START

008182

DOE/RL 88-27

Copy No. 48

Vol 6 of 6

GROUT TREATMENT FACILITY DANGEROUS WASTE PERMIT APPLICATION

BEST AVAILABLE COPY

United States
Department of Energy
Richland, Washington

Reference herein to any trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

9 0 1 1 7 8 6 1 3 4 6

CONTENTS

VOLUME I

Foreword

Acronyms and Abbreviations

Part A

Part B

1.0	Introduction
2.0	Facility Description and General Provisions
3.0	Waste Characteristics
4.0	Process Information
5.0	Groundwater Monitoring
6.0	Procedures to Prevent Hazards
7.0	Contingency Plan
8.0	Personnel Training
9.0	Exposure Information Report
10.0	Waste Minimization Plan
11.0	Closure/Postclosure Requirements
12.0	Reporting and Recordkeeping
13.0	Other Relevant Laws
14.0	Certification

VOLUME II

Appendix 1A	Notice-of-Deficiency Response Table
Appendix 2A	Engineering Drawings
Appendix 2B	Hanford Site and Area Maps
Appendix 2C	Topographic Maps

9011786134 7

CONTENTS (cont)

Appendix 2D Legal Description of the Grout Treatment Facility Property Boundary

Appendix 2E Engineering Report--Road Evaluation for the Grout Treatment Facility

Appendix 2F Department of Ecology Certificate of Non-Designation for Centralia Fly Ash

Appendix 3A Double-Shell Tank Waste Compositional Modeling

Appendix 3B Laboratory Analysis Reports for Double-Shell Tank Waste Stored in Tanks 241-AN-106, 241-AW-101, and 241-AN-103

Appendix 3C Thermal Analysis in Support of Grout Temperature Limits and Heat-Loading Guidelines

Appendix 3D Test Results for Extraction Procedure Toxicity Testing

Appendix 3E Test Results for Toxicity Testing of Double-Shell Tank Grout

Appendix 3F Pilot-Scale Test Report--Evaluation of Grout Processing Parameters

VOLUME III

Appendix 3G Pilot-Scale Test Report--Correlate Lab to Plant

Appendix 3H Below-Liquid-Surface Supernatant Sampling Procedure for Underground Storage Tanks

Appendix 3I Laboratory Procedures and Grout 222-S/RCRA Laboratory Quality Assurance Plan

Appendix 3J Grout Campaign Waste Composition Verification

Appendix 4A Engineering Drawings

VOLUME IV

Appendix 4A Engineering Drawings

Appendix 4B Plant Operating Procedures

9 0 1 1 7 8 6 1 3 4 8

CONTENTS (cont)

VOLUME V

Appendix 4C Equipment List--Transportable Grout Equipment

Appendix 4D Instrument List--Transportable Grout Equipment

Appendix 4E Waste/Concrete Compatibility Test Program

Appendix 4F Vendor Information

Appendix 4G Grout Disposal Facilities Construction Quality Assurance Plan

Appendix 4H Flexible Membrane Liner/Waste Compatibility Test Results

Appendix 4I Vault Design

VOLUME VI

Appendix 4J Run-on/Run-off Control Design

Appendix 4K Asphalt Compatibility with 90-Degree Centigrade Double-Shell Slurry Feed

Appendix 5A Geologic Data

Appendix 5A-1 Particle Size Analyses and Calcium Carbonate Determinations

Appendix 5A-2 Chemical Analyses of Sediment Samples

Appendix 5A-3 Radionuclide Analyses of Sediment Samples

Appendix 5A-4 Sediment Moisture Data

Appendix 5A-5 Lithologic Sections for the Detection Monitoring Wells and Site Baseline Wells

Appendix 5B Hydrologic Data

Appendix 5B-1 Liquid Effluent Discharge Volumes of Nearby Disposal Facilities, January 1985 through December 1987

Appendix 5B-2 Results of Shallow Borehole and Laboratory Permeability Tests for the Unsaturated Zone

Appendix 5B-3 Hydrologic Test Data and Analyses

Appendix 5B-4 Water-Level Elevation Data

CONTENTS (cont)

Appendix 5B-5 Baseline Water-Chemistry Data Collected Between September 1985 and July 1987

Appendix 5C Groundwater Monitoring Program Information

Appendix 5C-1 Well Completion Information

Appendix 5C-2 Analyses Performed to Justify Well Spacing, Detectability of Chromium, and Detectability of Technetium-99

Appendix 5D Detection Monitoring Program

Appendix 5D-1 Sampling and Analysis Plan

Appendix 5D-2 Establishing Background

Appendix 5D-3 Statistical Procedures for Evaluating Changes in Groundwater Parameters

Appendix 5D-4 Quality Assurance Project Plan

Appendix 5E Groundwater Characterization Drawings

Appendix 7A Response Action Plan for Grout Treatment Facility

Appendix 8A Organizational Chart

Appendix 8B Job Titles, Positions, and Descriptions

Appendix 8C Sample Grout Facilities Employee Training Matrix

Appendix 8D Environmental and Hazardous Material Safety Training Requirements

Appendix 8E Sample Training Course Summaries

Appendix 9A Overview of the Hanford Site Grout Performance Assessment

Appendix 9B Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste from N Reactor Operations

Appendix 9C Land Use and Zoning Map

Appendix 11A Cover Design Engineering Report

Appendix 11B Closure Plan Drawing

Appendix 11C Clay Liners (Admixtures) in Semiarid Environments

CONTENTS (cont)

Appendix 13A Grout Treatment Facility Hazardous Air Pollutant Permit Application

Appendix 13B Grout Treatment Facility Approval of Construction

Appendix 13C Grout Treatment Facility Cultural Resources Review

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AEA	Atomic Energy Act of 1954
AFFF	aqueous film-forming foam
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
API	American Petroleum Institute
ARM	area radiation monitor
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BED	building emergency director
CABF	Cochran's approximation to the Behrens-Fisher (t-test)
CAM	continuous air monitor
CASS	Computer Automated Surveillance System
CC	concentrated complexed
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CRT	cathode ray tube
DMF	Dry Materials Facility, formerly called DMRHF
DMRHF	Dry Materials Receiving and Handling Facility
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy-Richland Operations Office
DOT	U.S. Department of Transportation
DSSF	double-shell slurry feed
DST	double-shell tank
DW	dangerous waste
EACT	Emergency Action Coordination Team (DOE-RL/EACT)
EC	equivalent concentration
E/C	Engineer/Constructor Contractor
ECC	Emergency Control Center
Ecology	Washington State Department of Ecology
EDO	emergency duty officer
EDTA	ethylenediaminetetraacetic acid
EHW	extremely hazardous waste
EMT	emergency medical technician
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
EP/APC	emergency procedures and abnormal plant conditions
EPDM	ethylene-propylene diene monomer
FFTF	Fast Flux Test Facility
FML	flexible membrane liner

FTMS	federal test method standard
FY	fiscal year
GR-CO	general radio-chemical operator
GTF	Grout Treatment Facility
HDPE	high-density polyethylene
HEHF	Hanford Environmental Health Foundation
HELP	hydrologic evaluation of landfill performance (computer model)
HEPA	high-efficiency particulate air
HMRT	hazardous materials response team
HSWA	Hazardous and Solid Waste Amendments
HWVP	Hanford Waste Vitrification Plant
HVAC	heating, ventilating, and air conditioning
IARC	International Agency for Research on Cancer
IC	ion chromatography
ICBO	International Conference of Building Officials
ICP	inductively coupled plasma
JRPT	junior radiation protection technologist
LA	analytical laboratory procedure
LCT	liquid-collection tank
LDCRS	leachate detection/collection and removal system
LR	laboratory reference (material specification procedure)
MHSC	Medical and Health Services Contractor
MOU	Memorandum of Understanding
MSDS	material safety data sheet
NA	not applicable
NCAW	neutralized current acid waste
NCRW	neutralized cladding removal waste
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NO	nuclear operator
NPDES	National Pollutant Discharge Elimination System
NPO	nuclear process operator
NRC	U.S. Nuclear Regulatory Commission
NRCR	nonradioactive compositionally representative
NSF	National Sanitation Foundation
OEC	Operations and Engineering Contractor
OHP	Operational Health Physics
OJT	on-the-job training
ORM	other regulated material
OT	operator trainee
PCA	Portland Cement Association
PFP	Plutonium Finishing Plant
pH	negative logarithm of the hydrogen-ion concentration

PIH	portable instrument house
PISCES	Plant Instrumentation Surveillance Calibration Evaluation System
PLC	programmable logic controller
PSPL	Puget Sound Power and Light
PSW	phosphate and sulfate waste
PUREX	Plutonium/Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
RAP	response action plan
RCRA	Resource Conservation and Recovery Act of 1976
RCW	Revised Code of Washington
RDC	Research and Development Contractor
RN	registered nurse
ROD	record of decision
RPT	radiation protection technologist
SARA	Superfund Amendments and Reauthorization Act of 1986
SCBA	self-contained breathing apparatus
SRPT	senior radiation protection technologist
SST	single-shell tank
SWP	special work permit (clothing)
TGE	Transportable Grout Equipment
TGF	Transportable Grout Facility
TOB	top of basalt
TOC	total organic carbon
TOX	total organic halogen
TRU	transuranic (waste)
TSD	treatment, storage, and/or disposal
UHF	ultra-high frequency
VHF	very-high frequency
WAC	Washington Administrative Code
WDOE	Washington Department of Ecology
WESF	Waste Encapsulation and Storage Facility
WL	water level
WMA	Waste Management Area
WNP	Washington Nuclear Power (reactor name)
WRAP	Waste Receiving and Processing (Facility)

ABBREVIATIONS

ac	alternating current
Ci	curie
Ci/L	curies per liter
cm	centimeter
cm/s	centimeters per second
cm^3	cubic centimeters
°C	degrees centigrade
d	day
dia	diameter
e.g.	for example
et al.	and others
et seq.	and following
°F	degrees Fahrenheit
ft	foot
ft/d	feet per day
ft^3/s	cubic feet per second
g	standard acceleration of free fall (gravity)
gal	gallon
gal/min	gallons per minute
h	hour
hp	horsepower
i.e.	that is
in.	inch
km	kilometer
kVA	kilovoltampere
kW	kilowatt
L	liter
L/s	liters per second
lb	pound
lbf	pound force
lbf/in^2	pound force per square inch
lb/h	pounds per hour
lbm/ft^3	pound mass per cubic foot
lb/min	pounds per minute
m	meter
mi	mile
mi^2	square mile
Mgal	million gallons
mil	mils

min	minute
mL	milliliter
mo	month
Mrad	megarad
mR/h	milliroentgen per hour
mrem/h	millirem per hour
µm	micrometer
m.s.l.	mean sea level
p/b	parts per billion
pCi/L	picocuries per liter
r/min	revolutions per minute
s	second
$stdft^3/min$	standard cubic feet per minute
V	volt
wk	week
wt%	weight percent
yd	yard
yr	year

APPENDIX 4J

RUN-ON/RUN-OFF CONTROL SYSTEM DESIGN

APPENDIX 4J

RUN-ON/RUN-OFF CONTROL SYSTEM DESIGN

Appendix 4J contains a certified engineering report for the run-on/run-off control system at the near-surface disposal site.

9 0 1 1 7 8 6 1 3 5 8

DOE/RL 88-27
Rev. 1, 01/17/90

ENGINEERING REPORT

RUN-ON/RUN-OFF CONTROL SYSTEM DESIGN

Prepared for

WESTINGHOUSE HANFORD COMPANY

September 1989

For the U.S. Department of Energy
Contract DE-AC06-87RL10900

Prepared by

KAISER ENGINEERS HANFORD COMPANY
Richland, Washington

KEH-88-31
ER9089

KAISER ENGINEERS
HANFORD

9011178613 59

KEH-88-31

ENGINEERING REPORT

FOR

RUN-ON/RUN-OFF CONTROL SYSTEM DESIGN

Prepared by

KAISER ENGINEERS HANFORD COMPANY
Richland, Washington

for

WESTINGHOUSE HANFORD COMPANY

Principal Lead Engineer	6/5/89 Date	Technical Documents	6-5-89 Date
Safety	6-6-89 Date	Environmental	6.6.89 Date
Chief Design Engineer	6-7-89 Date	Quality Assurance	6/12/89 Date
Project Manager	9-15-89 Date		

Westinghouse Hanford Company

Projects Department — 9/15/89 Date

9011178613 60

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	SUMMARY	1
III.	PURPOSE	1
IV.	DESCRIPTION	3
	A. Run-On Control System	3
	B. Run-Off Control System	3
V.	CONCLUSIONS AND RECOMMENDATIONS	5
	A. Run-On Control System	5
	B. Run-Off Control System	5
VI.	REFERENCES	6
	APPENDICES	
	Appendix A. Calculations	
	Appendix B. HELP Model Results	

ENGINEERING REPORT
RUN-ON/RUN-OFF CONTROL SYSTEM DESIGN

I. INTRODUCTION

Components of the Grout Treatment Facility (GTF) include the Transportable Grout Equipment and Waste Management Area (WMA). The WMA includes underground vaults in which the grouted waste is disposed. The facility layout is shown on figure 1.

This report describes the run-on and run-off control system designed for the WMA. The run-on control system diverts storm water from running onto the WMA. A run-off control system manages the precipitation that falls onto the WMA.

These systems are designed to control the surface water resulting from a storm of 24-hr duration and 25-yr recurrence.

II. SUMMARY

Environmental Protection Agency (EPA) regulations require that run-on from surrounding areas be controlled in a manner that prevents flow onto the active portion of the facility. Run-on will be intercepted by a ditch and diverted to a collection/infiltration basin. A sloping cover will be constructed over the active portions of the site to remove run-off.

III. PURPOSE

Precipitation in the form of snow or rain follows several paths after reaching the ground surface. One portion is temporarily retained in the soil and is then returned to the atmosphere by evaporation and transpiration by plants. Another portion of the precipitation infiltrates into the ground and ultimately reaches the ground water. A third portion flows overland and is called surface run-off.

