweathered

Buried West Landfill Pond Sediments

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet



FIII

Buried West Landfill
Pond Sediments

III Alluvium

ntiated
and Laramie Formations
ed

red

= 50 feet
= 50 feet

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

Geologic Cross-Section G - G′

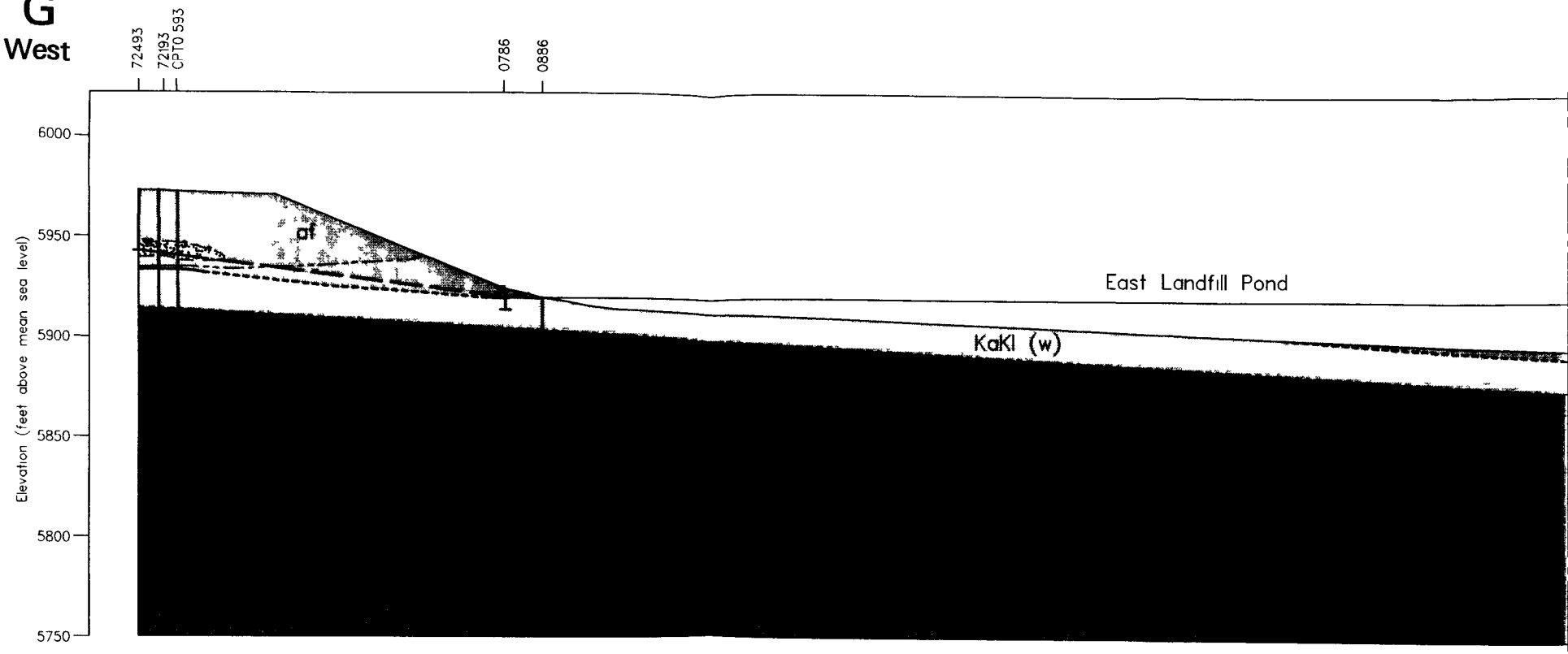
Revised Work Plan

Operable Unit No. 7

Date: April 1994

Figure 2-15

G
West



TH047292 — Well/Borehole Number

71193 — Well/Borehole Number

CPT00493 — CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

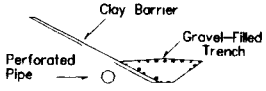
ontact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes. 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

af – Artificial Fill

Quaternary

Qvf – Valley-Fill Alluvium

Cretaceous

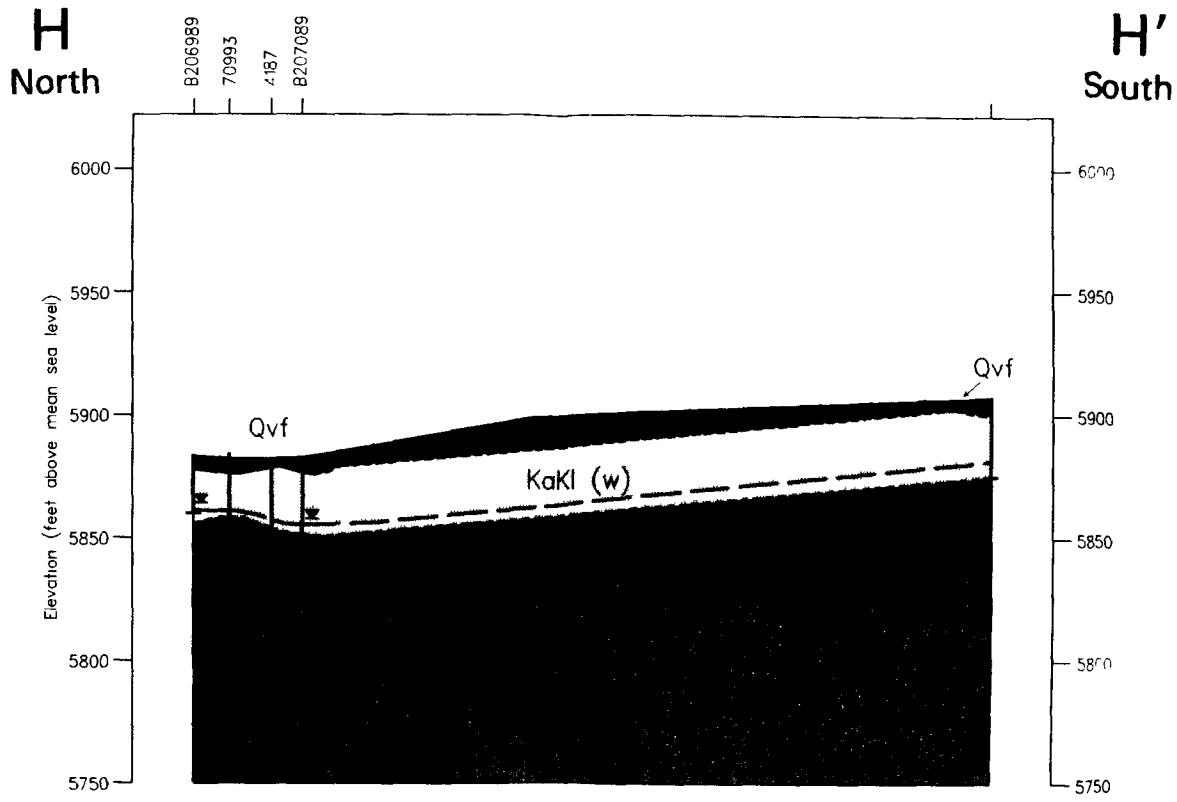
KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

Vertical Scale 1 inch = 50 feet



71193 Well/Borehole Number

CPT00493 CPT Number

Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Geologic Contact (dashed where inferred)

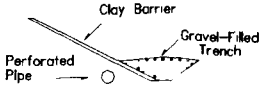
Contact Between Weathered and Unweathered Bedrock

Base of Waste Material

Estimated Potentiometric Surface (Upper Hydrostratigraphic Unit)

(Lower Hydrostratigraphic Unit)

Water Level Measured in March 1993



Groundwater Intercept System

Notes 1) Refer to borehole logs (Appendix E) for detailed geologic description

2) Refer to well construction diagrams (Appendix F) for well construction details

3) Refer to CPT profiles (Appendix D) for data generated during CPT

Quaternary

Qvf – Valley-Fill Alluvium

Qc – Colluvium

Cretaceous

KaKl – Undifferentiated Arapahoe and Laramie Formations

(w) – Weathered

(u) – Unweathered

Horizontal Scale 1 inch = 50 feet

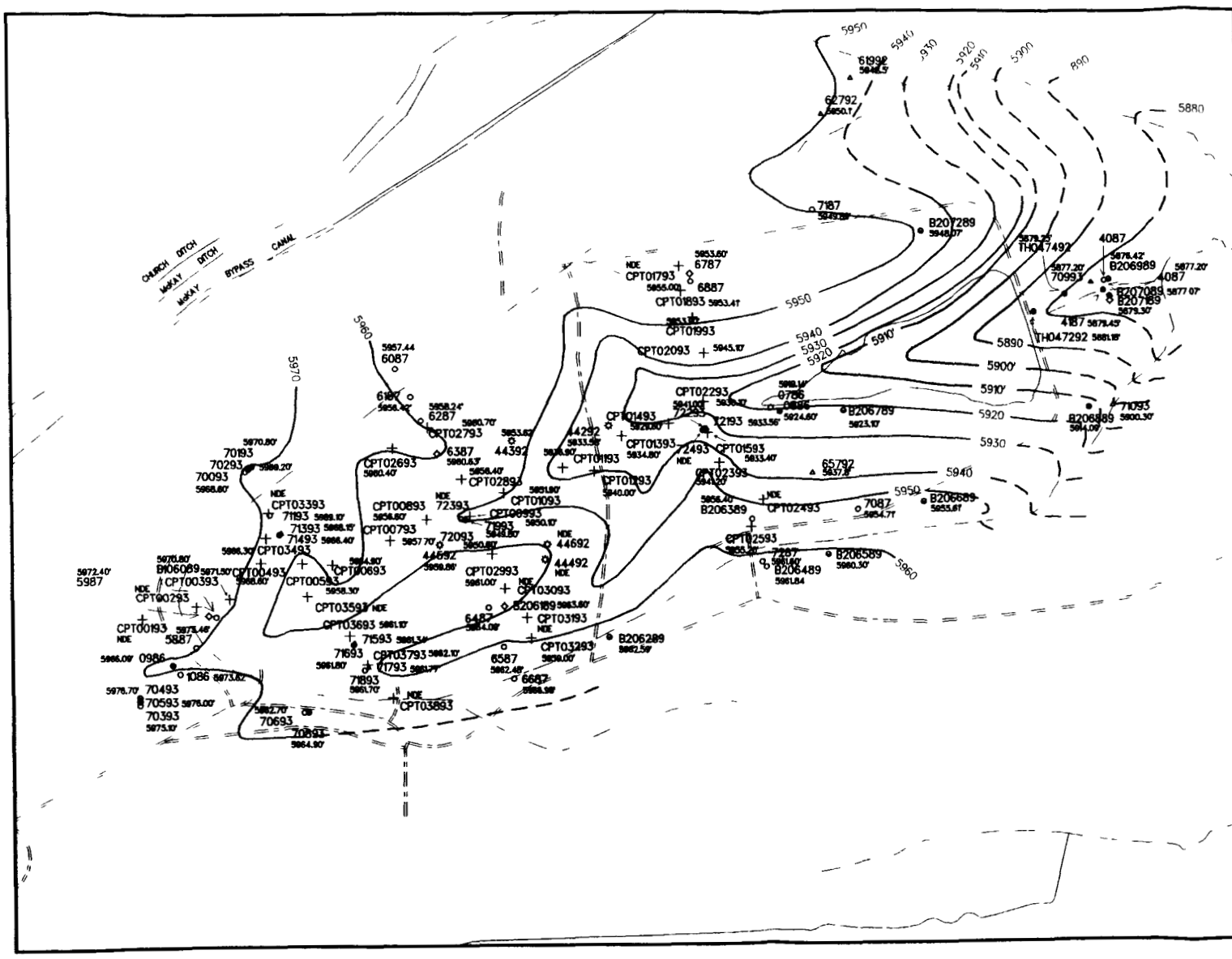
Vertical Scale 1 inch = 50 feet

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

Geologic Cross-Section H - H'

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-16



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Gas Venting Well
- Borehole
- Piezometer
- CPT Location
- Ditch
- Intermittent Stream
- Dirt Road
- Lines of Equal Elevation (dashed where inferred)

NDE – Not Deep Enough

N

0 Feet 250 500

Contour Interval = 10 Feet

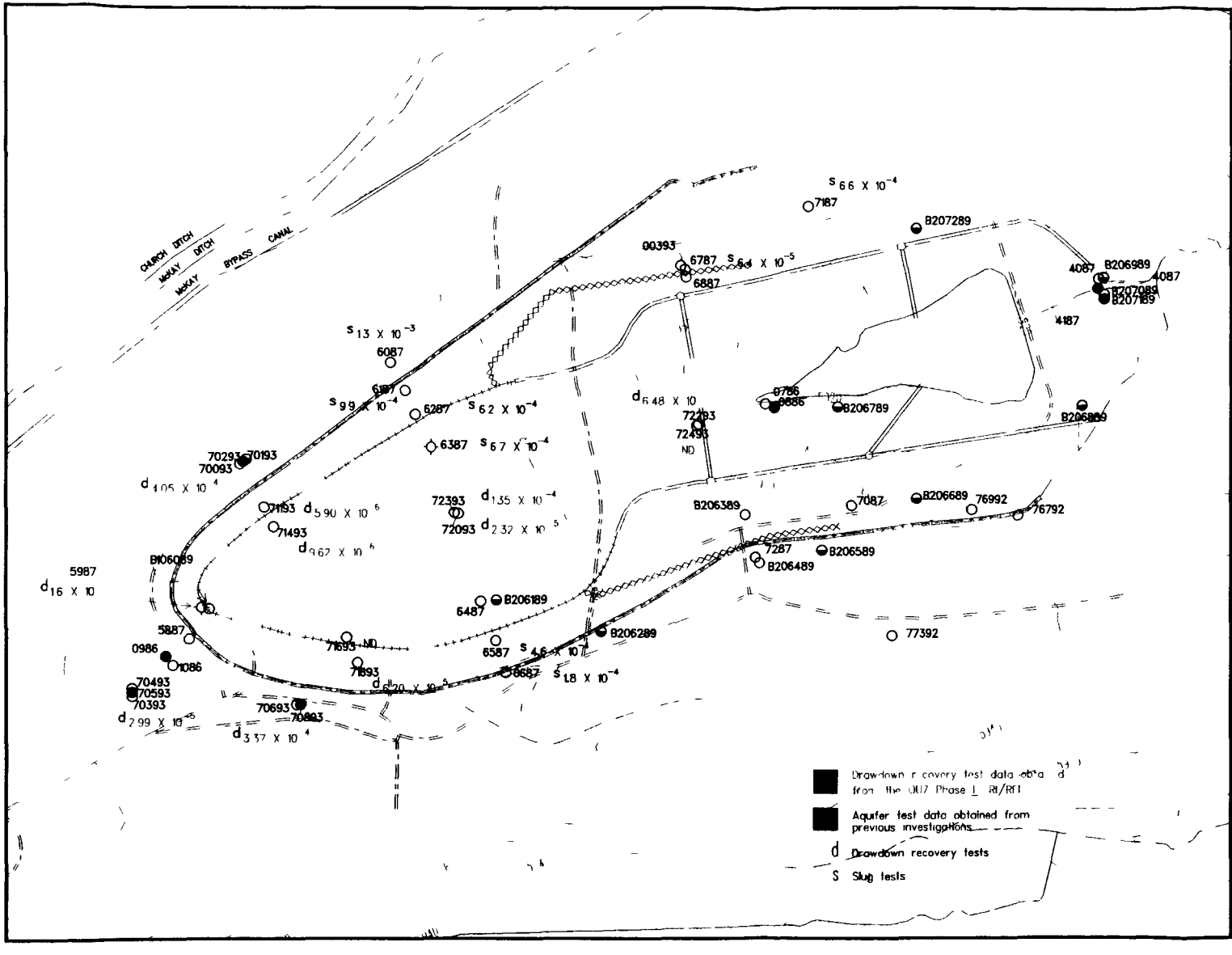
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

Weathered Bedrock Topography

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-17

04/04/94 WBEDTOPOMAP



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)

0 Feet 250 500

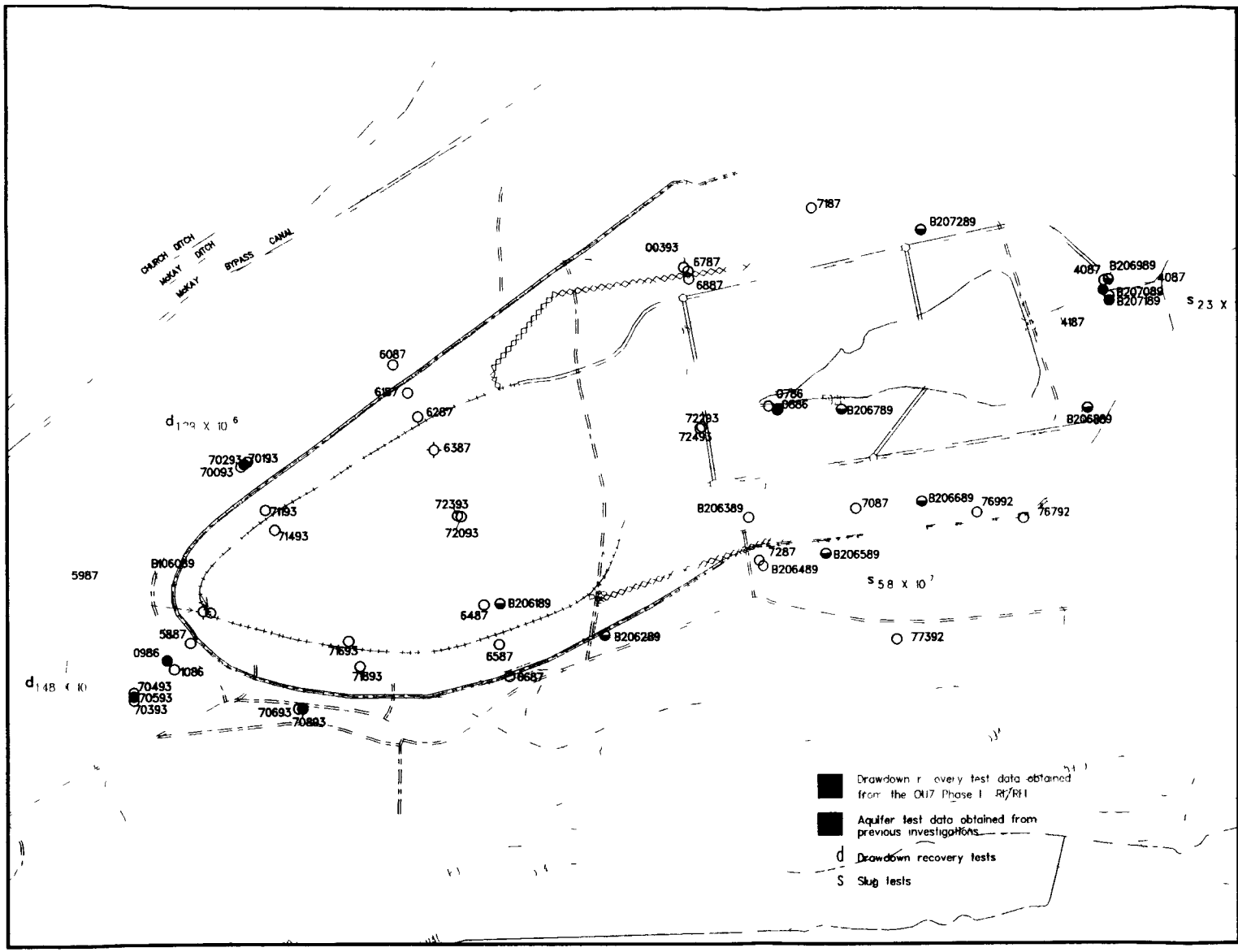
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Surficial Materials

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-18

04/04/94 SMEW.MAP HYDCOND.AML



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)

N

0 Feet 250 500

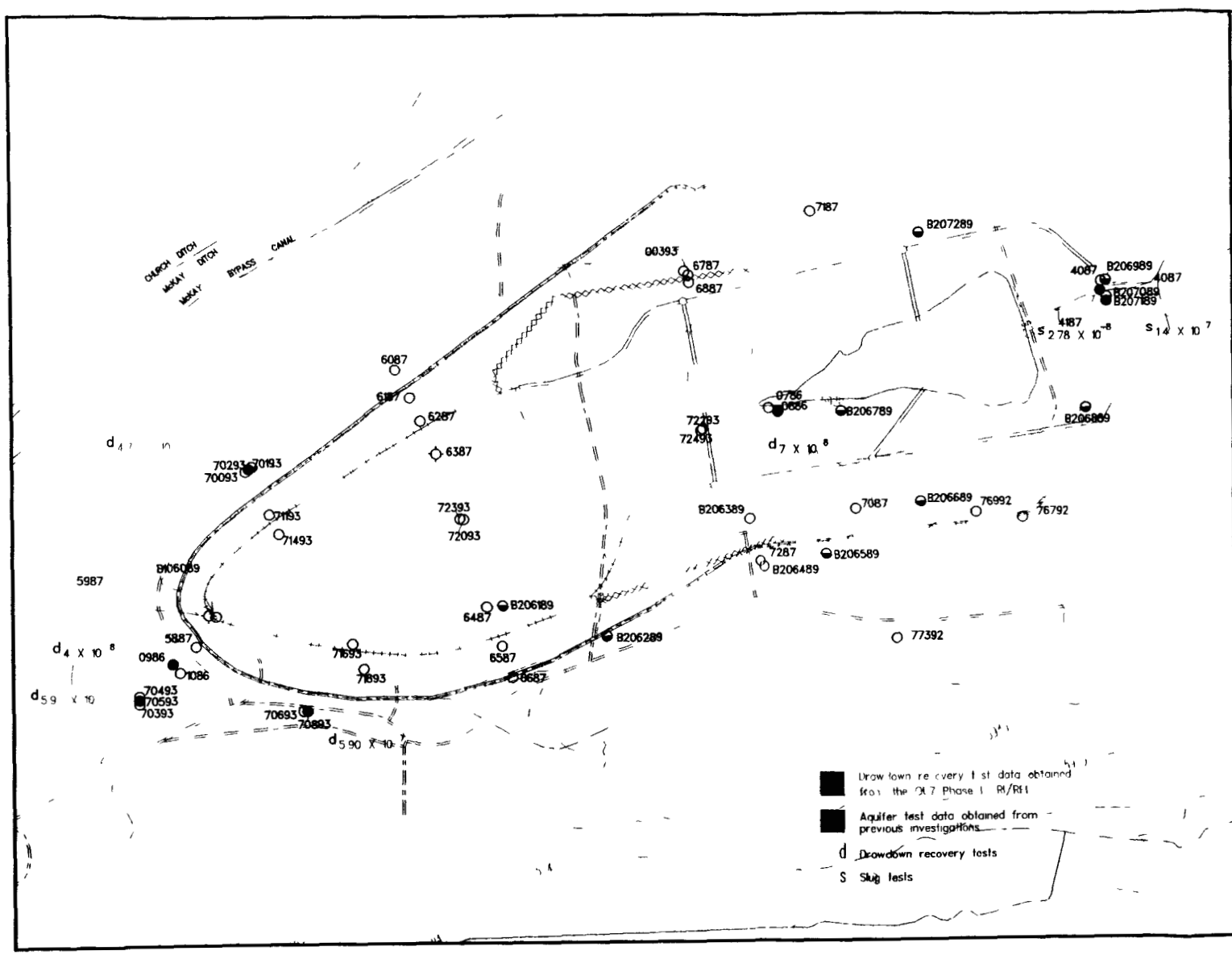
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Weathered Bedrock

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-19

04/04/94 WBCW.MAP HYDCONAML



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)

N

0 Feet 250 500

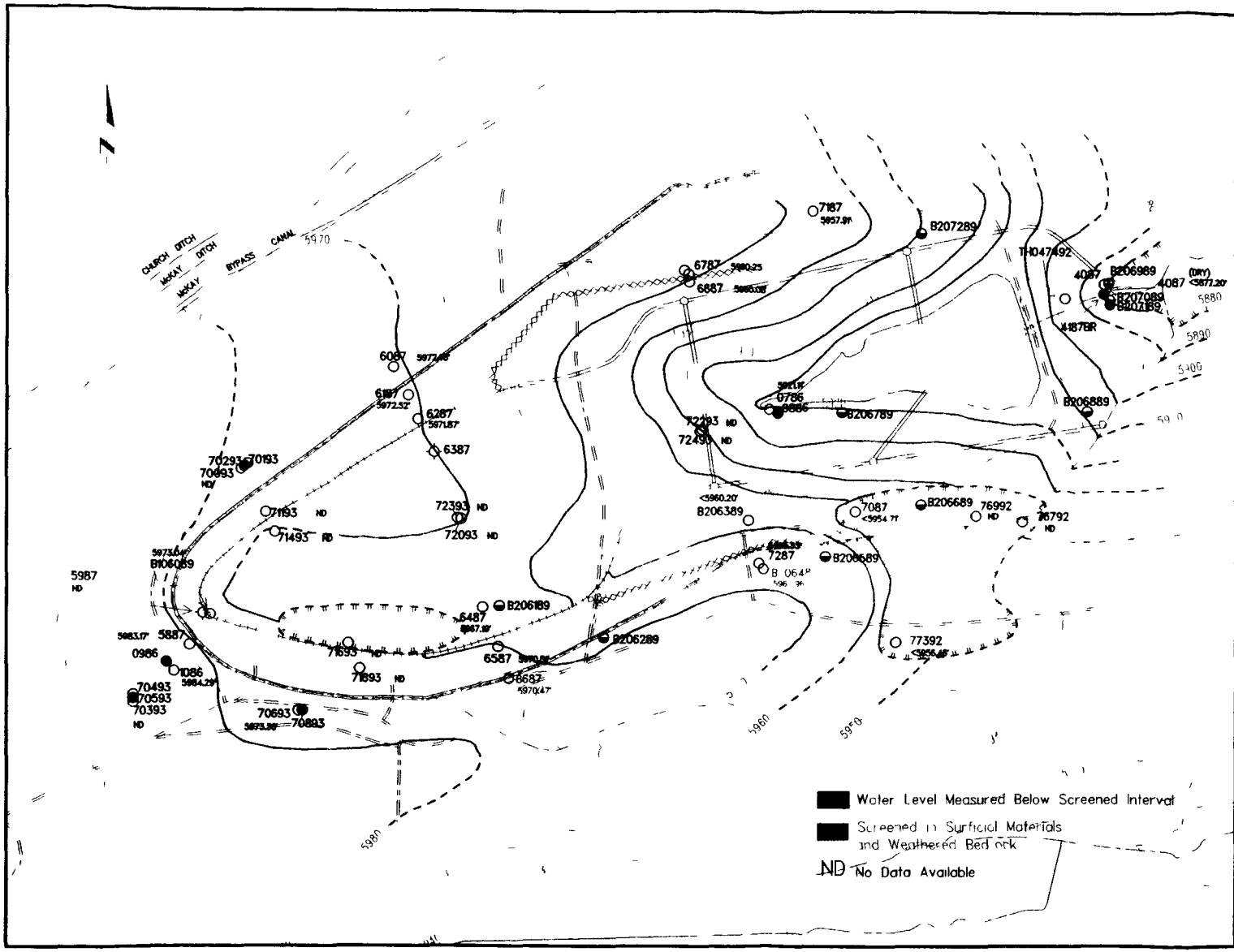
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Hydraulic Conductivity Distribution in Unweathered Bedrock

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-20

04/04/94 UBGWMAP HYDCONUM.



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

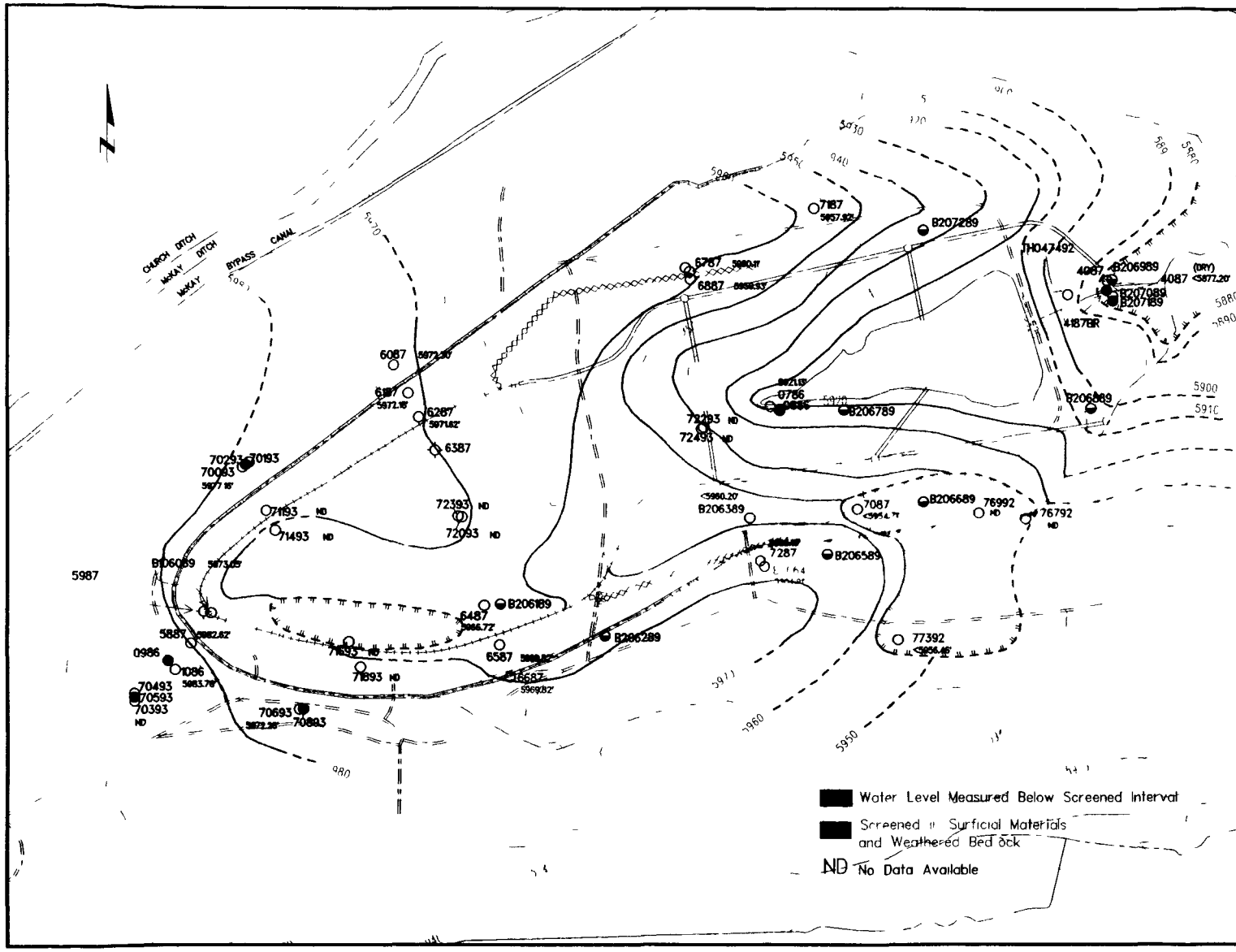
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (December 1992)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-21

04/04/94 DEC92SURF.map GWANNOS



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

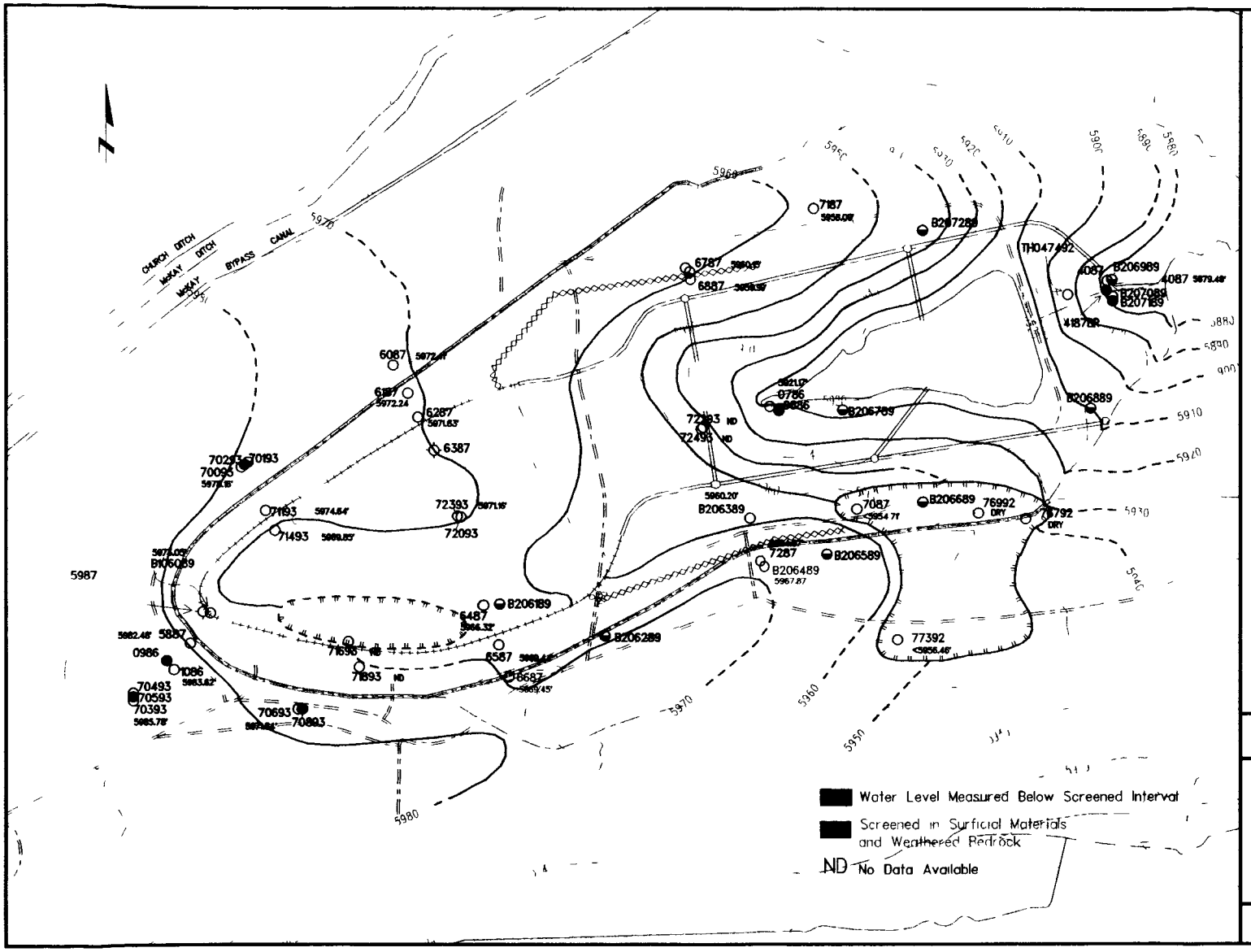
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (January 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-22

04/04/94 JANBSSURF.map GWANN06



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

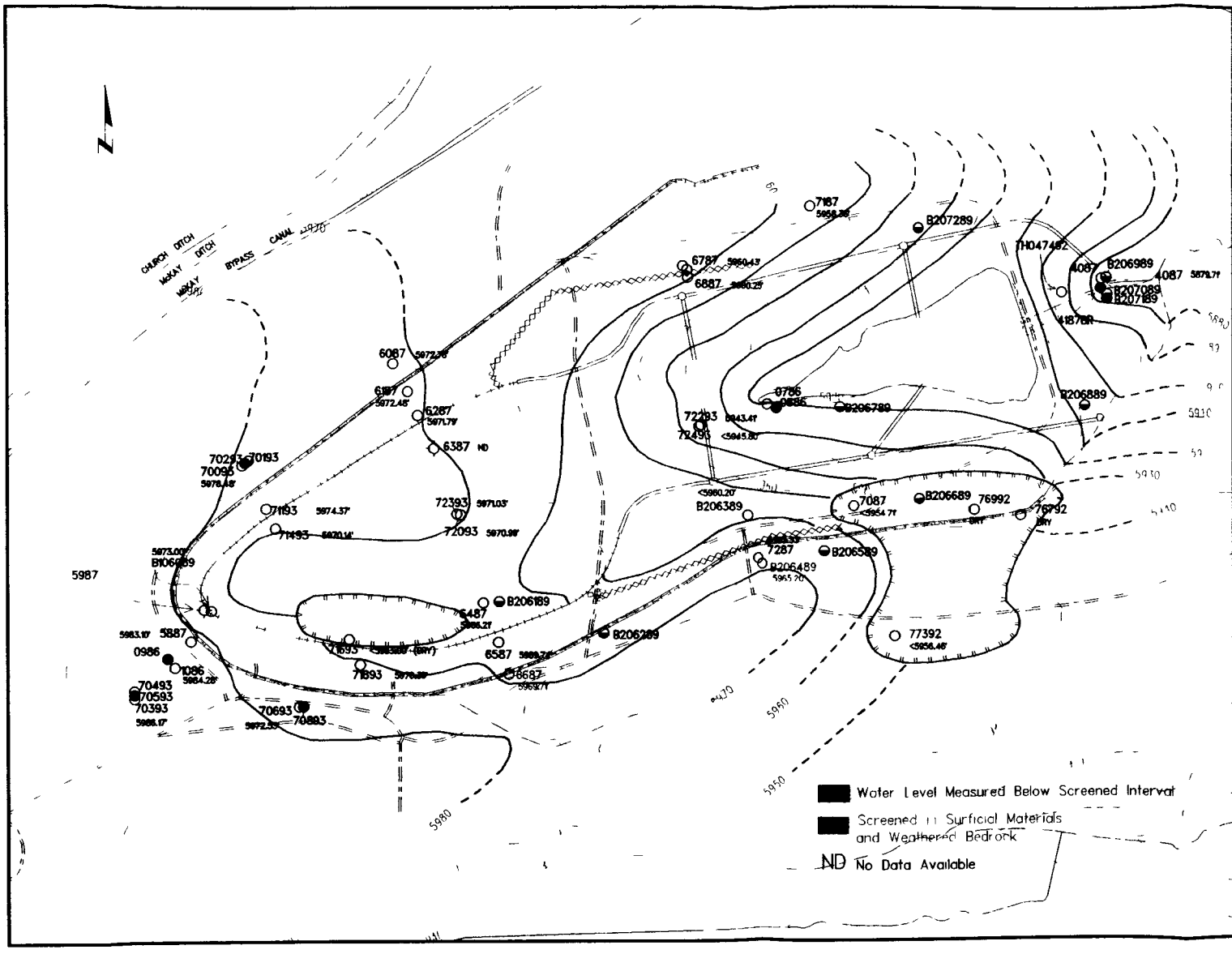
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (February 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-23

04/04/94 FEB93SURF.map GWANN07



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Surficial Material Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

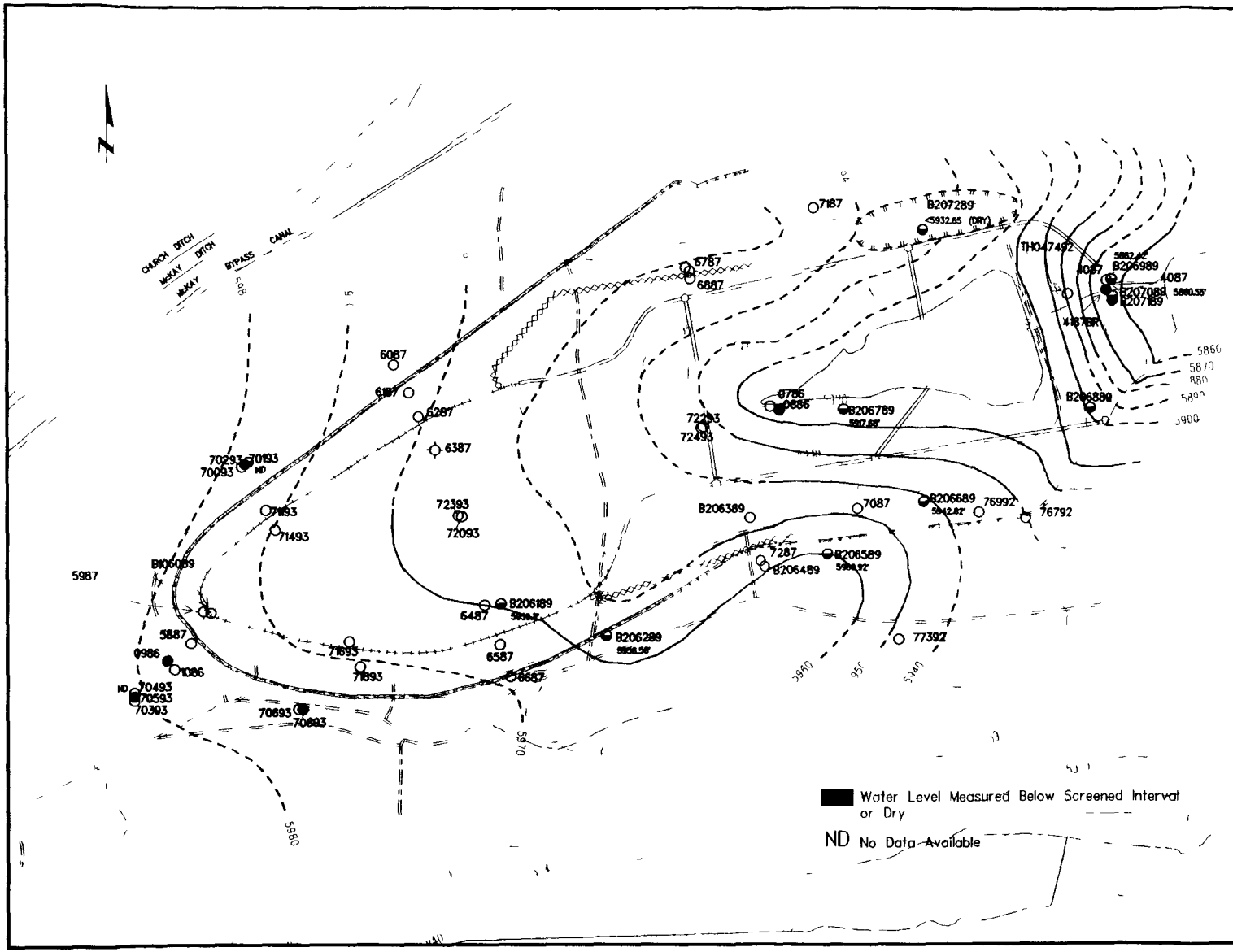
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Surficial Material (March 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-24

04/04/94 MAR93SURF.mxp GWANNOB



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

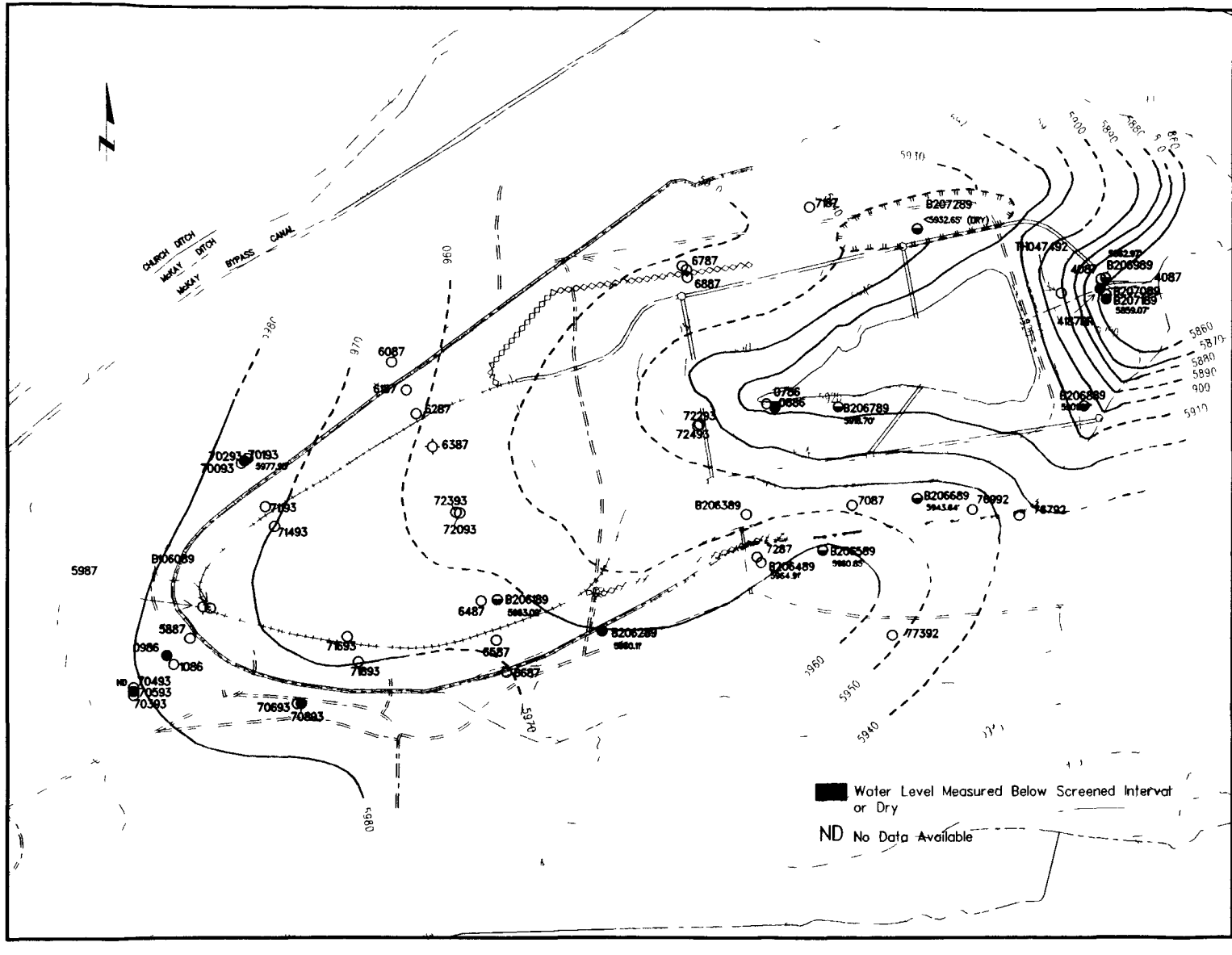
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (December 1992)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-25

04/04/94 DEC92WR.map GWANNOT



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

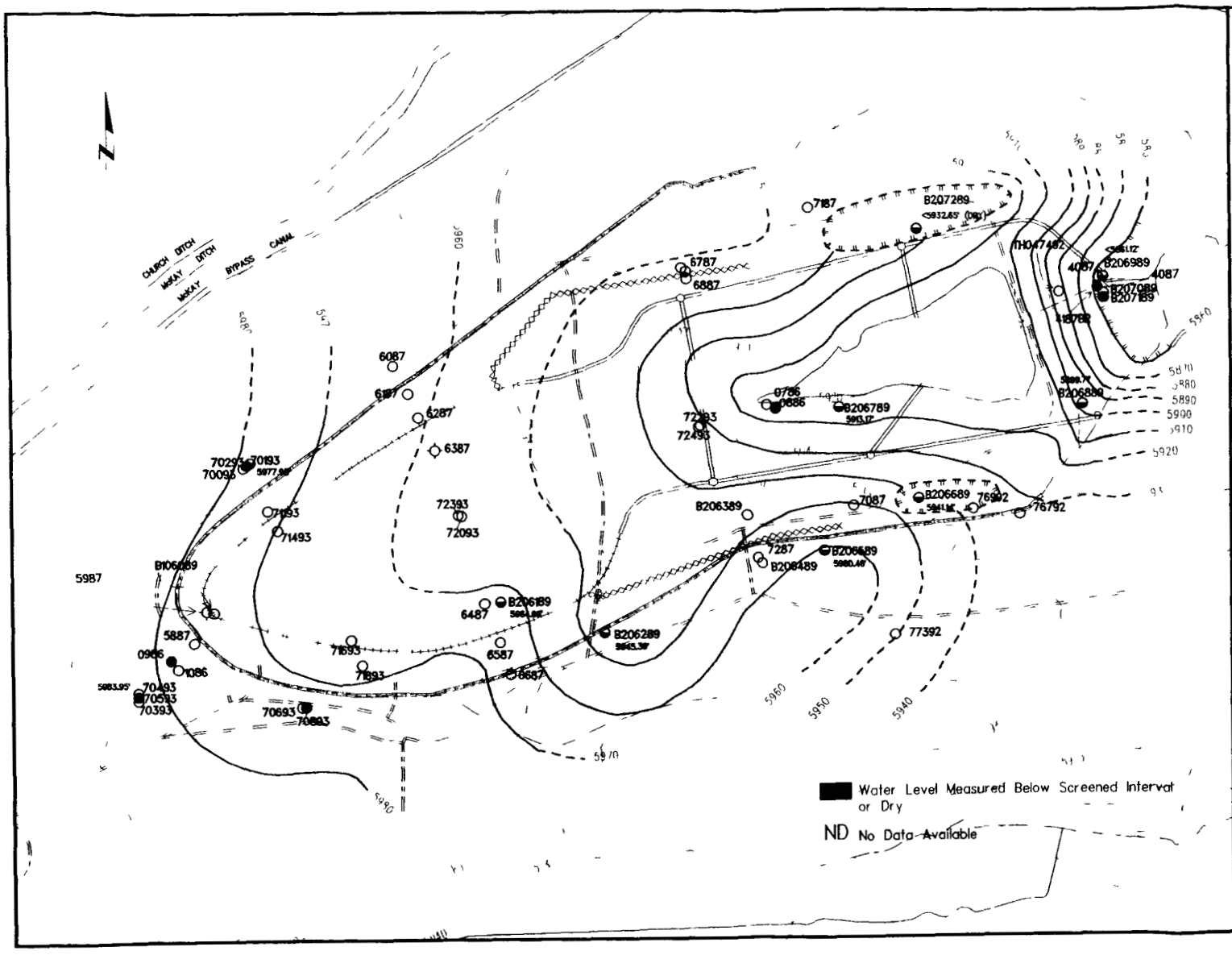
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (January 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-26

04/04/94 JAN93WB.map GWANN02



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

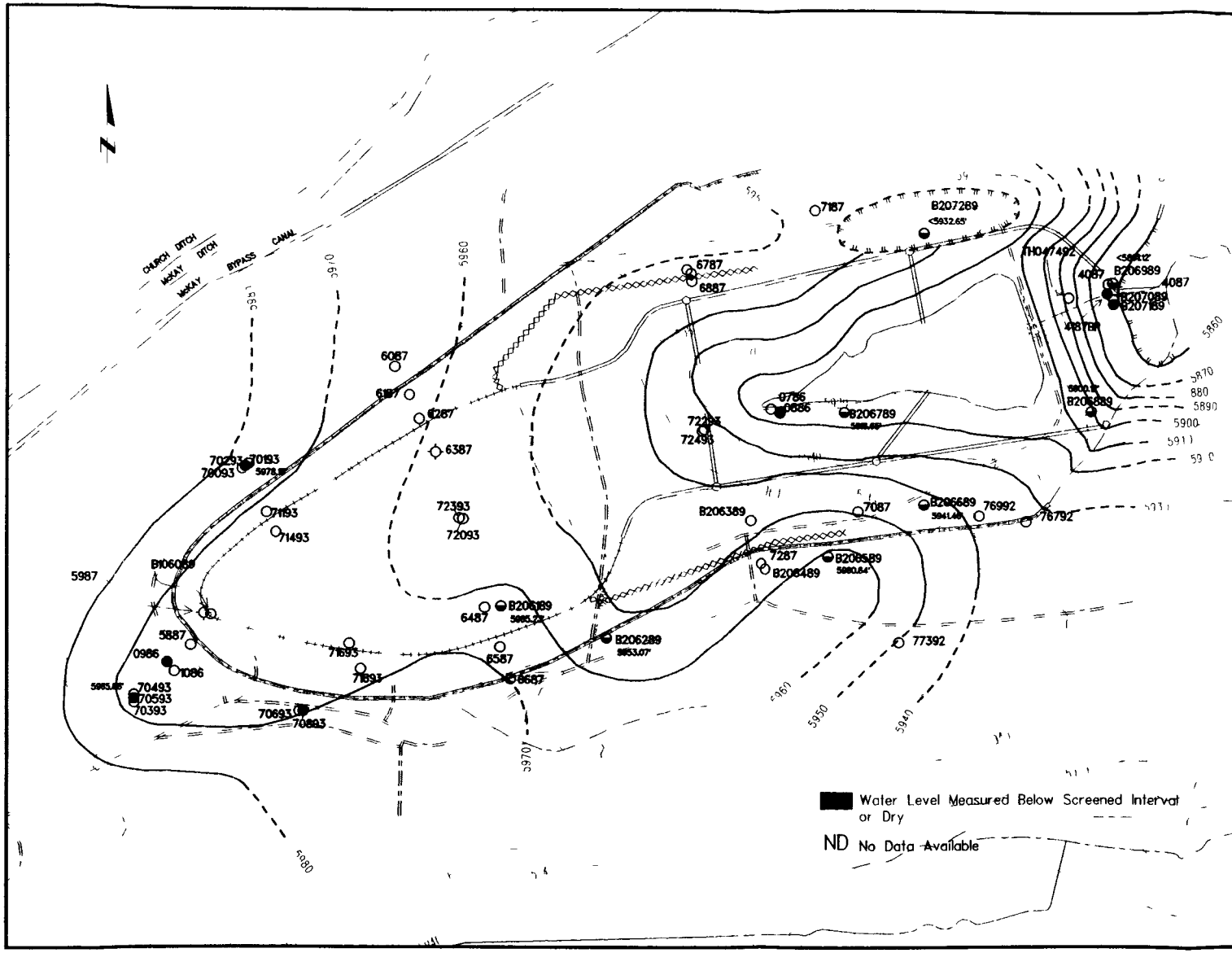
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (February 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-27

04/04/94 FEB93WB.map CWANN03



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)
- Line of Equal Potentiometric Surface (feet above sea level) Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

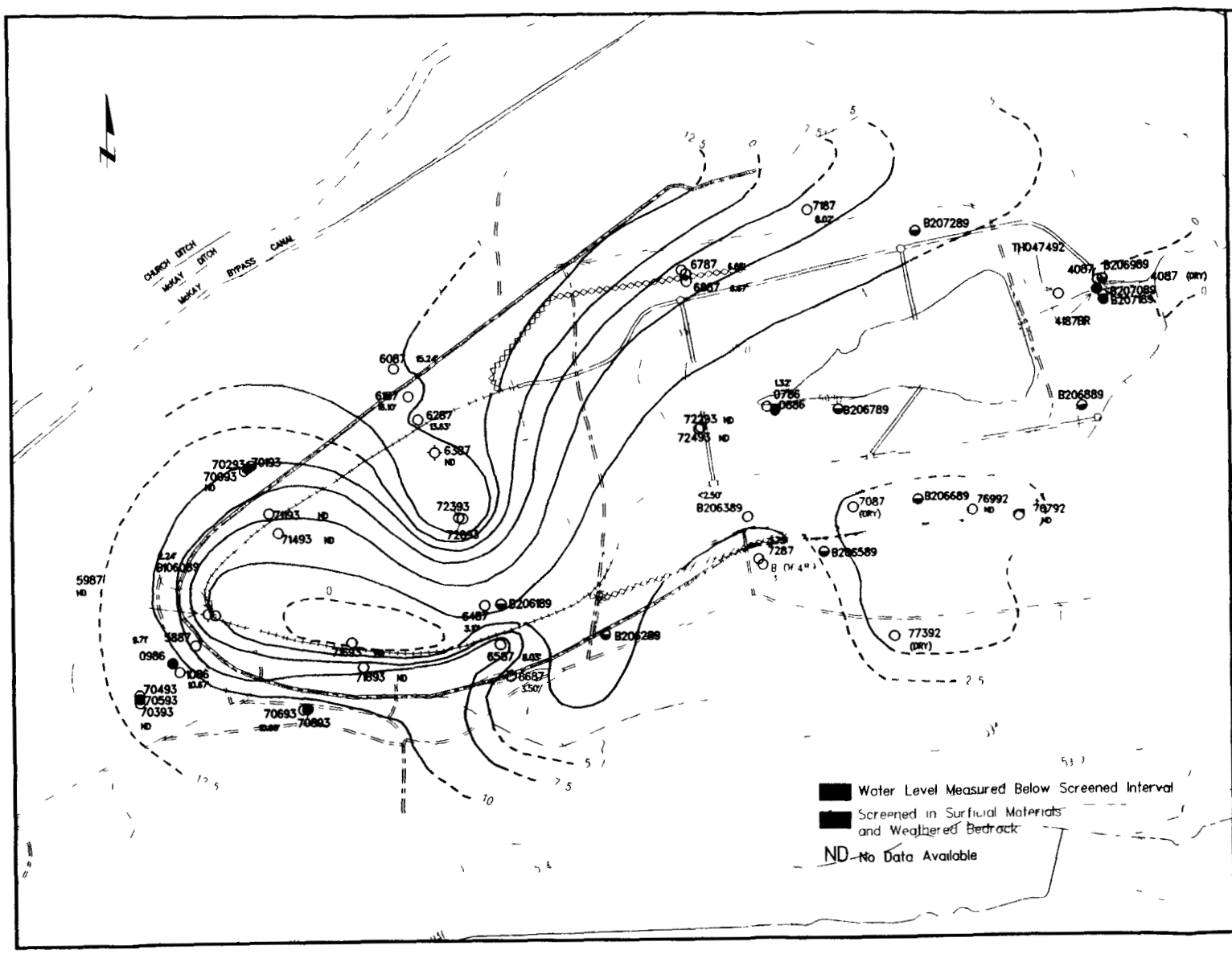
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Potentiometric Map of Weathered Bedrock (March 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-28

04/04/94 MAR93WB.map CWANN04



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)
- Line of Equal Saturated Thickness Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

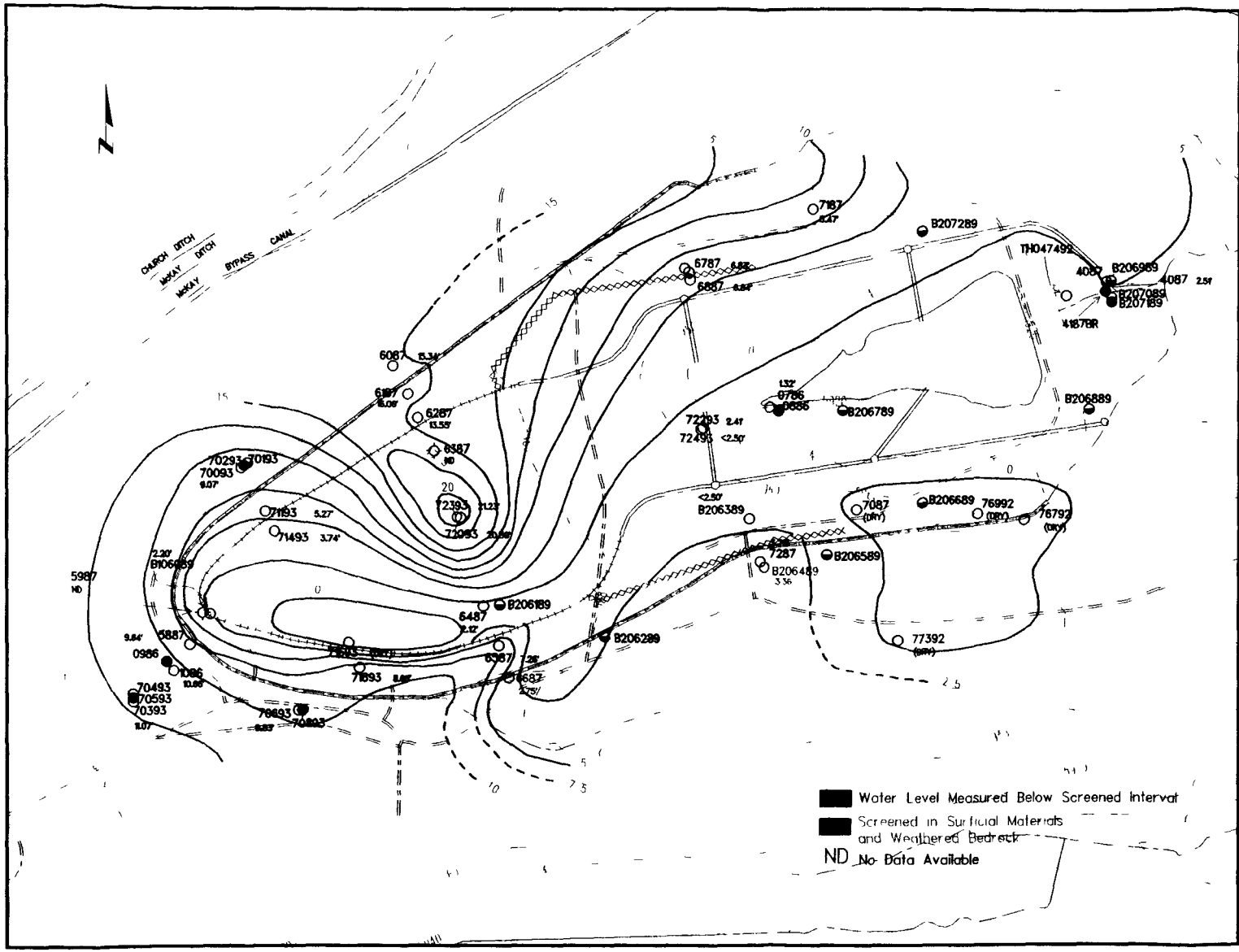
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Saturated Thickness of Surficial Material (December 1992)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-29

04/04/94 DEC92SM.mcp GWANDS



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)
- Line of Equal Saturated Thickness Dashed Where Inferred
- Areas of Unsaturated Bedrock Dashed Where Inferred

0 Feet 250 500

Topographic Contour Interval = 20 Feet

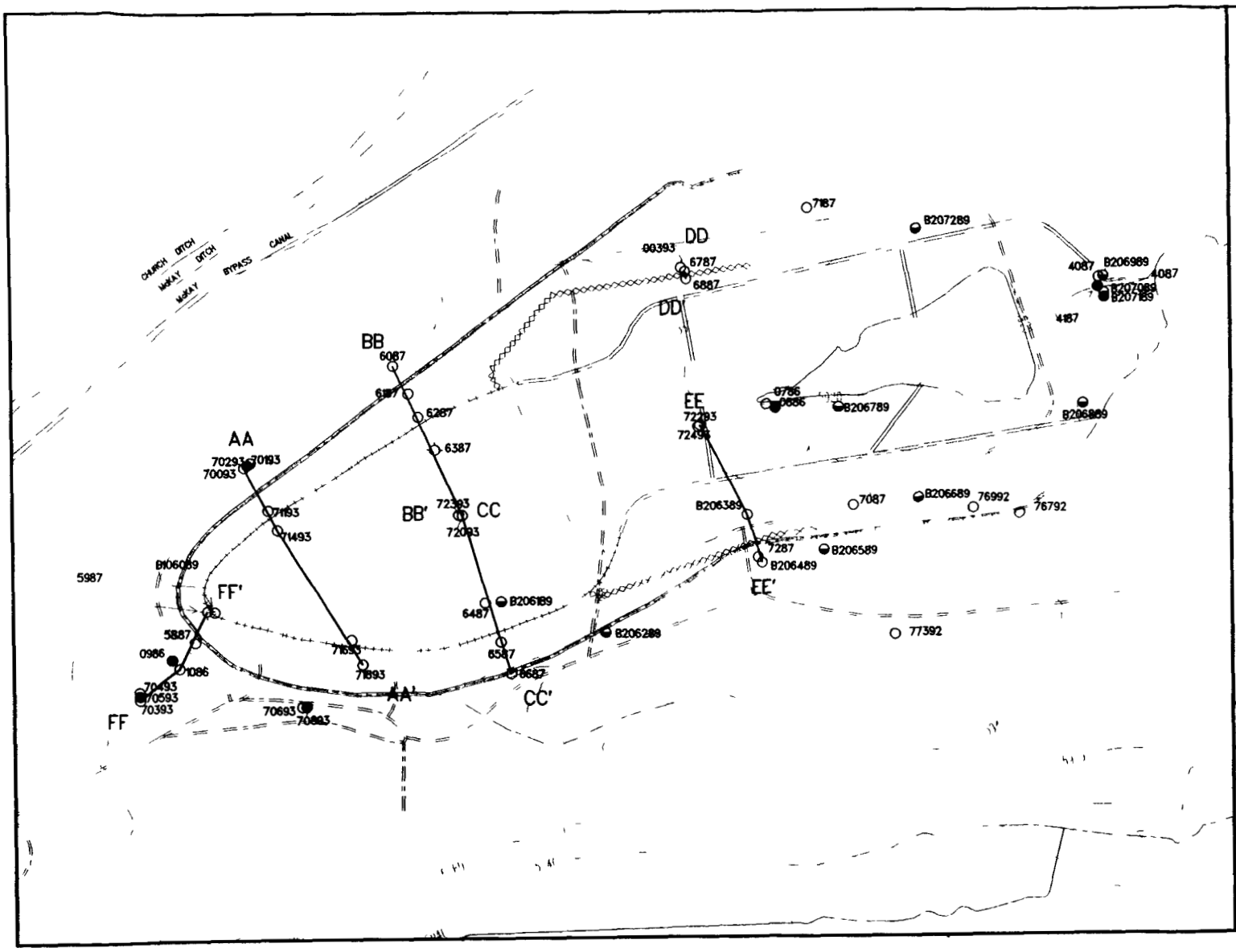
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Saturated Thickness of Surficial Material (March 1993)

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-30

04/04/94 MAR93SM.map GWANNOD



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)
- Well Hydrograph Transects

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

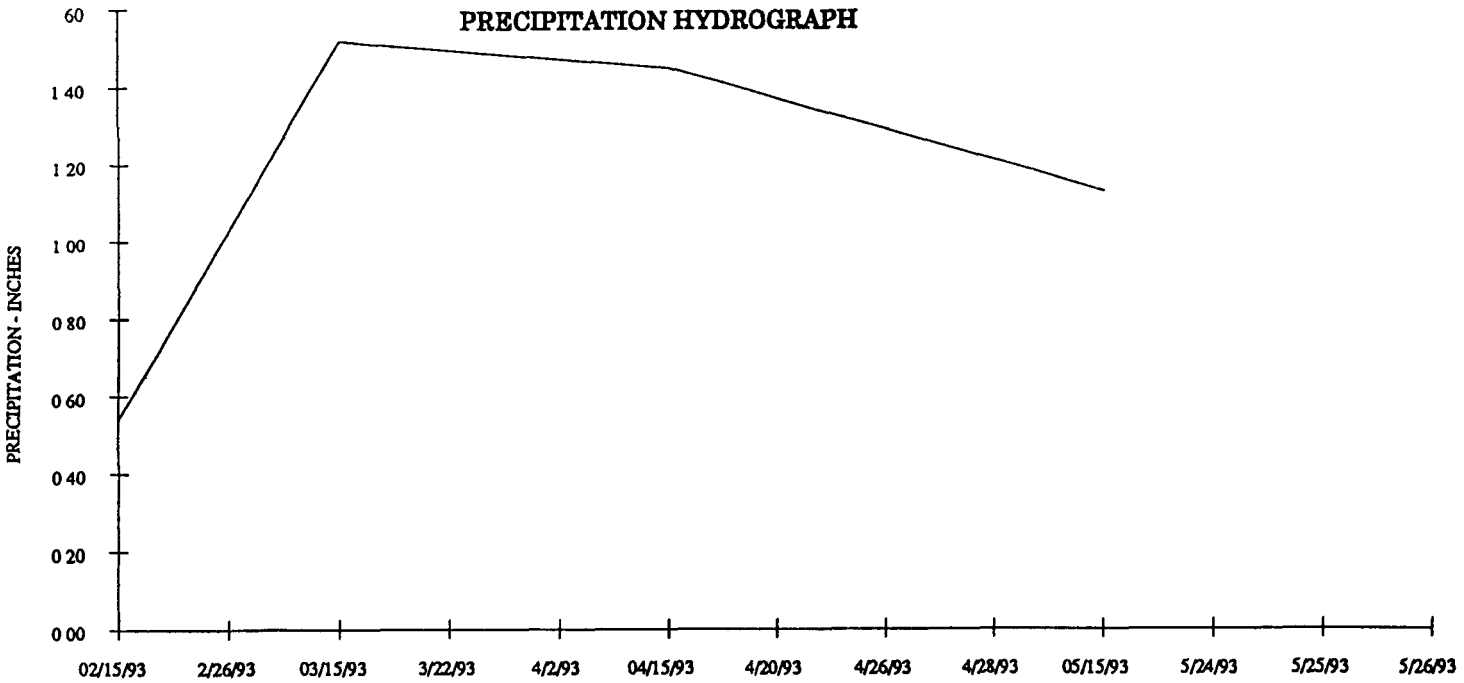
Well Hydrograph Transect Location Map

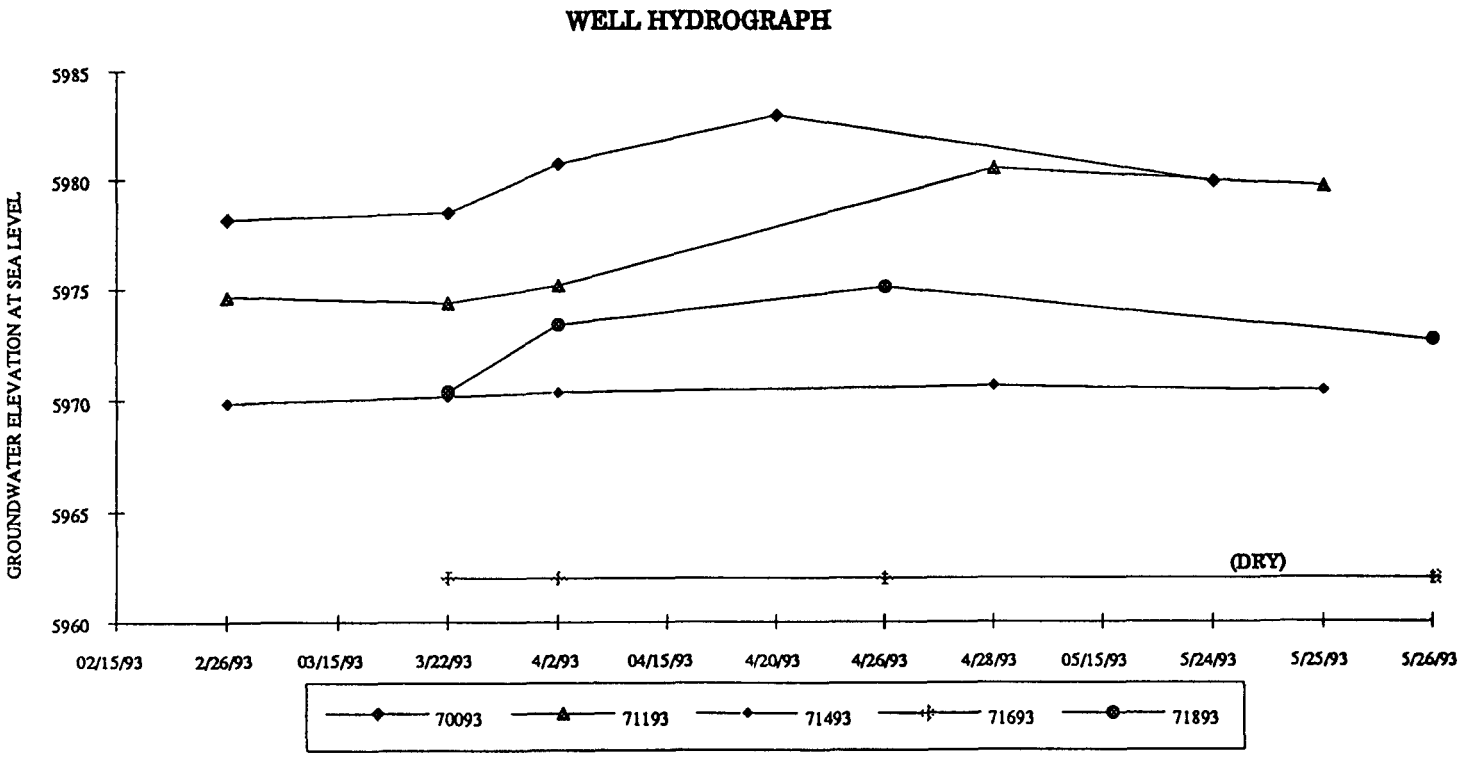
Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-31

04/04/94 HYDROFLE.MAP

TRANSECT AA-AA'

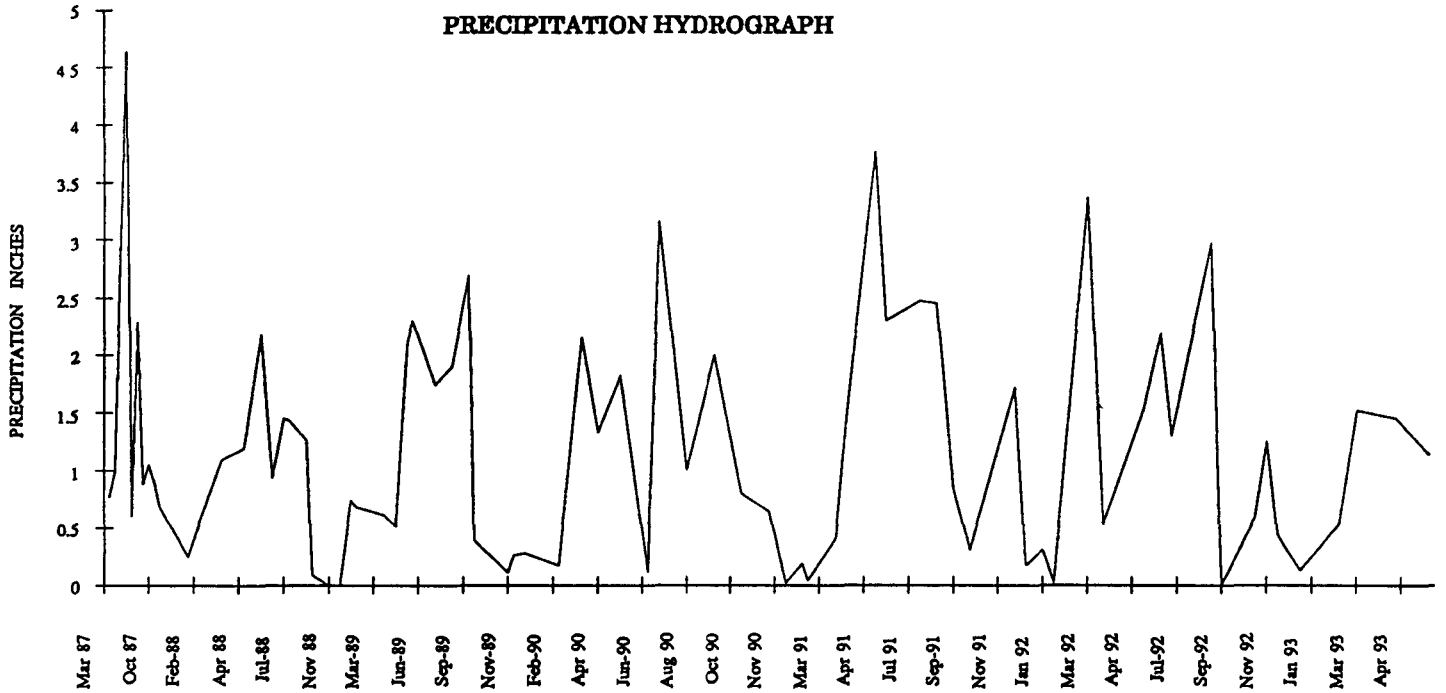


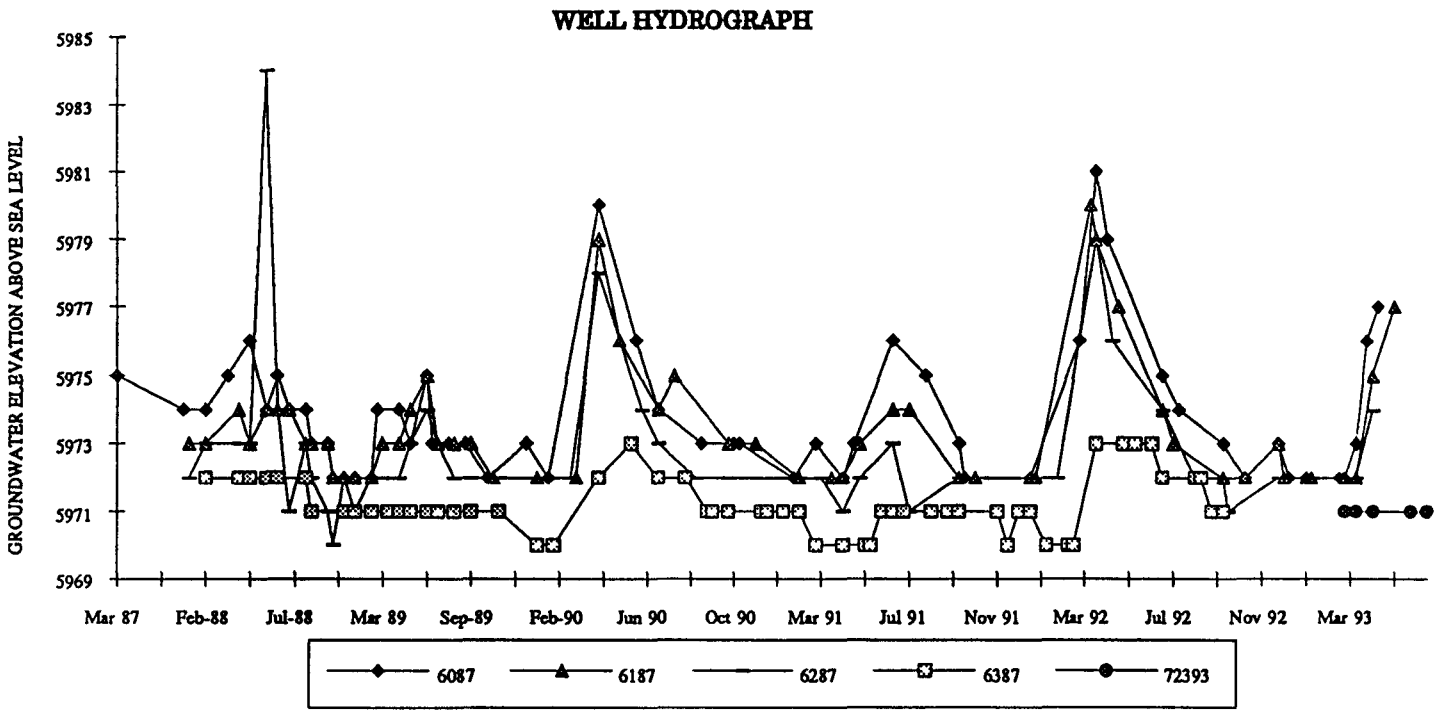


TRANSECT AA-AA'
Wells 70093, 71193, and 71893 are located outside the groundwater intercept system.
Well 71693 is located inside the groundwater intercept system.

U S DEPARTMENT OF ENERGY Rocky Flats Site Golden Colorado	
Hydrograph AA-AA'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 32

TRANSECT BB-BB'

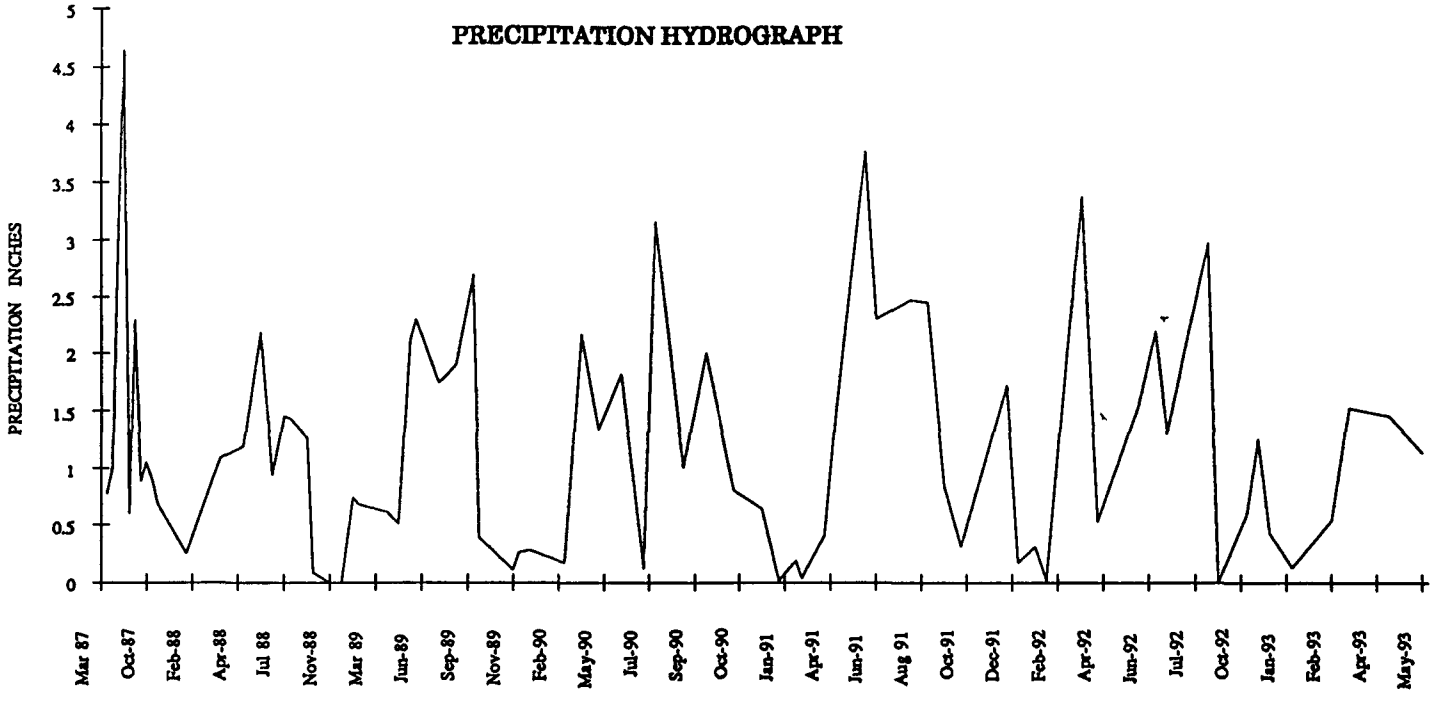


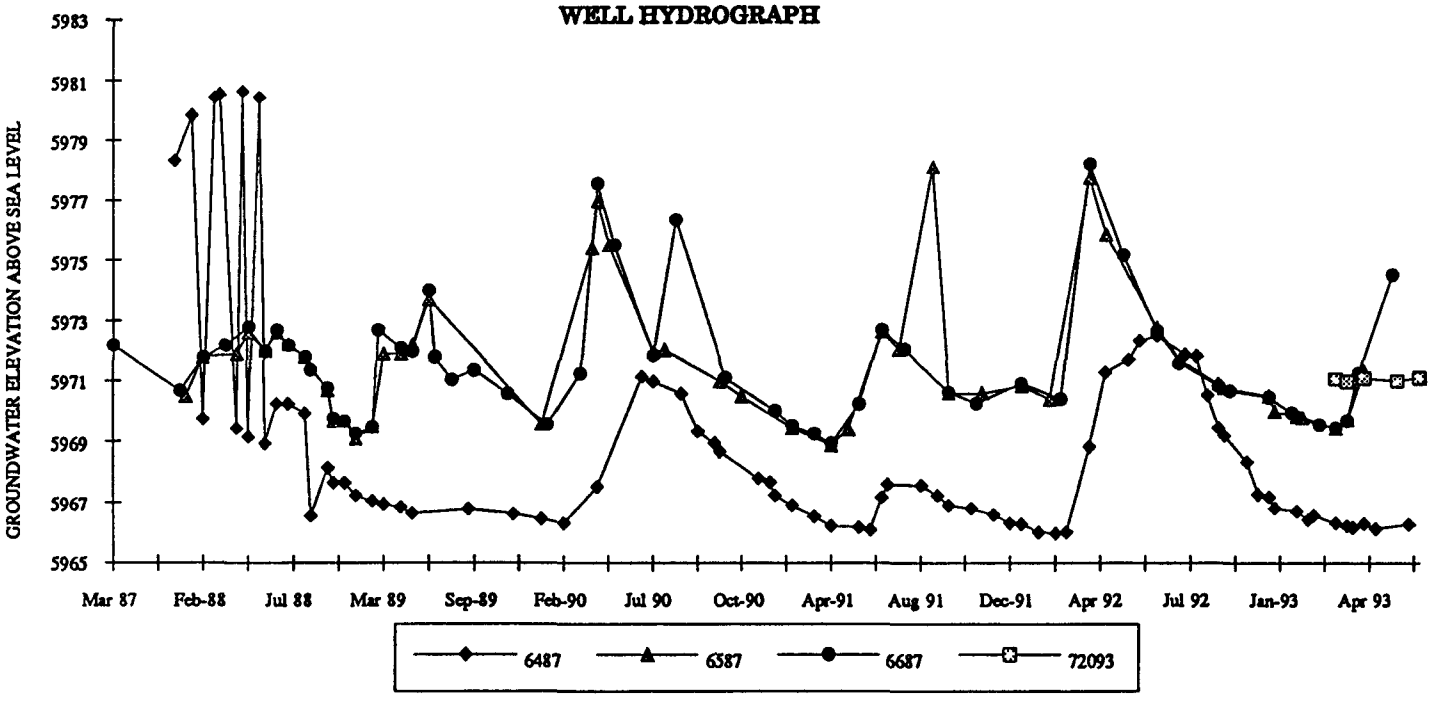


TRANSECT BB-BB'
Wells 6087, 6187, and 6287 are located outside the groundwater intercept system.
Wells 6387 and 72393 are located inside the groundwater intercept system.