9011786136 2

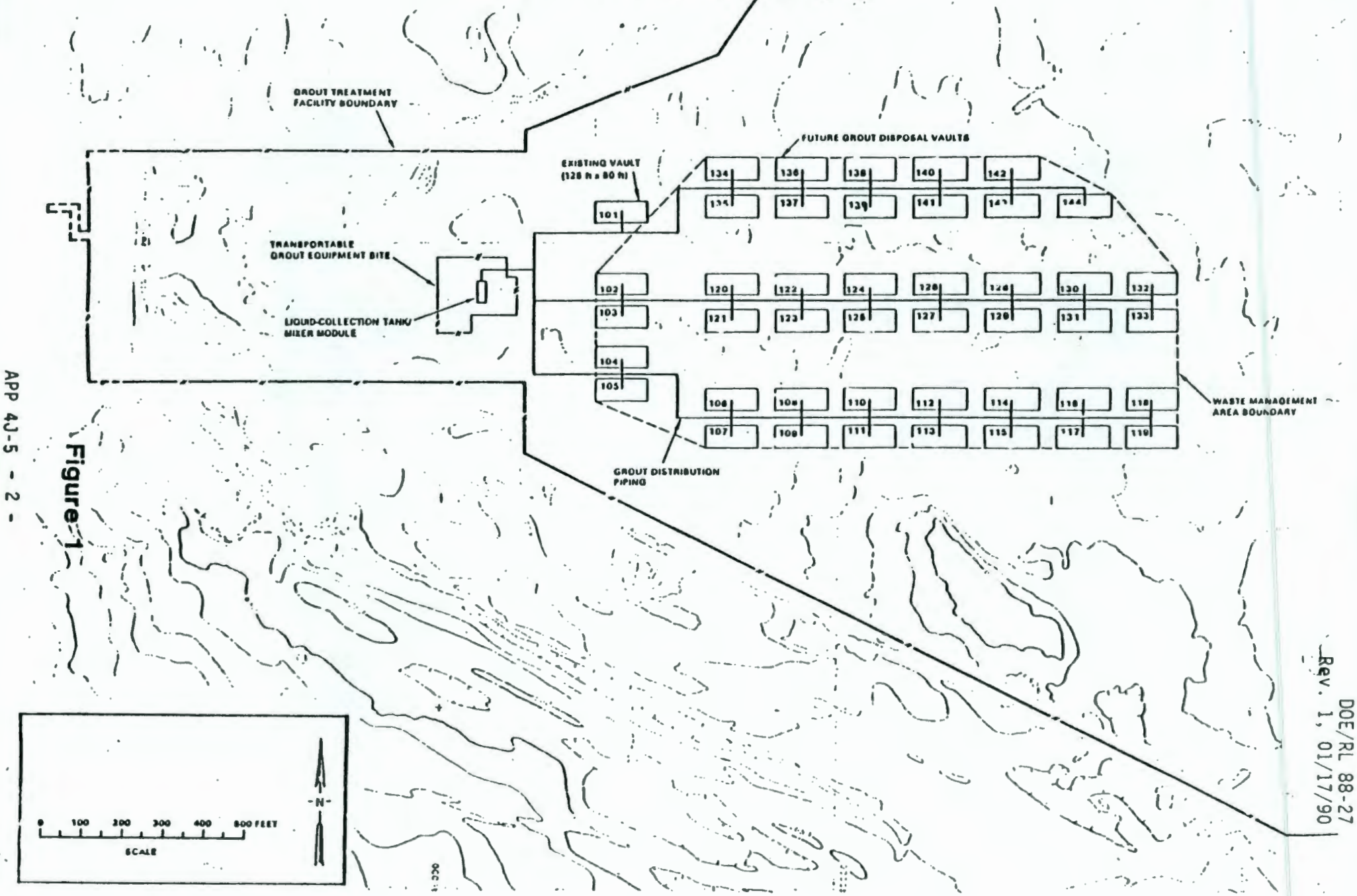

GROUT TREATMENT FACILITY BOUNDARY
FUTURE GROUT DISPOSAL VAULTS
EXISTING VAULT (128 ft x 80 ft)
TRANSPORTABLE GROUT EQUIPMENT SITE
LIQUID-COLLECTION TANK/ MIXER MODULE
GROUT DISTRIBUTION PIPING
WASTE MANAGEMENT AREA BOUNDARY
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
0 100 200 300 400 500 FEET
SCALE
N

Figure 1

This overland flow running on or off the WMA is the subject of this report. The run-on control system is designed to prevent surface water from adjacent land areas from running onto the WMA. The run-off control system manages the surface water that runs off of the WMA.

This report evaluates the run-on and run-off control system for inclusion in a Part B permit application for the GTF.

IV. DESCRIPTION

As additional rows of vaults are constructed, the run-on/run-off features (shown in appendix A) will be extended and at final completion, will provide control for the entire WMA. Berms around the excavation will direct run-on away from the active area and act as a safety barrier. Materials and methods of construction are specified in construction specification B-714-C7 (ref 6).

A. Run-On Control System

Run-on control will be provided by embankments around the perimeter of the WMA. Any liquid collected will be routed around the WMA by the embankment or drained to the run-on collection/infiltration basin. The watershed area which produces the run-on is a 157 acre predominantly unimproved area. Ground cover consists of sagebrush and poor grass. None of the watershed area or WMA is below the 100 yr flood plain. The run-on control system was designed to handle run-on from a 24-hr, 25-yr storm as well as water resulting from snowmelt. The peak surface flow has been identified as 2.50 cfs. Calculations for peak surface flow and depth of flow in the ditches may be found in appendix A.

B. Run-Off Control System

The closure cover will slope 0.5% to the north. The purpose of this slope is to allow the closure cover to match closely the topography without the need for construction of steep embankment slopes. The natural topography of the land will drain any run-off away from the WMA.

9011178513364

Calculations to predict the amount of run-off are contained in appendix A. The method used to calculate the peak flowrate is from the Benton County Hydrology Manual (ref 1). In addition to these calculations, the Hydrologic Evaluation of Landfill Performance (HELP) computer program developed by the EPA was used to evaluate run-off from the closure cover (HELP Model Results, appendix B). The model computes run-off using the Soil Conservation Service run-off curve number method. The run-off model and calculations assumed that the cover surface will have a topsoil of silty fine sand with scattered grass.

The computer analysis indicated that no run-off would have occurred from precipitation recorded for the years 1981 through 1987. These 7 years were chosen for use in the model because the average annual precipitation equaled 7.23 in. which exceeded the average between 1912 and 1988 of 6.42 in. Run-off is dependent on the time of year a storm occurs, the soil moisture content, the intensity of the rainfall, and the slope of the surface. This model uses a slope between 2 to 7%. Run-off was predicted when the model included data for rainfall that exceeded 1 in. in a 24-hr period. Daily precipitation has equalled or exceeded 1 in. only twice during the period from 1946 through 1987 according to data from the Hanford Meteorology Station (ref 2 and 3).

The 25-yr, 24-hr design storm equals 1.56 in. according to Table 61 of the Climatological Summary for the Hanford Area (ref 2). This amount includes both rain and the water equivalent of snow. The chinook event, which occurs when the snowpack is quickly melted by above freezing temperatures, is also included in the precipitation values. The design storm produced the largest run-off volume (2,211 ft^3 from a cover area of 161,200 ft^2) when calculated from modified data from the winter of 1985-1986 (HELP Model Results, appendix B).

V. CONCLUSIONS AND RECOMMENDATIONS

A. Run-On Control System

The Benton County Hydrology Manual by Advanced Engineering Consultants Inc. (ref 1) was used to determine the run-on flowrate from the surrounding area. The manual uses the formula $Q = C_f \times C \times I \times A$ where:

Q = flowrate (cfs)
C_f = frequency factor
C = run-off coefficient
I = rainfall intensity (in./hr)
A = area (acres)

The run-on using this formula, including a correction factor for snowmelt, is 2.50 cfs.

B. Run-Off Control System

The formula used to determine run-on flowrate (Benton County Hydrology Manual, 1979) was used to calculate the peak run-off rate of 0.53 cfs for the 25-yr, 24-hr design storm (appendix A). This flowrate, calculated with a conservative run-off coefficient, produced a total volume from the design storm which was almost three times the volume predicted by the HELP model. Using a less conservative value, the calculated volume of run-off was almost the same as the HELP model prediction.

The results of the HELP model normally predicted no run-off from the closure cover when precipitation was less than 1 in. in a 24-hr period. The exception was when a storm of 0.90 in. per 24 hr was added following the snowmelt of a heavy winter and over 0.50 in. of rain. Factors contributing to the predicted lack of run-off for most storms of less than an inch per 24 hr include:

- Low average annual rainfall (6.42 in.).

9011178613366

- High average annual evaporation rate (40 in., U.S. National Weather Service).

- Relatively high-hydraulic conductivity of the soil (0.0001 to 0.001 cm/sec).

The calculated run-off flow is insignificant when compared to the run-on flow (.48 as compared to 2.5 cfs). The run-off area for the project is 27 acres compared to the 157 acres of run-on area. Intermediate run-off collection features are unnecessary because of the small run-off area and flowrate.

All run-on flow can be diverted around the site or contained in the run-on collection/infiltration basin without need for upstream drainage features.

VI. REFERENCES

1. Benton County Hydrology Manual and Drainage Design Review Procedure. Advanced Engineering Consultants, Inc., 1979.

2. Stone, W. A., Thorpe, J. M., Gifford, O. P., and Hoitink, D. J., "Climatological Summary for the Hanford Area," Battelle Memorial Institute, Pacific Northwest Laboratory. PNL-4622, 1983.

3. Hanford Meteorology Station, Climatological Data - Monthly Records. Battelle Memorial Institute, Pacific Northwest Laboratory, 1981-1987.

4. Schroeder, P. R., "Hydrologic Evaluation of Landfill Performance," HELP Version 2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 1988.

5. Drawing H-2-77577, Rev. 0 Sh 1 and 2, Civil Run-On/Run-Off Plan

6. Construction Specification for Run-On/Run-Off Drainage Control Ditch for Grouted Waste Disposal Facilities Grouted Vault Pair (218-E-16), prepared by Kaiser Engineers Hanford Company.

APPENDIX A

Calculations

Run-On Calculations

9011178613 70

DESIGN ANALYSIS

Client	WHC	WO/Job No.	ER9089		
Subject	RUN-ON CONTROL	Date	5/30/89	By	R. G. HOLLENBECK
		Checked	5/31/89	By	[illegible]
Location	218-E-16	Revised		By	

PURPOSE

A run-on control ditch is required to divert precipitation run-on around the waste facility. Thee calculations will determine the run-on flowrate and the required size. These calculations are required by EPA 530 SW-84-004.

DESIGN CRITERIA

Design storm = 24 hour duration, 25 year frequency.

ASSUMPTIONS

All run-on reaching the site will flow into only one ditch.

There is no infiltration from the ditch into the ground.

REFERENCES

1. Benton County Hydrology Manual and Drainage Design Review Procedure. Advanced Engineering Consultants, Inc., 1979.

2. Stone, W. A., Thorpe, J. M., Gifford, O. P., and Hoitink, D. J., "Climatological Summary for the Hanford Area", Battelle Memorial Institute, Pacifica Northwest Laboratory. PNL-4622, 1983.

3. French, R. H., "Open Channel Hydraulics", 1985.

4. Aisenbrey, A. J. Jr., Hayes, R. B., Warren, H. J., Winsett, D. L., Young, R. B., "Design of Small Canal Structures", U. S. Dept. of the Interior, 1978.

5. Permit applicants Guidance Manual for Hazardous Waste Land Treatment and Storage, and Disposal Facilities. EPA 530 SW-84.004, May 1984.

RESULTS

Maximum flowrate from the total watershed area is 2.5 CFS. Water depth in the drainage ditch with a bottom slope of 1/2% is 0.905 feet.

CALCULATIONS

RATIONAL FORMULA METHOD
PEAK RUN-ON RATE

Project Name: Grouted Waste Disposal Facilities.
Location: Near Eastern border of the 200-E Area of the Hanford Site

BASIN CONDITION: Natural
Drainage Area A = 157 acres (See attachment 1).

OVERLAND FLOW TIME OF CONCENTRATION:
Average slope: S = 0.013 foot/foot
Ground condition: Silty sand covered with native grasses and sagebrush.
Roughness coefficient: K = 1.08 (See reference 1, Figure 5).

RAINFALL INTENSITY:
Design return period = 25 years.
Rainfall intensity I = 0.065 inches/hour for a 24 hour 25 year storm. (See reference 2, Figure 36).
Frequency Factor C_f = 1.1 (reference 1, pg. 5.5).

RUN-ON COEFFICIENT:
Impervious area - 0 acres.
Pervious area - 157 acres.
Pervious C = 0.20 (reference 1, Table 2).

PEAK RUN-ON RATE:
$Q = c_f CIA = 1.1(0.20)(0.065)(157) = 2.25$ CFS.
Increase the value by 10% for the presence of snow and frozen ground (reference 1, pg 5-13). (2.25)(1.10) = 2.5 CFS.

RUN-ON VOLUME:
V = TQ = 24 x 60 x 60 x 2.5 = 216,000 CF. (Conservative)

COLLECTION/INFILTRATION BASIN
Construct basin large enough to contain the entire run-on volume.
Basin dimensions: Bottom width = 75′, bottom length = 175′, depth = 10′, side slope = 3 to 1x. Capacity = 218,000 CF.

9011786137 2

DESIGN ANALYSIS

Client WHC	WO/Job No. ER9089		
Subject RUN-ON CONTROL	Date 5/30/89	By R. G. HOLLENBECK	
	Checked 5/3[illegible]	By [illegible]	
Location 218-E-16	Revised	By	

CALCULATIONS (Con't)

DETERMINE REQUIRED DITCH SIZE FOR 2.5 CFS

Mannings Equation $Q = (1/n)(1.49)AR^{2/3}S^{1/2}$

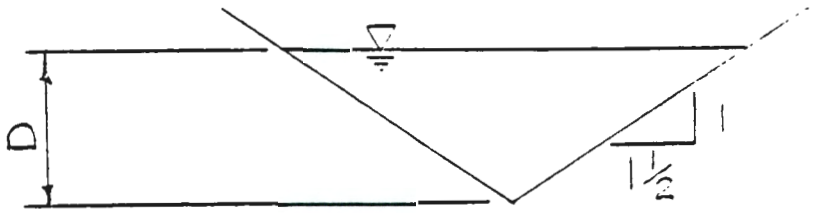
Where:

Q = 2.5 CFS from page 2 of these calculations
n = 0.027 roughness coefficient (reference 3, Table 4.8)
D = Depth of flow in ft
$A = 1.5D^2$ area in ft^2
$R = A/2[(1.5D)^2 + D^2]^{0.5}$ hydraulic radius in ft
S = 0.005 slope in ft/ft

Try D = 0.905

$Q = (1/0.027)(1.49)(1.229)(0.377^{2/3})(.005)^{1/2} = 2.50$ CFS OK

Depth of flow = 0.905 feet



TYPICAL DITCH SECTION
No Scale

Run-Off Calculations

DESIGN ANALYSIS

Client	WHC	WO/Job No.	FR9089		
Subject	RUN-OFF CONTROL	Date	10/10/88	By	S.D. CONSORT
		Checked	8/29/89	By	RG Hollenbeck
Location	218-E-16	Revised		By	

PURPOSE

These calculations will determine the runoff flowrate from the closure cover for all 44 proposed vaults.

DESIGN CRITERIA

Design storm = 24 hour duration, 25 year frequency.

ASSUMPTIONS

A uniform slope is assumed for the entire closure cover.

The vegetative cover is scattered grass to allow for maximum runoff.

The current run-on/run-off features will be extended as additional vaults are cunstructed.

REFERENCES

1. Benton County Hydrology Manual and Drainage Design Review Procedure. Advanced Engineering Consultants, Inc., 1979.

2. Stone, W.A., J.M. Thorpe, O.P. Gifford and D.J. Hoitink, Climatological Summary for the Hanford Area". Battelle Memorial Institute, Pacific North west Laboratory, PNL-4622, 1983.

3. Hanford Meteorology Station, Climatological Data - Monthly Records. Battelle Memorial Institute, Pacific Northwest Laboratory, 1981-1987.

RESULTS

Flowrate from the closure cover is 0.48 CFS using a runoff coefficient of 0.25.

9011786137 5

Client	WHC	WO/Job No.	ER9089		
Subject	RUN-OFF CONTROL	Date	10/10/88	By	
		Checked	8/25/[illegible]	By	
Location	218-E-16	Revised		By	

CALCULATIONS

RATIONAL FORMULA METHOD
PEAK RUNOFF RATE

Project Name: Grouted Waste Disposal Facilities.
Location: Near eastern border of the 200-E Area of the Hanford Site.

BASIN CONDITION: Ultimate
Drainage Area: A = 27 acres (See Attachment 1)

OVERLAND FLOW TIME OF CONCENTRATION:
Average slope: S = 0.005 foot/foot
Ground condition: Silty fine sand covered with scattered grass.
Roughness coefficient: K = 0.83 (See reference 1, Figure 5)
Overland flow distance: L = 740 feet
Overland flow time of concentration: T_c = 27.6 minutes (See reference 1, Figure 5)

RAINFALL INTENSITY:
Mean annual precipitation (1912-1987): 6.42 inches
Design return period: 25 years
Rainfall intensity: I = 0.065 inches/hour for a 24 hr, 25 yr storm (See reference 2, Figure 36)
Frequency Factor: C_f = 1.1 (See reference 1, pg. 5-5)

RUNOFF COEFFICIENT:
Pervious area: 27 acres
Pervious C : 0.25 (See reference 1, Table 2; cover design does not exactly fit any of the categories, so this value was chosen from values pertaining to improved grassy areas)

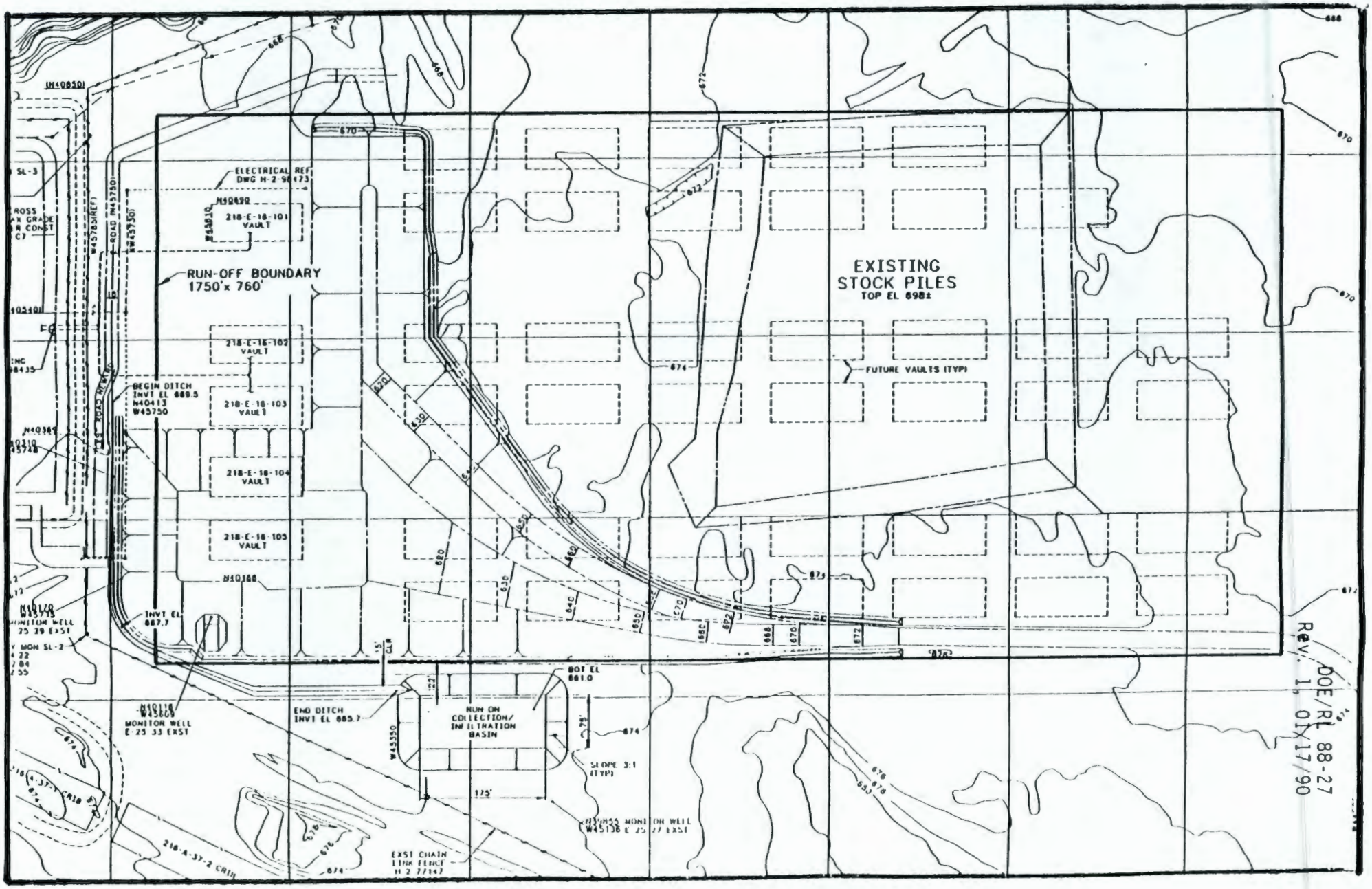
PEAK RUNOFF RATE:
$Q = C_f CIA = 1.1(0.25)(0.065)(27) = 0.48$ CFS
Increase the value by 10% to account for the presence of snow and frozen ground (see reference 1, pg. 5-13).
Q = 1.1(0.48) = 0.53 CFS

If C = 0.10 (considering the use of uncompacted sandy topsoil for the cover), then Q = 0.19 CFS. Q = 0.21 CFS with snow.

TOTAL VOLUME PRODUCED BY DESIGN STORM:
$V = T_c Q(60 \text{ sec/min})$
= 27.6(0.53)(60) = 878 cubic feet in 27.6 minutes for C = 0.25
878 + 0.53(24 hr - 27.6 min) = 45792 cubic feet in 24 hours

V = 27.6(0.21)(60) = 348 cubic feet in 27.6 minutes for C = 0.10
348 + 0.21(24 hr - 27.6 min) = 18144 cubic feet in 24 hours

9011178513376


RUN-OFF BOUNDARY
1750'x 760'
EXISTING
STOCK PILES
TOP EL 698±
FUTURE VAULTS (TYP)
ELECTRICAL REF
DWG H-2-98473
218-E-18-101
VAULT
218-E-18-102
VAULT
218-E-18-103
VAULT
218-E-18-104
VAULT
218-E-18-105
VAULT
BEGIN DITCH
INVT EL 669.5
N40413
W45750
INVT EL
667.7
END DITCH
INVT EL 665.7
BOT EL
661.0
RUN ON
COLLECTION/
INFILTRATION
BASIN
SLOPE 3:1
(TYP)
175'
EXST CHAIN
LINK FENCE
H 2 77147
MONITOR WELL
E 25 33 EXST
MONITOR WELL
25 29 EXST
218-A-37-2 CRIB

APPENDIX B

HELP Model Results

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP)

MODEL RESULTS

The results of the run-off evaluation by the HELP program (Schroeder, 1988; see Ref 4 in Run-on/Run-off report) were produced using daily precipitation and temperature data from the years 1981 through 1987. The average monthly and annual totals for the years 1982 and 1983 are included on pages B-4 and B-5. October of 1982 included the 0.93 inch storm which is the largest 24-hr storm that occurred in these 7 yrs. The 11.07 inches of precipitation in 1983 is the third highest annual total on record since 1912.

The surface of the closure cover was assumed to be 6 inches of uncompacted silty, fine sand with an approximate hydraulic conductivity of 0.0007 cm/s. The vegetation, according to HELP model classification, was poor grass with an evaporative zone depth of 20 inches.

The 25-yr, 24-hr design storm was inserted into the portions of the precipitation data which would model the greatest amount of run-off from the cover. The 1.56 inches of rainfall was added to the data of late January in the heaviest winter (1985-1986) of the 7 yrs used. All the snow had melted followed by 3 days of rainfall that totalled about a half inch. The addition of the design storm on the fourth day produced 0.165 inch of run-off. Reducing the amount of added precipitation on this day to 0.90 inch produced 0.010 inch of run-off giving a total volume of only 26 cubic feet.

AVERAGE ANNUAL TOTALS (AND STD. DEVIATIONS) FOR 81 THROUGH 87

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	7.21	(2.016)	19251.	100.0
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	6.608	(1.636)	18174.	94.39
LATERAL DRAINAGE FROM LAYER 3	0.3409	(0.2390)	910.	4.71
PERCOLATION FROM LAYER 4	0.0000	(0.0000)	0.	0.00
PERCOLATION FROM LAYER 6	0.0179	(0.0000)	48.	0.25

PEAK DAILY VALUES FOR 81 THROUGH 87

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	2482.5
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 3	0.0029	7.6
PERCOLATION FROM LAYER 4	0.0000	0.0
HEAD ON LAYER 4	0.9	
PERCOLATION FROM LAYER 6	0.0002	0.5
HEAD ON LAYER 6	0.5	
SNOW WATER	1.15	3074.9

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2588

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0849

MONTHLY TOTALS FOR 82

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	0.33 0.22	0.57 0.20	0.17 0.55	0.75 1.33	0.26 0.91	0.75 1.76
				INCLUDES STORM OF 0.93 IN.		
RUNOFF (INCHES)	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000
EVAPOTRANSPIRATION (INCHES)	0.669 0.509	0.730 0.191	0.495 0.278	0.384 0.419	0.645 0.782	1.630 0.311
LATERAL DRAINAGE FROM LAYER 3 (INCHES)	0.0014 0.0025	0.0013 0.0027	0.0015 0.0027	0.0016 0.0029	0.0020 0.0029	0.0022 0.0031
PERCOLATION FROM LAYER 4 (INCHES)	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000
PERCOLATION FROM LAYER 6 (INCHES)	0.0026 0.0020	0.0022 0.0019	0.0024 0.0018	0.0022 0.0018	0.0022 0.0017	0.0024 0.0017

ANNUAL TOTALS FOR 82

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	7.85	20954.	100.00
RUNOFF	0.000	0.	0.00
EVAPOTRANSPIRATION	7.654	20432.	97.51
LATERAL DRAINAGE FROM LAYER 3	0.0266	71.	0.34
PERCOLATION FROM LAYER 4	0.0000	0.	0.00
PERCOLATION FROM LAYER 6	0.0246	66.	0.31
SOIL WATER AT START OF YEAR	20.43	54540.	
SOIL WATER AT END OF YEAR	20.64	55106.	
SNOW WATER AT START OF YEAR	0.07	180.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

****

MONTHLY TOTALS FOR 83

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	1.44 0.31	1.36 0.12	1.00 0.46	0.42 0.50	0.52 2.12	0.28 2.12
RUNOFF (INCHES)	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000	0.000 0.000
EVAPOTRANSPIRATION (INCHES)	0.658 0.566	1.344 0.120	1.594 0.433	0.574 0.218	0.718 0.790	1.648 0.340
LATERAL DRAINAGE FROM LAYER 3 (INCHES)	0.0030 0.0158	0.0031 0.0170	0.0051 0.0170	0.0076 0.0177	0.0109 0.0171	0.0130 0.0175
PERCOLATION FROM LAYER 4 (INCHES)	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000	0.0000 0.0000
PERCOLATION FROM LAYER 6 (INCHES)	0.0016 0.0014	0.0014 0.0013	0.0015 0.0013	0.0014 0.0013	0.0015 0.0012	0.0014 0.0012

****

ANNUAL TOTALS FOR 83

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	11.07	29350.	100.00
RUNOFF	0.000	0.	0.00
EVAPOTRANSPIRATION	9.203	24586.	83.14
LATERAL DRAINAGE FROM LAYER 3	0.1450	387.	1.31
PERCOLATION FROM LAYER 4	0.0000	0.	0.00
PERCOLATION FROM LAYER 6	0.0166	44.	0.15
SOIL WATER AT START OF YEAR	20.64	55106.	
SOIL WATER AT END OF YEAR	21.60	57657.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.75	2001.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

****

9011178613 82

MONTHLY TOTALS FOR 86

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES) INCLUDES 25-YR 24-HR STORM	3.31	1.08	0.76	0.00	0.30	0.00
	0.21	0.02	0.96	0.29	0.65	0.77
RUNOFF (INCHES)	0.165	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION (INCHES)	0.584	1.458	0.962	0.413	0.712	1.100
	0.210	0.020	0.341	0.246	0.222	0.236
LATERAL DRAINAGE FROM LAYER 3 (INCHES)	0.0223	0.0322	0.0937	0.1399	0.1686	0.1679
	0.1656	0.1504	0.1296	0.1152	0.1003	0.0914

ANNUAL TOTALS FOR 86

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION (INCLUDES 25-YR, 24-HR STORM)	6.33	112168.	100.00
RUNOFF	0.165	2211.	1.97
EVAPOTRANSPIRATION	6.683	89806.	80.08
LATERAL DRAINAGE FROM LAYER 3	1.3803	18542.	16.51
PERCOLATION FROM LAYER 4	0.0000	0.	0.00
PERCOLATION FROM LAYER 6	0.0083	111.	0.10
SOIL WATER AT START OF YEAR	20.75	278690.	
SOIL WATER AT END OF YEAR	21.46	288273.	
SNOW WATER AT START OF YEAR	0.60	8086.	