U S DEPARTMENT OF ENERGY Rocky Flats Site Golden Colorado	
Hydrograph BB-BB'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 33

TRANSECT CC-CC'

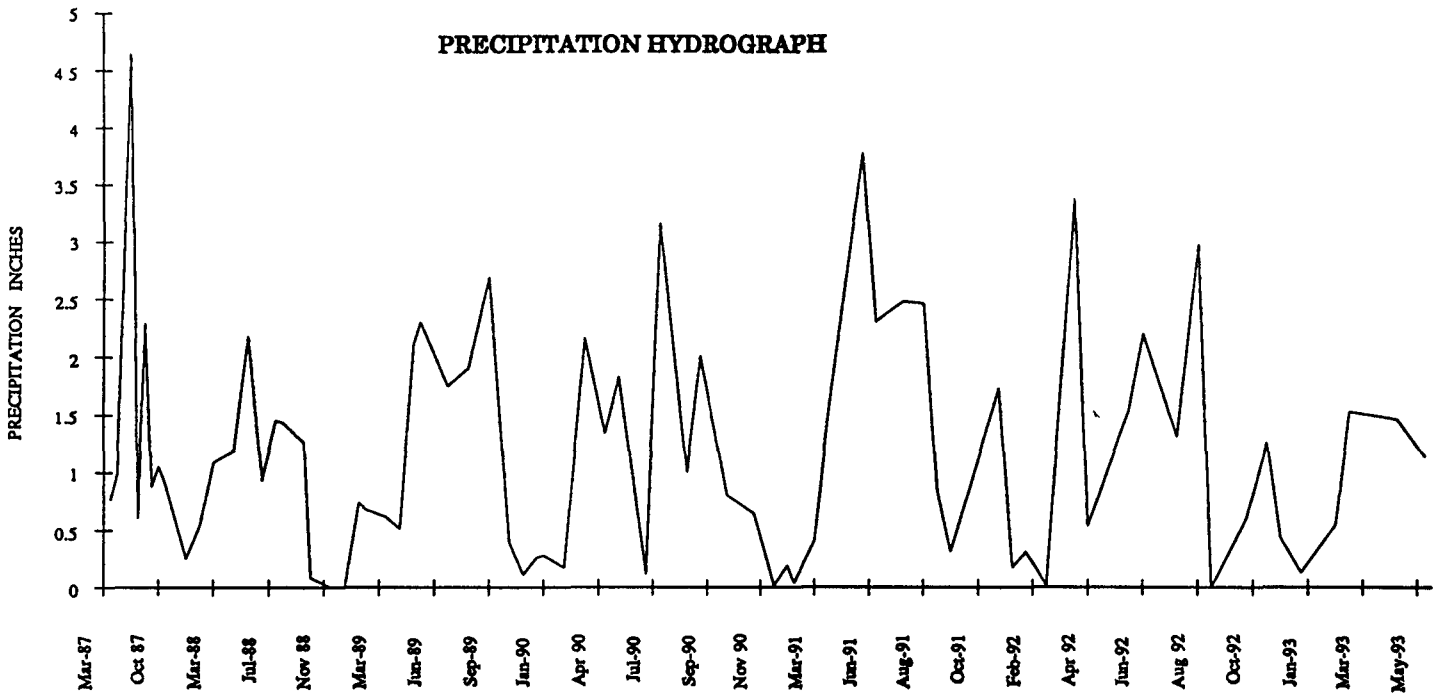


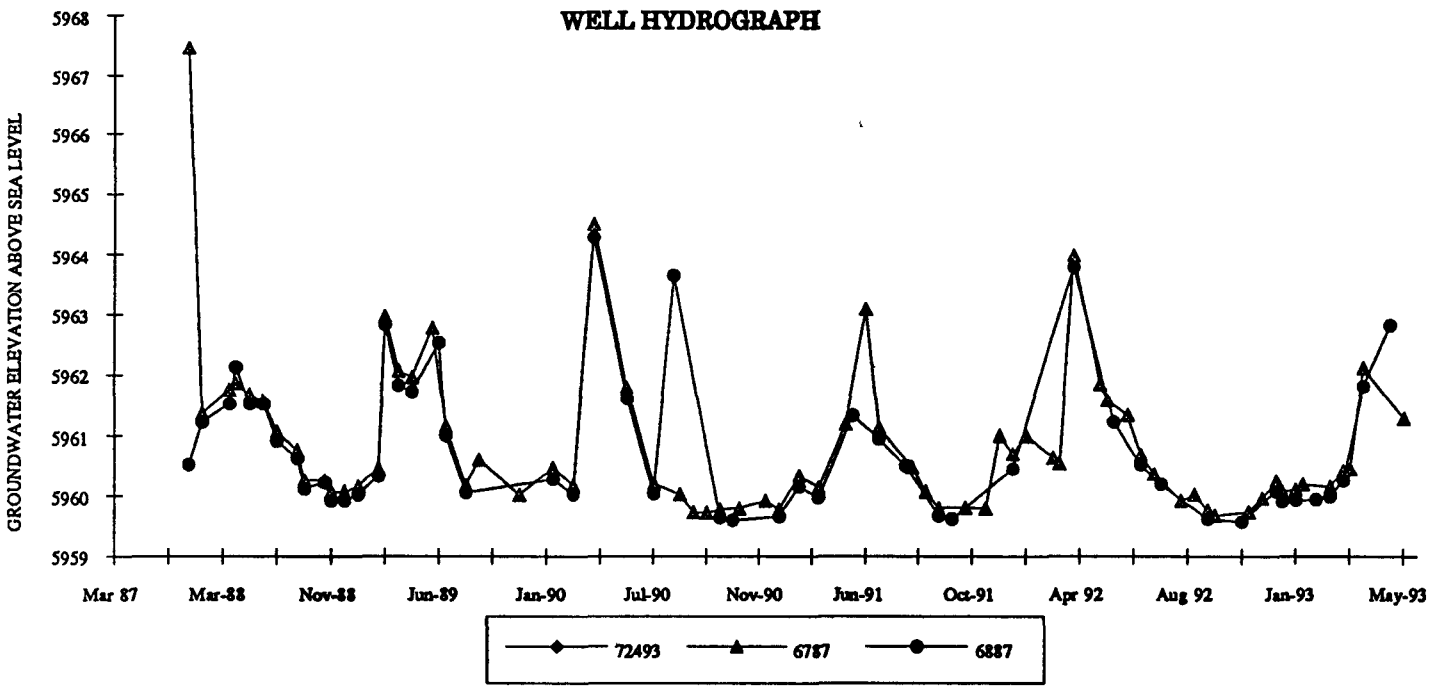


TRANSECT CC-CC'
Wells 72093 and 6487 are located inside the groundwater intercept system.
Wells 6587 and 6687 are located outside the groundwater intercept system.

U S DEPARTMENT OF ENERGY Rocky Flats Site Golden Colorado	
Hydrograph CC-CC'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 34

TRANSECT DD-DD'

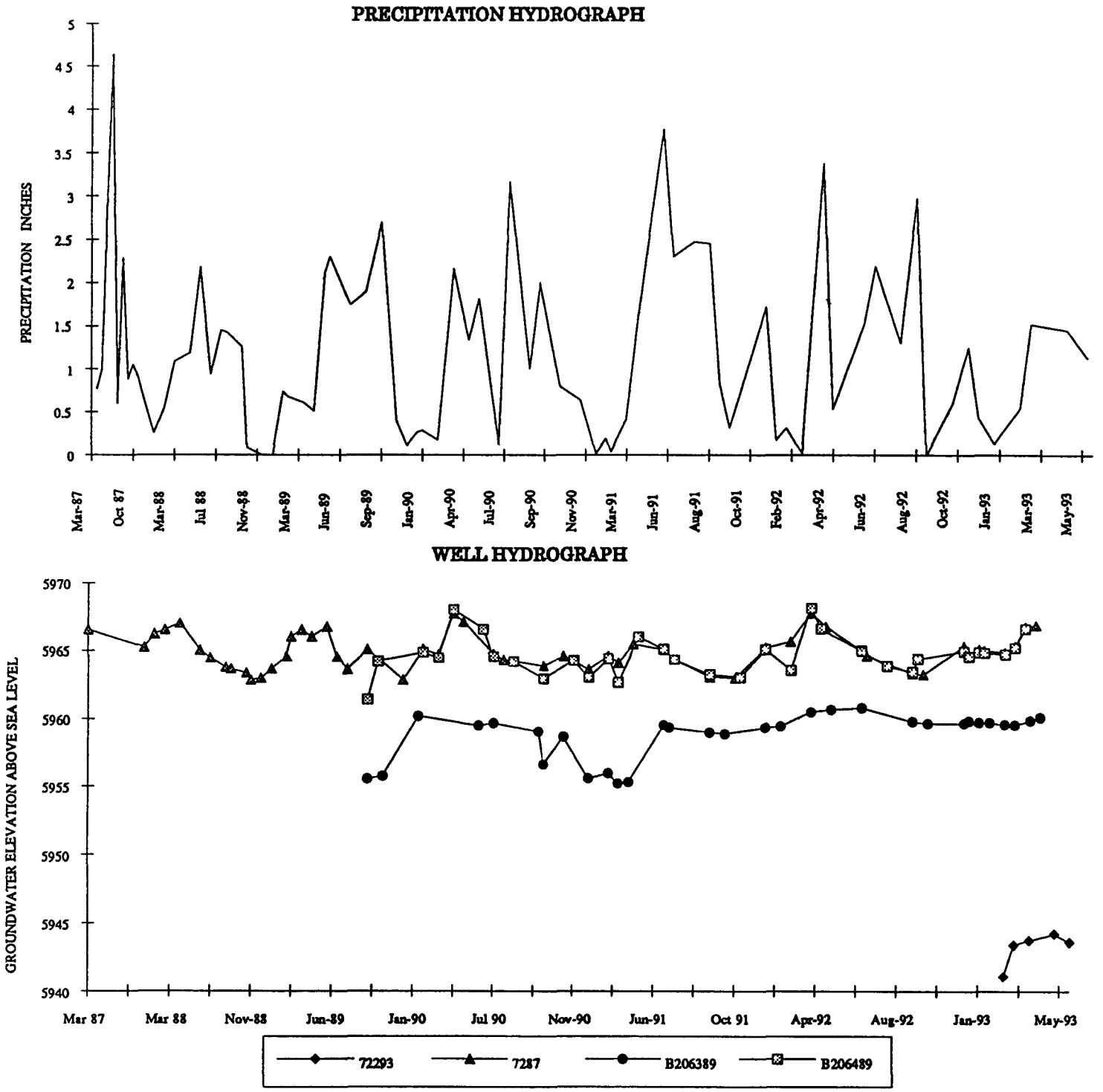




TRANSECT DD-DD'
Wells 6787 is located outside the north slurry wall.
Well 6887 is located inside the north slurry wall.

U S DEPARTMENT OF ENERGY Rocky Flats Site, Golden, Colorado	
Hydrograph DD-DD'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 35

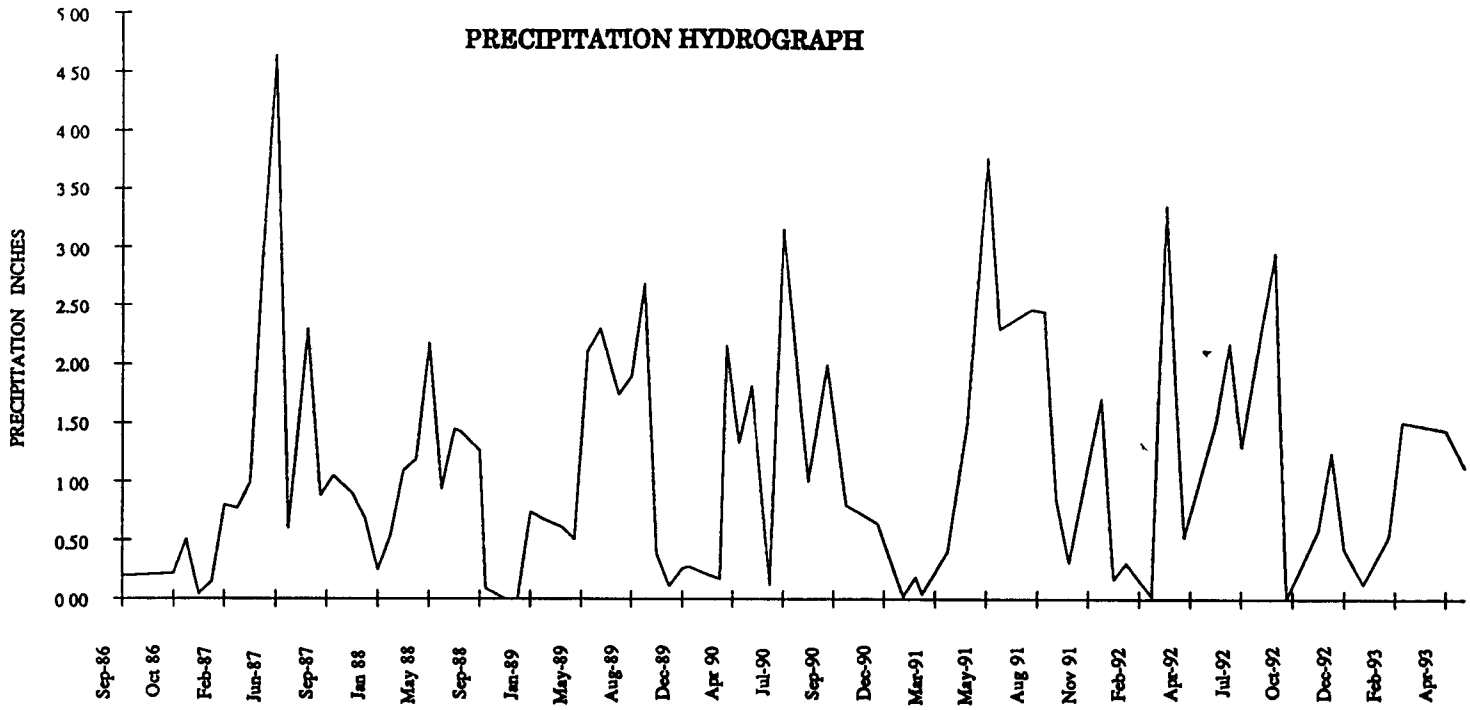
TRANSECT EE-EE'

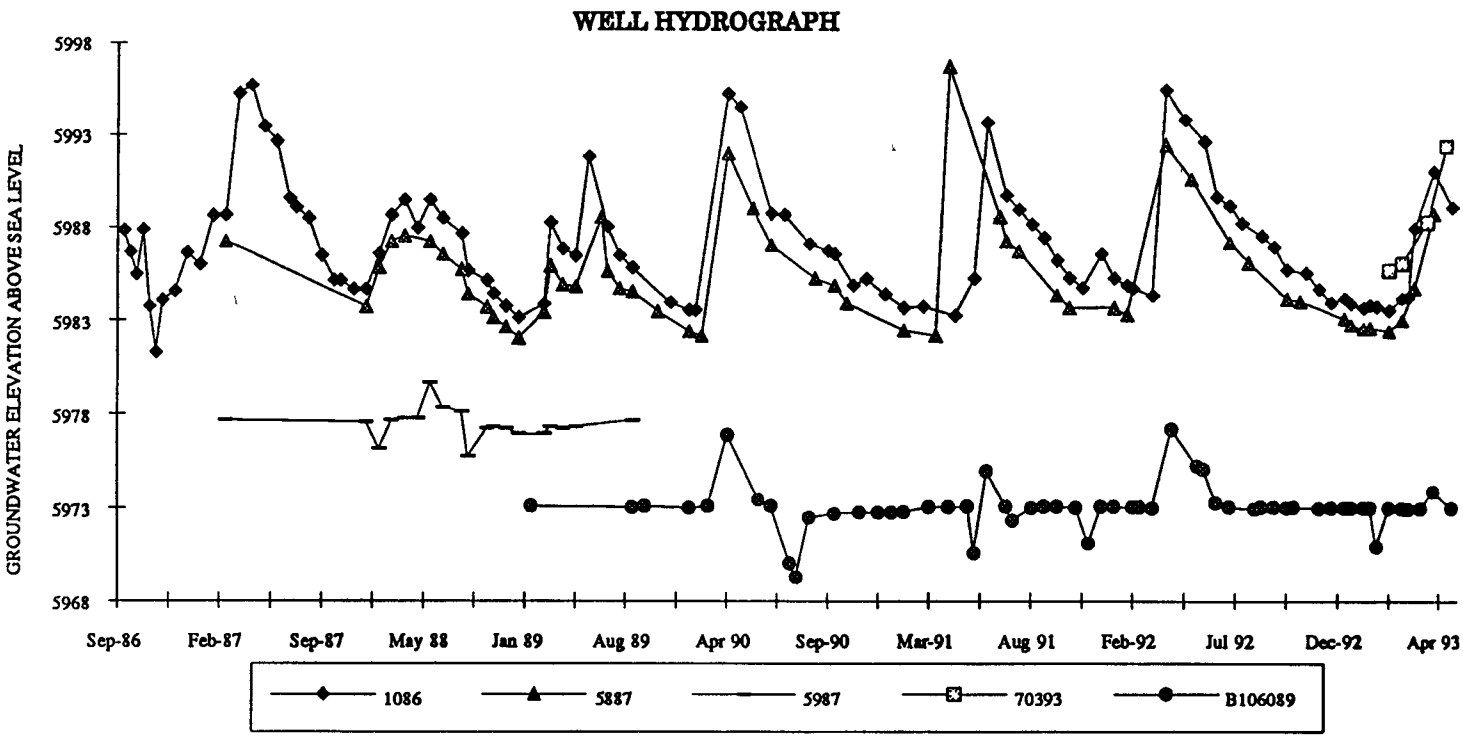


TRANSECT EE-EE'
Wells 7287 and B206489 are located outside the south slurry wall.
Wells 72298 and B206389 are located inside the north slurry wall.

U S DEPARTMENT OF ENERGY Rocky Flats Site, Golden Colorado	
Hydrograph EE-EE'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 36

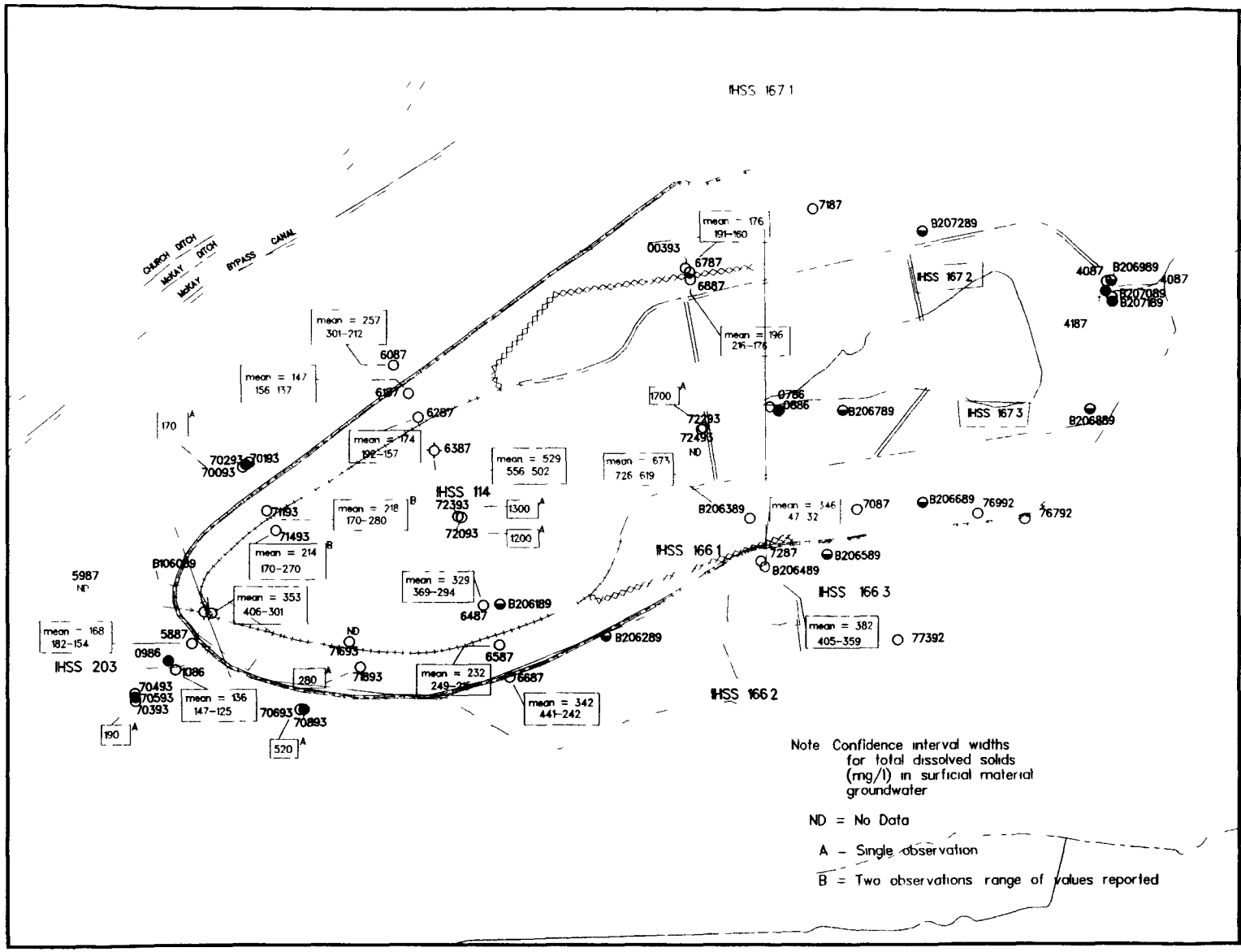
TRANSECT FF-FF'





TRANSECT FF-FF'
Wells 70393, 1086, 5887, 5987, and B106089 are located outside the groundwater intercept system.

U S DEPARTMENT OF ENERGY Rocky Flats Site, Golden Colorado	
Hydrograph FF-FF'	
Revised Work Plan	Operable Unit No 7
Date April 1994	Figure 2 37



Note Confidence interval widths for total dissolved solids (mg/l) in surficial material groundwater

ND = No Data

A = Single observation

B = Two observations range of values reported

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)
- OU7 IHSS Boundary
- OU6 IHSS Boundary

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

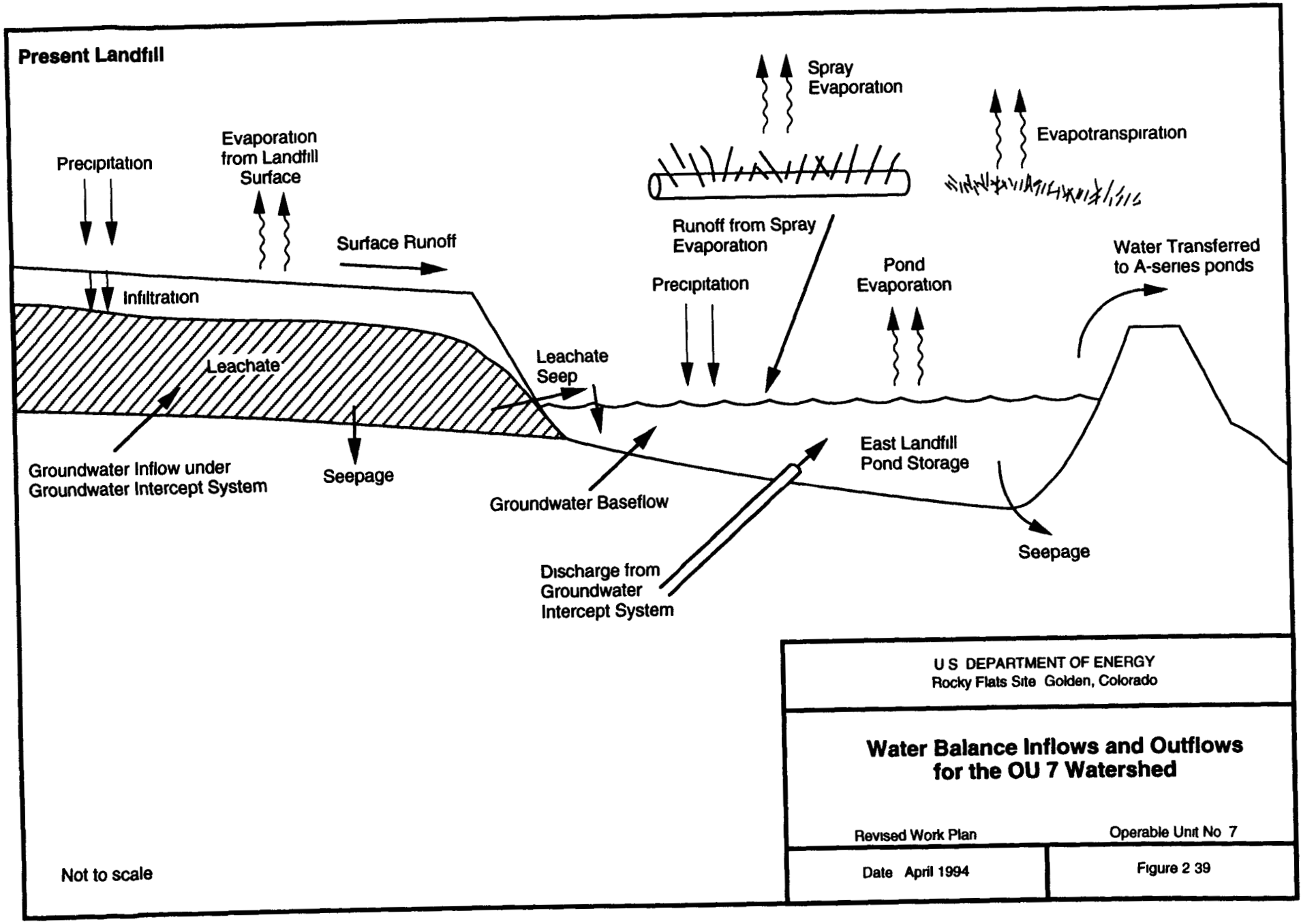
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Total Dissolved Solids Distribution Map

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-38

04/04/94 TDS.MAP



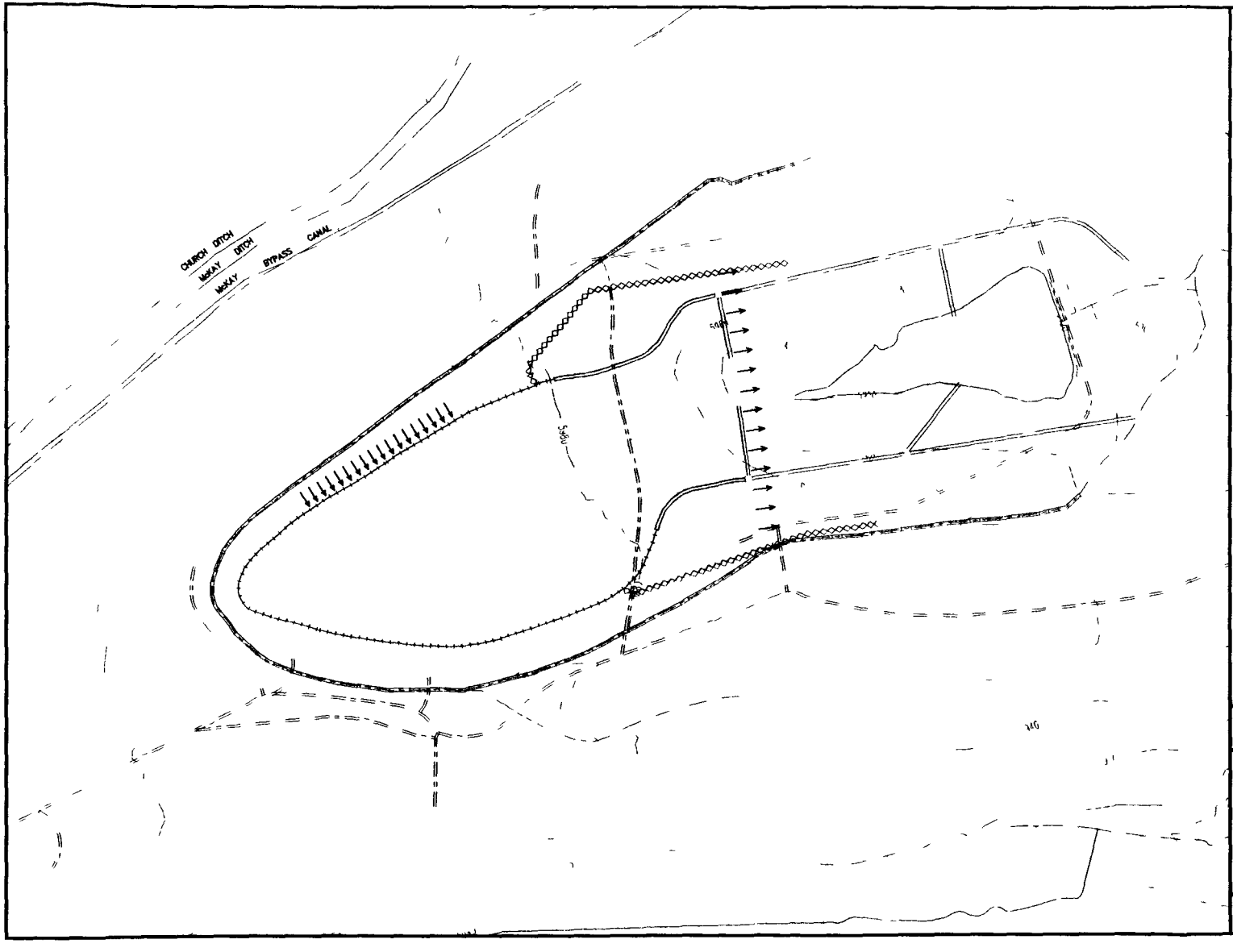
U S DEPARTMENT OF ENERGY
Rocky Flats Site Golden, Colorado

Water Balance Inflows and Outflows for the OU 7 Watershed

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 2 39

M:\ES\Fig 3-7 Mon Wells mdw/4-5-94



EXPLANATION

Ditch

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall

Groundwater Intercept System
(perforated)
(non-perforated)

Area of Recharge From Infiltration (Appendix I)

Groundwater Inflow/Outflow Boundaries

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

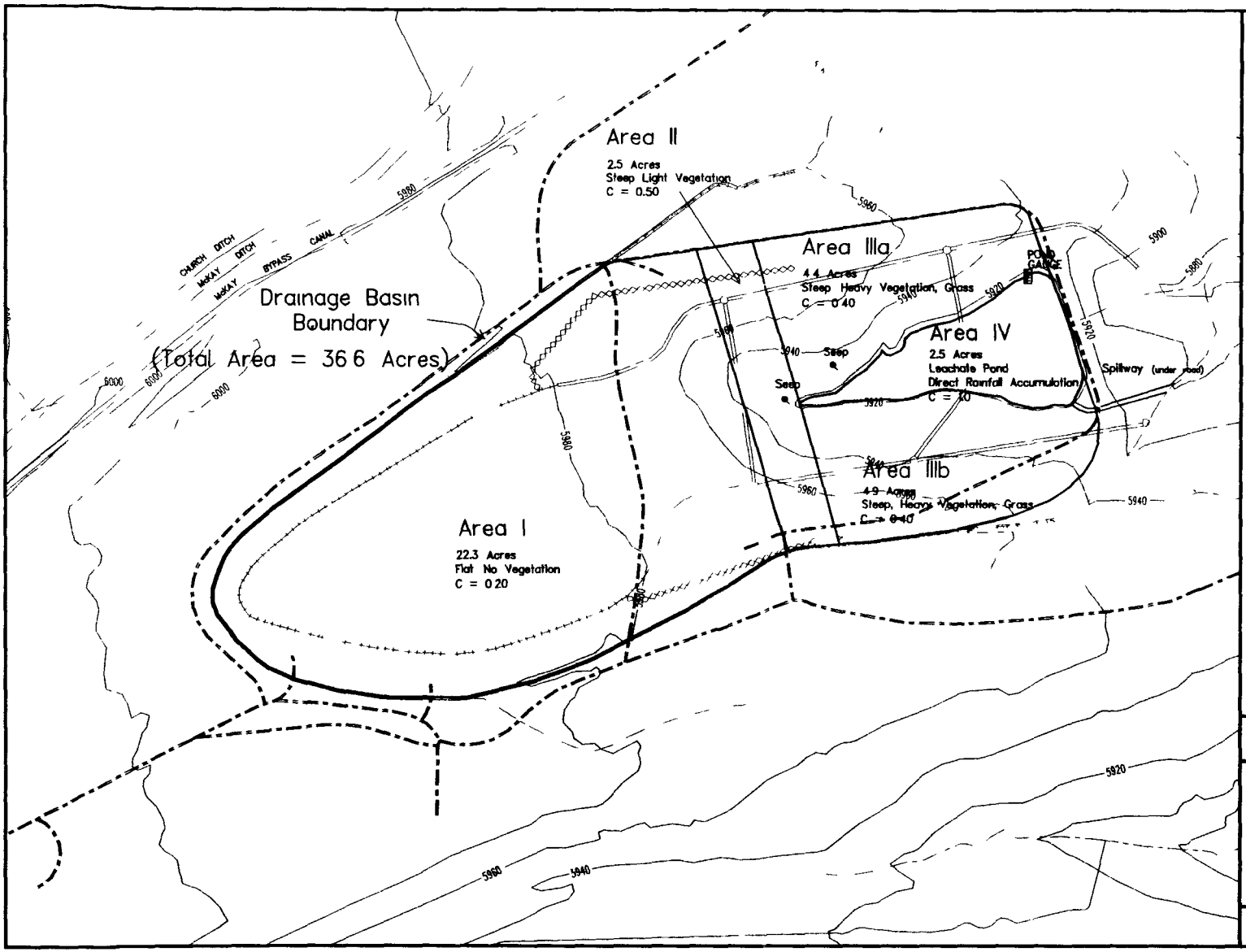
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Groundwater Inflow and Outflow Boundaries of the Present Landfill Area

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-40

04/04/94 RECHARGE.MAP



EXPLANATION

Ditch

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall Groundwater Intercept System
(perforated)
(non-perforated)

Basin Boundary

C = Runoff Coeffecient

0 Feet 250 500

Topographic Contour Interval = 20 Feet

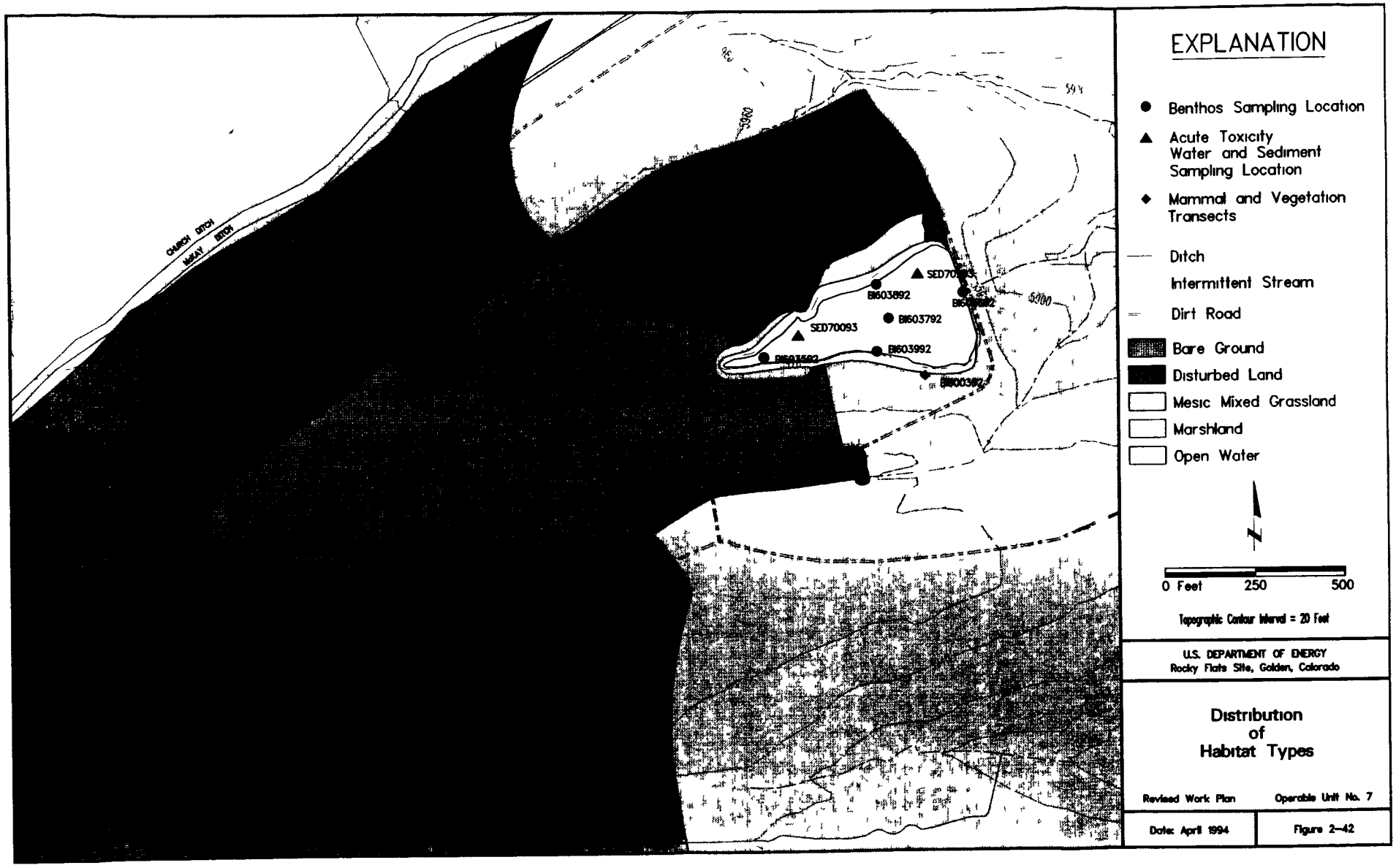
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

OU 7 Drainage Basin and Surface-Runoff Subareas

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-41

04/04/94 BASIN5.MAP



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

Distribution of Habitat Types

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 2-42

04/04/94 HABITAT.MAP

3 DATA QUALITY AND USABILITY

The data quality objectives and their measurement criteria for the OU 7 Phase I RFI/RI were specified in the OU 7 Phase I work plan (DOE 1991b) to ensure that sample-collection and analytical methods used provided data of appropriate quality to characterize the site and describe the nature and extent of contamination

The primary quality-assurance objective for analytical data is to ensure that the data generated are of documented quality and are defensible for the intended data uses In order to meet this objective, appropriate steps were taken to ensure that the OU 7 data are (1) of known quantitative significance in terms of precision and accuracy at levels appropriate for the intended data use, (2) representative of actual physical and chemical conditions, (3) comparable to previous data, and (4) complete to the extent that conclusions can be made and supported Quality of OU 7 data is discussed in Section 3 1

Data usability describes what data can be used, how and why it is used, and when and where it can be used Different types of data and data from various sources may vary in quality and, thus, in their usability Absolute criteria regarding whether data can be used or not do not exist for all circumstances Data usability for the OU 7 Phase I RFI/RI is determined by the data-quality needs and documentation of the field sampling, laboratory, and QA/QC protocols Usability of OU 7 data is discussed in Section 3 2

3 1 Data Quality

The OU 7 Phase I RFI/RI field activities were conducted in accordance with the OU 7 Phase I work plan (DOE 1991b), the OU 7 quality assurance addendum (QAA) which is included in the work plan, the sitewide quality assurance project plan (QAPjP) (EG&G 1990c), and standard operating procedures (SOPs) (EG&G 1992c)

3 1 1 Field Quality-Control Sampling

Field QC samples provide information to assess sampling and analysis precision and to identify potential biases in analytical data resulting from cross contamination during sampling or contamination during sample transport and storage At OU 7, QC samples were collected concurrently with real samples Table 3-1 presents the required frequency

of QC sample collection and Table 3-2 summarizes the actual QC samples collected during each OU 7 Phase I RFI/RI sampling activity

The field QC samples collected during the OU 7 Phase I RFI/RI include field duplicates, equipment rinsate blanks (equipment rinses), trip blanks, and field preservation blanks (field blanks) Among the various types of QC samples, field duplicates provide additional sample volume for a duplicate laboratory analysis These results, when compared to analytical results for the real samples, assess the precision of both the field sampling methods and analytical procedures

Duplicate samples are collected at the same time as the real samples, using the same procedures and the same types of containers They are also preserved in the same manner and submitted for the identical suite of analyses as required for the real samples

Equipment rinses are collected upon completing decontamination procedures to evaluate whether or not decontamination activities are adequate to prevent cross contamination Equipment rinses are obtained by pouring distilled water on decontaminated sample-collection equipment The rinsate is collected and submitted for the same analyses as the real samples For soil-gas samples, equipment blanks may also be collected by drawing ambient air through sampling equipment to evaluate decontamination procedures

Trip blanks and field blanks are collected for water samples to provide information on the potential for contamination during sample collection and transport Trip blanks and field blanks are not collected for solid media samples, therefore, contamination by ambient conditions during sample storage and shipping cannot be evaluated for the surface soil, subsurface geologic material, or sediment samples

Trip blanks consisting of distilled water are prepared either by the laboratory or the sampling team and accompany each shipment of water samples for volatile organic compound (VOC) analysis Analysis of these blanks indicates possible contamination by VOCs or any problems associated with sample shipment, handling, or storage

Field blanks of distilled water, preserved according to the applicable preservation requirements, are prepared by the sampling team and are used to provide an indication of any contamination introduced during field sampling preparation Field blanks are only applicable to samples requiring chemical preservation

3 1 2 Laboratory Qualifiers and Validation Codes

Two types of data qualifiers are used to describe data laboratory qualifiers and validation codes Validation codes are more important than laboratory qualifiers because they are determined as an independent quality check and are applied to the data after the laboratory qualifiers are applied

3 1 2 1 Laboratory Qualifiers

Environmental samples were analyzed using EPA and other well-established analytical methods identified in General Radiochemistry and Routine Analytical Services Protocol (GRRASP) (EG&G 1991g) All laboratory analyses for target analyte list (TAL) metals and target compound list (TCL) organic compounds were performed using EPA Contract Laboratory Program (CLP) procedures Methods for non-CLP analytes, including major ions and radionuclides, were based on EPA methods specified in the GRRASP

Laboratory qualifiers are defined in Table 3-3 The table also specifies whether or not data with a particular qualifier should be included in the data analysis, whether or not the data are detected, and what value should be used for statistical analysis

3 1 2 2 Validation Codes

EPA CLP methods and protocols were used in the validation process for these data Because EPA guidelines for validating non-CLP analytes are not currently available, non-CLP data were validated by an independent subcontractor in accordance with guidelines developed by the Rocky Flats Environmental Management Department (EMD) These non-CLP guidelines are based on EPA validation protocol and are modified for non-CLP analytical methods Data were validated at EPA Level IV or the equivalent for non-CLP analyses

Laboratory QA/QC results, including laboratory control-sample analyses, are not available from the Rocky Flats Environmental Database System (RFEDS) However, this information is reported to the data validation subcontractor and is reviewed to evaluate the precision and accuracy of laboratory analyses After reviewing laboratory QC results, the data validation subcontractor may qualify data as necessary

Validated data are qualified as either (1) V = valid and usable without qualification, (2) A = acceptable for use with qualification(s), or (3) R = rejected and thus unacceptable for use Valid data meet the following objective standards, where applicable

- Analytical methods were followed (primary validation criteria)
- Acceptance criteria were achieved
- Sufficient numbers and types of QC samples were analyzed
- QC limits were achieved (primary validation criteria)
- Compounds and analytes were correctly identified (primary validation criteria)
- Equipment and instrumentation calibration criteria were achieved (primary validation criteria)
- Sample holding times were met

Data that are acceptable with qualifications meet most, but not all, of the above-listed standards At a minimum, all of the primary validation criteria are achieved within acceptable limits Rejected data fail to meet primary validation criteria Data that were rejected were not used in any of the statistical calculations or in the data-quality assessment for OU 7 Data qualified as V or A are considered of equal utility, and both are used in computing statistics and evaluating data quality Table 3-4 presents the validation codes

Table 3-5 presents a summary of the data validation status for OU 7 as of December 1, 1993 Approximately 87 percent of all results have been validated The percentage validated varies by medium and analyte group The percentage of data validated by medium varies from 72 percent for groundwater to 100 percent for biota and soil gas The percentage of data validated by analyte group varies from 55 percent for dissolved radionuclides to 96 percent for total metals VOCs and SVOCs are above 90 percent Section 3 1 8 presents a detailed evaluation of the completeness of the data, including percentage validated and percentage rejected

3 1 3 Data Management

Data used for this report were extracted on December 1, 1993, from RFEDS, which is an electronic database that contains all data collected at the site In addition to analytical data for environmental samples, the RFEDS database includes information such as field measurements, QC samples, and analytical results for sample dilutions RFEDS contains all validated and unvalidated results Prior to determining data quality and usability, the entire database was reformatted and made internally consistent using the following five steps

1 Records reported with undefined units, laboratory qualifiers, or validation codes, blank results or unit fields, and non-radionuclide results equal to zero were researched If a resolution was not possible, these records were labeled as unusable

2 Tentatively identified compound (TIC) records were labeled based on a result type of TIC or laboratory qualifier of "A" or "N "

3 Unvalidated result values, detection limits, and units were replaced with validated result values, detection limits, and units if validated data were included with the record

4 Result values were converted to consistent units of measurement for each group of analytes as follows

metals—milligrams per kilogram (mg/kg) and micrograms per liter (µg/L)

organic compounds—micrograms per kilogram (µg/kg) and micrograms per liter(µg/L)

radionuclides—picocuries per gram (pCi/g) and picocuries per liter (pCi/L)

water-quality parameters—milligrams per kilogram (mg/kg) and micrograms per liter (µg/L)

5 Duplicate records were identified and researched to determine which record to use based on the result type (for example, TRG [target], DIL [dilution], REP [replicate], REX [re-extraction]), laboratory qualifier, and validation code The record not to be used was labeled For example, with an E-qualified organic compound TRG record and DIL record pair, retain the DIL record and label the TRG record as unusable

An internally consistent database of supportable data, standardized units of measure, and unique records for each analyte for each sample was developed using these cleanup steps Detect and nondetect criteria, summaries of the quantity, validation status, and usability status of the records were compiled from this database

Five additional steps were performed to produce the final "working" database

1 Records were labeled with usability categories based on the laboratory qualifiers and validation codes as presented in Table 3-6

2 TIC records were removed

3 Records labeled as unusable or rejected were removed

4 Results that indicate detection of an analyte (hits) and results that indicate non-detections were labeled based on the combination of laboratory qualifier and validation code as specified in tables 3-3 and 3-4, respectively

5 Two separate files, the "working" database (real sample results) and the QC database (QC sample results), were created as follows

   a Records of real and duplicate sample pairs were identified and copied to the QC database, duplicate sample records were removed from the working database

   b Records for field blanks, trip blanks, equipment rinses, and matrix spikes were moved from the working database to the QC database

Data from the working database are used to perform statistical comparisons of site data to background data and to evaluate the nature and extent of contamination Data from the QC database are used to describe the quality of data collected for the Phase I RFI/RI in terms of the data-quality indicators described below

3 1 4 Data-Quality Indicators

Data quality is assessed in terms of precision, accuracy, representativeness, comparability, and completeness, also known as the five precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters PARCC parameters apply to both laboratory and field data.

Precision is a measure of the reproducibility of analytical results Accuracy is a measure of how closely an analytical result corresponds to the actual concentration in a sample Representativeness is a qualitative measure of how well data meet the project goal of representing true background concentrations Completeness is a measure of the amount of valid data derived from the sampling program Comparability expresses the extent to which data collected over a period of years and analyzed by different methods can be considered to be equivalent

Sections 3 1 5 through 3 1 9 briefly describe each PARCC parameter, summarize the QC data available to assess the parameter, present the results of the data-quality evaluation for each analyte group for each media sampled, and evaluate the overall quality of the environmental data over the sampling period for each analyte group in each medium sampled Table 3-7 presents a summary of the PARCC parameter QC criteria for each analyte group for each media for the sampling period

3 1 5 Precision

Precision is a quantitative measure of variability that is evaluated by comparing analytical results for real samples to analytical results for corresponding duplicate samples Evaluating precision among duplicate samples provides information not only on reproducibility of sampling methods but also on reproducibility of analytical methods

Quantitative estimates of precision are made by calculating the relative percent difference (RPD) as defined by the following equation

$$RPD = (R - D) / ([R + D]/2) \times 100$$

where

R = concentration of analyte in real sample

D = concentration of analyte in duplicate sample

Data that were rejected during data validation were eliminated from the data set prior to any data-quality assessment calculations Data that were qualified as usable (V, A, or J) or that did not have a data validation code were used in the precision calculations Data that were qualified with a U, indicating nondetect results, were also used in the precision calculations When both real and duplicate results for a sample pair were nondetects, the

RPD was calculated to be zero percent Although poor reproducibility is inherent in results at levels near the detection limits, the occurrence of nondetect results in real and duplicate sample pairs indicates excellent precision For those sample pairs where a detectable result is reported for one sample and a nondetect result (U qualifier) is reported for the other sample, RPDs were calculated by substituting the detection limits for the nondetect result

QC criteria for RPD are specified in the QAPjP (EG&G 1990c), the GRRASP (EG&G 1991g), and the QAA to the OU 7 Phase I work plan (DOE 1991b) Acceptable RPDs are less than 20 percent for all analytes in water (surface water and groundwater) and less than 35 percent for all analytes in soil (surface soils, subsurface geologic materials, and sediments)

Where data are sufficient, summary statistics for RPDs were calculated by analyte group for each media sampled The statistics include the number of duplicates for which the RPD could be calculated, the number of duplicates for which RPDs exceed the QC criterion (that is, 20 or 35 percent), the arithmetic average, the standard deviation, and the coefficient of variation and are presented in Appendix J In most cases, the number of duplicates exceeding the QC criterion and the average RPD calculated is indicative of the overall precision of the data However, when the number of samples is small or when the coefficient of variation exceeds 100 percent, the average may not be a good measure of the central tendency of the data, and it is important to examine the other parameters as well

The assessment of precision by analyte group for the media sampled are discussed below

3 1 5 1 Soil-Gas Assessment

Ten soil-gas duplicate sample pairs were collected during the OU 7 Phase I RFI/RI and analyzed for VOCs Because the soil-gas results are based on Level II screening activities, the results were not formally validated As presented in Table J-1 (Appendix J), there are no data validation codes nor laboratory qualifiers associated with these results

Approximately 20 percent of the VOC results for soil gas duplicate sample pairs were reported as nondetects (RPD is zero percent), including all benzene results RPDs calculated for the remainder of the VOCs range from 0 to 197 percent Based on the

number of sample pair RPDs exceeding 20 percent and the average RPD, precision for VOCs in soil gas is fair

3 1 5 2 Landfill Leachate–Groundwater Assessment

Two duplicate sample pairs of leachate–groundwater were collected within the landfill using the Bengt-Arne Torstensson (BAT®) system during the OU 7 Phase I RFI/RI These samples were collected as part of the Level II field screening activities, and therefore, the results have not been formally validated

Table J-2 (Appendix J) presents the RPDs for real and duplicate sample pairs Approximately 20 percent of the VOC results were nondetects (RPD is zero percent) RPDs calculated for the remainder of the analytes ranged from 5 to 172 percent Based on the number of duplicate sample pairs with RPDs exceeding 20 percent and average RPD, overall precision for VOCs in landfill leachate–groundwater is fair

3 1 5 3 Surface-Soils Assessment

Twenty-nine duplicate surface-soil samples were collected during the OU 7 Phase I RFI/RI Precision of surface-soil sample analytical results for metals, radionuclides, semivolatile organic compounds (SVOCs), PCBs, anions, and soil-sampling parameters was assessed Table J-3 (Appendix J) presents the RPDs for all real and duplicate sample pairs

Metals

Approximately 23 percent of the metal results from surface-soil duplicate sample pairs were reported as U-qualified by the laboratory All results for cesium were reported as nondetects (RPD is zero percent) Metals for which most of the results were reported as nondetects include antimony, cadmium, mercury, molybdenum, selenium, silver, thallium, and tin Of these, approximately 12 percent have a result for one sample of the pair and a nondetect for the other sample The remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, vanadium, and zinc, have fewer than one-half of the results reported as nondetects

RPDs calculated for metals in surface soils are presented in Table J-3 Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD,

overall precision for metals is very good Although RPDs exceed 35 percent for the majority of metals for individual surface-soil sample pairs, the average RPD does not exceed the QC criterion All RPDs calculated for aluminum, iron, magnesium, potassium, strontium, and vanadium are below 35 percent It should be noted that it is difficult to reproduce metal concentrations between duplicate soil samples because of the heterogeneous nature of the matrix Resultant RPDs may reflect poor sampling precision due to the soil matrix, rather than poor laboratory precision

Radionuclides

Two percent of the radionuclide results for surface-soil duplicate sample pairs were reported as nondetects Approximately 30 percent of the radionuclide results were reported by the laboratory with a J- or an X-qualifier, indicating estimated or calculated concentrations, respectively RPDs calculated for radionuclides in surface soils are presented in Table J-3 Overall precision is fair for the majority of radionuclides None of the RPDs calculated for individual sample pairs exceed 35 percent for gross beta. At least one-half of all RPDs for individual surface-soil sample pairs exceed the QC criterion of 35 percent for americium-241, cesium-134, tritium, and uranium-235 Reproducibility of radionuclide concentrations among field duplicates can be difficult to achieve due to analytical limitations Many of the concentrations detected in surface soils were at levels very near the minimum detectable activity, several results were reported as negative values

SVOCs

Approximately 87 percent of the SVOC results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent) Of the remaining 13 percent, several analytes have a result for one sample of the pair and a nondetect for the other sample RPDs calculated for SVOCs are presented in Table J-3 Based on the number of sample pairs exceeding the QC criterion for precision and average RPD, overall precision is very good for SVOCs in surface soils

PCBs

Approximately 92 percent of the PCB results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent) The U-qualified results include Aroclor-1016, -1221, -1232, -1242, and -1248 for all surface soil duplicate

samples The only PCBs with RPDs in excess of 35 percent are Aroclor-1254 and Aroclor-1260 (Table J-3) In both cases, a result was reported for one sample of the pair and a nondetect was reported for the other sample Based on the number of sample pairs where the RPD exceeds QC criterion and the average RPD, overall precision for PCBs in surface soils is excellent

Anions and Soil-Sampling Parameters

Approximately 17 percent of the anions and soil-sampling parameter results for surface-soil duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent) Table J-3 presents RPDs calculated for anions and soil-sampling parameters RPDs are generally below 35 percent indicating that overall precision is very good for the majority of these analytes, including percent solids, pH, and alkalinity as $CaCO_3$ RPDs were not calculated for nitrate/nitrite

3 1 5 4 Subsurface Geologic Materials Assessment

Sixteen duplicate subsurface geologic material samples were collected during the OU 7 Phase I RFI/RI Precision of subsurface geologic material sample analytical results for metals, radionuclides, VOCs, SVOCs, pesticides, PCBs, major ions, and inorganic parameters was assessed Table J-4 (Appendix J) presents the RPDs for all real and duplicate sample pairs

Metals

Approximately one-half of all metal results for subsurface geologic material duplicate sample pairs were reported with a U qualifier by the laboratory Metals for which all results were reported as nondetects include cadmium and cesium (RPD is zero percent) Metals for which most of the results were reported as nondetects (RPD is zero) include antimony, mercury, molybdenum, selenium, silver, thallium, and tin Of these, approximately 20 percent have a result for one sample of the pair and a nondetect for the other sample The remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, vanadium, and zinc, have results reported

RPDs calculated for metals in subsurface geologic materials are presented in Table J-4 RPDs for individual soil samples exceed 35 percent for all metals except magnesium and sodium, however, average RPDs do not exceed the QC criterion for many metals Based

on the number of sample pair RPDs exceeding the QC criterion for precision and the average RPD, overall precision is very good It is difficult to reproduce metal concentrations between duplicate soil samples because of the heterogeneous nature of the matrix The RPDs calculated may reflect poor sampling precision due to the soil matrix rather than poor laboratory precision

Radionuclides

Approximately 30 percent of the radionuclide results for subsurface geologic material duplicate sample pairs were reported by the laboratory with a J qualifier to indicate estimated values Approximately 5 percent of all radionuclide results were reported with a U qualifier (RPD is zero percent), including all results for cesium-134 and approximately 29 percent of the results for cesium-137 RPDs calculated for radionuclides in subsurface geologic materials are presented in Table J-4 Based on the number of sample pair RPDs exceeding 35 percent and the average RPDs, overall precision is fair for the majority of radionuclides RPDs significantly exceed 35 percent for americium-124, cesium-137, plutonium-239,240, strontium-89,90, and tritium RPDs are below the precision limit for gross beta It is difficult to reproduce radionuclide concentrations because of equipment limitations

VOCs

RPDs were not calculated for VOCs in subsurface geologic material duplicate sample pairs Therefore, precision for VOCs in subsurface geologic materials cannot be evaluated

SVOCs

Over 99 percent of the SVOC results for subsurface geologic material duplicate sample pairs were reported with a U qualifier by the laboratory Results for benzo(b)fluoranthene and di-n-butyl phthalate were reported with a J qualifier The RPD calculated for benzo(b)fluoranthene is 10 percent The RPD calculated for di-n-butyl phthalate is 14 percent These percentages indicate excellent precision for those SVOCs

Pesticides and PCBs

All pesticide and PCB results for subsurface geologic material duplicate sample pairs were reported as U-qualified by the laboratory (RPDs are zero percent)

Major Ions and Inorganic Parameters

Approximately 60 percent of the major ions and inorganic parameter results for subsurface geologic material duplicate sample pairs were reported by the laboratory with a U or UX qualifier (RPD is zero percent), including sulfide and total organic carbon RPDs were not calculated for nitrate, nitrate/nitrite, and nitrite RPDs were calculated for pH and percent solids Based on the number of sample pair RPDs exceeding the QC criterion for precision and the average RPD, overall precision is excellent for these parameters

3 1 5 5 Sediments Assessment

One sediment duplicate sample pair was collected during the OU 7 Phase I RFI/RI Precision of sediment sample analytical results for metals, radionuclides, VOCs, SVOCs, major ions, and inorganic parameters was assessed Table J-5 (Appendix J) presents all RPDs for this sample pair

Metals

Approximately 18 percent of the metal results for the sediment duplicate sample pair were reported as U-qualified by the laboratory Metals for which both results were reported as nondetect (RPD is zero percent) include cesium, mercury, molybdenum, and thallium Metals for which only one of the results was a nondetect include cadmium and tin For the remaining metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, selenium, silicon, silver, sodium, strontium, vanadium, and zinc, both the real and duplicate sample have results reported RPDs calculated for sediment are presented in Table J-5 Based on the number of sample pair RPDs exceeding the QC criterion for precision and the average RPD, overall precision is excellent for the majority of metals RPDs exceeded 35 percent for only lithium and silver RPDs for these metals are 37 percent and 39 percent, respectively

Radionuclides

Approximately 36 percent of the radionuclide results for the sediment duplicate sample pair were reported by the laboratory with either a J or an X qualifier Approximately 36 percent of the duplicate analyses have RPDs in excess of the QC criterion for precision RPDs exceed 35 percent only for cesium-137, plutonium-239,240, strontium-89,90, and

uranium-235 and range from 44 to 117 percent (Table J-5) Based on these percentages, overall precision is good for radionuclides in sediments

VOCs

Approximately 94 percent of the VOC results for the sediment duplicate sample pair were reported as U-qualified by the laboratory All results for 31 of the 33 VOCs analyzed were reported as nondetects (RPD is zero percent) As presented in Table J-5, the RPD calculated for acetone is 114 percent The RPD calculated for toluene is 23 percent Based on the QC criterion of 35 percent, precision for acetone (a common laboratory contaminant) is poor whereas precision for toluene in sediments is very good

SVOCs

Approximately 95 percent of the SVOC results for the sediment duplicate sample pair were reported by the laboratory with a U qualifier For bis(2-chloroisopropyl)ether, fluoranthene, phenanthrene, and pyrene, one result was reported as a nondetect and the other as a detect Estimated values, reported by the laboratory with a J qualifier, were reported for benzoic acid The RPD calculated for benzoic acid is 133 percent (Table J-5) indicating that precision for this analyte is very poor

Major Ions and Inorganic Parameters

Approximately 60 percent of the major ions and inorganic parameter results (including nitrate, nitrate/nitrate, and total organic carbon) for the sediment duplicate sample pair were reported by the laboratory with either a U or an X qualifier, indicating nondetect or calculated results, respectively RPDs were not calculated for these analytes RPDs calculated for percent solids and pH are 2 percent and 4 percent, respectively (Table J-5) These values indicate that precision is excellent for these parameters

3 1 5 6 Surface-Water Assessment

Two duplicate surface-water samples were collected from the East Landfill Pond at location SW098 Precision of surface-water sample analytical results for dissolved metals, total metals, dissolved radionuclides, total radionuclides, VOCs, SVOCs, pesticides, PCBs, anions, cyanide, and water-quality parameters was assessed Table J-6 presents the RPDs for all real and duplicate samples pairs

Dissolved Metals

Over 50 percent of the dissolved metal results were reported as U-qualified by the laboratory Metals for which all results were reported as nondetects (RPD is zero percent) include aluminum, beryllium, cesium, chromium, cobalt, mercury, selenium, silver, thallium, tin, and vanadium Metals for which most of the results were reported as nondetects include antimony, cadmium, copper, molybdenum, and nickel Of these, approximately 60 percent have a result for one sample of the pair and a nondetect for the other sample The remaining dissolved metals, including arsenic, barium, calcium, iron, lead, lithium, magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than one-half of the results reported as nondetects

RPDs calculated for dissolved metals in surface water are included in Table J-6 Based on the number of samples pairs exceeding the QC criterion for precision and the average RPD, overall precision is very good Individual RPDs exceed 20 percent only for iron and zinc

Total Metals

Approximately 56 percent of the total metal results for surface-water duplicate sample pairs were reported as U-qualified results by the laboratory Metals for which all results were reported as nondetects (RPD is zero percent) include antimony, arsenic, beryllium, cadmium, cesium, cobalt, lead, mercury, selenium, silver, thallium, and vanadium Metals for which at least one-half of all results were reported as nondetects include aluminum, chromium, copper, molybdenum, nickel, and tin Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample The remaining total metals, including barium, calcium, iron, lithium, magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than half of the results reported as nondetects

RPDs calculated for total metals in surface water are presented in Table J-6 Based on the overall number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is excellent for total metals in surface water Individual RPDs exceed 20 percent only for iron and zinc

Dissolved Radionuclides

Approximately 12 percent of the dissolved radionuclide results for surface-water duplicate sample pairs were reported as U-qualified or UE-qualified (detection limit reported as result) by the laboratory In addition, many results are qualified with a J All of the RPDs calculated for americium-241, cesium-137, gross alpha, plutonium-239,240, and uranium-235 exceed 20 percent RPDs for these analytes range from 26 to 447 percent One-half of the RPDs calculated for gross beta, uranium-233,234, and uranium-238 exceed 20 percent (Table J-6) The values for much of the radionuclide activity observed were at levels indistinguishable from the minimum detectable activity and in many cases were negative Reproducibility is difficult to achieve under these circumstances because of analytical limitations, and this does not necessarily indicate poor field precision

Total Radionuclides

Approximately 11 percent of the total radionuclide results for surface-water duplicate sample pairs were reported by the laboratory with a U or UC qualifier Many of the results are J-qualified All but one RPD calculated for total radionuclides exceeds 20 percent (Table J-6) The majority of activity observed was at levels indistinguishable from minimum detectable activity In several cases, the radionuclide results are negative Reproducibility can be difficult to achieve due to analytical limitations, and this may not necessarily indicate poor precision

VOCs

All VOC results for surface-water duplicate sample pairs are U-qualified by the laboratory indicating that there were no VOCs detected Consequently, RPDs calculated for these analytes are zero percent (Table J-6) The occurrence of nondetect results in both real and duplicate samples indicates excellent precision for VOCs in surface water

SVOCs

Approximately 99 percent of the SVOC results for surface-water duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent) The only SVOCs detected in duplicate samples are bis(2-ethylhexyl)phthalate and di-n-butyl phthalate Estimated analytical results were reported for bis(2-ethylhexyl)phthalate, the RPD is 120 percent (Table J-6) An estimated result and a nondetect result were reported

for di-n-butyl phthalate Based on consistent nondetect results in real and duplicate samples, overall precision for SVOCs in surface water is excellent

Pesticides and PCBs

As presented in Table J-6, all pesticide and PCB results for surface-water duplicate sample pairs are nondetects (RPD is zero percent)

Anions, Cyanide, and Water-Quality Parameters

Approximately 40 percent of the anion, cyanide, and water-quality parameter results for surface-water duplicate sample pairs are U-qualified by the laboratory, including all results for carbonate, cyanide, sulfide, and total suspended solids (TSS) The only analytes that exceed the QC criterion for precision are nitrate and TDS RPDs for these analytes are 123 percent and 21 percent, respectively Based on the number of sample pairs exceeding the QC criterion and the average RPD, overall precision is very good for the majority of analytes

3 1 5 7 Groundwater Assessment

Three duplicate groundwater samples were collected during the OU 7 Phase I RFI/RI Precision of groundwater-sample analytical results for dissolved metals, total metals, dissolved radionuclides, total radionuclides, VOCs, SVOCs, anions, cyanide, and water-quality parameters was assessed Table J-7 in Appendix J presents the RPDs for all real and duplicate sample pairs

Dissolved Metals

More than 60 percent of the dissolved metal results for groundwater duplicate sample pairs were reported by the laboratory with a U qualifier (analyte not detected at the quantitation limit) or a UN qualifier (sample result below detection limit) Metals for which all results were reported as nondetects (RPD is zero percent) include antimony, arsenic, beryllium, cadmium, cesium, chromium, mercury, molybdenum, nickel, selenium, silver, thallium, tin, and vanadium Metals for which most of the results were reported as nondetects include aluminum, cobalt, copper, and lead Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample The remaining dissolved metals, including barium, calcium, iron, lithium,

magnesium, manganese, potassium, silicon, sodium, strontium, and zinc, have fewer than half of the results reported as nondetects

RPDs calculated for dissolved metals in groundwater are presented in Table J-7 (Appendix J) Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is very good for the majority of these analytes Individual RPDs exceed 20 percent only for iron, manganese, potassium, and zinc RPDs for these metals range from 27 to 170 percent

Total Metals

Approximately 30 percent of the total metal results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory Metals for which all results were reported as nondetects (RPD is zero percent) include cesium, mercury, molybdenum, selenium, silver, and thallium Metals for which at least one-half of all results were reported as nondetects include antimony, cadmium, and selenium Of these, approximately 50 percent have a result for one sample of the pair and a nondetect for the other sample The remaining total metals, including aluminum, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, tin, vanadium, and zinc, have fewer than 50 percent of the results reported as nondetects

RPDs calculated for total metals in groundwater are presented in Table J-7 Based on the number of sample pairs exceeding the QC criterion for precision and the average RPD, overall precision is poor for the majority of these analytes Approximately 60 percent of the RPDs exceed the QC criterion RPDs for aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silicon, tin, vanadium, and zinc exceed 20 percent RPDs for these metals range from 22 to 110 percent RPDs are below 20 percent for calcium, sodium, and strontium only

Dissolved Radionuclides

Approximately 40 percent of the dissolved radionuclide results for groundwater duplicate sample pairs were reported by the laboratory with a J qualifier to indicate estimated values None of the results were reported as nondetects

The RPDs calculated for dissolved radionuclides including americium-241, cesium-134, cesium-137, gross alpha, gross beta, plutonium-239,240, strontium-89,90, uranium-

233,234, uranium-235, and uranium-238 are presented in Table J-7 Many of the RPDs calculated exceed 20 percent, however, many activities observed were at levels indistinguishable from the minimum detectable activity and in many cases are negative values Reproducibility under these circumstances is difficult to achieve because of analytical limitations, and this does not necessarily reflect poor field precision All RPDs for americium-241, cesium-134, cesium-137, plutonium-239-240, strontium-89,90, uranium-233,234, uranium-235, and uranium-238 exceed 20 percent and range from approximately 64 percent to 1,088 percent One-half of the RPDs calculated for both gross alpha and gross beta exceed 20 percent

Total Radionuclides

One-half of the total radionuclide results for groundwater duplicate sample pairs were reported as J-qualified results by the laboratory Approximately 85 percent of the RPDs calculated exceed the QC criterion of 20 percent and include all values for americium-241 and plutonium-239,240 and the majority of values for tritium These elevated RPDs, which range from approximately 51 to 250 percent (Table J-7) reflect the difficulty of obtaining consistent reproducibility with radionuclide results because of analytical limitations Therefore, the high RPDs do not necessarily represent poor field precision

VOCs

Approximately 96 percent of the VOC results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory All results for 31 of 34 VOCs analyzed are reported as nondetects For 1,1,1-TCA, the majority of individual results are nondetects, however, for one sample pair the result for one member was reported as nondetect whereas a detectable result was reported for the other member Those analytes for which the laboratory reported detectable results for each sample in a pair include 1,2-DCE and TCE RPDs for VOCs in groundwater are presented in Table J-7 The RPD calculated for 1,2-DCE is 18 percent The RPD calculated for TCE ranges from 0 to 75 percent These percentages indicate very good precision for 1,2-DCE and fair precision for TCE

SVOCs

Approximately 99 percent of the SVOC results for groundwater duplicate sample pairs were reported as U-qualified results by the laboratory (RPD is zero percent) These

results include analysis for 63 of 65 SVOCs For di-n-butyl phthalate, one result was reported as an estimated value although the other five results were reported by the laboratory with a U qualifier Similarly, the laboratory results for diethyl phthalate included an estimated value and a nondetect value RPDs for SVOCs in groundwater are presented in Table J-7

Anions, Cyanide, and Water-Quality Parameters

More than 30 percent of the anion, cyanide, and water-quality parameter results for groundwater duplicate sample pairs were reported as U-qualified by the laboratory The only analyte for which all results are reported as nondetects is bicarbonate as calcium carbonate (RPD is zero percent) For cyanide, fluoride, and sulfide, the majority of individual results are nondetects (RPD is zero percent) However, for approximately 5 percent of the cyanide, fluoride, and sulfide results, one result is reported as a nondetect and the other as a detect

RPDs calculated for bicarbonate as $CaCO_3$, chloride, nitrate, nitrate/nitrite, nitrite, sulfate, TDS, and TSS in groundwater are presented in Table J-7 Based on the number of sample pairs exceeding the QC criterion and the average RPD, overall precision is good for the majority of these analytes Individual RPDs exceed 20 percent only for bicarbonate as $CaCO_3$, nitrate/nitrite, TDS, and TSS RPDs for these analytes range from 23 to 103 percent

3 1 6 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value Analytical accuracy is determined by laboratory analyses of materials with known analyte concentrations such as laboratory standards, laboratory control samples, and matrix spike samples This measure is expressed as bias and is determined by calculating percent recovery from spiked samples Percent recovery (%R) is defined as

$$\%R = (SSR - SR) / SA \times 100$$

where

SSR = spiked sample result

SR = sample result

SA = spike added

Percent recovery is reported in the data set and is presented for each analyte group in each medium sampled The QC criterion for percent recovery, specified in the QAA for OU 7 (DOE 1991b) and the GRRASP (EG&G 1991g), is 80 percent to 120 percent for all analytes in all media.

Where sufficient data are available, summary statistics for accuracy are calculated Because %R can be either positive or negative, summary statistics are reported in terms of the absolute value of the percent bias (%Bias) to better express variations around 100-percent recovery (%Bias = 100 - %R) In terms of %Bias, the QC criterion is 20 percent Data presented in the OU 7 summary tables (Appendix J) for accuracy include %R, %Bias, number of %Rs reported, number of %Biases exceeding 20 percent, and data qualifiers provided by RFEDS

Spike data in the OU 7 data set consist of matrix spike (MS) and matrix spike duplicate (MSD) data The only medium for which spikes were collected and analyzed is groundwater Total and dissolved metals were used as the spike analytes No information on spike concentrations is available, thus possible correlations between accuracy and concentration cannot be evaluated

3 1 6 1 Groundwater Assessment

One MS and one MSD groundwater sample were collected and analyzed during the OU 7 Phase I RFI/RI Table J-8 in Appendix J presents the %Bias results for the groundwater spike samples collected

Dissolved Metals

For the MS sample, all dissolved metals, with the exception of cesium and selenium, meet the QC criterion for accuracy of 20 percent These metals measure %Biases of 517 percent (reported by the laboratory with a U qualifier) and 26 percent, respectively The MSD was analyzed for two dissolved metals, cesium and silicon Only silicon has a %Bias that exceeds the QC criterion of 20 percent The %Bias for silicon is 44 percent

Total Metals

Table J-8 presents %R and %Bias for total metals All MS and MSD results, with the exception of those for aluminum, arsenic, cesium, iron, and silicon, are below the QC criterion for accuracy of 80 percent to 120 percent for %R and 20 percent for %Bias These five metals measure %Biases ranging from 34 to 517 percent Based on the MS and MSD data, total metals generally meet the %Bias criterion for accuracy

3 1 7 Representativeness

Representativeness is a qualitative parameter that expresses the degree to which sample data accurately and precisely represent the characteristics of a particular site or condition Representativeness is evaluated through the careful development and review of the sampling and analysis strategy The representativeness of OU 7 samples is determined by evaluating whether or not the samples collected are truly representative of the concentrations in the field, or if they have been affected by the introduction of contamination during collection and handling Adherence to the field sampling plan for OU 7 ensured that samples collected from environmental media are representative Possible contamination in the laboratory is addressed during data validation

Possible contamination of the environmental samples is evaluated by examining analytical results for field blanks, equipment rinses, and trip blanks Field blanks were prepared in the field using distilled water These blanks accompany environmental water samples (groundwater and surface water) through collection, preparation, shipping, and analytical procedures Analytical results of the field blanks can identify contamination that may have been introduced during any of these steps The only field blanks collected during the OU 7 Phase I RFI/RI are surface water samples

Equipment rinses are used to evaluate the effectiveness of the decontamination process and potential for cross-contamination between samples Equipment rinses are prepared in the field using distilled water that has been used to clean decontaminated sampling equipment Equipment rinses are handled in the same manner as environmental samples tables J-9 through J-15 summarize the analytes detected in all field QC samples collected during the OU 7 Phase I RFI/RI

Trip blanks are used to assess the possibility that environmental water samples become contaminated during storage and transportation Only one trip blank was analyzed during

OU 7 Phase I RFI/RI sampling activities, this blank was collected in conjunction with surface-water sampling The trip blank was prepared in the sample preparation area of the OU 7 field trailer and accompanied the sample containers to the field and then to the laboratory for analysis

3 1 7 1 Soil-Gas Assessment

Four equipment rinses were collected in conjunction with soil-gas sampling at IHSS 114 Seven equipment blanks were collected during soil-gas sampling at IHSS 203 Table J-9 presents the equipment rinse and equipment blank results

Results for the equipment rinses collected at IHSS 114 indicate that residual concentrations of several VOCs present may have affected the representativeness of the soil-gas screening samples Several VOCs were also detected in the equipment blanks collected at IHSS 203 However, based on the frequency of detection and the concentrations detected, their presence does not appear to have affected the representativeness of soil-gas samples collected at IHSS 203

3 1 7 2 Landfill Leachate–Groundwater Assessment

Two equipment rinses were collected at the landfill in conjunction with leachate–groundwater sampling using the BAT® system Table J-10 presents the results for these QC samples Several VOCs were detected in these samples indicating that their presence may have affected the representativeness of the leachate–groundwater screening samples

3 1 7 3 Surface-Soils Assessment

Thirteen equipment rinses were collected in conjunction with surface-soil sampling Table J-11 summarizes the analytical results

Metals

Metals detected include aluminum, arsenic, barium, beryllium, calcium, copper, iron, magnesium, manganese, potassium, selenium, silicon, sodium, and zinc With the possible exception of arsenic and zinc, these metals were most likely present in the distilled water used to rinse sampling equipment Arsenic and zinc were detected relatively infrequently and at concentrations that should not affect the representativeness of the surface-soil samples

Radionuclides

Equipment rinses were also analyzed for radionuclides Because of the nature of reporting requirements, all radionuclide results are reported as hits

VOCs

One of the 13 equipment rinses collected in conjunction with surface-soil sampling was analyzed for VOCs As presented in Table J-11, VOCs were not detected in this sample indicating that decontamination procedures were adequate to prevent cross contamination of samples

SVOCs

The equipment rinse analyzed for VOCs was also analyzed for SVOCs The only SVOC detected was bis(2-ethylhexyl)phthalate at a concentration that should not affect the representativeness of the surface-soil samples

PCBs

Five of the 13 equipment rinses collected during surface-soil sampling activities were analyzed for PCBs, specifically Aroclor compounds Because no PCBs were detected, surface-soil samples collected and analyzed for PCBs are representative of site conditions and were not affected by cross contamination

Major Ions and Inorganic Parameters

Ten of the 13 equipment rinses collected were analyzed for nitrate/nitrite, and all of the rinsate samples were analyzed for total organic carbon (TOC) Nitrate/nitrite and TOC were detected in at least one sample Their presence does not occur with the frequency or the concentration levels that should affect the representativeness of the surface-soil samples.