BEST AVAILABLE COPY

ANNUAL TOTALS FOR 80

	INCHES	CU. FT.	PERCENT
PRECIPITATION (INCLUDES 0.90 IN STORM FOLLOWING SNOWMELT AND 0.50 IN OF RAIN)	7.84	20527.	100.0
RUNOFF	0.010	26.	0.1
EVAPOTRANSPIRATION	6.864	17842.	86.9
LATERAL DRAINAGE FROM LAYER 3	0.4637	2071.	10.1
PERCOLATION FROM LAYER 4	0.0000	0.	0.0
PERCOLATION FROM LAYER 6	0.0083	22.	0.1
SOIL WATER AT START OF YEAR	7.75	20319.	
SOIL WATER AT END OF YEAR	21.37	56079.	
SNOW WATER AT START OF YEAR	0.60	1600.	

9011178613 84

B-714-C7

CONSTRUCTION SPECIFICATION FOR

RUN-ON/RUN-OFF DRAINAGE CONTROL DITCH

FOR
GROUTED WASTE DISPOSAL FACILITIES
GROUT VAULT PAIR (218-E-16)

CAUTION
NOT COMPLETE WITHOUT
CURRENT STATUS OF OUTSTANDING
ECNS FROM DATA BASE

SECTION 01300

SUBMITTALS

PART 1 - GENERAL

1.1 DESCRIPTION

1.1.1 This Section summarizes submittals required in Part 1 of each section of this Specification. It explains type of submittals required, and describes procedures for submittals and review.

1.1.2 Submittals required in Part 1 of each section are summarized in Schedule of Submittals. Each submittal is identified by Submittal Number, Reference Section, and Title. Submittals are required for either Review and Approval or Review for Record.

1.1.2.1 Submittals requiring Review and Approval are those which shall receive approval before procurement, fabrication, or construction is started.

1.1.2.2 Submittals requiring Review for Record are those which Contractor may proceed with procurement, fabrication, construction, or acceptance testing, but acceptance is contingent upon compliance with Drawings and Specifications.

1.1.3 Supplemental Submittals are initiated by Contractor in accordance with Section 01630 for consideration of substitute products or corrective procedures and require Review and Approval.

1.2 SUBMITTAL PROCEDURES

1.2.1 Transmit submittals to KEH by Data Transmittal form.

1.2.2 Identify each submittal by Submittal Number, Reference Section, and Title noted in the Schedule of Submittals. Number of copies required for retention by KEH are shown in Schedule and include 2 copies to be returned to Contractor. Additional copies required for Contractor uses shall be added.

1.2.3 Review each submittal for completeness, compliance with Contract Documents, and proper identification before sending to KEH. Submittal data shall either be stamped showing review process has taken place or Data Transmittal form may be signed with statement of "Reviewed for Compliance." Submittals not stamped or signed to show review will be returned without consideration.

1.2.4 Submittals requiring Review and Approval will be stamped by KEH and marked "Approved", "Approved with Exception," or "Not Approved, Revise and Resubmit." Approval of submittals does not relieve Contractor of responsibility for errors which may be contained therein.

9 0 1 1 7 8 6 1 3 8 6

1.2.4.1 Approved submittals are identified by submittal stamp with "Approved" or "Approved with Exception" box checked. "Approved" signifies general concurrence to achieve conformance with design concept of Project and compliance with requirements of Contract Documents. "Approved with Exception" signifies general concurrence with noteworthy comments or clarifications. Approval of submittals does not relieve Contractor of responsibility for errors contained therein. Approval of specific item shall not be construed as approval of system or assembly of which item is a component.

1.2.4.2 A submittal which is not approved is identified as "Not Approved, Revise and Resubmit." Submittal is considered by KEH to be technically deficient or incomplete and therefore, unacceptable. Resubmittal is required, hence fabrication, procurement, or performance of procedures shall not proceed.

1.2.4.3 Upon receipt of deficient submittal data, Contractor shall make corrections noted on transmittal and resubmit data to KEH within 10 calendar days.

1.2.5 Materials and equipment fabricated or installed without required approved submittals, or which differ from approved Drawings or vendor data are subject to rejection and replacement at Contractor's expense.

1.2.6 Delays arising out of Contractor's failure to submit in timely manner required Drawings and other related data described in Contract Documents shall not constitute excusable delays for extensions, unless excusable under other provisions of Contract. Contractor shall allow 15 calendar days for KEH review and disposition of submittals, including shop drawings and vendor information, required to be furnished by Contractor. Time period will be measured from date of receipt of submittal in KEH's office to date of return mailing to Contractor.

1.2.7 Contractor is responsible for dimensions to be confirmed and correlated at worksite.

1.2.8 Submittals for Review and Record will be reviewed and filed. Incomplete or inaccurate data will be returned to Contractor marked "Resubmit" with appropriate comments, and items procured or work performed shall be corrected. Payment for equipment will not be made unless required Commercial Vendor Information (CVI) has been furnished.

1.2.9 Supplemental Submittals shall contain sufficient data required in Section 01630 to show substantial compliance with Drawings and Specifications. Substitute product submittals shall contain as minimum, outline dimensions, operating clearances, and engineering data. Identify each submittal by Specification Section number and Paragraph number or referenced Drawing number and detail. Improperly identified or incomplete submittals will be returned without consideration.

1.2.10 Procedures for performing certain items of work are required to be submitted for Review and Approval before work is commenced. Those work

9011178613397

procedures which have been approved by KEH for work similar to that to be accomplished on Project may not need to be reapproved. Forward 1 copy of previously approved procedure to KEH by Data Transmittal form and identify by Submittal Number, Reference Section, Title, and either Contractor's procedure number or project number for which procedure was approved. Submittal will be reviewed by KEH and if acceptable retained for record. If previously approved procedure is not acceptable submittal will be returned with requirements for resubmittal.

1.3 SCHEDULE OF SUBMITTALS

Submittal Number	Submittal Title	Quantity	Review and Approval	Review For Record
CONTRACT GENERAL CONDITIONS				
55.2	Safety Program and Job Safety Analysis	5	5 days before start of work	
55.3	Industrial Injury/ Illness Experience	5		5 days before start of work and each month
55.5.1	OSHA Form No. 200 Report	5		5th working day, each month
55.6	Equipment Certi-fication	5		2 days before bringing equipment onsite
PROGRESS SCHEDULES				
01310/1.2.1	Progress Schedule	5	10 days after notice to proceed	
CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS				
01500/1.2.1	Anchoring and Enclosure Methods	10	Before placing field office	
EARTHWORK				
02200/1.2.1	Method to Prevent Damage During Excavation	10	Before excavation	

PART 2 - PRODUCTS

Not Used

PART 3 - EXECUTION

Not Used

END OF SECTION

SECTION 02200

EARTHWORK

PART 1 - GENERAL

1.1 REFERENCES

1.1.1 Reference Standards and Specifications: The following standards and specifications, including documents referenced therein, form part of this Section to extent designated herein.

1.1.1.1 American Society for Testing and Materials (ASTM)

D 653-87	Standard Terminology Relating to Soil, Rock, and Contained Fluids

1.1.1.2 Washington State Department of Transportation (WSDOT)

M41-10-88	Standard Specifications for Road, Bridge, and Municipal Construction

1.2 SUBMITTALS: Refer to Section 01300 for submittal procedures.

1.2.1 Method to Prevent Damage During Excavation: Submit procedure proposed to prevent overstressing existing structures or interrupting service to existing facilities.

PART 2 - PRODUCTS

2.1 MATERIALS

2.1.1 General: Obtain select soils from excavation or other designated locations. Obtain on-site approval for soils.

2.1.2 Corrugated Metal Pipe: Meeting the requirements of WSDOT M41-10, Section 9-05.4.

2.1.3 Fill or Backfill: Well graded soil mixtures which may contain cobbles up to 3 inches in greatest dimension if uniformly distributed and not constituting more than 20 percent of volume of fill.

2.1.4 Riprap: Meeting the requirements of WSDOT M41-10, Section 9-13.1(2).

2.1.5 Stabilization: Gravel, defined in ASTM D 653. Maximum size of particles 2 inch minus.

PART 3 - EXECUTION

3.1 EXCAVATION

3.1.1 Before performing excavation, obtain excavation permit. Excavation permits will be furnished as set forth in Section 01065.

3.1.2 Locate underground utilities by hand tools. Use of heavy equipment and machinery is subject to approval of KEH.

3.1.3 Do not store excavated or other material closer than 2 feet from edge of excavation unless barrier is erected to retain excavated materials. Maintain materials in manner that they are prevented from falling or sliding into excavation. Dispose of excess excavated material at area designated by KEH.

3.1.4 Soils in Contaminated Zones

3.1.4.1 Salvage in situ stabilization material and reuse after backfilling and compacting.

3.1.4.2 In place density tests will be conducted by KEH on in situ soils, using nuclear density gage, during excavation. Results of tests will be used by KEH for testing compaction of backfill.

3.1.5 Where riprap is required, excavate in accordance with WSDOT M41-10, Section 8-15.3(1).

3.1.6 Where stabilization is required, finish subgrade 3 inches below elevations shown on the Drawings.

3.2 INSTALLATION

3.2.1 Corrugated Metal Pipe Culverts: Install in accordance with WSDOT M41-10, Section 7-02.3(1)B.

3.2.2 Fill and Backfill

3.2.2.1 General

a. Backfill Permit: Do not start fill or backfill without approved permit as set forth in Section 01065.

b. Remove debris and organic matter from area to be filled or backfilled.

c. Use only select materials for fill or backfill. Keep materials free of frozen particles, lumps, organic matter and trash.

d. Do not place fill or backfill on frozen ground.

e. Filling or backfilling by sluicing or flooding with water will not be permitted.

3.2.2.2 Structural

a. Before placement of fill or backfill, demonstrate, to KEH by physical test at site, that procedure proposed for installation and compaction of soils will provide degree of compaction specified. Prepare "Soil Compaction Procedure" Form KEH-382, sample appended, in accordance with printed instructions. Forms will be furnished by KEH.

b. Place backfill in accordance with WSDOT M41-10, Section 2-03.3(14)C, Method B under trenches and roads, and within 5 feet of fences or poles supporting electric lines or pipe.

c. Compaction control tests will be in accordance with WSDOT M41-10, Section 2-03.3(14)D.

3.2.2.3 Soils in contaminated zones

a. Compact backfill by depositing soils in 8 inch layers and compacting to density equal to in situ density determined by tests made during excavation. Maintain uniformity of compaction throughout backfill.

b. Do not use soils containing rocks larger than 3 inches in greatest dimension for compacted backfill.

3.2.3 Riprap: Place in accordance with WSDOT M41-10, Section 8-15.3(2).

3.2.4 Finish Grading and Stabilization

3.2.4.1 Rake area disturbed by work, remove surface stones larger than 6 inches and dispose of excess material and debris at area designated by KEH.

3.2.4.2 Stabilize roadway shoulders, ramps, and run-on/run-off control ditches with 3 inch course of gravel meeting the requirements of Paragraph 2.1.6. Finish stabilization course to elevations shown on the Drawings.

3.3 FIELD QUALITY CONTROL

3.3.1 Soil Compaction Tests: Sampling and testing of compacted fill and backfill will be performed by KEH.

9011786139 2

SOIL COMPACTION PROCEDURE

Project No.	Project Title	Date
Contract No.	Procedure No.	Location of Demonstration

A

REQUIREMENTS	EQUIPMENT DEMONSTRATED
Applicable Spec./Dwg.	Type
Compaction Required %	Manufacturer
Maximum Lift Size	Model

B

LABORATORY SOIL TEST RESULTS

☐ Non-granular Materials (WSDOT Test Method No. 609)

☐ Granular Materials (WSDOT Test Method No. 606-A)

C

COMPACTION DEMONSTRATION TEST RESULTS

Formula for Percent Compaction:

$$\frac{\text{dry density}}{\text{max density}} \times 100 = \text{Percent Compaction}$$

No. of Passes	Depth of Lift	Percent Moisture	Lbs/ft^3 Dry	Maximum Density	Percent Compaction	Accept	Reject

Observations or Comments

TEST METHOD USED FOR DEMONSTRATION

☐ Nuclear Gage (ASTM D2922 & D3017)

☐ Sand Cone (ASTM D1556)

☐ Other _____

Apparatus No. _____

D

Contractor Representative		Date
Government Representative		Date

INSTRUCTIONS

This Soil Compaction Procedure form, when approved by the Government Representative, constitutes an approved compaction procedure.