3 1 7 4 Subsurface Geologic Materials Assessment

Ten equipment rinses were collected during subsurface geologic material sampling at OU 7 Table J-12 presents the analytical results

Metals

Metals detected in equipment rinses include aluminum, antimony, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, potassium, selenium, silicon, silver, sodium, tin, and zinc With the possible exception of cadmium, copper, silver, and zinc, these metals are major-ion constituents of natural waters and may have originated from the distilled water used to rinse sampling equipment Cadmium, copper, silver, and zinc were detected at frequencies and concentrations low enough so that their presence should not affect the representativeness of subsurface geologic material samples

Radionuclides

Nine of the 10 equipment rinses collected during subsurface geologic material sampling were analyzed for radionuclides Due to the nature of reporting requirements, all radionuclide results are reported as hits (Table J-12)

VOCs

All ten of the equipment rinses were analyzed for VOCs The only VOCs detected were acetone and methylene chloride, both of which are common laboratory contaminants Based on these data, it appears that decontamination procedures were adequate to prevent cross contamination and that analytical results for VOCs in subsurface geologic material samples are representative of actual site concentrations

SVOCs

All equipment rinses were also analyzed for SVOCs SVOCs were not detected in any of the equipment rinse samples indicating that decontamination procedures were adequate to prevent cross contamination of samples collected during subsurface geologic material sampling

Pesticides and PCBs

Neither pesticides nor PCBs were detected in any of the 10 equipment rinses indicating that any pesticides or PCBs detected in the subsurface geologic material samples are representative of site concentrations and not the result of inadequate decontamination procedures

Major Ions and Inorganic Parameters

The only major ions detected in any of the 10 equipment rinses are nitrate and nitrate/nitrite, both analytes were detected in one rinse sample only Their presence in equipment rinses does not occur with the frequency that could adversely affect the representativeness of the subsurface geologic material samples

3 1 7 5 Sediments Assessment

One equipment rinse was collected in conjunction with sediment sampling during the OU 7 Phase I RFI/RI Table J-13 presents the analytical results

Metals

The only metals detected were arsenic, cadmium, iron, silicon, sodium, and zinc With the possible exception of arsenic, cadmium, and zinc, the most likely source for these metals is the distilled water used to rinse sampling equipment The concentrations of arsenic, cadmium, and zinc detected are low and should not affect the representativeness of the sediment samples

Radionuclides

Equipment rinses were also analyzed for radionuclides Because of the nature of reporting requirements, all radionuclide results are reported as hits

VOCs

The only VOC detected in the equipment rinse was acetone, which is a common laboratory contaminant These data indicate that decontamination procedures conducted during OU 7 sediment sampling were adequate to prevent cross contamination of samples

SVOCs

SVOCs were not detected in the equipment rinse indicating that decontamination activities were adequate Therefore, concentrations of SVOCs detected in sediment samples should be representative of environmental concentrations

Major Ions and Inorganic Parameters

The only inorganic parameter detected in the equipment rinse collected during sediment sampling was TOC Based on these data, it does not appear that cross contamination occurred during sediment sampling

3 1 7 6 Surface-Water Assessment

Three equipment rinses were collected and analyzed for metals during surface-water sampling at OU 7 One field blank was also collected Table J-14 presents the analytical data

Metals

Aluminum, antimony, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, manganese, silicon, sodium, tin, and zinc were detected in at least one of the three equipment rinses collected The most likely source for the metals, with the possible exception of copper and zinc, is the distilled water used to rinse sampling equipment Based on the concentrations detected, it does not appear that the presence of these metals affects the representativeness of the surface-water samples

The only metals detected in the field blank were beryllium, calcium, iron, lead, molybdenum, silicon, sodium, and zinc All metals, with the possible exception of lead and zinc, most likely were present in the distilled water used to rinse sampling equipment The levels of lead and zinc detected do not appear to affect the representativeness of surface-water samples

Radionuclides

The equipment rinses and field blank were also analyzed for radionuclides Because of the nature of reporting requirements, all radionuclide data are reported as hits

VOCs

All of the equipment rinses were analyzed for VOCs The only VOCs detected, at relatively low levels, were acetone and methylene chloride, both of which are common laboratory contaminants Based on these data, it appears that decontamination procedures were adequate to prevent cross contamination

In addition, a trip blank was prepared and accompanied surface-water samples to the laboratory There were no VOCs detected in this blank, indicating that surface-water samples were not subject to introduced contamination during storage or transportation to the laboratory Based on these data, surface-water samples collected are representative of actual environmental conditions

SVOCs

The only SVOC detected in any of the equipment rinses associated with surface-water sampling was bis(2-ethylhexyl)phthalate, which was detected at a low concentration in one of the three rinses The presence of this compound does not occur with the frequency or the concentration level that should affect the representativeness of the surface-water samples

Pesticides and PCBs

All of the equipment rinses were analyzed for pesticides and PCBs As presented in Table J-14, no pesticides nor PCBs were detected in the equipment rinses collected after the field sampling equipment was decontaminated Therefore, it appears that decontamination procedures during surface-water sampling were adequate to prevent cross contamination and that samples collected are representative of site conditions

Anions, Cyanide, and Water-Quality Parameters

All equipment rinses were analyzed for anions, cyanide, and water-quality parameters Sulfate and TDS were the only analytes/parameters detected in the three equipment rinses The most likely source for these analytes/parameters is the distilled water used to rinse sampling equipment These data indicate that surface-water samples collected are representative of site conditions The field blank collected during surface-water sampling was analyzed for nitrate/nitrate, which was not detected

3 1 7 7 Groundwater Assessment

Two equipment rinses were collected and analyzed in conjunction with groundwater sampling during the OU 7 Phase I RFI/RI Table J-15 presents the analytical results for these equipment rinses, including the frequency of "hits" with detectable concentrations reported

Metals

The metals detected in at least one of the two equipment rinses include aluminum, arsenic, calcium, copper, iron, lead, manganese, potassium, silicon, sodium, strontium, and zinc The most likely source for these metals, with the possible exception of arsenic, copper, lead, and zinc, is the distilled water used to collect the equipment rinses The presence of the metals detected does not occur with the frequency or at the concentration levels that should affect the representativeness of the groundwater samples

Radionuclides

Because of the nature of reporting requirements, all radionuclide results are reported as hits in the equipment rinses Table J-15 presents the data, including the minimum, maximum, and mean results

VOCs

There were no VOCs detected in the equipment rinses, indicating that decontamination procedures conducted during groundwater sampling were adequate to prevent cross contamination Based on the VOC data, groundwater samples collected and analyzed during the OU 7 Phase I RFI/RI appear to be representative of site conditions

SVOCs

SVOCs were not detected in either of the two equipment rinses Based on the data, it appears that decontamination of the groundwater sampling equipment was adequate to prevent cross contamination

Anions, Cyanide, and Water-Quality Parameters

As presented in Table J-15, the only analytes/parameters detected in one of two equipment rinses were sulfide, TDS, and TSS No analytes were detected in the other equipment rinse TDS is a common constituent of natural waters and may originate from the distilled water used to rinse sampling equipment Sulfide and TSS were detected in one of the two equipment rinses Their occurrence may indicate that decontamination procedures associated with these rinses may not have been adequate to prevent cross contamination

3 1 8 Completeness

Completeness is a measure of the amount of usable data resulting from a data collection activity The target completeness objective for the OU 7 Phase I RFI/RI field and analytical data is 100 percent with a minimum acceptable limit of 90 percent (DOE 1991b) The completeness of field activities is defined by the actual number of samples or measurements collected relative to the number of samples or measurements specified in the work plan Analytical data completeness is defined as the percentage of measurements made that are judged to be valid

The completeness of field activities is described in Appendix C of this report Completeness for the OU 7 Phase I RFI/RI is evaluated by comparing the planned to the actual number of samples collected and analyzed Table C-2 (Appendix C) presents this comparison It is difficult to quantify completeness in strict accordance with the guidelines noted above In general, the number of samples collected and types of analyses performed at each sampling location matched those specified in the work plan Samples not collected were due to extenuating circumstances related to field conditions (that is, location inaccessible to the rig, dry wells) Additional samples were collected beyond those specified in the work plan (that is, methane survey at the Present Landfill) to further characterize the site and determine the nature and extent of contamination

Based on the information presented in Table C-2, the OU 7 Phase I RFI/RI data are approximately 95 percent complete Specific field activities for which completeness did not meet the target of 90 percent include soil-gas and landfill leachate–groundwater sampling using the BAT® system, subsurface geologic material sampling in boreholes, groundwater sampling, surface-water sampling and flow-rate measuring at the groundwater intercept system discharge points, and radiation field screening using a Geiger-Mueller detector Specific field activities for which completeness exceeded 100 percent because additional samples were collected include the screening-level methane survey, well tests, soil-gas sampling, surface-soil sampling, and surveying at IHSS 203, and surface-soil sampling and surveying around the East Landfill Pond

Analytical results should be validated to be considered in an assessment of completeness Table 3-5 presents a summary of the data validation results as of December 1, 1993 (date of most recent RFEDS extraction), including the percent validated and percent rejected A percentage rejected of more than approximately 10 percent is used as an indicator of poor completeness The percentage validated varies by medium and by analyte group

Percentage validated by medium ranges from 73 percent (groundwater) to 100 percent (biota) Of the total data that have been validated, less than 3 percent has been rejected

With the exception of VOCs, all analyte groups for surficial soils had less than 8 percent of their data rejected Approximately 37 percent of the VOC results were rejected Overall, the number of results rejected for surface soils is 2 percent indicating excellent completeness As presented in Table 3-5, completeness for subsurface geologic materials and sediments is also excellent, the total results rejected are 2 percent and 4 percent, respectively

For groundwater, the percentage of results rejected for each analyte group was less than 3 percent The total percentage rejected is 2 percent indicating excellent completeness Similarly, the total percentage of results rejected for surface water is 7 percent With the exception of SVOCs, which had 18 percent of results rejected, all analyte groups for surface water had less than 5 percent of their results rejected These data indicate that completeness for surface-water analytical results is very good

3 1 9 Comparability

Comparability expresses the confidence with which data are considered comparable Because data are collected over a period of months or years and analyzed by different analytical laboratories or methods, comparability of different data sets is critical to data analysis Comparability is a qualitative parameter that is ensured by implementation of an approved sampling and analysis plan, standardized analytical protocols, and standard operation procedures for field investigations

In order to achieve comparability, work has been performed at OU 7 in accordance with an approved work plan (DOE 1991b), standard analytical protocols outlined in the GRRASP (EG&G 1991g), and approved SOPs for data collection (EG&G 1992c) OU 7 Phase I RFI/RI data are reported in uniform units µg/L, µg/kg, milligrams per liter (mg/L), mg/kg, pCi/L, pCi/g

Prior data collection activities employed variable sample collection and laboratory analytical methods As a result, historical data may not always be comparable to data obtained during the OU 7 Phase I RFI/RI

3 1 10 Summary of Data Quality by Media

Data quality by sample media for soil gas, landfill leachate–groundwater, surface soils, subsurface geologic materials, sediments, surface water, and groundwater is summarized below

3 1 10 1 Soil Gas

Precision for soil-gas data is fair The majority of RPDs calculated for several individual VOCs exceeded the QC criterion of 20 percent, including 2-butanone, 1,2-DCE, acetone, toluene, TCE, 1,1,1-TCA, and xylenes

Accuracy was not determined for soil gas sampling

Representativeness is good Almost all of the VOCs analyzed for were detected in at least one of the equipment rinses or equipment blanks, however, the concentrations detected are generally low For the purpose of Level II screening data, the results of the soil-gas samples do provide a qualitative assessment of the location and relative concentrations of any "hotspots "

Completeness of the soil-gas sampling activities was 84 percent This value is below the minimum acceptable limit of 90 percent

Comparability of the soil-gas data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c)

3 1 10 2 Landfill Leachate–Groundwater

Precision for landfill leachate–groundwater data is poor VOCs with at least half of the RPDs exceeding the QC criterion of 20 percent include 2-butanone, 1,2-DCE, hydrogen sulfide, methane, methylene chloride, toluene, TCE, and xylenes

Accuracy was not determined for landfill leachate–groundwater samples

Representativeness is good Several VOCs, including 1,2-DCE, acetone, methane, 2-butanone, methylene chloride, and TCE, were detected in the field QC samples, however, the concentrations detected were generally low These samples were used as a screening

tool, and their qualitative results were backed up with Level III and IV data (that is, groundwater samples collected from monitoring wells)

Completeness of the leachate–groundwater sampling activities was 40 percent Although this level of completeness did not meet DQO objectives, data obtained were supplemented with data from groundwater monitoring wells to achieve overall objectives

Comparability of the data has been established using an approved sampling and analysis plan, standard analytical protocols, and an SOP currently in preparation (EG&G in progress)

3 1 10 3 Surface Soils

Precision for most analytes for surface soils is good, even though it can be difficult to achieve reproducibility in soil samples because of the heterogeneity of the matrix Precision for radionuclides in surface soils, including americium-241, cesium-134, strontium-89,90, tritium, and uranium-235 was poor, particularly at levels near the minimum detectable activity

Accuracy was not determined for surface-soil sampling

Representativeness is good Although several metals were detected in the equipment rinses collected during surface-soil sampling, the majority are major ions commonly found in water and most likely originated in the distilled water used to rinse sampling equipment Arsenic and zinc, which were most likely not present in the distilled water, were detected relatively infrequently and at low concentrations

Completeness of surface-soil sampling activities at IHSS 203 and the areas around the East Landfill Pond exceeded 100 percent because additional samples were collected at each area. Additional soil sampling at IHSS 114 also exceeded the DQOs for completeness Of the total results available as of December 1, 1993, over 88 percent have been validated and less than 3 percent rejected

Comparability of Phase I RFI/RI surface-soil data from IHSS 114 is not comparable to surface-soil data from IHSS 203 and the East Landfill Pond because the sampling methods were different

3 1 10 4 Subsurface Geologic Materials

Precision for most analytes in subsurface geologic material samples is generally very good, with the exception of manganese, nickel, and the majority of radionuclides Reproducibility associated with these metals is poor as indicated by the number of RPDs exceeding the QC criterion of 35 percent Similarly, reproducibility among the radionuclides is generally poor with the exception of gross alpha, gross beta, radium-226, radium-228, uranium-233,234, uranium-235, uranium-238, particularly at levels near the minimum detectable activity

Accuracy was not determined for subsurface geologic material sampling

Representativeness is good Several metals were detected in the field QC samples, however, most analytes, with the possible exception of cadmium, copper, silver, and tin, probably originated in the distilled water used to rinse sampling equipment Cadmium, copper, silver, and tin occurred infrequently and at low concentrations

Completeness of subsurface geologic material sampling was 100 percent for upgradient boreholes, 95 percent for downgradient boreholes, and 56 percent for landfill boreholes (48 percent complete in artificial fill and 95 percent complete in bedrock) The average completeness for subsurface geologic material sampling was 84 percent Of the total results available as of December 1, 1993, over 96 percent have been validated with less than 3 percent rejected indicating that analytical completeness is very high

Comparability of Phase I RFI/RI subsurface geologic material data to historical subsurface geologic material data has been ensured by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c)

3 1 10 5 Sediments

Precision is generally very good for all analytes, with the exception of lithium, silver, cesium-137, gross alpha, plutonium-239,240, strontium-89,90, uranium-235, acetone, and benzoic acid RPDs for these analytes exceed the QC criterion of 35 percent for solid media

Accuracy was not determined for sediment sampling

Representativeness is good Although acetone and several metals were detected in the equipment rinse collected in conjunction with sediment sampling, the majority of these analytes most likely were present in the distilled water used to prepare the rinsate sample Arsenic, cadmium, zinc, and acetone, which probably did not originate in the distilled water, were detected infrequently and at low concentrations

Completeness of sediment sampling is 100 percent indicating that supported conclusions can be made based on these data. Analytical completeness is very high Of the total results in RFEDS as of December 1, 1993, more than 97 percent have been validated with less than 4 percent of these rejected

Comparability of sediment data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c)

3 1 10 6 Surface Water

Precision of field sampling methods and laboratory analysis of surface water is very good, with the exception of iron, zinc, and radionuclides (except for strontium-89,90), which exceeded the QC criterion of 20 percent In general, reproducibility of radionuclide data is difficult to achieve, particularly at levels near the minimum detectable activity

Accuracy was not evaluated for surface-water samples

Representativeness is good based on the results of the field QC sample analysis However, several analytes were detected in the blank samples, including lead, zinc, acetone, methylene chloride, and bis(2-ethylhexyl)phthalate infrequently and at low concentrations

Completeness of surface-water sampling activities is 100 percent for two sampling locations (the leachate seep and surface water from the East Landfill Pond) Completeness is only 12 percent for the other two sampling locations (groundwater intercept system discharge points) as a result of field conditions The lack of data from these locations will not affect DQOs because groundwater apparently discharges to the East Landfill Pond, not to the discharge points Of the total results available as of

December 1, 1993, approximately 89 percent of the results have been validated Of those, only 7 percent have been rejected

Comparability of the surface-water data has been established by the use of an approved work plan (DOE 1991b), standard analytical protocols (EG&G 1991g), and approved SOPs (EG&G 1992c)

3 1 10 7 Groundwater

Precision of field sampling methods and laboratory analysis is generally very good Based on the number of RPDs that exceed the QC criterion of 20 percent for groundwater, however, several metals (aluminum, barium, chromium, cobalt, copper, iron, lithium, magnesium, manganese, nickel, potassium, silicon, vanadium, and zinc), nitrate/nitrite, TDS, and TSS exhibit poor precision In addition, radionuclides generally exhibit poor precision, particularly at levels near the minimum detectable activity

Accuracy goals were met using analytical results for the MS and MSD samples, with the exception of dissolved selenium and silicon and total aluminum, arsenic, and silicon Recovery of these metals in the QC spikes exceeded the QC criterion Several metals (arsenic, chromium, lead, and zinc) were detected in the equipment rinses and were most likely not present in the distilled water used to rinse sampling equipment However, these metals were detected infrequently and at low concentrations

Completeness of groundwater sampling activities is 78 percent for the 16 wells installed during the OU 7 Phase I RFI/RI These data indicate that for the wells sampled completeness DQOs have been met and defensible conclusions can be made regarding the nature and extent of groundwater contamination An evaluation of the analytical completeness reveals that, as of December 1, 1993, approximately 72 percent of the total results have been validated Of those, less than 2 percent have been rejected

Comparability of groundwater data has been established by the use of an approved work plan (DOE 1991b), standard analytical methods (EG&G 1991g), and approved SOPs (EG&G 1992c) Data were reported in uniform units

3 2 Data Usability

The usability of data was evaluated for each media sampled using the laboratory qualifier, the validation code, and the results of the data-quality analysis The usability of

individual records was defined by the laboratory and validation codes The usability of larger groups of data, such as all records for a specific analyte, was determined by the data-quality indicators

Four usability categories have been defined for data collected during the OU 7 Phase I RFI/RI based on laboratory qualifiers and validation codes Table 3-6 lists these categories and the qualifiers and codes associated with each one Fully usable data include validated records that are not qualified by the laboratory as estimated values Estimated results are those data considered acceptable by the validation code but reported by the laboratory as estimated values based on a variety of QA/QC criteria Unusable data include rejected results and unvalidated records with undefined laboratory qualifiers or qualifiers indicating poor analytical results (such as "E"-qualified organic compound results) The fourth category includes unvalidated records that may or may not be qualified by the laboratory The status of these records remains undetermined at this time, but they have been considered usable as estimated values similar to the estimated-results category

The percentages of the records for each medium that falls within each category are provided in Table 3-8 In general, the majority of data from all media types are fully usable The percentage of rejected or unusable data for each medium ranges from 0 percent for biota samples to 6 percent for surface-water samples Data in this category were removed from the working database

Data usability has been assessed for two distinct data sets (1) historical data collected prior to the Phase I RFI/RI and (2) data collected during the OU 7 Phase I RFI/RI

3 2 1 Historical Data

Historical data collected prior to first-quarter 1990 are considered not usable for two reasons Prior to 1989, there was no EPA CLP in effect at Rocky Flats, and prior to 1990, there were no documented SOPs for sample collection Some samples were analyzed by laboratories that did not provide adequate QA/QC documentation to conduct data validation Many results obtained prior to 1990 are unvalidated and will necessarily remain so Because there is no way to verify the results of analyses prior to 1990, these data should not be used in the human health risk assessment or the evaluation of remedial alternatives These data have only limited use for site characterization For example,

they may be used to evaluate general temporal trends, but they should not be used to describe the nature and extent of contamination

The quality of historical data collected from 1990 through 1992 was not evaluated These data are considered fully usable if they fall into one of the three usable categories defined by laboratory qualifiers and validation codes (refer to Table 3-6)

3 2 2 *Phase I RFI/RI Data*

Data collected during the Phase I RFI/RI have undergone rigorous review and data-quality evaluation Specific results of the data-quality analysis are summarized in Section 3 1 10 Results indicate that, with the exception of soil-gas samples and landfill leachate–groundwater samples collected using the BAT® system, data quality is generally good Therefore, data are usable for the intended purposes of characterizing site physical features and identifying contaminant sources

As of December 1993, approximately 87 percent of the records in the OU 7 Phase I RFI/RI data set have been reviewed and evaluated in accordance with EPA procedures for documentation and validation of Level IV data (Level V data for radiological analyses) The valid data are considered usable for site characterization, human health and environmental risk assessments, remedial alternative evaluation, engineering design and remedial actions, and potentially responsible party determination (EPA 1987)

Unvalidated data may not be as usable as the validated Level IV and Level V data According to EPA guidance (EPA 1992), unvalidated data may be used in risk assessments only qualitatively to identify analytes during preparation of a sampling and analysis plan The data used for a baseline risk assessment must also meet criteria for the PARCC parameters As presented in Section 3 1, data quality has been assessed for all Level IV and Level V data.

Data quality for the soil-gas samples and landfill leachate–groundwater samples collected using the BAT® system is fair Precision and representativeness for these samples, which were collected during screening activities, is generally poor These samples were analyzed on site using a portable field gas chromatogram (GC), results are EPA Level II screening data. Data of this level is typically subject to a wide range in data quality Level II data provide qualitative information on the presence of elevated compounds (that is, hotspots) and on relative concentrations to aid in characterizing the site

Table 3-8 provides a summary of specific data usability for each media sampled Fully usable data, including valid and estimated data, range from 69 percent (groundwater) to 100 percent (biota) of the total results These percentages indicate that the majority of data meet the data usability needs for addressing the Phase I RFI/RI objectives of characterizing the site and evaluating contaminant sources

Surface-soil results indicate that 85 percent of the total number are fully usable, 3 percent are rejected, and 13 percent are unvalidated Subsurface-soil results indicate that 89 percent of the total number are fully usable, 3 percent are rejected, and 8 percent are unvalidated Sediment results reflect that 90 percent of the total number are fully usable, 3 percent are rejected, and 7 percent are unvalidated Surface-water results indicate that 85 percent of the total number are fully usable, 6 percent are rejected, and 9 percent are unvalidated Groundwater results indicate that 69 percent of the total number are fully usable, 4 percent are rejected, and 28 percent are unvalidated Many of these unvalidated results were collected during the third and fourth quarters of 1993 and have not yet gone through data validation

Several specific deficiencies were identified during the data-quality assessment

- The frequency of metals detected in equipment rinses is relatively high The most frequently detected metals include calcium, iron, potassium, magnesium, silicon, sodium, and zinc Commercial-grade distilled water was used to prepare these rinsates and is a likely source of metals For this reason, analyses of these frequently detected metals in equipment rinses may not be useful in identifying field contamination of real samples The concentrations of most metals detected are lower than the EPA contract-required detection limit (CRDL), indicating that the presence of these analytes in equipment rinses should not affect the representativeness, and thus usability, of the environmental samples collected

- For radionuclide analyses, RPDs were extremely variable and typically high Elevated RPDs are associated with low radionuclide activities that are not within the range required to obtain reproducible results Because of the poor laboratory precision associated with measuring these activities, analyses of duplicate samples for radionuclides does not provide a measure of sampling precision

- VOC analyses of equipment rinses indicate that acetone was typically present in the rinsates This compound may originate from the commercial-grade distilled water

used to rinse the sampling equipment, and it has also been identified as a common laboratory contaminant (EPA 1988a) In accordance with procedures specified in EPA functional guidelines (EPA 1988a, EPA 1988b, and EPA 1992a), results for analytes detected in blanks may require results from associated real samples to be restated as undetected This assessment should be performed during data validation Until the results of such an assessment are available, the presence of acetone in a field sample should be considered as potentially resulting from laboratory contamination Results for this compound should be qualified in RFEDS and further evaluated At present, these results are considered usable as screening-level data.

Table 3-1
Required Field QC Sample-Collection Frequency

QC Sample	Frequency
Field Duplicate	1 per 10 real samples or 1 per sampling event[1]
Field Blank[2]	1 per shipping container (or a minimum of 1 per 20 real water samples)
Trip Blank[3]	1 per 20 real water samples
Equipment Rinse	1 per 20 real samples or 1 per day[4]
Triplicate Sample (benthic samples)[5]	For each sampling site

[1] Whichever is more frequent
[2] For samples to be analyzed for inorganic compounds
[3] For samples to be analyzed for volatile organic compounds only Trip blanks shall not be used for radiochemistry samples because these samples are less likely to be contaminated through the introduction of radionuclides from direct exposure to air than by the introduction of volatile organic compounds
[4] Whichever is more frequent for each specific sample matrix being collected when non-dedicated equipment is being used
[5] For samples collected for tissue analysis

Definitions

QC quality control

Source EG&G 1990c, DOE 1991b

Table 3-2
Field QC Sample-Collection Summary

QC Sample Type	Sample Type											
	IHSS 203 Soil Gas	IHSS 114 Soil Gas	IHSS 114 BAT Liquid	IHSS 203 Soil (0–2 inches)	IHSS 203 Soil (0–10 inches)	IHSS 114 Soil	East Landfill Pond Soil (0–2 inches)	East Landfill Pond Soil (0–10 inches)	Borehole Samples	Groundwater Samples	Surface-Water Samples	Sediment Samples
Real	48	67	26	31	17	22	139	67	125	69	9	3
Field Duplicate	2	8	2	4	2	2	14	6	16	5	2	1
Equipment Rinse[1]	7	4	2	3	1	1	8	3	10	3	2	1
Trip Blank	NR WP	NR WP	NR-WP	NR WP	NR-WP	NR WP	NR WP	NR WP	NR WP	1	2	NR WP
Field Blank	NR WP	NR WP	NR WP	NR WP	NR WP	NR WP	NR WP	NR WP	NR-WP	1	1	NR WP
Replicate	NR WP	19	4	NR WP	NR WP	NR WP	NR WP	NR WP	NR-WP	2	1	NR WP
Matrix Spike	NR WP	NR WP	NR WP	NR WP	NR WP	NR WP	NR WP	NR-WP	NR WP	2	NR WP	NR WP

[1] Equipment blank for soil-gas samples collected at IHSS 203

Definitions

IHSS individual hazardous substance site
NR-WP not required-work plan not required in accordance with the OU 7 Phase I work plan (DOE 1991b)
QC quality control

Table 3-3
Definition of Laboratory Qualifiers

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")	Value for Statistical Analysis
+	Inorganics correlation coefficient for the matrix spike analysis is less than 0 995 (estimated value)	yes	yes	result
*	Inorganics duplicate analysis is not within control limits (estimated value)	yes	yes	result
	Organics outside contract-required QC limits	yes	yes	result
A	Organics identifies TIC as a suspected aldol condensation product	yes remove to TIC table	no	not included
B	Inorganics reported value is less than CRDL but greater than IDL	yes	yes	result
	Organics warns that analyte also detected in blank	yes	yes	result
	Note for common laboratory contaminants[1] include as hit if blank result is greater than 10 times detection limit for all other organics include as hit if blank result is greater than 5 times detection limit	yes	yes	result
	Radionuclides constituent also detected in associated blank whose concentration was greater than CRDL and/or minimum detectable activity (estimated value)			
C	Organics pesticide result confirmed by GC/MS	yes	yes	result
	Radionuclides presence of high TDS in sample increased minimum detectable activity	yes	yes	result
D	Organics identified in an analysis at a secondary dilution	yes	yes	result
E	Inorganics value is an estimate due to interference (estimated value)	yes	yes	result
	Organics compound exceeded calibration range of instrument, sample must be re-analyzed	no	no	not included
F	Organics compound off scale (estimated value)	yes	yes	result
	Radionuclides for alpha spectrometry - FWHM exceeded acceptable limits (estimated value)	yes	yes	result
G	Inorganics native analyte is greater than 4 times spike added	yes	yes	result
	TOC dilution result exceeded range of instrument estimated result	yes	yes	result
H	Radionuclides sample analysis performed outside of method-specified maximum holding time	yes	yes	result
I	Organics interference with target peak (estimated value)	yes	yes	result
J	Inorganics value greater than IDL but control sample analysis not within control limits (estimated value)	yes	yes	result
	Organics MS data indicate presence of compound but below detection limit (estimated value)	yes	yes	result
JB	Organics result below detection limit and analyte detected in laboratory blank	yes	no	½ detection limit
K	Result is less than MDL (CRDL) but greater than IDL	yes	yes	result
L	Undefined	no	no	not included

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")	Value for Statistical Analysis
M	Inorganics duplication injection precision not met (estimated value)	yes	yes	result
N	Inorganics spiked sample recovery is not within control limits (estimated value)	yes	yes	result
	Organics compound presumed present (TIC)	yes remove to TIC table	no	not included
R	Validation code for rejected data entered in lab qualifier field/unusable data	no	no	not included
S	Inorganics the reported value determined by the method of standard additions	yes	yes	result
T	Compound found in TCLP extract blank and sample	yes	yes	result
U	Organics and inorganics analyte analyzed but not detected at the quantitation limit	yes	no	½ detection limit
UC	Organics pesticide result confirmed but below detection limit	yes	no	½ detection limit
UE	Radionuclides detection limit reported as result (?)	no	no	not included
UJ	Organics analyzed but not above the detection limit (estimated value)	yes	no	½ detection limit
UN	Inorganics spiked sample recovery not within control limits and sample result below detection limit	yes	no	½ detection limit
	Organics compound presumed present but below detection limit	yes remove to TIC table	no	not included
UW	Inorganics post-digestion spike for GFAA analysis is out of control limits and sample result is below detection limit	yes	no	½ detection limit
UX		yes	no	½ detection limit
V	Validation code for valid data entered into laboratory qualifier field	yes	yes	result
W	Inorganics post-digestion spike for GFAA analysis is out of control limits while sample absorbance is less than 50% of spike absorbance	yes	yes	result
X[2]	Inorganics (pre-1992) detection limit greater than normal, sample matrix interference	yes	yes	result
	Organics (pre-1992) laboratory software flag (combines more than one qualifier) - not defined	no (unless accompanied by a validated result)	no	not included
	Other (OU 7 RFI/RI samples) result by calculation defined in GRRASP	yes	yes	result
Y	Organics indistinguishable isomer in TIC	yes remove to TIC table	no	not included
	Radionuclides chemical yield exceeded acceptable limits (estimated value)	yes	yes	result
Z	Organics "quest identification matrix interference of column"	no	no	not included

[1] common laboratory contaminants 2-butanone, acetone, common phthalate esters methylene chloride toluene

[2] Note on use of X qualifiers X is defined in the GRRASP as a result determined by calculation not by direct laboratory analysis Therefore, for samples analyzed during the period that GRRASP has been in effect (since January 1992) the results qualified by an X will be treated as estimated values (similar to J) For historic data, when GRRASP was not used by laboratories, an X qualifier has two definitions For organics the X is a flag entered manually by the laboratory, but is not defined in RFEDS Therefore organic results qualified by X are not considered usable data, unless a validated result is given For inorganics, an X qualifier indicates that the detection limit for the analyte is higher than normal due to matrix interference An inorganic qualified with an X will be treated like a J result The X qualifier is sometimes also used with other qualifiers (for example, UX, XJ) In these cases the meaning of X depends on the analyte and the date of the analysis

Definitions

CRDL	contract-required detection limit
FWHM	full width at half maximum (the width of the distribution at a level that is just half the maximum ordinate of the peak)
GC/MS	gas chromatography/mass spectrometry
GF \A	graphic furnace atomic adsorption
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
IDL	instrument detection limit
MDL	method detection limit
MS	matrix spike
OU	operable unit
QC	quality control
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA facility investigation/remedial investigation
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TIC	tentatively identified compound
TOC	total organic carbon

Table 3-4
Definition of Validation Codes

Code	Definition	Include in Data Analysis
A	Acceptable result	yes
B	Laboratory qualifier	no
C	Laboratory qualifier	no
J	Estimated result	yes
JA	Acceptable result (for estimated value)	yes
N	Laboratory qualifier	no
P	Undefined	no
R	Rejected result	no
S	Laboratory qualifier	no
V	Valid result	yes
Y	Analytical results in validation process	yes
Z	Validation not required or performed	no

Table 3-5
Data Validation Summary (as of December 1, 1993)

Medium/Analyte Group	Total Number of Results	Number of Validated Results	Number of Rejected Results	% Results Validated	% Results Rejected
Subsurface Geologic Materials					
Metals, Total	3315	3315	40	100	1
Pesticides and Polychlorinated Biphenyls	1247	1163	36	93	3
Radionuclides, Total	1231	894	93	73	8
Semivolatile Organic Compounds	7462	7397	26	99	<1
Volatile Organic Compounds	3597	3464	148	96	4
Water-Quality Parameters	592	568	87	96	15
TOTAL	17444	16801	430	96	2
Biota					
Metals, Total	252	252	0	100	0
Radionuclides, Total	81	81	0	100	0
TOTAL	333	333	0	100	0
Groundwater					
Metals, Dissolved	1815	1351	17	74	1
Metals, Total	1758	1294	23	74	1
Pesticides and Polychlorinated Biphenyls	61	3	0	5	0
Radionuclides, Dissolved	601	220	0	37	0
Radionuclides, Total	236	39	1	17	<1
Semivolatile Organic Compounds	4859	4202	78	86	2
Volatile Organic Compounds	2654	1566	72	59	3
Water-Quality Parameters	675	506	5	75	1
TOTAL	12659	9181	196	73	2
Sediment					
Metals, Total	77	77	2	100	3
Pesticides and Polychlorinated Biphenyls	32	32	0	100	0
Radionuclides, Total	33	30	0	91	0
Semivolatile Organic Compounds	254	247	12	97	5
Volatile Organic Compounds	121	121	5	100	4
Water-Quality Parameters	15	14	0	93	0
TOTAL	532	521	19	98	4
Soil Gas					
Volatile Organic Compounds	187	187	0	100	0
TOTAL	187	187	0	100	0

Medium/Analyte Group	Total Number of Results	Number of Validated Results	Number of Rejected Results	% Results Validated	% Results Rejected
Surface Soils					
Metals, Total	7321	7233	35	99	<1
Pesticides and Polychlorinated Biphenyls	545	435	0	80	0
Radionuclides, Total	3483	2495	255	72	7
Semivolatile Organic Compounds	1555	1435	17	92	1
Volatile Organic Compounds	54	54	20	100	37
Water-Quality Parameters	887	590	0	67	0
TOTAL	13845	12242	327	88	2
Surface Water					
Metals, Dissolved	238	238	1	100	<1
Metals, Total	237	237	4	100	2
Pesticides and Polychlorinated Biphenyls	81	54	0	67	0
Radionuclides, Dissolved	99	71	4	72	4
Radionuclides, Total	97	81	0	84	0
Semivolatile Organic Compounds	726	589	131	81	18
Volatile Organic Compounds	392	392	3	100	1
Water-Quality Parameters	78	78	1	100	1
TOTAL	1948	1740	144	89	7

Table 3-6
Usability Categories

Category	Definition	Validation Codes	Laboratory Qualifiers
VALID	Fully usable	A, V	blank, U
ESTIMATE	Usable as estimated result	A, J, V, JA[1]	+, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, UJ, UN, UW, UX, W, X, Y, Z
REJECT	Not valid	B, C, N, P, R, S, Z	E (organics), L, R, UE (radionuclides)
BLNK/Y VAL	Acceptable or estimated result, no validation code	Y, blank	blank, +, *, B, C, D, E (inorganics), F, G, H, I, J, N, S, U, UJ, UN, UW, UX, W, X, Y, Z

[1] *If the validation code is J or JA, then U and blank lab qualifiers are considered to be estimates*

Table 3-7
PARCC Parameter QC Criteria by Media Sampled

Medium	PARCC Parameters				
	Precision	Accuracy	Representativeness	Completeness	Comparability
Groundwater	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Surface Water	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 Percent	Qualitative
Surface Soils	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Subsurface Geologic Materials	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Sediments	RPD < 35 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Soil Gas	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative
Leachate–Groundwater Collected Using BAT® System	RPD < 20 percent	% Bias < 20 percent	Qualitative	> 90 percent	Qualitative

Definitions

PARCC precision, accuracy, representativeness, completeness, and comparability, used to assess data quality
QC quality control
RPD relative percent difference
% Bias percent bias, equal to 100-percent recovery

Table 3-8
Data Usability by Media Sampled

Medium	Total Results	Valid Results—Fully Usable		Estimated Results—Fully Usable		Rejected or Unusable Results		Unvalidated Results—Usability Not Determined	
		Number of Results	Percent of Total Results	Number of Results	Percent of Total Results	Number of Results	Percent of Total Results	Number of Results	Percent of Total Results
Subsurface Geologic Materials	21,656	16,458	76%	2,889	13%	652	3%	1,657	8%
Biota	333	256	77%	77	23%	0	0%	0	0%
Groundwater	13,971	8,035	58%	1,497	11%	490	4%	3,949	28%
Sediment	859	558	65%	216	25%	29	3%	56	7%
Surface Soils	15,992	10,040	63%	3,455	22%	497	3%	2,000	13%
Surface Water	3,073	2,052	67%	550	18%	184	6%	287	9%

4. NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination related to sources within OU 7 were evaluated by analysis of chemical data from environmental media collected during the Phase I RFI/RI and during sitewide surface water and groundwater monitoring programs This evaluation was based on the following information descriptive summary statistics for each analyte from each media type, graphical presentations of concentration data for each analyte from each media type, analyte-distribution maps for selected media (landfill gas, surface soils, and groundwater), comparisons of chemical data from OU 7 to chemical data from background media to identify PCOCs, and qualitative analysis of chemical data to evaluate the spatial and temporal variations in contaminant concentrations The statistical data-analysis methods are described in Section 4 1 The summary statistics for each media type are included in Appendix M, graphical presentations of chemical concentration data are included in Appendices K and L, and the results of statistical comparison tests are provided in Appendix M A detailed description of contaminant sources is provided in Section 4 2 Sections 4 3 through 4 8 describe the nature and extent of contamination to environmental media in the vicinity of the landfill

4 1 Methodology for Background Comparison and PCOC Identification

Data from OU 7 samples were compared to data from background samples for each media type sampled during the Phase I RFI/RI The background geochemical characterization report (EG&G 1993a) supplied data for background samples of sediment, geologic media, groundwater, seep water, and surface water The characteristics of background soils were described from samples collected in the Rock Creek drainage (EG&G 1993a) The data from each media type were aggregated in comparable subsets for comparison to background data to meet specific investigation objectives and to identify PCOCs The rationale for the data aggregation schemes used is presented in Section 4 1 1 The procedures used for statistical analysis and comparisons are described in Section 4 1 2

Qualitative comparisons of site data to background data were made for each media type sampled at OU 7 Histograms and box-and-whisker plots (box plots) for each analyte from each media type were generated for both site and background data. The graphic presentations of the data were used to evaluate the magnitude, variability, and distribution

of concentrations for each analyte These graphs are presented in Appendices K and L, respectively

Chemical concentration data from various media sampled at OU 7 were statistically evaluated to identify analytes present at concentrations elevated relative to their concentrations in media from background locations Analytes having elevated concentrations in media from OU 7 were considered PCOCs as defined in EG&G (1994b) PCOCs were identified by comparison to background data using the statistical and qualitative methods outlined in Statistical Comparisons of Site-to-Background Data in Support of RFI/RI Investigations (EG&G 1994b) The site-to-background comparison methods were used to identify inorganic analytes and radionuclide PCOCs Organic compounds were considered PCOCs if detected in samples from OU 7.

4 1 1 *Data Aggregation for Background Comparisons at OU 7*

Chemical concentration data from various environmental media sampled at OU 7 were evaluated with the following two distinct objectives to identify PCOCs and to describe the nature and extent of contamination Prior to comparison of chemical concentration data from OU 7 to background values, data were aggregated by media Data aggregation was based on the statistical assumption that all samples within a data set were independent but comparable (collected and analyzed using the same methods), and represented by a single population characterized by a fixed mean and variance

The media types at OU 7 include surface soil, surface water, seeps, pond sediments, geologic materials, and groundwater (Table 4-1) Within each media, samples were further subdivided by depth, sampling method, sample location, hydrostratigraphic unit, geologic unit, and location relative to contaminant sources, as needed, for comparability with background data Table 4-1 presents the primary groups of data by media, defines the appropriate subdivisions of those groups, and describes the aggregation scheme that will be used to perform the statistical comparisons to background data The rationale for the aggregation approach used for each media is discussed below

Surface soil data from OU 7 are comprised of samples collected from three areas the East Landfill Pond area, the Inactive Hazardous Waste Storage Area (IHSS 203), and the Present Landfill (IHSS 114) Surface soil samples from the 0- to 2-inch depth interval at the East Landfill Pond and IHSS 203 were collected using the grab method Surface soil

samples from the 0- to 10-inch depth interval at these locations were collected using the hand auger method Surface soil samples from IHSS 114 were collected using a different sampling method—the Rocky Flats method for composite samples As a result, the samples collected from IHSS 114 cannot be directly compared to samples from the East Landfill Pond or IHSS 203, and the three areas were evaluated individually during statistical testing Similarly, soil samples collected from the two different depth intervals at the East Landfill Pond and IHSS 203 are not considered directly comparable Soils from the 0- to 2-inch depth interval may have different origins and contaminant transport pathways than soils from the 0- to 10-inch depth interval As a result, the soils from the East Landfill Pond and IHSS 203 have been further subdivided by depth The result is five subsets of surface soils as shown in Table 4-1 Statistical comparisons with background data were performed separately for each of the subsets

Borehole samples were collected from subsurface geologic materials upgradient, within, and downgradient of the Present Landfill The two downgradient locations (70993 and 71093) were grouped separately because they have separate sources of potential contamination, borehole 70993 was drilled downgradient of the north intercept system discharge point, and borehole 71093 was drilled downgradient of the south intercept system discharge point As a result, subsurface geologic materials were initially grouped into three subsets of data upgradient (70493 and 70593), downgradient (70993), and downgradient (71093) Data in these subsets were further subdivided by geologic unit as follows Rocky Flats Alluvium, colluvium, and weathered Arapahoe and Laramie Formation Data in these subsets were compared against sitewide borehole data for each geologic unit

Sediment was collected from three locations at the East Landfill Pond The sediment samples were collected using a coring device, and multiple cores were collected at each location and composited for analysis The sediment thickness ranged from 6 to 10 inches Sources of sediment to the pond include original stream sediments in the drainage, surface runoff, eolian material, and sediments associated with flow from the seep Sediment from all three pond locations was grouped together and compared to stream sediments from background locations

Surface water samples were collected from three locations the East Landfill Pond (SW098) and the two discharge points for the groundwater-intercept system (SW099 and SW100) Sources of water to the East Landfill Pond are precipitation, surface runoff,

groundwater base flow, and—to a lesser extent—leachate from the landfill The sources of water to the intercept system are groundwater entering the system around the perimeter of the landfill and, potentially, leachate generated outside the intercept system Thus, the surface water locations constitute two distinct groups the East Landfill Pond water and water from intercept system discharge points (Table 4-1) Water from the two intercept system discharge points was compared separately to background data to determine if different analytes were elevated above background concentrations at the two discharge points These data were used to investigate the impact to water quality of a potential breach in the groundwater intercept system along the northern perimeter of the landfill (Section 2 5)

Seep water was collected from one location—a seep at the bottom of the east face of the landfill (SW097) The source of the seep water is leachate from the landfill Seep water data from this location were compared to natural seep water data from background locations

Groundwater samples were collected from wells screened in the UHSU and LHSU Because these units comprise separate flow systems, the data were divided by hydrostratigraphic unit The UHSU comprises Rocky Flats Alluvium, colluvium, valley-fill alluvium, artificial fill, weathered bedrock, and bedrock sandstones in direct hydraulic connection with other units in the UHSU (subcropping sandstones) The LHSU is composed of unweathered bedrock Wells that screen the UHSU have been further subdivided into three areas upgradient, within the landfill, and downgradient Groundwater samples from these areas constitute three distinct populations Wells that screen the LHSU have been further subdivided into two areas upgradient and downgradient of the landfill No LHSU wells exist within the landfill Groundwater samples from these areas constitute two distinct populations PCOCs in the UHSU were identified by comparing all UHSU data to sitewide background UHSU data PCOCs in the LHSU were identified by comparing data from LHSU wells downgradient of the landfill to sitewide background LHSU data The LHSU and UHSU wells upgradient of the landfill were compared to background data to evaluate the nature and extent of contamination The nature and extent of contamination in the UHSU were also evaluated by comparing UHSU wells within the landfill to background UHSU data Background comparisons for groundwater are summarized in Table 4-1

4 1 2 Statistical Analysis Procedures for PCOC Identification

The flow chart presented in Figure 4-1 illustrates the process for identifying PCOCs The statistical methodology for site-to-background comparisons for inorganic analytes and radionuclides followed the procedures outlined in Statistical Comparisons of Site-to-Background Data in Support of RFI/RI Investigations (EG&G 1994b) The PCOC identification process consisted of the following steps (1) a hot-measurement test, (2) the Gehan test, (3) the Quantile test, (4) the Slippage test, (5) the t-test, and (6) professional judgment Analytes having concentrations elevated relative to background concentrations, as indicated by the hot-measurement test or any of the inferential statistical tests (Gehan, Quantile, Slippage, and t-test), are considered PCOCs The five comparison tests are described below

Chemical data from OU 7 were evaluated using a hot-measurement test, which compares each measurement with an upper tolerance limit (UTL) value for the corresponding analyte in the background data. The hot-measurement test is useful as a screening tool to ensure that unusually large measurements are adequately evaluated regardless of the output of the more formal inferential statistical tests The UTL concentration used during comparison of site to background data was the $UTL_{99/99}$ value This UTL represents a value for which there is 99-percent confidence that the UTL is equal to or greater than the true 99th percentile of the background population The UTL values for background data were reported in the background geochemical characterization report (EG&G 1993a)

Statistical inference tests (Gehan, Quantile, Slippage, and t-tests) were used to compare the means and medians of the OU 7 and background populations The null (H_o) and alternative (H_a) hypotheses used during the statistical analyses are as follows (Gilbert 1993)

H_o Chemical concentrations within OU 7 are not significantly greater than those in the background area

H_a Chemical concentrations within OU 7 are significantly greater than those in the background area

The nonparametric Gehan test (Palachek et al 1993, Gehan 1965) can be used to evaluate data sets with multiple detection limits and nondetects and can be used regardless of the distribution of the data The Gehan test is a generalization of the more common non-

parametric ANOVA Wilcoxon Rank Sum test The Gehan test was performed for all analytes The parametric ANOVA t-test was used only when background and site data contained less than 20 percent nondetects and normality assumptions based on the Shapiro-Wilk test were satisfied

Other nonparametric tests used to compare background and site data included the Quantile and Slippage tests The Slippage test consists of counting the number of OU measurements that exceed the maximum background measurement If the number of measurements exceeding the maximum background measurement was greater than a critical value obtained from tables in Rosenbaum (1954), then the analyte was considered a PCOC

The Quantile test is similar to the Slippage test and was performed by listing the combined background and OU measurements from smallest to largest The test counts the number of measurements from the OU that are among the largest measurements of the combined data sets If the number of measurements is greater than a critical value, the analyte was considered a PCOC The largest measurement and critical values were determined from tables in Gilbert and Simpson (1992)

The inferential statistical tests (Gehan, Slippage, Quantile, and t-test) compare background and OU 7-wide concentration distributions The hot-measurement test compares each measurement to a corresponding $UTL_{99/99}$ value The difference in the two methods is that the inferential tests compare differences between population distributions and the hot-measurement test compares individual measurements to a single value The hot-measurement test is not considered a formal statistical test because false positive and power requirements are not explicitly stated

The final identification of PCOCs was subject to professional review of the test results and graphic presentation of the data The professional judgment of the analyst is required to consider other factors such as the spatial and temporal distribution of analytes, historic information regarding past operations at the site, inter-element correlations, mass balance calculations, and knowledge of the hydrology, geochemistry, and geology of the site

4.2 Sources

The primary sources of contamination at OU 7 are landfilled wastes and associated leachate and gas within the Present Landfill Potential secondary sources of

contamination at IHSS 114 include (1) soils and other geologic material beneath the landfill that may have been contaminated by leachate, (2) leachate seeping from the landfill, (3) surface water in the East Landfill Pond, (4) sediments in the East Landfill Pond, and (5) potentially contaminated surface soils in the spray evaporation areas At IHSS 203, the primary source of contamination, if any, is surface soil affected by past spills or chemical releases

Primary sources at OU 7 are discussed below Section 4 2 1 describes the characteristics of the landfill solids Section 4 2 2 discusses gases detected within the landfill during the OU 7 Phase I RFI/RI methane survey and soil-gas sampling Section 4 2 3 presents data describing leachate within the landfill and its role as a source

Potential secondary sources are discussed in Sections 4 3 through 4 7 These sections present the nature and extent of contamination in surface soils and vadose zone, subsurface geologic materials, sediments, surface water, and groundwater, respectively, originating from sources at IHSSs 114 and 203

4 2 1 Landfill Solids

Characteristics of the landfill solids are based on historical information characterizing waste disposal and information obtained during the OU 7 Phase I RFI/RI Physical and chemical factors affecting the degradation of landfill wastes are also presented based on information from similar solid waste (municipal) landfills

4 2 1 1 Waste Volume

The volume of landfill solids has been estimated using historical and future waste disposal rates and information obtained during the OU 7 Phase I RFI/RI characterizing the areal and vertical extent of landfill material

From 1968 to 1978, the landfill received approximately 20 cubic yards (cy) of compacted waste per day By 1974, the surface area covered by the landfill had expanded to approximately 300,000 square feet The volume occupied by the landfill was estimated by areal photographs to be approximately 95,000 cy (Table 4-2) The volume of cover material included in this total was estimated at 30,000 cy The remaining 65,000 cy consisted of compacted waste intermixed with the daily cover material placed during disposal Estimates made in 1986 indicate that approximately 160,000 cy of material had been placed between 1974 and 1986, for a total landfill volume of 225,000 cy The

4 2 1 2 Waste Composition

As discussed previously in Section 1 3 1, the landfill was designed for disposal of nonradioactive solid waste In 1986 and 1987, waste streams were characterized under the WSIC program Limited analytical testing, including the extraction procedure toxicity test, was performed as part of the WSIC program Approximately 1,500 waste streams were identified, 338 of which were being sent to the landfill for disposal This included 241 waste streams identified as nonhazardous and 97 solid waste streams that contained hazardous waste or hazardous waste constituents Appendix A presents tables of the nonhazardous and hazardous waste streams identified during the WSIC program

The nonhazardous waste streams disposed in the landfill include office trash, paper, rags, demolition materials, empty cans and containers, used filters, various electrical components, dried sanitary sewage sludge (disposed in the 1970s), solid sump sludge, and other miscellaneous sludges These sludges were classified as nonhazardous, although radioactively contaminated sludge from the sanitary wastewater treatment plant (Building 995) was also, reportedly, routinely disposed in the landfill from August 1968 through May 1970 These sludges may instead have been disposed in trenches A, B, and C south of the landfill (which were investigated as part of the OU 6 RFI/RI)

Four general categories of hazardous waste streams were identified by the WSIC program as discussed in Section 1 3 1 These categories include (1) containers partially filled with paint, solvents, degreasing agents, and foam polymers, (2) wipes and rags contaminated with these materials, (3) paint and oil filters, and (4) metal cuttings and shavings, including mineral and asbestos dust and miscellaneous metal chips coated with hydraulic oil and carbon tetrachloride In the fall of 1986, wastes with hazardous constituents were no longer placed in the landfill

Dried sanitary sewage sludge (placed during the 1970s), solid sump sludge, and other miscellaneous sludges were also disposed in the landfill These sludges were classified as nonhazardous based on an evaluation of the processes that generated the waste sludge and on the likelihood that RCRA-listed wastes were generated or that the sludge might be a characteristic waste under RCRA However, radioactively contaminated sludge from the sanitary wastewater treatment plant was reportedly routinely disposed at the landfill from 1968 through 1970 (DOE 1992a) The contaminated sludge contained uranium and plutonium, which had entered the sanitary sewage system with laundry water Approximately 2,200 pounds of sludge containing an estimated total of 8 milligrams of

plutonium, as well as an undetermined amount of depleted uranium, were buried in the landfill This practice ceased in May 1970 when offsite shipment of sludge as a low-level waste began (DOE 1992a)

The landfill was also the site of asbestos and PCB disposal (DOE 1992a) In 1985, asbestos generated onsite was reportedly disposed in a designated 10-foot-deep pit (DOE 1992a) The asbestos-containing material was placed in heavy plastic bags, disposed in the pit, and covered with soil when the pit became full Warning signs were placed near the pit By December 1988, asbestos was disposed in several pits in specified areas near the center of the landfill According to landfill records, disposal of asbestos continued until at least April 1990 (DOE 1992a) During the OU 7 Phase I RFI/RI, soil samples were collected at the estimated locations of these pits and analyzed for asbestos as described in Appendix C A trace (less than one percent) of chrysotile asbestos was detected in surface soil samples from only these two locations at IHSS 114 In addition, materials containing small quantities of PCBs were routinely disposed in the landfill (DOE 1992a) It is unknown when the disposal of PCBs in the landfill ceased Soil samples collected from IHSS 203 and analyzed for PCBs are described in Section 4 3

Incidents of non-routine disposal of nonradioactive hazardous wastes have occurred, including the disposal of a mercaptan (odor additive to natural gas) tank and disposal and subsequent puncturing of a bag containing tear gas powder (DOE 1992a) Contaminated materials associated with cleanup of a 700-gallon fuel oil spill in January 1971 were also reportedly disposed in the landfill

As of 1989, waste streams at the Rocky Flats site have been characterized under the WSRIC program, which includes more detailed characterization and analytical testing of the waste streams Under the WSRIC program, only nonhazardous solid waste is currently being placed in the landfill, including office trash, paper, rags, personal protective equipment, demolition materials, scrap metal, empty drums, cans and containers, used filters, and various electrical components Table 4-4 summarizes the waste streams, as characterized by WSRIC, that are currently being disposed at the landfill

4 2 1 3 Factors Affecting Waste Degradation

There are several factors affecting the degradation of landfill waste and its impact as a potential source of contamination These factors include age of waste, porosity, degree of

settling and compaction, moisture content, and amount of organic material The age of the waste varies across the site In general, the oldest waste is located near the western portion of the landfill and younger wastes are located near the eastern portion as a result of expansion eastward However, during the OU 7 Phase I RFI/RI, waste was being placed near the central portion of the landfill on top of relatively older waste

Typically, porosity associated with landfill waste is estimated to be high (in the range of 30 percent) due to the heterogeneous nature of the material and the uneven distribution and packing common in landfilled waste (EPA 1991a) As the landfill waste undergoes natural settling over time, the porosity usually decreases as the material becomes compacted

Waste material encountered during the OU 7 Phase I RFI/RI was commonly moist However, perched zones within the landfill were not observed The moisture content commonly associated with waste at the time of placement is approximately 25 percent. Moisture content is one of many factors affecting waste decomposition and gas production rates High moisture contents (i e , in the range of 60 to 80 percent) favor maximum methane production rates (Emcon Associates 1982)

Wastes disposed in the Rocky Flats landfill include primarily waste generated by maintenance operations, construction debris, nonhazardous industrial wastes, and sludges Municipal landfills commonly contain a heterogeneous mixture of materials primarily composed of household refuse such as yard and food wastes and paper, and commercial waste such as plastics, inert mineral waste, glass, and metals (EPA 1991a) Consequently, the amount of biodegradable organic material in the landfill is probably smaller than the amount typically found in municipal solid waste landfills Waste composition directly affects both the rate of landfill gas generation and total yield The lower the percentage of biodegradable materials, the lower the gas generation rate and total yield For moderately decomposable wastes in a typical landfill, the gas generation rate peaks within six years after initial waste placement and declines steadily afterwards (EPA 1991a)

4 2 2 Landfill Gases

Landfill gases are 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 a landfill, as the waste undergoes aerobic microbial degradation As oxygen is depleted, anaerobic microbial degradation produces methane and carbon dioxide The composition of landfill gas produced under anaerobic conditions is typically 50 to 70 percent methane and 30 to 50 percent carbon dioxide In addition to the methane and carbon dioxide generated by waste degradation, trace concentrations of hydrogen sulfide, ammonia, and other VOCs may be present in landfill gases (EPA 1991a) depending on the types of wastes present

The composition and distribution of landfill-generated gases were evaluated on the basis of data obtained during the methane survey Details of the methane survey are discussed in Appendix C Measurements were made using field instruments that provide screening level data (i e , EPA Level II) on total combustible gases, methane, non-methane organic compounds (NMOCs), and carbon dioxide Concentrations of NMOCs were determined by subtracting methane concentrations from the concentrations of total combustible gases As a result, concentrations of NMOCs may include minor amounts of inorganic gases such as hydrogen sulfide Table 4-5 presents results of the methane survey Eight cross sections were constructed to illustrate the nature and extent of gases at the landfill during the OU 7 Phase I RFI/RI Figure 4-4 presents the cross-section location map figures 4-5 through 4-12 present the cross sections The composition of landfill gas at OU 7 is typically 45 to 70 percent methane and 20 to 40 percent carbon dioxide indicating anaerobic conditions Concentrations of methane and carbon dioxide are highest in the eastern portion of the landfill where wastes are thickest and youngest (figures 4-5 and 4-6) In general, landfill-generated gases appear to be contained within the existing intercept system as shown in figures 4-13 and 4-14 Concentrations of methane and carbon dioxide are low, as expected, in the vicinity of the gas-venting wells such as 44492 and 44692 (figures 4-13 and 4-14)

In situ soil-gas sampling was performed to characterize VOCs in the unsaturated zone of the landfill Details of the soil-gas sampling are discussed in Appendix C Halogenated VOCs detected at the landfill include 1,2-DCE, 1,1,1-TCA, TCE, and methylene chloride Non-halogenated VOCs detected include acetone, 2-butanone, toluene, xylenes, and hydrogen sulfide No distinct spatial patterns in VOC concentrations were observed probably as a result of the extreme heterogeneity of the materials disposed in the landfill Table 4-6 presents the results of the soil-gas sampling at IHSS 114

The volume of landfill gas present within IHSS 114 was determined by calculating the volume of void space in unsaturated material within the landfill mass assuming an estimated porosity of 30 percent (EPA 1991a) The volume of material comprising the unsaturated zone is approximately 320,171 cy based on the areal extent of the landfill and an estimated average unsaturated zone thickness of approximately 11 feet The volume of landfill gas occupying the pore space of unsaturated material is approximately 96,051 cy However, the estimated volume is expected to vary temporally as a result of fluctuations in the potentiometric surface in response to precipitation events

Gas flow through landfill waste and soils occurs in response to pressure gradients (i e , advective flow), concentration gradients (i e , diffusive flow), compaction and settling of wastes, barometric pressure changes, and displacement due to potentiometric surface fluctuations Advection of landfill gas is typically the predominant transport mechanism (EPA 1991a) Off-gassing pressures up to 0 44 pounds per square inch were measured during the OU 7 Phase I RFI/RI Gas pressures exceeding approximately 0 05 pounds per square inch indicate an advective, pressure driven system (Emcon Associates 1982)

Soil gas samples were also collected at IHSS 203 during the OU 7 RFI/RI investigation These samples were collected at approximately 5 feet below ground surface and analyzed for VOCs Appendix C discusses soil gas sampling at IHSS 203 Table 4-7 summarizes the analytical results Individual analyte concentrations varied significantly within the sampling area and distinct sources were not identified that could be confidently interpreted as contamination associated with spills or releases during waste storage activities at IHSS 203 Total soil-gas concentration contours for NMOCs are shown in Figure 4-15 Measured concentrations were highest in the northeast section of the sampling area Because landfill wastes underlie IHSS 203, VOCs in soil gas in this area are probably associated with the landfill

4 2 3 Leachate

Leachate from landfills is a product of natural biodegradation, infiltration of precipitation, and migration of groundwater through waste (EPA 1991a) This section discusses the volume and composition of leachate at IHSS 114 Volume estimates are based on all relevant OU 7 Phase I RFI/RI data The composition of leachate discussed in this section is based on the field screening data (EPA Level II) obtained from the samples collected using the BAT® system Chemical data (EPA Levels IV and V) characterizing landfill

leachate are discussed in Section 4 7 along with comparable chemical data for groundwater at OU 7

Figure 4-16 presents an isopach map of saturated landfill waste The volume of leachate within the landfill is approximately 5,756,000 gallons assuming that the porosity of the saturated material is 30 percent However, the volume of leachate is expected to vary as the potentiometric surface fluctuates in response to infiltration of precipitation through the interim soil cover

As discussed in Appendix C, leachate screening samples were collected during the OU 7 Phase I RFI/RI at specific depths within saturated landfill material using the BAT® system Headspaces of these samples were analyzed for methane, methylene chloride, acetone, 2-butanone, 1,2-DCE, 1,1,1-TCA, TCE, xylene (para, meta, and ortho isomers), toluene, and hydrogen sulfide Equilibrium concentrations of these analytes in the liquid phase (i e , leachate), presented in Table 4-8, were calculated using Henry's Law constants and the measured headspace concentrations

Concentrations of volatile compounds within leachate vary significantly throughout the landfill Due to dry conditions and refusal of the BAT® system during sampling, insufficient data were obtained to fully evaluate vertical chemical gradients within the leachate However, at locations where multiple samples were obtained, no consistent trends in chemical gradients were observed In general, analyte concentrations in samples collected using the BAT® system exceed the concentration of analytes in samples collected from monitoring wells by approximately three orders of magnitude This difference is probably a result of the sampling methodology The BAT® system obtains a sample *in situ* from a small discrete interval The BAT® sample is never exposed to air, and thus, no loss of volatile compounds can occur due to vaporization In contrast, leachate is sampled from monitoring wells using a baler that allows a contact with air to occur prior to containerization of the sample

Methane concentrations in leachate ranged from 0 003 to 31 4 mg/L (Table 4-8) and typically approached the solubility limit of 35 mg/L at 17°C (Merck Index 1989) Concentrations at OU 7 were also consistent with methane concentrations of 25 mg/L observed at other landfills (Beadecker and Back 1979)

The following sections describe the environmental media in the vicinity of the landfill and the nature and extent of contamination that have resulted from proximity to contaminant sources within OU 7

4.3 Surface Soils and Vadose Zone

This section describes the nature and extent of contamination in surface soils at OU 7 and identifies the PCOCs for soils using data collected during the Phase I RFI/RI Analytical results for surface soil samples collected during the Phase I RFI/RI were used in this analysis Sample collection methods, sampling locations, and analytical suites are described in Appendix C Surface soil data were aggregated by area (East Landfill Pond, IHSS 203, and IHSS 114) and depth (0 to 2 inches and 0 to 10 inches) as described in Section 4 1 1 Surface soil data from the 0- to 2-inch horizon within each subset were independently compared to background soil data from OU 1 and OU 2 Similarly, the 0- to 10-inch surface soil data from IHSS 203 and the East Landfill Pond area were independently compared to background soil data Inferential statistical analyses discussed in Section 4 1 2 were used to determine which analytes in OU 7 surface soils were detected at concentrations that exceeded background Spatial trends in analyte concentration and samples exceeding the $UTL_{99/99}$ concentration are also described Box plots and histograms were generated for all analytes with at least 50 percent detects Box plots are presented in Appendix K Histograms are presented in Appendix L Summary statistics and statistical test results for inferential analyses and for the hot-measurement test for OU 7 surface soils are presented in Appendix M

4 3 1 Inactive Hazardous Waste Storage Area (IHSS 203)

Surface soil samples collected at IHSS 203 were analyzed for PCBs, metals, and radionuclides, samples were not analyzed for VOCs or SVOCs PCOCs identified in surface soil at IHSS 203 include PCBs, metals, and radionuclides (Table 4-9) Calcium and copper concentrations were elevated in both the 0- to 2-inch and the 0- to 10-inch soil horizons The distribution of calcium in surface soils is shown in Figure 4-17 The distribution of copper in surface soils is shown in Figure 4-18 The highest copper concentrations were associated with a dark brown, very gravelly loam covering the northern portion of the IHSS 203 sample grid (Figure 4-18) Radium-226 activities in the 0- to 2-inch horizon at IHSS 203 were elevated relative to background activities However, a relationship between soil location and radium-226 activity could not be discerned from the available data.

Results of a hot-measurement test, performed to identify soil samples with analyte concentrations exceeding background $UTL_{99/99}$ concentrations, are presented in Table 4-10 The following metals were detected at concentrations that exceeded the $UTL_{99/99}$ concentration at one or more locations calcium, copper, sodium, cobalt, and vanadium Only calcium concentrations displayed a spatial correlation (Figure 4-17) Samples exceeding the $UTL_{99/99}$ define an area of high calcium concentration along the northeast portion of the sample grid

One uranium-235 and four americium-241 activities exceeded the $UTL_{99/99}$ value The soil sample exceeding the $UTL_{99/99}$ for uranium-235 was collected along the eastern edge of the IHSS 203 sample grid, whereas the four soil samples exceeding the $UTL_{99/99}$ for americium-241 were located along the southwestern boundary of the sample grid (Figure 4-19) The uranium-235 activity was 1 4 times the maximum background activity The americium-241 activities ranged from 1 5 to 8 5 times the maximum reported background activities

Two PCBs, aroclor-1254 and aroclor-1260, were detected in 14 of 67 and 13 of 67 soil samples, respectively 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 µg/kg Surface soil samples with detectable PCB concentrations are not spatially correlated, and of the 27 PCB detections, only three were in samples collected from the 0- to 10-inch horizon These results indicate that PCBs are probably present at low concentrations throughout IHSS 203 surface soils

4 3 2 *Present Landfill (IHSS 114)*

Surface soil samples collected at IHSS 114 were analyzed for SVOCs, metals, and radionuclides, samples were not analyzed for VOCs Surface soil at IHSS 114 consists of interim soil cover material, not native soil Calcium was the only analyte identified by the inferential statistical tests as having elevated concentrations relative to background (Table 4-11) In addition, soils from an area in the northeast corner of the sample grid contained calcium concentrations that exceeded the $UTL_{99/99}$ concentration (Figure 4-20)

Two surface soil samples at IHSS 114 contained copper concentrations exceeding the $UTL_{99/99}$ value These two concentrations were 2 0 and 3 7 times the maximum background copper concentration and were not spatially correlated Gross beta and strontium-89,90 activities exceeded the $UTL_{99/99}$ value in one sample each The gross

beta and strontium-89,90 activities were 1 3 and 2 9 times the maximum background activity and occurred at two separate locations near the center of the IHSS 114 sample grid All $UTL_{99/99}$ exceedances in IHSS 114 soil samples are listed in Table 4-12

Twenty-one SVOCs were detected in surface soil samples from IHSS 114 (Table 4-11) Eight of those SVOCs were detected in more than 50 percent of the samples These data indicate that surface soils at IHSS 114 contain low levels of some SVOCs These contaminants may be associated with the interim soil cover material itself, or they may be introduced to the soil by leaks or emissions from construction equipment and vehicles used within IHSS 114

4 3 3 *East Landfill Pond Area*

Surface soil samples collected adjacent to the East Landfill Pond were analyzed for metals and radionuclides, samples were not analyzed for VOCs or SVOCs Statistical tests identified only three PCOCs in soil from the East Landfill Pond area calcium, strontium, and radium-226 (Table 4-13) Calcium concentrations in both the 0- to 2-inch and the 0- to 10-inch surface soil horizons were elevated relative to sitewide background concentrations Strontium concentrations and radium-226 activities were elevated relative to background only in the 0- to 2-inch soil horizon

The hot-measurement test resulted in a list of 12 analytes present at concentrations in soil that exceeded the $UTL_{99/99}$ values for background (Table 4-14) Concentrations of the following metals exceeded their respective $UTL_{99/99}$ concentration arsenic, barium, calcium, lead, magnesium, selenium, sodium, vanadium, and zinc Higher concentrations (exceedances) of these metals were not spatially correlated except for calcium Calcium concentrations in soil exceeded the $UTL_{99/99}$ concentration in both the 0- to 2-inch and the 0- to 10-inch horizons in the area covered by the northwest corner of the sampling grid This area of elevated calcium concentrations is in the vicinity of a seep may be associated with a leak in the northern portion of the groundwater intercept system The calcium enrichment at this location could be the result of evaporation of seep water (Figure 4-21) However, high concentrations of other major ions, such as magnesium and sodium, that would also be present in seep water and be concentrated in these soils were not present

Ten surface soil samples from the 0- to 2-inch horizon had nitrate/nitrite concentrations that exceeded the $UTL_{99/99}$ (Figure 4-23) Two of these samples were collected from the spray area in IHSS 167 3 on the southern edge of the pond Four of the samples were

collected from the slope east of the pond embankment Concentration isopleth maps display areas where the concentrations of lead, vanadium, and selenium and are greater than the $UTL_{99/99}$ (figures 4-22, 4-24, and 4-25)

Four surface soil samples at the East Landfill Pond had americium-241 activities that exceeded the $UTL_{99/99}$ These samples were collected along the southern edge of the pond and along the southern surface water diversion ditch below the dam (Figure 4-26) The activities ranged from 1 5 to 26 6 times the maximum background concentration All but one of the samples with an americium-241 activity greater than the $UTL_{99/99}$ value were from the 0- to 2-inch horizon The sample from the 0- to 10-inch horizon was collected downslope of the point of discharge from the southern groundwater intercept system This was the only sample from the 0- to 10-inch soil horizon with a radionuclide activity that exceeded the $UTL_{99/99}$

Radium-226 activities exceeded the $UTL_{99/99}$ at six soil sample locations in the 0- to 2-inch soil horizon (Figure 4-27) Three of the samples were located in the center of the spray evaporation area along the northern edge of the pond The other three samples were located along the slope immediately east of the landfill pond dam The maximum radium-226 activity was 1 6 times the maximum background value.

4.4 Subsurface Geologic Materials

This section describes the nature and extent of contamination in subsurface geologic materials at OU 7 and presents the PCOCs identified by site-to-background comparisons Drilling methods, borehole locations, sample collection methods, and analytical suites are described in Appendix C Borehole logs are presented in Appendix E Data from subsurface geologic materials were aggregated by location (upgradient and downgradient) and by geologic unit as described in Section 4 1 1 to make comparisons with the background data. Inferential statistical analyses described in Section 4 1 2 were used to determine which analytes were detected in subsurface geologic materials at concentrations that exceeded background concentrations

Chemical data for subsurface geologic materials obtained during the Phase I RFI/RI at OU 7 were used in this analysis Statistical comparisons were made using data from borehole samples collected both upgradient and downgradient of the Present Landfill The two upgradient boreholes, 70493 and 70593, are immediately adjacent to one another and located approximately 200 feet upgradient of IHSS 203 Downgradient borehole

70993 is located approximately 50 feet directly downslope of the north groundwater intercept system discharge point, and downgradient borehole 71093 is located approximately 50 feet downslope of the south groundwater intercept system discharge point

Statistical test results for subsurface geologic materials are presented in Appendix M Box plots and histograms were generated for all analytes having greater than 50 percent detectable concentrations and are presented in Appendices K and L, respectively The PCOCs for subsurface geologic materials from OU 7 are presented in tables 4-15 and 4-16

4 4 1 Surficial Geologic Deposits

Surficial geologic deposits at the borehole locations upgradient of OU 7 consist entirely of Rocky Flats Alluvium, whereas surficial deposits at the boreholes downgradient of OU 7 consist of colluvium Statistical analysis of chemical data for surficial deposits upgradient of OU 7 did not identify any metals with elevated concentrations relative to sitewide background However, seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-238) have elevated activities in upgradient borehole samples relative to activities in background surficial deposits In addition, cesium-137 and radium-228 activities and lead and chromium concentrations exceed the $UTL_{99/99}$ values of background data

At downgradient borehole 70993, aluminum and manganese concentrations and cesium-137 and uranium-238 activities are higher in the surficial geologic deposits than in deposits from background locations However, no analyte concentrations or activities exceeded the $UTL_{99/99}$ in samples from this borehole At downgradient borehole 71093, surficial deposits contained elevated concentrations of aluminum, barium, lead, strontium, and zinc and elevated tritium activity relative to background data Tritium was identified as a PCOC in water discharged from the south groundwater intercept system discharge (Section 4 6) Cesium-137 activities and barium and nitrate/nitrite concentrations exceeded the $UTL_{99/99}$ values in surficial material at borehole 71093

Toluene was detected in 100 percent of surficial deposit samples collected from both the upgradient and downgradient boreholes No other organic parameters were consistently identified at concentrations above the detection limit in borehole samples from these locations At borehole 70993, ten organic compounds other than toluene were detected

These detections were not co-located, and eight of the ten results were J qualified indicating that the results are estimated concentrations below the detection limit A list of VOCs and SVOCs detected in geologic materials at OU 7 is presented in Table 4-15

4 4 2 Bedrock Geologic Materials

Bedrock geologic materials consist of weathered Arapahoe and Laramie Formation claystone Statistical tests indicated that barium, calcium, lead, and strontium concentrations and radium-226 activities were elevated relative to background concentrations in bedrock material upgradient of OU 7 Concentrations of strontium in the upgradient bedrock material exceeded the $UTL_{99/99}$ concentration in all sample intervals Calcium and zinc concentrations in upgradient bedrock material exceeded the $UTL_{99/99}$ value once and twice, respectively

Bedrock geologic materials from downgradient borehole 70993 have elevated calcium, cobalt, copper, lead, nickel, selenium, sodium, strontium, and zinc concentrations and radium-226 activities relative to background bedrock materials At downgradient borehole 71093, bedrock materials have elevated barium, calcium, cobalt, lead, manganese, nickel, selenium, sodium, strontium, and zinc concentrations and radium-226 and strontium-89,90 activities relative to background bedrock materials

Strontium concentrations exceeded the $UTL_{99/99}$ value in bedrock samples from both downgradient boreholes as in samples from the upgradient boreholes The apparently high strontium concentrations in bedrock in the vicinity of OU 7 may be due to differences in the types of geologic materials present at OU 7 compared to those used to calculate background $UTL_{99/99}$ concentrations Other analytes that exceeded the $UTL_{99/99}$ values in bedrock materials from downgradient boreholes included arsenic, barium, calcium, cobalt, lead, manganese, and zinc These values that exceeded UTL concentrations did not occur consistently in the same samples or in samples from the same depth interval

4 5 Sediments

This section discusses the nature and extent of contamination in the East Landfill Pond sediments The statistical methodology described in Section 4 1 2 was used to identify PCOCs by determining which inorganic analytes, metals, and radionuclides are present at higher concentrations in pond sediments than in sediments from background locations

Organic compounds detected in pond sediment samples were also identified as PCOCs The following description of the pond sediments is based on data from samples collected and analyzed during the OU 7 Phase I RFI/RI

Samples of pond sediment were collected from three sampling locations at the East Landfill Pond (Figure C-3 [Appendix C]) Sampling locations were chosen to assess the impact of nearby point sources of contamination (leachate seep, north groundwater intercept outfall, and south groundwater intercept system outfall) Sample location SED70093 is located near the landfill leachate seep, SED70193 is located near the south groundwater intercept system discharge outfall point, and SED70293 is located approximately 100 feet northeast of the north groundwater intercept system discharge outfall, near the pond embankment The pond also receives runoff containing sediment from adjacent slopes Sediment derived from slope runoff may be a large component of the sediment now present along the edges of the pond Sediment samples collected from stations SED70193 and SED70293 were analyzed for VOCs, SVOCs, radionuclides, metals, and inorganics Sediment samples collected from SED70093 were analyzed for Appendix IX SVOCs and VOCs, radionuclides, metals, and inorganics Sampling and analytical methods are described in Appendix C

Only three VOCs were detected in pond sediment samples (Table 4-17) toluene was detected at all three locations, acetone was detected at SED70193 and SED70293, and 2-butanone was detected at SED70093 The following SVOCs were detected in the East Landfill Pond sediments Acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, benzoic acid, bis(2-chloroisopropyl)ether, and bis(2-ethylhexyl)phthalate With the exception of fluoranthene, the reported concentrations of all of these compounds were qualified with a J to indicate that these are estimated concentrations below the detection limit Table 4-17 lists the SVOCs detected in the pond sediment samples

The greatest number of SVOCs was detected in sediment from SED70093, the location closest to the leachate seep In the sediment sample from SED70293, located near the north groundwater intercept system discharge point, five SVOCs were detected Benzoic acid was the only compound detected in sediment from all three locations and the only organic compound detected at SED70193, located near the south groundwater intercept system discharge point Landfill leachate discharges to the pond along its western edge

and is the most likely source of SVOCs to sediments in the pond SVOCs occur in leachate seep water (Section 4 6) and in leachate within the landfill (Section 4 7)

Statistical tests indicated that concentrations of the following metals and inorganic compounds were elevated in pond sediments relative to background concentrations aluminum, arsenic, barium, beryllium, calcium, chromium, copper, iron, lead, magnesium, nickel, potassium, selenium, strontium, vanadium, and zinc However, none of these analytes was present at concentrations that exceed background $UTL_{99/99}$ values

Cesium-137 was the only radionuclide with elevated activities in sediments relative to background activities None of the radionuclide activities measured from pond sediments exceeded $UTL_{99/99}$ values The sample collected from SED70093, closest to the leachate seep, had the highest cesium-137 activity and the highest activities of americium-241, plutonium-239,240, gross beta, strontium-89,90, uranium-233,234, and uranium-238

The results of the statistical analyses are presented in Appendix M, and the PCOCs for metal and inorganic parameters, based on results of the statistical inference tests, are listed in Table 4-18

These results suggest that the leachate seep may be a source of radionuclides, VOCs, and SVOCs to sediments in the pond Some of the PCOCs identified for the pond sediments were not identified as PCOCs in water from the leachate seep or from the pond (cesium-137, beryllium, chromium, copper, lead, selenium, and vanadium) The sample from SED70193 had the highest concentrations of the three sediment samples for all of these analytes except cesium-137 The SED70193 is located closest to the edge of the pond These results suggest that sediments transported to the pond via runoff may be the source of some metals

4 6 Surface Water

This section discusses the extent and magnitude of surface water contamination at OU 7 and identifies PCOCs in surface water based on comparisons of surface water data from the site to background surface water data The statistical analysis procedures described in Section 4 1 2 were used to identify PCOCs Statistical comparisons of site to background data were based on the data aggregations shown in Table 4-1 Chemical data from leachate seep water (SW097) were statistically compared to sitewide background seep data. Chemical data from the East Landfill Pond (SW098) and the two groundwater

intercept system discharge points (SW099 and SW100) were each independently compared to sitewide background surface water data for PCOC identification All chemical data were also compared to the $UTL_{99/99}$ concentration for each analyte Any analyte exceeding the $UTL_{99/99}$ concentration was also identified as a PCOC The results of all statistical tests for OU 7 surface water are given in Appendix M

Surface water data used for the statistical evaluations included data collected quarterly from 1990 through 1993 and data obtained during the Phase I RFI/RI at OU 7 Data collected since 1990 were considered fully usable because they represent the first full year of data collection following the implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific standard operating procedures (SOPs) (EG&G 1991g) Analytes measured in surface water are given in Appendix C

4 6 1 Leachate Seep (SW097)

Statistical analysis of surface water data from the leachate seep (SW097) identified 12 total and 11 dissolved metals as PCOCs Three total and three dissolved radionuclides and nitrite were also identified as PCOCs Radionuclides identified as PCOCs based on the results of the inferential statistics included total and dissolved gross beta and strontium-89,90 and total tritium In addition, the uranium-235 activity of one sample exceeded the $UTL_{99/99}$ value

Nineteen VOCs were detected in the seep water at SW097 Benzene, toluene, ethylbenzene, and xylenes (BTEX) were frequently detected in SW097 surface water with detection frequencies ranging from 58 percent to 100 percent Ethylbenzene, toluene, and total xylenes were the most commonly detected BTEX compounds The most common chlorinated hydrocarbons detected in the seep water were 1,1-dichloroethane (1,1-DCA) (90 percent), chloroethene (79 percent), TCA (58 percent), and 1,2-DCE (53 percent) Detection frequencies for SVOCs in leachate seep water ranged from 25 to 100 percent These data indicate that seep water emanating from the front of the landfill has been contaminated by VOCs and SVOCs Chemical data for groundwater within the landfill displayed similar analytes at elevated concentrations (BTEX, SVOCs, nitrite, and tritium) as seep water (Section 4 7) The PCOC list for seep water is given in Table 4-19

4 6 2 East Landfill Pond (SW098)

The inferential statistical tests identified 11 total and 14 dissolved metals as PCOCs at station SW098 (East Landfill Pond) Seven total and four dissolved radionuclides were elevated relative to background surface water data. Total and dissolved strontium-89,90 and tritium activities were elevated in pond water relative to background, as in seep water Uranium-235, uranium-238, americium-241, gross alpha, and gross beta activities were also elevated in pond water relative to the background data In addition, the activity of one americium-241 sample from SW098 exceeded the $UTL_{99/99}$ value

Two VOCs were detected in East Landfill Pond waters Acetone and vinyl acetate were each detected in one of twenty and in one of nineteen samples, respectively Two SVOCs were each detected in one of seven samples These infrequent and non-repeatable occurrences of VOCs and SVOCs indicate that the quality of water in the East Landfill Pond is not adversely affected by organic compounds Although data from the leachate seep indicate that VOCs and SVOCs may be introduced to the pond, volatilization, photolysis, and other degradation processes may effectively remove VOCs from the pond water Table 4-20 lists PCOCs identified at surface water station SW098

4 6 3 Northern Groundwater-Intercept System Discharge Point (SW099)

Statistical analysis of chemical data from samples collected at station SW099 identified eight total and eight dissolved metals and four total and two dissolved radionuclides as PCOCs Total uranium-235, uranium-238, gross alpha, and americium-241 activities and dissolved strontium-89,90 and uranium-238 activities were elevated relative to background This list of radionuclides is similar to the list generated for water from the East Landfill Pond except that it does not include tritium

Three dissolved metals (calcium, lead, and sodium) were present at concentrations exceeding the $UTL_{99/99}$ value The remaining five dissolved metals were barium, cadmium, lithium, magnesium, and strontium

The PCOC list for SW099 (northern groundwater-intercept discharge point) is given in Table 4-20 and includes six VOCs and one SVOC detected Table 4-21 also shows that VOCs and SVOCs were infrequently detected in discharge from the north groundwater intercept system The low frequency of detection and relatively low repeatability of these

data indicate the VOC and SVOC contamination is not significant in surface water at SW099

4 6 4 Southern Groundwater-Intercept Discharge System Point (SW100)

The inferential statistical tests identified eight total and eleven dissolved metals as PCOCs at surface water station SW100 Three total and three dissolved radionuclides were also identified as PCOCs based upon the results of the inferential statistics Radionuclides identified as PCOCs include total and dissolved americium-241 and gross beta, tritium, and dissolved uranium-238

Six VOCs were detected at SW100 Three BTEX compounds (ethylbenzene, toluene, and total xylenes) and three chlorinated hydrocarbons (1,1-DCA, chloroethane, methylene chloride) were each detected once in the seven sample data set No SVOCs were detected in water from station SW100 The infrequent detection of VOCs and absence of SVOCs at SW100 indicate that organic contamination at SW100 is not significant However, because volatilization or degradation (i e , photolysis) processes may effectively remove VOCs from water at SW100, the presence or absence of VOCs in water within the southern groundwater intercept system has not been determined Table 4-22 presents PCOCs identified at surface water station SW100

4.7 Groundwater

This section discusses the nature and extent of groundwater contamination at OU 7 and identifies PCOCs based on site-to-background comparisons of chemical data The statistical analysis procedure described in Section 4 1 2 was used to identify PCOCs by determining which metals, radionuclides, and water-quality parameters are present at higher concentrations in groundwater at OU 7 than in groundwater from background locations Statistical analysis and PCOC identification were performed separately for wells screened in the UHSU and LHSU In addition, spatial trends in analyte concentration and individual samples exceeding the background $UTL_{99/99}$ concentration were identified within each hydrostratigraphic unit

Data from all wells included in the OU 7 monitoring network were used to describe extent and magnitude of groundwater contamination at OU 7 The groundwater monitoring network at OU 7 includes 40 wells screened in the UHSU and 7 wells

screened in the LHSU Well construction diagrams are given in Appendix F, and historical analytical data from monitoring wells are given in Appendix N

Groundwater chemical data collected from 1990 through 1993 were used to describe groundwater contamination at OU 7 Included in this data set are data collected during the Phase I RFI/RI and data obtained since 1990 as part of the quarterly groundwater monitoring program at OU 7 Data collected since 1990 were considered fully usable because they represent the first full year of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific SOPs (EG&G 1992c)

Comparisons of site-to-background data were made to identify PCOCs in groundwater based on the data aggregation scheme shown in Table 4-1 Background values for groundwater chemical data were obtained from the Background Geochemical Characterization Report (EG&G 1993a) Data from all wells in the UHSU and LHSU at OU 7 were compared to their respective sitewide background hydrostratigraphic unit (HSU) data The PCOCs in the UHSU were identified using all UHSU data. PCOCs in the LHSU were identified using downgradient LHSU wells

To assist in describing contaminants present in leachate (water in contact with landfilled wastes), data from wells screened within the landfill were also compared to sitewide background data from UHSU groundwater Data from upgradient LHSU wells were also separately compared to LHSU background data to assist in evaluating the nature and extent of LHSU groundwater contamination

4 7 1 PCOCs for Metals, Radionuclides, and Water-Quality Parameters

Statistical comparison of UHSU and LHSU groundwater concentration data for metals, radionuclides, and water-quality parameters to sitewide background data determined that the concentrations of the analytes shown in tables 4-23 and 4-24 were elevated in groundwater relative to background concentrations The results of statistical tests for the data aggregations shown in Table 4-1 are given in Appendix M

Using total analyte concentrations, 28 analytes were identified as PCOCs in the UHSU groundwater compared to 15 analytes in LHSU groundwater The PCOC list developed using total analyte concentrations for the UHSU consisted of 24 metals and 3

radionuclides compared to 14 metals for the LHSU Nitrate/nitrite was also identified as a PCOC in UHSU groundwater

Using dissolved concentrations, 16 analytes were identified as PCOCs in the UHSU groundwater compared to 23 analytes in the LHSU groundwater The dissolved concentration PCOC list for the UHSU consisted of 13 metals and 3 radionuclides compared to 20 metals and three radionuclides for the LHSU

4 7 2 *Analysis of Organic Compound Distribution in Groundwater*

Contamination of UHSU and LHSU groundwater by organic compounds was evaluated by determining which organic analytes have been detected in groundwater from OU 7, determining detection frequencies for these analytes, analyzing spatial trends in average "total" VOC concentrations, and attempting to correlate total VOC concentrations with concentrations of other parameters indicative of landfill-generated contamination This approach was necessary because individual VOCs were detected infrequently at any one location and their spatial distribution could not be evaluated

Total VOC concentrations were estimated by summing the concentrations of the most frequently detected volatile organic parameters at OU 7 Volatile organic parameters detected at least 5 percent of the time were used to estimate the total VOC concentration in the UHSU In the LHSU, all detected VOCs were used to calculate total VOC concentrations Total VOC concentrations were calculated quarterly from 1990 to 1993 for each well, and these data were used to calculate an average total-VOC concentration Average total-VOC concentrations represent the average concentration using sampling periods during which VOCs were detected at a well These data were used to analyze the spatial distribution of VOC concentrations within groundwater and should not be interpreted as unbiased estimates of the true average concentration at each well Average total-VOC concentrations were utilized to minimize variable data availability caused by water-level fluctuations and dry wells, sampling techniques, data rejection during the validation process, and variable sample recovery throughout the monitoring network for any given monitoring event These data provide a conservative estimate of the spatial extent and relative levels of VOC contamination within groundwater The data do not provide an unbiased estimate of true average total-VOC concentrations for the period of analysis However, given the intrinsic and extrinsic factors affecting VOC concentrations during any given sampling event, average total-VOC concentrations provide a useful

estimate of VOC concentrations within groundwater for the purpose of examining the spatial extent of contamination

Total-VOC concentrations were subdivided into average chlorinated hydrocarbon and average BTEX concentrations These data were mapped separately in the UHSU Average total concentrations of SVOCs detected in more than 5 percent of samples were also mapped The spatial correlation of total VOC and landfill indicator-parameter concentrations was also investigated Table 4-25 displays the frequency of detections of all organic parameters for both the UHSU and LHSU at OU 7 The organic parameters listed in Table 4-25 represent the PCOCs for organic compounds in groundwater at OU 7 The statistics used to generate all total VOC maps are given in Appendix M

4 7 3 *Nature and Extent of UHSU Groundwater Contamination*

Tables 4-23 and 4-25 list PCOCs for UHSU groundwater at OU 7 Groundwater concentration data from all UHSU wells and from UHSU wells screened within the landfill were compared to sitewide background UHSU data Two PCOC lists were developed from these analyses Comparison of chemical data (total concentrations) from UHSU wells within the landfill to sitewide background UHSU data resulted in 23 metals and 3 radionuclides being identified as PCOCs compared to 24 metals and 1 radionuclide identified comparing all UHSU wells within OU 7 to sitewide background data Table 4-26 presents the results of UHSU statistical comparisons

Some notable differences exist between the analytes identified as PCOCs using only data from landfill wells compared to using all OU 7 UHSU data. Nitrate/nitrate is identified as a PCOC using all OU 7 UHSU data but not when using data from landfill wells alone This may indicate a source of nitrate/nitrite outside the landfill or may be the result of a more limited set of nitrate/nitrite data from wells within the landfill However, nitrite is elevated for background concentrations within the landfill, and the Gehan test (0 07) indicated that nitrite may also be elevated sitewide for background data. Elevated nitrite in landfill leachate relative to other UHSU groundwater may be indicative of more reducing conditions within the landfill

Other analytes not identified as PCOCs in landfill leachate that were identified as PCOCs using all OU 7 UHSU data include total antimony and selenium, total strontium-89,90, and dissolved copper and strontium Total americium-241 and radium-226 activities were elevated with respect to background using all OU 7 UHSU data and data from the

landfill wells alone Tritium was identified as elevated for background in landfill leachate but not in all OU 7 UHSU groundwater This finding is consistent with the documented disposal of tritium-contaminated waste in the landfill (Rockwell International 1987c)

Groundwater concentration data from UHSU wells downgradient of the landfill were also compared to sitewide background UHSU data This comparison resulted in nine metals and two radionuclides (total concentrations) being identified as PCOCs compared to 24 metals and 3 radionuclides using all OU 7 UHSU data. Dissolved concentrations of 12 metals and 5 radionuclides were identified as PCOCs using downgradient UHSU data compared to 13 metals and 2 radionuclides using all OU 7 UHSU data

Different analytes appear on the downgradient PCOC list than on the PCOC list generated using all OU 7 UHSU data. Uranium-235 and uranium-238 (both total and dissolved) are identified as PCOCs in downgradient UHSU groundwater These radionuclides were not identified as PCOCs when all OU 7 USHU data or data from UHSU wells located within the landfill were compared to sitewide background data Dissolved gross alpha and dissolved gross beta were also identified as PCOCs in downgradient UHSU groundwater Dissolved gross beta was also identified as a PCOC using both OU 7-wide data and data from landfill wells Dissolved gross alpha was not identified as a PCOC in either of the other comparisons These data may indicate that a source of uranium-235 and uranium-238 exists outside of the landfill or that these analytes are elevated at downgradient wells as the result of discharges from the groundwater intercept system

4 7 3 1 Isoconcentration Maps

Isoconcentration maps generated using average concentrations were used to analyze the nature and extent of groundwater contamination in the UHSU at OU 7 and to investigate possible contaminant sources and transport pathways Average concentrations were determined from quarterly groundwater monitoring data collected from 1990 through 1993 Quarterly data were averaged to minimize the influence of seasonality and natural variability in intra-well concentrations Analytes were selected for mapping based on their frequency of occurrence, contaminant transport characteristics, and association with specific waste types Average concentration contour maps for the UHSU were constructed for inorganic indicator parameters (TDS and nitrate/nitrite), organic parameters (total VOCs, total chlorinated hydrocarbons, BTEX, and total SVOCs), and

radionuclides (dissolved and total uranium-235 and uranium-238, dissolved radium-226, and total americium-241)

Indicator Parameters

The highest average TDS concentrations occurred in leachate and in groundwater downgradient of the landfill (Figure 4-28) The highest average TDS concentration in landfill leachate (2,211 mg/L) was from well 72293 within the central portion of the landfill The highest average TDS concentration in UHSU groundwater (5,100 mg/L) occurred at downgradient well B206989 located near the discharge of the northern groundwater intercept system Other wells downgradient of the landfill located near the groundwater intercept system discharge points (B206889, B207089, and 4087) also had average TDS concentrations greater than 1,000 mg/L Discharges from the groundwater intercept system may introduce high TDS water from the landfill to the UHSU groundwater in the vicinity of the outfall points

Average concentrations of nitrate/nitrite were mapped within the UHSU (Figure 4-29) with the highest concentrations of nitrate/nitrite present in groundwater downgradient of the landfill near the groundwater intercept system discharge points Average nitrate/nitrite concentrations of 160 and 51 mg/L were in groundwater from wells B206889 and B206989, respectively These concentrations are much higher than the average nitrate/nitrite concentrations in water from within the landfill, which were generally less than 1 0 mg/L Nitrate/nitrite concentrations in the range of 1 to 5 mg/L (slightly higher than mean background concentrations) occur along the northern, western, and southern perimeter of the landfill Although these concentrations are higher than those within the landfill, an upgradient source of nitrate/nitrite has not been identified

Total Organic Compounds

Total concentrations of organic compounds frequently detected in UHSU groundwater were mapped to determine their spatial distribution in groundwater and to identify possible sources of these compounds The parameters included in the total concentrations of VOCs, chlorinated hydrocarbons, BTEX, and SVOCs are listed in Table 4-25

The highest average total VOC concentration and highest average TDS concentration occur in the east-central portion of the landfill in leachate from well 72293 (730 µg/L)

(Figure 4-30) Water from this portion of the landfill probably has the longest residence time within the landfill and, therefore, may have the highest contaminant concentrations

Elevated total VOC concentrations in wells located upgradient south and southwest of the landfill indicate that source(s) of VOC contamination is also present outside of the landfill Upgradient groundwater from well 70393 had an average total VOC concentration of 71 µg/L These VOCs may be associated with past activities at the PU&D yard as discussed in Section 2 1 Groundwater from wells located within IHSS 166 1, which is southeast of the landfill, had average total VOC concentrations of 36 and 76 µg/L, respectively

Groundwater downgradient of the landfill and below the discharge points of the groundwater intercept system contains relatively low concentrations of total VOCs compared to water from within the landfill None of the organic compounds detected at B206889 (methylene chloride, acetone, benzene, ethylbenzene, toluene, or total xylenes) was detected in subsequent analyses Isolated detections of VOCs have occurred at well 7187 located northeast of the landfill

Maps of average total chlorinated hydrocarbon and total BTEX concentrations were constructed to identify patterns in the types of VOC contamination occurring at the site The total chlorinated hydrocarbon map (Figure 4-31) indicates that the highest concentration of chlorinated hydrocarbons occurred in groundwater upgradient of the landfill at well 70693 (416 µg/L) VOC contamination at this upgradient well was composed entirely of chlorinated hydrocarbons Upgradient well 70393 had an average (detected) chlorinated hydrocarbon concentration of 72 µg/L Concentrations of chlorinated hydrocarbons were much higher in groundwater upgradient of the landfill than in leachate from the central portion of the landfill, with the exception of well B206389 (average concentration of 278 µg/L) Well B206389 is located downgradient from IHSS 166 1 Chlorinated hydrocarbon concentrations in groundwater from within IHSS 166 1 (wells B206489 and 7287) were also elevated (32 and 68 µg/L, respectively) for leachate from the landfill

In contrast, average BTEX concentrations were highest in leachate collected from the landfill (Figure 4-32) The BTEX compounds were not detected in upgradient groundwater from wells 70393 and 70693 (where the highest total chlorinated hydrocarbon concentrations were found) The highest average BTEX concentrations occurred in water from wells 72293 and 72393 (423 and 345 µg/L, respectively) within

the central portion of the landfill Wells B206489 and 7287 within IHSS 166 1 had average BTEX concentrations of 8 and 56 µg/L, respectively Thus, different types of VOC contamination are present within the landfill and upgradient (southwest) of the landfill, suggesting that a distinct source of VOC contamination is present upgradient of the landfill

Average total SVOC concentrations were highest in leachate from the east-central portion of the landfill at wells 72293 and 72393 (710 and 717 µg/L, respectively) (Figure 4-33) Isolated detections of SVOCs occurred at wells 70693 and 716593 (21 and 25 µg/L, respectively) These data indicate that SVOC contamination is largely contained within the central portion of the landfill

In summary, the organic parameter maps indicate that the landfill is not the sole source of contamination to groundwater in the vicinity of OU 7 Within the landfill, a VOC plume characterized by relatively high BTEX and low chlorinated hydrocarbon concentrations exists The VOC concentrations within the landfill increase in the downgradient direction A second, chemically distinct VOC plume exists southwest and upgradient of the landfill This plume is composed entirely of chlorinated hydrocarbons and may be associated with activities at the PU&D yard A third plume within and downgradient of IHSS 166 1 is characterized by a mixture of BTEX and chlorinated hydrocarbon compounds Other regions of isolated VOC contamination occur at IHSS 203 (BTEX compounds), downgradient at the groundwater intercept system discharge points (BTEX and chlorinated hydrocarbons), and northeast of the landfill at well 7187 (chlorinated hydrocarbons) Leachate collected from the northern portion of the landfill had the lowest concentrations of VOCs and SVOCs Also, groundwater near the discharge of the northern groundwater intercept system had lower concentrations of VOCs than groundwater near the southern groundwater intercept system discharge

Radionuclides

Maps of average dissolved and total uranium-235 activity (figures 4-34 and 4-35) indicate that dissolved and total activities of uranium-235 were highest in groundwater from wells B206589 (located upgradient and south of the landfill) and B206889 (located downgradient of the landfill near the southern groundwater intercept discharge) Both dissolved and total activities of uranium-235 were relatively low in water from within the landfill with total activities less than 0 5 pCi/L Average total and dissolved uranium-238 (figures 4-36 and 4-37) followed the same general distribution pattern in groundwater as

uranium-235 The highest activities of uranium-238 occurred in groundwater from wells B206589 and B206889 and indicate that a source(s) of uranium-235 and uranium-238 may be present outside and south of the landfill Uranium-235 and uranium-238 activities were also relatively high at wells located near the discharge of the north groundwater intercept system discharge, and at well 0786 located near the East Landfill Pond

The map of average dissolved radium-226 activity indicated that the highest activities occur within the southern and central portions of the landfill at wells B206389, 6987, 72093, 72293, and 72393 (Figure 4-38) Both total and dissolved radium-226 were identified as PCOCs The highest americium-241 levels also occur within the landfill at wells 72093, 72393, and abandoned well 6387 (Figure 4-39)

Dissolved Oxygen and pH Maps

The average pH and dissolved oxygen content (field measurements) of groundwater were mapped to identify their spatial relationship to other contaminants (figures 4-40 and 4-41) Groundwater within the landfill (leachate) generally has pH values ranging from 6 5 to 7 5 The lowest pH values occur in the northern portion of the landfill Dissolved oxygen contents were lowest in leachate from the central and southern portion of the landfill The lowest dissolved oxygen concentration (1 63 mg/L) occurred at well 72293 in the east-central portion of the landfill These data indicate that landfill leachate is generally neutral and mildly oxidizing Because dissolved oxygen was measured in samples exposed to air, the dissolved oxygen contents reported may not be representative of redox conditions within the landfill

4 7 3 2 Exceedances of the $UTL_{99/99}$ Concentration

All inorganic and radionuclide data from UHSU wells at OU 7 were compared to background $UTL_{99/99}$ values The list of values that exceed the $UTL_{99/99}$ concentration, by well, are given in Appendix M

Additional analytes identified as PCOCs using the comparison to the $UTL_{99/99}$ concentration include dissolved aluminum, antimony, cadmium, chromium, lithium, molybdenum, and selenium Comparison of total concentrations to the $UTL_{99/99}$ concentration resulted in cadmium, cyanide, molybdenum, tin, and cesium-137 being

identified as additional PCOCs Table 4-23 lists all analytes exceeding the $UTL_{99/99}$ concentration and the range of values that exceed the UTL

4 7 4 *Nature and Extent of LHSU Groundwater Contamination*

Data from wells downgradient of the landfill were used to develop the PCOC list for LHSU groundwater Data from LHSU wells upgradient of the landfill were then separately compared to sitewide LHSU background data to determine if LHSU groundwater upgradient of the landfill contains analytes at concentrations elevated with respect to background concentrations

Statistical comparison of upgradient LHSU groundwater data to sitewide background resulted in identification of 22 analytes with elevated concentrations relative to background 6 dissolved metals and 1 dissolved radionuclide and 14 total metals and 1 total radionuclide Using downgradient LHSU data, 20 dissolved metals and 3 dissolved radionuclides and 8 total metals were identified as elevated relative to background Table 4-27 presents the results of the LHSU statistical comparisons These analytes are all PCOCs in LHSU groundwater as summarized on Table 4-24

Dissolved analytes that were identified as PCOCs using downgradient data, but were not elevated in the upgradient data set, include aluminum, beryllium, cadmium, chromium, cobalt, copper, lithium, potassium, selenium, silver, sodium, strontium, thallium, and tin The greater number of dissolved metals identified as PCOCs in downgradient groundwater may be the result of increased contact between downgradient groundwater and landfill materials or other sources of contaminants

Dissolved radionuclides identified as PCOCs comparing downgradient data to sitewide background included gross alpha, gross beta, and uranium-238 Comparison of upgradient dissolved radionuclide data to background data indicated that uranium-235 was elevated for background activities Using total activities, cesium-137 was found to be elevated with respect to background in upgradient groundwater

4 7 4 1 Isoconcentration Maps

Maps of average analyte concentrations were used to analyze the nature and extent of LHSU contamination and to investigate possible contaminant sources and transport pathways Isoconcentration contour maps for the LHSU were constructed for average total dissolved solids, average total VOCs, and average dissolved uranium-238 activity

Due to the limited spatial extent of LHSU chemical data, especially underlying the landfill, only general conclusions could be reached regarding the extent of LHSU contamination

Inorganic Indicator Parameters

The highest average TDS concentrations were present in groundwater downgradient of the landfill (Figure 4-42) Average TDS concentrations at downgradient wells 4187 and B207189 were 1,885 and 1,688 mg/L, respectively These concentrations exceed the mean and maximum reported background TDS concentrations of 406 and 1,430 mg/L, respectively These data may indicate that LHSU groundwater downgradient of the landfill may have been adversely affected by discharges from the groundwater intercept system

Total Organic Compounds

Average total concentrations of organic compounds frequently detected in LHSU groundwater were mapped to determine the spatial distribution of these compounds and to identify possible source areas of VOC contamination to LHSU groundwater (Figure 4-43) The parameters included in total concentrations of VOCs are listed in Table 4-24

The average total VOC concentration map indicates that VOCs have been detected in five of eight LHSU groundwater wells However, detections of VOCs are infrequent and generally not repeated at single wells As discussed below, these detections probably do not indicate contamination of groundwater in the LHSU

At downgradient well B207189, methylene chloride was detected once in 1991 at a concentration of 8 µg/L Methylene chloride was detected in samples collected from this well on two other occasions, but on those occasions, it was also reported in the laboratory blanks Because there have been no additional detections of methylene chloride in LHSU well B207189, the 1991 detection is questionable Acetone has been detected twice at B207189 In one instance, acetone was also detected in the laboratory blank, on the other occasion it was reported below the detection limit as a suspected aldol condensation product These data do not provide sufficient evidence of VOC contamination at downgradient well B207189

Eight of the nine VOC detections reported in downgradient well 4187 were detected in the laboratory blank, suspected as an aldol condensation product, or estimated at a

concentration less than the detection limit Methylene chloride, detected during one sampling event, was the only valid VOC detected from 1990 to 1993 Methylene chloride was detected on four other occasions but was present in the laboratory blank, suspected as an aldol condensation product, or both on these occasions Because there have been no subsequent VOC detections, the methylene chloride detection in LHSU well 4187 was not considered to indicate contamination

In upgradient well 70893, only acetone was detected during one 1993 sampling event However, the laboratory reported this analyte as a suspected aldol condensation product Therefore, this detection does not represent actual groundwater contamination in well 70893 The lack of verification of acetone in subsequent samples also indicates that VOC contamination is not present at well 70893

In well 0886, located near the East Landfill Pond, nine of the ten VOC detections were either also detected in the laboratory blank, reported as an estimated concentration below the detection limit, or suspected as an aldol condensation product Methylene chloride was detected at 16 µg/L once in 1992 However, this detection was not verified in subsequent sampling events This one sample does not provide evidence of VOC contamination at well 0886 In upgradient well 0986, acetone and methylene chloride were detected at 24 and 9 µg/L, respectively, in one sampling event in 1992 However, these detections were not verified in subsequent sampling events

Radionuclides

The highest average dissolved uranium-238 activities occurred in groundwater from upgradient wells 70293 and 70593 (3 2 and 2 1 pCi/L) (Figure 4-44) The average dissolved uranium-238 activity in downgradient groundwater from well 4187 was 1 1 piC/L These values are within the range of background values (up to 11 00 pCi/L) for dissolved uranium-238 in groundwater from weathered claystone (EG&G 1993d)

4 7 4 2 Exceedances of $UTL_{99/99}$ Concentration

Inorganic and radionuclide data from LHSU wells at OU 7 were compared to the $UTL_{99/99}$ concentration for each analyte The list of values that exceed the $UTL_{99/99}$ concentration, by well, are given in Appendix M

Additional analytes identified as PCOCs using the comparison to the $UTL_{99/99}$ concentration include dissolved antimony, arsenic, iron, lead, mercury, strontium-89,90,

vanadium, and uranium-235 and total aluminum, americium-241, arsenic, cesium-137, copper, iron, lead, lithium, manganese, nitrate/nitrite, potassium, silicon, silver, tin, uranium-235, and zinc Table 4-24 lists all analytes exceeding the $UTL_{99/99}$ concentration and the range of the excesses for the UTL value

4.8 Contaminant Distribution Summary

A comprehensive list of PCOCs for all of the media described above is presented in Table 4-28

4 8 1 Surface Soils

Statistical evaluation of surface soils at IHSS 203 and IHSS 114 revealed that calcium, copper, and radium-226 (IHSS 203 only) occurred at elevated concentrations or activities relative to background Two PCBs were detected at low concentrations in approximately 20 percent of the soil samples from IHSS 203 At IHSS 203, americium-241 and uranium-235 activities exceeded the $UTL_{99/99}$ and at IHSS 114 strontium-89,90 and gross beta exceeded the $UTL_{99/99}$ in some soil samples

Three PCOCs (calcium, strontium, and radium-226) were identified in soils from the East Landfill Pond area based on results of the inferential statistical tests Nine metals, two radionuclides, and nitrate/nitrite were also identified as PCOCs based on $UTL_{99/99}$ comparisons These exceedances were generally in the range of 2 to 3 times the maximum background concentration The americium-241 activity of one sample was 27 times higher than the maximum background activity Radionuclides exceeded background activities only in the 0- to 2-inch soil samples

4 8 2 Subsurface Geologic Materials

Seven radionuclides (americium-241, cesium-137, gross beta, radium-226, radium-228, uranium-235, and uranium-238) were identified as PCOCs in surficial deposits upgradient of OU 7 However, only radium-226 was identified as a PCOC in upgradient bedrock material, indicating that significant downward transport of these radionuclides has not occurred At downgradient borehole 70993 (located near the north groundwater intercept system discharge outfall), cesium-137 and uranium-238 were identified as PCOCs in surficial deposits Uranium-238 was also identified as a PCOC in north groundwater intercept system discharge water (Section 4 6) These data suggest that the north groundwater intercept system discharge water may be a source of uranium-238 to

geologic materials downgradient of the landfill However, the ultimate source of uranium-238 may be located upgradient of the landfill, as indicated by the upgradient borehole data Tritium was identified as a PCOC in downgradient borehole 71093 (located near the south groundwater intercept system discharge) and also in south groundwater intercept system discharge surface water (Section 4 6) Five VOCs and six VOCs were also detected in geologic materials and identified as PCOCs

4 8 3 Sediments

Statistical comparisons of East Landfill Pond sediments to background stream sediments identified metal, radionuclide, and inorganic analytes present at concentrations elevated with respect to background concentrations Two VOCs and 15 SVOCs were detected in the East Landfill Pond sediments and are considered PCOCs Because the number of sediment samples collected from the pond was small (3 samples), additional sampling and analysis may be required to better characterize pond sediments

Fifteen SVOCs were detected in East Landfill Pond sediment at SED70093 near the leachate seep Fourteen of the detected concentration values were qualified as estimated concentrations below the detection limit However, the occurrence of these in sediments close to a potential source of SVOCs indicates that SVOC contamination of East Landfill Pond sediments has probably occurred

Cesium-137 was the only radionuclide found at activity levels higher than background activities No single sediment sample had measured radionuclide activities higher than the $UTL_{99/99}$ value The highest radionuclide activities were present in the sample collected from the west end of pond, closest to the leachate seep These data indicate that radionuclide contamination in East Landfill Pond sediments is not extensive

4 8 4 Surface Water

Surface waters at OU 7 are not contaminated by VOCs and SVOCs, except at the leachate seep BTEX, chlorinated hydrocarbons, and SVOCs were consistently detected only in water samples from the leachate seep

Tritium activities were elevated relative to background activities in the leachate seep, the East Landfill Pond, and the southern groundwater intercept discharge Americium-241 was elevated above background in the East Landfill Pond, southern groundwater intercept discharge, and the northern groundwater intercept discharge Uranium -235 and uranium-

238 were both elevated relative to background at the pond and the northern discharge point, whereas only uranium-238 was elevated above background at the southern discharge point As may be expected, water in the East Landfill Pond reflects the quality of the water from the leachate seep and from the groundwater intercept system except that seep water contains VOCs and SVOCs more often

4 8 5 Groundwater

Groundwater in the UHSU at OU 7 contains higher-than-background concentrations of metals, radionuclides, organic parameters, and nitrates Sources of radionuclide and chlorinated hydrocarbon contamination to UHSU groundwater may be located upgradient of the landfill and within IHSS 166 1 (within OU 6) The landfill appears to be the main source of metals and BTEX compounds to UHSU groundwater Additional data are necessary to characterize the downgradient extent of UHSU groundwater contamination, especially in areas north and south of the East Landfill Pond embankment and No Name Gulch

PCOCs were identified in groundwater from the LHSU However, in LHSU groundwater collected downgradient of the landfill, radionuclide and VOC concentrations were not significantly higher than in LHSU groundwater from background wells

Table 4-1
Data Aggregation at OU 7 to Support Site Characterization and Risk Assessment

Media	OU 7 Data Set	Background Data Set	Objective
Surface Soil	IHSS 203 (0 to 2 inches)	OU 1 and OU 2 background data	nature and extent remedial investigation and design potential contaminant of concern
	IHSS 203 (0 to 10 inches)	OU 1 and OU 2 background data	nature and extent remedial investigation and design, potential contaminant of concern
	IHSS 114 (0 to 2 inches)	OU 1 and OU 2 background data	potential contaminant of concern
	East Landfill Pond (0 to 2 inches)	OU 1 and OU 2 background data	nature and extent, potential contaminant of concern
	East Landfill Pond (0 to 10 inches)	OU 1 and OU 2 background data	nature and extent, potential contaminant of concern
Subsurface Geologic Materials (i e , borehole samples)	Samples downgradient of landfill 70993, by geologic unit	Sitewide borehole data for each geologic unit	nature and extent potential contaminant of concern
	Samples downgradient of landfill, 71093, by geologic unit	Sitewide borehole data for each geologic unit	nature and extent, potential contaminant of concern
	Combined upgradient boreholes 70493 and 70593 by geologic unit	Sitewide borehole data for each geologic unit	nature and extent evaluation of upgradient contamination impacting OU 7
Pond Sediments	East Landfill Pond sediments (SED70093, SED70193 and SED70293)	Sitewide background data for stream sediments	potential contaminant of concern
Surface Water	(SW098) East Landfill Pond	Sitewide background data for surface water	nature and extent, fate and transport remedial investigation and design, potential contaminant of concern
	(SW099) North intercept system discharge	Sitewide surface water data	nature and extent, remedial investigation and design potential contaminant of concern
	(SW100) South intercept system discharge	Sitewide surface water data	nature and extent, remedial investigation and design potential contaminant of concern
Leachate Seep	SW097 leachate seep	Sitewide background data for seep waters/regional information	nature and extent, potential contaminant of concern
Groundwater	All wells in UHSU	Sitewide background data for UHSU	OU-wide potential contaminant of concern identification
	Landfill wells in UHSU	Sitewide background data for UHSU	nature and extent
	Downgradient wells in UHSU	Sitewide background data for UHSU	nature and extent fate and transport
	Downgradient wells in LHSU	Sitewide background data for LHSU	nature and extent, fate and transport potential contaminant of concern
	Upgradient wells in LHSU	Sitewide background data for LHSU	nature and extent

Definitions

IHSS	individual hazardous substance site
LHSU	lower hydrostratigraphic unit
OU	operable unit
UHSU	upper hydrostratigraphic unit

Table 4-2
Volume Estimates of Previous Landfill Operations

Year	Volume of Compacted Trash (cubic yards)	Volume of Compacted Trash & Fill[1] (cubic yards)	Cumulative Compacted Trash & Fill to Date (cubic yards)	Estimated Volume of Trash & Fill by Photo (cubic yards)	Weight of Trash & Fill[2] (pounds)	Weight of Trash & Fill (kilograms)
1968	10 178	13,571	13 571		13 571 000	6 155 806
1969	10 178	13,571	27 142		13 571 000	6,155 806
1970	10 178	13,571	40 713		13,571 000	6,155,806
1971	10 178	13,571	54 284		13,571 000	6,155 806
1972	10,178	13,571	67,855		13,571,000	6,155,806
1973	10,178	13,571	81,426		13,571 000	6 155,806
1974	10 178	13 571	94,997	95,000	13 571 000	6 155 806
1975	10,000	13 333	108 330		13,333 000	6,047 849
1976	10 000	13 333	121 663		13,333,000	6,047,849
1977	10,000	13,333	134 996		13 333,000	6,047,849
1978	10 000	13 333	148 329		13 333,000	6 047 849
1979	10 000	13,333	161,662		13,333,000	6,047,849
1980	10 000	13 333	174 995		13,333 000	6,047,849
1981	10 000	13 333	188,328		13 333 000	6,047 849
1982	10 000	13,333	201 661		13,333 000	6,047,849
1983	10 000	13,333	214 994		13,333,000	6,047,849
1984	10 000	13,333	228 327		13,333,000	6 047,849
1985	10 000	13,333	241 660		13 333 000	6 047 849
1986	10 000	13,333	254 993	255,000	13 333,000	6 047,849
1987	28 125	37,500	292,493		37,500,000	17,010,000
1988	28,125	37,500	329 993	330,000	37 500 000	17 010 000
1989	28 031	37 375	367,368		37,375,000	16 953,300
1990	28 125	37,500	404 868		37,500,000	17,010,000
1991	28 125	37 500	442 368		37,500,000	17,010,000
1992	11 964	15 952	458 320		15,952,000	7,235,827
1993	11,964	15 952	474 272		15 952,000	7,235 827
TOTAL	355,705	474,272			474,272 000	215 129 779

[1] Based on a trash to fill ratio of 3 to 1

[2] Based on a compacted trash density of 1000 pounds per cubic yard (Brunner and Keller 1972)

Table 4-3
Volume Estimates of Future Landfill Operations

Year	Volume of Compacted Trash (cubic yards)	Volume of Compacted Trash & Fill[1] (cubic yards)	Cumulative Compacted Trash & Fill to Date (cubic yards)	Weight of Trash & Fill[2] (pounds)	Weight of Trash & Fill (10^6 Kilograms)
1994	11,964	15,952	490 224	15,952 0	7,235,827
1995	11,964	15 952	506 176	15 952,0	7 235,827
1996	11 964	15 952	522,128	15,952,0	7,235,827
1997	11 964	15 952	538 080	15,952,0	7,235 827
TOTAL	47 856	63,808			28,943,308

[1] Based on a trash to fill ratio of 3 to 1

[2] Based on a compacted trash density of 1000 pounds per cubic yard (Brunner and Keller 1972)

Table 4-4
Waste Streams Disposed in the Landfill from 1989 to Present (WSRIC)[1]

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
025/026	025/026-1-4	Scrap or Reject Drums	Empty Containers	Nonhazardous	insufficient data
111	111-1-4	Empty Containers	Empty Containers	Nonhazardous	100/year
111	111-1-5	Empty Ink Cans	Empty Containers	Nonhazardous	120/year
111	111-1-6	Empty Solvent Containers	Empty Containers	Nonhazardous	12/year
111	111-1-12	Aerosol Cans	Empty Containers	Nonhazardous	16/year
111	111-1-13	Machine Cleaning Waste	Solid	Nonhazardous	insufficient data
112	112-1-1[3]	Wire	Metal	Nonhazardous	insufficient data
112	112-1-2	Dry Combustibles	Solid	Nonhazardous	< 10 gal/year
119	119-1-3	Waste Parts	Solid	Nonhazardous	insufficient data
119	119-1-4	Empty Containers	Empty Containers	Nonhazardous	insufficient data
119	119-1-8	Empty Aerosol Containers	Empty Containers	Nonhazardous	insufficient data
123	123-16-4	Alkaline Batteries	Solid	Nonhazardous	insufficient data
124	124-1-5	Rubber Gloves	Solid	Nonhazardous	1 pair/mo
125	125-1-3	Kimwipes® Cont with Presolve/Ethanol	Solid	Nonhazardous	10 gal/year
125	125-1-4	Wipes & Rags w/Oil and/or Ethanol	Solid	Nonhazardous	60 gal/year
125	125-2-5	Used Cotton Gloves	Solid	Nonhazardous	< 1 gal/year
125	125-3-7	Broken Glass	Solid	Nonhazardous	insufficient data
125	125-3-9	Uncontaminated Kimwipes®	Solid	Nonhazardous	< 10 gal/year
125	125-6-2	Uncontaminated Kimwipes®	Solid	Nonhazardous	260 gal/year
130	130-6-2	Dry Combustibles	Solid	Nonhazardous	insufficient data
218	218-1-1	Dry Combustibles	Solid	Nonhazardous	10 rags/year
333	333-3-2[4]	Empty Paint Cans	Empty Containers	Nonhazardous	100 cans/year
333	333-3-4[4]	Spent Paint Booth Filters	Solid	Unknown	1900 panels/year
334	334-1-9	Greasy Kimwipes®	Solid	Nonhazardous	variable
334	334-1-11	Contact Cleaner Containers	Empty Containers	Nonhazardous	24 cans/year
334	334-1-12	Used Light Bulbs	Solid	Nonhazardous	variable
334	334-2-2[3]	Metal Cuttings	Metal	Nonhazardous	variable
334	334-2-7	Rags and Kimwipes®	Solid	Nonhazardous	550 gal/year
334	334-3-3	Rags and Kimwipes®	Solid	Nonhazardous	insufficient data
334	334-4-5	Wood Scraps and Sawdust	Solid	Nonhazardous	24 cu yds/year
334	334-4-6	Plastic Shavings and Scraps	Solid	Nonhazardous	60 gal/year
334	334-4-9	Glass Scrap	Solid	Nonhazardous	1 cu yd/year
334	334-4-10	Kimwipes® and Rags	Solid	Nonhazardous	6 gal/year
334	334-5-7	Freon Cans	Solid	Nonhazardous	60 cans/year
334	334-5-10	Waste Glue Cans	Solid	Nonhazardous	24 cans/year
334	334-5-13	Rags and Brushes	Solid	Nonhazardous	insufficient data
334	334-5-14	Rags and Kimwipes®	Solid	Nonhazardous	insufficient data
371	371-9-4	Used Kimwipes®	Solid	Nonhazardous	12 cases/year
371	371-12-2[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
371	371-13-2[4]	Paint Rags Brushes, and Rollers	Solid	Nonhazardous	variable
371	371-13-4[4]	Empty Paint Cans	Empty Containers	Nonhazardous	variable

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
371	371-15-1	Expired Leaded Glovebox Gloves	Solid	Nonhazardous	insufficient data
439	439-2-1[3]	Metal Chips	Metal	Nonhazardous	1/2 ton/mo
439	439-3-4	Kimwipes® with Coolant Sludge	Solid	Nonhazardous	insufficient data
442	442-1-2	Used Kimwipes® and Rags	Solid	Nonhazardous	15 gal/year
442	442-1-4	Rejected Respirator Cartridges	Solid	Nonhazardous	900 cartridges/year
442	442-1-7	Defective HEPA Filters	Solid	Nonhazardous	500 filters/year
443	443-1-13	Contaminated Rags/Wipes	Solid	Nonhazardous	55 gal every 2 years
444	444-4-7	Silica	Solid	Nonhazardous	250 lbs/year
444	444-4-14	Air Filters	Solid	Nonhazardous	8 filters/year
444	444-9-2[3]	Metal Scraps	Metal	Nonhazardous	50 dumpsters/year
444	444-9-7[3]	Metal Chips w/Used Cutting Oil	Metal	Nonhazardous	insufficient data
444	444-22-1	Shredded Papers	Solid	Nonhazardous	15 lbs/year
444	444-22-4	Wipes with Oil Residue	Solid	Nonhazardous	5 gal/year
444	444-25-8	Sanitary Solid Waste	Solid	Nonhazardous	insufficient data
444	444-26-4	Furnace Filter Pads	Solid	Nonhazardous	800 gal/year
444	444-29-16	Light Metal	Metal	Nonhazardous	insufficient data
444	444-29-26	Dry Combustibles	Solid	Nonhazardous	insufficient data
444	444-31-6	Non-RCA Plenum Prefilters	Solid	Nonhazardous	variable
445	445-1-1[3]	Metal Fines	Metal	Nonhazardous	100 lbs/wk
445	445-1-2[3]	Scrap Material	Metal	Nonhazardous	100 lbs/wk
445	445-1-3	Combustible Waste	Solid	Nonhazardous	25 lbs/wk
447	447-8-5	Furnace Filters (uncontaminated)	Solid	Nonhazardous	insufficient data
448	448-1-5	Reject Metal Drums	Empty Containers	Nonhazardous	variable
449	449-1-4	Empty Containers	Empty Containers	Nonhazardous	660 lbs/year
449	449-1-8[4]	Rollers, Tape Brushes Paper Containers	Solid	Nonhazardous	100 lbs/year
454	454-1-3	Sump Sludge	Solid	Nonhazardous	200 lbs/year
460	460-6-2	Wipes	Solid	Nonhazardous	insufficient data
460	460-6-9[3]	Grinding Wheels	Metal	Nonhazardous	insufficient data
460	460-13-14	Used Coolant Filters	Solid	Nonhazardous	variable
460	46-13-15	Used Exhaust Filters	Solid	Nonhazardous	variable
460	460-21-15	Used Compressor Filters	Solid	Nonhazardous	insufficient data
460	460-21-25	Ful-Flo Filters	Solid	Nonhazardous	10 filters/year
460	460-21-26	Used Cuno Filters	Solid	Nonhazardous	100 filters/year
460	460-29-6	Sanitary Trash/Discarded Containers	Solid	Nonhazardous	insufficient data
460	460-31-22	Fluorescent Ballast	Metal	Nonhazardous	Insufficient data
460	460-32-2	Combustibles	Solid	Nonhazardous	insufficient data
460	460-32-3	Scrap PVC Pipe	Solid	Nonhazardous	insufficient data
460	460-32-9	Rags and Wipes	Solid	Nonhazardous	insufficient data
460	460-33-3	Construction Scrap	Solid	Nonhazardous	insufficient data
460	460-34-1[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
460	460-34-2	Scrap Neoprene Rubber	Solid	Nonhazardous	insufficient data
460	460-34-3	Scrap Fiberglass	Solid	Nonhazardous	insufficient data

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
462	462-1-4	Sludge	Solid	Nonhazardous	30 gal/year varies
549	549-1-10[3]	Scrap Metal	Metal	Nonhazardous	insufficient data
551	551-3-10	Uncontaminated Solids	Solid	Nonhazardous	insufficient data
551	551-3-14[3]	Scrap Stainless Steel	Metal	Nonhazardous	insufficient data
553	553-1-2[3]	Scrap Metal	Metal	Nonhazardous	< 50 gal/year
553	553-2-4[3]	Copper Wire Waste	Metal	Nonhazardous	< 1 gal/year
553	553-3-2[3]	Scrap Metal	Metal	Nonhazardous	400 gal/year
559	559-26-10	Roll-a-Mat Filters	Solid	Nonhazardous	insufficient data
563	563-1-2	Sump Sludge	Solid	Nonhazardous	insufficient data
563	563-1-4	Dry Combustibles	Solid	Nonhazardous	insufficient data
563	563-1-8	Wet Combustibles	Solid	Nonhazardous	insufficient data
566	566-1-14	Sanitary Waste	Solid	Nonhazardous	insufficient data
662	662-2-3	Used Kimwipes® (with Oil)	Solid	Nonhazardous	variable
662	662-2-5	Used Rags (with Oil)	Solid	Nonhazardous	variable
662	662-2-7	Used Syringes	Solid	Nonhazardous	36/year
662	662-2-9	Used Pipettes	Solid	Nonhazardous	36/year
662	662-2-11	Used Sample Bottles	Empty Containers	Nonhazardous	36 bottles/year
662	662-3-2	Oil-Soaked Rags	Solid	Nonhazardous	insufficient data
662	662-3-3	Oil-Soaked Floor Dri	Solid	Nonhazardous	insufficient data
662	662-6-8	Plastic	Solid	Nonhazardous	variable
662	662-7-1	Sanitary Waste	Solid	Nonhazardous	variable
662	662-7-2	Dry Combustible	Solid	Nonhazardous	variable
662	662-7-3	Plastic	Solid	Nonhazardous	variable
662	662-7-4	Glass	Solid	Nonhazardous	variable
662	662-7-5	Light Metal	Metal	Nonhazardous	variable
663	663-1-3	Miscellaneous Scrap	Solid	Nonhazardous	insufficient data
663	663-1-4	Drywall Scraps	Solid	Nonhazardous	insufficient data
663	663-1-5	Kimwipes®	Solid	Nonhazardous	insufficient data
663	663-1-8	Scrap Lumber	Solid	Nonhazardous	insufficient data
663	663-1-9	Plastics	Solid	Nonhazardous	insufficient data
663	663-1-11	General Trash and Scrap Lumber	Solid	Nonhazardous	insufficient data
663	663-1-12	Empty Adhesive Cans	Empty Containers	Nonhazardous	insufficient data
664	664-1-3[4]	Empty Containers	Empty Containers	Nonhazardous	8-9 gal/year
664	664-1-10	Empty Non-Spray Paint Containers	Empty Containers	Nonhazardous	100 gal/year
664	664-1-12	Incandescent Bulbs & Non-PCB Ballast	Solid	Nonhazardous	30 bulbs/year
701	701-2-4	Empty Bags	Solid	Nonhazardous	780 bags/year
701	701-2-5	HEPA Filters	Solid	Nonhazardous	variable
701	701-4-3[3]	Metals	Metal	Nonhazardous	insufficient data
701	701-5-5[3]	Metals	Metal	Nonhazardous	insufficient data
702	702-1-7	Kimwipes®	Solid	Nonhazardous	insufficient data
703	703-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
707	707-29-3	Bag Filters	Solid	Nonhazardous	insufficient data
707	707-29-6	Roll-a-mat Filters	Solid	Nonhazardous	a roll/year
708	708-1-1	Used HEPA Filters	Solid	Nonhazardous	2 every 20 years

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
708	708-2-2	Brine Leakage	Solid	Nonhazardous	105 gal/year
708	708-3-10	Kimwipes® Contaminated with Oil	Solid	Nonhazardous	insufficient data
712	712-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
713	713-1-1	Kimwipes®	Solid	Nonhazardous	insufficient data
715	715-1-3	Kimwipes® and Rags	Solid	Nonhazardous	10 gal/year
715	715-1-15	Oil Dri	Solid	Nonhazardous	insufficient data
727	727-1-7	Contaminated Wipes	Solid	Nonhazardous	< 1 gal/year
750	750-1-2	Rags/Kimwipes®	Solid	Nonhazardous	15 lbs/year
771	771-22-4	Chemical Containers	Empty Containers	Nonhazardous	insufficient data
771	771-30-7	Dry Cell Batteries	Solid	Nonhazardous	insufficient data
774	774-2-11	Nonline Dry Combustibles	Solid	Nonhazardous	1560 bags/year
774	774-3-11	Dry Combustibles	Solid	Nonhazardous	1560 bags/year
774	774-5-8	Sanitary Trash	Solid	Nonhazardous	100 drums/year
776	776-7-9	Alkaline Batteries	Solid	Nonhazardous	insufficient data
776	776-8-2	Wood and Plastic Chips	Solid	Nonhazardous	4000 lbs/year
778	778-3-2[4]	Empty Paint Cans	Empty Containers	Nonhazardous	variable
778	778-3-5	General Waste	Solid	Nonhazardous	7500 gal/year
778	778-3-8[4]	Dry Brushes and Rollers	Solid	Nonhazardous	variable
778	778-4-1[3]	Metal Waste	Metal	Nonhazardous	60 gal/year
779	779-35-1	Dry Combustibles	Solid	Nonhazardous	insufficient data
779	779-35-2	Wet Combustibles	Solid	Nonhazardous	insufficient data
779	779-35-3	Light Metal	Metal	Nonhazardous	insufficient data
779	779-35-5	Plastic	Solid	Nonhazardous	insufficient data
782	782-1-5	Used Furnace Filters	Solid	Nonhazardous	insufficient data
783	783-1-4	Kimwipes® with Lubrication Grease	Solid	Nonhazardous	10-12 wipes/year
783	783-1-5	Dry Kimwipes®	Solid	Nonhazardous	insufficient data
790	790-1-1	Dry Combustibles	Solid	Nonhazardous	10 gal/wk
865	865-9-5	Roughing Filters	Solid	Nonhazardous	64 filters/wk
865	865-9-11	Wipes and Rags	Solid	Nonhazardous	insufficient data
865	865-9-14	Air Filters	Solid	Nonhazardous	insufficient data
865	865-11-3	Sanitary Combustible Waste	Solid	Nonhazardous	insufficient data
881	881-49-1	Waste Scrap Paper	Solid	Nonhazardous	400 cu ft/year
883	883-11-6	Wipes and Rags	Solid	Nonhazardous	variable
883	883-11-14	Prefilters-Air Comp /Intake/HVAC	Solid	Nonhazardous	variable
903A	903A-1-9	Combustibles	Solid	Nonhazardous	insufficient data
910	910-4-1	Sanitary Waste	Solid	Nonhazardous	insufficient data
910	910-4-3	Glass	Solid	Nonhazardous	insufficient data
910	910-4-6	Dry Combustibles	Solid	Nonhazardous	insufficient data
910	910-4-8	Light Metal	Metal	Nonhazardous	insufficient data
910	910-4-11	Plastic	Solid	Nonhazardous	insufficient data
965	965-1-4	Floor Sweepings	Solid	Nonhazardous	insufficient data
980	980-2-8	Used Drop Cloths & Plastic Sheeting	Solid	Nonhazardous	insufficient data
989	989-1-10	Used Kimwipes®	Solid	Nonhazardous	< 1 lb/year
991	991-1-11[3]	Uncontaminated Scrap Metal	Metal	Nonhazardous	variable

Building	Process Number[2]	Waste Description	Waste Type	Hazardous/ Nonhazardous	Generation Rate
991	991-3-9	Mounting Compound	Solid	Nonhazardous	insufficient data
991	991-5-2	Furnace Filters	Solid	Nonhazardous	30 filters/year
991	991-6-2	Glass	Solid	Nonhazardous	variable
991	991-6-4	Wood	Solid	Nonhazardous	variable
991	991-6-8	Wire and Switches	Metal	Nonhazardous	variable
991	991-6-12	Belts	Solid	Nonhazardous	variable
991	991-6-17	Combustibles	Solid	Unknown	variable
991	991-6-22	Insulation	Solid	Nonhazardous	insufficient data
T707S	T707S-1-7	Floor Dri	Solid	Nonhazardous	variable
T900D	T900D-1-4	Empty Chemical Bags	Solid	Nonhazardous	23 bags/mo
T900D	T900D-1-5	Personal Protective Equipment	Solid	Nonhazardous	2 bags/mo
T900D	T900D-1-12	Air Filters	Solid	Nonhazardous	1 filter/mo

[1] This information is obtained from the Waste Stream Residue Identification and Characterization (WSRIC) Program which was developed in 1989 Therefore, this list of nonhazardous waste streams disposed in the Rocky Flats landfill covers the period from 1989 to the present.

[2] The process numbers, which were assigned by the WSRIC Program include the building number, the process number, and the output number

[3] According to the WSRIC program, these wastes are either placed in a metal dumpster and taken to the Property Utilization and Disposal (PU&D) yard as scrap or placed in the landfill

[4] As of June 1993, these wastes are no longer being sent to the landfill

Definitions

cu ft cubic feet
cu yd cubic yard
gal gallon
lb pound
mo month
wk week

Table 4-5
Results of Methane Survey

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in Hg)	Total Gas (ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
MET00293	3 28	< 10	0	330	75	255	NP-EQUIP
MET00393	3 28	< 10	0	510	210	300	NP-EQUIP
	8 20	< 10	0	5,000	375	4,625	NP-EQUIP
	13 12	< 10	0	≥67,600[4]	≥0	67,600	54,000
	16 73	< 10	0	95,000	1,260	93,740	NP-EQUIP
MET00493	3 28	< 10	2	1,900	65	1,835	NP-EQUIP
	8 20	< 10	8	120,000	23,000	97,000	72,000
	13 12	< 10	11 5	100,000	24,000	76,000	70,000
	18 04	< 10	13	1,200	50	1,150	NP-EQUIP
	22 96	< 10	13 5	140	26	114	NP-EQUIP
MET00593	3 28	< 10	2	700	90	610	NP-EQUIP
	8 2	< 10	5	150,000	31,000	119,000	6,800
	13 12	< 10	0	270,000	57,000	213,000	111,000
	18 04	< 10	12	640	18	622	NP-EQUIP
	22 96	< 10	12 5	6,000	2,000	4,000	6,000
MET00693	3 28	< 10	10	200,000	41,000	159,000	113,000
	8 20	< 10	12	360,000	58,000	302,000	166,000
	13 12	< 10	11 5	380,000	74,000	306,000	149,000
	18 04	< 10	12	330,000	48,000	282,000	164,000
	22 96	< 10	14	340	6	334	NP-EQUIP
MET00793	3 28	< 10	12	270,000	45,000	225,000	102,000
	8 20	< 10	12	70,000	29,000	41,000	34,000
	13 12	< 10	12	390,000	73,000	317,000	156,000
	18 04	< 10	13	≥17,000[5]	≥0	17,000	16,000
	22 14	< 10	13 5	9,600	220	9,380	NP-EQUIP
MET00893	3 28	< 10	12 5	65 000	27,000	38,000	16,000
	8 20	< 10	0	3,700	49	3,651	5,000
	13 12	< 10	13	180,000	37 000	143,000	60,000
	18 04	25/< 10/< 10/< 10/< 10	13 5	100,000	26,000	74,000	37,000
	22 96	< 10	13	68	6	62	NP-EQUIP
MET00993	3 28	21/ 21/ 21/ 21/ 21	3	360,000	85,000	275,000	191,000
	8 20	< 10	2	≥25 000[5]	≥0	25,000	22,000
	13 12	20/ 20/ 20/ 20/ 20	3	140,000	41,000	99,000	64,000
	18 04	< 10	12	260,000	59,000	201,000	108,000
MET01093	3 28	< 10	0	520,000	81,000	439,000	218,000
	8 20	< 10	0	380,000	35,000	345,000	219,000
	13 12	< 10	13 5	65,000	27,000	38,000	29,000
	18 04	< 10	13	200,000	33,000	167,000	88,000
	22 96	< 10	13 5	120,000	24,000	96,000	65,000
	27 88	< 10	11 5	110	0	110	NP-EQUIP

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in Hg)	Total Gas (ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET01193	3 28	< 10	0	560,000	70,000	490,000	173,000
	8 20	< 10	13	180,000	41,000	139,000	54,000
	13 12	< 10	0	570 000	101,000	469,000	160,000
	18 04	30/ 31/ 31/ 32/ 32	12 5	200,000	46 000	154,000	55,000
MET01293	3 28	< 10	14 5	54	2	52	NP-EQUIP
	8 20	< 10	14 5	100	0	100	NP-EQUIP
	13 12	< 10	10	400,000	32,000	368,000	155,000
	18 04	< 10	14 5	50	0	50	NP-EQUIP
MET01393	3 28	< 10	3	510,000	74,000	436,000	173,000
	8 20	< 10	8	480,000	54,000	426,000	181,000
	13 12	< 10	5	520,000	72,000	448,000	188,000
	18 04	< 10/< 10/ 20/ 20/ 20	14 5	880	12	868	NP-EQUIP
	22 96	< 10	6 5	470,000	75,000	395,000	189,000
	27 88	19/ 19/ 19/ 19/ 19	13 5	570	58	512	NP-EQUIP
	32 80	< 10	13	52	0	52	NP-EQUIP
	37 72	< 10	13	540	22	518	NP-EQUIP
MET01493	3 28	< 10	14	22	0	22	NP-EQUIP
	8 20	20/ 20/ 20/ 20/ 20	6	520,000	118,000	402,000	133 000
	13 12	19/ 19/ 19/ 19/ 19	5	480,000	107,000	373,000	160,000
	18 04	< 10	5	540,000	118,000	422,000	161,000
	22 96	< 10/ 20/ 20/ 20/ 19	7 5	440,000	49,000	391,000	168,000
	27 88	20/ 20/ 20/ 20/ 20	6	510,000	108,000	402,000	175 000
	32 80	19/ 20/ 20/ 20/ 20	7 25	450 000	75,000	375,000	190 000
	37 72	23/ 23/ 23/ 23/ 23	6	470,000	102,000	368,000	170 000
	42 64	24/ 24/ 24/ 24/ 24	13 5	200,000	43,000	157,000	62 000
MET01593	3 28	< 10	0	370	4	366	NP-EQUIP
	8 20	< 10	0	640,000	147,000	493,000	114 000
	13 12	< 10	0	520,000	48,000	472,000	114 000
	18 04	< 10	2	430,000	30,000	400,000	202 000
	22 96	< 10	1	470,000	45,000	425,000	213 000
	27 88	< 10	2 75	470,000	82,000	388,000	199 000
	32 80	31/ 35/ 31/ 28/ 25	12 5	310,000	79,000	231,000	59 000
MET01693	NP-ACC	NP-ACC	NP ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
MET01793	NP-REF	NP-REF	NP REF	NP-REF	NP-REF	NP-REF	NP-REF
MET01893	3 28	22/ 22/ 22/ 22/ 22	0	140	24	116	NP EQUIP
	8 20	< 10	12 75	250	98	152	NP-EQUIP
	13 12	< 10	12 50	140	0	140	NP-EQUIP
MET01993	3 28	< 10	11 75	140,000	35 000	105,000	52 000
	8 20	< 10	7 5	105	3	102	NP-EQUIP
	13 10	< 10	12 0	38	0	38	NP-EQUIP
MET02093	3 28	< 10	10 0	92	0	92	NP-EQUIP
	8 20	25/ 25/ 25/ 25/ 25	7 0	470,000	112,000	358,000	86 000
	13 10	19/ 19/ 19/ 19/ 19	0	570,000	152,000	418,000	103 000
	18 04	19/ 19/ 19/ 19/ 19	0	600,000	122,000	478,000	78 000
	22 96	19/ 19/ 19/ 19/ 19	8	100	0	100	NP-EQUIP
	27 88	< 10	5 5	590,000	85,000	505,000	132 000
	32 80	< 10	11	120	26	94	NP-EQUIP

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in Hg)	Total Gas (ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
MET02293	3 28	< 10	1	360,000	40,000	320,000	135,000
	8 20	< 10	0	480,000	95,000	385,000	165,000
	13 12	< 10	0	370,000	15,000	355,000	169,000
	18 04	37/ 44/ 44/ 44/ 44	12	230,000	7,000	223,000	125,000
	22 96	< 10	5	430,000	74,000	356,000	149,000
	27 88	< 10	4 5	470,000	114,000	356,000	145,000
	32 80	< 10	6	440,000	69,000	371,000	160,000
	37 72	< 10	6 5	490,000	95,000	395,000	128,000
	41 00	< 10	6	410,000	10,000	400,000	156,000
	42 64	< 10	12 5	230,000	61,000	169,000	75,000
MET02393	3 28	< 10	5	2,300	46	2,254	4,000
	8 20	< 10	2 5	390,000	43,000	347,000	106,000
	13 12	< 10	14	130,000	23,000	107,000	44,000
	18 04	< 10	13	340,000	54,000	286,000	111,000
	22 96	< 10	12 5	360,000	84,000	276,000	108,000
	27 88	< 10	13 75	230,000	2,000	228,000	94,000
MET02493	3 28	< 10	4	280	2	278	NP-EQUIP
	8 20	< 10	3 5	430,000	76,000	354,000	162,000
	13 12	< 10	6	480,000	67,000	413,000	171,000
	17 71	--	14 5	1,400	80	1,320	NP-EQUIP
MET02593	3 28	< 10	14 5	2	0	2	NP-EQUIP
	8 20	< 10	1	140,000	1,000	139,000	76,000
	13 12	< 10	13 75	38	4	34	NP-EQUIP
MET02693	3 28	< 10	13	≥18,000[5]	≥0	18,000	23,000
	8 20	< 10	12	≥9,000[5]	≥0	9,000	12,000
	13 12	< 10	12	130,000	26,000	104,000	52 000
	18 04	< 10	12	180,000	62,000	118,000	57 000
	22 96	< 10	13	1,800	12	1,788	4 000
MET02793	3 28	< 10	14	48	0	48	NP-EQUIP
	5 90	< 10	0	26	2	24	NP-EQUIP
MET02893	3 28	< 10	0	160,000	27,000	133,000	147 000
	8 20	< 10	0	≥15,000[5]	≥0	15,000	25 000
	13 12	< 10	13 75	1,100	12	1,088	2,000
	18 04	< 10	11	430,000	98,000	332,000	135 000
	22 96	< 10	13 75	740	6	734	2 000
	27 88	< 10	13 5	580	8	572	2 000
	32 80	< 10	14	350	2	348	NP-EQUIP
MET02993	3 28	< 10	13	290	28	262	NP-EQUIP
	8 20	< 10	13	4,200	80	4,180	2 000
	13 12	< 10	12	320,000	66,000	254,000	90 000
	18 04	< 10	14	68	2	66	NP-EQUIP
	22 96	< 10	14 5	38	0	38	NP-EQUIP

Methane Survey Location[1]	Depth (feet)	Off-Gas Pressure[2] (psi)	Vacuum[3] (in Hg)	Total Gas (ppm)	NMOCs (ppm)	Methane (ppm)	Carbon Dioxide (ppm)
MET03093	3 28	< 10	0	820	76	744	NP-EQUIP
	8 20	< 10	7 5	170 000	56,000	114,000	88 000
	13 12	< 10	12	170,000	40,000	130,000	85,000
	18 04	< 10	11 5	150,000	45 000	105,000	73,000
	22 96	< 10	12 5	1,900	83	1,817	NP-EQUIP
	27 88	< 10	11 5	4,000	120	3,880	NP-EQUIP
	32 80	< 10	12	5,600	60	5,540	NP-EQUIP
MET03193	3 28	< 10	1	1,000	46	954	NP-EQUIP
	8 20	< 10	12 5	900	64	836	NP-EQUIP
	13 12	< 10	8	520,000	77,000	443,000	175,000
	18 04	< 10	12 5	160 000	41,000	119,000	51,000
	22 96	< 10	9	390,000	67,000	323,000	219,000
MET03293	3 28	< 10	0 25	1,200	8	1,192	NP-EQUIP
	8 20	< 10	0	5,200	120	5,080	NP-EQUIP
	13 12	< 10	11	≥14,000[5]	≥0	14,000	10,000
	18 04	< 10	12	350	12	338	NP-EQUIP
MET03393	3 28	< 10/< 10/< 10/ 21/ 20	0	5 600	205	5,395	NP-EQUIP
MET03493	3 28	< 10	8	167,390	390	167,000	77,000
	8 20	< 10	5	380,000	84,000	296,000	173,000
	13 12	< 10	5	291,000	64,000	227 000	136,000
	18 04	< 10	9	194,000	60,000	134,000	110,000
MET03593	3 28	< 10	13 5	55	0	55	NP-EQUIP
	8 20	< 10	1	10 000	0	10 000	10 000
	13 12	< 10	11	250,000	48,000	202,000	150 000
	18 04	< 10	13	120	4	116	NP-EQUIP
	22 47	< 10	13 5	92	3	89	NP-EQUIP
MET03693	3 28	< 10	0	18	0	18	NP-EQUIP
	8 20	< 10	5 5	430,000	70,000	360 000	146,000
	13 12	< 10	6	470,000	51,000	419,000	181,000
	18 04	< 10	6 25	480,000	61,000	419,000	178,000
	22 96	< 10	14 5	760	12	748	NP-EQUIP
MET03793	3 28	< 10	14	5	0	5	NP-EQUIP
	8 20	< 10	7	320,000	48,000	272,000	146,000
	13 12	< 10	14 5	52	0	52	NP-EQUIP
	18 04	< 10	14 5	110	0	110	NP-EQUIP
	22 96	< 10	13 5	52	0	52	NP-EQUIP
MET03893	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each methane survey location is within approximately 10 feet of the corresponding cone penetration test (CPT) location For example, MET02093 is within approximately 10 feet of CPT02093 CPT locations are presented in Figure C-1 (Appendix C)

[2] Prior to collecting a gas sample at a given depth, off-gas pressures were measured and recorded for 5 one-minute intervals When a detectable off-gas pressure was measured for any of the five one-minute intervals, all five measurements are presented

[3] A vacuum pump was used to collect gas samples Prior to collecting a sample, the vacuum created was measured and recorded

[4] Exact concentration of total gas not available due to low batteries in the Digiflam analyzer

[5] Concentration of total gas was between detection limits of the Digiflam analyzer and the GasTech Tank-Techtor The Digiflam analyzer was used to detect concentrations above approximately 10,000 ppm, while the GasTech Tank-Techtor was used to measure concentrations below approximately 10,000 ppm

Definitions

in Hg	inches of mercury
NMOCs	non-methane organic compounds
NP-ACC	not performed-access, methane survey not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond
NP-DUP	not performed-duplication of effort, methane survey not performed at this site because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond and landfill gas measurements were obtained at these locations
NP-EQUIP	not performed-equipment, instruments used were not capable of detecting low concentrations (i e , <2,000 ppm) of carbon dioxide
NP-REF	not performed-refusal, methane survey was not performed at this location due to shallow refusals encountered at this site during the CPT investigation
ppm	parts per million
psi	pounds per square inch
--	due to equipment malfunction, off-gas pressure not measured

Table 4-6
Results of Soil-Gas Sampling at IHSS 114

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
SGS00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
SGS00293	4 92	Qrf	6 550	<0 005	7 308	<0 005	1 940	<0 005	<0 005	0 013	0 013	0 018	1 113
	8 20	Qrf	5 361	<0 005	5 509	0 081	11 387	<0 005	0 005	0 009	0 010	0 015	0 519
SGS00393	4 92	af	3,478 184	<0 005	2 367	0 147	9 337	<0 005	0 007	0 062	0 013	0 005	1 113
	14 76	af	41 727 187	472 302	17 643	3 558	46 857	<0 005	0 024	2 768	0 032	0 035	<0 005
SGS00493	4 92	af	20 814 895	<0 005	0 413	0 810	12 298	<0 005	<0 005	0 034	0 017	0 415	<0 005
	14 17	af	32 835 785	146 250	<0 005	0 505	11 501	<0 005	0 041	0 017	0 008	0 054	<0 005
	18 04	af	49 598 161	625 720	0 260	0 532	80 562	<0 005	0 011	0 023	0 030	0 015	<0 005
SGS00593	4 92	af	4 512 908	<0 005	3 287	0 074	9 678	<0 005	<0 005	0 013	0 013	<0 005	<0 005
	18 24	Qrf	6 6267 820	1,138 456	0 424	0 330	129 070	24 260	0 030	0 016	0 015	<0 005	<0 005
SGS00693	4 92	af	7 2199 208	1 708 544	13 333	7 851	57 560	<0 005	0 282	0 252	0 632	0 543	78 783
	13 94	af	ND-GC	ND-GC	ND-GC	ND GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
SGS00793	4 92	af	3 265 010	<0 005	1 390	<0 005	<0 005	<0 005	0 006	0 005	<0 005	0 010	<0 005
	10 66	af	2 0201 456	<0 005	1 085	0 108	16 283	<0 005	0 005	0 058	0 009	0 015	<0 005
SGS00893	4 92	af	27 679 441	6 309	3 600	0 355	4 099	<0 005	<0 005	0 009	0 016	0 011	0 223
	10 66	af	56 588 440	459 971	4 279	0 732	92 119	<0 005	0 180	0 252	0 891	0 753	<0 005
SGS00993	4 92	af	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
	7 87	af	83 348 084	228 265	14 282	1 000	74 640	<0 005	0 207	0 315	0 957	0 771	<0 005
	10 66	af	42 39 654	<0 005	4 062	0 561	6 950	<0 005	<0 005	0 007	0 020	0 008	<0 005
SGS01093	4 92	af	79 982 274	3,108 529	24 021	5 020	165 394	<0 005	1 288	2 196	3 887	3 277	<0 005
	13 12	af	69 081 420	2 292 397	19 855	7 436	275 107	<0 005	1 110	2 037	3 697	3 211	<0 005
SGS01193	4 92	af	74 848 183	1 975 750	4 490	0 699	67 638	<0 005	0 017	0 119	0 015	0 017	4 525
	9 84	af	84 390 297	1,834 721	13 157	7 454	131 404	148 340	0 054	1 261	0 109	0 127	<0 005
SGS01293	4 92	af	31 209 705	<0 005	5 612	0 763	13 664	<0 005	0 920	1 543	3 373	2 802	0 371
	9 84	af	48 916 812	676 191	6 170	2 389	29 037	<0 005	0 662	1 135	1 805	1 335	<0 005
	15 58	af	23 785 121	40 721	5 173	0 518	24 994	<0 005	0 740	1 166	2 180	1 667	0 223
SGS01393	4 92	af	47 712 570	759 639	6 357	1 679	44 295	<0 005	0 874	1 636	4 740	4 404	<0 005
	19 02	af	84 514 457	1 759 302	80 010	21 866	145 296	<0 005	0 641	2 928	2 819	2 430	<0 005
	23 78	af	75 164 838	1 652 625	32 656	26 007	115 064	<0 005	0 504	3 824	2 284	1 899	<0 005

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
SGS01493	4 92	af	57 335 528	798 352	8 455	0 432	78 455	<0 005	0 090	0 046	0 016	0 010	<0 005
	36 08	af	27 609 744	88 897	0 857	0 271	12 753	<0 005	<0 005	0 006	0 007	<0 005	0 148
SGS01593	4 92	af	56 003 925	322 610	6 884	1 784	79 253	<0 005	0 240	0 948	1 253	0 945	<0 005
	27 88	af	10,7694 860	1 497 485	27 359	4 326	59 098	<0 005	0 297	0 805	1 016	0 744	<0 005
SGS01693	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
SGS01793	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
SGS01893	4 92	af	1 0612 069	145 677	4 662	1 299	6 604	<0 005	0 185	0 346	1 064	0 801	0 223
	7 38	af	143 520	<0 005	2 212	0 389	17 080	<0 005	0 270	0 437	1 159	0 832	0 297
SGS01993	4 92	af	27 654 507	<0 005	22 170	<0 005	6 035	<0 005	0 008	0 103	<0 005	0 010	0 074
	8 20	Qrf	292 490	<0 005	2 350	0 189	20 382	<0 005	0 073	0 095	0 133	0 115	<0 005
SGS02093	4 92	af	73 272 652	730 103	7 049	4 002	43 384	<0 005	0 074	0 099	0 094	0 088	<0 005
	27 88	KaKl(w)	67 085 072	751 897	18 160	0 449	679 966	<0 005	0 131	0 005	5 234	<0 005	<0 005
	32 80	KaKl(w)	61 100	<0 005	7 623	<0 005	<0 005	<0 005	0 005	0 126	<0 005	4 830	0 816
SGS02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
SGS02293	4 92	af	63 551 063	1 027 191	9 525	3 289	34 047	<0 005	0 258	1 041	1 035	0 768	<0 005
	35 26	af	79 584 264	1 924 765	12 155	0 420	43 042	72 890	0 221	0 377	0 962	0 702	<0 005
SGS02393	4 92	af	1 680 200	<0 005	0 491	0 526	27 556	<0 005	<0 005	0 012	0 081	<0 005	0 519
	18 04	af	42 172 256	405 485	4 868	1 547	30 573	<0 005	0 021	0 260	0 011	0 006	<0 005
SGS02493	4 92	af	54 907 939	802 368	17 529	4 557	38 317	<0 005	0 217	0 346	0 759	0 530	<0 005
	10 66	af	67 023 886	3 437 735	18 718	<0 005	43 669	338 700	0 209	0 502	0 910	0 689	<0 005
SGS02593	4 92	af	12,227 512	<0 005	5 013	0 347	10 362	<0 005	0 156	0 245	0 728	0 525	0 742
	8 20	af	61 411 280	580 412	7 742	<0 005	24 254	66 860	0 243	0 250	0 005	0 558	<0 005
SGS02693	4 10	af	24 420	65 382	0 997	0 052	6 43	2 320	<0 005	0 010	0 006	0 006	0 223
SGS02793	4 92	af	946 135	<0 005	4 098	0 168	58 187	<0 005	0 134	0 317	0 673	0 480	0 890
SGS02893	4 92	af	52 083 532	749 024	10 879	<0 005	67 866	1 303 950	0 181	0 030	0 060	1 103	<0 005
	22 14	af	69 280 552	3,431 713	23 442	2 947	164 198	<0 005	0 232	0 338	0 919	0 290	<0 005
SGS02993	4 92	af	7 931 054	52 765	2 853	0 247	14 063	<0 005	0 048	0 067	0 207	0 155	0 074
	9 84	af	38 382 694	247 191	5 633	0 347	126 280	<0 005	0 038	0 071	0 203	0 177	0 148
SGS03093	4 92	af	40 635	<0 005	0 703	<0 005	14 404	<0 005	0 005	0 013	0 011	<0 005	<0 005
	16 40	af	57 490 540	575 824	0 672	5 809	59 382	<0 005	0 008	0 011	0 011	0 016	0 668
SGS03193	4 92	af	93 14 813	<0 005	2 440	<0 005	34 331	<0 005	0 151	0 183	0 581	0 461	0 074
	13 12	af	83 035 599	1 355 250	15 514	5 933	190 960	96 690	0 107	0 686	0 282	0 229	<0 005
SGS03293	4 92	af	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC

Sampling Location[1]	Depth (feet)	Stratigraphic Unit Sampled[2]	Volatile Organic Compounds[3] (parts per million)										
			Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
	9 84	af	56 182 980	196 150	0 750	1 262	44 983	<0 005	0 230	0 290	0 778	0 636	0 074
SGS03393	4 26	af	46 725 969	452 515	0 171	0 142	36 096	< 0 005	0 007	0 015	0 007	<0 005	<0 005
	5 12	af	56 181 452	404 338	0 206	0 211	6 377	<0 005	0 006	0 049	0 007	0 034	<0 005
SGS03493	4 92	af	45,191 456	157 950	1 143	0 168	24 482	<0 005	0 010	0 012	0 012	0 010	<0 005
	18 04	af	47 422 423	308 530	1 674	0 129	21 407	<0 005	0 006	0 009	0 007	0 016	0 816
SGS03593	4 92	af	53 932 955	1 007 118	6 429	0 312	58 415	<0 005	0 030	0 008	0 012	0 017	<0 005
SGS03693	4 92	af	69 528 620	1 468 465	9 096	3 405	98 724	<0 005	0 069	1 243	0 055	0 053	<0 005
	18 86	af	8 053 299	<0 005	2 532	0 242	8 597	<0 005	<0 005	0 081	0 021	0 005	<0 005
SGS03793	4 92	af	12 822 144	<0 005	5 220	0 250	10 818	<0 005	<0 005	0 007	0 014	0 010	<00 005
	18 86	af	10 665 681	26 096	4 840	0 170	9 110	<0 005	<0 005	0 023	0 014	0 020	0 074
SGS03893	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each soil gas sampling location is within approximately ten feet of the corresponding cone penetration test (CPT) location For example, SGS02093 is within approximately ten feet of CPT02093 CPT locations are presented in Figure C-1 (Appendix C)

[2] The stratigraphic units from which soil gas samples were collected are as follows

af artificial fill

Qrf Rocky Flats Alluvium

KaKl(w) weathered undifferentiated Arapahoe and Laramie Formation

[3] Volatile organic compounds were analyzed onsite using a field gas chromatogram (GC) equipped with a photoionization detector (PID) and a flame ionization detector(FID)

Definitions

DCE dichloroethene

IHSS individual hazardous substance site

ND-GC no data-gas chromatogram, soil gas samples were not analyzed due to GC malfunction

NP-ACC not performed - access, soil gas sampling was not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond

NP-DUP not performed - duplication of effort, soil gas sampling was not performed at this location because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond and soil gas samples were collected from these locations

NP-REF not performed - refusal, soil gas sampling was not performed at this location due to shallow refusals encountered at this site during the CPT investigation

TCA trichloroethane

TCE trichloroethene

Table 4-7
Results of Soil-Gas Sampling at IHSS 203

		Volatile Organic Compounds (micrograms per liter)[2]								
Sampling Location	Depth (feet)	Acetone	2-Butanone	1,2-DCE	Dichloromethane	1,1,1- TCA	TCE	Benzene	Toluene	Xylenes
SS712593	4 4	ND	0 4	ND	ND	0 08	0 62	ND	ND	ND
SS712693	4 4	0 9	ND	ND	ND	0 5	3	ND	ND	ND
SS712793	4 7	1	ND	ND	ND	0 07	2	ND	ND	ND
SS712893	3 3	ND	ND	ND	ND	ND	ND	ND	ND	ND
SS712993	4 0	ND	ND	ND	ND	0 02	0 8	ND	ND	ND
SS713093	3 1	1	0 2	ND	ND	0 6	3	ND	ND	ND
SS713193	5 0	0 8	0 7	ND	ND	3	0 4	ND	ND	ND
SS713293	5 0	0 6	ND	ND	0 3	3	0 3	ND	ND	ND
SS713393	5 2	1	0 2	ND	ND	0 4	3	ND	ND	ND
SS713493	4 6	0 2	ND	ND	ND	3	2	ND	ND	ND
SS713593	5 3	0 1	ND	0 3	0 1	2	2	ND	ND	ND
SS713693	5 0	1 3	ND	ND	0 3	4	4	0 4	ND	1
SS713793	5 2	0 3	0 2	0 5	0 01	0 95	0 02	ND	ND	ND
SS713893	5 1	0 3	0 1	ND	0 01	0 93	0 09	ND	ND	ND
SS713993	5 2	0 8	0 1	1	2	0 01	0 08	0 2	1	ND
SS714093	5 2	0 4	ND	3	0 02	0 01	0 3	ND	1	ND
SS714193	5 1	ND	ND	1	0 04	ND	0 04	ND	ND	ND
SS714293	5 2	2	ND	22	0 8	0 03	0 04	1	2	5
SS714393	5 0	1	ND	3	0 3	2	1	ND	ND	ND
SS714493	5 0	0 9	0 4	3	0 03	2	2	0 3	ND	ND
SS714593	3 1	ND	ND	0 1	ND	0 2	0 1	ND	ND	ND
SS714693	5 0	2	0 5	3	0 4	0 3	1	ND	ND	ND
SS714793	5 0	0 5	0 2	9	0 3	0 06	2	0 2	6	12
SS714893	5 1	2	0 5	20	0 1	0 09	0 4	0 4	11	18
SS714993	5 1	3	0 9	25	0 47	0 5	2	0 6	3	8
SS715093	5 0	2	0 7	20	0 07	0 05	0 4	0 6	1	8
SS715193	5 2	0 3	ND	2	0 07	0 03	0 6	ND	ND	ND
SS715293	5 2	ND	ND	ND	3	0 05	0 22	ND	ND	ND
SS715393	5 4	ND	ND	ND	0 8	0 08	0 6	ND	ND	ND

		Volatile Organic Compounds (micrograms per liter)[2]								
Sampling Location	Depth (feet)	Acetone	2-Butanone	1,2-DCE	Dichloromethane	1,1,1-TCA	TCE	Benzene	Toluene	Xylenes
SS715493	5 2	0 5	ND	2	0 3	0 12	3	ND	ND	6
SS715593	5 4	4	1	29	0 2	0 05	1	2	3	23
SS715693	5 0	2	ND	17	0 09	0 4	3	0 7	2	3
SS715793	4 9	2	1	17	0 6	0 2	3	1	31	87
SS715893	4 9	0 7	1	8	2	0 07	1	2	27	79
SS715993	5 3	0 7	1	9	0 1	0 4	2	2	2	12
SS716093	4 7	3	6	ND	ND	0 2	3	ND	ND	3
SS716193	4 9	2	4	0 7	ND	ND	1	0 2	1	4
SS716293	5 1	1	2	15	0 14	0 08	1	1	9	12
SS716393	4 8	1	2	18	0 12	0 32	4	0 6	0 6	1
SS716493	5 0	2	ND	1	ND	0 07	3	ND	0 7	2
SS716593	5 0	ND	ND	ND	ND	0 2	1	ND	ND	0 4
SS716693	5 0	0 8	ND	1	2	0 14	1	ND	9	4
SS716793	5 1	ND	ND	ND	ND	ND	0 3	ND	ND	ND
SS716893	4 8	1	ND	0 7	0 2	1	1	ND	0 5	1
SS716993	5 1	0 4	ND	ND	ND	ND	0 5	ND	ND	1
SS717093	5 0	0 9	0 8	ND	6	0 3	0 8	ND	ND	0 7
SS717193	5 1	3	ND	ND	ND	1	ND	ND	ND	1
SS717293	5 2	1	ND	6	0 06	ND	0 5	0 5	0 9	5
SS717393	5 0	0 9	ND	10	0 08	0 5	4	0 4	0 5	6

[1] Figure C-4 (Appendix C) presents the soil gas sampling locations at IHSS 203

[2] Volatile organic compounds analyzed using an onsite field gas chromatogram (GC) equipped with a photoionization detector (PID) and an electron capture detector (ECD)

Definitions

DCE dichloroethene
IHSS individual hazardous substance site
ND no data
TCA trichloroethane
TCE trichloroethene

Table 4-8
Results of Leachate–Groundwater Sampling

Sampling Location[1]	Depth Interval[2] (feet)	Volatile Organic Compounds[4] (milligrams per liter)[3]										
		Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
BAT00193	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
BAT00293	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT00393	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00493	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00593	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT00693	18 99-19 35	16 319	0 463	0 045	0 150	4 124	<0 005	0 013	0 025	0 022	0 028	<0 005
BAT00793	16 86-17 22	30 821	0 564	1 128	0 268	4 698	<0 005	<0 005	<0 005	0 020	0 033	<0 005
	20 30-20 66	31 431	1 187	1 235	0 201	0 165	<0 005	<0 005	<0 005	0 012	0 043	<0 005
BAT00893	17 68-18 04	26 804	0 488	7 188	0 328	10 894	<0 005	0 009	0 019	0 074	0 110	<0 005
	20 14-20 50	25 227	0 361	5 889	0 194	8 522	<0 005	0 012	0 016	0 025	0 042	<0 005
	25 06-25 42	24 380	<0 005	20 340	0 370	4 009	<0 005	<0 005	0 024	0 040	0 118	<0 005
BAT00993	NS-REF	NS REF	NS-REF	NS REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT01093	21 78-22 14	15 817	2 018	5 958	0 982	9 700	<0 005	0 018	0 055	0 203	0 138	<0 005
	27 52 28 70	17 784	11 452	7 701	9 909	21 396	<0 005	0 028	0 180	0 100	0 112	97 774
	33 26-33 62	31 333	21 601	14 671	6 306	38 564	<0 005	0 064	0 122	0 049	0 066	27 745
BAT01193	14 73-15 09	16 488	2 490	0 620	0 420	4 853	<0 005	0 013	0 325	0 030	0 040	<0 005
	27 68-28 37	18 616	1 647	0 619	1 269	3 630	<0 005	0 028	0 087	0 196	0 042	<0 005
	37 03-37 39	15 928	0 329	1 418	0 316	4 020	<0 005	0 011	0 062	0 032	0 029	<0 005
BAT01293	10 30-10 66	8 728	0 240	1 940	0 320	0 275	<0 005	0 039	0 130	0 080	0 095	<0 005
BAT01393	32 44-32 80	12 453	5 270	<0 005	0 219	4 399	<0 005	0 021	0 042	0 168	0 149	<0 005
	34 90-35 26	18 055	0 494	0 335	0 194	3 383	<0 005	<0 005	0 011	0 005	<0 005	<0 005
BAT01493	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT01593	35 72-36 08	19 489	0 184	3 352	0 281	2 777	<0 005	<0 005	0 029	0 007	0 007	<0 005
BAT01693	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC	NP-ACC
BAT01793	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF
BAT01893	9 48-9 84	0 488	0 079	0 320	0 029	0 214	0 005	< 0 005	< 0 005	< 0 005	< 0 005	< 0 005
BAT01993	22 83-23 19	ND-GC	ND-GC	ND-Gc	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC	ND-GC
BAT02093	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT02193	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP	NP-DUP
BAT02293	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY

Sampling Location[1]	Depth Interval[2] (feet)	Volatile Organic Compounds[4] (milligrams per liter)[3]										
		Methane	Methylene Chloride	Acetone	2-Butanone	1,2-DCE	1,1,1-TCA	TCE	Toluene	para, meta Xylene	ortho Xylene	Hydrogen Sulfide
BAT02393	29 00-23 19	16 090	0 003	1 423	0 976	1 223	< 0 005	0 008	0 254	0 006	0 006	< 0 005
BAT02493	15 22-15 58	20 949	1 849	0 556	0 376	0 214	< 0 005	< 0 005	0 051	< 0 005	< 0 005	< 0 005
BAT02593	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY	NS-DRY
BAT02693	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT02793	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT02893	26 04-26 40	22 346	1 631	1 316	0 186	5 755	0 080	< 0 005	0 005	0 037	0 073	< 0 005
BAT02993	19 32-19 68	9 878	0 369	0 569	0 159	7 087	< 0 005	0 006	0 017	0 018	0 013	< 0 005
	21 78-22 14	16 787	0 327	0 476	0 090	6 950	< 0 005	< 0 005	0 010	0 010	0 009	< 0 005
BAT03093	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT03193	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF	NS-REF
BAT03293	16 04-16 40	22 919	1 842	1 573	0 359	0 262	< 0 005	0 037	< 0 005	< 0 005	0 030	< 0 005
	18 50-18 96	13 714	0 407	3 249	0 354	0 686	< 0 005	0 048	< 0 005	< 0 005	0 005	< 0 005
BAT03393	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03493	20 14-20 50	0 072	0 159	0 331	0 169	0 209	< 0 005	0 026	0 041	0 039	0 044	1 039
BAT03593	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03693	NP-DRY	NP-DRY	NP DRY	NP DRY	NP DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY	NP-DRY
BAT03793	23 09-23 45	0 728	0 198	0 958	0 098	< 0 005	< 0 005	0 119	< 0 005	0 005	0 293	< 0 005
BAT03893	NP-REF	NP REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF	NP-REF

[1] Each leachate–groundwater sampling location is within approximately ten feet of the corresponding cone penetration test (CPT) location For example, BAT02093 is within approximately ten feet of CPT02093 CPT locations are presented in Figure C-1 (Appendix C)

[2] In general the depth interval sampled was 11 centimeters (0 36 foot) which is the length of the filter screen used in the BAT® Enviroprobe Due to insufficient volume two 11-centimeter sample intervals were sometimes combined for the purpose of collecting a sufficient sample volume

[3] Volatile organic compounds were analyzed onsite using a field gas chromatogram (GC) equipped with a photoionization detector (PID) and a flame ionization detector (FID)

DCE dichloroethene

ND-GC no data-gas chromatogram, leachate–groundwater samples were not analyzed due to GC malfunction

NP-ACC not performed - access, leachate–groundwater sampling was not performed at this location due to safety concerns associated with mobilizing the rig down the hillside to the sampling location located below the steep face of the landfill along the western boundary of the East Landfill Pond

NP-DRY not performed dry leachate–groundwater sampling was not performed at this location because nearby groundwater monitoring wells (71193 and 71693) installed during recent OU 7 field activities were dry or nearly dry

Definitions (continued)

NP-DUP	not performed - duplication of effort, leachate–groundwater sampling was not performed at this site because two other locations (CPT01593 and CPT02293) encountered the buried sediments of the West Landfill Pond, and leachate–groundwater samples were collected from one of these locations
NP-REF	not performed - refusal, leachate–groundwater sampling was not performed at this location due to shallow refusals encountered at this site during the CPT investigation
NS-DRY	not sampled - dry leachate–groundwater samples were not collected at this location because leachate–groundwater was not encountered during BAT® sampling or because the water table surface was interpreted as being below the top of bedrock
NS-REF	not sampled - refusal leachate–groundwater samples were not collected at this location due to shallow refusal encountered during BAT® sampling
TCA	trichloroethane
TCE	trichloroethene

Table 4-9
PCOCs in Surface Soils at IHSS 203

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Calcium	X	X	49/49	10,064	439 - 87 000
Cobalt		X	49/49	6	1 1 - 27 1
Copper	X	X	49/49	16	5 7 - 34 9
Vanadium		X	49/49	27	8 4 - 66 2
Radionuclides					
Americium-241		X	49/49	0 03	0 00363 - 0 3427
Radium-226	X		28/28	1 0	0 665 - 1 41
Uranium-235		X	49/49	0 039	-0 0149 - 0 199
Polychlorinated Biphenyls					
Aroclor-1254	NA	NA	12/49	40	9 9 - 100
Aroclor-1260	NA	NA	12/49	43	11 - 160
0 to 10 inches					
Metals					
Calcium	X	X	16/16	9 437	972 - 22 300
Copper	X	X	16/16	18	9 - 41 6
Sodium		X	16/16	403	37 8 - 3 000
Polychlorinated Biphenyls					
Aroclor-1254	NA	NA	2/16	46	46 - 95
Aroclor-1260	NA	NA	1/16	44	20 - 100

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations report in picocuries per gram Polychlorinated biphenyl concentrations reported in micrograms per kilogram

Definitions

IHSS	individual hazardous substance site
NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-10
IHSS 203 Surface-Soil Samples Exceeding the Background $UTL_{99/99}$ Concentrations

Analyte	Sample Location	Sample Interval (inches)	Result[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals					
Calcium	SS716393	0 to 2	16 800	1 2	see Figure 4-17
Calcium	SS716293	0 to 2	17,100	1 3	see Figure 4-17
Calcium	SS717393	0 to 2	17 700	1 3	see Figure 4-17
Calcium	SS717093	0 to 2	18 900	1 4	see Figure 4-17
Calcium	SS716593	0 to 2	19 900	1 5	see Figure 4-17
Calcium	SS716993	0 to 2	20,400	1 5	see Figure 4-17
Calcium	SS716493	0 to 2	24,200	1 8	see Figure 4-17
Calcium	SS714293	0 to 2	87,000	6 4	see Figure 4-17
Calcium	SS716793	0 to 10	17 100	1 3	Distribution correlates with soil type
Calcium	SS717193	0 to 10	17 100	1 3	Distribution correlates with soil type
Calcium	SS715793	0 to 10	20 900	1 5	Distribution correlates with soil type
Calcium	SS716993	0 to 10	22 300	1 6	Distribution correlates with soil type
Cobalt	SS712893	0 to 2	27 1	1 1	No spatial correlation
Copper	SS716693	0 to 2	34 9	1 6	No spatial correlation
Copper	SS715393	0 to 10	41 6	1 9	No spatial correlation
Sodium	SS715393	0 to 10	1 280	5 1	No spatial correlation
Sodium	SS716793	0 to 10	3 000	12 0	No spatial correlation
Vanadium	SS714293	0 to 2	66 2	1 4	No spatial correlation
Radionuclides					
Americium-241	SS712693	0 to 2	0623	1 5	see Figure 4-19
Americium-241	SS713093	0 to 2	08495	2 1	see Figure 4-19
Americium-241	SS712993	0 to 2	2104	5 2	see Figure 4-19
Americium-241	SS712893	0 to 2	3427	8 5	see Figure 4-19
Uranium-235	SS715893	0 to 2	199	1 4	No spatial correlation

[1] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations reported in picocuries per gram

Definitions

IHSS individual hazardous substance site

$UTL_{99/99}$ upper tolerance interval of the 99th percentile at the 99-percent confidence level

Table 4-11
PCOCs in Surface Soils at IHSS 114

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Calcium	X	X	22/22	13 351	4,910 - 27 800
Copper		X	22/22	17	8 6 - 81 5
Radionuclides					
Gross Beta		X	22/22	30	23 82 - 53 5
Strontium-89,90		X	16/16	0 26	0 054 - 2 87
Semivolatile Organic Compounds					
2-Methylnaphthalene	NA	NA	1/22	183	200 - 390
Acenaphthene	NA	NA	9/22	186	46 - 800
Acenaphthylene	NA	NA	1/22	176	38 - 390
Anthracene	NA	NA	11/22	190	46 - 650
Benzo(k)fluoranthene	NA	NA	13/22	185	44 - 590
Benzo(ghi)perylene	NA	NA	8/22	190	99 - 450
Benzo(a)pyrene	NA	NA	13/22	282	59 - 1 000
Benzo(b)fluoranthene	NA	NA	16/22	362	64 - 1 400
Benzo(a)anthracene	NA	NA	16/22	294	84 - 1,100
Benzoic Acid	NA	NA	1/15	867	110 - 1 900
Bis(2-ethylhexyl)phthalate	NA	NA	7/22	155	36 - 390
Butylnenzylphthalate	NA	NA	1/22	191	350 - 390
Di-n-Butyl Phthalate	NA	NA	6/22	147	40 - 390
Di-n-Octyl Phthalate	NA	NA	2/22	170	40 - 390
Dibenzo(a h)anthracene	NA	NA	4/22	165	61 - 390
Dibenzofuran	NA	NA	3/22	177	45 - 390
Fluoranthene	NA	NA	20/22	599	42 - 2,800
Fluorene	NA	NA	9/22	174	37 - 680
Naphthalene	NA	NA	3/22	194	42 - 690
Phenanthrene	NA	NA	19/22	528	64 - 3,500
Pyrene	NA	NA	20/22	597	41 - 2 600

[1] Statistical tests including the Gehan test, Quantile test, Slippage test, and t test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to a background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations report in picocuries per gram Semivolatile organic compound concentrations reported in micrograms per kilogram.