Section A is the responsibility of the Construction Contractor. It is to be completed at the time of backfill compaction demonstration and presented to the Government Representative.

Section B is completed by the Government Representative. Data entered is obtained from the agency that performs the laboratory testing.

Section C is completed by the Government Representative as the demonstration is performed. Using the applicable formula, the percent compaction achieved is determined and entered. Acceptance is based on the results as compared with the compaction percent required in Section A.

Section D is signed and dated by the Construction Contractor Representative acknowledging responsibility for this procedure and compliance thereto for applicable backfill operations. Section D is signed and dated by the Government Representative to signify approval.

END OF SECTION

APPENDIX 4K

ASPHALT COMPATIBILITY WITH 90-DEGREE CENTIGRADE DOUBLE-SHELL SLURRY FEED

This page intentionally left blank.

A Letter Report for Westinghouse Hanford Company

ASPHALT COMPATIBILITY WITH 90°C DSSF

P. F. C. Martin

March 1989

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland Washington

SUMMARY

Based on results of 120-day compatibility testing on three asphalt-based materials, Lion Nokorode 705M® (Lion 705M) has been shown to be the most suitable material for use as a grout vault liner. In addition to experiencing less penetration change and weight gain on exposure to 90°C Double Shell Slurry Feed (DSSF) supernate, Lion 705M possessed superior elasticity and presented fewer application difficulties than the other two materials. ATCO 1850® was clearly unsuitable because of its tendency to become molten at 90°C. Lion Nokorode Seal Kote® (Seal Kote) was also found unsuitable because of chemical incompatibility.

INTRODUCTION

Current construction plans for vaults that will contain grouted double-shell tank (DST) wastes include the use of interior liners. These liners are intended to enhance the grout vault's barrier function by preventing the wicking of grout fluids into the vault concrete before the grout has set, and by preventing any leakage of excess liquid that may develop during the initial phase of grout curing. Asphalt-based materials are being considered because they possess several desirable attributes that make them well suited for use as liners. These attributes include ease of application, good adhesion to concrete surfaces, and the ability to seal or span small cracks in the concrete that may develop during and following grouting operations. Because of these attributes, asphalt-based materials have gained widespread use as

® Nokorode 705M and Nokorode Seal Kote are registered trademarks of the Lion Oil Company, El Dorado, AR
® ATCO 1850 is a registered trademark of the American Tar Company, Seattle, WA

9011178613998

moisture barriers and therefore constitute possible choices for use in grout vaults. However, the compatibility of asphaltic materials with the treated waste, at conditions expected in the vaults, needed to be addressed. Because temperatures within the grout vault may approach 90°C, a demonstration of suitability at this temperature was required. This report presents the results of a 120-day experiment assessing the suitability of three asphaltic materials considered for use as grout vault liners.

MATERIALS

Based on conversations with vendors, three materials were chosen for chemical compatibility testing. Each material is suitable for spray application at ambient temperatures above 60°F. The materials included: 1) ATCO 1850 (fibered roof emulsion, water-based, heavy-duty), 2) Lion Nokorode Seal Kote (fibered, medium-grade, mastic), and 3) Lion Nokorode 705M (two-part elastomeric polyisocyanate-based coating). Simulated DSSF[1] (see Table 1) was allowed to settle and the supernatant liquid was collected for use as an exposure fluid.

PROCEDURE

Samples were prepared for immersion testing by pouring a thin layer of well-mixed test material into a metal sample cup. Each layer was allowed to cure before the next layer was added. Because of the slow cure rate of Seal Kote, curing was accelerated by placing the sample cups in a 70°C oven. After curing, the samples were placed in

[1] Claghorn, R. D. 1987. Compositional Limits for Grout Feed: Double Shell Slurry Feed and Retrieved Double Shell Slurry Formulation Experiments. RHO-RE-EV-96, Rockwell Hanford Operations, Richland, WA.

TABLE 1. Composition of Simulated DSSF Waste

Species	Concentration, mol/L
Ag	1.50 E-03
Al	7.50 E-01
Ba	4.54 E-03
Cl	1.09 E-01
Ca	5.00 E-03
SO_4	5.25 E-02
Fe	2.52 E-02
PO_4	5.95 E-02
K	2.49 E-01
OH	2.05 E+00
F	2.96 E-02
Mn	5.00 E-02
Na	5.30 E+00
B_4O_7	2.43 E-03
CO_3	1.50 E-01
Cr_2O_7	1.11 E-02
NO_3	2.49 E+00
NO_2	5.00 E-01
Ni	5.00 E-04
Zn	2.49 E-02
TOC	1.29 E-01

immersion baths of DSSF supernate, deionized water, and water vapor; inverted to prevent loss of asphalt; and weighted. The baths were then placed in a 90°C oven and monitored for temperature and liquid level. Deionized water was added, when necessary, to compensate for evaporative losses. At intervals of 30, 60, 90, and 120 days the samples were removed from the immersion baths. The samples were rinsed under water

9011178614006

and allowed to dry in air overnight before net weight change and penetration values were determined (ASTM D5). Penetration was determined using a 50 gram tapered needle assembly that was allowed to sink into the sample for five seconds. The penetration reading was taken in tenths of a millimeter using a dial caliper gauge. If the material was penetrated more deeply, indicating softening or compositional changes, the penetration readings increased. Changes in appearance were also noted and evaluated.

RESULTS

Table 2 summarizes a qualitative ranking of the materials relative to each other. Because the number of materials considered was small, a more quantitative ranking was not possible. Where the characteristic was similar between two materials the better-performing material was ranked "good" and the other "OK." For quantitative measures, where applicable, see Tables 3 and 4 and figures 1 through 4.

TABLE 2. Summary of 120-Day Compatibility Testing with DSSF

	ATCO	705M	Seal Kote
Curing Rate	good	good	poor
Percent Penetration Change	med	low	high
Weight Change, DSSF	high	low	med
Surface Changes, DSSF	melts	low	pits
Water	melts	swells	swells
Vapor	low	concave	convex
90°C compatibility	no	yes	yes
Shrinkage resistance (during cure)	poor	good	OK
Adherence	poor	good	OK
Elasticity/Resilience	poor	good	poor

TABLE 3. Penetration Values, 0.1-mm depth

Exposure		ATCO	Seal Kote	705M
As-prepared		18	5	38
DSSF.....	30 day	45	14	52
	60 day	47	16	74
	90 day	35	17	82
	120 day	47	17	81
Water.....	30 day	20	15	57
	60 day	28	10	78
	90 day	28	9	83
	120 day	28	10	99
Water Vapor..	30 day	10	3	18
	60 day	8	2	17
	90 day	4	2	16
	120 day	3	1	15

TABLE 4. Percent Weight Change Through 120 Days Exposure

Exposure		ATCO	Seal Kote	705M
DSSF.....	30 day	31.1	3.9	0.1
	60 day	42.1	4.6	0.3
	90 day	42.5	6.3	0.1
	120 day	45.5	7.1	0.3
Water.....	30 day	4.9	3.6	2.8
	60 day	7.8	2.4	4.3
	90 day	6.8	2.6	5.4
	120 day	13.7	2.7	6.1
Vapor.....	30 day	0.9	-1.9	-8.5
	60 day	2.3	-2.6	-10.0
	90 day	2.2	-2.9	-11.1
	120 day	2.1	-0.6	-11.0

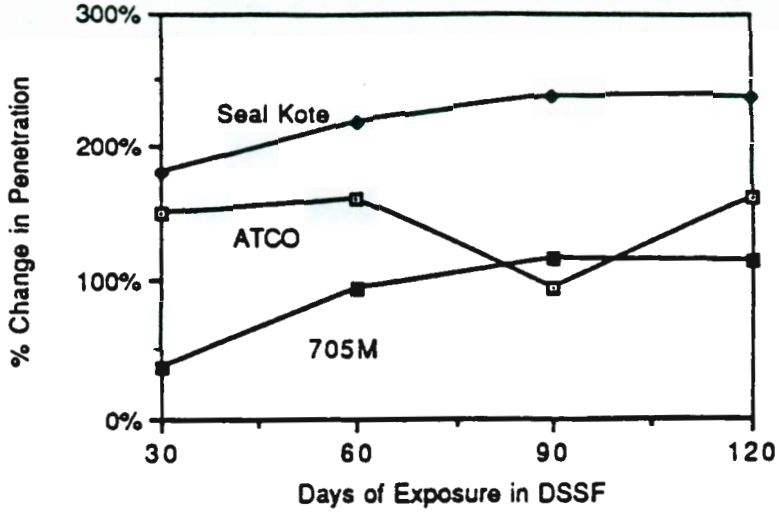


FIGURE 1. Average Change in Penetration Through 120 Days Exposure to DSSF

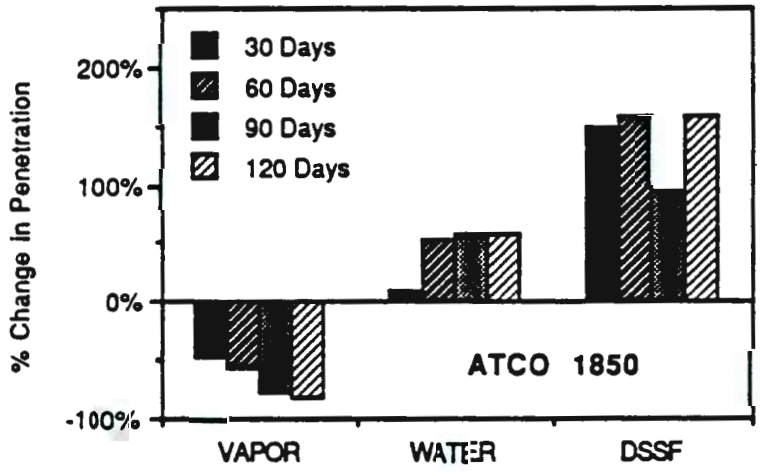


FIGURE 2. Average Change in Penetration at 120 Days Exposure for ATCO 1850

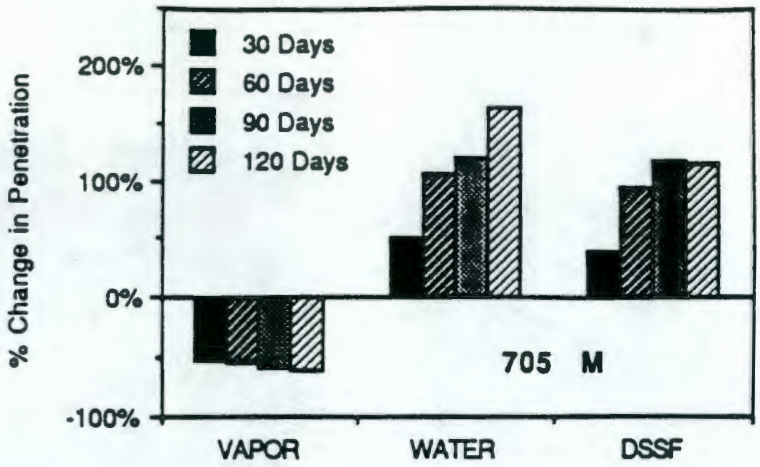


FIGURE 3. Average Change in Penetration at 120 Days Exposure for 705M

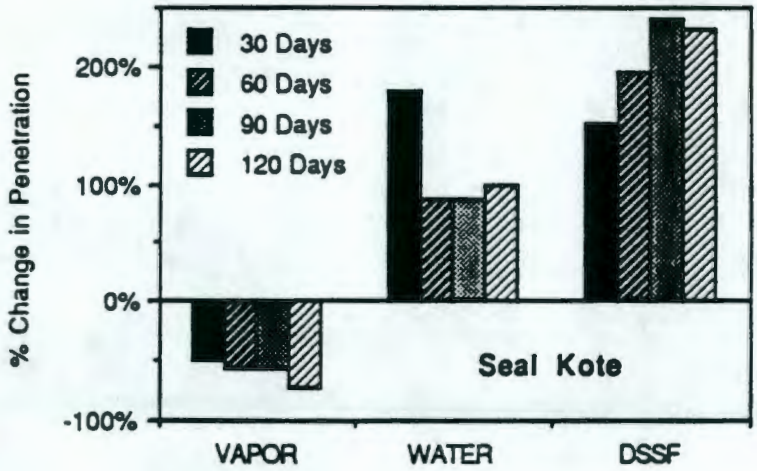


FIGURE 4. Average Change in Penetration at 120 Days Exposure for Seal Kote

DISCUSSION

A straightforward method was employed to evaluate the suitability of the liner materials. A combination of physical measurements, observations, and experience gained from sample preparation was used to

9011785140 4

determine which material was most suited for application as a grout vault liner. First, and most importantly, the material had to have a melting point above 90°C. If a material melts below 90°C the liner may thin over wide areas of the grout vault and therefore could no longer provide containment.

Penetration measurement was used to indicate the possibility of detrimental change to the liner. If a relatively large change in penetration occurred, a close examination of the specimen was made to determine the cause of the change and to evaluate the likely effect on its suitability as a grout vault liner. An increase of penetration may result from (in order of increasing severity) simple heat expansion, incorporation of water, penetration of DSSF into the liner, or dissolution of asphalt and/or reinforcement fibers. Weight change and surface observation were used to confirm the likely cause of penetration change. For instance, the appearance of crystals, on the surface of the sample, in conjunction with weight gain would indicate the penetration of DSSF into the liner material. Conversely, the absence of crystals would indicate only the incorporation of water.

Consideration of rate and uniformity of cure, resistance to shrinkage, adherence, and elasticity were used to supplement the judgement of suitability. Rate and uniformity of cure are important when these materials are applied to vertical surfaces. If the material cures slowly there is increased likelihood that the material would flow following spray application and result in uneven thickness. If a skin forms that slows the curing of the rest of the material (non-uniform cure), there is a possibility that underlying material will flow, again resulting in uneven thickness. Strong attachment to the concrete of the

vault constrains the direction in which the asphalt may shrink. Excessive shrinkage during cure may result in tears if there are areas where the liner is poorly adhered. Where asphalt is poorly attached, and therefore movement is not constrained by the vault wall, thinning will result. If the poorly attached area is sufficiently large a tear may occur when it is stretched beyond the limits of its elasticity. It is also felt that an inelastic liner will be less resistant to damage from construction equipment during liner application.

In summary, assuming satisfactory temperature and chemical compatibility, it would be desirable to use a material that cured quickly and uniformly, that did not shrink excessively during cure, or if shrinkage occurred that the material was sufficiently elastic to compensate. The three test materials will be considered in turn evaluating their performance against the two primary compatibility criteria, namely temperature compatibility and lack of physical degradation on exposure. The material's elasticity and resistance to shrinkage will also be evaluated in relation to the preceding discussion.

ATCO 1850 was found to be clearly unsuitable for the application. At 90°C the material becomes very soft and flows easily. For this reason its ability to seal the grout vault under the expected conditions is suspect. The matte surface that developed on this material was a layer of fine crystals. Therefore the DSSF had been incorporated into the liner and was largely responsible for the material's increased penetration. This material was also observed to gain the most weight during immersion exposure (see Table 4). Note also that this material

9011178614006

gained weight during exposure in a 100% RH (water vapor) atmosphere at 90°C when the other two materials lost weight.

Although Lion Seal Kote did not melt at 90°C and had the lowest absolute penetration values of the materials tested, its average penetration change (%) was the greatest. An increase in penetration this large is an indication of sample degradation. Close observation of the liner surface revealed that, after 120 days of exposure to DSSF, asphalt did not stick to the fibers, in the top layer of the sample, as thoroughly as in an unexposed sample. Exposed fibers were also observed on the sides of the exposure cup. This may be explained by the partial dissolution of asphalt, and therefore may represent a compositional change. The appearance of small pits in the surface of the composite, surrounded by small rings of shiny asphalt, is another indication of chemical imcompatibility. It can be speculated that the fibers used in this asphalt are chemically incompatible with DSSF and, through dissolution or reaction, these small pits formed on the surface. These two indications of chemical incompatibility with DSSF eliminate Seal Kote as a possible choice as a grout vault liner.

Lion 705M is recommended over the other two materials because it does not suffer the same limitations discussed above and, on average, appeared the least affected by exposure to 90°C DSSF supernate (see figure 1). Lion 705M does not become molten at 90°C, and a quick check at 150°C indicated that it may be capable of withstanding higher temperatures. Although Lion 705M's initial penetration values were higher than those for the other two materials, because it lacks fibers, it's average change (%) was much less. In addition, weight gain in DSSF was very low, and surface change was limited to the development of a

9011785140 7

slight stickiness. These observations indicate that physical degradation caused by chemical incompatibility was minimal.

The inherent elasticity of Lion 705M makes it a better choice over the other tested materials. Curing of 705M occurs by reaction, not by solvent loss, so the material retains a "springiness" and does not become hard and inelastic as ATCO 1850 and Seal Kote. Problems with prolonged curing (Seal Kote) and shrinkage (ATCO 1850) are avoided.

Curing of Seal Kote is slowed by a skin that forms on its surface. Unless applied in a thin layer, testing on vertical surfaces would be required to determine if uncured material under the cured skin would flow and result in an uneven application. A second consequence of curing by solvent loss is shrinkage. Although not as pronounced as shrinkage for ATCO 1850, it was observed that the cured product pulled away slightly from the sides of the sample cup as the material cured. As previously stated, an inelastic liner that shrinks may thin, and eventually tear, if movement is not constrained by uniform attachment to the vault. Even though weight loss was higher in 90°C water vapor than for the other two materials, resulting in shrinking, (the surface was noticeably concave), the product adhered very well to the sides of the sample cup. In this case the elasticity of 705M was sufficient to compensate for the shrinkage.

At ambient temperatures ATCO 1850 and Seal Kote were judged inelastic as evidenced by: 1) lack of "spring," 2) permanence of penetration holes, and 3) shrinkage away from the walls of the sample cup. This combination of factors may result in damage to liner integrity during cure, and may render the material incapable of spanning cracks in vault concrete if they develop following liner application.

9011178514 08

It is also likely that ATCO 1850 and Seal Kote will not "heal" if punctured during the construction process. Because Lion 705M is elastic, small punctures may still be capable of excluding grout fluids.

The good curing rate for Lion 705M will be beneficial during application because the material is not as viscous as the other materials. The manufacturer calls its thin consistency "self-leveling," referring to its most common application to flat roofs. Because of this thinness the material will have to be applied in fairly thin layers. Subsequent layers will need to be applied within six hours, or the previous layer roughened before the next coat can be applied. Despite this limitation Lion 705M possesses the thermal stability, chemical compatibility, and an inherent elasticity that make it suitable for use as a grout vault liner.

1 This page intentionally left blank.

APPENDIX 5

GROUNDWATER PROTECTION

APPENDIX 5

GROUNDWATER PROTECTION

5A Geologic Data

5B Hydrologic Data

5C Groundwater Monitoring Program Information

5D Detection Monitoring Program

5E Groundwater Characterization Drawings

APPENDIX 5A

GEOLOGIC DATA

APPENDIX 5A

GEOLOGIC DATA

5A-1 Particle Size Analyses and Calcium Carbonate Determinations

5A-2 Chemical Analyses of Sediment Samples

5A-3 Radionuclide Analyses of Sediment Samples

5A-4 Sediment Moisture Data

5A-5 Lithologic Sections for the Detection Monitoring Wells and Site Baseline Wells

APPENDIX 5A-1

PARTICLE SIZE ANALYSES AND CALCIUM CARBONATE DETERMINATIONS

1 This page intentionally left blank.

APPENDIX 5A-1

PARTICLE SIZE ANALYSES AND CALCIUM CARBONATE DETERMINATIONS

This appendix presents particle size analyses and calcium carbonate determinations for sediment samples collected during the construction of monitoring wells 299-E25-25 through 299-E25-32. Sediment samples were collected by the field geologist or driller in 1-pint glass jars. Field descriptions were made by the geologist and recorded in black ink on driller's log sheets. The glass jars were transported to the Hanford Geotechnical Sample Facility located in the 2101 M Building, 200 East Area, and were formally received by the facility. Samples were dried and sieved for particulate size distribution and calcium carbonate content determination according to standard procedures presented in this appendix. Data obtained from the particle size analyses and calcium carbonate content determinations are presented in Table 5A1-1.

The weight of each grain size is presented in a sediment analysis report from the laboratory and is entered into the sieve analysis (ROCKSAN) data base. The ROCKSAN program calculates the weight percent of each major grain-size constituent and sediment class. The grain-size scale used in the ROCKSAN calculations is the modified Wentworth scale used by American geologists.

The sediment class is determined using the sediment classification scheme used by Tallman et al. (1979) (Fig. 5A1-1). The sediment class determined by ROCKSAN may be different than the sediment class noted on the lithologic logs for each well. This is because of the inherent subjectivity of the geologist's interpretation, and it is also dependent on the drilling method used, as noted on the lithologic sections in Appendix 5A-5. Depth is the distance, in feet, below ground surface where the sample was collected. The calcium carbonate content is reported in weight percent. The weight percent for each grain-size group, gravel, sand, and mud are presented. The notation N/A indicates results are not available.

Table 5A1-1. Particle Size Analyses and Calcium Carbonate Determinations for Wells 299-E25-25 through 299-E25-32.

Well 299-E25-25

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.0	0.0	0.1	1.5	1.1	2.2	28.6	36.1	30.4	0.0	33.5	66.5	N/A	sM
10	0.0	0.1	0.5	4.4	6.5	29.7	39.8	9.2	9.9	0.1	80.8	19.1	N/A	(m)S
15	1.3	2.3	16.9	46.2	11.8	8.2	4.8	1.8	6.7	3.7	87.8	8.5	N/A	S
20	0.0	1.3	8.2	49.6	32.6	4.1	1.7	0.7	1.9	1.3	96.1	2.6	N/A	S
25	0.2	1.4	21.9	57.2	10.1	3.6	2.2	0.9	2.6	1.5	95.0	3.5	N/A	S
30	0.1	0.6	13.1	62.6	12.1	4.3	2.7	1.1	3.3	0.7	94.8	4.5	N/A	S
35	0.8	0.7	6.5	40.4	32.2	7.0	4.9	2.1	5.5	1.5	91.0	7.5	N/A	S
40	5.7	2.0	4.9	36.1	38.9	5.5	2.8	1.1	3.1	7.7	88.1	4.2	N/A	(g)S
45	0.5	0.2	1.7	29.9	52.1	7.5	3.3	1.2	3.6	0.7	94.5	4.8	N/A	S
50	0.0	0.2	2.8	33.3	42.9	10.7	4.1	1.6	4.3	0.2	93.9	5.9	N/A	S
55	0.7	1.9	9.5	38.3	31.7	8.8	4.0	1.5	3.7	2.6	92.3	5.1	N/A	S
60	0.1	1.1	10.9	45.3	30.9	7.2	2.5	0.7	1.4	1.1	96.8	2.1	N/A	S
65	0.3	1.1	14.2	42.9	25.1	7.7	4.0	1.3	3.5	1.5	93.8	4.8	N/A	S
70	0.0	0.1	1.4	20.4	51.0	14.1	5.9	2.2	5.0	0.1	92.8	7.2	N/A	S
75	0.0	0.1	0.1	5.1	38.1	34.2	12.1	3.0	7.4	0.1	89.5	10.4	N/A	(m)S
80	0.0	0.5	4.0	24.5	44.6	14.5	5.3	2.0	4.6	0.5	92.9	6.5	N/A	S
85	0.0	0.4	3.3	21.4	44.5	17.2	6.2	2.1	4.9	0.4	92.6	7.0	N/A	S
90	0.0	0.2	0.6	4.0	21.3	43.4	17.8	4.3	8.5	0.2	87.0	12.8	N/A	(m)S
95	0.7	0.4	2.1	5.6	30.5	37.3	12.9	3.3	7.1	1.1	88.5	10.4	N/A	(m)S
100	6.2	0.4	2.8	13.0	34.2	24.6	9.1	3.2	6.5	6.6	83.7	9.7	N/A	(gm)S
105	0.0	0.3	3.2	17.9	43.6	20.1	7.6	2.4	4.8	0.3	92.5	7.2	N/A	S
110	0.0	0.5	3.6	21.2	43.0	14.4	7.1	2.9	7.3	0.5	89.4	10.1	N/A	(m)S
115	0.0	0.3	2.8	20.9	54.7	13.4	4.0	1.2	2.8	0.3	95.7	3.9	N/A	S
120	0.1	0.4	1.8	8.9	31.3	34.9	12.4	3.5	6.8	0.5	89.2	10.3	N/A	(m)S
125	0.0	0.3	1.0	7.7	36.2	33.4	11.2	3.0	7.2	0.3	89.5	10.2	N/A	(m)S
130	0.0	0.9	5.2	11.3	30.5	28.5	13.3	4.0	6.4	0.9	88.7	10.4	N/A	(m)S
135	0.7	0.7	2.4	12.6	44.7	24.9	7.9	1.9	4.2	1.4	92.5	6.1	N/A	S
140	0.0	0.7	3.5	18.7	41.4	22.2	7.4	2.0	4.2	0.7	93.2	6.1	N/A	S
145	0.1	2.7	9.9	30.9	31.2	12.4	6.0	1.8	5.0	2.8	90.4	6.8	N/A	S
150	4.7	10.3	31.4	29.9	11.0	5.1	3.1	1.2	3.2	15.0	80.6	4.4	N/A	gS
155	0.7	3.9	15.1	25.4	20.6	12.6	8.8	2.9	10.0	4.6	82.5	12.9	N/A	(m)S
160	0.1	0.3	3.2	17.5	36.1	20.0	9.8	3.5	9.6	0.3	86.6	13.1	N/A	(m)S
165	1.5	4.7	12.2	29.4	25.9	11.3	7.0	2.1	5.9	6.3	85.8	8.0	N/A	(g)S
169	1.1	4.1	10.0	22.8	16.7	11.2	15.4	6.9	11.6	5.3	76.2	18.6	N/A	(gm)S
175	7.7	13.1	14.1	14.1	12.2	11.1	9.2	3.8	14.8	20.9	60.6	18.6	N/A	gmS
180	8.8	14.6	14.6	12.4	11.6	10.3	8.5	4.5	14.8	23.4	57.3	19.3	N/A	gmS
185	0.6	6.7	15.2	23.8	17.5	11.6	8.8	3.6	12.3	7.2	76.9	15.9	N/A	(gm)S
190	11.9	15.9	15.7	20.9	13.1	7.6	5.5	2.3	7.1	27.9	62.8	9.4	N/A	(m)gS
195	9.2	21.5	14.9	11.0	10.5	8.3	6.8	3.1	14.7	30.8	51.4	17.8	N/A	msG
200	0.9	7.9	14.5	15.2	15.9	12.4	10.4	5.1	17.8	8.8	68.3	22.9	N/A	(g)mS
205	17.2	20.1	14.6	10.1	7.2	8.1	6.8	3.2	12.6	37.4	46.9	15.8	N/A	msG
210	13.3	18.0	14.2	11.2	11.2	8.9	7.3	3.6	12.3	31.2	52.9	15.9	N/A	msG
215	3.4	9.7	18.3	21.2	15.8	9.7	7.1	2.8	12.2	13.1	72.0	15.0	N/A	(m)gS
220	12.3	19.8	15.4	12.2	10.6	8.8	7.1	2.9	10.9	32.1	54.1	13.8	N/A	msG
225	0.5	2.3	7.4	12.5	14.6	16.3	14.0	6.2	26.3	2.8	64.8	32.4	N/A	mS