Definitions

IHSS individual hazardous substance site
NA not applicable
PCOCs potential contaminants of concern
X denotes that analyte was identifed as a PCOC using the test(s) as noted

Table 4-12
IHSS 114 Surface-Soil Samples Exceeding the Background $UTL_{99/99}$ Concentrations

Analyte	Sample Location	Sample Interval (inches)	Result[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals					
Calcium	SS718093	0 to 2	17,600	1 3	see Figure 4-20
Calcium	SS718793	0 to 2	18,500	1 4	see Figure 4-20
Calcium	SS718893	0 to 2	18 800	1 4	see Figure 4-20
Calcium	SS718693	0 to 2	19 600	1 4	see Figure 4-20
Calcium	SS719493	0 to 2	21 900	1 6	see Figure 4-20
Calcium	SS719093	0 to 2	23,600	1 7	see Figure 4-20
Calcium	SS719593	0 to 2	27 800	2 0	see Figure 4-20
Copper	SS718793	0 to 2	43 4	2 0	No spatial correlation
Copper	SS718593	0 to 2	81 5	3 7	No spatial correlation
Radionuclides					
Gross Beta	SS717993	0 to 2	53 5	1 3	No spatial correlation
Strontium-89 90	SS718393	0 to 2	2 87	2 9	No spatial correlation

[1] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations reported in picocuries per gram

Definitions

IHSS individual hazardous substance site

$UTL_{99/99}$ upper tolerance interval of the 99th percentile at the 99-percent confidence level

Table 4-13
PCOCs in Surface Soils at the East Landfill Pond

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
0 to 2 inches					
Metals					
Arsenic		X	133/133	5	1 8 - 13 2
Barium		X	133/133	191	56 3 - 1 120
Calcium	X	X	132/132	9,277	1,890 - 5 480
Lead		X	133/133	27	6 4 - 167
Magnesium		X	133/133	2 631	921 - 7 910
Sodium		X	127/133	117	22 6 - 1,280
Strontium	X		9/9	50 1	36 1 - 80 6
Vanadium		X	133/133	31	11 9 - 86 2
Zinc		X	133/133	56	21 5 - 101
Radionuclides					
Americium-241		X	119/119	0 03	0 - 1 076
Radium-226	X	X	79/79	1 0	0 4355 - 1 787
Water-Quality Parameters					
Nitrate/Nitrite		X	104/133	4	1 - 45
0 to 10 inches					
Metals					
Arsenic		X	67/67	5	1 2 - 15 7
Barium		X	67/67	201	30 - 546
Calcium	X	X	67/67	7 790	2 410 - 37 700
Selenium		X	36/67	0 4	0 24 - 2 4
Radionuclides					
Americium-241		X	66/66	0 0088	0 00057 - 0 05813

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] Metal and water-quality parameter concentrations reported in milligrams per kilogram Radionuclide concentrations report in picocuries per gram

Definitions

PCOCs potential contaminants of concern

X denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-14
East Landfill Pond Surface-Soil Samples Exceeding the Background $UTL_{99/99}$ Concentrations

Analyte	Sample Location	Sample Interval (inches)	Result[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Metals					
Arsenic	SS705393	0 to 2	13 2	1 5	No spatial correlation
Arsenic	SS702293	0 to 10	15 7	1 8	No spatial correlation
Barium	SS705193	0 to 2	1 120	2 4	No spatial correlation
Barium	SS708493	0 to 10	544	1 2	No spatial correlation
Barium	SS708093	0 to 10	546	1 2	No spatial correlation
Calcium	SS711393	0 to 2	18 500	1 4	see Figure 4-21
Calcium	SS706893	0 to 2	21 800	1 6	see Figure 4-21
Calcium	SS719793	0 to 2	22 700	1 7	No spatial correlation
Calcium	SS720293	0 to 2	24,100	1 8	see Figure 4-21
Calcium	SS709393	0 to 2	24 400	2 1	see Figure 4-21
Calcium	SS705193	0 to 2	28 600	2 1	see Figure 4-21
Calcium	SS708293	0 to 2	29 000	2 5	see Figure 4-21
Calcium	SS705993	0 to 2	34 000	2 7	see Figure 4-21
Calcium	SS706093	0 to 2	37 200	3 1	see Figure 4-21
Calcium	SS705293	0 to 2	41 600	3 2	see Figure 4-21
Calcium	SS720193	0 to 2	43 500	4 0	see Figure 4-21
Calcium	SS705093	0 to 2	54 800	2 4	see Figure 4-21
Calcium	SS704393	0 to 10	18 900	1 4	No spatial correlation
Calcium	SS705593	0 to 10	20 700	1 5	No spatial correlation
Calcium	SS708093	0 to 10	27,300	2 0	No spatial correlation
Calcium	SS708593	0 to 10	37 700	2 8	No spatial correlation
Lead	SS707893	0 to 2	122	3 3	see Figure 4-22
Lead	SS708893	0 to 2	167	1 5	see Figure 4-22
Lead	SS700593	0 to 2	77 6	1 2	see Figure 4-22
Magnesium	SS700293	0 to 2	7 910	2 1	No spatial correlation
Selenium	SS710693	0 to 10	1 7	2 2	see Figure 4-27
Selenium	SS702993	0 to 10	2 1	2 8	see Figure 4-27
Selenium	SS702593	0 to 10	2 4	3 2	see Figure 4-27
Sodium	SS708293	0 to 2	1 280	5 1	No spatial correlation
Vanadium	SS706093	0 to 2	68 2	1 5	see Figure 4-24
Vanadium	SS705293	0 to 2	86 2	1 9	see Figure 4-24
Zinc	SS707393	0 to 2	101	1 1	No spatial correlation
Radionuclides					
Americium-241	SS702593	0 to 2	05817	1 4	see Figure 4-25
Americium-241	SS700993	0 to 2	06255	1 5	see Figure 4-25
Americium-241	SS703793	0 to 2	1 076	26 6	see Figure 4-25
Americium-241	SS711493	0 to 10	05813	1 4	No spatial correlation
Radium-226	SS707593	0 to 2	1 505	1 4	see Figure 4-26
Radium-226	SS707793	0 to 2	1 513	1 4	see Figure 4-26
Radium-226	SS710993	0 to 2	1 596	1 5	see Figure 4-26
Radium-226	SS711393	0 to 2	1 672	1 5	see Figure 4-26
Radium-226	SS703293	0 to 2	1 681	1 5	see Figure 4-26

Analyte	Sample Location	Sample Interval (Inches)	Result[1]	Ratio of Analyte Concentration to Maximum Background Concentration	Comment
Radium-226	SS711193	0 to 2	1 787	1 6	see Figure 4-26
Water-Quality Parameters					
Nitrate/Nitrite	SS700493	0 to 2	10	2 1	see Figure 4-23
Nitrate/Nitrite	SS710193	0 to 2	10	2 1	see Figure 4-23
Nitrate/Nitrite	SS710493	0 to 2	10	2 1	see Figure 4-23
Nitrate/Nitrite	SS708293	0 to 2	14	2 9	see Figure 4-23
Nitrate/Nitrite	SS704093	0 to 2	16	3 3	see Figure 4-23
Nitrate/Nitrite	SS711093	0 to 2	17	3 5	see Figure 4-23
Nitrate/Nitrite	SS711393	0 to 2	22	4 6	see Figure 4-23
Nitrate/Nitrite	SS701093	0 to 2	31	6 5	see Figure 4-23
Nitrate/Nitrite	SS710693	0 to 2	41	8 6	see Figure 4-23
Nitrate/Nitrite	SS710893	0 to 2	45	9 4	see Figure 4-23

[1] Metal and water-quality parameter concentrations reported in milligrams per kilogram Radionuclide concentrations reported in picocuries per gram

Definitions

$UTL_{99/99}$ upper tolerance interval of the 99th percentile at the 99 percent confidence level

Table 4-15
PCOCs in Subsurface Geologic Materials

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Borehole 70993 - Qc					
Metals					
Aluminum	X		3/3	11,967	11,000 - 12,900
Manganese	X		3/3	240	221 - 262
Radionuclides					
Cesium-137	X		3/3	0 0376	0 006 - 0 070
Uranium-238	X		3/3	1 06	1 013 - 1 11
Volatile Organic Compounds					
4-Methyl-2-pentanone	NA	NA	1/2	32	13 - 58
Toluene	NA	NA	2/2	1 080	160 - 2,000
Total Xylenes	NA	NA	1/2	3	2 - 6
Semivolatile Organic Compounds					
Benzo(a)anthracene	NA	NA	1/3	148	48 - 400
Chrysene	NA	NA	1/3	146	43 - 400
Fluoranthene	NA	NA	1/3	168	110 - 400
Phenanthrene	NA	NA	1/3	165	100 - 400
Pyrene	NA	NA	1/3	168	110 - 400
Borehole 70993 - KaKI(w)					
Metals					
Arsenic		X	5/5	4 5	1 8 - 11 4
Calcium	X		5/5	4,418	3,480 - 5,670
Cobalt	X		5/5	6	3 8 - 11 7
Copper	X		5/5	17	13 2 - 20 8
Lead	X	X	5/5	23 1	17 7 - 31 2
Nickel	X		5/5	12	7 4 - 19 2
Selenium	X		3/5	0 5	0 27 - 1 4
Sodium	X		5/5	720	565 - 939
Strontium	X	X	5/5	91	60 2 - 113
Zinc	X	X	5/5	67	41 9 - 79 3
Radionuclides					
Radium-226	X		5/5	1 19	1 07 - 1 31
Volatile Organic Compounds					
1 1 1-Trichloroethane	NA	NA	1/5	3	2 - 6
Toluene	NA	NA	5/5	334	220 - 580
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/5	192	180 - 400
Butyl Benzyl Phthalate	NA	NA	1/5	328	320 - 860
Borehole 71093 - Qc					
Metals					
Aluminum	X		4/4	13,175	10,400 - 16,100
Barium	X	X	4/4	298	91 4 - 624
Lead	X		4/4	25	23 - 27 9
Strontium	X		4/4	76	56 5 - 107
Zinc	X		4/4	64	55 1 - 72 2

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Radionuclides					
Cesium-137		X	3/3	0 0792	-0 0142 - 0 2386
Tritium	X		3/3	158 2	122 7 - 199 1
Volatile Organic Compounds					
Toluene	NA	NA	6/6	288	120 - 550
Water-Quality Parameters					
Nitrate/Nitrite		X	1/3	6 667	1 - 20 000
Borehole 71093 - KaKI(w)					
Metals					
Barium	X	X	6/6	117	24 5 - 254
Calcium	X	X	6/6	7 385	2,770 - 15,900
Cobalt	X	X	6/6	11	2 2 - 21
Copper	X		6/6	20	13 4 - 24 3
Lead	X	X	6/6	22	12 6 - 29
Manganese	X	X	6/6	422	20 2 - 896
Nickel	X		6/6	22	3 1 - 38 2
Selenium	X		4/6	1 0	0 27 - 1 9
Sodium	X		6/6	308	256 - 398
Strontium	X	X	6/6	103	46 6 - 197
Zinc	X	X	6/6	72 5	49 3 - 84 4
Radionuclides					
Radium-226	X		6/6	1 068	0 9136 - 1 256
Strontium-89 90	X		6/6	0 2814	0 0228 - 0 802
Volatile Organic Compounds					
Toluene	NA	NA	6/6	288	120 - 550
Borehole 70493 & 70593 - Qrf					
Metals					
Chromium		X	11/11	26	8 8 - 144
Lead		X	11/11	7	3 4 - 31 4
Radionuclides					
Americium-241	X		11/11	0 002	0 - 0 0035
Cesium-137	X	X	11/11	0 0218	-0 032 - 0 202
Gross Beta	X		11/11	28 14	23 42 - 32 91
Radium-226	X		11/11	0 696	0 592 - 0 848
Radium-228	X	X	11/11	1 576	1 123 - 2 166
Uranium-235	X		11/11	0 0471	-0 0025 - 0 090
Uranium-238	X		11/11	1 078	0 8235 - 1 411
Volatile Organic Compounds					
Toluene	NA	NA	11/11	95	51 - 200
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	2/11	341	310 - 1 800
Di-n-Octyl Phthalate	NA	NA	1/11	176	120 - 380
Borehole 70493 & 70593 - KaKI(w)					
Metals					
Barium	X		8/8	87	49 3 - 120
Calcium	X	X	8/8	7 203	4 830 - 15,600
Lead	X		8/8	19	15 - 22 3

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Strontium	X	X	8/8	62	37 - 88 5
Zinc		X	8/8	48	13 8 - 88 6
Radionuclides					
Radium-226	X		8/8	0 911	0 7725 - 1 085
Volatile Organic Compounds					
Methylene Chloride	NA	NA	2/8	6	5 - 11
Toluene	NA	NA	8/8	172	83 - 240
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/8	183	47 - 430

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations report in picocuries per gram Organic compound concentrations reported in micrograms per kilogram

Definitions

KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
NA	not applicable
PCOCs	potential contaminants of concern
Qc	colluvium
Qrf	Rocky Flats Alluvium
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-16
Subsurface Geologic Material Samples Exceeding the Background $UTL_{99/99}$ Concentration

Analyte	Result[1]	Sample Depth (feet)
Borehole 70993 - Qc		
None		
Borehole 70993 - KaKl(w)		
Metals		
Arsenic	11 4	23 2-27 2
Lead	31 20	7 2-11 2
Lead	27 10	19 2-23 2
Strontium	86 50	7 2-11 2
Strontium	60 20	11 2-15 2
Strontium	87 00	15 2-19 2
Strontium	107 00	19 2-23 2
Strontium	113 00	23 2-27 2
Zinc	70 80	7 2-11 2
Zinc	73 90	11 2-15 2
Zinc	71 00	19 2-23 2
Zinc	79 30	23 2-27 2
Borehole 71093 - Qc		
Metals		
Barium	624 00	4 1-6 1
Radionuclides		
Cesium-137	0 24	0 0-2 1
Water-Quality Parameters		
Nitrate/Nitrite	20,000 00	0 0-2 1
Borehole 71093 - KaKl(w)		
Metals		
Barium	254 00	8 4-12 1
Calcium	12,100 00	12 1-16 1
Calcium	15,900 00	20 1-24 1
Cobalt	19 20	12 1-16 1
Cobalt	21 00	16 1-20 1
Lead	26 80	12 1-16 1
Lead	29 00	16 1-20 1
Manganese	896 00	24 1-28 1
Strontium	197 00	8 4-12 1
Strontium	85 70	12 1-16 1
Strontium	85 60	16 1-20 1
Strontium	95 30	20 1-24 1
Strontium	105 00	24 1-28 1
Strontium	46 60	28 1-32 1
Zinc	76 10	12 1-16 1
Zinc	84 40	16 1-20 1
Zinc	80 90	20 1-24 1
Zinc	81 60	24 1-28 1

Analyte	Result[1]	Sample Depth (feet)
Boreholes 70493 & 70593 - Qrf		
Metals		
Chromium	144 00	18 0-20 0
Lead	31 40	0 0-2 0
Radionuclides		
Cesium-137	0 20	0 0-2 0
Radium-228	2 01	2 0-4 0
Radium-228	2 17	4 0-6 0
Boreholes 70493 & 70593 - KaKl(w)		
Metals		
Calcium	15,600 00	30 4-34 1
Strontium	37 70	22 0-26 0
Strontium	37 00	26 0-30 0
Strontium	88 50	30 4-34 1
Strontium	78 40	34 1-38 1
Strontium	51 20	38 1-42 1
Strontium	71 00	42 1-46 1
Strontium	64 60	46 1-50 1
Strontium	67 40	50 1-54 1
Zinc	88 60	34 1-38 1
Zinc	76 10	42 1-46 1

[1] Metal and water-quality parameter concentrations reported in milligrams per kilogram Radionuclide concentrations report in picocuries per gram

Definitions

KaKl(w)	weathered undifferentiated Arapahoe and Laramie Formation
Qc	colluvium
Qrf	Rocky Flats Alluvium
$UTL_{99/99}$	upper tolerance interval of the 99th percentile at the 99 percent confidence level

Table 4-17
Reported Concentrations of Organic Compounds in the East Landfill Pond Sediments

Analyte	Concentrations in Sediment Samples		
	SED70093	SED70193	SED70293
Volatile Organic Compounds (micrograms per kilogram)			
Acetone	ND	130(B)	63
2-Butanone	35	ND	ND
Toluene	180	300	400
Semivolatile Organic Compounds (micrograms per kilogram)			
Acenaphthene	100(J)	ND	ND
Anthracene	160(J)	ND	ND
Benzo(a)anthracene	340(J)	ND	ND
Benzo(a)pyrene	320(J)	ND	ND
Benzo(b)fluoranthene	470(J)	ND	ND
Benzo(ghi)perylene	200(J)	ND	ND
Benzo(k)fluoranthene	130(J)	ND	ND
Benzoic Acid	870(J)	480(J)	260(J)
Bis(2-ethylhexyl)phthalate	80(J)	ND	ND
Bis(2-Chloroisopropyl)ether		ND	47(J)
Chrysene	310(J)	ND	ND
Fluoranthene	830	ND	79(J)
Fluorene	92(J)	ND	ND
Indeno(1,2,3-cd)pyrene	180(J)	ND	ND
Phenanthrene	630(J)	ND	73(J)
Pyrene	750(J)	ND	74(J)

Definitions

B laboratory qualifier indicating that the chemical was also detected in the laboratory blank

J laboratory qualifier indicating an estimated value below the quantitation limit

ND nondetect

Table 4-18
PCOCs in East Landfill Pond Sediments

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Metals					
Aluminum	X		2/2	14 450	12,300 - 16,600
Arsenic	X		3/3	4	2 7 - 5
Barium	X		3/3	198	174 - 215
Beryllium	X		3/3	1 2	0 81 - 1 5
Calcium	X		2/2	7,070	6 290 - 7,850
Chromium	X		3/3	14 7	12 3 - 17 5
Copper	X		3/3	16 0	11 2 - 18 6
Iron	X		2/2	13 500	11,600 - 15 400
Lead	X		3/3	29 7	21 6 - 33 7
Magnesium	X		2/2	2 710	2 170 - 3 250
Nickel	X		3/3	12 7	9 3 - 15 3
Potassium	X		2/2	1 995	1,350 - 2,640
Selenium	X		3/3	0 8	0 41 - 1 1
Sodium	X		2/2	367	286 - 447
Strontium	X		2/2	52 5	43 5 - 61 5
Vanadium	X		3/3	34	28 8 - 41
Zinc	X		3/3	106	49 2 - 187
Radionuclides					
Cesium-137	X		3/3	0 458	0 286 - 0 732
Volatile Organic Compounds					
2-Butanone	NA	NA	1/3	17	13 - 35
Toluene	NA	NA	3/3	307	180 - 440
Semivolatile Organic Compounds					
Acenaphthene	NA	NA	1/3	220	100 - 670
Acenaphthylene	NA	NA	2/3	68	63 - 180
Anthracene	NA	NA	1/3	240	160 - 670
Benzo(a)anthracene	NA	NA	1/3	300	340 - 670
Benzo(a)pyrene	NA	NA	1/3	293	320 - 670
Benzo(b)fluoranthene	NA	NA	1/3	343	450 - 670
Benzo(ghi)perylene	NA	NA	1/3	253	200 - 670
Benzo(k)fluoranthene	NA	NA	1/3	230	130 - 670
Benzoic Acid	NA	NA	3/3	537	260 - 870
Bis(2-chloroisopropyl)ether	NA	NA	1/3	259	47 - 790
Bis(2-ethylhexyl)phthalate	NA	NA	1/3	213	80 - 670
Chrysene	NA	NA	1/3	290	310 - 670
Fluoranthene	NA	NA	2/3	415	79 - 830
Fluorene	NA	NA	1/3	217	92 - 670
Indeno(1 2 3-cd)pyrene	NA	NA	1/3	247	180 - 670
Phenanthrene	NA	NA	2/3	346	73 - 670
Pyrene	NA	NA	2/3	386	74 - 750

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] Metal concentrations reported in milligrams per kilogram Radionuclide concentrations reported in picocuries per gram Organic compound concentrations reported in micrograms per kilogram

Definitions

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-19
PCOCs in Seep Water (SW097)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes					
Metals					
Antimony		X	4/20	22	14 - 60 4
Barium	X		21/21	640	297 - 1550
Calcium	X	X	21/21	151 000	126,000 - 212 000
Iron	X		21/21	80 510	61 300 - 155,000
Lithium	X		17/21	48	34 - 107
Magnesium	X		21/21	34 719	29 300 - 49 000
Manganese	X		21/21	1,611	1 320 - 2,490
Potassium	X		20/21	6 436	5,000 - 11,700
Silicon	X	X	14/14	13 508	7,060 - 44 000
Sodium	X	X	21/21	71,367	57 700 - 110,000
Strontium	X		19/21	919	814 - 1,370
Zinc	X	X	21/21	2 945	857 - 16,000
Radionuclides					
Gross Beta	X	X	10/10	11	3 753 - 17
Strontium-89 90	X	X	10/10	1 30	0 66 - 4 06
Tritium	X		22/22	349	-110 - 1500
Water-Quality Parameters					
Nitrite	X		6/9	30 33	20 00 - 63 00
Volatile Organic Compounds					
1 1-Dichloroethane	NA	NA	17/20	6	2 - 10
2-Butanone	NA	NA	6/19	12	6 - 76
2-Hexanone	NA	NA	1/20	5	1 - 10
4-Methyl-2-pentanone	NA	NA	5/20	11	10 - 87
Acetone	NA	NA	11/21	33	10 - 220
Benzene	NA	NA	11/20	2	1 - 5
Carbon Disulfide	NA	NA	1/20	3	5 - 6
Chloroethane	NA	NA	15/20	22	10 - 57
Chloromethane	NA	NA	2/20	5	4 - 10
Ethylbenzene	NA	NA	19/20	13	1 - 18
Methylene Chloride	NA	NA	10/20	14	3 - 190
o-Xylene	NA	NA	3/4	6	5 - 8
Tetrachloroethene	NA	NA	2/20	2	1 - 5
Toluene	NA	NA	19/20	38	5 - 88
Total Xylenes	NA	NA	19/20	14	1 - 25
Trichloroethene	NA	NA	11/20	2	1 - 5
Vinyl Acetate	NA	NA	1/19	7	10 - 49
Vinyl Chloride	NA	NA	5/20	5	3 - 11
Semivolatile Organic Compounds					
2 4-Dimethylphenol	NA	NA	1/4	5	3 - 10
2-Methylnaphthalene	NA	NA	4/4	16	12 - 23
4-Methylphenol	NA	NA	3/4	4	2 - 10
Acenaphthene	NA	NA	4/4	3	2 - 3

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Bis(2-ethylhexyl)phthalate	NA	NA	1/4	5	2 - 12
Dibenzofuran	NA	NA	4/4	1	1 - 2
Diethyl Phthalate	NA	NA	4/4	3	1 - 10
Fluorene	NA	NA	4/4	2	2 - 3
Naphthalene	NA	NA	4/4	18	14 - 22
Phenanthrene	NA	NA	4/4	4	4 - 5
Dissolved Analytes					
Metals					
Barium	X		20/20	567	447 - 673
Calcium	X	X	20/20	149 500	123 000 - 207 000
Iron	X	X	20/20	71,050	51,100 - 95,800
Lithium	X		16/20	47	34 - 111
Magnesium	X		20/20	34 690	28 700 - 47 500
Manganese	X		20/20	1 581	1 300 - 2 040
Potassium	X		19/20	5 912	3,500 - 8 790
Sodium	X	X	20/20	71,720	55,100 - 116,000
Strontium	X	X	19/20	939	778 - 1,350
Tin	X		10/19	67	14 8 - 306
Zinc	X		20/20	1 530	240 - 3430
Radionuclides					
Gross Beta	X		13/13	8	0 5469 - 11
Strontium-89,90	X		9/9	1 16	0 6806 - 1 933
Uranium-235		X	12/12	0 1	-0 0094 to 0 7

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter except radionuclide concentrations, which are reported in picocuries per liter

Definitions

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-20
PCOCs in Surface Water from the East Landfill Pond (SW098)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes					
Metals					
Arsenic	X		11/24	2	0 9 - 10
Calcium	X		25/25	39 745	3 180 - 55 000
Lithium	X		23/24	81	7 7 - 109
Magnesium	X		25/25	39,640	4,270 - 48 300
Manganese	X		24/25	101	2 5 - 430
Molybdenum	X		4/24	38	3 -100
Nickel	X		17/25	11	6 3 - 40
Potassium	X		25/25	8 816	1 360 - 10 900
Sodium	X	X	25/25	16,1245	19,900 - 196,000
Strontium	X		24/24	476	44 9 - 598
Thallium	X		3/24	3	0 9 - 10
Tin	X		8/24	58	10 - 100
Radionuclides					
Americium-241	X	X	18/18	0 011	0 0005655 - 0 075
Gross Alpha	X		13/13	2	-0 67 - 5
Gross Beta	X		13/13	12	7 9 - 16
Strontium-89 90	X		5/5	1 4	0 6635 - 1 924
Tritium	X		26/26	143	-10 - 257 8
Uranium-235	X	X	10/10	0 1	-0 01 - 0 3
Uranium-238	X	X	10/10	1 1	0 6996 - 1 964
Volatile Organic Compounds					
Acetone	NA	NA	1/21	5	6 - 58
Chlorinated Hydrocarbons					
Methylene Chloride	NA	NA	3/21	3	4 - 8
Vinyl Acetate	NA	NA	1/20	9	10 - 80
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/8	5	1 - 11
Di-n-Butyl Phthalate	NA	NA	1/8	5	1 - 11
Dissolved Analytes					
Metals					
Antimony	X		8/23	23	8 - 60
Arsenic	X		8/20	2	0 7 - 10
Barium	X		24/24	167	135 - 204
Calcium	X		24/24	41 182	26 100 - 55 900
Lithium	X		22/23	86	62 9 - 110
Magnesium	X		24/24	41 914	35,600 - 48 200
Manganese	X		21/24	63	1 - 250
Molybdenum	X		8/22	23	2 5 - 100
Nickel	X		8/23	10	4 - 40
Potassium	X		24/24	9 308	7 470 - 10 900
Sodium	X	X	24/24	170 594	142 000 - 197 000
Strontium	X		23/23	497	366 - 596

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Tin	X		7/21	41	10 4 - 100
Vanadium	X		8/23	9	2 - 50
Radionuclides					
Gross Alpha	X		7/7	1 9	-0 294 - 4 2
Gross Beta	X		13/13	12	4 206 - 22
Strontium-89,90	X		10/10	1	0 4 - 1 613
Uranium-238	X	X	15/15	2	0 3 - 15

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter

Definitions

NA not applicable

PCOCs potential contaminants of concern

X denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-21
PCOCs in Surface Water from the North Groundwater Intercept System Discharge Point (SW099)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes					
Metals					
Barium	X		15/18	170	59 5 - 382
Calcium	X	X	19/19	62 968	35 700 - 92 000
Lithium	X		16/19	16	6 2 - 100
Magnesium	X		19/19	22,826	13,300 - 54,600
Selenium	X		3/17	4	1 - 37 7
Sodium	X	X	19/19	44 063	13 700 - 166 000
Strontium	X		17/19	738	368 - 1 230
Zinc	X		16/17	33	9 5 - 92 4
Radionuclides					
Americium-241	X	X	12/12	0 013	0 - 0 052
Gross Alpha	X		6/6	3 2	1 512 - 6 002
Uranium-235	X		6/6	0 15	0 06293 - 0 2733
Uranium-238	X	X	6/6	2 5	1 67 - 3 652
Volatile Organic Compounds					
Acetone	NA	NA	2/16	6	1 - 17
Benzene	NA	NA	1/17	3	3 - 5
Carbon Disulfide	NA	NA	1/17	3	3 - 5
Methylene Chloride	NA	NA	3/17	3	2 - 18
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	1/3	4	2 - 10
Dissolved Analytes					
Metals					
Barium	X		13/16	162	52 6000 - 370
Cadmium	X		0/14	NC	1 - 5
Calcium	X	X	17/17	95 224	35,200 - 643 000
Lead	X		7/15	3	0 8 - 5
Lithium	X		12/17	16	4 8 - 100
Magnesium	X		17/17	34 571	14,100 0 - 208,000
Sodium	X	X	17/17	55 771	13 500 - 198 000
Strontium	X		16/18	730	528 - 1,200
Radionuclides					
Strontium-89,90	X		5/5	1 272	0 5767 - 1 778
Uranium-238	X		5/5	3 2	0 3 - 6 192

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter, except radionuclides concentrations, which are reported in picocuries per liter

Definitions

NA	not applicable
NC	not calculated
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-22
PCOCs in Surface Water from the South Groundwater Intercept System Discharge Point (SW100)

Analyte	Inferential Statistical Tests[1]	Hot Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Total Analytes					
Metals					
Calcium	X	X	8/8	83 163	40 900 - 156 000
Lithium	X		4/8	32	10 - 100
Magnesium	X		8/8	12 853	5 590 - 21 700
Potassium	X		6/8	14 670	5,000 - 26 000
Selenium	X		3/8	3	1 - 6 6
Sodium	X	X	8/8	41 250	21 500 - 86 000
Strontium	X		5/8	577	323 - 1000
Zinc	X		8/8	67	10 - 167
Radionuclides					
Americium-241	X	X	3/3	0 017	0 003996 - 0 041
Gross Beta	X	X	3/3	33	20 4 44
Tritium	X		5/5	273	16 41 - 450
Water-Quality Parameters					
Nitrite	X		2/4	29 25	20 00 - 65 00
Volatile Organic Compounds					
1,1-Dichloroethane	NA	NA	1/8	3	5 -7
Chloroethane	NA	NA	1/8	8	10 -25
Ethylbenzene	NA	NA	1/8	4	5 - 15
Methylene Chloride	NA	NA	1/8	4	2 - 17
Toluene	NA	NA	1/8	8	5 - 47
Total Xylenes	NA	NA	1/8	4	5 - 11
Dissolved Analytes					
Metals					
Arsenic	X		2/11	3	0 9 - 10
Barium	X		8/11	92	25 6 - 200
Calcium	X	X	11/11	137 782	36 700 - 268 000
Lithium	X		6/10	28	10 - 100
Magnesium	X		10/11	17 368	4 660 - 29 800
Manganese	X		9/11	109	4 5 - 733
Potassium	X		9/11	19 700	5 000 - 32 400
Selenium	X		4/11	3	1 - 5 5
Sodium	X		11/11	45 482	19,500 - 86 000
Strontium	X		8/11	859	265 - 1 600
Zinc	X		8/10	30	20 - 56
Radionuclides					
Americium-241		X	2/2	0 4	0 045 to 0 8
Gross Beta	X	X	3/3	17	6 - 33
Uranium-238	X	X	3/3	1 7	0 2 - 2 475

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t-test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter

Definitions

NA	not applicable
PCOCs	potential contaminants of concern
X	denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-23
PCOCs for UHSU Groundwater

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Dissolved Analytes					
Metals					
Aluminum		X	156/325	201	5 - 13 700
Antimony		X	57/329	25	6 - 66 8
Arsenic	X		54/321	20	0 7 - 1 000
Barium	X	X	330/330	154	7 6 - 940
Cadmium		X	24/329	2	1 - 15 8
Calcium	X	X	330/330	73,581	11,700 - 566,000
Chromium		X	68/328	6	2 - 34 3
Cobalt	X	X	67/330	18	2 - 68 3
Copper	X	X	110/390	26	1 - 1 170
Iron	X	X	180/325	5 061	2 4 - 146,000
Lithium		X	240/327	189	1 - 10,000
Magnesium	X	X	325/330	16 487	2,700 - 102,000
Manganese	X	X	277/330	510	1 - 9,230
Molybdenum		X	62/330	515	2 - 9 000
Nickel	X	X	121/329	21	2 - 795
Potassium	X		249/330	2 702	112 - 48 700
Selenium		X	76/328	30	1 - 924
Sodium	X	X	330/330	60,479	5,600 - 493 000
Strontium	X	X	323/330	758	65 7 - 81 700
Zinc	X	X	216/330	45	1 3 - 1 240
Radionuclides					
Gross Beta	X	X	312/312	5	-7 2 - 43 17
Radium-226	X	X	71/71	0 8	0 12 - 2 17
Strontium-89 90	X	X	230/230	0 5	-0 18 - 11 17
Total Analytes					
Metals					
Aluminum	X	X	164/173	15 953	13 - 456,000
Antimony	X	X	26/169	27	8 - 115
Arsenic	X	X	86/172	5	0 7 - 70 70
Barium	X	X	163/173	314	16 1 - 5 060
Beryllium	X	X	41/171	3	0 8 - 32
Cadmium		X	35/173	3	1 - 19
Calcium	X	X	173/173	80,210	14,300 - 560,000
Chromium	X	X	120/174	26	2 - 580
Cobalt	X	X	72/173	22	2 - 228
Copper	X	X	109/173	160	2 - 7 140
Iron	X	X	168/173	27 358	16 4 - 656 000
Lead	X	X	133/173	14	1 - 263
Lithium	X	X	132/173	38	2 6 - 266
Magnesium	X	X	171/173	19 479	3 010 - 118 000
Manganese	X	X	170/173	841	2 2 - 9 260
Mercury	X	X	22/173	0 2	0 2 - 1 50

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Molybdenum		X	29/170		2 - 60 3
Nickel	X	X	107/173	41	2 - 1 070
Potassium	X	X	155/173	5 098	319 - 47 800
Selenium	X	X	29/165	27	1 - 815
Silicon	X	X	121/121	34 223	2 720 - 288,000
Silver	X	X	23/173	38	2 - 3 040
Sodium	X	X	172/172	59 379	8 200 - 1 230 000
Strontium	X	X	164/168	538	83 2 - 3 720
Tin		X	38/169	76	10 - 267
Vanadium	X	X	115/172	40	2 - 754
Zinc	X	X	148/171	185	6 3 - 8,000
Radionuclides					
Americium-241	X	X	267/267	0 01	-0 43 - 0 63
Cesium-137		X	140/140	0 1	-0 756 - 1 13
Radium-226	X	X	7/7	0 60	0 35 - 1 32
Strontium-89,90	X		19/19	0	0 - 1
Volatile Organic Compounds					
1 1-Dichloroethane	NA	NA	63/393	3	0 5 - 50
1 1-Dichloroethene	NA	NA	36/394	4	1 -100
1 1 1-Trichloroethane	NA	NA	68/393	9	2 - 370
1 1 2-Trichloroethane	NA	NA	2/394	2	0 4 - 50
1,2-Dichloroethane -D4	NA	NA	5/5	105	102 - 111
1 2-Dichloroethene	NA	NA	72/388	4	1 - 130
1 2-Dichloropropane	NA	NA	20/394	3	1 - 50
1 4-Dichlorobenzene	NA	NA	3/56	5	6 - 100
2-Butanone	NA	NA	6/276	13	2 - 1,300
2-Hexanone	NA	NA	3/374	5	2 - 100
4-Methyl-2-pentanone	NA	NA	8/378	12	3 - 1 100
Acetone	NA	NA	40/358	12	1 - 990
Benzene	NA	NA	33/393	3	0 1 - 50
Bromodichloromethane	NA	NA	1/394	3	1 - 50
Bromofluorobenzene	NA	NA	5/5	103	93 - 112
Bromoform	NA	NA	2/394	2	1 - 50
Carbon Disulfide	NA	NA	2/389	3	0 1 - 50
Carbon Tetrachloride	NA	NA	18/393	3	1 - 50
Chlorobenzene	NA	NA	5/394	3	0 3 - 50
Chloroethane	NA	NA	13/393	6	2 - 83
Chloroform	NA	NA	35/393	3	1 - 50
Ethylbenzene	NA	NA	18/394	4	0 3 - 110
Methylene Chloride	NA	NA	59/391	3	0 4 - 50
Tetrachloroethene	NA	NA	80/391	4	0 4 - 170
Toluene -D8	NA	NA	5/5	102	99 - 109
Toluene	NA	NA	32/394	7	0 2 - 580
Total Xylenes	NA	NA	25/393	6	0 4 - 270
Trichloroethene	NA	NA	100/392	9	1 - 190
Vinyl Chloride	NA	NA	26/394	5	2 - 100

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Semivolatile Organic Compounds					
2-Chloronaphthalene	NA	NA	1/56	5	5 - 100
2-Methylphenol	NA	NA	3/55	5	3 - 100
2 4-Dimethylphenol	NA	NA	4/55	5	7 - 100
2 4 5-Trichlorophenol	NA	NA	1/55	25	3 - 500
4-Methylphenol	NA	NA	11/55	84	6 - 2 100
4-Nitrophenol	NA	NA	1/53	26	42 - 500
Acenaphthene	NA	NA	2/56	5	2 - 100
Benzoic Acid	NA	NA	11/48	102	6 - 1,300
Bis(2-ethylhexyl)phthalate	NA	NA	16/56	7	2 - 100
Di-n-Butyl Phthalate	NA	NA	5/56	5	2 - 100
Diethyl Phthalate	NA	NA	11/56	8	3 - 50
Fluorene	NA	NA	1/56	5	2 - 100
Naphthalene	NA	NA	9/56	6	3 - 100
Pentachlorophenol	NA	NA	3/55	25	4 - 500
Phenanthrene	NA	NA	3/56	5	2 - 100
Phenol	NA	NA	4/55	10	8 - 130
Water-Quality Parameters					
Chloride		X	295/318	54 593	760 - 530,000
Cyanide		X	29/225	5	-0 6 - 20
Fluoride		X	316/326	542	100 - 8 600
Nitrate/Nitrite	X	X	276/313	7 258	20 - 290 000
Sulfate		X	322/326	175,331	500 - 19 000 000
Total Dissolved Solids		X	342/342	550,219	85 000 - 5,100,000

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations which are reported in picocuries per liter

Definitions

NA not applicable

PCOCs potential contaminants of concern

UHSU upper hydrostratigraphic unit

X denotes that analyte was identified as a PCOC using the test(s) as noted

Table 4-24
PCOCs for LHSU Groundwater

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Dissolved Analytes					
Metals					
Aluminum	X	X	20/39	79	13 - 264
Antimony		X	9/39	23	10 - 97 1
Arsenic		X	8/39	5	0 7 - 39 80
Barium	X	X	37/39	175	9 40 - 516
Beryllium	X	X	1/39	2	0 3 - 5
Cadmium	X	X	4/39	2	1 - 9 6
Calcium	X	X	39/39	71 485	13 000 - 601,000
Chromium	X	X	9/39	8	2 - 67 9
Cobalt	X	X	3/39	17	2 - 50
Copper	X	X	16/39	11	1 - 63
Iron		X	24/39	48	2 6 - 288
Lead		X	5/39	2	0 7 - 100
Lithium	X	X	32/39	49	10 7 - 261
Magnesium	X	X	37/39	13 238	1,280 - 185,000
Manganese	X	X	32/39	37	1 - 195
Mercury		X	0/38	NC	0 1 - 0 2
Molybdenum	X	X	22/39	63	4 - 435 00
Nickel	X	X	10/39	17	2 1 - 125
Potassium	X	X	38/39	4,386	1 560 - 12 100
Selenium	X	X	12/39	12	1 - 360
Silver	X	X	9/39	5	2 - 11 5
Sodium	X	X	39/39	185 046	31 900 - 490 000
Strontium	X	X	39/39	794	185 - 5 700
Thallium	X	X	1/39	4	1 00 - 10
Tin	X	X	6/39	63	10 - 152
Zinc		X	20/39	14	2 - 91 2
Radionuclides					
Gross Alpha	X	X	3/3	14 8	2 9 - 33 1
Gross Beta	X	X	50/50	6	1 36 - 16 27
Strontium-89 90		X	22/22	0 29	-0 039 - 0 980
Uranium-235		X	50/50	0 06	-0 021 - 0 334
Uranium-238	X	X	50/50	1 2	0 - 4 196
Total Analytes					
Metals					
Aluminum		X	19/19	14,795	1,140 - 79 800
Arsenic		X	12/19	6	0 7 - 36 40
Barium	X	X	19/19	272	27 70 - 1 180
Calcium	X	X	19/19	39,174	22 700 00 - 108 000
Chromium	X		17/19	36	3 00 - 204
Copper		X	19/19	33	3 3 - 229
Iron		X	19/19	14 831	1 020 - 63 400
Lead		X	18/19	19	1 1 - 115

Analyte	Inferential Statistical Tests[1]	Hot-Measurement Test[2]	Detection Frequency	Sample Mean[3]	Sample Concentration Range[3]
Lithium		X	15/19	30	10 8 - 91 9
Magnesium	X		19/19	9 994	2 850 - 27 000
Manganese		X	19/19	196	30 70 - 616
Nickel	X		9/19	32	3 - 173
Potassium		X	19/19	5 366	3 110 - 11 700
Selenium	X	X	8/19	2	1 00 - 3 10
Silicon		X	16/16	25 951	4 210 - 88,900
Silver		X	2/19	4	2 - 5 3
Sodium	X	X	19/19	75,189	32 700 - 437,000
Strontium	X	X	19/19	474	241 - 1 470
Tin		X	3/19	55	10 - 53 2
Zinc		X	19/19	122	14 - 572
Radionuclides					
Americium-241		X	26/26	0 004	-0 002 - 0 015
Cesium-137		X	7/7	0 12	-0 23 - 0 48
Tritium		X	52/52	12	-330 - 300
Uranium-235		X	1/1	0 08	0 08 - 0 08
Volatile Organic Compounds					
1 1-Dichloroethene	NA	NA	1/64	2	2 - 5
1,1,1-Trichloroethane	NA	NA	1/64	3	5 - 10
Acetone	NA	NA	6/58	6	4 - 36
Chlorobenzene	NA	NA	1/64	2	1 - 5
Methylene Chloride	NA	NA	14/64	4	1 - 19
Toluene	NA	NA	5/64	3	1 - 5
Total Xylenes	NA	NA	1/64	2	1 - 5
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	NA	NA	2/14	6	4 - 24
Di-n-Butyl Phthalate	NA	NA	1/14	5	5 - 11
Naphthalene	NA	NA	1/14	5	2 - 11
Water-Quality Parameters					
Nitrate/Nitrite		X	36/44	858	20 - 2400

[1] Statistical tests, including the Gehan test, Quantile test, Slippage test, and t test, used to identify PCOCs

[2] Statistical test used to identify PCOCs based on a comparison to the background $UTL_{99/99}$ concentration The $UTL_{99/99}$ is defined as the upper tolerance interval of the 99th percentile at the 99-percent confidence level

[3] All concentrations reported in micrograms per liter, except radionuclide concentrations, which are reported in picocuries per liter

Definitions

LHSU lower hydrostratigraphic unit
NA not applicable
PCOCs potential contaminants of concern
X denotes that analytes was identified as a PCOC using the test(s) noted

Table 4-25
Frequency of Detection of Organic Compounds in Groundwater

Analyte	Detection Frequency	Total VOCs	Total Chlorinated VOCs	Total BTEX	Total SVOCs
		UHSU			
Volatile Organic Compounds					
1 1 1-Trichloroethane	68/393	X	X		
1 1,2-Trichloroethane	2/394				
1 1-Dichloroethane	63/393	X	X		
1 1-Dichloroethene	36/394	X	X		
1 2 Dichloroethane - D4[1]	5/5				
1 2-Dichloroethene	72/388	X	X		
1,2-Dichloropropane	20/294	X	X		
2-Butanone	6/276				
2-Hexanone	3/374				
4-Methyl-2-pentanone	8/378				
Acetone	40/358	X			
Benzene	33/393	X		X	
Bromoform	2/394				
Carbon Disulfide	2/389				
Carbon Tetrachloride	18/393	X	X		
Chlorobenzene	5/394				
Chloroethane	13/393				
Chloroform	35/393	X	X		
Ethylbenzene	18/394	X		X	
Methylene Chloride	59/391	X	X		
Tetrachloroethene	80/391	X	X		
Toluene	32/394	X		X	
Toluene - D8[1]	5/5				
Total Xylenes	25/393	X		X	
Trichloroethene	100/392	X	X		
Vinyl Chloride	26/394	X	X		
Semivolatile Organic Compounds					
1 4-Dichlorobenzene	3/56	X	X		
2,4,5-Trichlorophenol	1/55				
2 4-Dimethylphenol	4/55				X
2-Chloronaphthalene	1/56				
2-Methylphenol	3/55				X
4-Methylphenol	11/55				X
4-Nitrophenol	1/53				
Acenaphthene	2/56				
Benzoic Acid	11/48				X
Bis(2-ethylhexyl)phthalate	16/56				X
Bromodichloromethane	1/394				
Bromofluorobenzene[1]	5/5				
Di-n-Butyl Phthalate	5/56				X
Diethyl Phthalate	11/56				X
Fluorene	1/56				
Naphthalene	9/56				X

Analyte	Detection Frequency	Total VOCs	Total Chlorinated VOCs	Total BTEX	Total SVOCs
Pentachlorophenol	3/55				X
Phenanthrene	3/56	X	X		X
Phenol	4/55				X
LHSU					
Volatile Organic Compounds					
1 1 1-Trichloroethane	1/64	X	X		
1 1-Dichloroethene	1/64	X	X		
Acetone	6/58	X			
Chlorobenzene	1/64	X	X		
Methylene Chloride	14/64	X	X		
Toluene	5/64	X		X	
Total Xylenes	1/64	X		X	
Semivolatile Organic Compounds					
Bis(2-ethylhexyl)phthalate	2/14				X
Di-n-Butyl Phthalate	1/14				X
Naphthalene	1/14				X

[1] not used in total VOC calculations because of infrequent analysis

Definitions

BTEX benzene, toluene, ethylbenzene, and xylenes
LHSU lower hydrostratigraphic unit
SVOCs semivolatile organic compounds
UHSU upper hydrostratigraphic unit
VOCs volatile organic compounds
X denotes that analyte was used to calculate total concentrations

Table 4-26
Results of UHSU Statistical Comparisons

Data Compared to Sitewide Background Data	Number of Analytes Identified as PCOCs using Statistical Inference Tests		
	Metals (Dissolved/Total)	Radionuclides (Dissolved/Total)	Other
All OU 7 UHSU Data[1]	14/25	2/2	1 (Nitrate/Nitrite)
Landfill UHSU Data	12/23	2/2	1 (Nitrite)
Downgradient UHSU Data	12/9	5/2	1 (Nitrate/Nitrite)

[1] Used to develop OU 7 PCOC list

Definitions

OU operable unit
PCOCs potential contaminants of concern
UHSU upper hydrostratigraphic unit

Table 4-27
Results of LHSU Statistical Comparisons

Data Compared to Sitewide Background Data	Number of Analytes Identified as PCOCs Using Inferential Statistical Tests		
	Metals (Dissolved/Total)	Radionuclides (Dissolved/Total)	Other
Downgradient OU 7 LHSU Data[1]	20/8	3/0	None
Upgradient LHSU Data	6/14	1/1	None

[1] Used to develop OU 7 PCOC list

Definitions

LHSU lower hydrostratigraphic unit
OU operable unit
PCOCs potential contaminant of concerns

Table 4-28
Summary of PCOCs by Media

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Dissolved Analytes (in water)					
Metals					
Aluminum					X
Antimony				X	X
Arsenic				X	X
Barium				X	X
Beryllium					X
Cadmium				X	X
Calcium				X	X
Chromium					X
Cobalt					X
Copper					X
Iron				X	X
Lead				X	X
Lithium				X	X
Magnesium				X	X
Manganese				X	X
Mercury					X
Molybdenum				X	X
Nickel				X	X
Potassium				X	X
Selenium				X	X
Silver					X
Sodium				X	X
Strontium				X	X
Thallium					X
Tin				X	X
Vanadium				X	
Zinc				X	X
Radionuclides					
Americium-241				X	
Gross Alpha				X	X
Gross Beta				X	X
Radium-226					X
Strontium-89,90				X	X
Uranium-235				X	X
Uranium-238				X	X
Total Analytes					
Metals					
Aluminum		X	X		X
Antimony				X	X
Arsenic	X	X	X	X	X
Barium	X	X	X	X	X
Beryllium			X		X

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Cadmium					X
Calcium	X	X	X	X	X
Chromium		X	X		X
Cobalt	X	X			X
Copper	X	X	X		X
Iron			X	X	X
Lead	X	X	X		X
Lithium				X	X
Magnesium	X		X	X	X
Manganese		X		X	X
Mercury					X
Molybdenum				X	X
Nickel		X	X	X	X
Potassium			X	X	X
Selenium	X	X	X	X	X
Silicon				X	X
Silver					X
Sodium	X	X	X	X	X
Strontium	X	X	X	X	X
Thallium				X	
Tin				X	X
Vanadium	X		X		X
Zinc	X	X	X	X	X
Radionuclides					
Americium-241	X	X		X	X
Cesium-137		X	X		X
Gross Beta	X	X		X	
Gross Alpha				X	
Radium-226	X	X			X
Radium-228		X			
Strontium-89,90	X	X		X	X
Tritium		X		X	X
Uranium-235	X	X		X	X
Uranium-238		X		X	
Volatile Organic Compounds					
1,1-Dichloroethane				X	X
1,1-Dichloroethene					X
1,1,1-Trichloroethane		X			X
1 1 2-Trichloroethane					X
1 2-Dichloroethane -D4					X
1 2-Dichloroethene					X
1 2-Dichloropropane					X
1,4-Dichlorobenzene					X
2-Butanone			X	X	X
2-Hexanone				X	X
4-Methyl-2-pentanone		X		X	X
Acetone				X	X

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Benzene				X	X
Bromodichloromethane					X
Bromofluorobenzene					X
Bromoform					X
Carbon Disulfide				X	X
Carbon Tetrachloride					X
Chlorobenzene					X
Chloroethane				X	X
Chloroform					X
Chloromethane				X	
Ethylbenzene				X	X
Methylene Chloride		X		X	X
o-Xylene				X	
Tetrachloroethene				X	X
Toluene -D8					X
Toluene		X	X	X	X
Total Xylenes		X		X	X
Trichloroethene				X	X
Vinyl Acetate				X	
Vinyl Chloride				X	X
Semivolatile Organic Compounds					
2-Chloronaphthalene					X
2-Methylnaphthalene	X			X	
2-Methylphenol					X
2,4-Dimethylphenol				X	X
2 4,5-Trichlorophenol					X
4-Methylphenol				X	X
4-Nitrophenol					X
Acenaphthene	X		X	X	X
Acenaphthylene	X		X		
Anthracene	X		X		
Benzo(a)anthracene	X	X	X		
Benzo(b)fluoranthene	X		X		
Benzo(k)fluoranthene	X		X		
Benzo(ghi)perylene	X		X		
Benzo(a)pyrene	X		X		
Benzoic Acid	X		X		X
Bis(2-chloroisopropyl)ether			X		
Bis(2-ethylhexyl)phthalate	X	X	X	X	X
Butyl Benzyl Phthalate	X	X			
Chrysene		X	X		
Di-n-Butyl Phthalate				X	X
Di-n-Octyl Phthalate	X	X			
Dibenz(a h)anthracene	X				
Dibenzofuran	X			X	
Diethyl Phthalate				X	X
Fluoranthene	X	X	X		

Analyte	Surface Soil[1]	Subsurface Geologic Materials[2]	Sediments	Surface Water[3]	Groundwater[4]
Fluorene	X		X	X	X
Ideno(1,2 3-cd)pyrene			X		
Naphthalene	X			X	X
Pentachlorophenol					X
Phenanthrene	X	X	X	X	X
Phenol					X
Pyrene	X	X	X		
Polychlorinated Biphenyls					
Aroclor-1254	X				
Aroclor-1260	X				
Water-Quality Parameters					
Chloride					X
Cyanide					X
Fluoride					X
Nitrate/Nitrite	X	X			X
Nitrite				X	X
Sulfate					X
Total Dissolved Solids					X

[1] combined PCOCs for IHSS 203 and East Landfill Pond soils

[2] combined PCOCs for surficial deposits and bedrock materials

[3] combined PCOCs for seep, East Landfill Pond, and groundwater intercept system discharge

[4] combined PCOCs for UHSU and LHSU groundwater

Definitions

LHSU lower hydrostratigraphic unit

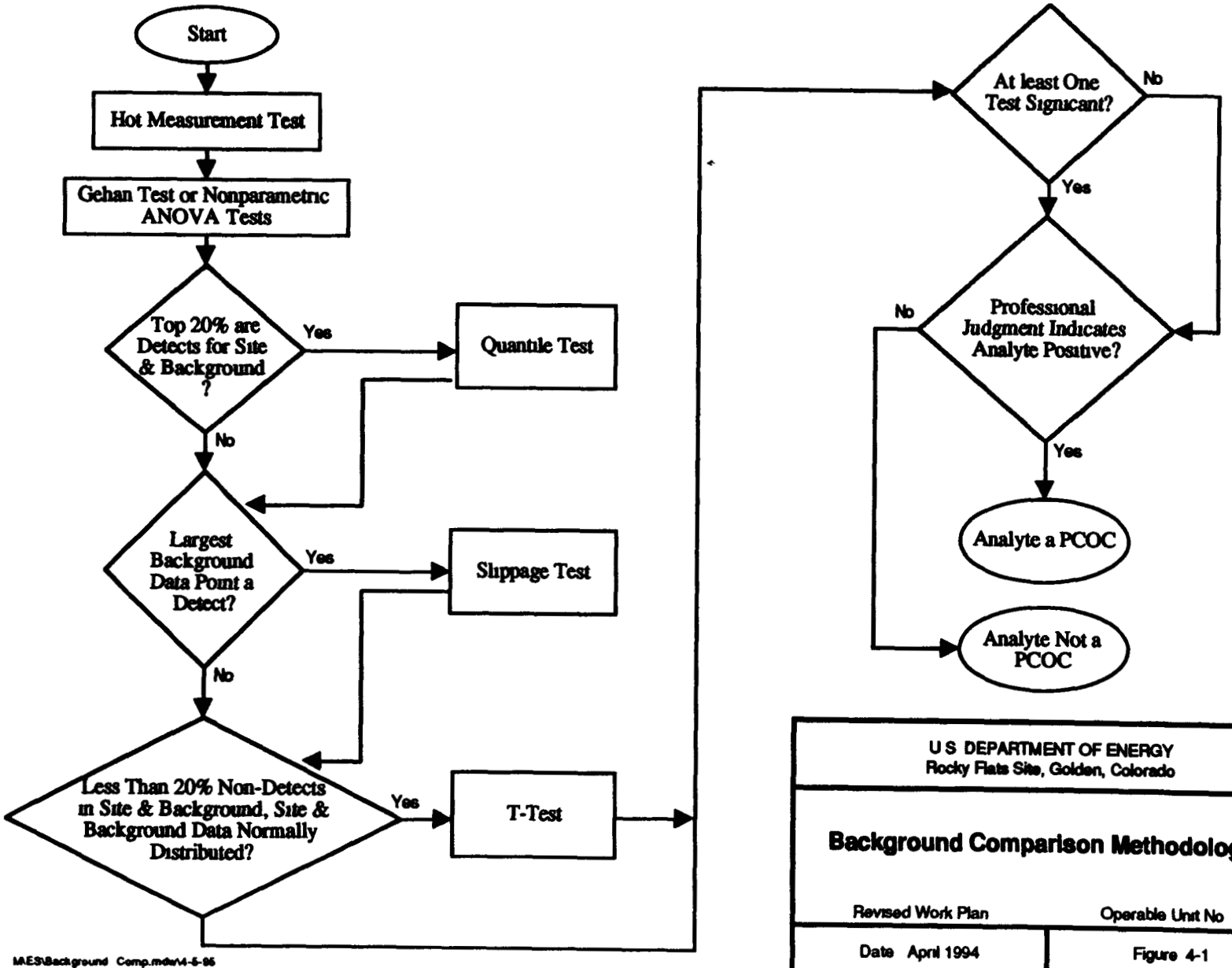
PCOCs potential contaminants of concern

UHSU upper hydrostratigraphic unit

X denotes that analyte was identified as a PCOC

Section 4

Figures



MES\Background Comp.mdw\4-5-95

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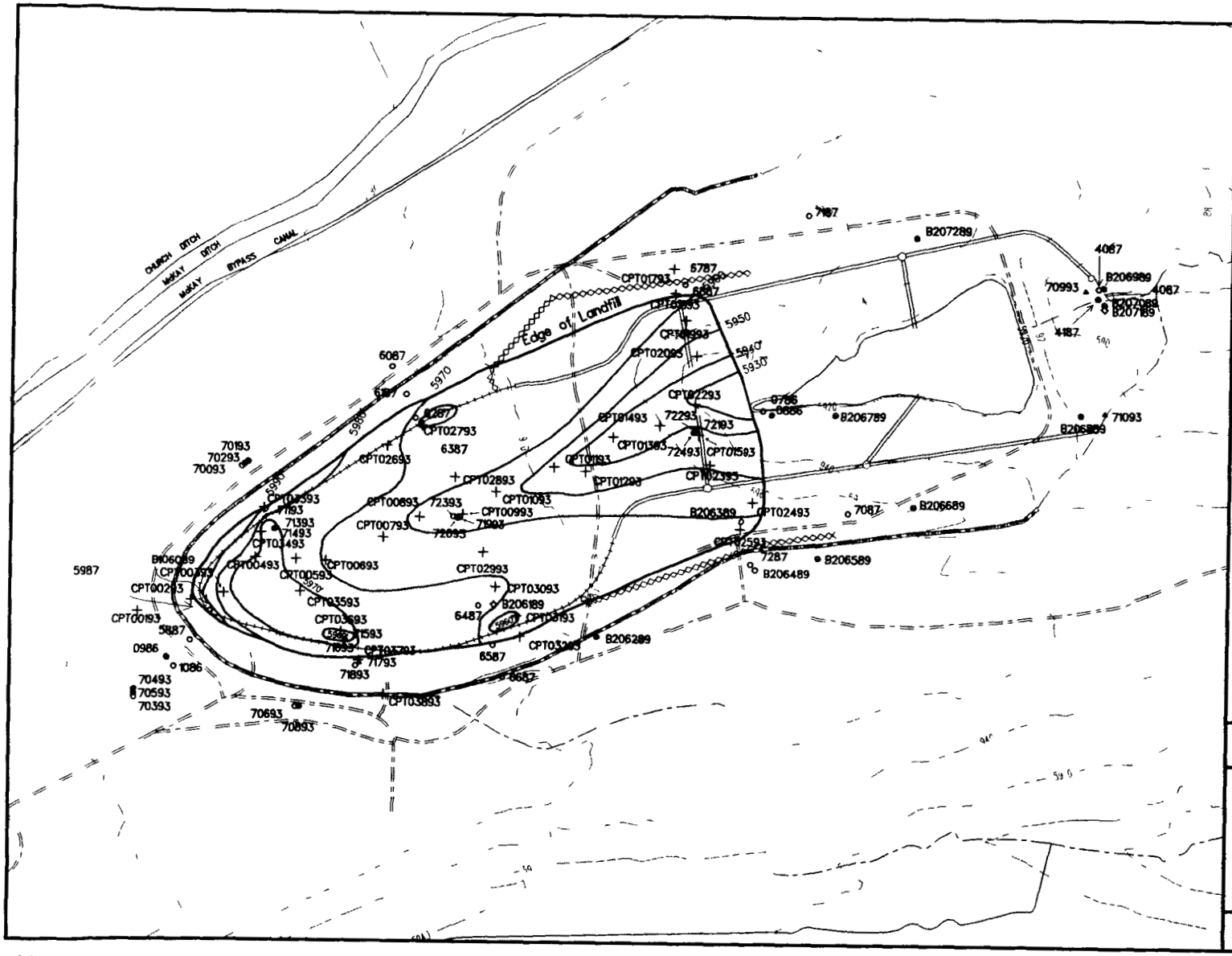
Rocky Flats Site, Golden, Colorado

Background Comparison Methodology

Revised Work Plan | Operable Unit No 7

Date April 1994 | Figure 4-1



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- CPT Location
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Elevation Contour (feet above mean sea level)

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

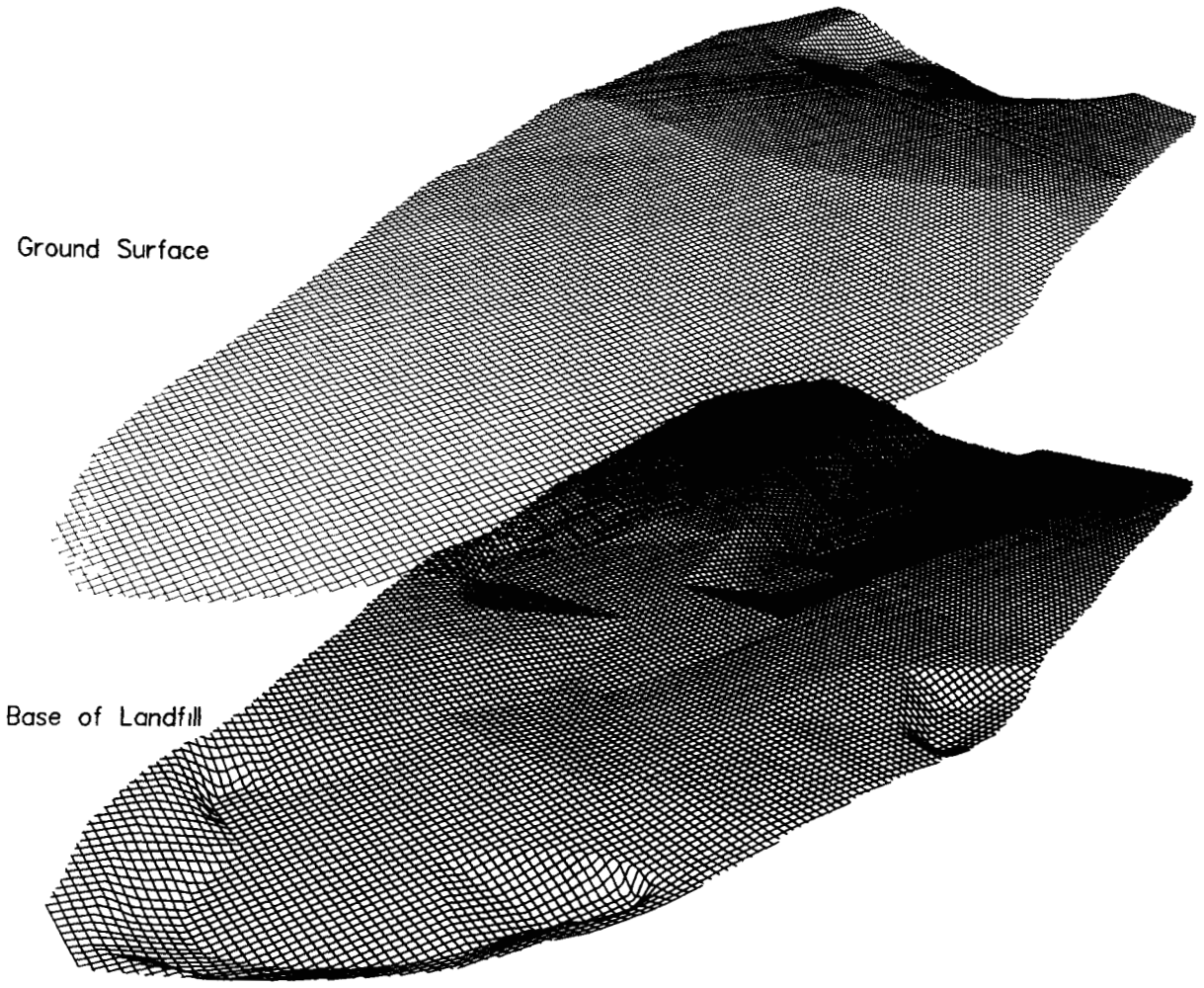
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Elevation of Base of Landfill

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-2

04/11/94 LANDBASE.MAP



Note Surfaces were generated using ARC/INFO TIN modeling software Input data was obtained from surface topography of the OU 7 area and base of landfill topography The base of landfill was obtained from contouring data from CPT and well locations indicating the contact between weathered bedrock and trash

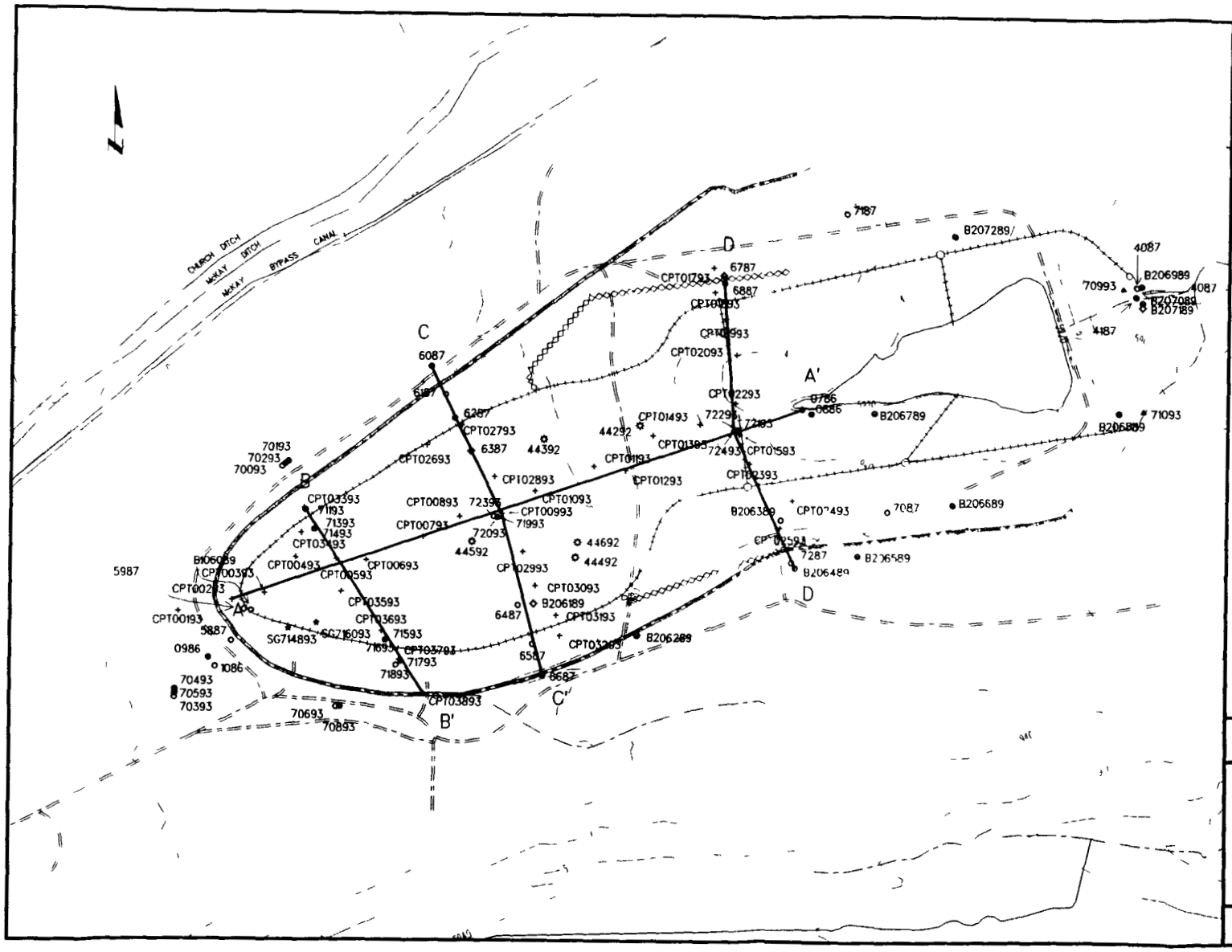
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Surfaces of Landfill Used to Calculate Volume of Waste Material

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-3

04/11/94 SURFACESMAP



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- Gas Venting Well
- CPT Location
- IHSS 203 Soil Gas Sampling Location
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- Gas Concentration Cross-Section

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

Landfill Gas Concentration Cross-Section Location Map

Revised Work Plan | Operable Unit No. 7

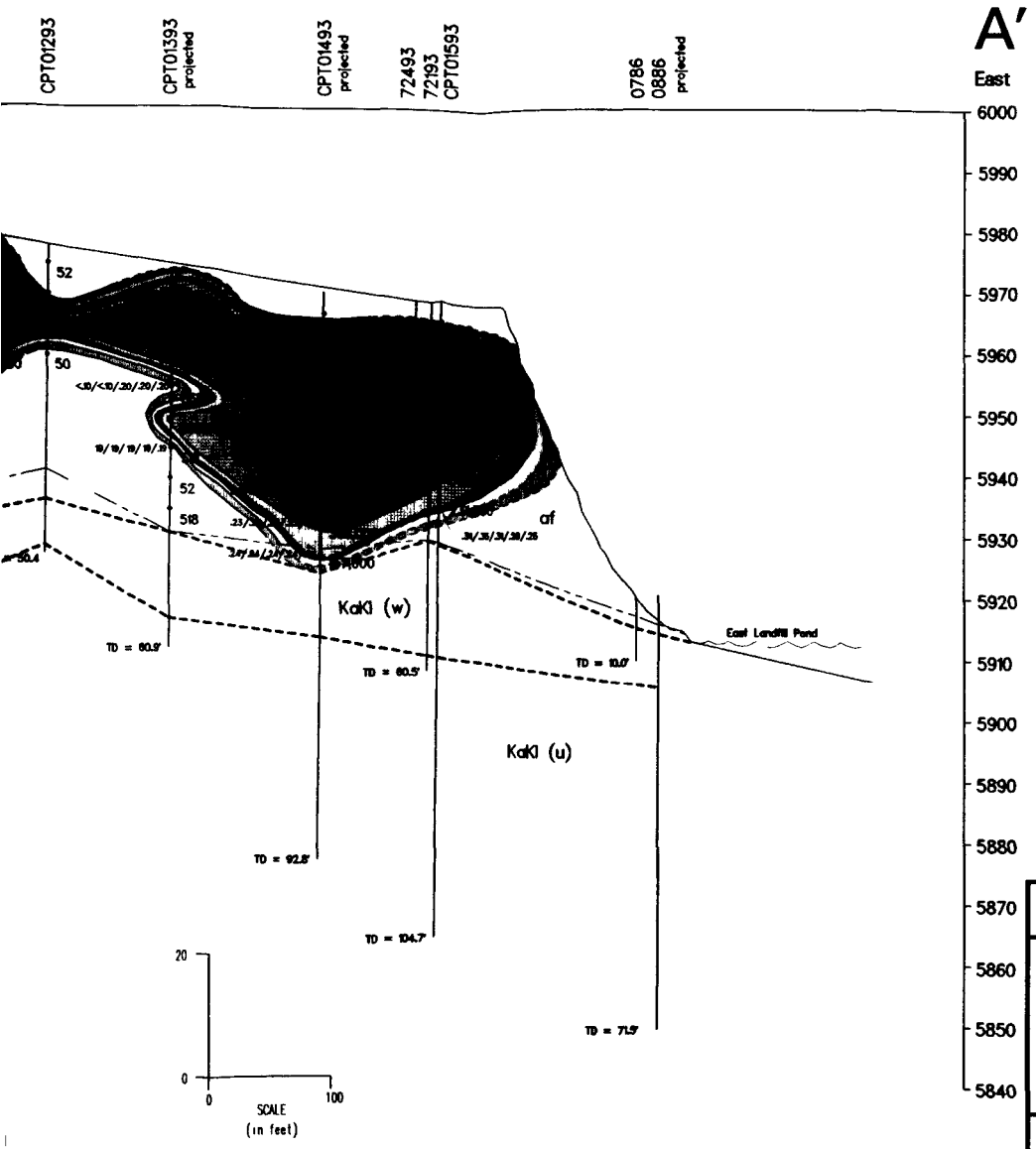
Date: April 1994 | Figure 4-4

03/28/94 GASPROFLEMAP

NOTICE:

Figure 4-5 through figure 4-6 have been divided into two parts but only the first page lists the figure number.

The Administrative Record Staff

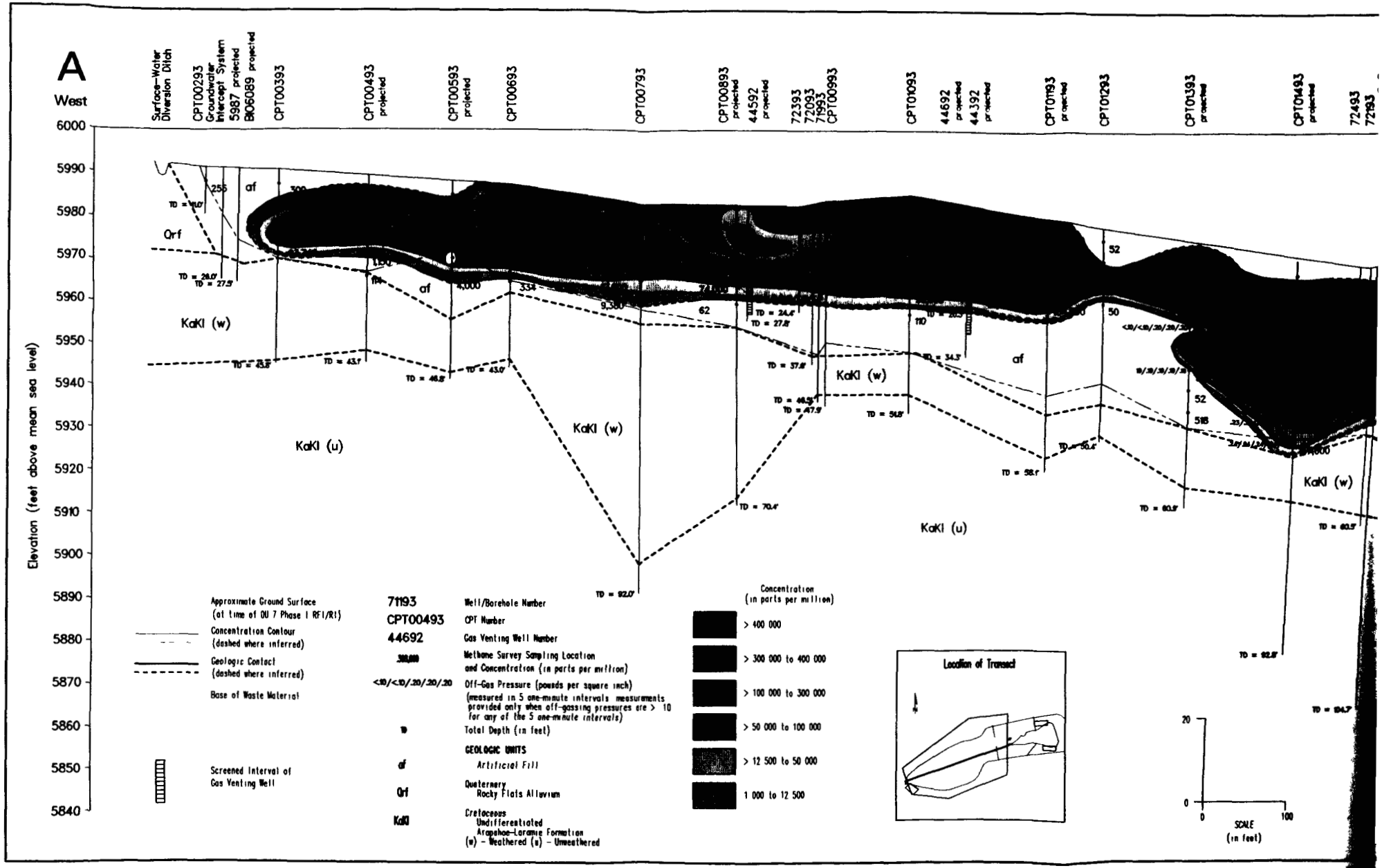


U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

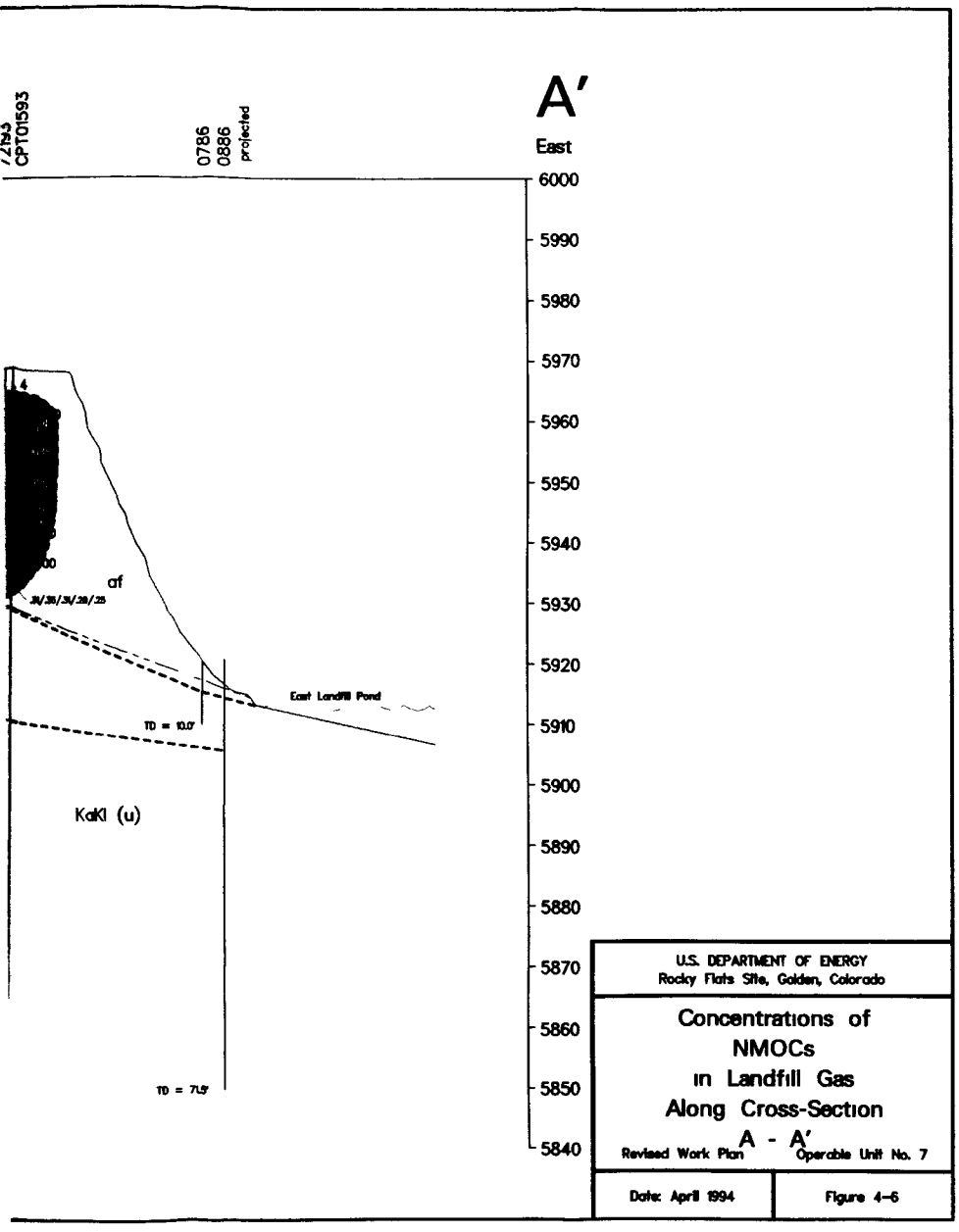
Concentrations of Methane in Landfill Gas Along Cross-Section A - A′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-5



04/8/94 AAMETHMAP

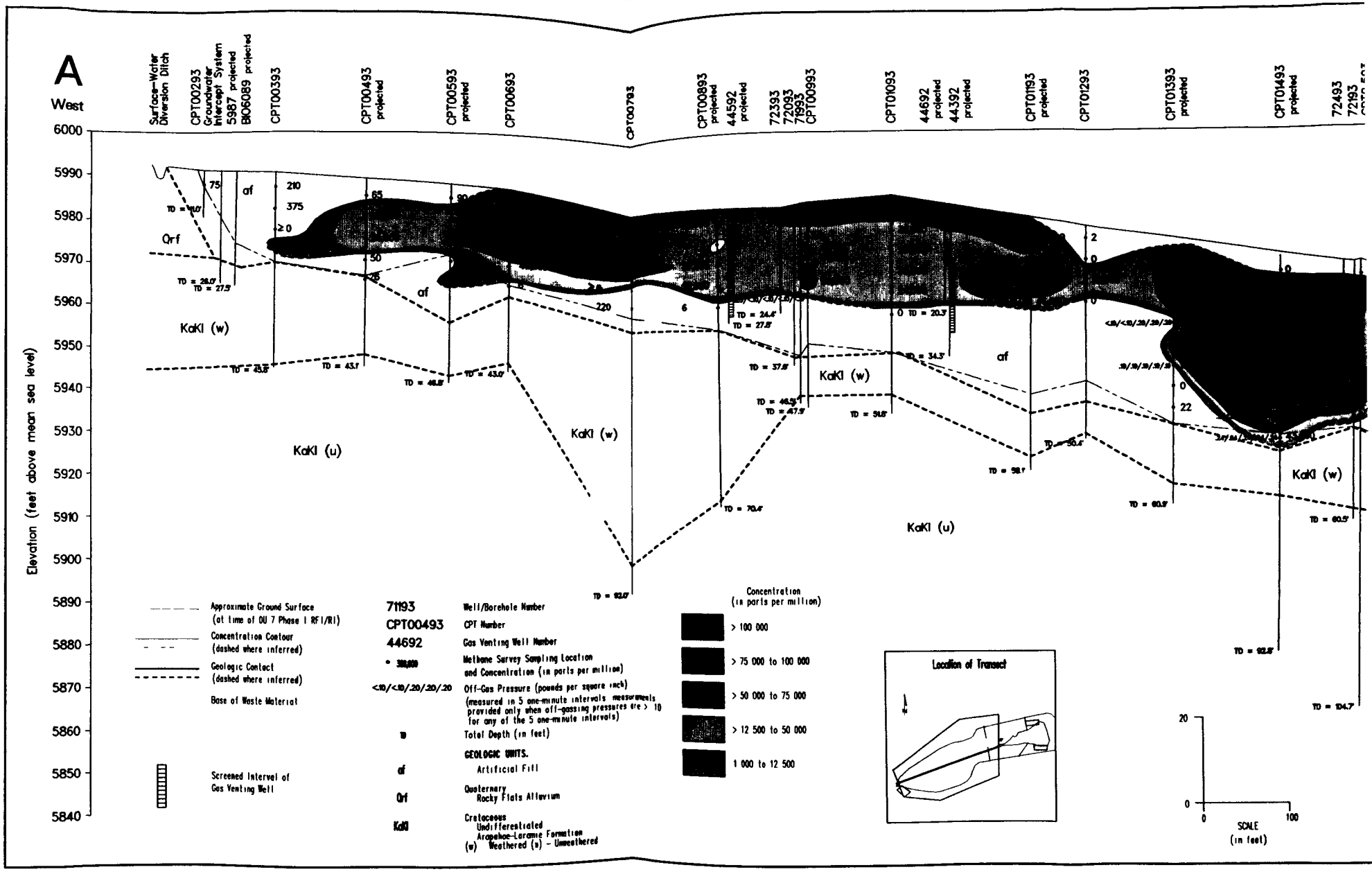


U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

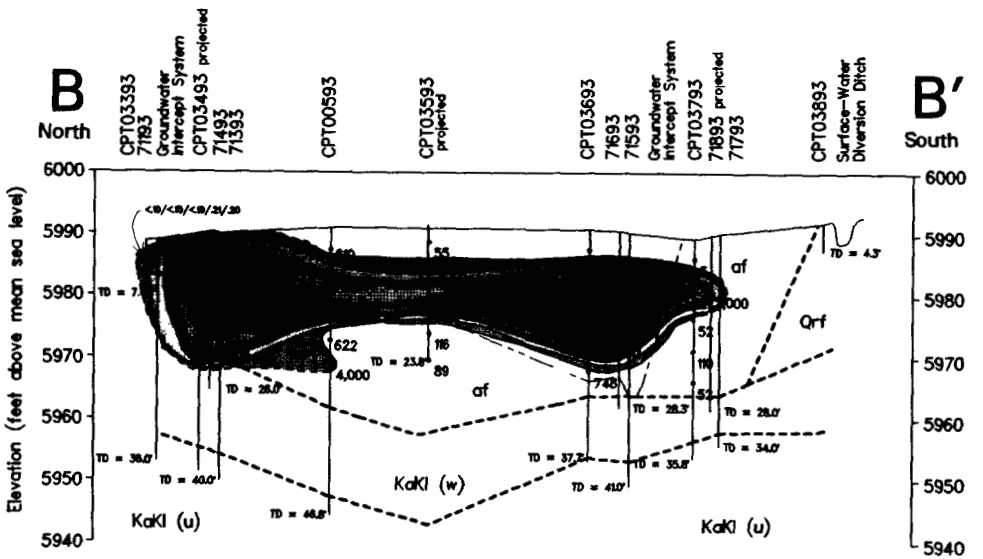
Concentrations of NMOCs in Landfill Gas Along Cross-Section A - A′

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-6



04/11/94 AANOMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

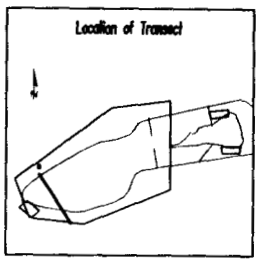
Base of Waste Material

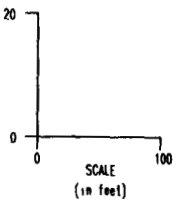
Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
• 300,000	Methane Survey Sampling Location and Concentration (in parts per million)
<10/<10/20/20/20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
	GEOLOGIC UNITS
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) – Weathered (u) Unweathered

Concentration (in parts per million)

- > 400 000
- > 200 000 to 400 000
- > 100 000 to 200 000
- > 50 000 to 100 000
- > 12 500 to 50 000
- 1 000 to 12 500





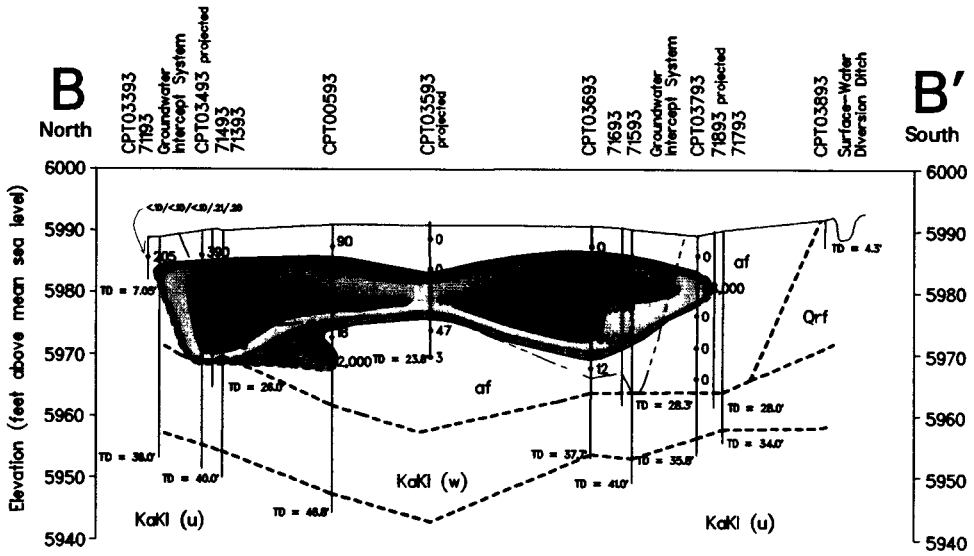
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Methane in Landfill Gas Along Cross-Section B - B′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-7

04/11/94 BBMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

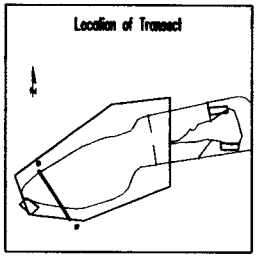
Base of Waste Material

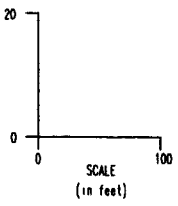
Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
390,000	Methane Survey Sampling Location and Concentration (in parts per million)
<.10/<.10/.20/.20/.20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
	GEOLOGIC UNITS
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered (u) - Unweathered

Concentration (in parts per million)

- > 75 000
- > 50 000 to 75 000
- > 12 500 to 50 000
- 1 000 to 12 500





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

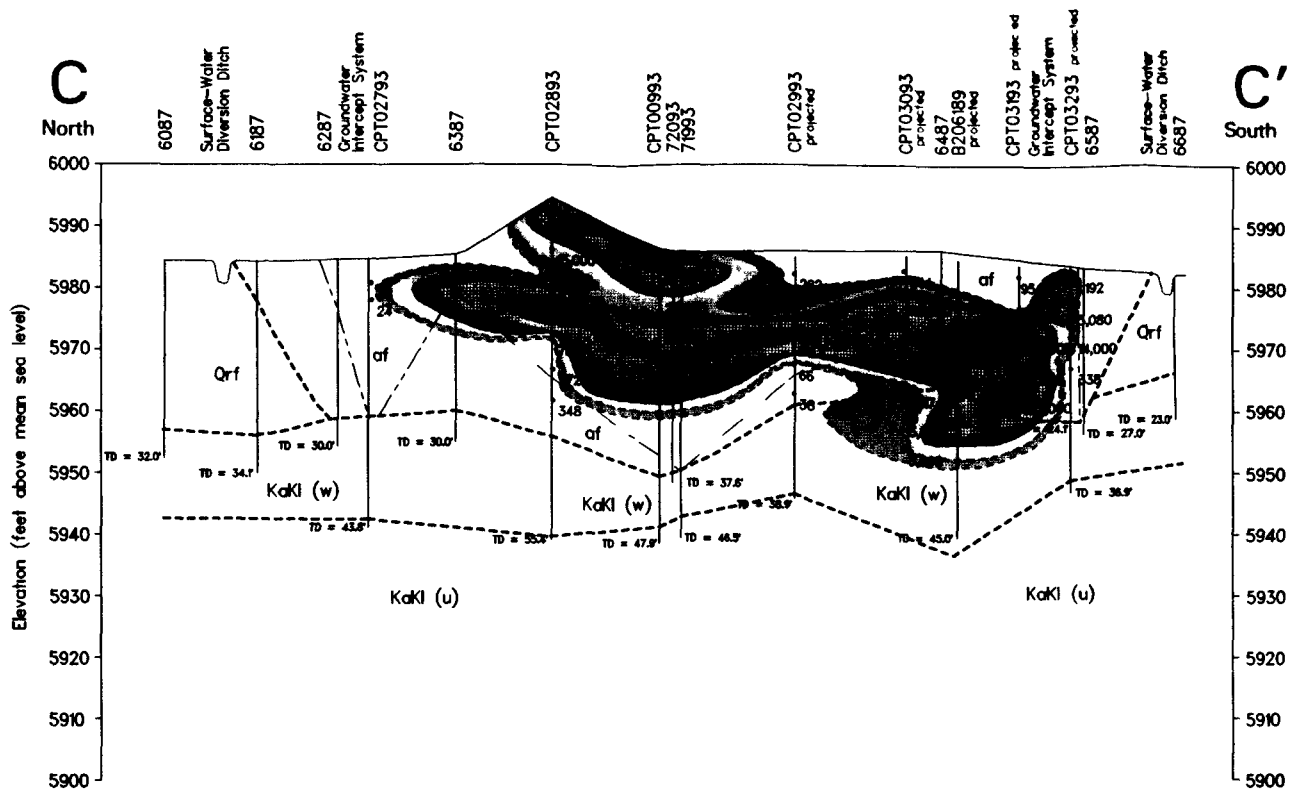
Concentrations of NMOCs in Landfill Gas Along Cross-Section B - B′