Well 299-E25-25

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
230	5.6	14.4	14.5	15.9	14.0	10.7	8.7	3.8	12.4	20.0	63.8	16.2	N/A	gmS
235	10.0	16.5	14.5	12.2	10.2	10.2	8.4	3.2	14.7	26.5	55.6	17.9	N/A	gmS
240	10.2	19.8	15.4	9.8	12.5	9.3	7.9	3.4	11.6	30.1	54.9	15.1	N/A	msG
245	6.7	18.5	17.3	12.1	12.1	9.5	7.8	3.9	12.2	25.1	58.8	16.1	N/A	gmS
250	13.9	19.1	14.3	10.6	10.1	8.4	7.2	3.7	12.7	33.0	50.6	16.4	N/A	msG
255	10.2	19.7	14.6	10.6	9.9	9.4	8.1	3.9	13.7	29.9	52.5	17.6	N/A	gmS
260	6.4	24.9	16.5	10.7	7.9	9.1	7.6	4.2	12.7	31.3	51.8	16.9	N/A	msG
265	0.2	2.5	14.6	18.3	14.7	13.7	11.7	6.0	18.5	2.7	72.9	24.4	N/A	mS
270	4.7	20.7	19.5	12.1	9.7	9.4	8.3	3.5	12.1	25.4	59.0	15.6	N/A	gmS
275	0.3	1.8	10.1	20.0	25.2	15.1	10.6	4.4	12.5	2.1	81.0	16.9	N/A	(m)S
280	0.2	1.4	7.6	26.3	32.5	12.9	7.6	2.9	8.6	1.6	86.9	11.5	N/A	(m)S
285	0.0	0.3	4.0	22.4	33.2	17.3	9.2	3.3	10.4	0.3	86.0	13.7	N/A	(m)S
288	0.2	4.1	15.7	32.0	21.7	9.4	6.3	2.5	8.1	4.3	85.2	10.6	N/A	(m)S

Well 299-E25-26

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	1.3	0.3	1.0	4.3	22.4	29.5	25.9	7.2	8.2	1.5	83.0	15.4	N/A	(m)S
10	1.1	1.1	2.8	7.5	27.6	27.0	18.4	6.1	8.3	2.2	83.3	14.5	1.4	(m)S
15	1.2	3.5	11.0	19.0	17.9	14.9	18.0	7.3	7.3	4.7	80.7	14.6	1.0	(m)S
19	0.7	3.7	12.6	31.1	19.3	10.5	11.7	4.4	6.1	4.4	85.2	10.4	1.0	(m)S
22	0.6	0.5	3.1	17.9	44.2	19.1	7.8	2.4	4.4	1.0	92.1	6.9	1.2	S
25	2.5	2.6	13.9	46.9	24.9	4.8	2.1	0.7	1.7	5.1	92.5	2.4	1.4	(g)S
30	0.1	1.0	12.0	51.4	19.4	6.9	4.5	1.6	3.3	1.0	94.1	4.9	0.9	S
35	0.0	0.1	1.7	25.2	51.3	12.6	5.3	1.3	2.5	0.1	96.1	3.8	0.9	S
40	2.0	1.8	9.5	40.3	31.7	8.6	3.1	0.9	2.2	3.7	93.1	3.1	0.6	S
45	0.8	0.8	7.4	35.8	32.7	9.5	6.3	2.4	4.4	1.6	91.6	6.8	0.8	S
50	0.0	0.4	3.9	33.0	45.9	9.3	3.7	1.2	2.6	0.4	95.8	3.8	0.9	S
55	0.4	0.1	6.1	35.4	35.7	9.9	2.6	3.3	6.6	0.4	89.6	9.9	1.3	S
60	0.1	0.2	2.6	22.7	44.7	15.7	7.0	2.3	4.8	0.4	92.6	7.0	0.9	S
65	0.0	0.2	2.2	30.3	52.4	9.2	2.9	1.0	1.8	0.1	97.0	2.9	1.5	S
70	0.6	1.0	3.1	18.3	39.2	24.5	7.1	1.9	4.3	1.6	92.1	6.2	1.4	S
75	0.0	0.1	1.1	10.8	42.9	31.1	8.3	2.3	3.5	0.1	94.1	5.8	1.4	S
81	1.3	6.0	12.6	28.7	30.0	11.6	4.9	1.4	3.7	7.3	87.6	5.1	1.0	(g)S
85	6.0	17.1	31.3	24.5	11.6	4.0	2.5	0.8	2.2	23.1	73.8	3.1	0.9	gS
90	16.6	15.3	25.3	20.1	10.5	5.4	3.3	1.0	2.5	31.9	64.6	3.5	1.1	sG
95	19.6	27.9	30.8	13.2	4.5	1.8	1.0	0.3	1.0	47.4	51.2	1.4	1.2	sG
100	8.2	23.9	32.5	16.1	7.1	4.3	3.6	1.3	2.9	32.1	63.7	4.2	0.9	sG
105	0.3	1.5	18.9	49.5	21.1	4.3	2.0	0.7	1.6	1.8	95.9	2.3	0.7	S
110	0.5	6.0	27.0	44.7	14.5	3.8	1.9	0.5	1.2	6.4	91.8	1.8	1.0	(g)S
115	0.0	0.6	13.5	57.8	19.7	4.4	2.0	0.6	1.4	0.6	97.4	2.0	1.4	S
120	2.4	6.4	29.7	38.5	12.1	4.8	2.9	0.8	2.5	8.7	87.9	3.3	0.9	(g)S
125	1.0	6.0	25.4	35.7	14.2	6.9	4.7	1.8	4.5	6.9	86.9	6.2	1.0	(g)S
130	0.2	1.9	28.4	50.2	13.1	3.3	1.5	0.4	1.0	2.1	96.5	1.4	1.1	S
135	1.9	8.3	35.2	32.4	12.8	5.3	2.1	0.7	1.4	10.2	87.7	2.0	1.0	gS
140	3.6	4.8	26.9	44.6	12.6	3.5	1.8	0.6	1.6	8.4	89.3	2.2	1.2	(g)S
145	3.3	9.0	31.4	31.9	10.2	4.9	3.7	1.6	4.2	12.2	82.0	5.8	1.2	gS
150	1.6	8.5	35.7	38.9	8.9	2.9	1.4	0.5	1.6	10.2	87.7	2.1	1.2	gS
155	1.3	5.9	31.5	39.7	11.3	4.5	2.6	0.9	2.4	7.2	89.6	3.2	1.3	(g)S

Well 299-E25-26

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
160	7.5	17.5	14.9	12.5	9.4	9.7	8.8	3.6	16.1	25.0	55.3	19.7	0.6	gmS
165	7.4	14.0	13.0	14.1	13.8	11.7	8.8	4.1	13.1	21.4	61.4	17.2	0.8	gmS
170	2.4	13.1	16.6	15.8	17.3	12.5	8.2	3.0	11.0	15.6	70.5	13.9	1.0	(m)gS
175	4.3	21.1	25.0	12.6	7.6	7.5	6.3	3.2	12.5	25.4	59.0	15.6	0.7	gmS
180	0.9	11.0	39.9	22.7	7.8	5.3	3.6	1.5	7.4	11.8	79.2	8.9	0.9	(m)gS
185	0.8	6.2	28.2	22.8	11.9	9.1	6.5	2.9	11.7	7.0	78.4	14.6	1.0	(gm)S
190	1.0	6.3	21.9	21.8	14.2	10.1	7.8	3.3	13.7	7.3	75.7	17.0	0.9	(gm)S
195	3.4	3.4	4.8	10.8	26.7	23.1	12.0	4.3	11.6	6.8	77.4	15.9	1.5	(gm)S
200	10.5	9.1	12.3	16.4	17.2	11.9	8.5	3.1	11.2	19.6	66.1	14.3	0.8	(m)gS
205	5.0	11.8	14.0	15.7	16.6	11.9	8.7	3.6	12.6	16.8	67.0	16.2	0.6	(m)gS
210	9.6	12.9	13.1	16.3	15.5	10.6	7.8	2.9	11.5	22.4	63.2	14.3	0.6	(m)gS
215	10.2	13.5	15.2	15.3	10.4	9.9	7.9	3.8	13.9	23.6	58.7	17.7	0.4	gmS
220	13.3	21.5	14.9	11.7	7.8	7.6	6.9	2.9	13.3	34.9	48.9	16.3	0.4	msG
225	19.5	15.8	14.9	10.9	7.8	8.5	7.0	3.5	12.2	35.2	49.2	15.6	0.4	msG
230	13.4	14.3	13.8	12.7	10.9	9.5	8.0	3.3	14.1	27.7	54.9	17.4	0.3	gmS
235	7.2	16.6	14.8	11.8	11.1	10.4	8.5	4.2	15.4	23.8	56.5	19.6	0.3	gmS
240	9.2	13.5	13.5	12.8	15.0	10.0	8.3	3.5	14.3	22.6	59.6	17.8	0.4	gmS
245	0.9	6.8	15.1	24.3	16.2	12.3	8.9	4.4	11.3	7.6	76.7	15.6	0.4	(gm)S
250	11.2	14.5	15.8	17.1	13.7	8.9	6.3	2.4	10.0	25.7	61.8	12.5	0.5	(m)gS
255	0.8	8.5	24.6	25.5	15.0	10.7	5.7	2.2	7.2	9.3	81.4	9.3	0.5	(gm)S
260	1.5	4.0	12.8	19.3	20.1	17.4	8.9	2.8	13.4	5.5	78.4	16.1	0.8	(gm)S
265	5.3	8.2	18.9	33.8	13.8	7.4	4.4	2.0	6.2	13.4	78.4	8.2	1.1	gS
270	3.9	8.3	17.0	32.0	15.5	7.9	5.5	2.2	7.8	12.1	77.9	10.0	0.9	(m)gS
275	0.9	6.0	14.1	36.4	22.4	8.3	4.8	1.7	5.5	6.8	86.0	7.2	0.9	(g)S
280	4.1	13.5	22.4	25.3	11.9	7.3	5.2	2.0	8.4	17.6	72.0	10.4	0.8	(m)gS
285	3.3	10.5	21.2	24.3	13.7	9.0	6.3	2.7	9.0	13.9	74.5	11.7	0.7	(m)gS
290	0.6	3.4	11.9	41.0	23.7	7.5	4.9	1.4	5.7	3.9	88.9	7.1	0.4	S

Well 299-E25-27

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.9	2.7	6.3	15.1	14.2	18.8	24.9	6.9	10.2	3.6	79.3	17.1	N/A	(m)S
10	4.4	5.1	11.7	19.6	14.3	13.9	18.3	5.1	7.6	9.4	77.9	12.7	N/A	(gm)S
15	2.8	6.4	24.4	40.5	15.7	4.2	2.5	1.1	2.5	9.2	87.3	3.5	N/A	(g)S
20	4.4	5.1	28.1	43.4	12.3	3.3	1.5	0.5	1.3	9.6	88.6	1.8	N/A	(g)S
25	0.3	0.7	6.6	39.7	37.3	8.1	3.5	1.1	2.8	1.0	95.2	3.9	N/A	S
30	0.0	0.7	3.4	26.6	41.7	16.4	6.7	1.5	3.0	0.7	94.8	4.5	N/A	S
35	0.5	1.5	5.4	27.0	32.9	13.9	10.3	2.7	5.8	2.1	89.5	8.5	N/A	S
40	0.1	0.2	2.4	23.7	43.0	17.1	6.6	2.0	5.0	0.3	92.7	7.0	N/A	S
45	0.3	1.1	7.6	45.3	28.9	7.3	3.9	1.5	4.2	1.3	93.0	5.7	N/A	S
50	0.0	0.0	0.1	14.3	53.4	15.0	7.3	3.3	6.7	0.0	90.1	9.9	N/A	S
55	0.0	0.5	5.8	40.8	32.7	9.1	4.4	1.8	4.9	0.5	92.8	6.6	N/A	S
60	0.3	0.3	3.4	27.7	42.3	14.3	5.1	1.9	4.8	0.7	92.7	6.7	N/A	S
65	0.0	0.3	3.7	18.0	34.2	16.6	11.8	5.2	10.2	0.3	84.3	15.4	N/A	(m)S
70	0.1	0.1	1.4	13.1	35.4	28.2	11.2	3.4	7.1	0.1	89.3	10.5	N/A	(m)S
75	0.5	1.2	7.3	31.4	38.1	11.1	4.3	1.6	4.4	1.7	92.3	6.0	N/A	S
80	0.3	1.1	7.7	37.4	33.7	8.2	4.6	1.7	5.3	1.4	91.7	6.9	N/A	S
85	2.8	1.0	6.3	28.8	31.7	12.6	6.7	2.6	7.5	3.8	86.1	10.1	N/A	(m)S