Revised Work Plan — Operable Unit No. 7

Date: April 1994

Figure 4-8

04/11/94 BENONMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

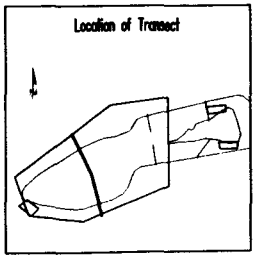
Base of Waste Material

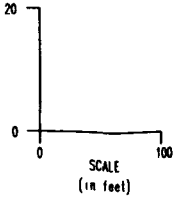
Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
• 300,000	Methane Survey Sampling Location and Concentration (in parts per million)
<.10/<.10/.20/.20/.20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
GEOLOGIC UNITS	
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) Weathered (u) – Unweathered

Concentration (in parts per million)

- > 300 000
- > 200 000 to 300 000
- > 100 000 to 200 000
- > 50 000 to 100 000
- > 12 500 to 50 000
- 1 000 to 12 500





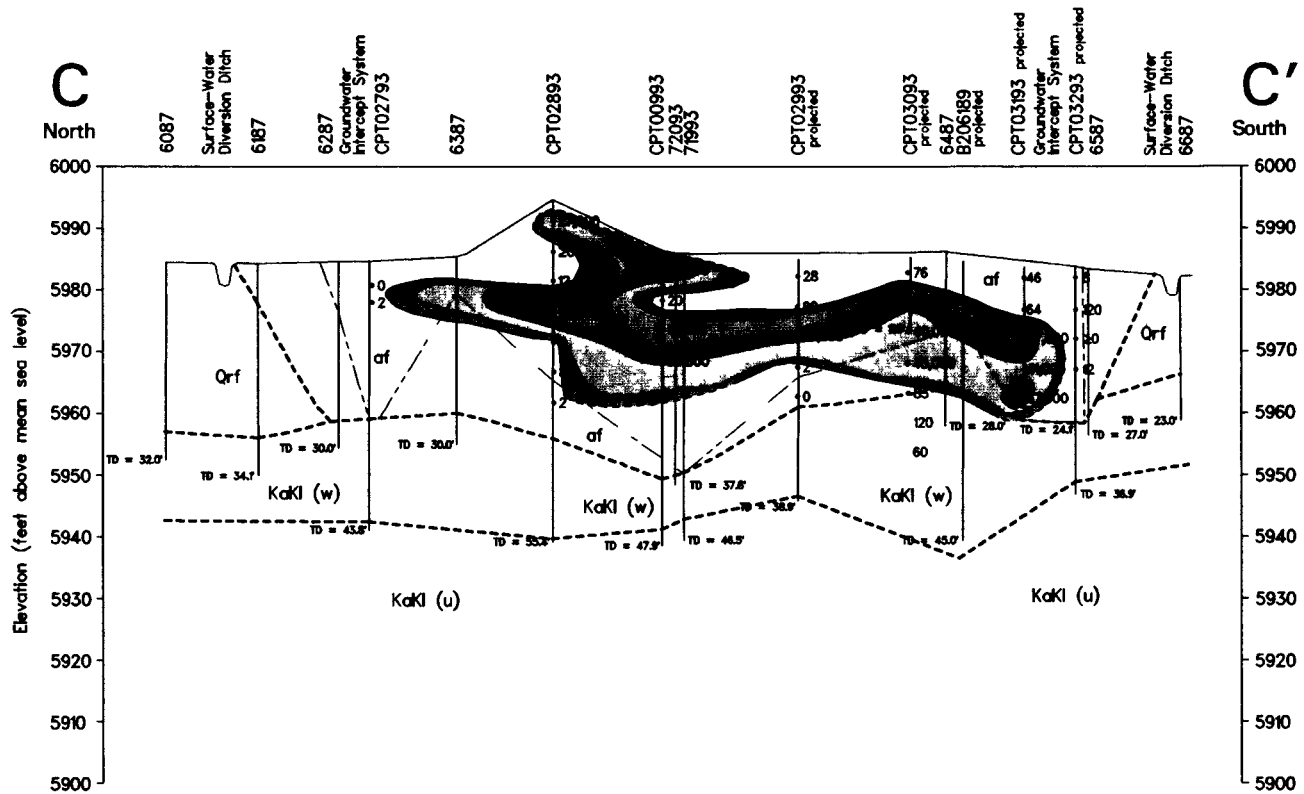
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of Methane in Landfill Gas Along Cross-Section C - C′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-9

04/11/94 COMETHLMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

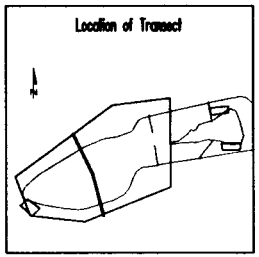
Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
• 300,000	Methane Survey Sampling Location and Concentration (in parts per million)
<.10/<.10/.20/.20/.20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
	GEOLOGIC UNITS
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered (u) - Unweathered

Concentration (in parts per million)

- > 75 000
- > 50 000 to 75 000
- > 12 500 to 50 000
- 1 000 to 12 500

Location of Transect



20
0
0
100
SCALE (in feet)

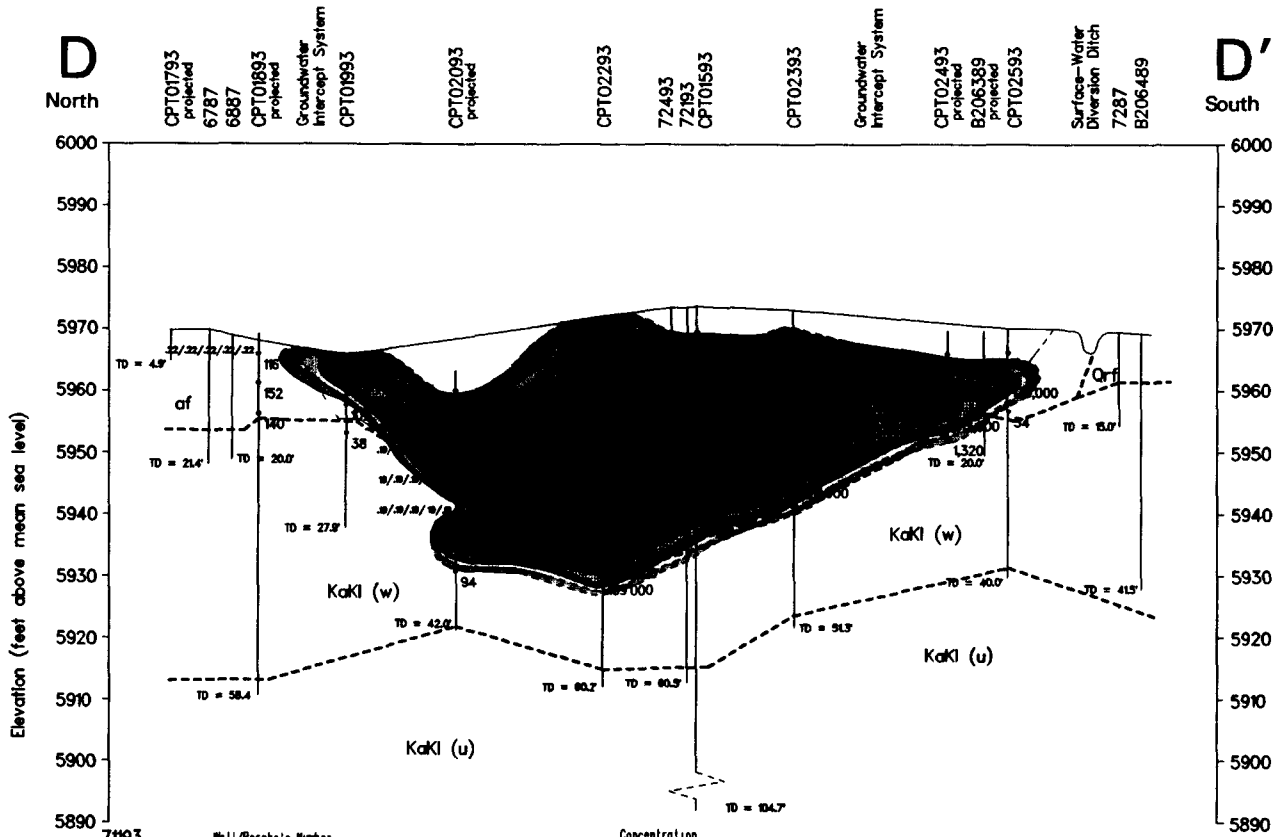
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of NMOCs in Landfill Gas Along Cross-Section C - C′

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-10

04/11/94 CONDMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
• 300,000	Methane Survey Sampling Location and Concentration (in parts per million)
<10/<10/20/20/20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
GEOLOGIC UNITS	
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered (u) - Unweathered

Concentration (in parts per million)

- > 400 000 to 500 000
- > 200 000 to 400 000
- > 100 000 to 200 000
- > 50 000 to 100 000
- > 12 500 to 50 000
- 1 000 to 12 500

Location of Transect

N

20
0
0
100
SCALE (in feet)

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

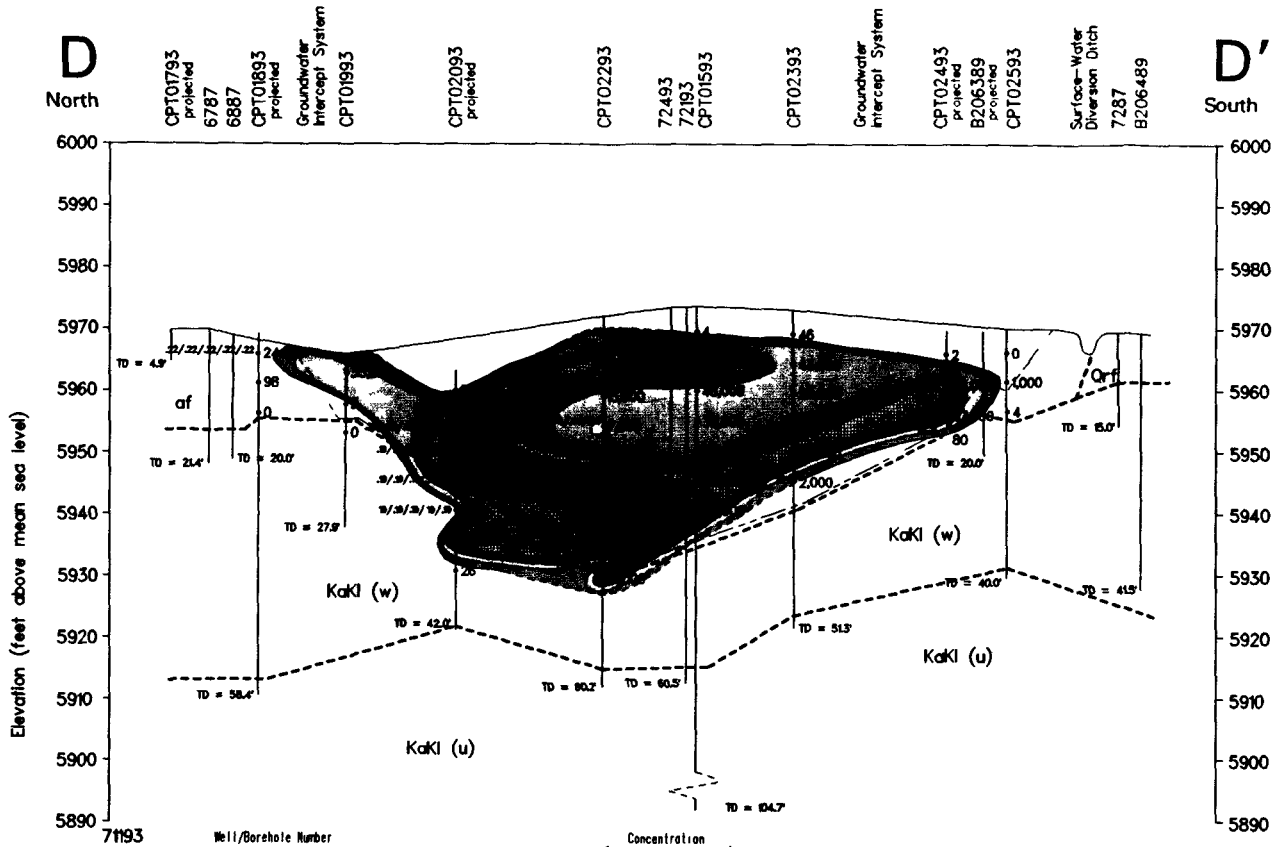
Concentrations of Methane in Landfill Gas Along Cross-Section D - D′

Revised Work Plan — Operable Unit No. 7

Date: April 1994

Figure 4-11

04/11/94 DOMETHMAP



Approximate Ground Surface (at time of OU 7 Phase I RFI/RI)

Concentration Contour (dashed where inferred)

Geologic Contact (dashed where inferred)

Base of Waste Material

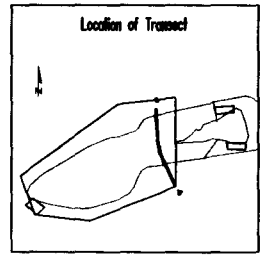
Screened Interval of Gas Venting Well

71193	Well/Borehole Number
CPT00493	CPT Number
44692	Gas Venting Well Number
• 30,000	Methane Survey Sampling Location and Concentration (in parts per million)
<10/<10/20/20/20	Off-Gas Pressure (pounds per square inch) (measured in 5 one-minute intervals measurements provided only when off-gassing pressures are > 10 for any of the 5 one-minute intervals)
TD	Total Depth (in feet)
	GEOLOGIC UNITS
af	Artificial Fill
Qrf	Quaternary Rocky Flats Alluvium
KaKl	Cretaceous Undifferentiated Arapahoe-Laramie Formation (w) - Weathered (u) Unweathered

Concentration (in parts per million)

- > 100 000
- > 75 000 to 100 000
- > 50 000 to 75 000
- > 12 500 to 50 000
- 1 000 to 12 500

Location of Transect



20
0
0
100
SCALE (in feet)

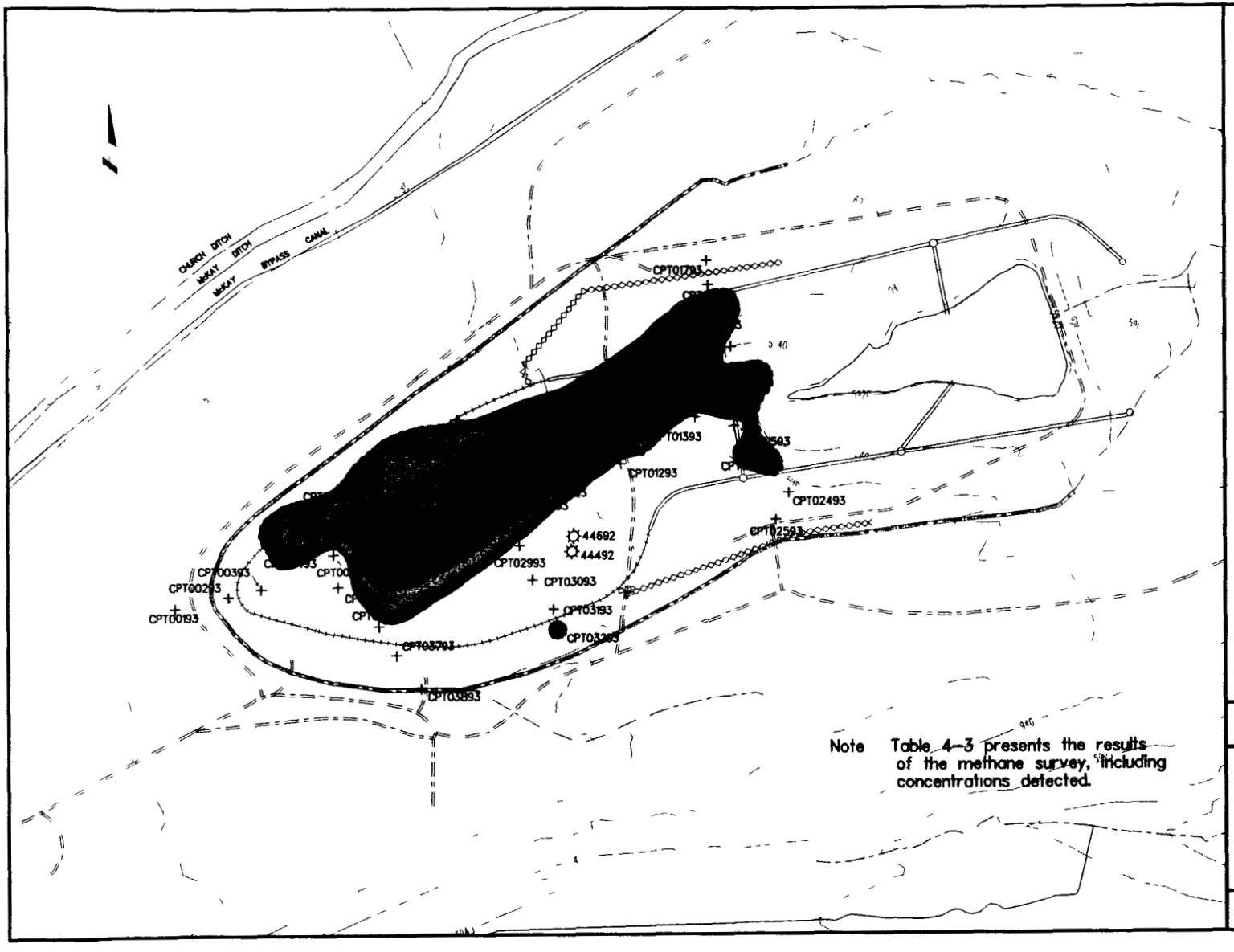
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Concentrations of NMOCs in Landfill Gas Along Cross-Section D - D'

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-12

04/11/94 DDNONMETH.MAP



EXPLANATION

- + CPT Location
- Gas Venting Well
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in parts per million

- > 400,000
- 200,000 to 400,000
- 100,000 to 200,000
- 10,000 to 100,000
- 1,000 to 10,000

0 Feet 250 500

Topographic Contour Interval = 20 Feet

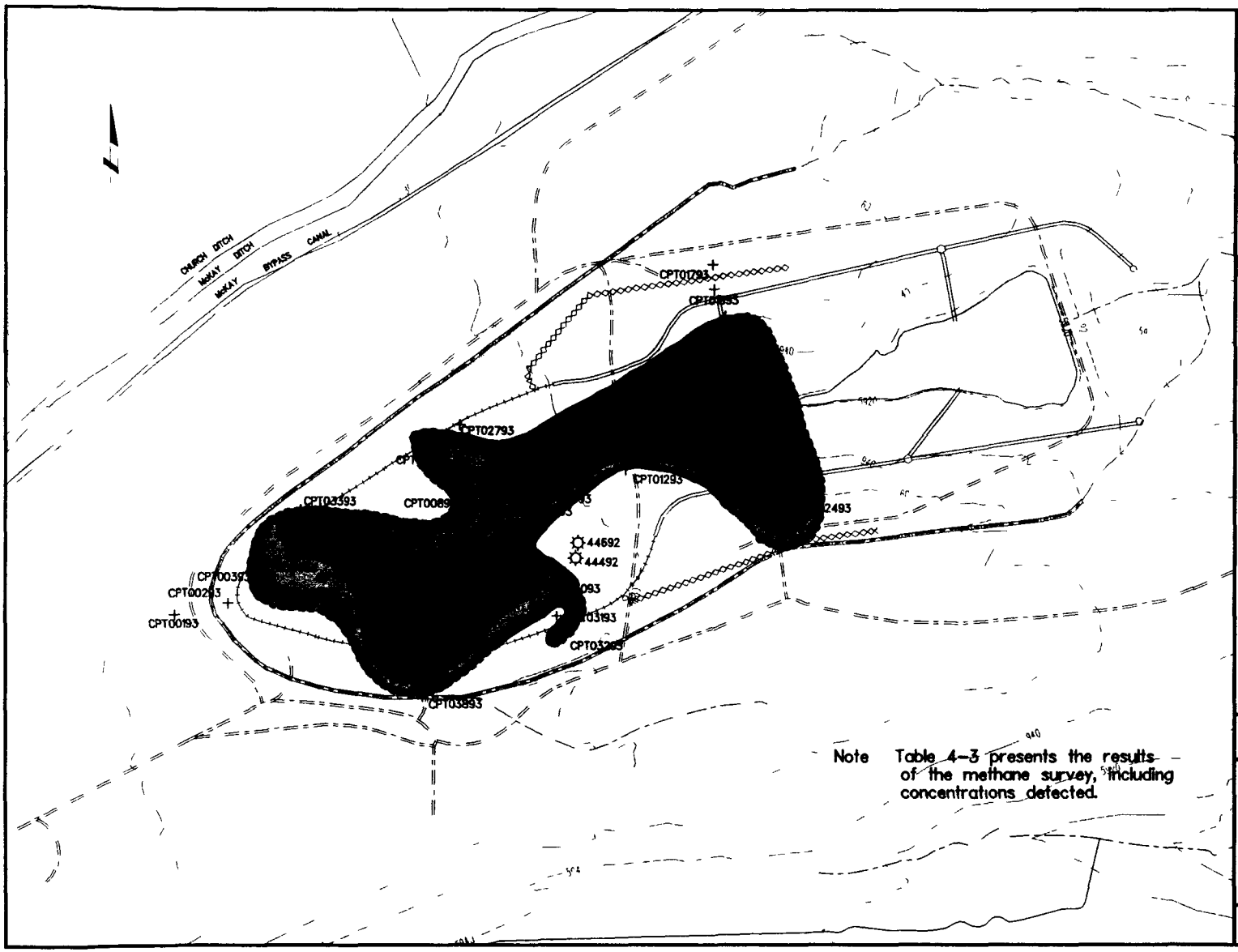
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Methane Concentrations in Landfill Gas at Three Feet Below Ground Surface

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-13

04/12/94 METHGFT.MAP



EXPLANATION

+ CPT Location

Gas Venting Well

Ditch and Drainage Feature

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall

Groundwater Intercept System
(perforated)
(non-perforated)

Concentration Contour
(dashed where inferred)

Concentrations in parts per million

- > 400,000
- 200,000 to 400,000
- 100,000 to 200,000
- 10,000 to 100,000
- 1,000 to 10,000

0 Feet 250 500

Topographic Contour Interval = 20 Feet

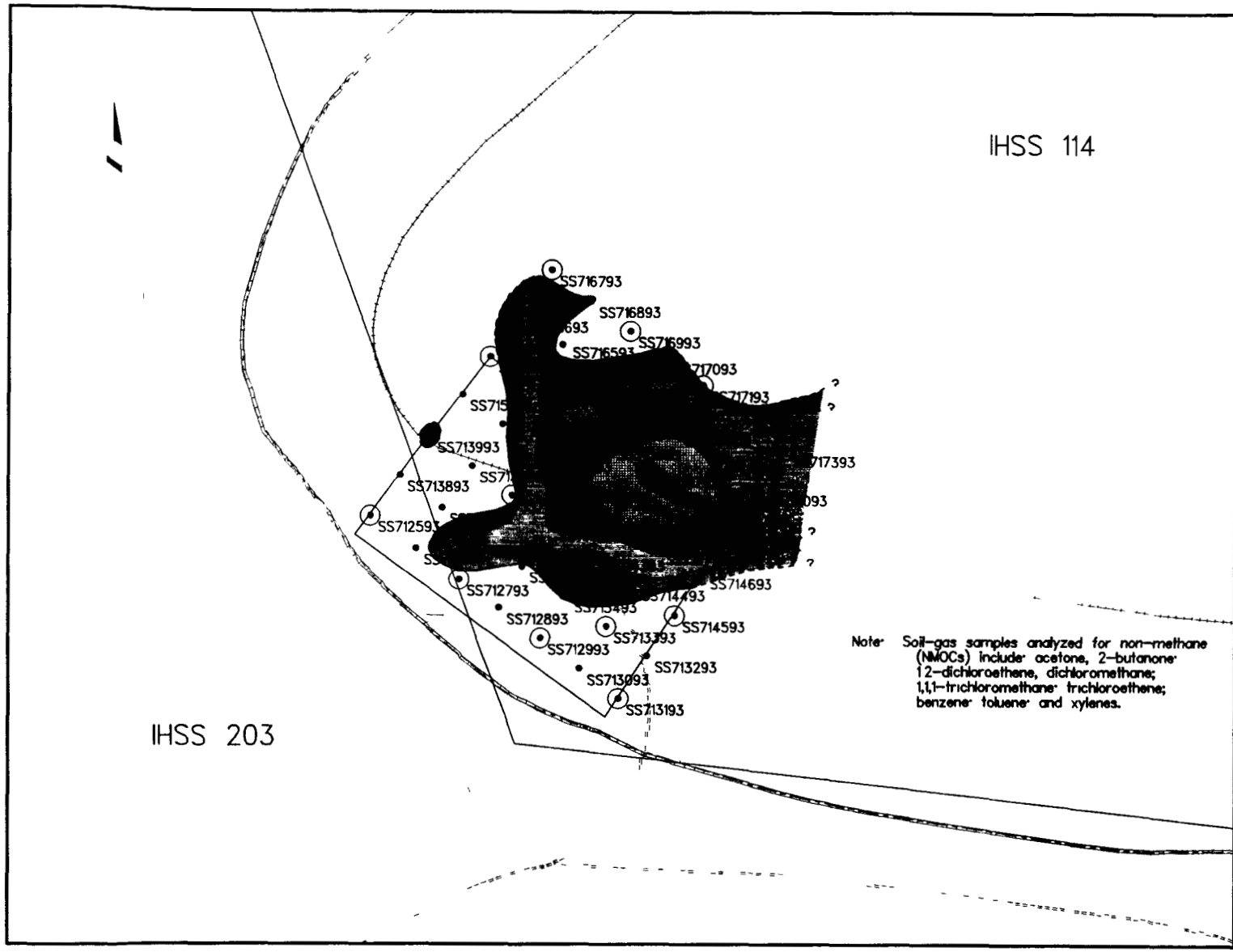
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Methane Concentrations in Landfill Gas at Eight Feet Below Ground Surface

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-14

04/12/94 METHRFT.MAP



EXPLANATION

- Surface Soil and Soil-Gas Sampling Location
- Additional Surface Soil and Soil-Gas Sampling Location
- Subsurface Soil Sampling Location
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in milligrams per liter

- > 100 mg/L
- 50 – 100 mg/L
- 25 – 50 mg/L
- 10 – 25 mg/L
- 5 – 10 mg/L

0 Feet 50 100

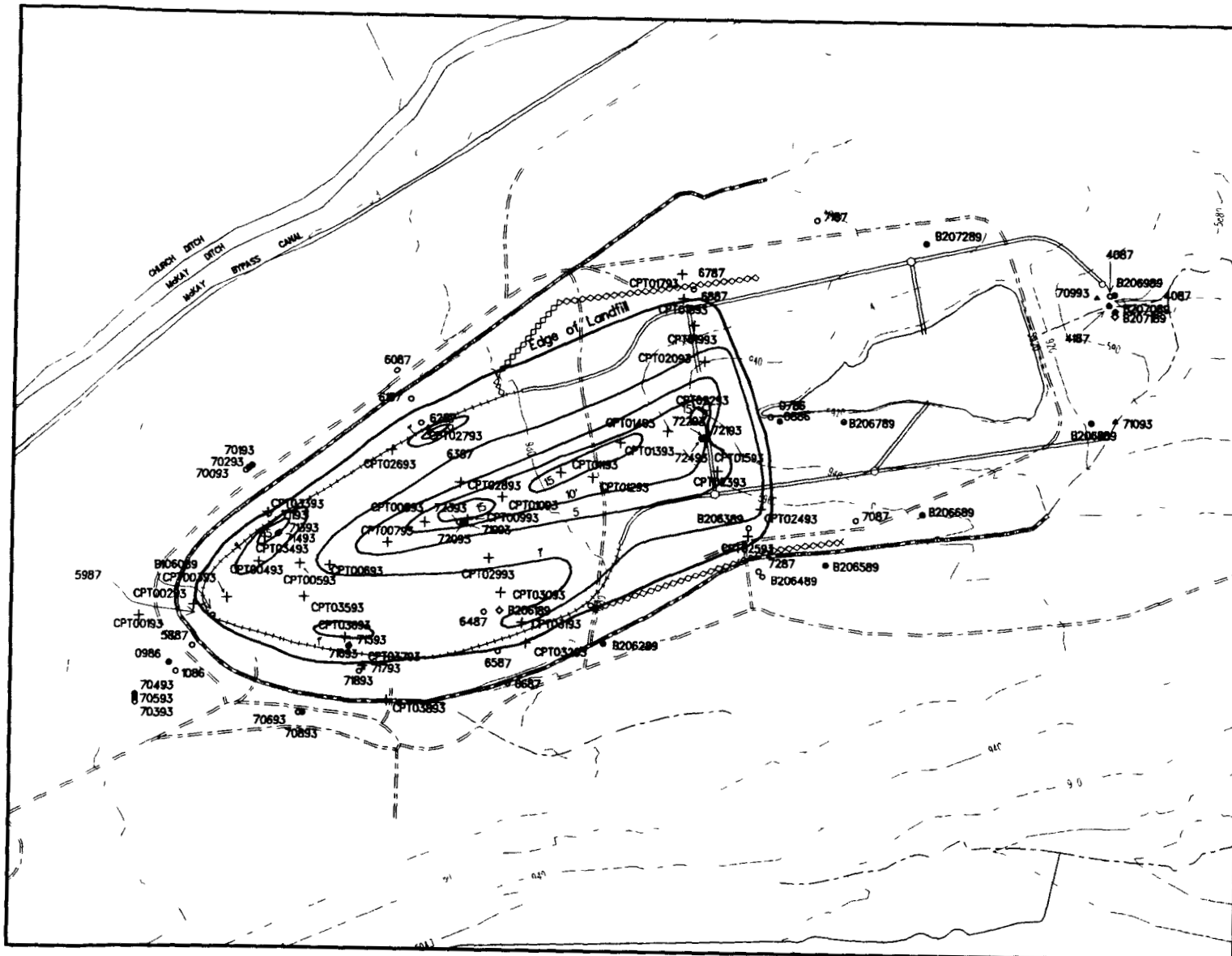
Topographic Contour Interval = 20 Feet

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

Concentrations of NMOCs in Soil Gas at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-15



EXPLANATION

- Alluvial Well
- Weathered Bedrock Well
- Unweathered Bedrock Well
- Abandoned Well
- Borehole
- CPT Location
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Thickness Contour (in feet)

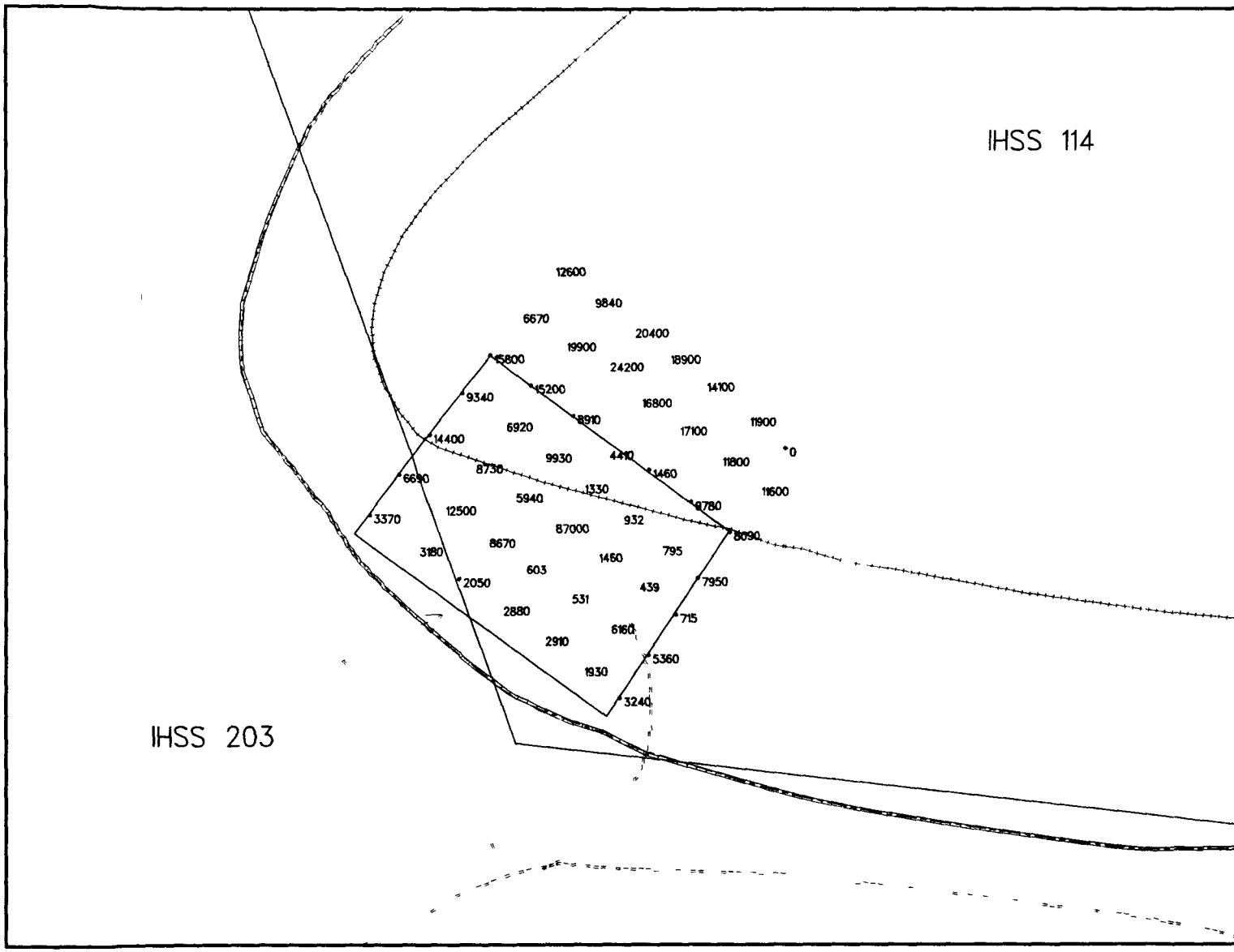
U.S. DEPARTMENT OF ENERGY
Rocky Flats Site, Golden, Colorado

Isopach Map of Saturated Landfill Waste

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-16

04/12/94 LANDISO.MAP



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992, EG&G 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-4 for sample location numbers.

0 Feet 50 100

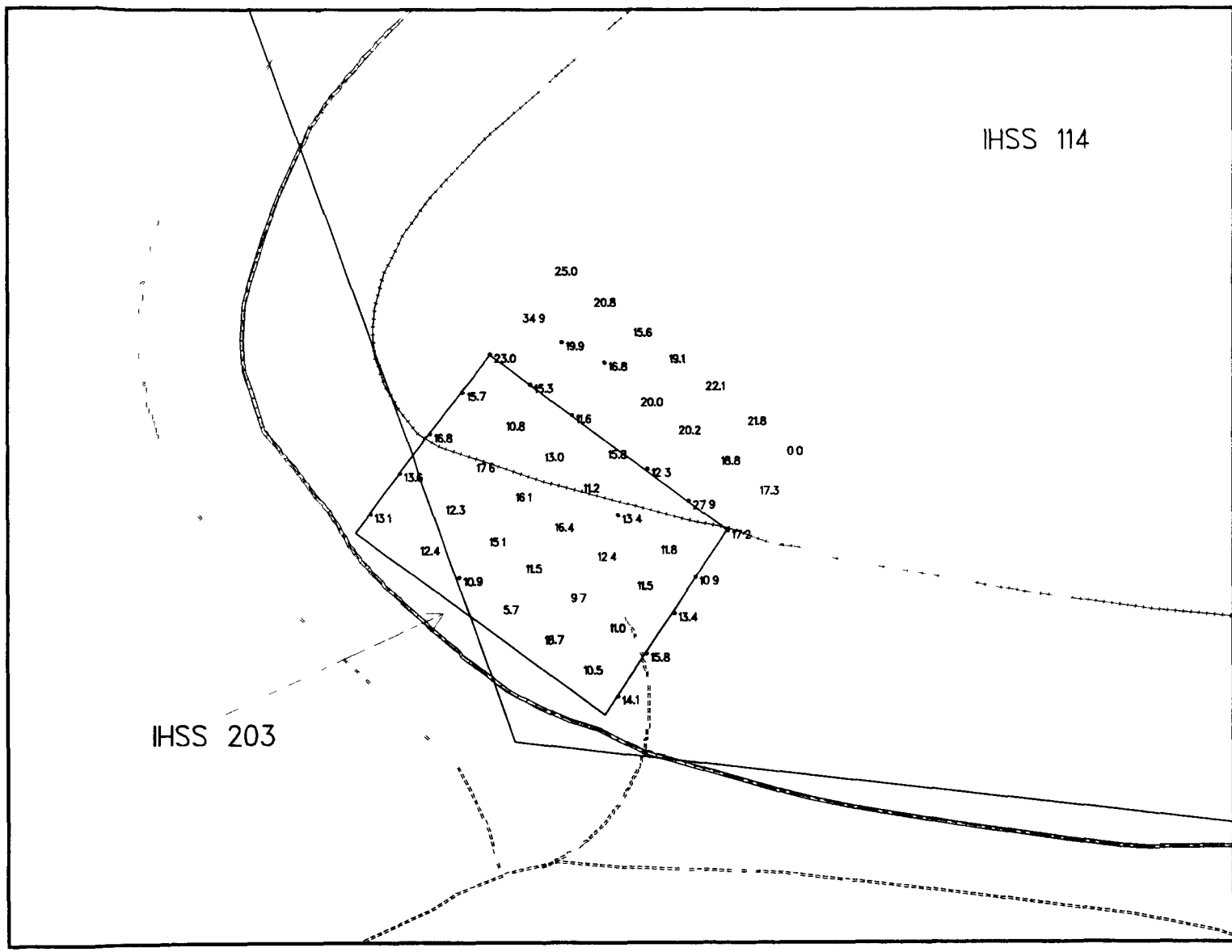
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Calcium Concentrations at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-17



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 30 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-4 for sample location numbers

N

0 Feet 50 100

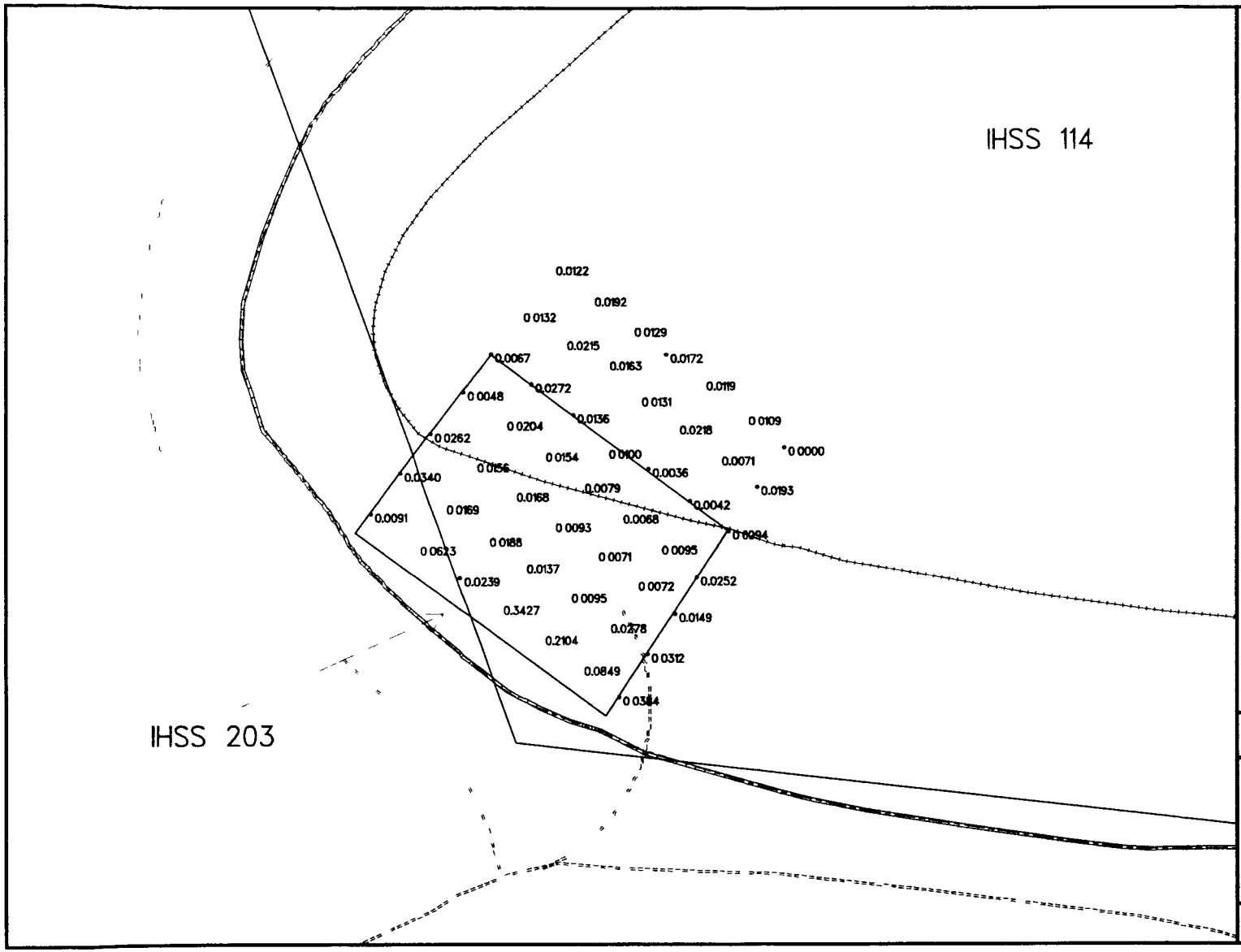
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Copper Concentrations at IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-18



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 0.058 pCi/g (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Activity exceeding the UTL 99/99 are posted in red.

Refer to Figure C-4 for sample location numbers.

N

0 Feet 50 100

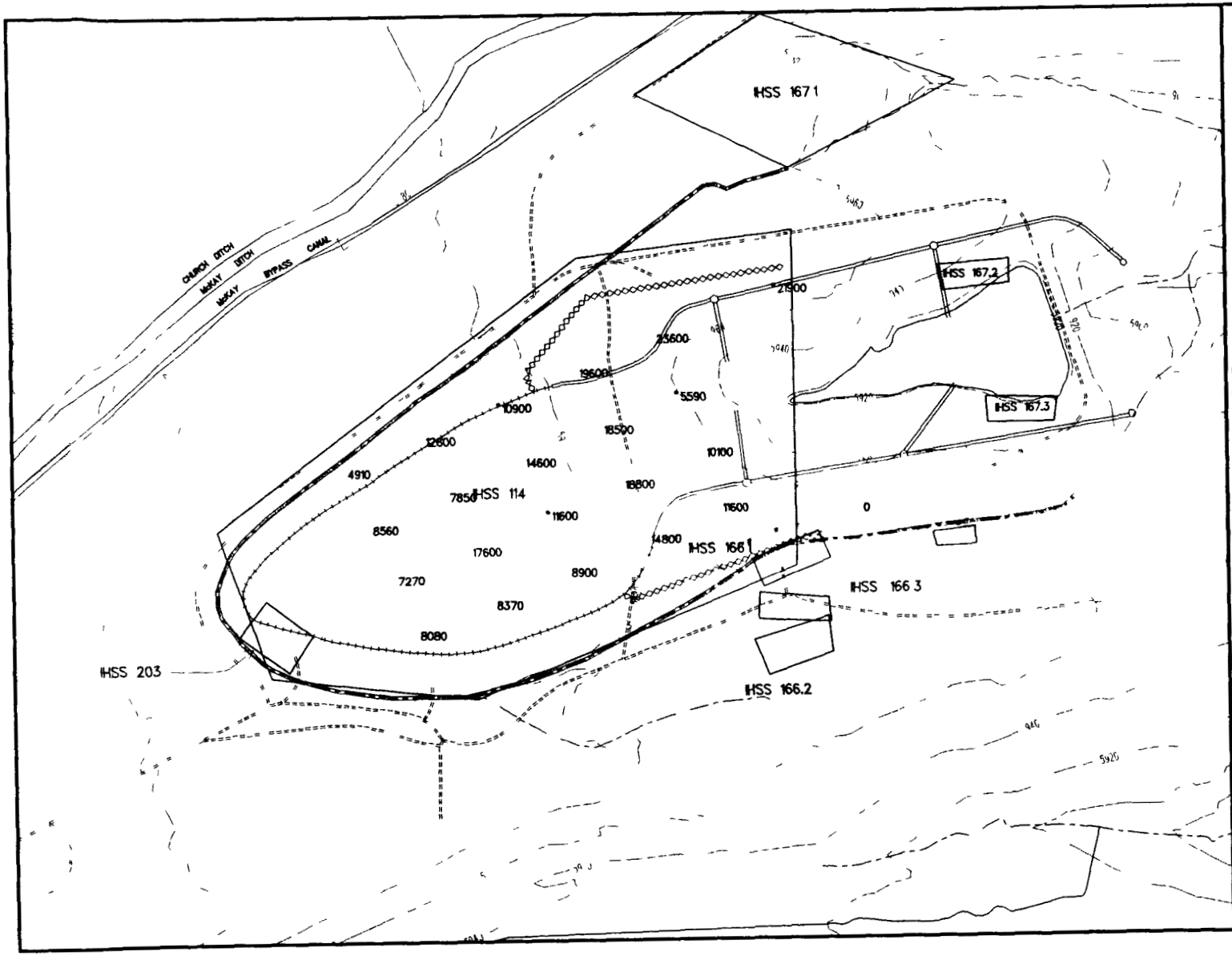
Topographic Contour Interval = 20 Feet

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

Surface Soil
(0 to 2 inches)
Americium-241 Activity
at
IHSS 203

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-19



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-6 for sample location numbers.

N

0 Feet 250 500

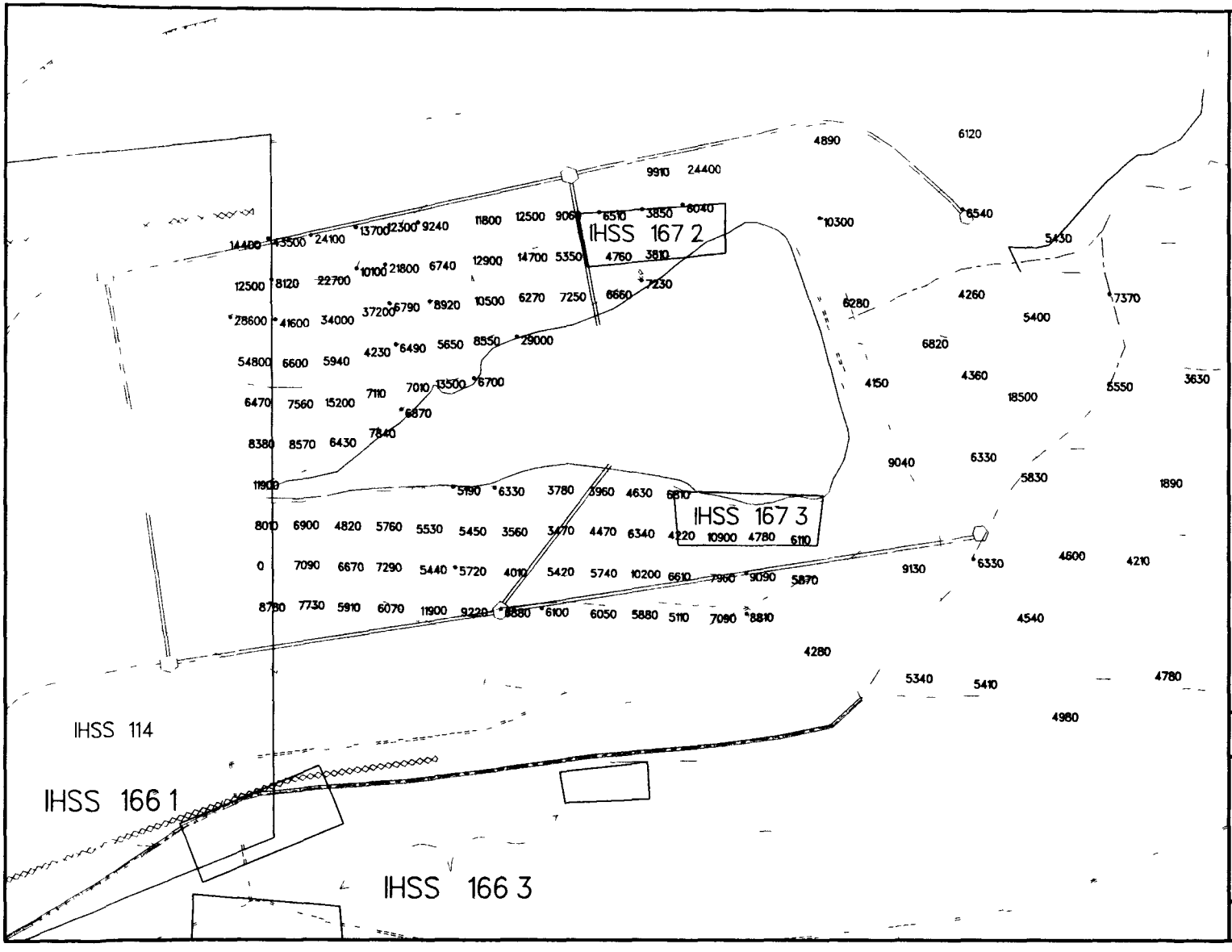
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Calcium Concentrations at IHSS 114

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-20



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note UTL 99/99 = 16659 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red

Refer to Figure C-5 for sample location numbers.

N

0 Feet 120 240

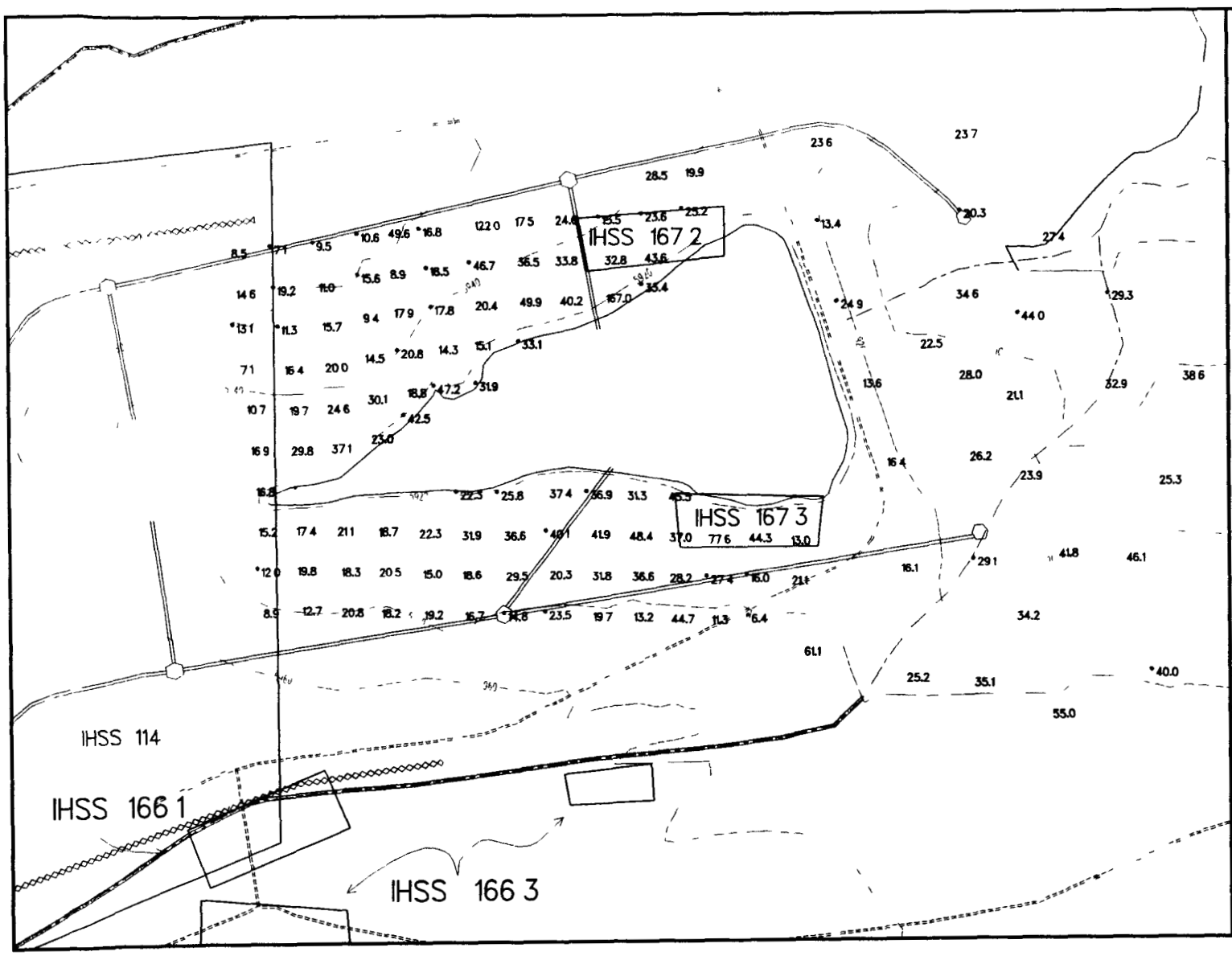
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Calcium Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-21



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 62 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-5 for sample location numbers.

N

0 Feet 120 240

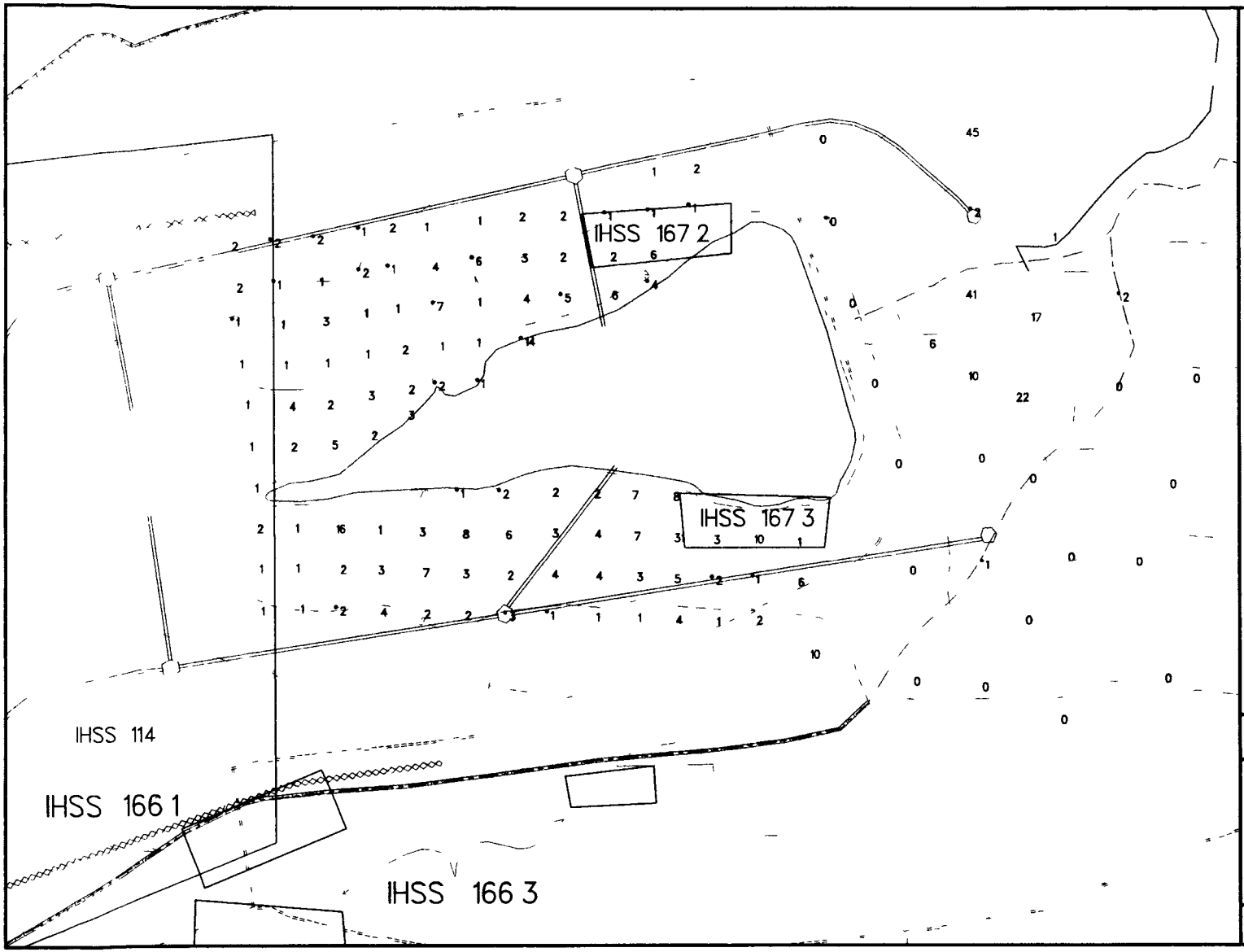
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Lead Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-22



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 9 6 mg/kg (Background Geochemical Characterization Report for 1992 EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red.

Refer to Figure C-5 for sample location numbers.

N

0 Feet 120 240

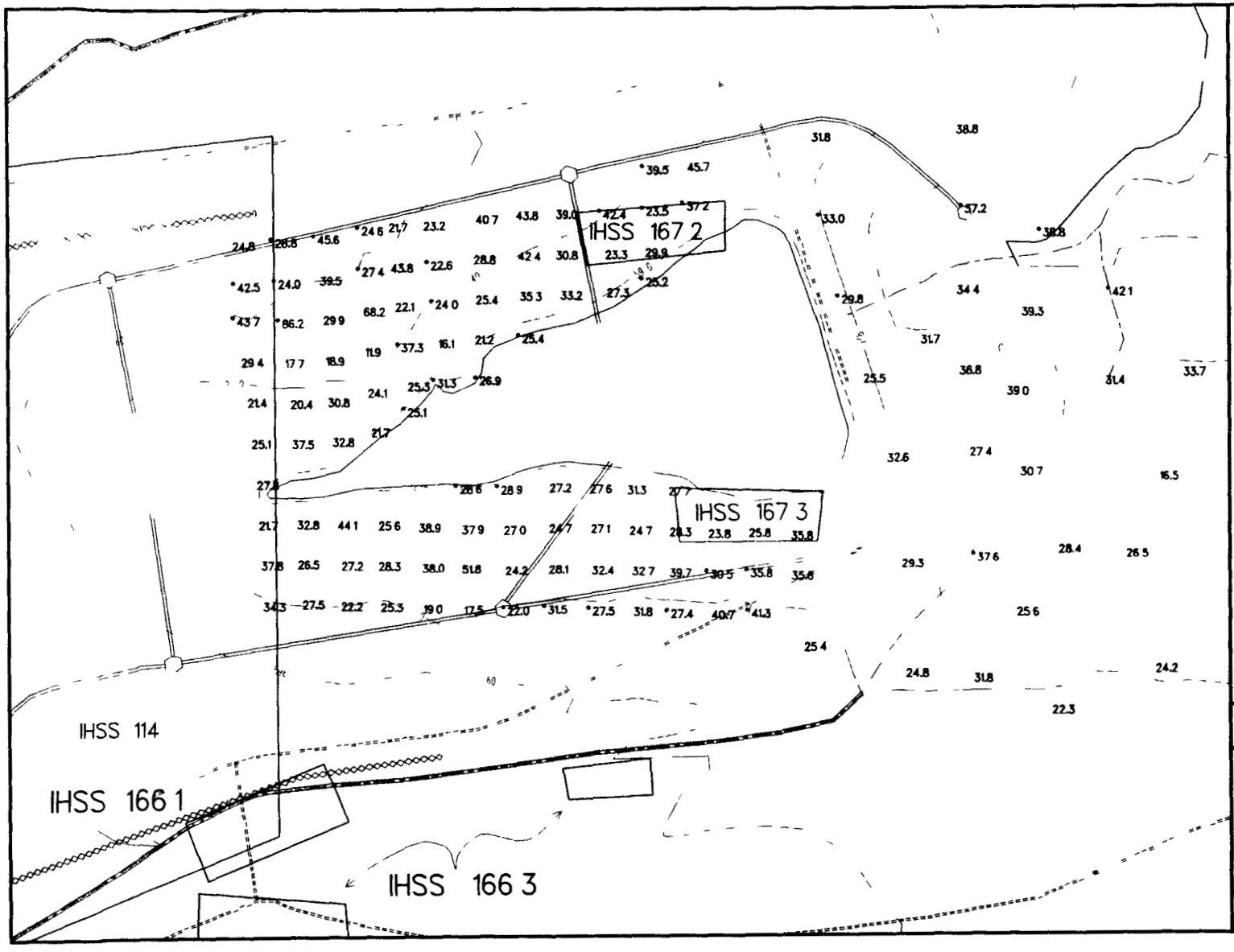
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Nitrate/Nitrite Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-23



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note: UTL 99/99 = 60 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red

Refer to Figure C-5 for sample location numbers

N

0 Feet 120 240

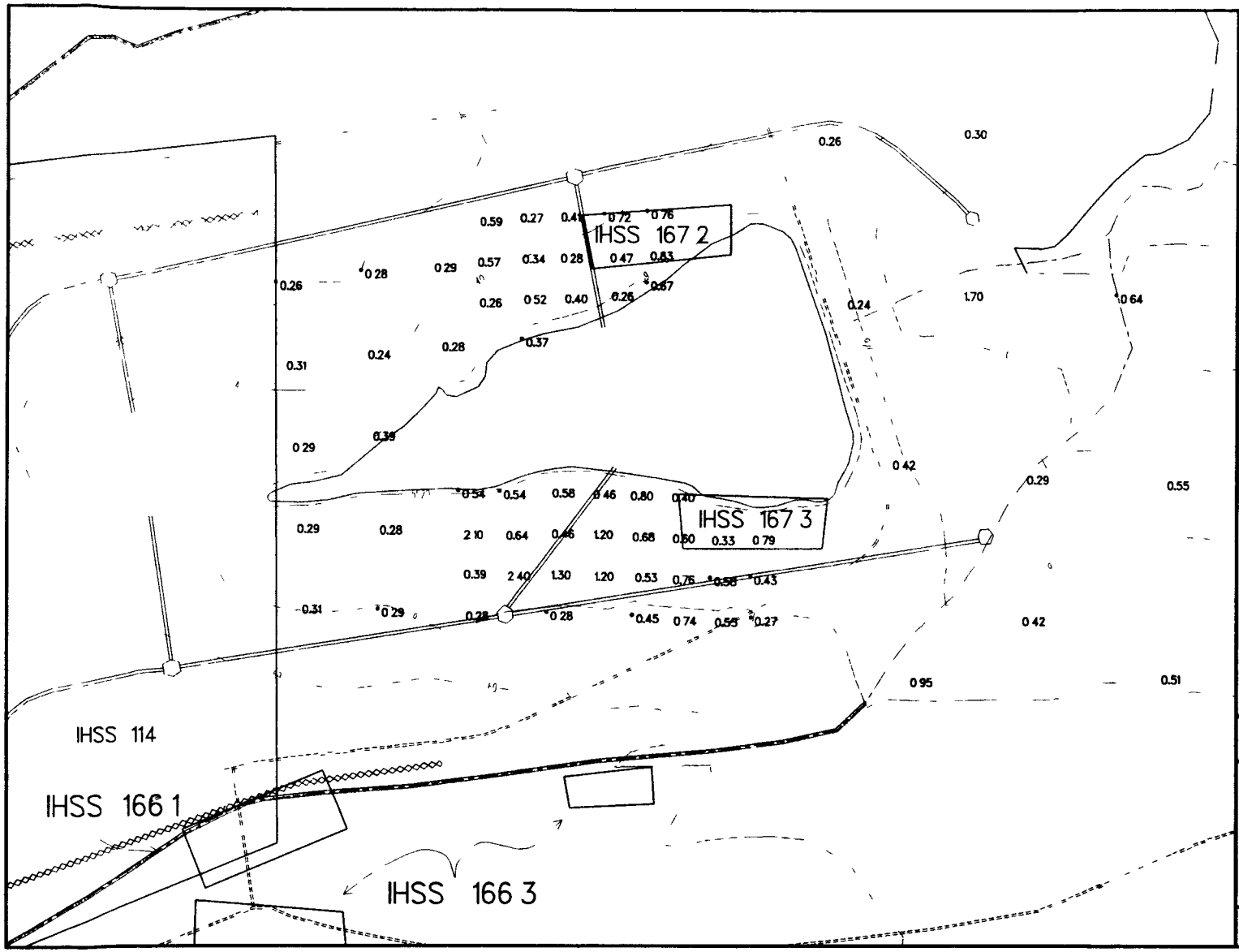
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Vanadium Concentrations at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-24



EXPLANATION

Ditch
Intermittent Stream
Dirt Road
Surface-Water Diversion Ditch
Slurry Wall
Groundwater Intercept System
(perforated)
(non-perforated)
OU 7 IHSS Boundary
OU 6 IHSS Boundary

Units in milligrams per kilogram.

Note UTL 99/99 = 1.4 mg/kg (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Concentrations exceeding the UTL 99/99 are posted in red

Refer to Figure C-5 for sample location numbers.

N

0 Feet 120 240

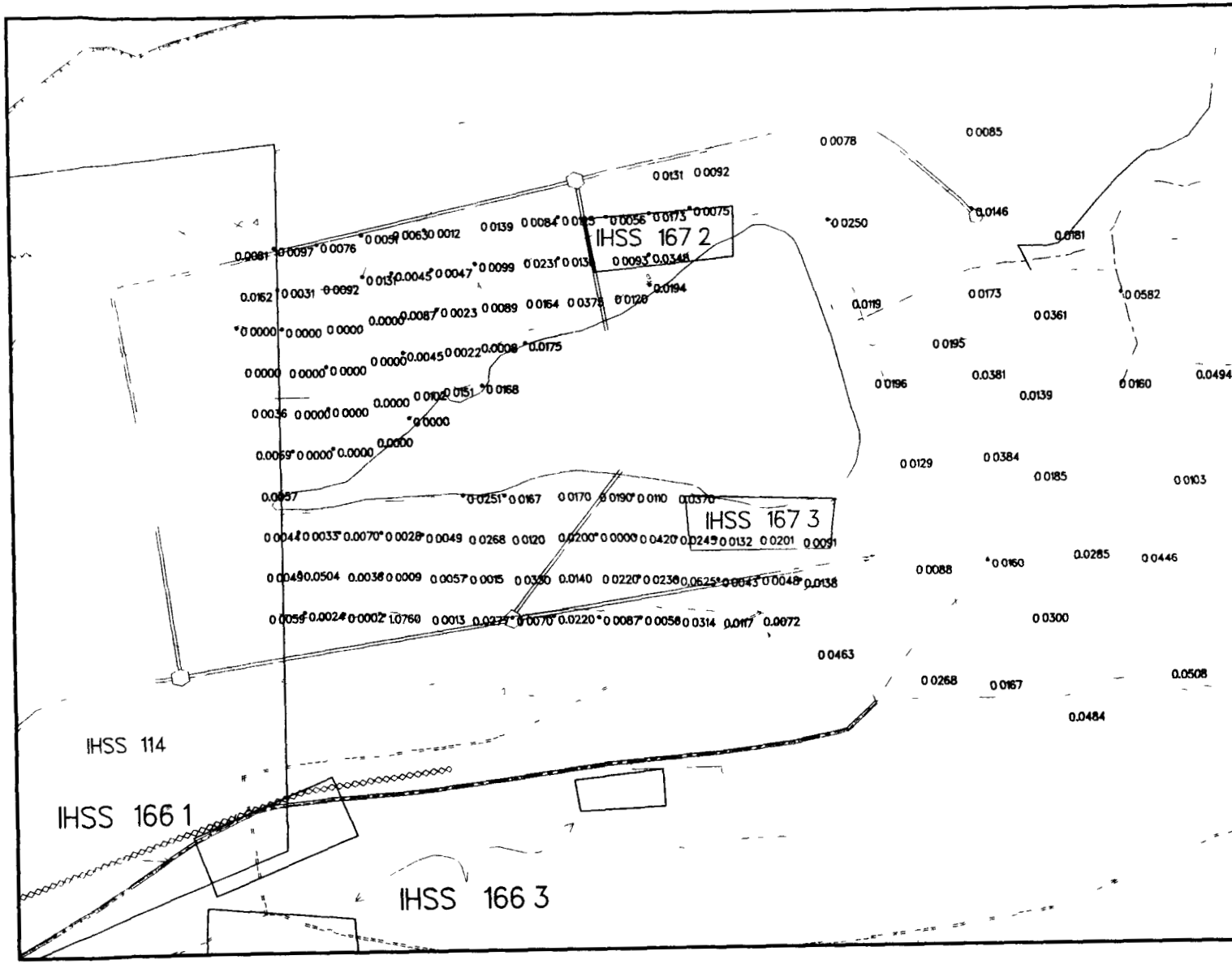
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 10 inches) Selenium Concentrations at East Landfill Pond

Revised Work Plan — Operable Unit No. 7

Date: April 1994 — Figure 4-25



EXPLANATION

Ditch
Intermittent Stream
Dirt Road
Surface-Water Diversion Ditch
Slurry Wall
Groundwater Intercept System
(perforated)
(non-perforated)
OU 7 IHSS Boundary
OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 0.058 pCi/g (Background Geochemical Characterization Report for 1992 EG&G 1993)

Activity exceeding the UTL 99/99 are posted in red

Refer to Figure C-5 for sample location numbers

0 Feet 120 240

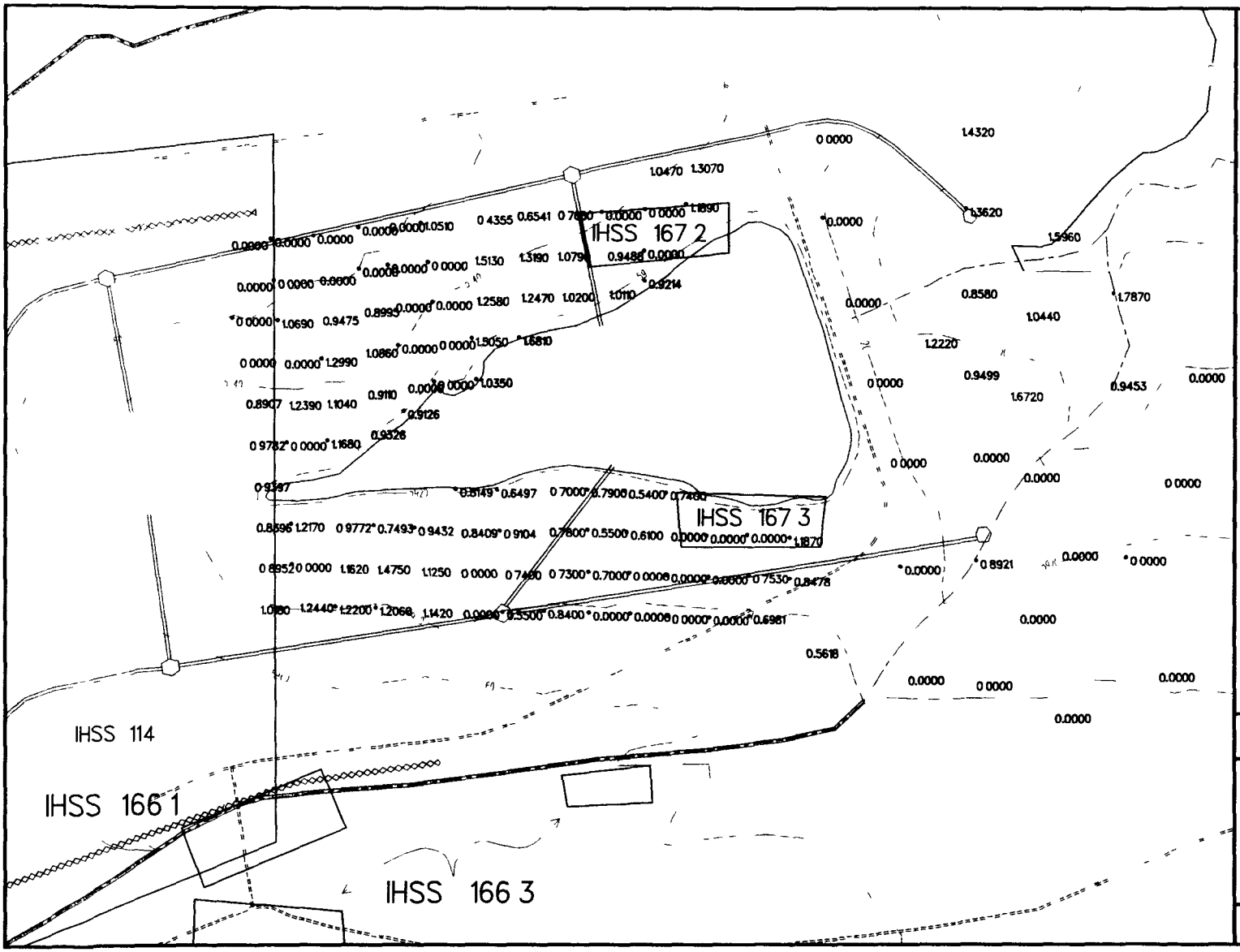
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Americium-241 Activity at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-26



EXPLANATION

- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- OU 7 IHSS Boundary
- OU 6 IHSS Boundary

Units in picocuries per gram.

Note: UTL 99/99 = 1.5 pCi/g (Background Geochemical Characterization Report for 1992, EG&G, 1993)

Activity exceeding the UTL 99/99 are posted in red.

Refer to Figure C-5 for sample location numbers.

0 Feet 120 240

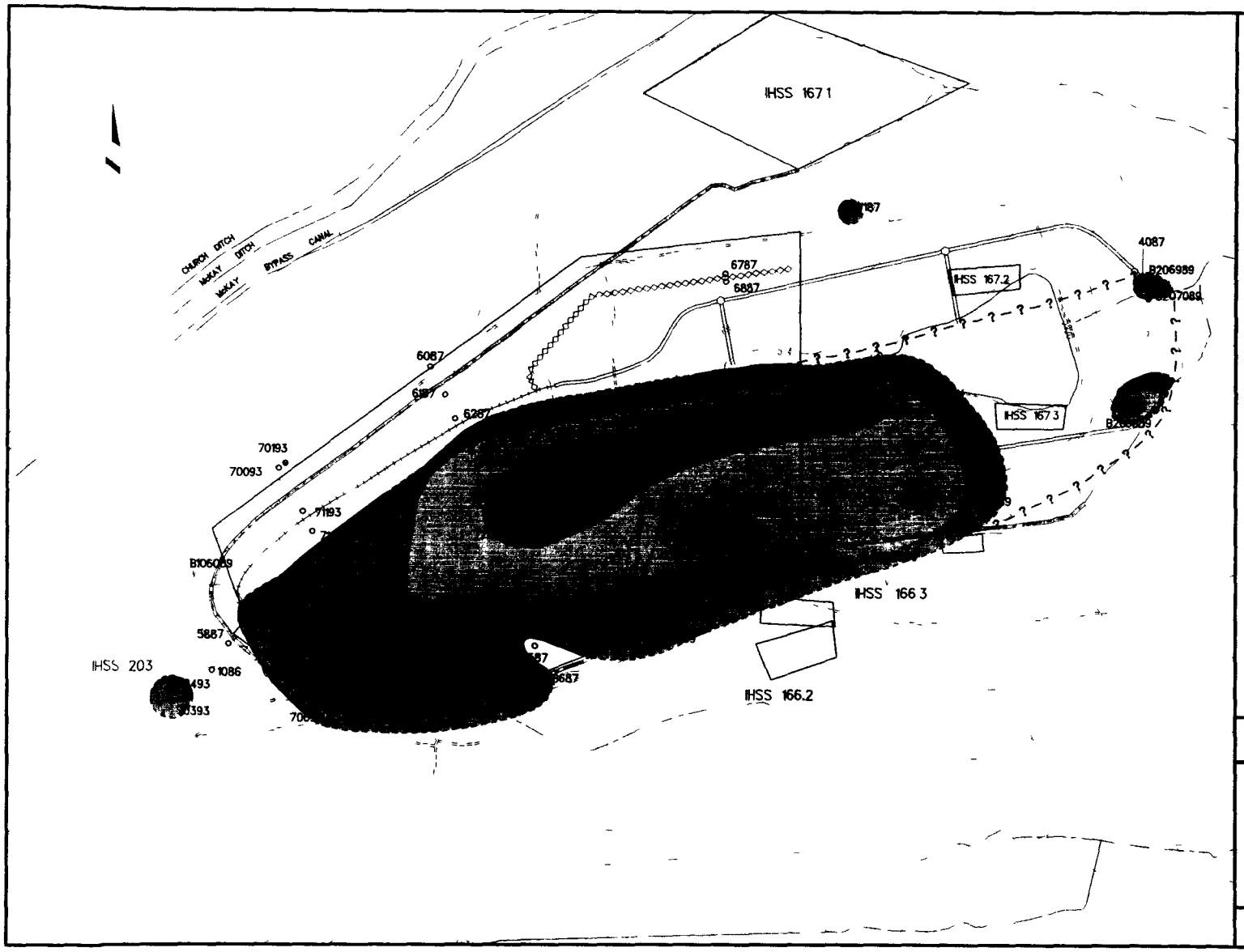
Topographic Contour Interval = 20 Feet

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

Surface Soil (0 to 2 inches) Radium-226 Activity at East Landfill Pond

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-27



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in milligrams per liter

- > 1000 mg/L
- 500 – 1,000 mg/L
- 250 – 500 mg/L

0 Feet 250 500

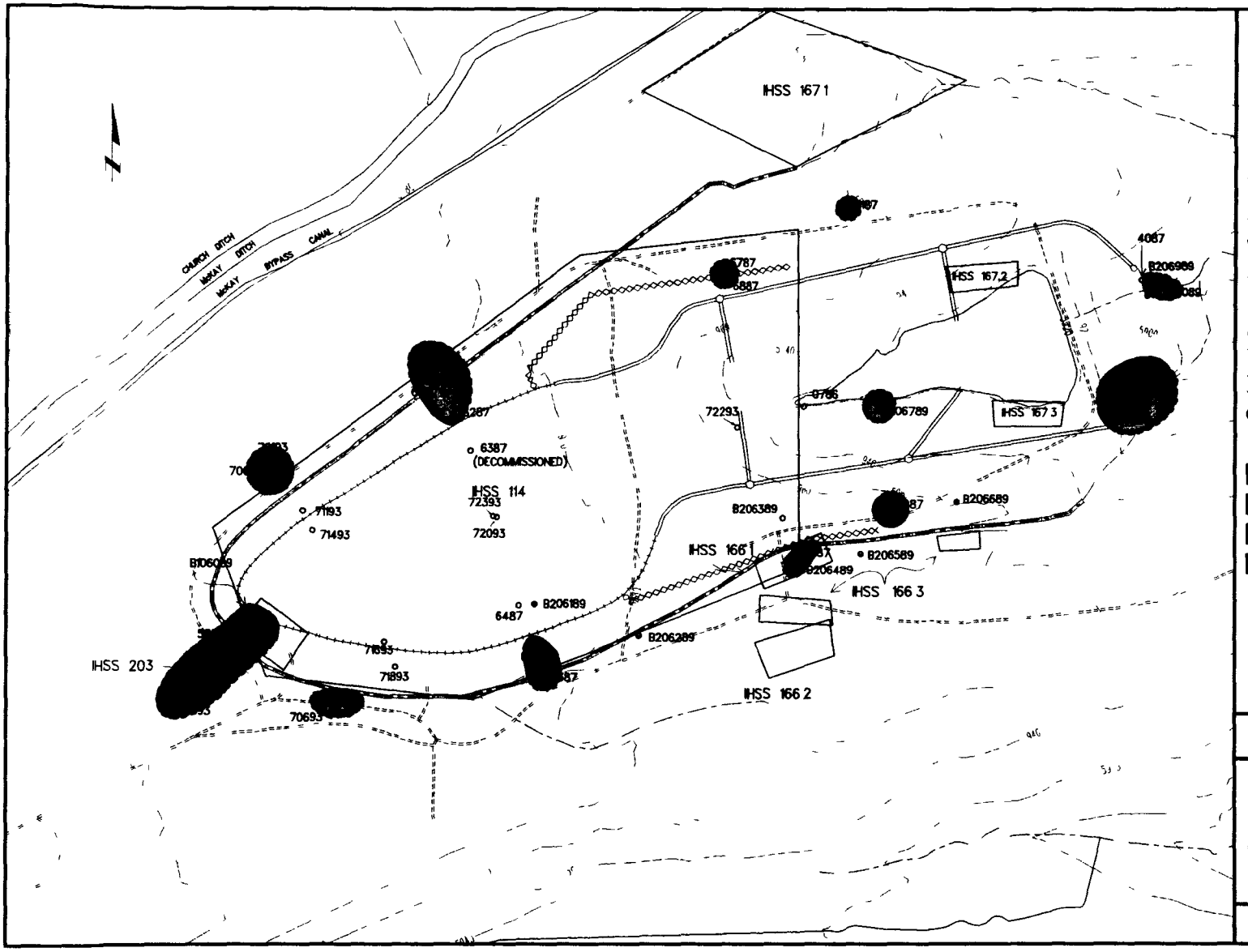
Topographic Contour Interval = 20 Feet

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

Average TDS in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-28



EXPLANATION

- ○ Well (Surficial Material; Upper Hydrostratigraphic Unit)
- ◒ Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in milligrams per liter

- > 100 mg/L
- 10 – 100 mg/L
- 5 – 10 mg/L
- 1 – 5 mg/L

0 Feet 250 500

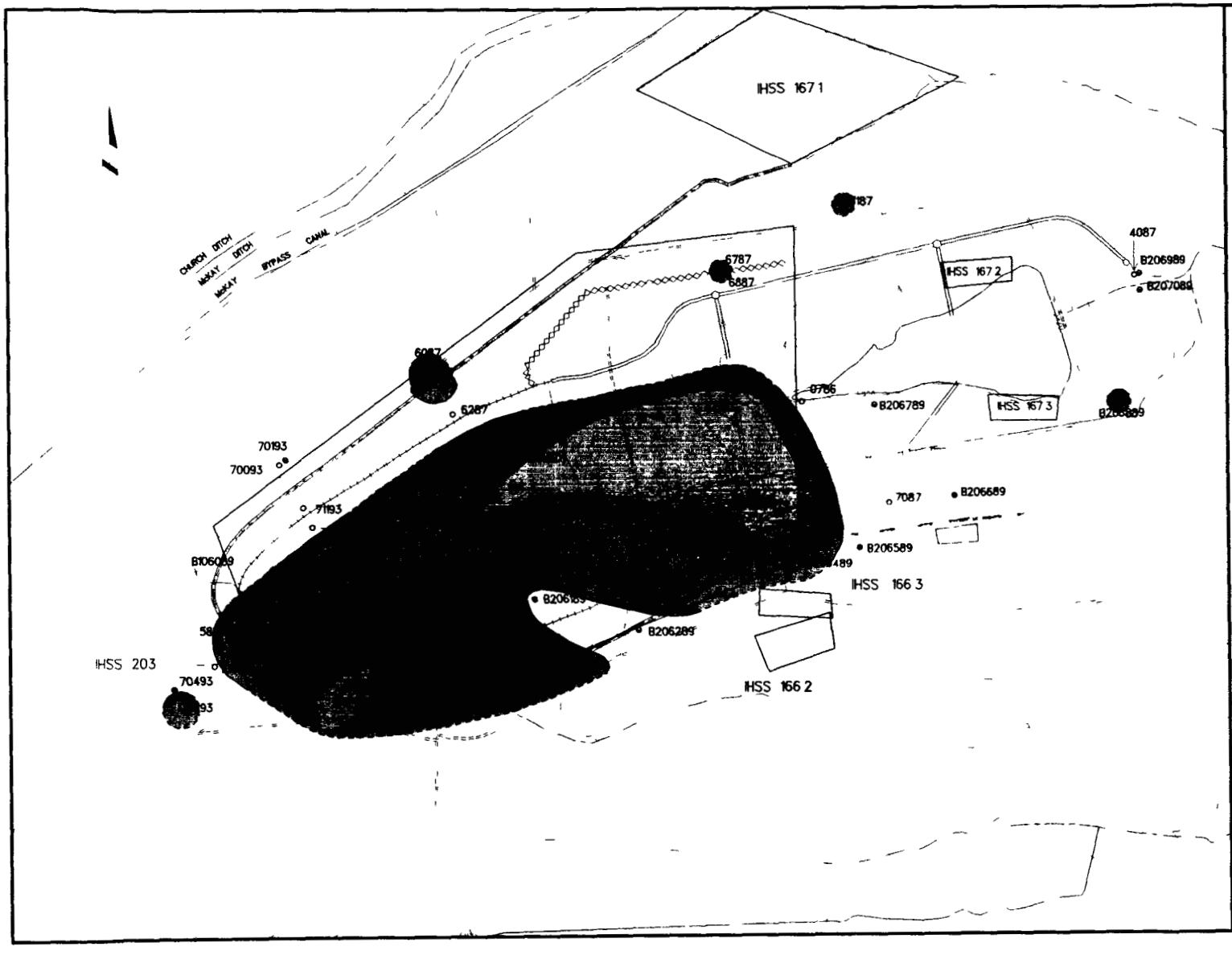
Topographic Contour Interval = 20 Feet

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

Average Nitrate/Nitrite in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-29



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in micrograms per liter

- > 100 µg/L
- 10 – 100 µg/L

0 Feet 250 500

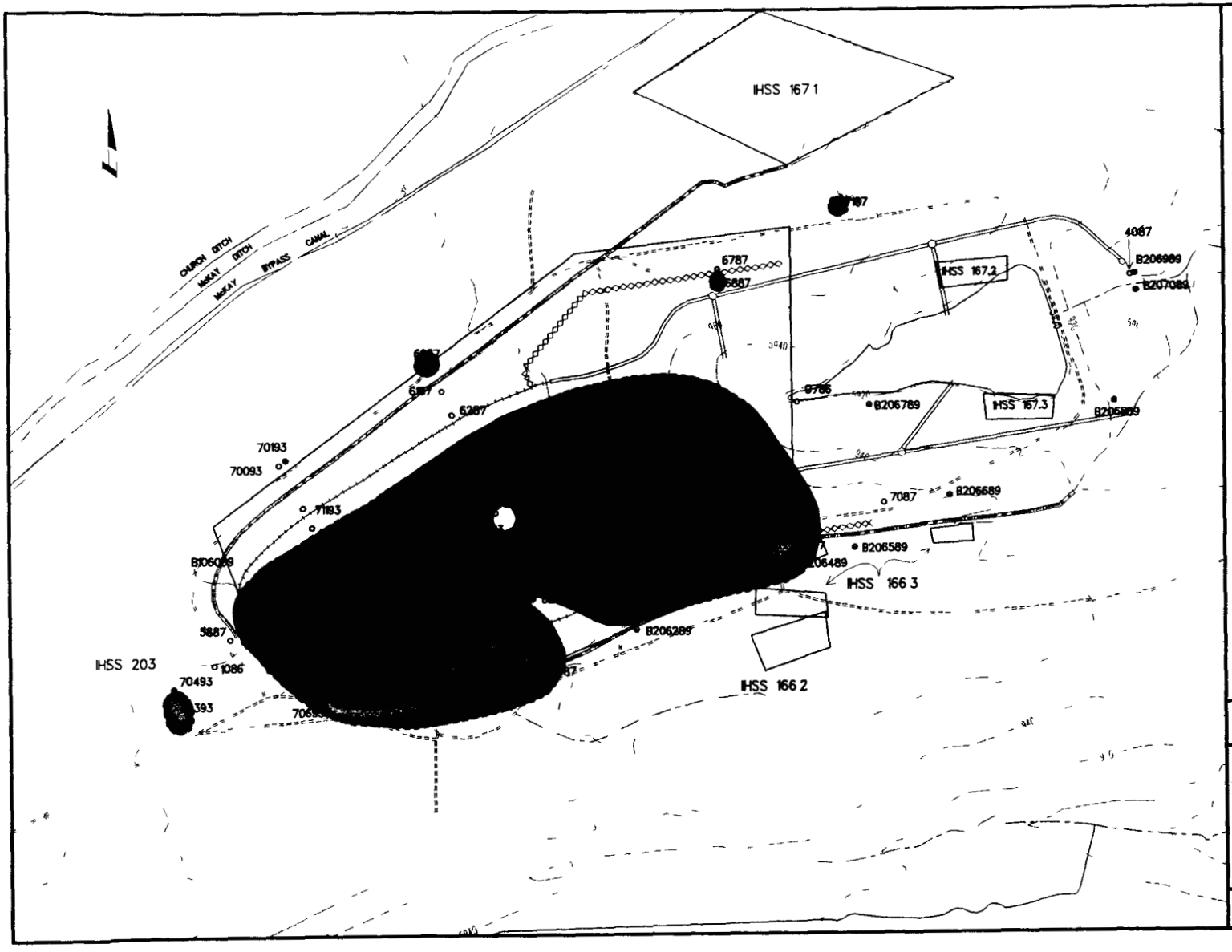
Topographic Contour Interval = 20 Feet

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

Average - Detected Total VOCs in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-30



EXPLANATION

- ○ Well (Surficial Material; Upper Hydrostratigraphic Unit)
- ◒ Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in micrograms per liter

- > 100 μg/L
- 50 – 100 μg/L
- 10 – 50 μg/L

0 Feet 250 500

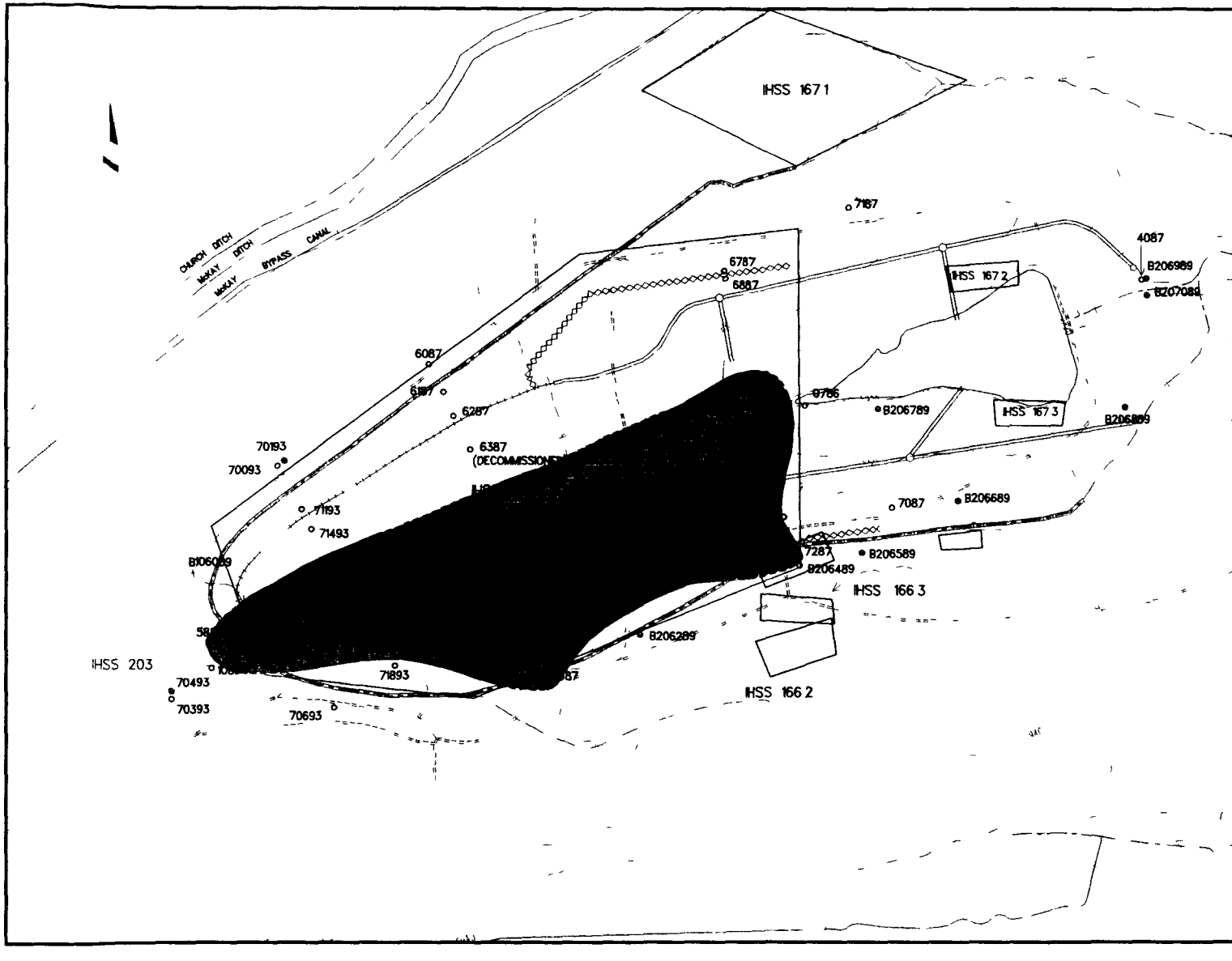
Topographic Contour Interval = 20 Feet

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

Average - Detected Total Chlorinated Hydrocarbons in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-31



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in micrograms per liter

- > 100 $\mu g/L$
- 10 – 100 $\mu g/L$

0 Feet 250 500

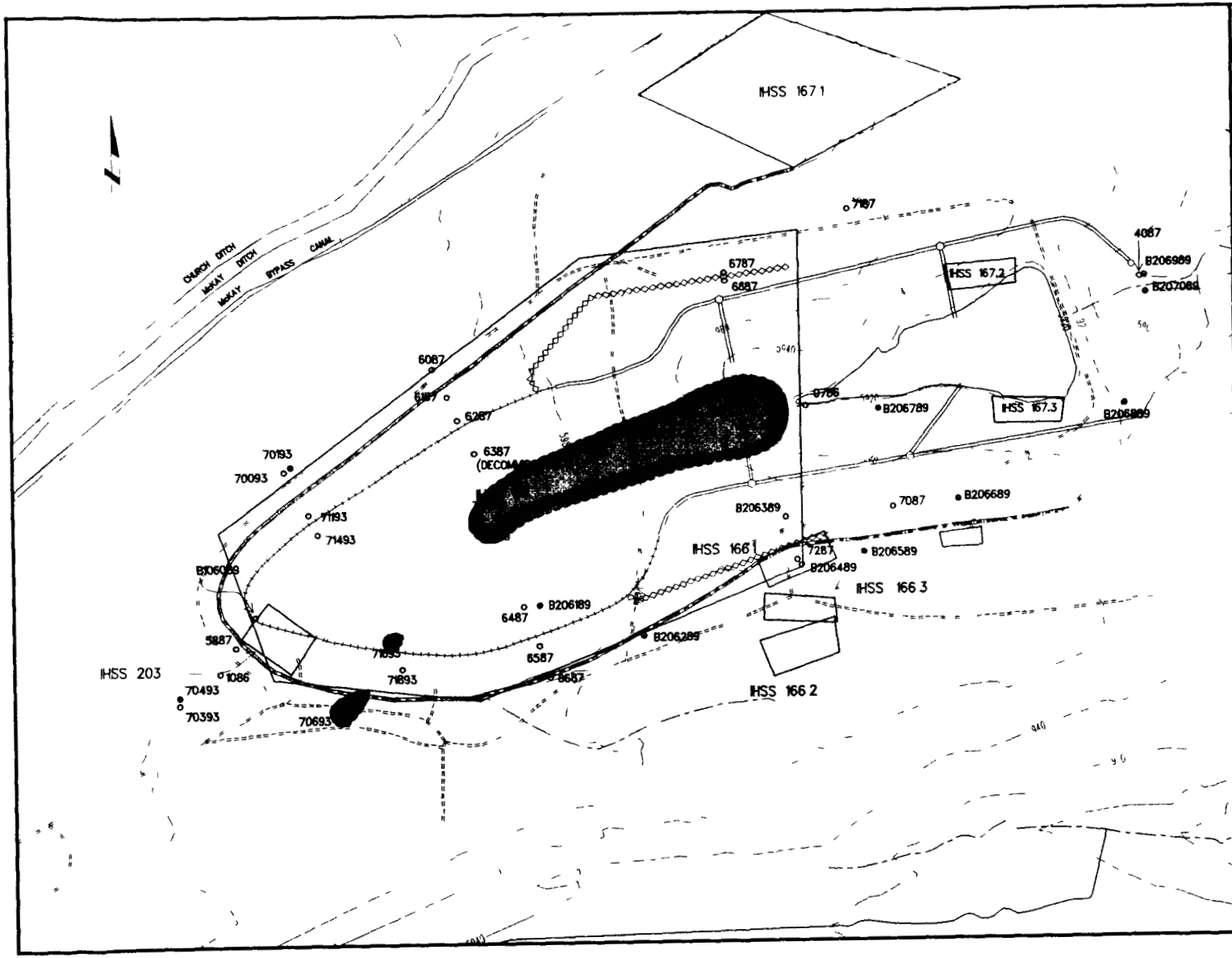
Topographic Contour Interval = 20 Feet

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

Average - Detected BTEX in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-32



EXPLANATION

○ Well
(Surficial Material; Upper Hydrostratigraphic Unit)

◒ Well
(Bedrock; Upper Hydrostratigraphic Unit)

Ditch

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall

Groundwater Intercept System
(perforated)
(non-perforated)

Concentration Contour
(dashed where inferred)

Concentrations in micrograms per liter

> 100 μg/L

10 – 100 μg/L

0 Feet 250 500

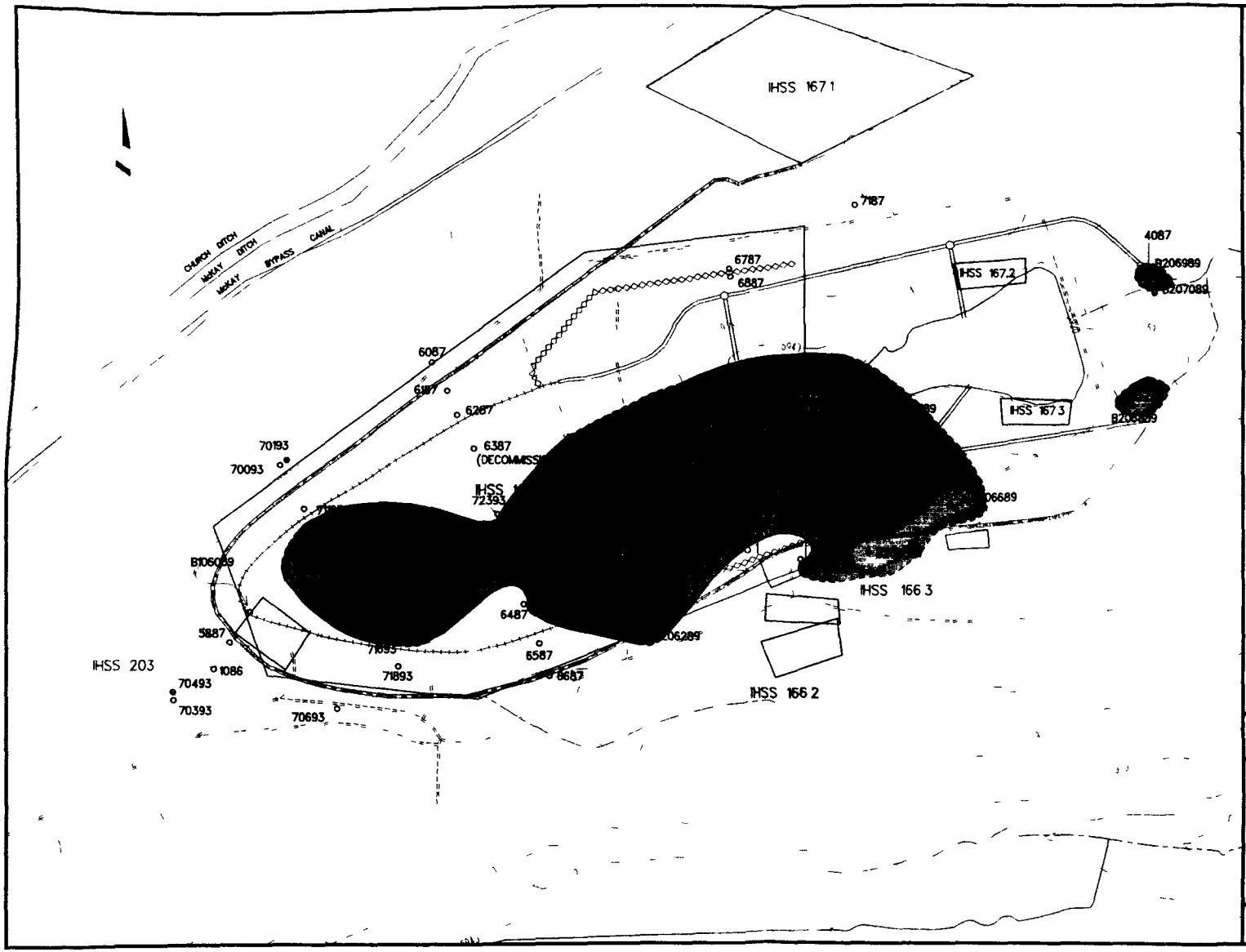
Topographic Contour Interval = 20 Feet

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

Average - Detected Total SVOCs in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-33



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in picocuries per liter

- > 0.5 pCi/L
- 0.1 – 0.5 pCi/L

0 Feet 250 500

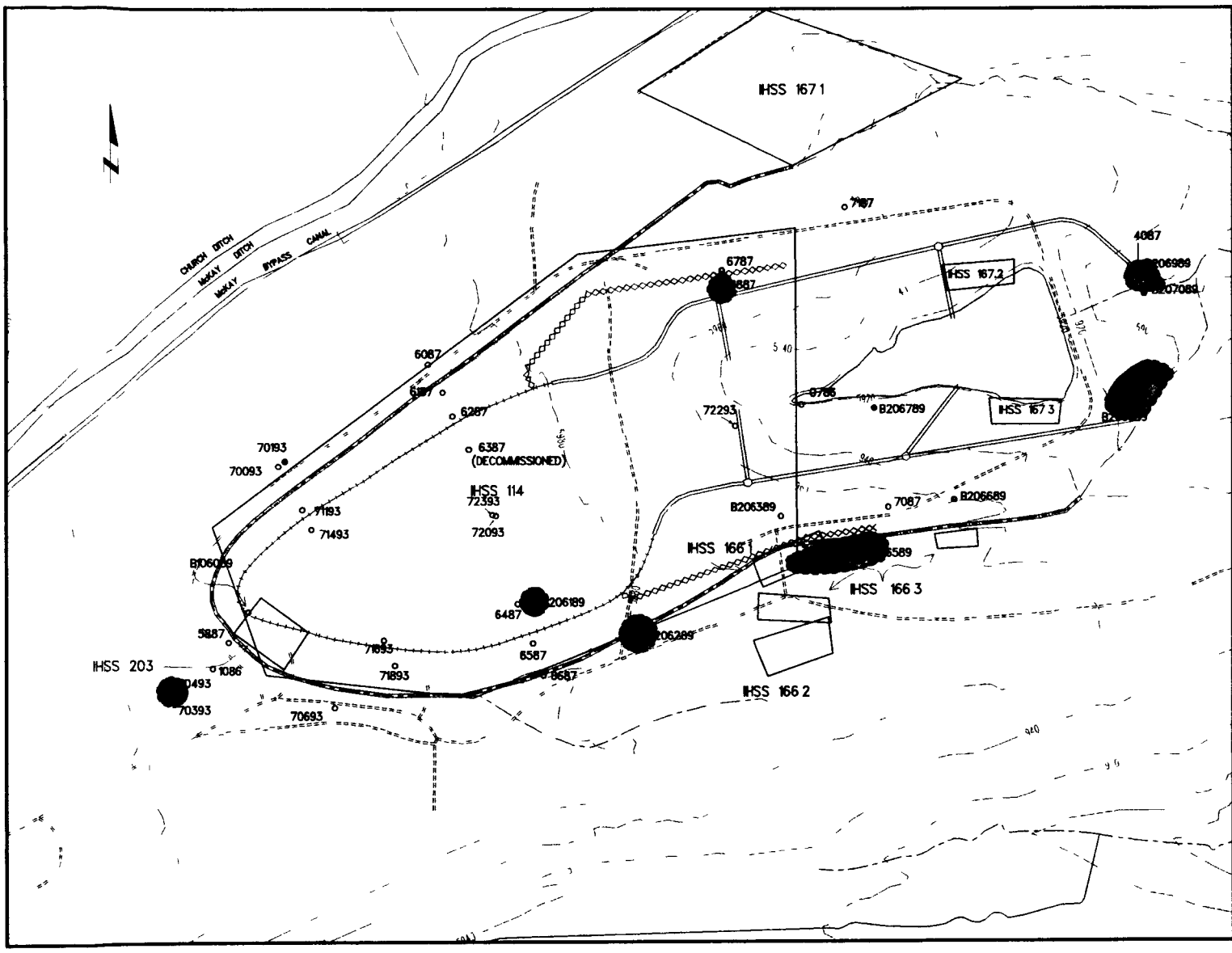
Topographic Contour Interval = 20 Feet

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

Average Dissolved Uranium-235 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-34



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in picocuries per liter

- > 2 pCi/L
- 1 – 2 pCi/L
- 0.5 – 1 pCi/L
- 0.1 – 0.5 pCi/L

0 Feet 250 500

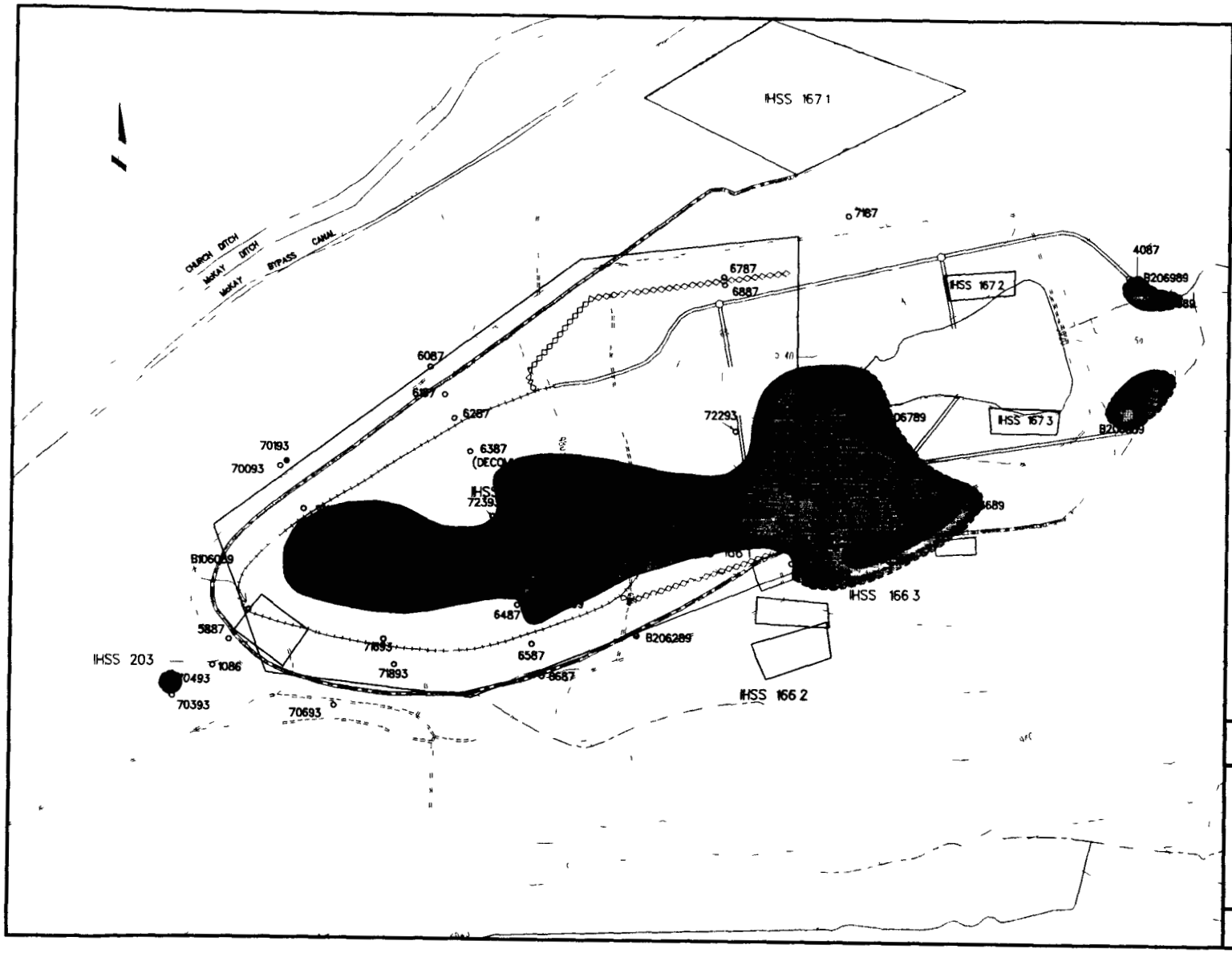
Topographic Contour Interval = 20 Feet

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

Average Total Uranium-235 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-35



EXPLANATION

- Well (Surficial Material: Upper Hydrostratigraphic Unit)
- Well (Bedrock: Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in picocuries per liter

- > 20 pCi/L
- 10 – 20 pCi/L
- 5 – 10 pCi/L
- 1 – 5 pCi/L

0 Feet 250 500

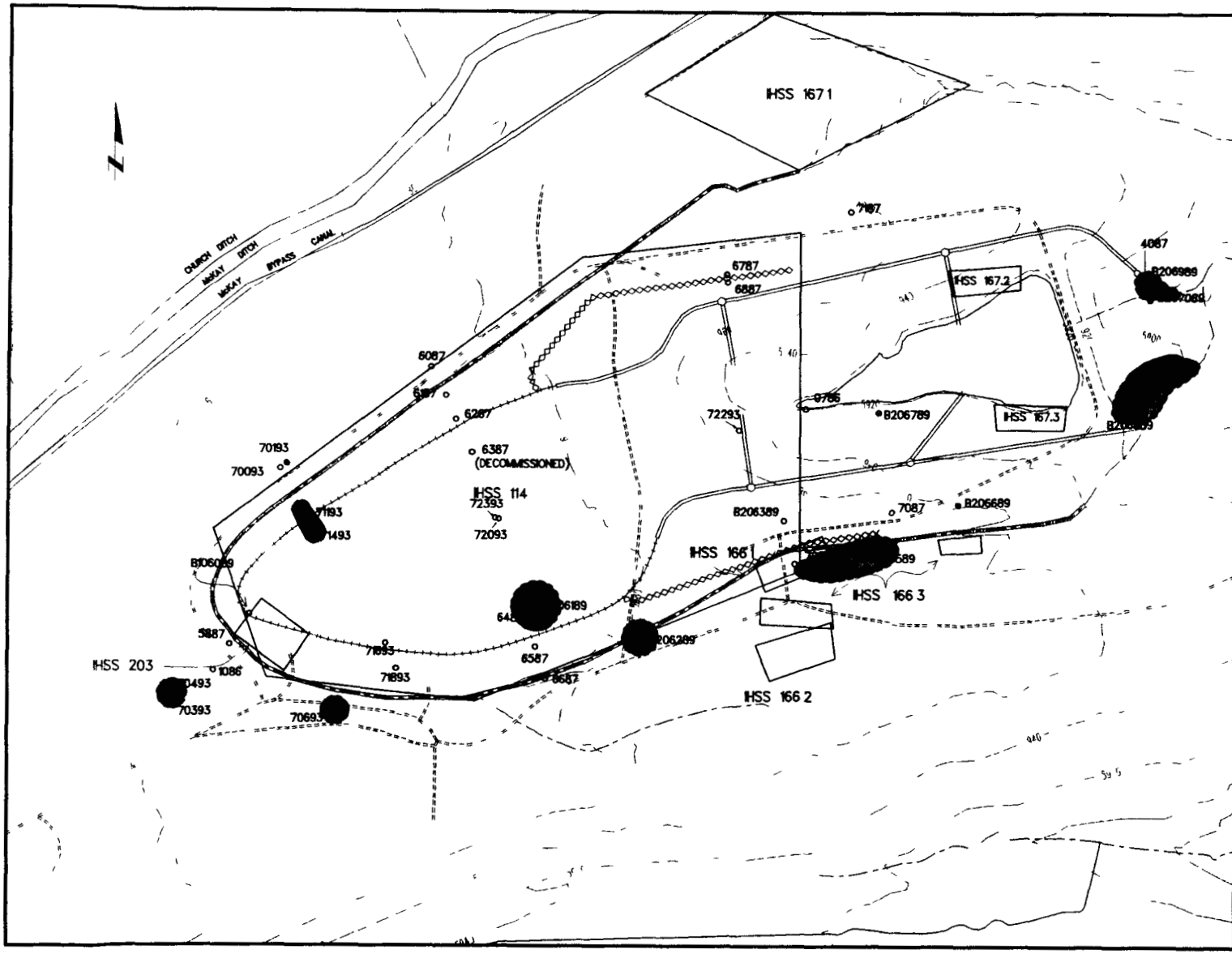
Topographic Contour Interval = 20 Feet

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

Average Dissolved Uranium-238 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-36



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in picocuries per liter

- > 30 pCi/L
- 20 – 30 pCi/L
- 10 – 20 pCi/L
- 1 – 10 pCi/L

0 Feet 250 500

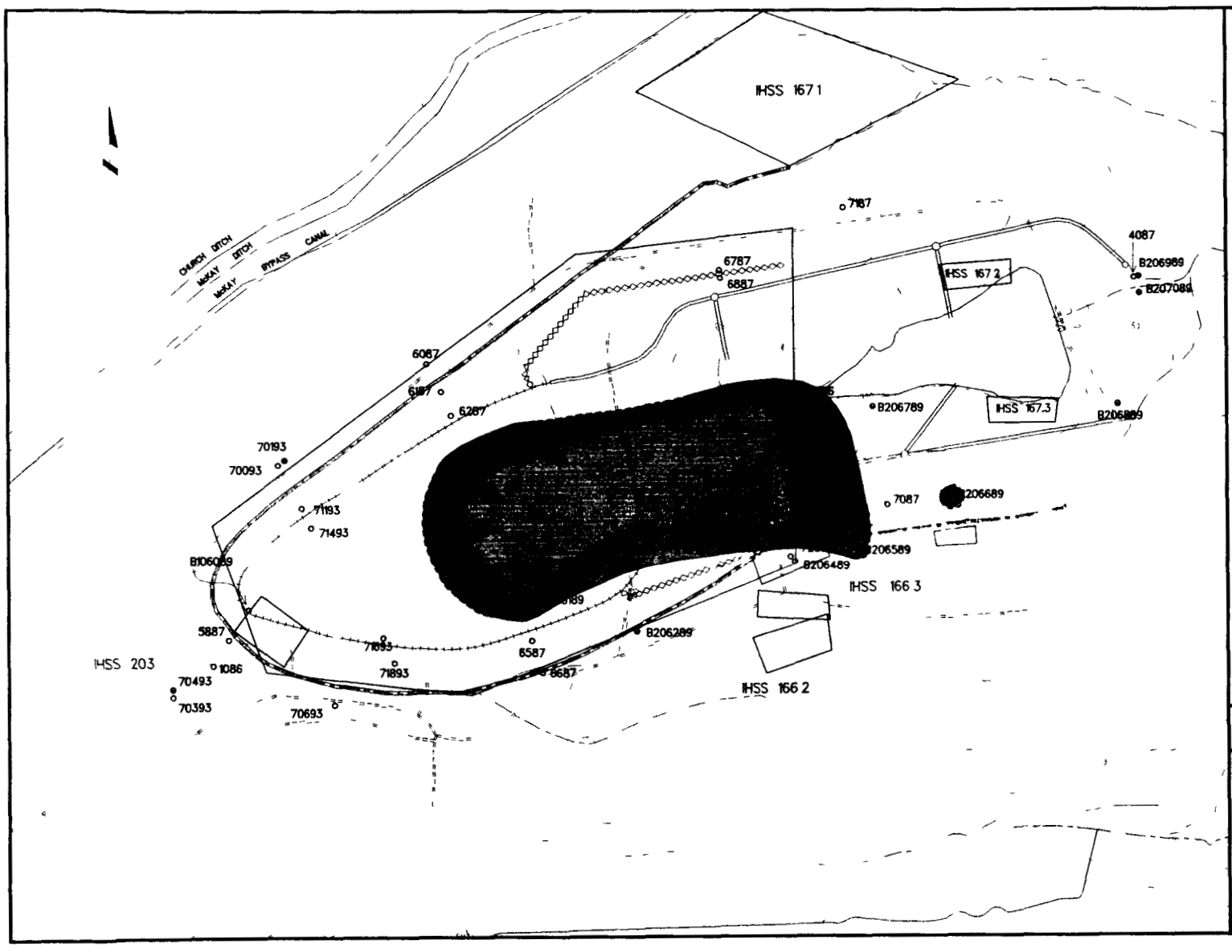
Topographic Contour Interval = 20 Feet

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

Average Total Uranium-238 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-37



EXPLANATION

○ Well
(Surficial Material; Upper Hydrostratigraphic Unit)

● Well
(Bedrock; Upper Hydrostratigraphic Unit)

Ditch

Intermittent Stream

Dirt Road

Surface-Water Diversion Ditch

Slurry Wall Groundwater Intercept System
(perforated)
(non-perforated)

Concentration Contour
(dashed where inferred)

Concentrations in picocuries per liter

> 1 pCi/L

0.5 – 1 pCi/L

0 Feet 250 500

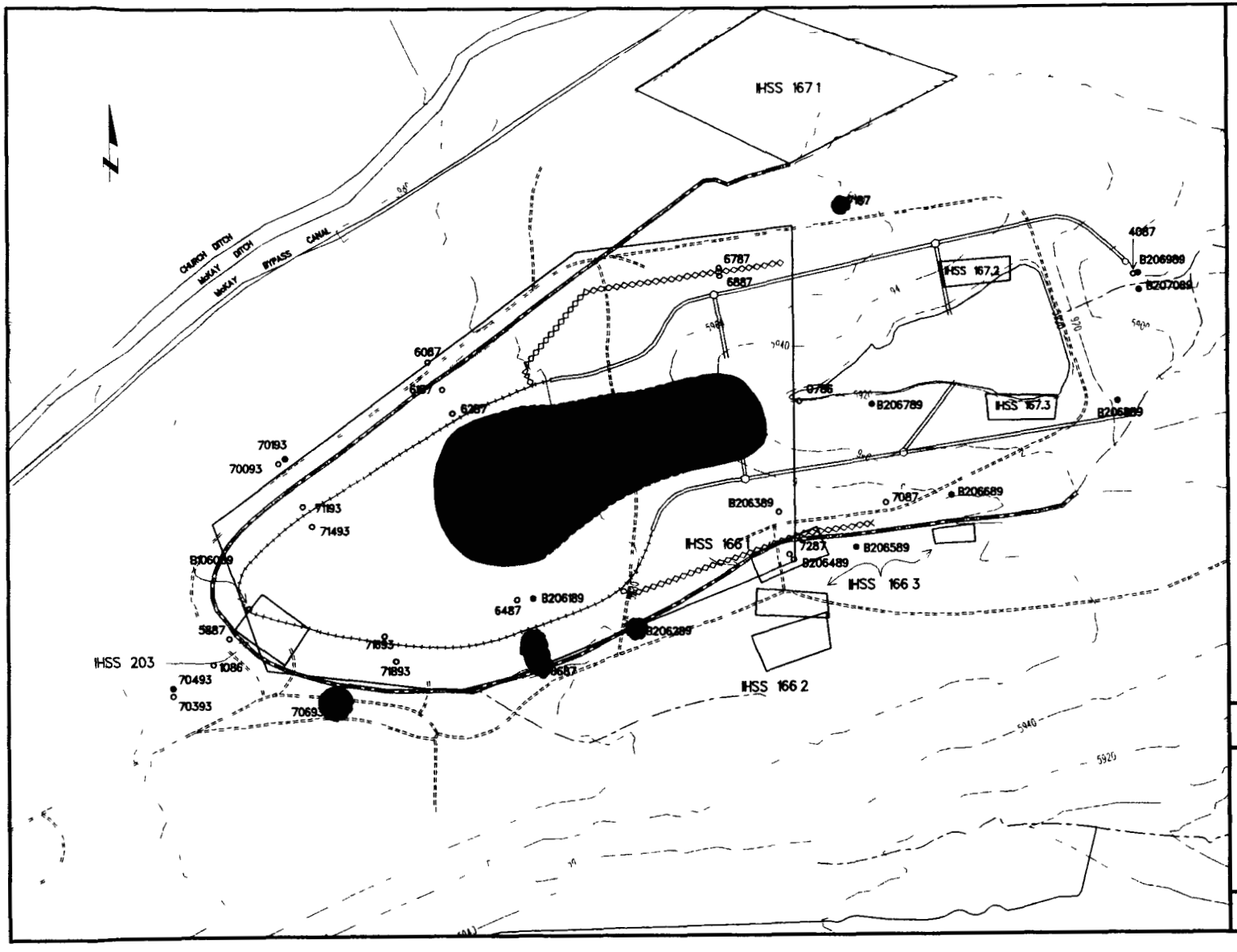
Topographic Contour Interval = 20 Feet

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

Average Dissolved Radium-226 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-38



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Concentrations in picocuries per liter

- > 0.1 pCi/L
- 0.05 – 0.1 pCi/L
- 0.01 – 0.05 pCi/L

0 Feet 250 500

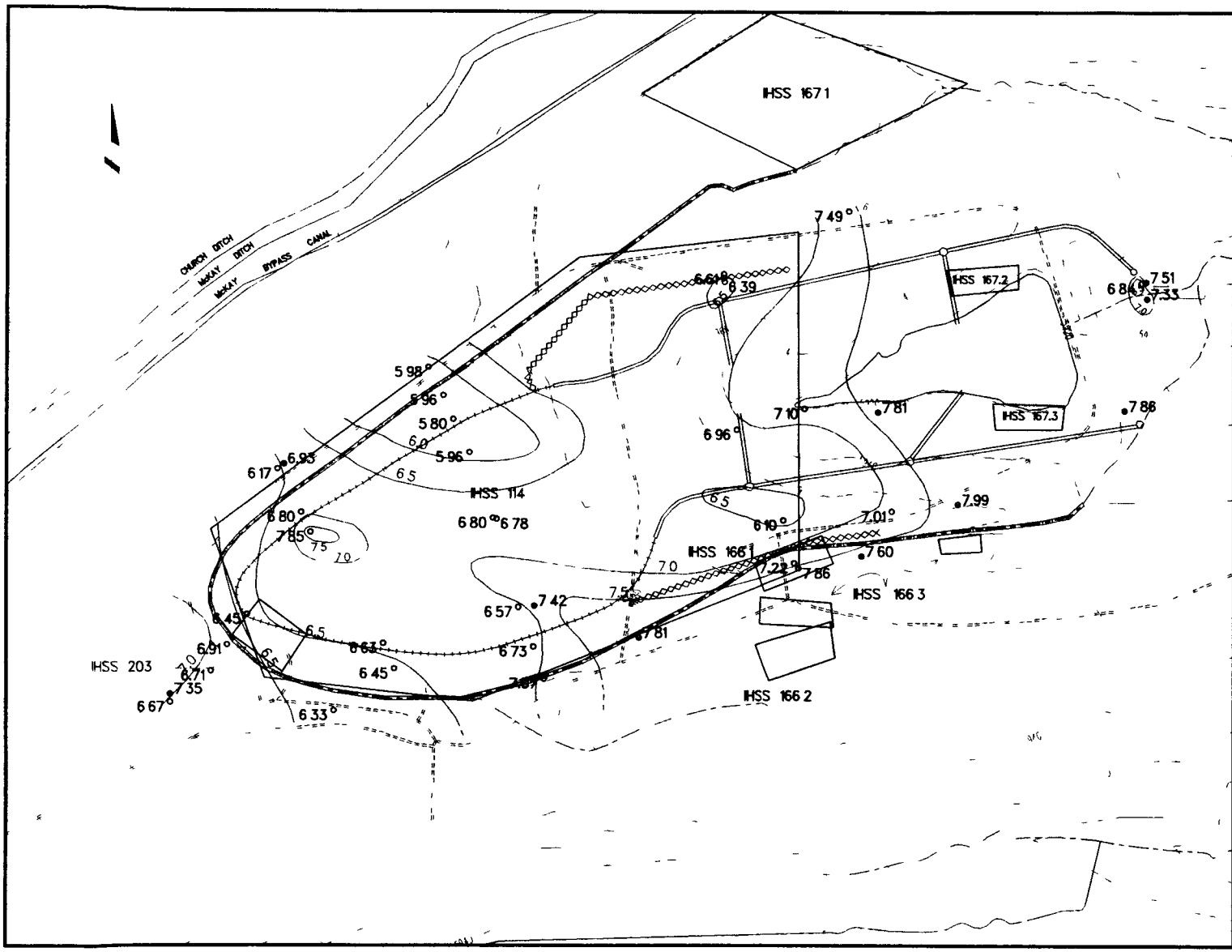
Topographic Contour Interval = 20 Feet

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

Average Total Americium-241 in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-39



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System
  - (perforated)
  - (non-perforated)
- pH Contour (dashed where inferred)

Note: Averages were calculated using field measurements of pH. Contour interval = 0.5 standard pH units.

0 Feet 250 500

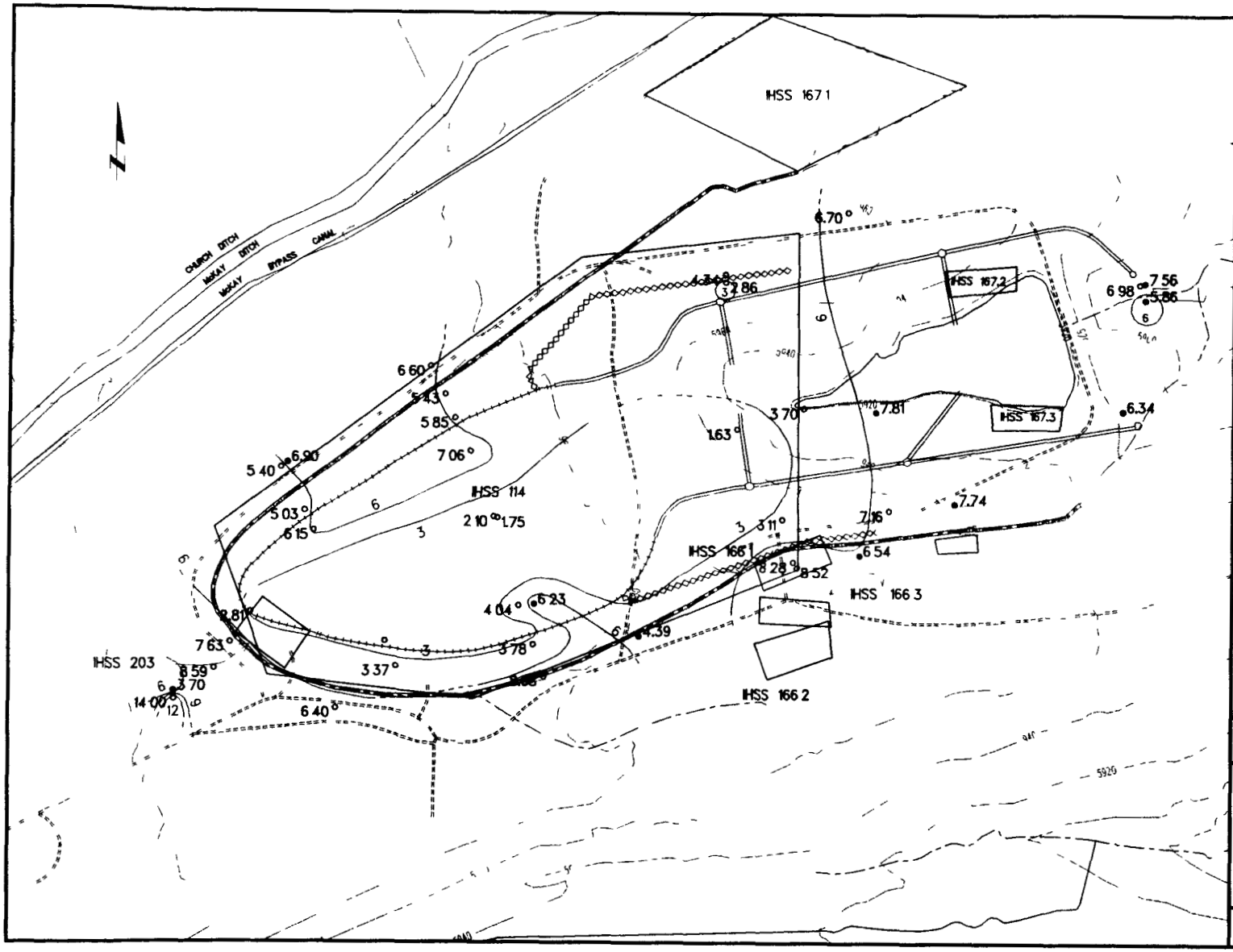
Topographic Contour Interval = 20 Feet

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

Average Field pH in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-40



EXPLANATION

- Well (Surficial Material; Upper Hydrostratigraphic Unit)
- Well (Bedrock; Upper Hydrostratigraphic Unit)
- Ditch
- Intermittent Stream
- Dirt Road
- Surface-Water Diversion Ditch
- Slurry Wall
- Groundwater Intercept System (perforated) (non-perforated)
- Concentration Contour (dashed where inferred)

Note: Averages were calculated using field measurements of dissolved oxygen. Concentration contour interval = 3 mg/L

0 Feet 250 500

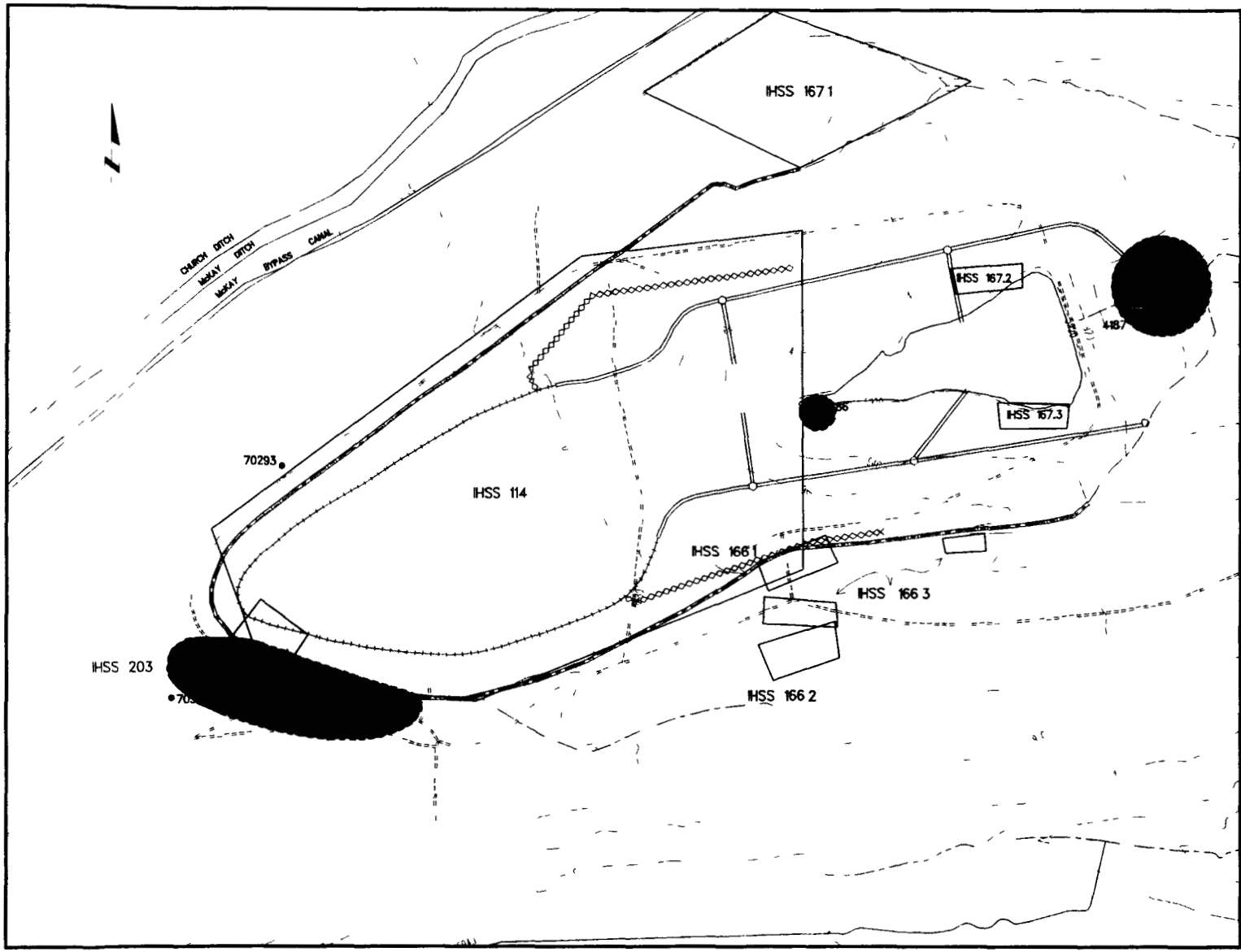
Topographic Contour Interval = 20 Feet

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

Average Dissolved Oxygen in Groundwater, 1990-1993 Upper Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-41



EXPLANATION

● Well
(Bedrock; Lower Hydrostratigraphic Unit)

Ditch
Intermittent Stream
Dirt Road
Surface-Water Diversion Ditch
Slurry Wall
Groundwater Intercept System
(perforated)
(non-perforated)
Concentration Contour
(dashed where inferred)

Concentrations in milligrams per liter

> 1,000 mg/L
500 – 1,000 mg/L
250 – 500 mg/L

0 Feet 250 500

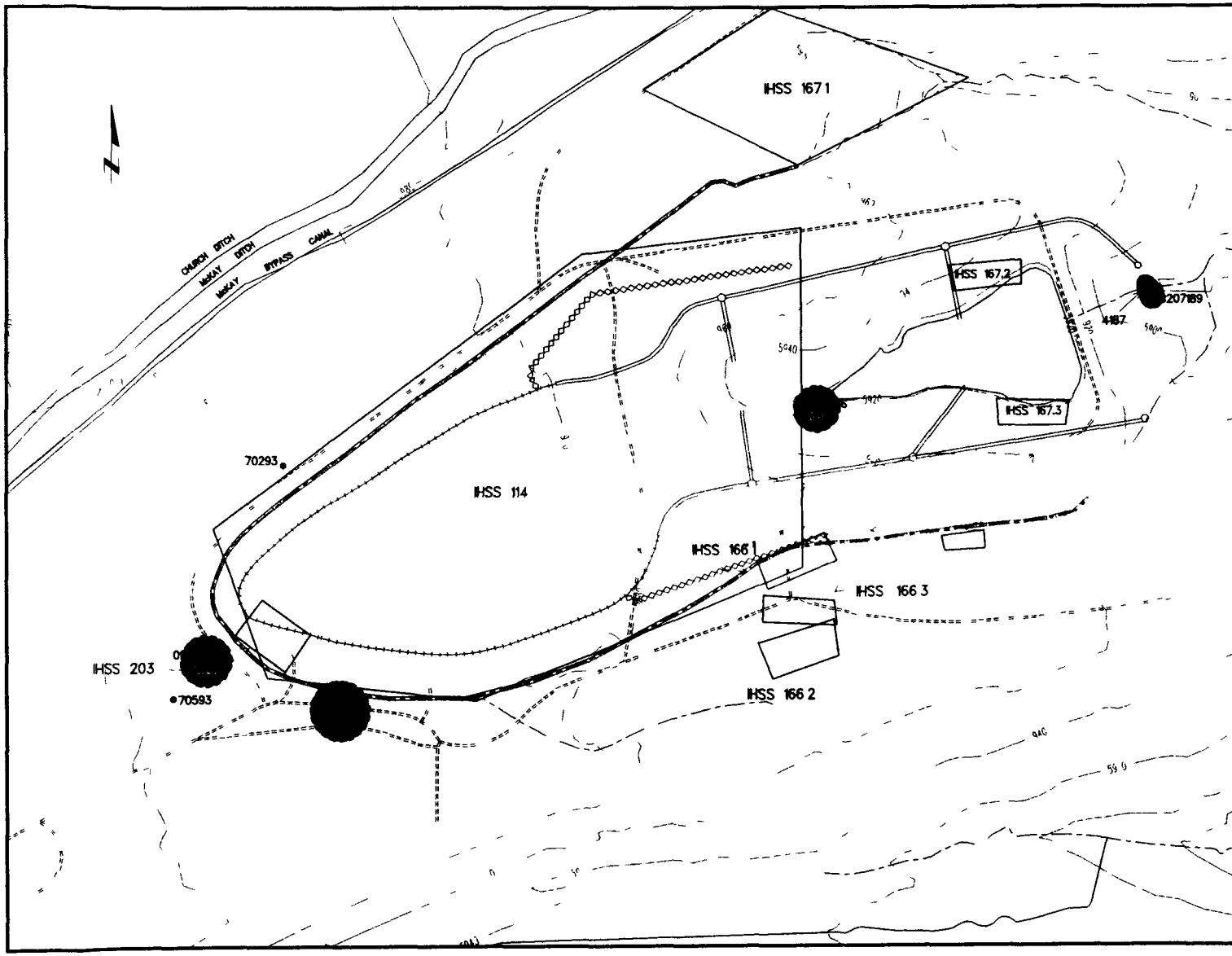
Topographic Contour Interval = 20 Feet

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

Average TDS in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-42



EXPLANATION

● Well
(Bedrock; Lower Hydrostratigraphic Unit)

Ditch
Intermittent Stream
Dirt Road
Surface-Water Diversion Ditch
Slurry Wall
Groundwater Intercept System
(perforated)
(non-perforated)
Concentration Contour
(dashed where inferred)

Concentrations in micrograms per liter

> 20 μg/L
10 – 20 μg/L
1 – 10 μg/L

0 Feet 250 500

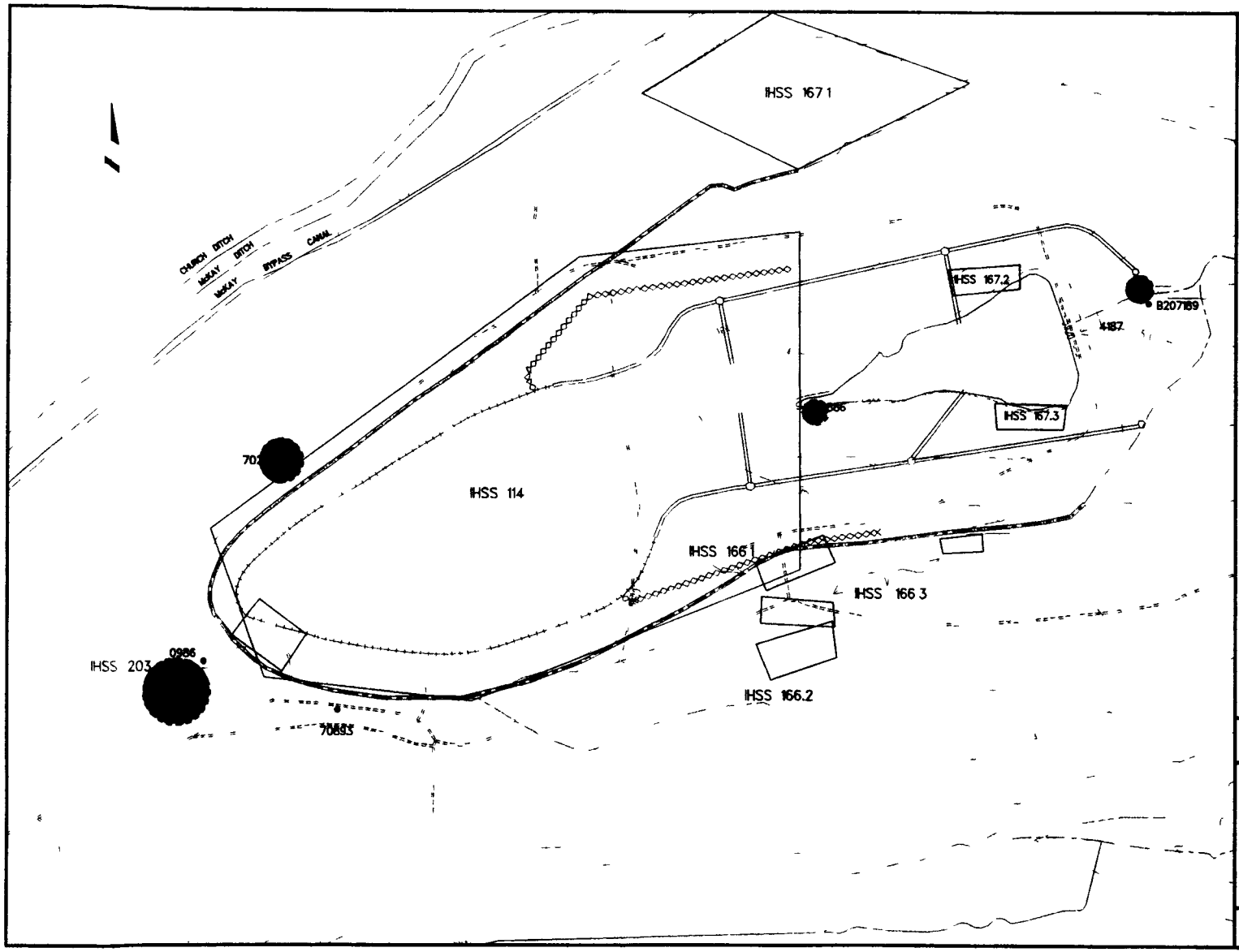
Topographic Contour Interval = 20 Feet

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

Average - Detected Total VOCs in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-43



EXPLANATION

● Well
(Bedrock; Lower Hydrostratigraphic Unit)

—— Ditch
— - - Intermittent Stream
— - = Dirt Road
═══ Surface-Water Diversion Ditch
◇◇◇◇ Slurry Wall
Groundwater Intercept System
+++++ (perforated)
═══ (non-perforated)
—— Concentration Contour
- - - - (dashed where inferred)

Concentrations in picocuries per liter

> 1 pCi/L

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

Average Dissolved Uranium-238 in Groundwater, 1990-1993 Lower Hydrostratigraphic Unit

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 4-44

5. DATA QUALITY OBJECTIVES

DQOs are qualitative and quantitative statements that specify the type, quality, and quantity of the data required to support agency decisions during remedial response activities The types of data, level of detail, and the data quality needed are determined by the intended uses of the data The quantity of data needed is determined by formulating mathematical expressions to solve the design problems and calculating the optimum sample size that satisfies DQOs DQOs should be specified for each data collection activity, and the work should be conducted and documented in a manner that ensures that sufficient data of known quality are collected to support sound decisions about remedial action selection (EPA 1987)

The DQO process consists of these seven steps (1) state the problem—review prior studies and existing information to gain an acceptable understanding of the problem and concisely describe it, (2) identify the decision—identify the decision that will solve the problem using new data, (3) identify inputs to the decision—identify the information needed to resolve the decision, (4) define the study area boundaries—specify the time period to which the decisions will apply and within which the data should be collected, (5) develop a decision rule—use the outputs from previous steps to devise an "if then" statement that defines conditions that would cause the decision maker to choose among alternative actions, (6) specify limits on decision errors—define acceptable decision error rates, considering the consequences of making an incorrect decision, and (7) optimize the design for obtaining data—develop alternative sampling designs using information from the previous steps (EPA 1993c) Developing DQOs is an iterative process, the conclusions from any step may influence prior steps and cause them to be redefined

This section defines the types of decisions that will be made about design of the presumptive remedies, assessment of the nature and extent of groundwater contamination, and development of a focused risk assessment Decisions were defined by identifying data users, developing a site conceptual model, and specifying objectives for the project The DQO process presented in the Interim Final Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process (EPA 1993c) was used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7

The DQO process has been integrated with the planning process, and the results are incorporated into the SAP, presented in Section 6 of this report

5 1 Data Users

Data users are divided into three groups decision makers, primary data users, and secondary data users The decision makers for OU 7 are personnel from EG&G, DOE, CDH, EPA, and the Natural Resource Trustee who are responsible for decisions related to management, regulation, investigation, and remediation of OU 7 The decision makers are involved through the review and approval process specified in the IAG Primary data users include project managers, geoscientists, biologists, statisticians, risk assessment scientists, lawyers, and remedial design engineers They will be involved in data collection, data analysis, human health risk assessment and environmental evaluation to support the National Environmental Policy Act (NEPA) environmental assessment, and design and implementation of an IM/IRA Secondary data users include database managers, QA personnel, records control personnel, and laboratory managers

5.2 Assessment of Existing Data

Surface features, meteorology and climate, soils, geology, hydrogeology, surface-water hydrology, and ecology of the Present Landfill, IHSS 203, the East Landfill Pond, and the adjacent spray evaporation areas within OU 7 are described in Section 2 of this report The quality and usability of all existing data are discussed in Section 3 Data aggregation and procedures for background comparison and PCOC identification, as well as an assessment of the nature and extent of contamination at the source (the landfill) and in soils, subsurface geologic materials, sediments, surface water, and groundwater, are presented in Section 4 This section presents the rationale used to identify the type, quantity, and quality of data needed to make decisions about remedial actions at OU 7 The resulting SAP is presented in Section 6 QA/QC requirements are presented in Section 7

5.3 Objectives and Approach

For the purpose of streamlined site characterization and site remediation, OU 7 has been divided into three areas groundwater and surface water, East Landfill Pond sediments and adjacent soils potentially affected by spray evaporation, and the Present

Landfill and IHSS 203 The DQO process outlined in the EPA guidance document (EPA 1993c) is most applicable to groundwater and surface water and East Landfill Pond sediments and adjacent soils because the quantitative environmental decisions to be made require the collection of field data The DQO process is least applicable to the Present Landfill because decisions are made on the basis of presumptive remediation (i e , experience gained from other similar sites) rather than quantification of environmental decisions, decision error rates, and uncertainty embodied in steps 5 and 6 of the DQO process, and the quantitative method in the DQO process is often not applicable to the types of data needed to support remedial design

5.4 East Landfill Pond Sediments and Adjacent Soils

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for East Landfill Pond sediments and adjacent soils is described in detail below

5 4 1 State the Problem

A Phase I RFI/RI was conducted at OU 7 in 1992 and 1993 to characterize the sources of contamination and to describe the nature and extent of contamination present at the source and in soils Results of the Phase I RFI/RI provide information that describes contamination in East Landfill Pond sediments and adjacent soils where spray evaporation of pond water occurred, such as analyte concentrations in soils collected from two depth intervals (0 to 2 inches and 0 to 10 inches) and analyte concentrations in pond sediments Information on soil type, vegetative cover over soils, climate data (wind directions, speeds and stability classes, precipitation and evapotranspiration rates), surface runoff rates, migration pathways for contaminants in soil and sediment (wind dispersion, vegetable or plant uptake, leaching, and direct contact), and exposure pathways for human and ecological receptors (inhalation, ingestion, and dermal contact) was also obtained (DOE 1993b) Other sources of data include background geochemical data describing soils (DOE 1993c) and sediments (EG&G 1993a) and data from sitewide hydrologic and geologic characterization programs (EG&G 1991a, EG&G 1992a, EG&G 1992e, EG&G 1994c)

Data collected during the Phase I RFI/RI are considered usable for site characterization, risk assessment, and remedial design activities Other data collected since 1990 are also considered fully usable The 1990 data represent the first full year

of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and SOPs (EG&G 1992c) Data collected prior to 1990 can be used qualitatively

A Corrective Action Management Unit (CAMU) strategy has been recommended to manage remediation wastes at OU 7 Under the final rule (58 Federal Register FR 8662), remediation wastes generated within the boundaries of a DOE site can be managed in a CAMU at the site without being subject to land disposal restrictions (LDRs) As applied to OU 7 and OU 6 IHSSs within OU 7, contaminated surface soils around the East Landfill Pond and in IHSSs 166 1, 166 2, 166 3, 167 1, 167 2, and 167 3, and contaminated pond sediments can be excavated and placed in the Present Landfill before the landfill is capped The CAMU will help implement a cost-effective remedy for contaminated soils and sediments Because the CAMU (Present Landfill) is a regulated unit, the previously applicable RCRA subtitle D groundwater monitoring, closure and post-closure care requirements will continue to apply

Data analysis activities to identify PCOCs for East Landfill Pond sediments and adjacent soils through statistical comparisons of onsite contaminant concentrations versus background concentrations are summarized in Section 4 As agreed by CDH, EPA, and DOE, PCOC identification is based on statistically significant differences in analyte concentrations in site data versus background data Professional judgment is applied only to spatial distribution, temporal distribution, historic information regarding past operations at the site, inter-element correlations, mass balance calculations, and knowledge of hydrology, geochemistry, and geology of the site to determine if analyte concentrations are indicative of contamination Section 4 also presents the nature and extent of contamination in sediments and surface soils

The remaining problems are to identify and to describe fully the effects to soils and sediments resulting from contaminant releases from the landfill (leachate that seeps into the pond) and spray evaporation areas around the pond, and to determine the contaminants that present a risk to human health and the environment and the appropriate response action required to reduce those risks

5 4 2 *Identify the Decision*

To resolve the remaining problems, it is necessary to determine if concentrations of constituents in pond sediments and soils present a risk to human health or the

environment Then, it is necessary to determine what response actions are required to reduce risk to an acceptable level

The actions or outcomes that result from resolution of the decision are either no action if there is no risk associated with contaminated environmental media or remediation if contaminated media pose a risk to human health or the environment The media (pond sediments and soils) comprise two distinct populations that have potentially different outcomes and associated actions

5 4 3 Identify the Inputs to the Decision

To determine whether remediation is needed, information that is not currently available, but required to make a decision, includes estimates of the risk to human health and the environment resulting from exposure to contaminants associated with the East Landfill Pond sediments and adjacent soils

Information needed to estimate exposures and potential toxicity includes contaminant release mechanisms, delineation and characterization of exposure pathways, and delineation of the nature and extent of contamination including volume of contaminated media and total areal concentrations of contaminants The approach and methods for estimating exposure to human and ecological receptors will also be required Contaminants of concern (COCs) for human receptors in East Landfill Pond sediments and adjacent soils will be identified Toxicological information such as slope factors and reference doses (RFD) associated with the COCs will be required, as will exposure point concentrations for COCs Determination of what constitutes unacceptable risk will be made by risk managers at DOE, CDH, and EPA, using site-specific information to develop the criteria

Response actions will be selected based on the amount of risk reduction required and the remediation technologies available Specific information needed to screen remediation alternatives includes exposure pathways and points that result in unacceptable risks to human health and ecological receptors Information on the effectiveness of remedial alternatives in reducing releases and exposures associated with exposure pathways will also be required

Sources for each item of information have been identified Approach and methods to use in estimating exposures will be identified in the revised human-health risk

assessment exposure scenarios technical memorandum and model description technical memorandum COCs will be presented in the COC identification technical memorandum, on the basis of site-specific data and toxicity information available through EPA Toxicological information on COCs will be developed in the toxicity assessment technical memorandum Each technical memoranda will be approved by CDH and EPA for use in the risk assessment Remedial alternatives will be evaluated in the IM/IRA decision document Pond sediment samples will be collected and physical properties measured under the SAP (Section 6), if necessary

An assessment to determine the risk associated with contaminated soils or sediments is needed to determine the action level EPA-approved field sampling techniques and analytical methods were used to collect the necessary data The risk assessment will be performed following EPA guidelines for exposure assessment (EPA 1991b, EPA 1992b)

5 4 4 *Define the Boundaries of the Study*

In general, the geographic area within which all decisions must apply includes all areas within the boundary of OU 7, including surface areas adjacent to the East Landfill Pond and pond sediments

Each population of interest is defined by several characteristics Pond sediments are defined by the concentrations of PCOCs in the sediment and by the volume and distribution of contaminated sediments Soils are defined by the concentrations of PCOCs in soil and the volume and distribution of contaminated soil

All data collected from 1990 through 1993 will be used to make the decisions Sufficient data have been collected to make decisions about the need for remediation However, potential designation of areas near the East Landfill Pond as wetlands may affect remediation activities

5 4 5 *Develop Decision Rules*

The first step to developing a decision rule is to specify the parameters that characterize the population of interest The average concentration of each PCOC, the distribution of contaminants, and the risk associated with contaminants provides a means of characterizing East Landfill Pond sediments The average areal concentration of each PCOC, concentrations of PCOCs at hot spots, the distribution of

contaminants, and the risk associated with contaminants characterizes the extent of contamination in soils The next step is to specify the action level for the study For sediments and soils, a risk-based value will be the action level

Two decision rules were developed for pond sediments

1 If the concentration of PCOCs in pond sediments does not exceed the risk-based standard, no action is required

2 If the concentration of PCOCs in pond sediments exceeds the risk-based standard, removal actions or other risk-reduction actions as part of the CAMU are required

Two decision rules for the extent of contamination in soils apply

1 If the concentration of PCOCs in surface and shallow subsurface soils does not exceed the risk-based standard, no action is required

2 If the concentration of PCOCs in surface and shallow subsurface soils exceeds the risk-based standard, removal or risk-reduction actions as part of the CAMU are required

5 4 6 Specify Acceptable Limits on Decision Errors

Decision error rates are based on consideration of the consequences of making incorrect decisions Decision error rates are used to establish appropriate performance goals for limiting uncertainty Establishing acceptable error rates is necessary prior to determining the appropriate number of data (samples or tests) necessary to support the decision with a specified level of confidence given potential effects on cost, schedule, resource expenditure, human health, and ecological conditions (EPA 1993c)

Two decision errors for East Landfill Pond sediments and adjacent surface soils are deciding that analyte concentrations exceed risk-based standards when they actually do not, and deciding that analyte concentrations do not exceed risk-based standards when they actually do The consequence of deciding that analyte concentrations exceed risk-based standards when they actually do not will be the additional cost incurred when excavating sediments or surface soils that are not contaminated The consequence of deciding that analyte concentrations do not exceed risk-based standards when they

actually do may possibly endanger human health or the environment Also, additional costs may be incurred at a later date for environmental cleanup

To reach a decision, a null hypothesis (H_0) is formulated so that any reading above the risk-based standard (delta) can be detected with a known probability This probability is known as the power of the test The power of a statistical test is defined as one minus the Type II error rate For East Landfill Pond sediments and adjacent surface soils, the H_0 is sediment or surface soil concentrations exceed risk-based standards The alternative hypothesis (H_a) is sediment or surface soil concentrations do not exceed risk-based standards False positive decision errors (Type I) occur when the H_0 is erroneously rejected (Table 5-1) This decision error occurs when sediment or surface soil concentrations are determined not to exceed risk-based standards when they actually do False negative decision errors (Type II) occur when the H_0 is erroneously accepted This decision error occurs when sediment or soil concentrations are determined to exceed risk-based standards when they actually do not

To define decision errors and assess potential consequences of incorrect decisions, it is necessary to determine the range of possible concentrations on either side of a numerical standard where the consequences of decision errors are relatively minor (defined by the value delta), assign probability values for Type I and Type II errors (i e , alpha and beta) that reflect the acceptable probability for the occurrence of decision errors, and check the limits on the decision errors to ensure that they accurately reflect the relative consequences for each type of decision error

A range of concentrations about the action level (risk-based standard) must be specified where the consequences of decision errors are relatively minor A range from plus 12 5 percent to minus 12 5 percent of the risk-based standard has been selected to reflect the concentration range where the consequences of decision errors are relatively minor and costs associated with improving the ability of the test to discern between the null and alternative hypotheses are high Increasing this range decreases the power of the test to detect concentrations greater than the risk-based standard However, increasing the width of the gray area decreases the number of samples necessary to achieve the desired performance of the test Choice of an area of plus or minus 12 5 percent of the risk-based standard is a compromise between increased performance of the statistical test and increased cost and schedule impacts Choice of the Type I error rate was based on common statistical practices

Probability values to points above and below the action level were chosen to reflect the acceptable probability for the occurrence of decision errors, acceptable decision error rates are chosen as 5 percent for the false positive decision error (Type I error) and 20 percent for the false negative decision error (Type II error)

5 4 7 *Optimize the Design*

The objective of this step is to identify the most resource-effective sampling design expected to generate data that satisfies the DQOs specified in the preceding steps The DQO outputs and existing environmental data were reviewed and general sampling and analysis design alternatives were developed

Statistical methods were used to estimate the sample sizes needed to meet DQOs and support decisions The sample sizes needed to meet DQOs for comparing mean concentrations of PCOCs in soils and sediments against ARARs or preliminary remediation goals (PRGs) were calculated for each PCOC with greater than 50 percent detectable results (EG&G 1994b) Assuming simple random sampling, the following equation (EPA 1993c) was used

$$n = \frac{\sigma^2 (Z_{1-\beta} + Z_{1-\alpha})^2}{\Delta} + 0.5 (Z_{1-\alpha})^2$$

where

n	=	number of samples
σ^2	=	sample variance
Z	=	standard normal probability values (from statistical tables)
α	=	Type I error rate
β	=	Type II error rate
Δ	=	25 percent of the ARAR (or PRG)

This method was used to calculate the sample sizes required to support decisions and meet the data quality objectives for surface soils and sediments as discussed below

5 4 7 1 Surface Soils

Statistical comparisons identified only three PCOCs in surface soils from the area around the East Landfill Pond However, numerous additional PCOCs were identified on the basis of UTL exceedances The sample locations with UTL exceedances are randomly distributed across the site Therefore, risk will be calculated on the basis of the area-wide exposure unit (EPA 1989b) and the sample-size calculations for soils give the number of samples required from the entire area around the East Landfill Pond

Table 5-2 presents the results of sample-size calculations for surface soils around the East Landfill Pond In general, the number of surface soil samples collected during the Phase I RFI/RI far exceed the minimum required to support the DQOs In cases where existing samples are not sufficient to characterize PCOC concentrations, a large number of samples must be collected The costs for collection and analysis of the additional samples are prohibitively high, and not justified to obtain more data in support of the risk assessment However, additional sampling is warranted to characterize the nature and extent of surface-soil contamination further and to assess the impacts of recent grading activities performed by Waste Operations since the Phase I investigation

Additional sampling is warranted at locations where analyte concentrations exceed ARARs or the $UTL_{99/99}$ concentration However, because few ARARs exist for soil, the draft preliminary remediation goals (PRGs) presented in Programmatic Preliminary Remediation Goals for Rocky Flats Plant (EG&G 1994c) were used as substitutes for ARAR values if necessary Verification samples at locations exceeding the $UTL_{99\ 99}$ concentration or ARARs/PRGs are justified because comparison to a UTL or PRG value is not a formal statistical test and, therefore, no false positive errors can occur Verification samples will be collected at each location where the UTL or PRG value was exceeded Additional samples will be collected adjacent to locations where the PRG value was exceeded to delineate the area of soil where PCOC concentrations exceed PRG values (Table 5-3) If future revisions of PRGs result in concentrations at certain locations no longer exceeding these values, verification sampling will not be conducted at these locations

PCOCs were identified for surface soils at IHSS 114 and IHSS 203 but presumptive remediation will address contamination Therefore, no additional surface soil sampling will be performed in these IHSS areas

5 4 7 2 Pond Sediments

A large number of PCOCs were identified for pond sediments The existing data are sufficient and adequate to support a risk assessment and determine the need to remediate However, additional sampling may be warranted to support selection of a remedial technology in the event that the CAMU strategy for OU 7 is not approved by the regulatory agencies

Table 5-4 presents the results of sample-size calculations (refer to Section 5 4 7) for East Landfill Pond sediments Only two samples are needed to characterize the 12 PCOCs in pond sediments for which there is an ARAR or PRG value Therefore, the three sediment samples currently available sufficiently characterize the concentrations of these PCOCs in sediment from the East Landfill Pond These 12 PCOCs include VOCs, SVOCs, metals, and radionuclides For the remaining PCOCs, a minimum of 400 additional samples are needed However, for these five PCOCs, the sample means all exceed the ARAR 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 pond sediments Because the available data already strongly support a decision to take remedial actions, no additional sampling and characterization of pond sediments is recommended The depth of and area covered by pond sediments will be determined after the pond has been drained and prior to development of remedial strategies

5 5 Groundwater and Surface Water

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for groundwater and surface water is described in detail below

5 5 1 State the Problem

A Phase I RFI/RI was conducted at OU 7 in 1992 and 1993 to characterize the sources of contamination and to describe the nature and extent of contamination present at the source and in soils Other sources of data for OU 7 include background geochemical

data (EG&G 1993a), RCRA groundwater monitoring results for the Present Landfill (EG&G 1993c), and data from sitewide groundwater and surface water characterization programs (EG&G 1991a, EG&G 1991e, EG&G 1992e) Results of the Phase I RFI/RI and other investigations provide information on groundwater and surface water quality at the site including dissolved and total analyte concentrations in groundwater from the UHSU and LHSU, and analyte concentrations in surface water from the pond and the two intercept system discharge points Information to determine groundwater flow paths and hydraulic gradients in the UHSU and LHSU in the vicinity of the landfill, hydraulic conductivity estimates for geologic units in the UHSU and LHSU, migration pathways for contaminants in surface water and groundwater, and exposure point concentrations and exposure pathways for human and ecological receptors described in the Exposure Scenarios Technical Memorandum for OU 7 (DOE 1993b) was also obtained

Data collected during the Phase I RFI/RI and other investigations are considered usable for site characterization, risk assessment, and remedial design activities In addition, other data collected since 1990 are considered fully usable because the 1990 data represent the first full year of data collection following implementation of sampling and data quality guidelines in the GRRASP (EG&G 1991g) and task-specific SOPs (EG&G 1992c) Data collected prior to 1990 can be used qualitatively

Data analysis activities to identify PCOCs for groundwater and surface water through statistical comparisons of OU 7 contaminant concentrations versus background concentrations are summarized in Section 4 As agreed to by CDH, EPA, and DOE, PCOC identification is based on statistically significant differences in analyte concentrations in site data versus background data Professional judgment is applied only to spatial distribution, temporal distribution, historic information regarding past operations at the site, inter-element correlations, mass balance calculations, and knowledge of hydrology, geochemistry, and geology of the site to determine if analyte concentrations are indicative of contamination Section 4 also presents the nature and extent of contamination in groundwater and surface water

As discussed previously, a presumptive-remedy strategy has been adopted for the landfill to streamline site characterization and site remediation The East Landfill Pond will be clean-closed in concert with the presumptive-remedy strategy Surface water may be considered a listed waste under RCRA, and therefore, leachate flow to

the pond must be stopped before the surface water can be delisted After being delisted, surface water from the pond will probably be pumped to a treatment facility at the site It is assumed that remediation of pond sediments will be addressed under the CAMU strategy discussed in the next section The presumptive remedy does not address the long-term groundwater response action

The remaining problems are to

1 Identify and fully describe the impacts to groundwater resulting from contaminant releases from the landfill (nature and extent of contamination) to determine whether these impacts require a response action,

2 Design a monitoring network that will meet requirements for post-closure care of the Present Landfill based on an analysis of contaminant fate and transport, and plug and abandon existing wells that will not be part of the monitoring network, and

3 Identify discharge requirements (or regulations for delisting) for surface water to clean close the East Landfill Pond

5 5 2 *Identify the Decision*

The following three decision questions have been identified to resolve the remaining problems

1 Are concentrations of PCOCs in UHSU or LHSU groundwater above or below ARARs and will response actions be required?

2 Are locations of existing wells adequate to meet ongoing groundwater monitoring and post-closure care requirements?

3 Are analyte concentrations in surface water above or below discharge requirements and will response actions be required?

The actions or outcomes that result from resolution of each of the decisions are as follows

1 No action is required if analyte concentrations in the UHSU or LHSU groundwater are below ARARs Collection and treatment of groundwater is required if analyte concentrations exceed ARARs

2 No action is required if locations of wells are adequate for ongoing groundwater monitoring and post-closure care requirements Additional wells are required if locations of existing wells do not meet requirements for ongoing groundwater monitoring and post-closure care

3 No action is required if analyte concentrations in surface water are below ARARs Treatment of surface water prior to discharge is required if analyte concentrations exceed ARARs

5 5 3 Identify the Inputs to the Decision

Information that is not currently available but that will be required to make decisions includes chemical-specific ARARs for OU 7, developed from Rocky Flats benchmarks, location-specific ARARs, action-specific ARARs, requirements for the post-closure groundwater-monitoring program, vertical and areal extent (downgradient limit) of impacted groundwater, and requirements for clean closure of surface impoundments and treatment or delisting of listed waste (RCRA FO 39)

Sources for each item of information identified above include the draft ARARs document for OU 7 (EG&G 1994d), State Subtitle D and RCRA Subtitle C closure requirements (if applicable), additional downgradient monitoring wells along groundwater migration pathways from known source areas, and clean-closure requirements for the East Landfill Pond and RCRA requirements for delisting an FO 39 listed waste

The action level is the measurement threshold that provides the criterion for choosing between alternative actions (EPA 1993c) ARARs are the basis for action levels for groundwater and surface water, when and where available

EPA-approved field sampling techniques were and will be used to collect the necessary data (EG&G 1992c) Samples collected will be subjected to Level IV and V analytical

procedures and reporting requirements The detection and quantitation limits for analyses are specified in the GRRASP (EG&G 1991g)

5 5 4 *Define the Boundaries of the Study*

The geographic area within which all decisions must apply includes the East Landfill Pond, the groundwater intercept system discharge points for surface water, and the areal extent of contaminant plumes in groundwater outside the Present Landfill that originate from OU 7 (includes the vertical extent of contamination)

Each population of interest is defined by several characteristics UHSU and LHSU groundwater is defined by the concentrations of PCOCs within each HSU and the downgradient limit of concentrations exceeding applicable or relevant and appropriate requirements (ARARs) The extent of groundwater contamination is defined by the monitoring-well network configuration with respect to current and predicted plume geometry Surface water from the pond and intercept system discharge points is defined by the concentrations of PCOCs at each location sampled

All data collected from 1990 through 1993 will be used to make the decision Practical constraints on the data collection include limited road access in No Name Gulch to collect samples and install wells, if required, wetlands' issues for the drainage, schedule constraints, and sample independence issues on the number and frequency of groundwater samples needed from all groundwater monitoring wells, including new in No Name Gulch, if required, and schedule constraints related to the time required to perform laboratory analysis and validate laboratory analytical procedures

5 5 5 *Develop Decision Rules*

The first step in developing a decision rule is to specify the parameters that characterize the population of interest The spatial extent of groundwater with concentrations exceeding ARARs provides a means of characterizing UHSU and LHSU groundwater The average concentration of PCOCs at each well is used to define the spatial extent of groundwater concentrations exceeding ARARs The average concentration of PCOCs at each sampling location characterizes surface water from the pond and intercept system discharge points The next step is to specify the action level for the study ARARs are the action level for groundwater and surface water

Two decision rules were developed for UHSU and LHSU groundwater

1 If the concentration of PCOCs does not exceed ARARs, no action is required

2 If the concentration of PCOCs exceeds ARARs, design and implement a response action as part of the IM/IRA decision document

Two decision rules were developed for groundwater monitoring requirements

1 If downgradient monitoring wells are located along migration pathways and are adequate for defining the spatial extent of contamination, no further action is required

2 If downgradient monitoring wells are not located along migration or are not adequate for defining the spatial extent of contamination, install additional monitoring wells to detect contaminant releases downgradient of the landfill to fulfill the monitoring requirements for post-closure care and adequately define the extent of groundwater contamination Wells will be installed during Phase II and potentially during the IM/IRA for performance monitoring

Two decision rules were developed for surface water from the pond and intercept system discharge points

1 If the concentration of PCOCs does not exceed ARARs, no action is required

2 If the concentration of PCOCs exceeds ARARs, then treat or delist surface water as appropriate

5 5 6 *Specify Acceptable Limits on Decision Errors*

The decision error rates are based on consideration of the consequences of making incorrect decisions given potential impacts to cost, schedule, resource expenditure, human health, and ecological conditions (EPA 1993c) Decision error rates are used to establish appropriate performance goals for limiting uncertainty Establishing acceptable error rates is necessary prior to determining the acceptable number of data (samples or tests) necessary to support the decision with a specified level of confidence

The two decision errors for groundwater and surface water are deciding that analyte concentrations exceed ARARs when they actually do not, and deciding that analyte concentrations do not exceed ARARs when they actually do The consequence of deciding that analyte concentrations exceed ARARs when they actually do not will be additional cost incurred for installing unneeded treatment systems The consequence of deciding that analyte concentrations do not exceed ARARs when they actually do could possibly endanger human health or the environment Also, additional costs may be incurred at a later date for environmental cleanup

To reach a decision, an H_0 is formulated so that a given concentration above the ARAR (delta) can be detected with a known probability This probability is known as the power of the test The power of a statistical test is defined as one minus the Type II error rate For groundwater and surface water, the H_0 is groundwater or surface water concentrations exceed ARARs The H_a is groundwater or surface water concentrations do not exceed ARARs False positive decision errors (Type I) occur when the null hypothesis is erroneously rejected (Table 5-1) This decision error occurs when groundwater or surface water concentrations are determined not to exceed ARARs when they actually do False negative decision errors (Type II) occur when the H_0 is erroneously accepted The false negative decision error occurs when groundwater or surface water concentrations are determined to exceed ARARs when they actually do not

To define decision errors and assess potential consequences of incorrect decisions, it is necessary to determine the range of possible concentrations on either side of a numerical standard (ARAR) where the consequences of decision errors are relatively minor (defined by the value delta), assign probability values for Type I and Type II errors (i e , alpha and beta) that reflect the acceptable probability for the occurrence of decision errors, and check the limits on the decision errors to ensure that they accurately reflect the relative consequences for each type of decision error

A range of concentrations about each action level (ARAR) is specified where the consequences of decision errors are relatively minor A range from plus 12 5 percent to minus 12 5 percent of the ARAR concentration has been selected to reflect the concentration range where the consequences of decision errors are relatively minor and cost and schedule impacts associated with improving the ability of the test to discern between the null and alternative hypotheses are high Increasing this range decreases

the power of the test to detect concentrations greater than the ARAR However, increasing the range decreases the number of samples necessary to achieve the desired performance of the test A range of plus or minus 12 5 percent of the ARAR has been chosen as a compromise between increased performance of the statistical test and increased cost and schedule impacts The Type I error rate was chosen on the basis of common statistical practices

Probability values to points above and below the action level were chosen to reflect the acceptable probability for the occurrence of decision errors, acceptable decision error rates are chosen as 5 percent for the false positive decision error (Type I error) and 20 percent for the false negative decision error (Type II error)

5 5 7 *Optimize the Design*

The objective of this step is to identify the most resource-effective sampling design expected to generate data that satisfies the DQOs specified in the preceding steps The DQO outputs and existing environmental data were reviewed and general sampling and analysis design alternatives were developed Widespread contamination is present in the UHSU and additional wells are needed for plume delineation However, the number and location of additional wells needed to delineate contamination further in UHSU groundwater is determined qualitatively in Section 5 5 7 2 and presented in the SAP (Section 6)

PCOCs were identified in the UHSU, LHSU, and all surface water sampling locations Sample sizes needed to describe analyte concentrations and make comparisons of mean concentrations to ARARs were calculated for each PCOC with greater than 50 percent detects for groundwater and surface water Assuming simple random sampling, the following equation (EPA 1993c) was used

$$n = \frac{\sigma^2 (Z_{1-\beta} + Z_{1-\alpha})^2}{\Delta} + 05 (Z_{1-\alpha})^2$$

where

n = number of samples

σ^2 = sample variance

Z = standard normal probability values (from statistical tables)

α = Type I error rate

β = Type II error rate

Δ = 25 percent of the ARAR or PRG

The results of sample-size calculations for surface water and groundwater are presented in Table 5-5 and Table 5-6, respectively

5 5 7 1 Surface Water

The majority of the PCOCs in surface water are adequately characterized by the existing data (Table 5-5) Many of the analytes that are not sufficiently characterized have sample means that are orders of magnitude greater than the value of the ARAR to which they are compared indicating that some PCOCs clearly exceed ARARs and remediation of surface water will be necessary Additional data are not likely to affect the decision to remediate surface water Therefore, the collection of additional samples is not warranted and additional sampling of surface water, beyond that normally conducted as part of the quarterly monitoring program, is not recommended

5 5 7 2 Groundwater

The majority of PCOCs in groundwater are adequately characterized by existing data (Table 5-6) Some of the PCOCs that are not sufficiently characterized are major ions (aluminum, iron, and manganese) in groundwater The sample means and variances for the concentrations of some of these constituents are large values The sample-size calculations indicate that large numbers of samples are required to characterize the concentration of these PCOCs in groundwater for comparison with ARARs However, the mean concentrations of some of these PCOCs are orders of magnitude greater than ARARs indicating that some PCOCs clearly exceed ARARs and remediation of groundwater will be necessary Additional data are not likely to affect the decision to remediate groundwater Therefore, additional groundwater sampling, beyond that normally conducted as part of the quarterly monitoring program, is not recommended The installation of additional wells, however, is recommended to eliminate the data gaps discussed below

Sample size calculations for organic compounds were not performed for one of two reasons either the analyte was not detected in at least 50 percent of the samples, or no ARAR existed for the analyte Analytes detected in more than 50 percent of the samples but for which no ARAR exists included 1,2-dichloroethane-D4, toluene-D8, and bromofluorobenzene Sample size calculations for analytes with fewer than 50 percent detections are not appropriate because sample variances may be artificially reduced through substitution of detection limit values for results below the detection limit (nondetects) If multiple detection limits are reported in the data, sample size calculations would be largely based on the variability of detection limits Because the statistical methodology was not appropriate other quantitative techniques were used to determine the data required to characterize contamination of groundwater by organic compounds The decision to remediate organics in groundwater is based on the analysis of the nature and extent of groundwater contamination discussed in Section 4 7

Data gaps in the groundwater monitoring network were identified qualitatively based on the site conceptual model and the isoconcentration maps presented in Section 4 7 Additional wells are recommended to characterize potential contaminant migration pathways and improve descriptions of the spatial distributions of contaminants in groundwater Additional wells are recommended at four locations (1) north of the East Landfill Pond downgradient of IHSS 167 1, (2) south of the East Landfill Pond downgradient of IHSSs 166 1, 166 2, and 166 3, (3) downgradient of the East Landfill Pond in No Name Gulch above the confluence with the intermittent stream draining IHSS 167 1, and (4) in No Name Gulch below the confluence with the intermittent stream draining IHSS 167 1 An additional well installed in No Name Gulch above the confluence with North Walnut Creek as part of the site characterization program may also be used to characterize contaminant transport in No Name Gulch

5.6 Present Landfill and IHSS 203

The seven-step DQO process used to identify the type, quantity, and quality of data needed to make decisions about remedial actions for the Present Landfill and IHSS 203 is described in detail below

5 6 1 Statement of the Problem

A Phase I RFI/RI was conducted at the Present Landfill and IHSS 203 in 1992 and 1993 to characterize the sources of contamination within OU 7 and to describe the nature and extent of contamination present at the source and in soils Results of the Phase I RFI/RI provide information to develop a site hydrogeologic model, to calculate hydraulic conductivity values for bedrock underlying the landfill, and to describe groundwater flow paths and hydraulic gradients within the landfill

Information describing the contaminant source, such as total volume and areal extent of landfill waste, depth of landfill waste and elevation of subgrade, qualitative descriptions of waste materials, age of landfill waste, approximate amount of interim soil cover material per lift, and volume of saturated landfill waste was also obtained The volume and composition of leachate, leachate-head measurements, estimates of leachate-seep rates, volume and composition of landfill-generated gases, and areas with high concentrations of explosive gas were determined In addition, the effectiveness of the existing containment system (intercept system) was investigated and approximate areas were identified where the system is not functional

Information from the Phase I RFI/RI and other investigations include *in situ* permeability of the interim soil cover material estimated from existing geological information, classification of soils around the landfill using the Unified Soil Classification System (USCS), climate data such as evapotranspiration and precipitation data, input parameters for the LANDFIL2 model to predict gas emission rates, and exposure pathways for human and ecological receptors described in the human health risk assessment exposure scenarios technical memorandum (DOE 1993b) Other sources of data include background geochemical data (EG&G 1993a), RCRA groundwater monitoring results for the Present Landfill (EG&G 1993c), and data from sitewide groundwater, surface water, and geologic characterization programs (EG&G 1991a, EG&G 1991e, EG&G 1991f, EG&G 1992e)

Data collected during the Phase I RFI/RI are considered usable for site characterization and remedial design activities Other data collected since the start of 1990 are also considered fully usable The 1990 data represent the first full year of data collection following implementation of sampling and data quality guidelines outlined in the GRRASP (EG&G 1991g) and SOPs (EG&G 1992c) Data prior to 1990 can be used qualitatively

Prior to the completion of the Phase I RFI/RI and the initiation of Phase II, the focus of investigations at OU 7 shifted as a result of the adoption of the presumptive-remedy strategy for streamlined site characterization and site remediation The presumptive remedy for CERCLA municipal landfill sites relates primarily to containment of the landfill mass including the control or collection and treatment of leachate–groundwater and landfill gas The presumptive remedy does not address exposure pathways outside the source area, nor does it include the long-term groundwater response action

Thus, the problem is to determine what additional data are required from the Present Landfill and IHSS 203 to support closure under CHWA and RCRA, to design the landfill cap, leachate control system, leachate collection and treatment system, gas control system, and gas collection and treatment system, if necessary, and to meet the IAG milestone of July 1997 for IM/IRA implementation

5 6 2 *Identify the Decisions*

In accordance with CHWA regulations, RCRA closure requirements, and Superfund Accelerated Cleanup Bulletin, Presumptive Remedies for Municipal Landfill Sites (EPA 1993a) and Presumptive Remedy for CERCLA Municipal Landfill Sites (EPA 1993b), the basis for action will be the answers to the following decisions

1 What containment design (cap and institutional controls) will satisfy regulatory requirements (State Subtitle D and RCRA Subtitle C closure requirements)?

2 The control of leachate and groundwater is a necessary component of the presumptive remedy to prevent migration from the source area

3 If concentrations do not exceed chemical-specific ARARs, leachate collection and treatment is not required If concentrations exceed chemical-specific ARARs, leachate collection and treatment is required Do leachate concentrations, at the source, meet ARARs?

4 The control of landfill-generated gas is frequently a necessary component of the presumptive remedy to ensure cap integrity Will treatment of landfill-generated gas be required? Guidance is forthcoming on this issue (EPA 1991c, 1993a) In some cases, state ARARs may identify gas clean-up levels (i e , emissions) for such contaminants, and in some cases, health-based levels will be appropriate

5 6 3 Identify the Inputs to the Decisions

Information not currently available but required to make the decisions includes the following

1 Information required for landfill cap design includes a topographic map, the location of existing utilities, the physical properties of the interim soil cover material, and the location and soil characteristics of potential borrow areas

2 Information necessary for leachate control includes additional water levels, calculations of the horizontal gradient across the groundwater intercept system, the predicted rate of water infiltration through the landfill cap, and the seepage generation rate (HELP model output)

3 Information required for leachate collection and treatment is limited to the rate of leachate seepage

4 Information for landfill gas control and treatment is limited to landfill gas emission rates

Data not in existing sources will be collected under the OU 7 SAP (Section 6) Sources for the information required to make decisions is discussed for the (1) landfill cap, (2) leachate control, (3) leachate collection and treatment, and (4) landfill gas control and treatment

1 Information for the landfill cap design—A topographic contour map will be prepared using survey data The map will show the locations of property features, topographic contours, spot elevations, and areas that have recently been graded or mounded Plans for future mounding of waste will be modeled to determine final configuration of the landfill Location of utilities aboveground or underground that may interfere with construction will be identified In addition, the nearest service locations for electricity, water, and communication lines will be identified for construction and operation of the remedial system Physical properties (standard proctor density, grain size, Atterberg limits, *in situ* moisture content, and unconfined compressive strength) of interim soil cover material will be obtained from EG&G Waste Operations If these parameters are not available, the interim soil cover material will be sampled and analyzed Location and soil characteristics (*in situ* moisture, Atterberg limits, grain size, standard proctor density, and falling-

head permeability) of potential borrow areas for clay, sand and gravel, and topsoil will be obtained from existing sources or measured in the field, if necessary

2 Information for leachate control—Water levels and hydraulic conductivity values will be measured in temporary well points straddling the groundwater intercept system between existing well pairs on the north side The predicted rate of water infiltration through the landfill cap and the leachate-generation rate will be calculated using the HELP model (EPA 1986b)

3 Information for leachate collection and treatment—Leachate seep rates will be quantified in the field

4 Information for landfill gas treatment—Landfill gas emissions will be modeled using LANDFIL2 Input parameters will be based on site-specific information and EPA guidance (EPA 1991a)

The action level is the measurement threshold that provides the criterion for choosing between alternative actions (EPA 1993c) Presumptive remedies, CHWA regulations applicable to municipal solid waste landfills, RCRA closure requirements, and chemical-specific and action-specific ARARs are the basis of action levels for the Present Landfill EPA-approved field sampling techniques and analytical methods will be used to collect and analyze data

5 6 4 Define the Boundaries of the Study

The geographic area within which all decisions must apply is the Present Landfill including IHSSs 203 and underlying media to the first uncontaminated confining layer (i e , unweathered bedrock)

Each population of interest is defined by several characteristics The landfill waste is defined by the physical properties of the interim soil cover material, parameters for landfill cap design, areal extent, total volume, and depth of waste material, and the volume of saturated waste material Characterization of the waste is not required in accordance with the NCP Leachate control is defined by the infiltration rate, water levels, gradient, and the hydraulic connection at various points across the groundwater intercept system Leachate treatment is defined by the composition, volume, and flow rate of leachate Gas treatment is defined by the composition, volume, and generation rate of landfill gas

Additional data will be collected now through post-closure care Closure of the landfill will commence by July 1997 Practical constraints on data collection are IAG milestones

5 6 5 *Develop Decision Rules*

The first step in developing a decision rule is to specify the parameters that characterize the population of interest The parameters for final landfill cap design determine how the waste material of the Present Landfill will be treated Statistically significant differences in water levels on either side of the groundwater intercept system determine how leachate will be controlled The average and maximum concentrations for each analyte, and the average and peak flow rates determine how leachate will be treated The average and maximum concentrations for each analyte, and the landfill gas generation rates determine how gas will be treated

The next step is to specify the action level for the study, which is discussed by population of interest

1 Landfill waste—Regulatory guidance specifies containment of the landfill mass as the appropriate response action or "presumptive remedy" Therefore, specification of an action level is not required Design criteria specified in CHWA and RCRA regulations include a hydraulic conductivity value of 10^{7} cm/sec for the compacted clay liner of the double barrier cap and a 40 to 60 mil synthetic membrane

2 Leachate—Regulatory guidance indicates that containment or control of leachate is a component of the presumptive remedy Therefore, specification of an action level is not required The effectiveness of the existing containment structures (the intercept system and underlying unweathered bedrock) to control leachate migration must be evaluated

3 Treatment of leachate is also considered a component of the presumptive remedy under the National Pollutant Discharge Elimination System (NPDES) if leachate is detected at the compliance boundary in either surface water or groundwater

4 Landfill gas—Landfill gas collection is typically considered a necessary component of the remedy to ensure cap integrity To evaluate the need to treat landfill gas, an action level must be specified Based on proposed emission standards for EPA Office of Air Quality, Planning, and Standards, the action level

for emission of NMOCs is 150 megagrams per year Other action levels may be identified during the development of ARARs

A decision rule is developed for each population of interest

1 Landfill wastes—In accordance with regulatory guidance, construction of a containment structure is a presumed component of the response action

2 Leachate—Containment or control of leachate is a presumed component of the response action The performance (effectiveness) of the existing containment structure will be evaluated using hydrologic data If differences in water levels inside and outside the intercept system indicate that the system is effective, no action is required If differences in water levels inside and outside the intercept system indicate that the system is not effective, upgrades are required to contain leachate

3 Treatment of leachate is a presumed component of the response action

4 Landfill gas—Treatment of landfill gas may be required If concentrations of NMOCs in gas do not exceed 150 megagrams per year (or some other identified ARAR), no action is required If concentrations of NMOCs in gas exceed 150 megagrams per year (or some other identified ARAR), a gas treatment system is required

5 6 6 Specify Acceptable Limits on Decision Errors

The decision error rates are used to establish appropriate performance goals for limiting uncertainty (EPA 1993c) Establishing acceptable error rates is necessary prior to determining the appropriate number of data (samples or tests) necessary to support the decision with a specified level of confidence However, as mentioned previously, the statistically-based DQO process is least applicable to the Present Landfill because remedial action decisions are made on the basis of presumptive remediation (i e , experience gained from other similar sites) rather than quantitative evaluation of environmental data to "choose among alternative actions" (Step 5 of the DQO process) and the quantitative method in the DQO process is often not applicable to the types of data needed to support remedial design Table 5-7 presents types of information needed to support design of the presumptive remedy for the Present Landfill and identifies the appropriate methodology for establishing DQOs for each

type of information listed Discussed below are the types of information for which the quantitative DQO process is applicable

5 6 7 *Optimize the Design*

As previously discussed, the DQO process is least applicable to the Present Landfill because decisions are made on the basis of presumptive remediation (i e , experience gained from other similar sites) rather than on the basis of quantitative decision making, with specified error rates and uncertainties, as embodied in Steps 5 and 6 of the DQO process and because the quantitative DQO process is often not applicable to the types of data needed to support remedial design For example, a topographic map is needed to support the design of the landfill cap The appropriate contour interval and quality of the survey data for the map are determined on the basis of standard engineering and surveying practices rather than on quantitative data quality parameters determined from the statistically based DQO process Table 5-7 summarizes the type, quality, and quantity of data necessary to support design of the presumptive remedies These data will be collected during additional field activities at OU 7

To support landfill cap design, maps of topographic contours, future waste mounding, and utility locations will be developed using standard engineering practices These activities will be integrated with EG&G Waste Operations One soil sample per acre will be collected to determine the physical properties of the interim soil cover

Activities associated with identifying suitable cap materials and determining their physical characteristics will not be performed during the Phase II RFI/RI because these activities do not affect the development of design or performance criteria for the presumptive remedies These activities will be performed in cooperation with EG&G Waste Operations and other personnel

The effectiveness of the northern portion of the groundwater intercept system will be determined by installing two wells, one on either side of the groundwater intercept system, to monitor water levels adjacent to the system The composition of landfill leachate will be described through continued quarterly sampling and analysis

Table 5-1
Type I and Type II Decision Errors

Decision Reached Based on Data from Site	True Condition	
	Concentrations in Groundwater and Surface Water DO NOT Exceed Action Levels	Concentrations in Groundwater and Surface Water Exceed Action Levels
Do Not Exceed Action Levels	Correct Decision Reject H_0	Error (Type I) Accept H_0
Do Exceed Action Levels	Error (Type II) Reject H_0	Correct Decision Accept H_0

Type I error rate (probability) = alpha

Type II error rate (probability) = beta

Power (to reject H_0) = 1 - beta

Table 5-2
East Landfill Pond Surface Soils Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
0 to 2 inches								
Arsenic	0 3155	5	100 0	1 8	13 2	4	3,979	133
Barium	6 309	191	100 0	56 3	1,120	11,664	29 002	133
Strontium	165,000	50 1	100 0	36 1	80 6	166 41	2	9
Vanadium	1,920	31	100 0	11 9	86 2	81	2	133
Zinc	82,300	56	100 0	21 5	101	196	2	133
Americium-241	2 38	0 03	100 0	0	1 076	0 01	2	119
Radium-226	2 28	1 0	100 0	0 4355	1 787	0 09	4	79
Nitrate/Nitrite	439,000[1]	4	78 2	1	45	49	2	133
0 to 10 inches								
Arsenic	0 3155	5	100 0	1 2	15 7	4	3,979	67
Barium	6 309	201	100 0	30	546	11,881	29,541	67
Selenium	0 06309	0 4	53 7	0 24	2 4	0 16	3,980	67
Americium-241	2 38	0 0088	100 0	0 000571	0 05813	0 00007056	2	66

[1] PRG value for nitrate

Notes

Metal values reported in milligrams per kilogram
Radionuclide values reported in picocuries per gram.

Definitions

ARAR/PRG	applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq	relative frequency of detected analytes
Max Value	maximum reported value
Min Value	minimum reported value
N	calculated optimal sample size, values rounded up

Table 5-3
East Landfill Pond Surface-Soil Samples Exceeding Draft PRG Concentrations

Analyte	Sample Location	Sample Depth (inches)	Result[1]	Draft PRGs[2]	
				Residential Soil[1]	Commercial Soil[1]
Arsenic	SS705393	0 to 2	13 2	0 366	0 0215
Arsenic	SS702293	0 to 10	15 7	0 366	0 0215
Americium-241	SS702593	0 to 2	0 5817	2 38	0 0189
Americium-241	SS700993	0 to 2	0 06255	2 38	0 0189
Americium-241	SS703793	0 to 2	1 076	2 38	0 0189
Americium-241	SS711493	0 to 10	0 05813	2 38	0 0189
Radium-226	SS707593	0 to 2	1 505	2 28	0 197
Radium-226	SS707793	0 to 2	1 513	2 28	0 197
Radium-226	SS710993	0 to 2	1 596	2 28	0 197
Radium-226	SS711393	0 to 2	1 672	2 28	0 197
Radium-226	SS703293	0 to 2	1 681	2 28	0 197
Radium-226	SS711193	0 to 2	1 787	2 28	0 197

1 Metals reported in milligrams per kilogram Radionuclides reported in picocuries per gram

2 Draft preliminary remediation goals (PRGs) presented in Programmatic Preliminary Remediation Goals for Rocky Flats Plant (EG&G 1994) This document has been submitted to the regulatory agencies for review and approval

Table 5-4
Pond Sediments Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
Arsenic	0 3155	4	100 0	2 7	5	1	996	3
Barium	6 309	198	100 0	174	215	441	1,098	3
Beryllium	0 149	1 2	100 0	0 81	1 5	0 09	403	3
Chromium	0 3155	14 7	100 0	12 3	17 5	6 76	6,723	3
Copper	11,000	16 0	100 0	11 2	18 6	17 64	2	3
Nickel	5,490	12 7	100 0	9 3	15 3	9 61	2	3
Selenium	0 06309	0 8	100 0	0 41	1 1	0 09	2,240	3
Strontium	165,000	52 5	100 0	43 5	61 5	161 29	2	2
Vanadium	1 920	34	100 0	28 8	41	36	2	3
Zinc	82 300	106	100 0	49 2	187	5,184	2	3
Cesium-137	28 3	0 458	100 0	0 2863	0 732	0 0576	2	3
Benzoic Acid	1 00E+06	537	100 0	260	870	95 481	2	3
Fluoranthene	2 97E+07	415	66 7	79	830	145 924	2	3
Phenanthrene	13 980	346	66 7	73	670	77,841	2	3
Pyrene	4 08E+08	386	66 7	74	750	116,281	2	3
Acetone	5 17E+05	68	66 7	63	180	3,481	2	3
Toluene	1 17E+07	307	100 0	180	440	16,900	2	3

Notes

Metal values reported in milligrams per kilogram
Radionuclide values reported in picocuries per gram
Semivolatile and volatile organic compounds reported in micrograms per kilogram

Definitions

ARAR/PRG applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq relative frequency of detected analytes
Max Value maximum reported value
Min Value minimum reported value
N calculated optimal sample size, values rounded up

Table 5-5
Surface Water Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
SW097 Dissolved Analytes								
Barium	1,000	567	100 0	447	673	3,600	2	20
Iron	300	71,050	100 0	51 100	95,800	144,841,225	159,267	20
Manganese	50	1,581	100 0	1 300	2,040	38,416	1,523	20
Strontium	16,800,000	939	95 0	778	1,350	29,584	2	19
Zinc	110[1]	1 530	100 0	240	3,430 00	588,289	4,813	20
Zinc	2 000[2]	1,530	100 0	240	3,430 00	588 289	16	20
Americium-241	0 05[3]	0 1	100 0	-0 001	0 5	0 04	1,585	10
Gross beta	5	8	100 0	0 5469	11	9	37	13
Strontium-89 90	1 110 (d)	1 16	100 0	0 6806	1 933	0 2304	2	9
SW097 Total Analytes								
Barium	1,000	640	100 0	297	1,550	54 289	7	21
Iron	300	80,510	100 0	61,300	155,000	471,020,209	517,929	21
Manganese	50	1 611	100 0	1,320	2,490	68,121	2,698	21
Strontium	16,800,000	919	90 5	814	1,370	43,264	2	21
Zinc	110[1]	2,945	100 0	857	16,000	9,326,916	76,284	21
Zinc	2 000[2]	2,945	100 0	857	16,000	9,326,916	233	21
Gross beta	5	11	100 0	3 753	17	16	65	10
Strontium-89,90	1,110[4]	1 30	100 0	0 66	4 06	1 0201	2	10
Tritium	500	349	100 0	110	1 500	84 681	35	22
Uranium-238	5	1	100 0	-0 01	3 76	1	6	14
Nitrite	500	30 33	66 7	20 00	63 000	338 9281	2	9
1,1-Dichloroethane	2 810	6	85 0	2	10	4	2	20
4-Methylphenol	140	4	60 0	2	10	1	2	5
Benzene	5[5]	2	55 0	1	5	1	6	20
Benzene	0 66[6]	2	55 0	1	5	1	229	20
Diethyl phthalate	350,000	3	80 0	1	10	4	2	5
Ethylbenzene	700	13	95 0	1	18	25	2	20
Fluorene	1 120	2	100 0	2	3	1	2	5
Methylene chloride	5	14	47 6	3	190	1,681	6,656	21
Naphthalene	620	18	100 0	14	22	16	2	5
Toluene	1,000	38	95 0	5	88	576	2	20
Total Xylenes	10 000	14	95 0	1	25	36	2	20
Trichloroethene	5[5]	2	55 0	1	5	1	6	20
Trichloroethene	2 7[6]	2	55 0	1	5	1	15	20
SW098 Dissolved Analytes								
Barium	1,000	167	100 0	135	204	441	2	24
Manganese	50	63	87 5	1	250	4 900	196	24
Strontium	16 800,000	497	100 0	366	596	3,844	2	23
Gross Alpha	7	1 9	100 0	-0 294	4 2	1 96	6	7

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
Gross Beta	5	12	100 0	4 206	22	16	65	13
Strontium-89,90	1,110[4]	1	100 0	0 4	1 613	0	2	10
Uranium-238	5	2	100 0	0 3	15	16	65	15
SW098 Total Analytes								
Manganese	50	101	96 0	2 5	430	10 000	398	25
Nickel	100[5]	11	68 0	6 3	40	25	2	25
Nickel	13 4[6]	11	68 0	6 3	40	25	16	25
Strontium	16,800,000	476	100 0	44 9	598	11,025	2	24
Americium-241	0 05[3]	0 011	100 0	0 0005655	0 075	0 000324	15	18
Gross Alpha	7	2	100 0	-0 67	5	4	10	13
Gross Beta	5	12	100 0	7 9	16	4	18	13
Strontium-89,90	1 110[4]	1 4	100 0	0 6635	1 924	0 25	2	5
Tritium	500	143	100 0	-10	257 8	4 900	4	26
Uranium-235	5	0 1	100 0	-0 01	0 3	0 01	2	10
Uranium-238	5	1 1	100 0	0 6996	1 964	0 16	2	10
SW099 Dissolved Analytes								
Barium	1,000	162	81 3	52 6000	370	10,609	3	18
Strontium	16 800,000	730	88 9	528	1 200	56,644	2	19
Strontium-89,90	1 110[1]	1 272	100 0	0 5767	1 778	0 326041	2	2
Uranium-238	2,290	3 2	100 0	0 3	6 192	6 76	2	2
SW099 Total Analytes								
Barium	1 000	170	83 3	59 5	382	10 816	3	18
Zinc	110[1]	33	94 1	9 5	92 4	529	6	17
Zinc	2,000[2]	33	94 1	9 5	92 4	529	2	17
Americium-241	0 05[3]	0 013	100 0	0	0 052	0 000361	16	12
Gross Alpha	7	3 2	100 0	1 512	6 002	2 89	8	6
Uranium-235	5	0 15	100 0	0 06293	0 2733	0 0064	2	6
Uranium-238	5	2 5	100 0	1 67	3 652	0 81	5	6
SW100 Dissolved Analytes								
Barium	1,000	92	72 7	25 6	200	2,025	2	11
Manganese	50	109	81 8	4 5	733	44,521	1,764	11
Strontium	16,800,000	859	72 7	265	1 600	262,144	2	11
Zinc	110[1]	30	80 0	20	56	196	3	10
Zinc	2,000[2]	30	80 0	20	56	196	2	10
Gross Beta	5	17	100 0	6	33	196	778	6
Uranium-238	2,290	1 7	100 0	0 2	2 475	1 69	2	6
SW100 Total Analytes								
Zinc	110[1]	67	100 0	10	167	2,916	26	17
Zinc	2,000[2]	67	100 0	10	167	2,916	2	17
Americium-241	0 05[3]	0 017	100 0	0 003996	0 041	0 000441	19	3
Gross beta	5 00	33	100 0	20 4	44	144	572	3
Tritium	500 00	273	100 0	16 41	450	51 984	22	5
Nitrite	500 00	29 25	50 0	20 00	65 000	675 4801	2	9

[1] ARAR for agricultural activities
[2] ARAR for aquatic life
[3] ARAR for americium (total)
[4] PRG for strontium-90
[5] ARAR for Safe Drinking Water Act
[6] ARAR for water and fish ingestion

Notes

Metal and organic compound values reported in micrograms per liter

Radionuclide values reported in picocuries per liter

Definitions

ARAR/PRG	applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq	relative frequency of detected analytes
Max Value	maximum reported value
Min Value	minimum reported value
N	calculated optimal sample size, values rounded up

Table 5-6
Groundwater Optimal Sample Sizes

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
LHSU Dissolved Analytes								
Aluminum	50	79	51 3	13	264	3,136	126	39
Barium	1,000	175	94 9	9 40	516	17 689	4	39
Lithium	2,500	49	82 1	10 7	261	2 209	2	39
Manganese	50	37	82 1	1	195	1,521	62	39
Molybdenum	182	63	56 4	4	435 00	5,184	17	39
Strontium	21,900	794	100 0	185	5,700	970,225	2	39
Gross Alpha	7	5	100 0	-0 361	17 85	16	34	48
Gross Beta	5	6	100 0	1 357	16 27	16	65	50
Uranium-235	2 98	0 06	100 0	-0 021	0 334	0 0064	2	50
Uranium-238	2 98	1 2	100 0	0	4 196	1	13	50
LHSU Total Analytes								
Aluminum	50	14,795	100 0	1,140	79,800	398,002,500	15,754,963	19
Barium	1,000	272	100 0	27 70	1,180	77,841	10	19
Chromium	50	36	89 5	3 00	204	3,249	130	19
Iron	300	14 831	100 0	1 020	63,400	328,515,625	361 233	19
Lead	15	19	94 7	1 1	115	841	372	19
Strontium	21,900	474	100 0	241	1,470	96,721	2	19
Tritium	500	12	100 0	-330	300	16,384	8	52
UHSU Dissolved Analytes								
Barium	1,000	154	90 9	7 6	940	33,124	5	330
Iron	300	5,061	55 4	2 4	146,000	278,589,481	306,335	325
Lithium	2 500	189	73 4	1	10,000	7,634 169	123	240
Manganese	50	510	83 9	1	9,230	1,664 100	65,875	277
Nickel	100	21	36 8	2	795	2,209	24	121
Strontium	21 900	758	97 9	65 7	81,700 0	20,277,009	6	323
Zinc	2 000	45	65 5	1 3	1 240	12,996	2	216
Gross Beta	5	5	100 0	-7 2	43 17	36	144	312
Radium-226	0 397	0 8	100 0	0 12	2 166	0 36	228	71
Strontium-89,90	1 44[1]	0 5	100 0	-0 18	11 17	0 81	41	230
UHSU Total Analytes								
Aluminum	50	15,953	94 8	13 00	456,000	2,071,888,324	82,015,870	173
Arsenic	50	5	50 0	0 7	70 70	49	4	172
Barium	1 000	314	94 2	16 1	5 060	242,064	26	173
Chromium	50	26	69 0	2	580	3,136	126	174
Copper	200	160	63 0	2 00	7,140	624,100	1,546	173
Iron	300	27,358	97 1	16 4	656,000	4,234 885,776	4,656,621	173
Lead	15	14	76 9	1 00	263	1,225	541	133
Lithium	2,500	38	76 3	2 6	266	2,116	2	132
Manganese	50	841	98 3	2 2	9 260	2,765,569	109,477	173

Analyte	ARAR/PRG	Sample Mean	Hit Freq (%)	Min Value	Max Value	Variance	N	Number of Samples Collected
Nickel	100	41	61 8	2	1,070	8,836	89	107
Strontium	21 900	538	97 6	83 2	3 720	346,921	2	168
Vanadium	100	40	66 9	2 00	754	6,889	70	172
Zinc	2,000	185	86 5	6 3	8,000	469,225	13	148
Americium-241	0 198	0 01	100 0	-0 433	0 63	0 0036	11	267
Cesium-137	1 7	0 1	100 0	-0 756	1 13	0 16	7	140
Radium-226	0 397	0 60	100 0	0 35	1 32	0 1156	74	7
Strontium-89,90	1 44[1]	0	100 0	0	1	0	2	19
Nitrate/Nitrite	10,000	7,258	88 2	20 00	290,000	735,819,876	730	276

[1] PRG value for strontium-90

Notes

Metal values reported in micrograms per liter
Radionuclide values reported in picocuries per liter

Definitions

ARAR/PRG	applicable or relevant and appropriate requirements/preliminary remediation goals
Hit Freq	relative frequency of detected analytes
LHSU	lower hydrostratigraphic unit
Max Value	maximum reported value
Min Value	Minimum reported value
N	calculated optimal sample size, values rounded up
UHSU	upper hydrostratigraphic unit

Table 5-7
Approach to Establishing DQOs for Information Needed to Support Design of Presumptive Remedy for the Present landfill

Component of the Remedy	Information Type	DQO Methodology	Scope of Phase II Data Collection Activity
Landfill Cap Design	Topographic contour map	Standard engineering practices	Integrate activity with EG&G Waste Operations Personnel
	Map of future waste mounding	Standard engineering practices	Integrate activity with EG&G Waste Operations Personnel
	Location of utilities	Standard engineering practices	Integrate activity with EG&G Waste Operations Personnel
	Physical properties of interim soil cover	Standard engineering practices	Obtain one sample per acre (27 total)
	Location of cap materials	Standard engineering practices	Integrate activity with EG&G Waste Operations Personnel
	Physical properties of cap materials	Standard engineering practices	Integrate activity with EG&G Waste Operations Personnel
Leachate Control	Water levels straddling intercept system	Qualitative approach	Install two wells straddling intercept system on north side of landfill
Leachate Collection and Treatment	Composition	DQO process	Continue routine quarterly monitoring (see Section 5 5 7)
	Discharge rate	Predictive Modeling - HELP[1]	None
Landfill Gas Treatment	Emission rate	Predictive Modeling - LANDFIL2	None

[1] HELP = Hydrologic Evaluation of Landfill Performance Model (EPA 1986b)

Definition

DQO data quality objective

6. SAMPLING AND ANALYSIS PLAN

The DQO process has been integrated with the planning process and the results are presented below Site-specific objectives of additional data collection activities are presented in Section 6 1 The proposed collection approach, sampling locations, sampling activities, equipment and procedures, and proposed analytical suites are discussed for surface soils and groundwater in Sections 6 2 and 6 3 Other field activities to support the design of the landfill cap are discussed in Section 6 4

6.1 Objectives

Presumptive remedies dictate remedial actions at IHSS 114 and IHSS 203 Therefore, additional sampling and characterization of PCOCs in the environmental media within these IHSSs will not affect the decision to remediate Therefore, further characterization of media within IHSS 114 and IHSS 203 is not an objective of the Phase II investigation As discussed in Section 5, surface soils around the East Landfill Pond and groundwater have not been adequately characterized to support decisions concerning remedial actions Decisions on whether or not remediation is necessary require data from additional samples

The specific objectives of the Phase II field investigation are as follows

- Confirm contamination in surface soils at locations around the East Landfill Pond where analyte concentrations exceed the $UTL_{99/99}$
- Characterize the spatial extent of contamination in surface soils at locations around the East Landfill Pond where analyte concentrations exceed draft PRGs
- Evaluate effectiveness of groundwater intercept system north of the landfill
- Further delineate the contaminant plume in UHSU groundwater on the southeast side of the East Landfill Pond
- Further delineate the contaminant plume in UHSU groundwater on the north side of the East Landfill Pond downgradient of IHSS 167 1
- Further delineate the extent of groundwater contamination in the UHSU along No Name Gulch

- Determine the presence or absence of contamination in LHSU groundwater in No Name Gulch
- Design a monitoring network that will meet requirements for post-closure care of the Present Landfill
- Characterize the interim soil cover material

6.2 Surface Soils

Statistical comparisons of surface soil data to background data identified only three PCOCs in soils around the East Landfill Pond However, numerous additional PCOCs were identified on the basis of UTL exceedances Concentrations in excess of UTLs were generally two to three times greater than the maximum concentration of the analyte in background Additional surface soil sampling is warranted at "hotspot" locations where analyte concentrations exceeded the $UTL_{99/99}$ value to confirm that high concentrations are present and at locations where analyte concentrations exceeded draft PRGs (refer to Section 5 4 7) to delineate the area of soil contamination around each hotspot

Samples will be collected from the 0- to 2-inch horizon to verify analyte concentrations in excess of the $UTL_{99/99}$ at 34 locations (Figure 6-1) One sample will be collected per location At the 10 locations where analyte concentrations exceeded PRGs, four samples will be collected to determine the spatial distribution of contamination around the original sample location At each of the 10 locations the samples will be collected at a distance of 25 feet from the original sample location, one each to the north, south, east, and west of the original location Because two of the locations are adjacent, only one sample will be required between them, and a total of 39 samples will be collected

Samples will be collected from the 0- to 10-inch horizon to verify UTL exceedances at 10 locations (Figure 6-2) One sample will be collected per location At two locations where analyte concentrations exceeded PRGs, samples will be collected to determine the spatial distribution of contaminants Four samples will be collected per location as previously described, for a total of 8 samples

6 2 1 Proposed Soil Sampling Activities

Original Phase I locations will be surveyed and staked in accordance with Geotechnical SOP GT 17, Land Surveying (EG&G 1992c) for verification sampling Radiation field screening will be performed at each soil sampling location in accordance with procedures in Field Operations SOP FO 16, Field Radiological Measurements (EG&G 1992c) The prework radiation survey will be performed on a 17-point grid, centered on staked locations, using a Bicron Analyst FIDLER

Soils will be described in the field in accordance with Geotechnical SOP GT 01, Logging Alluvial and Bedrock Material (EG&G 1992c) Surface soil samples will be collected using the grab method, outlined in Geotechnical SOP GT 08, Surface Soil Sampling (EG&G 1992c), to be consist with Phase I sampling methods Grab samples will be collected from a depth of 0 to 2 inches using a stainless-steel scoop In order to collect enough material for all analyses, four scoops of soil will be obtained from each grid location, north, south, east, and west of the location stake The grab samples will be combined in a stainless-steel bowl, split, and then placed into individual sample jars Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7 1 Each soil sample will be assigned a unique sample number

Subsurface soil samples will be collected using the hand auger method outlined in Geotechnical SOP GT 08, Surface Soil Sampling (EG&G 1992c) Vegetation will be removed from the sampling location with a decontaminated shovel The thin layer of soil that contacts the shovel will then be removed with a stainless-steel scoop A hand auger will be used to collect the sample to a depth of 10 inches The soil will be combined in a stainless-steel bowl, split, and placed into individual sample jars Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7 1 Each soil sample will be assigned a unique sample number All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO 03, General Equipment Decontamination (EG&G 1992c)

6 2 2 Analytical Requirements for Soil Samples

Soil samples collected around the East Landfill Pond will be analyzed for metals, gross alpha, gross beta, plutonium-239,240, americium-241, uranium-233,234, uranium-235,

uranium-238, cesium-137, strontium-89,90, tritium, TOC, and nitrate as N This analyte list is the same as that used for surface soil samples at the East Landfill Pond during the OU 7 Phase I RFI/RI Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report, and Field Operations SOP FO 13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c) Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g)

6 3 Groundwater

The Phase I investigation identified contamination of groundwater in the UHSU Additional wells are now needed to delineate contaminant plumes thought to be present near the East Landfill Pond embankment and along No Name Gulch The number and locations of additional wells needed to further delineate contamination in UHSU groundwater was determined qualitatively by an analysis of plume maps and contaminant transport pathways (Section 5 5)

PCOCs were also identified in groundwater from the LHSU, but the extent of groundwater contamination appeared limited Professional judgment was used to assess whether (1) PCOCs are the result of natural variability in geologic materials, (2) the detections of VOCs are valid, and (3) the occurrence of PCOCs in the LHSU make geochemical sense on the basis of fate and transport characteristics Characterization of contamination in the LHSU directly beneath IHSS 114 will not be performed due to the potential problems associated with drilling through the landfill and the potential for enhancing vertical migration of contaminants during drilling A preliminary characterization of the vertical extent of contamination in the LHSU was performed only at the compliance boundary located just east of the landfill dam using existing data Additional characterization of LHSU groundwater farther east in No Name Gulch is warranted

Eight additional monitoring wells are proposed to meet the following three distinct objectives (1) evaluate the effectiveness of the groundwater intercept system in preventing groundwater flow into the landfill, (2) delineate contaminant plumes in UHSU groundwater, and (3) determine presence or absence of groundwater contamination in the LHSU

The effectiveness of the groundwater intercept system in preventing groundwater flow into the landfill will be investigated by installing two wells, one on each side of the intercept system The two wells will be located on the north side of the landfill approximately halfway between existing wells 71193 and 6287 Both wells will be screened across artificial fill material and the screened interval will be at a depth of approximately 10 to 20 feet

To further delineate the contaminant plume in UHSU groundwater on the southeast side of the East Landfill Pond, the installation of one additional well is proposed between wells B206689 and B206889 The well location (Figure 6-3) is at an elevation of approximately 5940 feet in a small tributary just south of the dirt road The borehole will be drilled to saturated weathered bedrock The well will be screened across weathered bedrock with the screened interval at a depth of approximately 15 to 20 feet below ground surface, similar to the screened interval in the existing nearby wells to ensure comparability of groundwater quality data One additional well is also proposed to further delineate the contaminant plume in UHSU groundwater on the north side of the East Landfill Pond downgradient of IHSS 167 1 The well will be located east of well 7187 and north of well B207289 (Figure 6-3) at an elevation of approximately 5950 feet The borehole will be drilled to the depth of the water table The well will be screened across colluvium The screened interval will be at a depth of approximately 15 to 20 feet below ground surface

A group of three wells is proposed to further delineate contaminant plumes in UHSU groundwater, determine the presence or absence of contamination in LHSU groundwater in No Name Gulch, and meet groundwater-monitoring requirements for post-closure care of the Present Landfill The well location (Figure 6-3) is approximately 300 feet downgradient of the compliance wells, west of the confluence of No Name Gulch, with the intermittent stream draining IHSS 167 1 One well will be screened in valley-fill alluvium with the screened interval at a depth of approximately 5 to 10 feet below ground surface The second well will be screened in weathered bedrock the screened interval at a depth of approximately 15 to 25 feet below ground surface The third well will be screened in unweathered bedrock sandstone with the screened interval at a depth of approximately 40 to 50 feet below ground surface One monitoring well is also proposed 250 feet east of the confluence of No Name Gulch and the tributary to the north that drains IHSS 167 1 The well will be installed in valley-fill alluvium with the screened interval at a depth of approximately 5 to 10 feet

Exploratory boreholes will be used to select the location and depth of the proposed wells in No Name Gulch and to maximize the probability of intercepting preferential groundwater flow paths

6 3 1 *Borehole Drilling Activities*

Boreholes will be drilled at eight locations (Figure 6-3) for the purpose of installing groundwater monitoring wells In addition, exploratory boreholes will be drilled to select the optimum location of the wells to be installed in No Name Gulch

Exploratory boreholes will be used in the vicinity of the proposed well locations to determine the location of preferential groundwater flow paths in No Name Gulch At each borehole location, measurements will be made of depth to groundwater, thickness of saturated valley-fill alluvium, pH, dissolved oxygen, and specific conductance in accordance with procedures outlined in Groundwater SOP GW 01, Water Level Measurements in Wells and Piezometers, and GW 05, Field Measurement of Groundwater of Groundwater Field Parameters (EG&G 1992c) Permanent wells will be installed to maximize the probability of intercepting groundwater flow paths at each of these locations based on data collected during exploratory drilling

Prior to invasive activities, Geotechnical SOP GT 24 requirements will be reviewed and followed to acquire soil-disturbance approval form Rocky Flats Construction Management Drilling locations will be staked and cleared in accordance with Geotechnical SOP GT 10, Borehole Clearing (EG&G 1992c) Radiation field screening will be performed at each drilling location on a 17-point grid using a Bicron Analyst FIDLER, in accordance with procedures in Field Operations SOP FO 16, Field Radiological Measurements (EG&G 1992c) After drilling, all borehole and well locations will be surveyed in accordance with Geotechnical SOP GT 17, Land Surveying (EG&G 1992c)

Locations will be drilled using hollow-stem augers equipped for continuous core sampling in accordance with Geotechnical SOP GT 02, Drilling and Sampling Using Hollow Stem Auger Techniques (EG&G 1992c) and a Mobil B-57 drill rig Continuous core samples will be collected from all locations using a 3-inch inside diameter, 2-foot-long sample barrel A moss system will be used to retrieve the core after each run while leaving the augers in place Drilling will be accomplished using 6 5/8-inch outside diameter hollow-stem augers and a 7-inch outside diameter bit

For boreholes drilled into bedrock, 6-inch PVC surface casing will be installed to isolate surficial materials from bedrock, in accordance with Geotechnical SOP GT 03, Isolating Bedrock from Alluvium with Grouted Surface Casing (EG&G 1992c) Drilling and sampling will continue using hollow-stem augers until sample collection activities are completed or poor core recovery becomes a problem At that point, rotary coring methods will be used in accordance with Geotechnical SOP GT 04, Rotary Drilling and Rock Coring (EG&G 1992c) Potable Rocky Flats water will be used as a drilling medium A continuous core will be obtained using 1¾-inch inside diameter, 5-foot-long core tubes, placed within and retrieved from the lead rod with an overshot system Drilling will continue until a bedrock sandstone unit is encountered, at which time a screened interval will be selected and a monitoring well will be installed

Preliminary core descriptions will be completed in the field, and all core not used for chemical sampling will be boxed at the site Wooden blocks will be labeled and placed in the core boxes to mark the beginning and end depth for each box, the beginning of each drilling interval, and to represent sections of no recovery or sections used for chemical samples After the core is brought to the field trailer, it will be described in detail in accordance with Geotechnical SOP GT 01, Logging Alluvial and Bedrock Material (EG&G 1992c)

Drill cuttings from all locations will be containerized in 30-gallon drums in accordance with Field Operations SOP FO 08, Handling of Drilling Fluids and Cuttings (EG&G 1992c) Characterization of the investigative-derived materials (IDM) contained in the drums will be based on analytical results of the borehole samples corresponding to the drill cuttings interval in the drums Drum handling will be conducted in accordance with Field Operations SOP FO 23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f)

Exploratory boreholes not used for well installation will be abandoned in accordance with guidelines in Geotechnical SOP GT 05, Plugging and Abandonment of Boreholes (EG&G 1992c) All downhole drilling equipment will be decontaminated at the main decontamination facility before being used at each new drilling location The drill rig will be decontaminated in accordance with procedures outlined in Field Operations SOP FO 04, Heavy Equipment Decontamination (EG&G 1992c)

6 3 2 *Drum Sampling Activities*

All proposed drilling activities that will generate residual soil or sediment will take place outside the IHSSs at OU 7 Sampling of the drill core material is not planned because the data from the Phase I RFI/RI show little or no contamination in samples from subsurface geologic materials

If verified field screening results are below background as defined in Field Operations SOP FO 08, Handling of Drilling Fluids and Cuttings, and FO 16, Field Radiological Measurements (EG&G 1992c), residual soil or sediment will be disposed as clean fill on site (if cuttings are from boreholes with less than 20 feet of bedrock) in accordance with Field Operations SOP FO 23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f) These materials will be dispersed and leveled within the disturbed area and reseeded following guidance from the EG&G Ecology Department Bedrock cuttings, if any, will be covered with alluvial materials For cuttings from boreholes with more than 20 feet of bedrock, residual soil or sediment will be disposed in the landfill in accordance with Field Operations SOP FO 23, Management of Soil and Sediment Investigative Derived Materials (EG&G 1994f) Cuttings containerized in drums will be taken to the landfill by EG&G Trucking for disposal

If verified field screening results are above background as defined in Field Operations SOP FO 08, Handling of Drilling Fluids and Cuttings, and FO 16, Field Radiological Measurements (EG&G 1992c), residual soil or sediment will be drummed at the drilling location in accordance with Field Operations SOP FO 08 and labeled in accordance with FO 10, Receiving, Labeling, and Handling Environmental Materials Containers A representative sample will be collected in accordance with Field Operations SOP FO 20, Sampling of Liquids and Solid Environmental Materials Containers (EG&G 1992c) and analyzed for appropriate constituents as discussed below Results of this analysis will be used to characterize the drum

6 3 3 *Analytical Requirements for Drum Samples*

Drum samples will be analyzed for VOCs, SVOCs, PCBs, metals (standard and additional), gross alpha, gross beta, plutonium-239,240, americium-241, uranium-233,234, uranium-235, uranium-238, strontium-89,90, cesium-137, tritium, TOC, pH, nitrate as N, and nitrate/nitrite, and sulfide This analyte list is the same as that used for borehole samples during the Phase I RFI/RI for OU 7 Samples will be containerized,

preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report, and Field Operations SOP FO 13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c) Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g)

6 3 4 Monitoring Well Installation and Development

A total of eight monitoring wells will be installed at six locations (Figure 6-3) in accordance with Geotechnical SOP GT 06, Monitoring Well and Piezometer Installation (EG&G 1992c) Advanced notification of monitoring well installation is necessary for the State of Colorado Division of Water Resources After the borehole or well is drilled to total depth, water and fine-grained sediment will be bailed using a sand bailer until the water is relatively clear The well assembly, comprised of a 2-foot sump, 2-inch diameter slotted screen, and 2-inch diameter blank casing, will then be placed in the borehole In open-hole installation, stainless-steel centralizers will be placed above and below the well screen to ensure that a 2-inch annulus is maintained Filter pack will be added through a tremie pipe to at least 6-inches above the top of the screen A minimum 2-foot bentonite pellet seal will be installed immediately above the filter pack Bentonite grout backfill will be placed from the top of the bentonite seal to the ground surface

After the bentonite grout is allowed to settle for 24 to 72 hours, a 5-foot-long, 6-inch diameter protective steel casing with a locking steel cap will be installed over the monitoring well riser Protrusion of the riser will be a minimum of 2 feet The protective casing will be embedded 2 to 3 feet below the ground surface in concrete or grout The annulus between the well riser and the protective casing will be filled with concrete and an external concrete pad approximately 3-feet square will be built around the protective casing at the ground surface The well designation will be inscribed in the concrete before it sets and welded to the protective casing

Alluvial wells will be installed with the base of the screen at the contact between alluvium and weathered bedrock Weathered bedrock wells will be installed with the base of the screen at the contact between weathered and unweathered bedrock The bentonite seal will be straddling the contact between the alluvium and the weathered bedrock to isolate the screen and filter pack from alluvial groundwater Bedrock wells will be constructed similarly, except that the bedrock will be isolated from alluvial materials with a grouted 8-inch steel surface casing installed in accordance with

Geotechnical SOP GT 03, Isolating Bedrock from Alluvium with Grouted Surface Casing (EG&G 1992c) Stainless-steel centralizers will be placed on the casing 3 to 5 feet below ground surface and 3 to 5 feet from the base of the casing to ensure a minimum 2-inch annular space After the casing is in place, a cement-grout mixture will be forced out through pre-drilled ports at the base of the casing into the annulus by pushing a plug down through the casing The annulus will be topped off with cement grout, if necessary, and the cement grout will be allowed to harden for a minimum of 24 hours

Drilling below the surface casing at bedrock monitoring well locations will be accomplished using 6 5/8-inch outside diameter hollow-stem augers until core recovery degrades The rig will then be converted for rotary core drilling, and drilling will continue in accordance with Geotechnical SOP GT 04, Rotary Drilling and Rock Coring (EG&G 1992c) After reaching total depth, bedrock wells will be installed in an open borehole using the procedure described above

Monitoring wells will be developed to remove drilling fluids and particulates from the groundwater and provide physically and chemically representative groundwater samples Well development will be performed in accordance with SOP GW 02, Well Development (EG&G 1992c) Equipment will be decontaminated before and after each use in accordance with Field Operations SOP FO 03, General Equipment Decontamination (EG&G 1992c) Water level and total depth measurements will be taken to determine the volume of water in the well casing The volume of water to be purged from the well will be calculated according to guidelines in Groundwater SOP GW 02, Well Development (EG&G 1992c) The purge amount is generally five well casing volumes During development, water is withdrawn from the wells using a bailer or an inertial pump The purge water will be emptied into a graduated bucket to measure the amount of water removed and transferred to a holding tank for proper disposal The purge and decontamination water will be handled in accordance with Field Operations SOP FO 07, Handling of Decontamination and Wash Water (EG&G 1992c)

Field parameters including pH, temperature, specific conductance, and turbidity will be measured at regular intervals at least once for each well casing volume following the procedures outlined in Groundwater SOP GW 05, Field Measurement of Groundwater Field Parameters (EG&G 1992c) A well is considered fully developed after a minimum of five casing volumes of water are removed, field parameter measurements range within

10 percent for three consecutive well casing volumes, and the purged water is free of suspended sediment

6 3 5 *Drawdown Recovery Tests*

Drawdown recovery tests will be performed at six of the recently installed wells to estimate the hydraulic conductivity of saturated geologic materials including colluvium, valley-fill alluvium, weathered Arapahoe and Laramie Formation, and the uppermost unweathered sandstone in the Arapahoe and Laramie Formation The drawdown recovery test method, which involves purging a volume of water from the well to lower the water level by approximately 2 to 6 feet, is considered more appropriate than the slug injection test method based on results during the Phase I investigation Tests will be performed after the wells are developed, the first month of groundwater sampling is completed, and the static water level has stabilized Tests will not be conducted at the wells that straddle the northern groundwater intercept system

The drawdown recovery tests will be performed in accordance with Groundwater SOP GW 04, Slug Tests (EG&G 1992c) After removing the well cap and monitoring the well for health and safety purposes, the static water level at the well will be measured and verified to the nearest 0 01 foot from the measuring point The total depth of the well will be measured and verified using a weighted tape measure Water level and total depth measurements will be recorded and compared to previous measurements to confirm water level stabilization When the water level has stabilized, the test will be conducted

A Hermit® SE 1000 data logger will be coupled to a transducer that has a sensitivity of 10 pounds per square inch and is capable of measuring hydraulic head to an accuracy of approximately three thousandths of a foot The data logger will be programmed to record change in hydraulic head (in feet) above the transducer at a logarithmic rate All transducer specifications provided by the manufacturer, including serial number, linearity, scale, and offset will be programmed into the data logger The transducer will be lowered into the well to a depth at which it will not be disturbed by a bailer The transducer cable will be secured to the well casing with tape to maintain the appropriate depth of the probe To ensure that the transducer and logger are working properly, the transducer cable will be raised and lowered in the well while the change in hydraulic head is observed on the data logger visual read out screen After the visual check has been completed, the water level will be allowed to stabilize and the test will be referenced to zero

After the test is set up, a 3-foot-long by 1 5-inch bailer will be lowered down the well Water will be purged from the well until an appropriate drawdown is achieved The test will be started immediately after the last bailer of water is removed from the well The water purged from the well will be containerized and disposed in accordance with Field Operations SOP FO 05, Handling of Purge and Development Water (EG&G 1992c) Purge rates, volumes of water removed, test-start times, and initial drawdowns will be recorded

The duration of each test will be dependent on the drawdown recovery rate or the rate at which the drawdown approaches zero The test will be considered complete when the water level recovers to 90 percent of the drawdown depth The drawdown and percent recovery will be checked by scanning the measurements recorded in the data logger When water levels have recovered, the test will be terminated Before and after each test, all down-hole equipment will be decontaminated following procedures in Field Operations SOP FO 03, General Equipment Decontamination (EG&G 1992c)

After the data logger reaches storage capacity, the data collected will be downloaded into a computer The time versus drawdown data will be imported into AQTESOLV (Geraghty and Miller 1991) to compute the estimated hydraulic properties using the appropriate analytical solutions

6 3 6 Groundwater Sampling

Groundwater samples will be collected from the eight new wells installed during the Phase II investigation to characterize groundwater quality downgradient of existing contaminant plumes Four samples will be collected at each location Frequency of sample collection will be monthly Duplicate, equipment rinse, and trip blank QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7 1 MS, MSD, and laboratory replicate QC samples will be collected in accordance with Groundwater SOP GW 06, Groundwater Sampling (EG&G 1992c) Each groundwater sample will be assigned a unique sample number

Groundwater samples will be collected in accordance with Groundwater SOPs GW 06, Groundwater Sampling, and GW 01, Water Level Measurements in Wells and Piezometers (EG&G 1992c) Water level and total depth measurements will be taken to determine the volume of water in the well casing These data will be used to calculate the casing and purge volumes Standing water will be purged from the well with a bailer

The equivalent of three well casing volumes will be purged to guarantee that the sample is representative of the groundwater in the formation

Field parameters including conductivity, pH, temperature, dissolved oxygen, and turbidity will be measured from an aliquot of the first bailer of water in accordance with Groundwater SOP GW 05, Field Measurement of Groundwater Field Parameters (EG&G 1992c) Conductivity, pH, and temperature will be measured for every half-casing volume of water removed from the well Turbidity and dissolved oxygen will be measured a second time during well purging Well purging will be considered complete when three casing volumes have been purged and the field parameter measurements have been stabilized Purge and decontamination water will be handled in accordance with Field Operations SOP FO 07, Handling of Decontamination and Wash Water (EG&G 1992c)

After completion of well purging, groundwater samples will be collected using a bailer VOC samples will be collected from the first bailer of water The remaining unfiltered samples will be transferred directly from the bailer to the appropriate sample containers using a bottom emptying device Samples for dissolved analyses will be transferred to a stainless-steel bucket and filtered using a peristaltic pump with a disposable 0 45-micron filter All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO 03, General Equipment Decontamination (EG&G 1992c)

6 3 7 *Analytical Requirements for Groundwater Samples*

Groundwater samples will be analyzed for VOCs, SVOCs, dissolved and total metals (standard and additional), water-quality parameters (Cl, F, SO_4, Si, CO_3, HCO_3, TDS, TSS), dissolved and total gross alpha, dissolved and total gross beta, dissolved and total plutonium-239,240, dissolved and total americium-241, dissolved and total uranium-233,234, dissolved and total uranium-235, dissolved and total uranium-238, dissolved and total strontium-89,90, dissolved and total cesium-137, tritium, nitrate/nitrite, cyanide, and sulfide This analyte list is the same as that used during the Phase I RFI/RI for OU 7 Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report, and Field Operations SOP FO 13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c) Sample analyses will be performed using EPA CLP and other standard methods as specified in the GRRASP (EG&G 1991g)

6.4 Field Activities Related to Landfill Cap Design

The physical properties of the existing soil cover material in IHSS 114 (interim soil cover) will be determined through additional soil sampling and analysis One soil sample will be collected per acre for a total of 27 samples Soil sampling locations will be determined using the same sampling grid used during the Phase I soil sampling (Figure 6-4) Samples will be collected from staked locations in the center of each 100-foot by 50-foot polygon Locations will be surveyed in accordance with Geotechnical SOP GT 17, Land Surveying (EG&G 1992c) Radiation field screening will be performed at each soil sampling location in accordance with procedures in Field Operations SOP FO 16, Field Radiological Measurements (EG&G 1992c) The prework radiation survey will be performed on a 17-point grid centered on staked locations using a Bicron Analyst FIDLER

Soils will be described in the field in accordance with Geotechnical SOP GT 01, Logging Alluvial and Bedrock Material (EG&G 1992c) Surface soil samples will be collected using the grab method, outlined in Geotechnical SOP GT 08, Surface Soil Sampling (EG&G 1992c), to be consist with sampling methods at the East Landfill Pond Grab samples will be collected from a depth of 0 to 2 inches using a stainless-steel scoop In order to collect enough material for all analyses, four scoops of soil will be obtained from each grid location, north, south, east, and west of the location stake The grab samples will be combined in a stainless-steel bowl, split, and then placed into individual sample jars Duplicate and equipment rinse QC samples will be collected in accordance with the QC sampling frequency guidelines in Section 7 1 Each soil sample will be assigned a unique sample number All sampling equipment will be decontaminated between locations in accordance with Field Operations SOP FO 03, General Equipment Decontamination (EG&G 1992c)

Samples of interim soil cover material collected in the Present Landfill will be measured for physical properties including standard proctor density, grain size, Atterberg limits, *in situ* moisture content, and unconfined compressive strength Samples will be containerized, preserved, handled, and shipped in accordance with QA/QC requirements specified in Section 7 of this report, and Field Operations SOP FO 13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples (EG&G 1992c) Sample analyses will be performed using standard methods as specified in the GRRASP (EG&G 1991g)

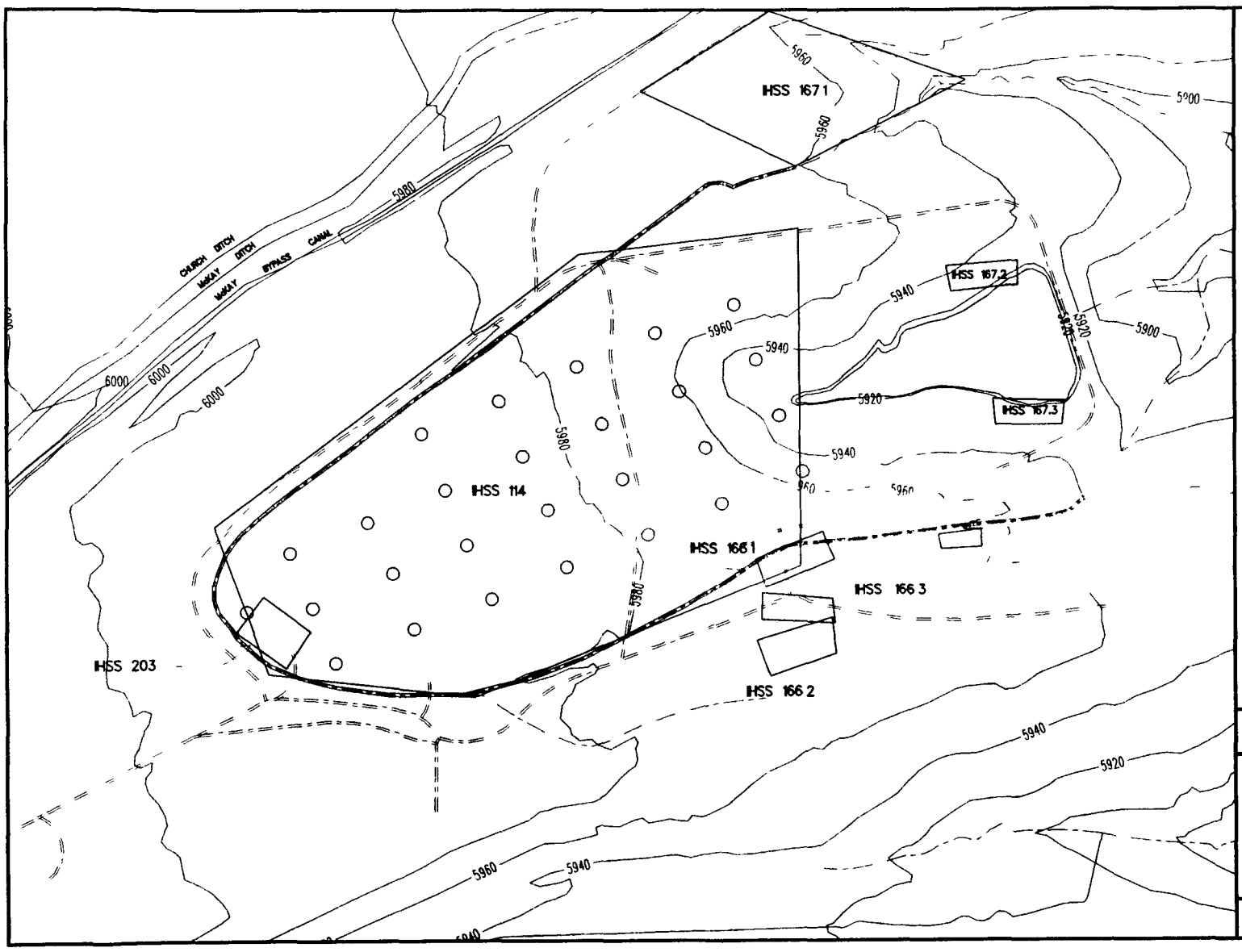
Section 6

Figures

NOTICE:

It appears that Figures 6-1, 6-2 and 6-3 are missing. The document was distributed without these figures. If replacement pages are distributed, they will be mircrofilmed and included in the Administrative Record file.

The Administrative Record Staff



EXPLANATION

- Phase II Surface-Soil Sample 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 Site, Golden, Colorado

Proposed Phase II Soil-Sampling Locations for Landfill Cap Design

Revised Work Plan | Operable Unit No. 7

Date: April 1994 | Figure 6-4

04/14/94 PROP_SSIHSS142.MAP

7. QUALITY ASSURANCE AND QUALITY CONTROL

Section 6 presents the SAP for the Phase II RFI/RI at OU 7 and addresses the proposed field activities and locations as well as the proposed analytical suites for the samples to be collected during the field investigation QA/QC objectives for data collection, analytical procedures, data-quality calibration, and data reduction, validation, and reporting are included in the QAPjP (EG&G 1991h) All field and analytical procedures will be performed in accordance with the GRRASP (EG&G 1991g) and appropriate SOPs (EG&G 1992c)

7.1 Quality Control Sample Collection

The objective of the QAPjP is to provide a framework to ensure that all sampling and analytical data achieve specific data-quality standards QC samples will be collected in conjunction with the real samples to provide information to assess data quality The field QC samples to be collected during the Phase II investigation include field duplicates, field blanks, equipment rinses, and trip blanks Trip blanks generally pertain only to VOC analyses, whereas other QC samples may pertain to all of the analytical parameters specified for investigative samples in the SAP

Field duplicates will be collected by the sampling team for use as a relative measure of the precision of the sample-collection process In addition to evaluating analytical precision, duplicate samples will provide information regarding the natural variability of the sampled media as well as the precision of the sampling methods

Field blanks of distilled water will be prepared and preserved as appropriate by the sampling team and will be used to provide an indication of any contamination introduced during field sample preparation

Equipment rinses will be collected from final decontamination rinse water to evaluate decontamination efforts on non-dedicated sampling equipment Equipment rinses are applicable to all analyses for water and soil samples to monitor the effectiveness of decontamination procedures

Trip blanks consisting of distilled will accompany each shipment of water samples for VOC analysis Trip blanks will be stored with the group of samples with which they are associated Analysis of trip blanks will indicate possible contamination by VOCs

or any problems associated with sample shipment, handling, or storage Information from the trip blanks will be used in conjunction with air monitoring data and other information to assess the influence of ongoing waste operations on the quality of data collected Table 7-1 presents the collection frequency for the field QC samples

7.2 Analytical Procedures

All samples sent for CLP Level IV analyses will be handled in accordance with CLP guidelines QC procedures for non-CLP methods will be developed as needed using standard methods

Sensitivity defines the lowest concentration (detection limit) a method can accurately and repeatedly detect for a particular chemical or compound The required detection limits for CLP analyses are outlined in Appendix B in the QAPjP (EG&G 1991h) Detection limits for non-CLP indicator parameter analyses are specified in the respective EPA methods

Analytical procedures and conditions are tested using laboratory blanks and replicates Laboratory MS and MSD samples measure analytical accuracy by providing data on matrix effects and interferences and components interfering with instrument responses The frequency of collection and analysis of laboratory QC samples is dictated by the prescribed analytical method as specified in the GRRASP (EG&G 1991g)

7 3 Data Quality

Data quality is assessed in terms of precision, accuracy, representativeness, completeness, and comparability, also known as the PARCC parameters

7 3 1 Precision

Precision is a quantitative measure of variability that is evaluated by comparing analytical results for real samples to analytical results for corresponding duplicate samples Analytical precision for a single analyte is expressed as the RPD between results of duplicate samples (and matrix spike duplicates) for a given analyte RPDs indicate the degree of reproducibility of both the sampling and analysis methods The control limits that have been established to achieve precision objectives for CLP Level IV data are outlined in Appendix B of the QAPjP (EG&G 1991h) Precision limits for inorganic analytes are outlined in this table as well The analyses for indicator

parameters are non-CLP Non-CLP analyses will be conducted according to SW-846 (EPA 1986) and EPA Methods for Chemical Analyses of Water and Wastes (EPA 1983) The precision criteria for these samples are specified in the respective methods For the OU 7 data, acceptable RPDs are less than 20 percent for all analytes in water (surface water and groundwater) and less than 35 percent for all analytes in soil (surficial soil, subsurface geologic material, and sediments)

7 3 2 *Accuracy*

Accuracy is a measure of the closeness of a reported concentration to the true value Analytical accuracy is expressed as percent recovery of a spike of a known concentration that has been added to an environmental sample before analysis The control limits that have been established to achieve accuracy objectives for CLP Level IV data are outlined in Appendix B of the QAPjP (EG&G 1991h) Accuracy limits for inorganic analytes are listed in this table as well The OU 7 QC criterion for acceptable percent recovery in CLP Level IV data is 80 percent to 120 percent for all analytes in all media

Samples requiring 24-hour turnaround (that is, indicator parameter analyses) have accuracy objectives consistent with CLP Level III data quality The analyses for indicator parameters are non-CLP Non-CLP analyses will be conducted according to SW-846 (EPA 1986) and EPA Methods for Chemical Analyses of Water and Wastes (EPA 1983) The accuracy criteria for these samples are specified in the respective methods

7 3 3 *Representativeness*

Representativeness is a qualitative parameter that expresses the degree to which the data accurately and precisely represent the characteristics of a particular site or condition Of specific concern to the OU 7 Phase II investigation is the potential for sample contamination that could be introduced during sample collection and handling This possibility is evaluated using field blanks, equipment rinses, and trip blanks Representativeness is ensured through the careful development and review of the sampling strategy outlined in the SAP and SOPs for sample collection, analysis, and field data collection

7 3 4 Completeness

Completeness is a measure of the amount of usable data resulting from a data-collection activity The target completeness objective for both field and analytical data for this project is 100 percent The minimum acceptable completeness value is 90 percent

7 3 5 Comparability

Comparability expresses the confidence with which one data set can be compared to another Differences in field and laboratory procedures greatly affect comparability Comparability is ensured by implementation of an approved SAP, standardized analytical protocols, SOPs for field investigations, and reporting data in uniform units, as specified in the OU 7 Phase II SAP

7.4 Sample Management

Sample management is a critical component of the OU 7 Phase II SAP and ensures that sample integrity is maintained from sampling through analysis All aspects of sample management, including sampling, decontaminating equipment, preserving and storing samples, following chain-of-custody procedures, and shipping will be conducted in accordance with applicable SOPs (EG&G 1992c) Table 7-2 lists the container types, preservation methods, and holding times for samples and/or sample suites for each media

Sample control and documentation is necessary to verify the quality and quantity of work performed in the field and to ensure that the data are defensible Documents used for accountability include logbooks, data-collection forms, sample labels or tags, chain-of-custody forms, photographs, and analytical records and reports Specific guidance defining the necessary sample control, identification, and chain-of-custody documentation is presented in SOP FO 13, Containerizing, Preserving, Handling, and Shipping of Soil and Waste Samples (EG&G 1992c)

7.5 Data Reduction, Validation, and Reporting

Field measurements, data, and observations will be recorded in project logbooks, on field data forms, or on similar permanent records, as specified in appropriate SOPs (EG&G 1992c) Field data and sampling records will become QA records Field QA

records will be transmitted to the EG&G EMD records center in accordance with SOP FO 02, Transmittal of Field QA Records (EG&G 1992c)

Field data will be managed as outlined in SOP FO 14, Field Data Management (EG&G 1992c) Field data will be collected, recorded, entered into electronic format, validated, transmitted to EG&G, and filed in RFEDS Sample tracking information will also be entered into electronic format, validated, transmitted, and filed in the database Computer hardware and software requirements and data security measures will also follow guidelines in the SOPs (EG&G 1992c)

The EPA-CLP sample results will be reported as specified in the GRRASP (EG&G 1991g) and in guidance for providing electronic deliverable laboratory data to RFEDS (EG&G 1991i) Laboratory data will be validated by an independent subcontractor in accordance with EPA guidelines for CLP data (EPA 1988a, EPA 1988b) Non-CLP data will be validated in accordance with guidelines developed by EMD at Rocky Flats Data will be assigned validation codes that will subsequently be used to determine data usability for developing the IM/IRA decision document and selecting remedial actions

Section 7

Tables

Table 7-1
Field Quality Control Sample Collection Frequency

QC Sample	Frequency
Field duplicate	1 per 10 real samples or 1 per sampling event[1]
Field blank[2]	1 per shipping container (or a minimum of 1 per 20 real water samples)
Equipment rinse	1 per 20 real samples or 1 per day[3]
Trip blank[4]	1 per 20 real water samples
Triplicate sample (benthic samples)[5]	For each sampling site

[1] Whichever is more frequent

[2] For samples to be analyzed for inorganic compounds

[3] Whichever is more frequent for each specific sample matrix being collected when non-dedicated sampling equipment is used

[4] For samples to be analyzed for organic compounds

[5] For samples collected for tissue analysis

Source EG&G 1991g

Table 7-2
Sample Containers, Preservation Methods, and Holding Times

Media	Parameter	Container	Preservative	Holding Time
Soil/Sediment	VOCs	1 x 4 oz wide-mouth Teflon®-lined glass vial	Cool, 4°C	7 days 14 days
	SVOCs, Pesticides, and PCBs	1 x 8-oz wide-mouth Teflon®-lined glass vial	Cool, 4°C	7 days until extraction, 40 days after extraction
	Metals (TAL)	1 x 8-oz wide-mouth glass jar	Cool, 4°C	180 days[1]
	Cyanide	1 x 8-oz wide-mouth glass jar	Cool, 4°C	14 days
	Sulfide	1 x 8-oz wide-mouth glass jar	Cool, 4°C	28 days
	Nitrate	1 x 8-oz wide-mouth glass jar	Cool, 4°C	48 hours
	Radionuclides	1 x 1-ℓ wide-mouth glass jar	None	45 days
Groundwater/ Surface Water	VOCs	2 x 40-mL VOA vials with Teflon®-lined septum lids	Cool, 4°C[2] with HCl to pH<2	7 days 14 days
	SVOCs, Pesticides, and PCBs	1 x 4 ℓ - amber[3] glass bottle	Cool, 4°C	7 days until extraction, 40 days after extraction
	Metals (TAL)	1 x 1 ℓ - polyethylene bottle	Nitric acid pH<2, Cool 4°C	180 days[1]
	Cyanide	1 x 1 ℓ - polyethylene bottle	Sodium hydroxide[4] pH>12, Cool, 4°C	14 days
	Anions	1 x 1 ℓ - polyethylene bottle	Cool, 4°C	14 days
	Sulfide	1 x 1 ℓ - polyethylene bottle	1 mL-zinc acetate sodium hydroxide to pH>9, Cool, 4°C	7 days
	Nitrate	1 x 1 ℓ - polyethylene bottle	Cool, 4°C	48 hours
	TDS	1 x 1 ℓ - polyethylene bottle	Cool, 4°C	48 hours
	Radionuclides	1 x 1 ℓ - polyethylene bottle	Nitric acid pH<2	180 days

1 Holding time for mercury is 28 days
2 Add 0 008% sodium thiosulfate ($Na_2S_2O_3$) in the presence of residual chlorine
3 Container requirement is for any or all of the parameters given.
4 Use ascorbic acid only if the sample contains residual chlorine Test a drip of sample with potassium iodine-starch test paper; a blue color indicates need for treatment Add ascorbic acid, a few crystals at a time, until a drop of sample produces no color on the indicator paper Then add an additional 0 6g of ascorbic acid for each liter of sample volume

Definitions

HCL	hydrochloric acid
mL	milliliter
oz	ounce
PCBs	polychlorinated biphenyls
SVOCs	semivolatile organic compounds
TAL	target analyte list
TDS	total dissolved solids
VOA	volatile organic analysis
VOCs	volatile organic compounds
ℓ	liter

Source

EG&G 1991g

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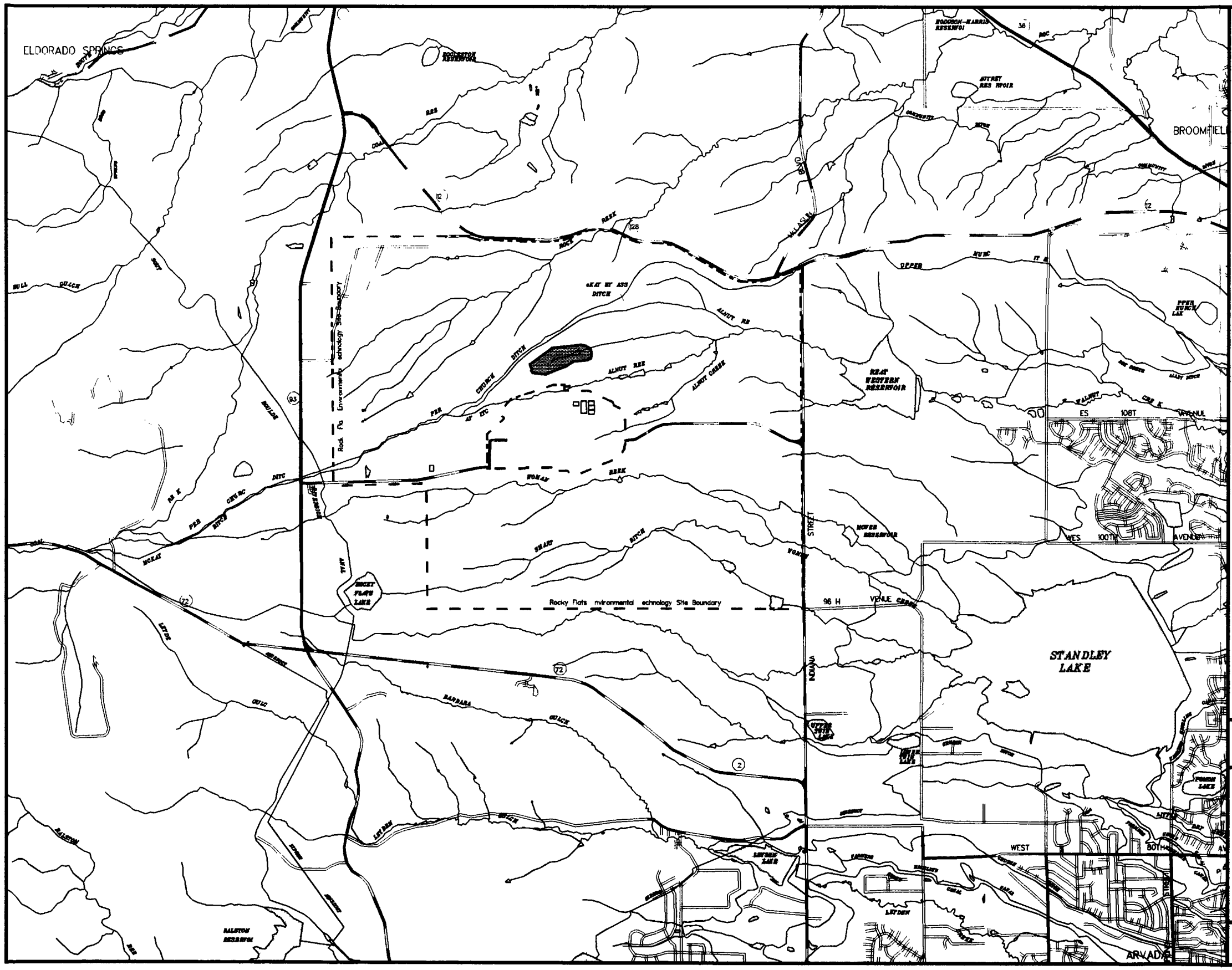


EXPLANATION

- Streams
- Rocky Flats Environmental Technology Site Boundary
- Primary Roads
- Secondary Roads
- Light-Duty Roads
- OU 7

N

0 Miles 1 2

0 Feet 4500 9000

Scale 1 inch = 4500 feet

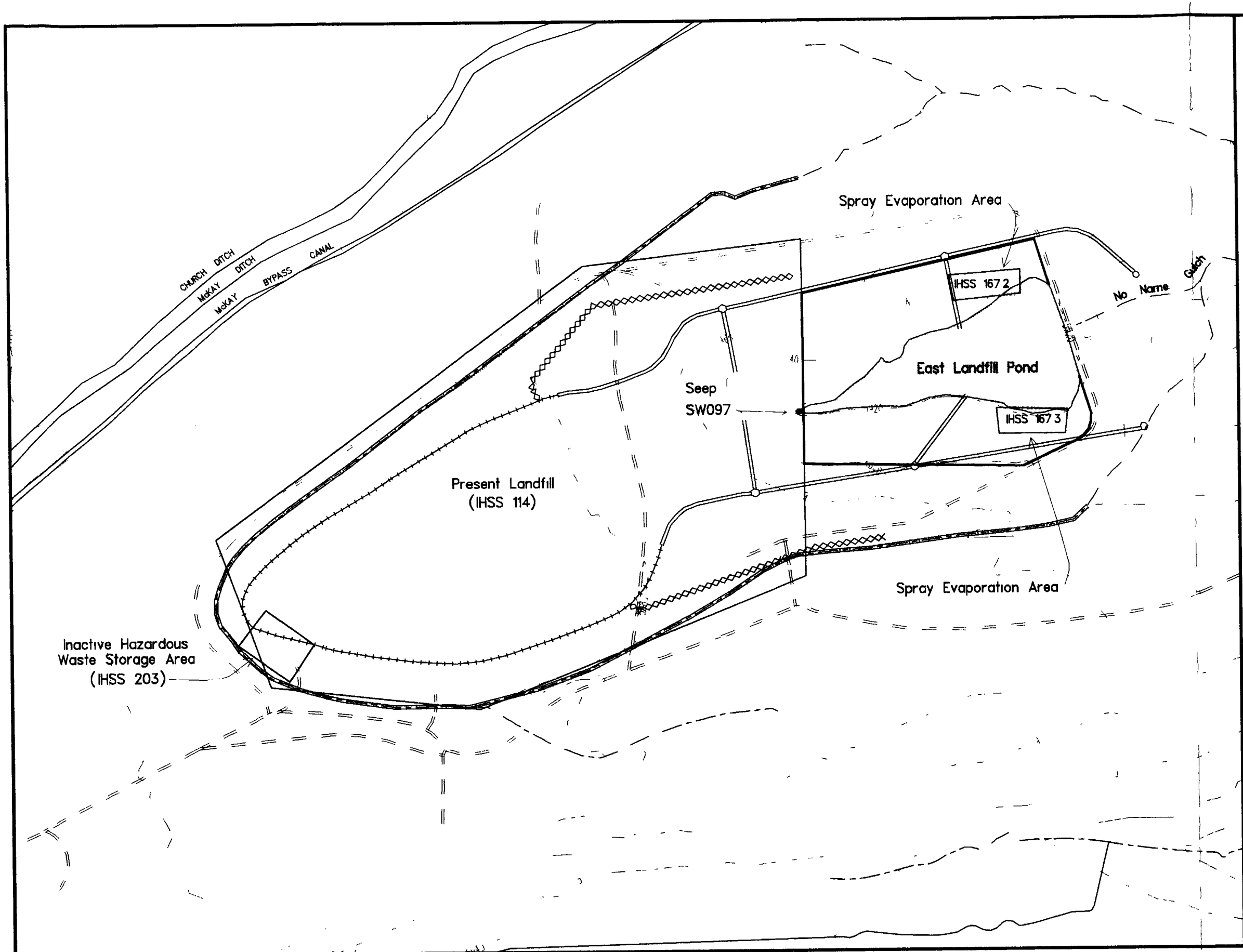
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site, Golden, Colorado

Location Map of OU 7 Rocky Flats Environmental Technology Site and Vicinity

Action Memorandum | Operable Unit No. 7

Date: December 1994 | Figure 1-1

12/15/94 VICINTY2.MAP



EXPLANATION

- OU 7 IHSS Boundary
- Spray Evaporation Area
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Perforated Subsurface Drainage Control System
- Non-perforated Subsurface Drainage Control System

N

0 Feet 250 500

Topographic Contour Interval = 20 Feet

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

Remedial Action Areas and Engineering Controls

Action Memorandum | Operable Unit No. 7

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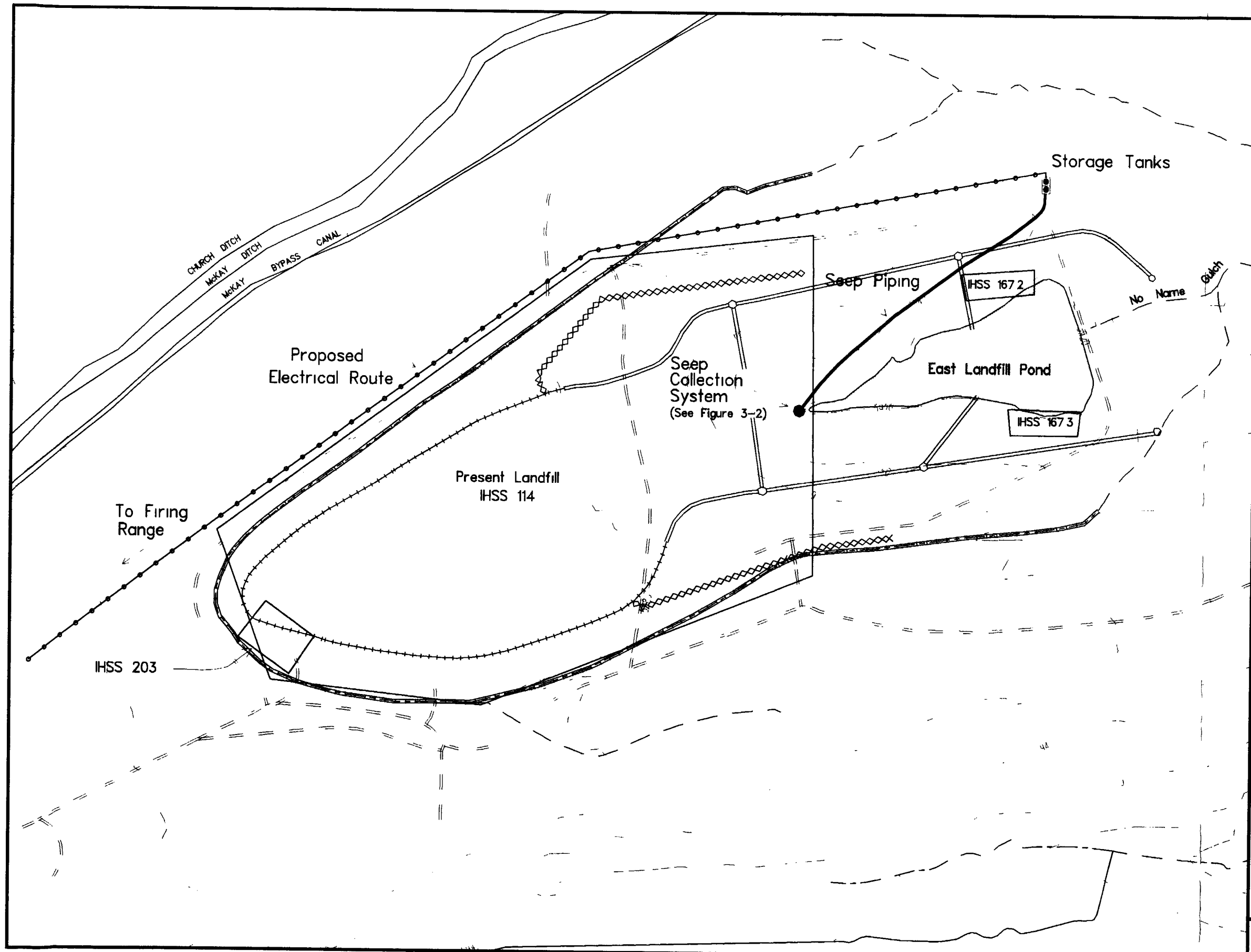
12/15/94 SITEPLAN2.MAP



EXPLANATION

- OU 7 IHSS Boundary
- Ditch and Drainage Feature
- Intermittent Stream
- Dirt Road
- Existing Surface-Water Diversion Ditch
- Existing Slurry Wall
- Perforated Subsurface Drainage Control System
- Non-perforated Subsurface Drainage Control System

N

0 Feet 250 500

Topographic Contour Interval 20 Feet

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

Seep Collection Facility Plan View

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12/15/94 SEEPFACIL.MAP