Well 299-E25-27

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
90	4.1	0.7	5.4	34.5	35.1	9.1	4.6	1.7	4.9	4.8	88.6	6.6	N/A	S
95	0.0	0.5	2.6	13.7	42.8	24.1	7.7	2.5	6.1	0.5	91.0	8.5	N/A	S
100	0.1	0.2	1.6	14.5	53.6	20.3	5.1	1.4	3.3	0.3	95.1	4.7	N/A	S
105	0.0	0.1	0.7	16.7	36.8	20.8	16.0	4.7	4.3	0.1	91.0	9.0	N/A	S
110	0.0	0.0	0.9	10.3	36.4	26.0	16.1	4.7	5.6	0.0	89.7	10.3	N/A	(m)S
115	0.0	0.1	0.1	5.1	32.1	33.9	18.4	5.1	5.2	0.1	89.6	10.3	N/A	(m)S
120	1.0	0.1	0.8	2.4	20.9	37.4	17.4	6.1	14.0	1.1	78.8	20.1	N/A	mS
125	0.0	0.1	1.0	9.5	39.1	26.1	12.8	4.5	7.0	0.1	88.5	11.4	N/A	(m)S
130	3.2	2.7	5.9	26.0	31.6	12.8	6.9	4.6	6.4	5.9	83.2	10.9	N/A	(gm)S
135	0.0	0.4	5.5	44.8	33.8	7.8	3.5	1.2	3.1	0.3	95.4	4.3	N/A	S
140	0.0	0.2	1.2	10.5	33.1	28.1	16.2	4.3	6.5	0.2	89.1	10.7	N/A	(m)S
145	0.1	1.8	7.3	36.0	35.4	10.1	4.4	1.4	3.6	1.9	93.1	4.9	N/A	S
150	1.4	4.8	13.7	32.3	26.4	10.1	5.2	1.9	4.3	6.2	87.7	6.2	N/A	(g)S
155	0.0	0.5	2.6	11.4	42.4	31.5	7.1	1.5	3.0	0.5	95.0	4.5	N/A	S
160	0.0	0.3	7.1	24.4	24.7	20.0	11.1	4.1	8.3	0.3	87.3	12.4	N/A	(m)S
165	1.8	4.1	9.7	22.9	25.0	17.0	9.3	3.2	6.9	5.9	84.0	10.1	N/A	(gm)S
170	8.1	16.9	14.5	20.9	13.2	9.3	6.8	2.8	7.5	24.9	64.7	10.3	N/A	(m)gS
175	14.5	19.3	17.3	13.4	10.3	7.3	6.3	2.3	9.2	33.8	54.7	11.5	N/A	msG
180	7.9	19.7	18.4	16.2	11.3	7.6	6.3	2.9	10.0	27.5	59.6	12.8	N/A	(m)gS
185	10.3	26.7	24.3	10.6	6.2	5.6	4.6	2.2	9.5	37.0	51.4	11.7	N/A	msG
190	6.9	23.6	27.5	16.5	7.5	5.4	4.4	2.1	6.2	30.4	61.3	8.3	N/A	msG
195	17.8	27.4	18.1	10.1	7.5	4.9	3.9	1.9	8.4	45.3	44.5	10.3	N/A	msG
200	0.8	8.2	28.9	27.2	12.6	8.3	5.9	2.3	5.9	9.0	82.8	8.2	N/A	(g)S
205	1.7	7.8	18.5	22.5	16.9	12.2	8.2	3.0	9.0	9.6	78.4	12.0	N/A	(gm)S
210	9.0	24.4	20.2	15.0	8.0	6.9	5.6	2.2	8.8	33.4	55.6	11.0	N/A	msG
215	0.0	1.3	6.4	25.4	32.5	17.2	7.6	2.3	7.2	1.3	89.2	9.5	N/A	S
220	0.5	2.4	8.4	21.4	25.1	19.7	10.0	3.4	9.2	2.9	84.5	12.6	N/A	(m)S
225	10.0	18.0	16.1	16.6	10.8	8.9	7.6	3.4	8.8	28.0	59.9	12.1	N/A	(m)gS
230	7.3	20.9	14.8	11.0	10.1	9.0	8.0	3.9	15.1	28.2	52.8	19.0	N/A	gmS
235	0.5	8.9	18.8	20.3	16.5	11.6	8.5	3.5	11.3	9.5	75.7	14.8	N/A	(gm)S
240	1.2	9.4	24.7	20.9	16.6	9.4	6.3	2.6	8.9	10.6	77.9	11.5	N/A	(m)gS
245	10.1	13.4	13.0	22.7	14.8	9.3	6.5	2.7	7.6	23.5	66.2	10.3	N/A	(m)gS
250	2.8	11.1	15.3	18.0	18.6	14.2	8.3	2.8	8.8	13.9	74.4	11.6	N/A	(m)gS
255	21.1	16.0	8.8	12.4	18.2	9.4	5.9	2.3	6.0	37.1	54.6	8.3	N/A	msG
260	1.7	12.0	15.6	15.2	19.2	12.7	8.7	3.5	11.4	13.7	71.4	14.9	N/A	(m)gS
265	3.7	9.4	18.3	18.7	15.4	11.5	8.4	3.4	11.4	13.1	72.2	14.8	N/A	(m)gS
270	0.5	1.2	4.3	13.6	15.6	40.1	10.5	3.6	10.7	1.6	84.1	14.3	N/A	(m)S
273	0.4	3.8	8.6	19.6	18.5	26.3	9.8	3.2	9.8	4.2	82.8	12.9	N/A	(m)S
275	0.2	2.5	9.5	27.8	19.8	17.8	9.1	3.5	9.7	2.7	84.1	13.2	N/A	(m)S
280	0.2	0.6	5.3	37.5	27.6	11.2	6.8	2.6	8.2	0.8	88.4	10.8	N/A	(m)S
285	0.9	3.0	9.2	36.9	25.0	10.0	6.3	2.3	6.7	3.8	87.2	9.0	N/A	S
290	0.3	1.4	1.6	6.5	19.9	28.1	21.4	6.3	14.6	1.6	77.5	20.9	N/A	mS
295	0.0	0.9	4.9	15.9	16.8	16.8	15.3	6.3	23.2	0.9	69.7	29.5	N/A	mS
300	1.5	2.6	7.8	20.9	26.4	15.7	9.8	3.7	11.6	4.2	80.5	15.3	N/A	(m)S

Well 299-E25-28

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.3	0.5	3.3	12.1	19.8	24.0	25.8	6.3	7.9	0.8	85.0	14.2	N/A	(m)S
10	0.2	1.4	8.6	61.6	17.6	4.9	2.9	1.0	1.8	1.6	95.5	2.9	N/A	S
15	0.0	0.0	0.2	0.5	22.1	41.3	28.5	4.0	3.4	0.0	92.6	7.4	N/A	S
20	3.4	3.6	12.7	40.0	29.6	5.6	2.6	0.8	1.7	7.0	90.5	2.5	N/A	(g)S
25	1.9	4.2	16.5	42.1	27.8	4.3	1.5	0.5	1.4	6.0	92.1	1.9	N/A	(g)S
30	0.0	0.9	4.7	30.5	48.2	8.9	3.6	1.0	2.2	0.9	95.9	3.2	N/A	S
35	0.3	0.4	4.4	26.6	45.4	15.6	4.2	1.1	2.1	0.7	96.2	3.2	N/A	S
40	1.4	0.9	8.5	40.5	35.2	7.4	3.1	0.9	2.2	2.3	94.7	3.1	N/A	S
45	0.0	0.2	3.9	41.0	45.9	5.9	2.0	0.6	0.5	0.2	98.7	1.1	N/A	S
50	0.0	0.1	0.4	12.6	66.9	15.5	4.1	0.3	0.2	0.1	99.5	0.5	N/A	S
55	0.0	0.2	3.9	40.4	46.7	5.6	1.8	0.5	1.0	0.2	98.3	1.5	N/A	S
60	0.0	0.1	0.1	9.0	47.0	29.1	8.1	2.1	4.5	0.1	93.3	6.6	N/A	S
65	0.1	0.3	1.2	14.0	66.5	11.9	3.1	0.9	2.1	0.3	96.7	2.9	N/A	S
70	1.3	6.0	11.2	26.5	37.9	11.2	3.2	0.9	1.9	7.3	90.0	2.8	N/A	(g)S
75	9.8	12.4	23.8	22.1	19.1	6.1	3.3	1.1	2.3	22.2	74.4	3.4	N/A	gS
80	4.5	18.0	34.6	28.2	10.0	2.4	1.1	0.3	0.8	22.4	76.4	1.1	N/A	gS
85	7.2	22.6	38.2	19.7	10.1	1.4	0.4	0.1	0.5	29.8	69.7	0.5	N/A	gS
90	6.6	20.6	36.9	22.6	8.3	2.3	1.2	0.4	1.1	27.2	71.3	1.5	N/A	gS
95	2.0	8.7	29.4	38.1	13.6	3.5	1.9	0.6	2.1	10.8	86.5	2.7	N/A	gS
100	9.8	12.0	32.5	32.0	7.6	2.1	1.4	0.5	2.1	21.8	75.5	2.7	N/A	gS
105	0.3	1.6	23.8	45.3	18.9	5.0	2.3	0.8	2.0	1.8	95.4	2.8	N/A	S
110	1.7	8.7	33.8	37.3	12.0	3.0	1.4	0.5	1.7	10.4	87.4	2.2	N/A	gS
115	2.1	7.1	30.2	40.6	13.0	3.2	1.7	0.5	1.6	9.2	88.7	2.1	N/A	(g)S
120	5.4	7.4	36.7	34.7	9.0	2.9	1.7	0.7	1.6	12.8	84.9	2.2	N/A	gS

Well 299-E25-29

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.00	0.20	3.87	11.26	31.68	24.42	15.60	5.43	7.53	0.20	86.84	12.96	1.2	(m)S
10	3.62	7.03	20.96	29.69	12.83	9.08	10.44	2.87	3.48	10.65	83.00	6.35	0.6	gS
15	13.40	6.36	16.20	29.19	13.94	6.63	6.15	2.05	6.08	19.75	72.11	8.13	0.8	(m)gS
20	15.95	3.42	8.98	28.55	19.77	10.19	6.37	2.41	4.36	19.37	73.86	6.77	1.3	gS
25	4.42	2.92	8.22	32.13	25.75	12.91	7.34	2.45	3.87	7.34	86.35	6.32	1.3	(g)S
30	2.08	1.08	5.45	41.43	27.64	11.63	6.52	2.49	1.68	3.16	92.67	4.17	1.4	S
35	0.20	0.74	5.09	47.86	29.69	7.84	4.09	1.47	3.02	0.94	94.57	4.49	1.3	S
40	0.41	0.54	3.46	24.27	37.42	17.49	7.73	2.71	5.97	0.95	90.37	8.68	1.0	S
45	0.00	0.68	6.12	51.39	30.59	7.48	2.18	0.68	0.88	0.68	97.76	1.56	0.7	S
50	1.10	0.55	5.51	35.51	32.35	12.66	5.64	2.27	4.40	1.65	91.67	6.68	0.9	S
55	0.20	0.61	7.66	39.86	30.51	9.36	5.08	2.03	4.68	0.81	92.47	6.71	0.9	S
60	14.95	0.41	2.87	20.14	32.63	12.56	6.62	2.94	6.89	15.36	74.81	9.83	1.2	(m)gS
65	0.00	0.22	3.34	30.70	45.79	10.60	5.01	2.03	2.32	0.22	95.43	4.35	1.1	S
70	0.00	0.14	1.80	10.10	43.22	29.81	8.30	2.63	4.01	0.14	93.22	6.64	1.5	S
75	0.00	0.13	0.67	5.70	42.28	39.60	6.71	1.81	3.09	0.13	94.97	4.90	1.0	S
80	0.00	0.39	3.26	14.02	44.85	20.99	8.02	3.26	5.22	0.39	91.13	8.47	1.8	S
85	0.14	0.49	4.38	22.96	42.73	16.63	6.61	2.23	3.83	0.63	93.32	6.05	1.5	S
90	0.34	0.34	3.03	19.76	33.38	26.84	8.56	2.76	4.99	0.67	91.57	7.75	1.5	S
95	0.00	0.68	2.73	14.96	35.04	27.05	11.20	3.62	4.71	0.68	90.98	8.33	2.2	S
100	0.00	0.48	3.31	15.30	43.90	23.78	7.58	2.21	3.45	0.48	93.87	5.65	2.1	S

Well 299-E25-29

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
105	0.00	0.00	1.42	34.77	29.37	8.31	13.44	8.58	4.12	0.00	87.31	12.69	1.2	(m)S
110	0.20	0.67	3.55	41.38	39.17	10.26	2.82	0.67	1.27	0.87	97.18	1.95	1.2	S
115	2.16	5.26	5.74	13.09	39.41	25.78	5.06	1.35	2.16	7.42	89.07	3.51	1.7	(g)S
120	0.76	2.22	8.74	37.52	35.71	10.06	3.40	0.69	0.90	2.98	95.42	1.60	0.9	S
125	0.84	5.92	25.40	44.40	17.40	3.83	1.32	0.35	0.56	6.75	92.35	0.90	0.8	(g)S
130	0.07	0.54	1.36	3.80	13.59	14.67	28.74	16.92	20.31	0.61	62.16	37.23	1.2	mS
135	0.28	1.77	23.69	47.38	17.89	5.02	1.98	0.71	1.27	2.05	95.97	1.98	1.0	S
140	0.61	3.86	17.25	40.60	28.28	6.09	1.83	0.54	0.95	4.47	94.05	1.49	1.3	S
145	1.99	7.01	22.68	44.19	18.28	3.85	1.10	0.34	0.55	9.00	90.10	0.89	1.0	(g)S
150	0.00	1.00	16.70	39.52	27.72	11.09	2.70	0.50	0.78	1.00	97.73	1.28	1.2	S
155	0.54	1.48	10.48	44.33	26.60	8.60	4.03	1.41	2.55	2.01	94.02	3.96	1.2	S
160	1.68	10.61	37.74	35.86	8.39	2.69	1.28	0.54	1.21	12.29	85.96	1.75	1.1	gS
165	0.82	6.59	28.78	44.99	11.47	3.43	1.72	0.69	1.51	7.42	90.38	2.20	1.1	(g)S
170	3.30	7.85	29.11	39.23	14.11	3.30	1.51	0.55	1.03	11.15	87.27	1.58	1.1	gS
175	13.18	31.37	32.45	11.56	4.53	2.43	1.83	0.81	1.83	44.56	52.81	2.64	1.1	sG
180	44.90	17.69	23.63	9.99	2.30	0.68	0.34	0.14	0.34	62.59	36.93	0.47	1.0	sG
185	3.40	22.38	47.07	18.03	4.63	1.90	1.09	0.48	1.02	25.78	72.72	1.50	0.7	gS
190	1.22	5.56	30.53	40.50	14.52	4.41	1.56	0.54	1.15	6.78	91.52	1.70	0.9	(g)S
195	7.92	3.86	25.71	44.52	12.79	3.04	1.15	0.41	0.61	11.77	87.21	1.01	0.9	gS
200	18.90	9.18	21.11	23.86	14.08	6.43	3.02	1.07	2.35	28.08	68.50	3.42	1.1	gS
205	17.57	2.26	3.81	12.28	28.86	20.25	7.76	2.47	4.73	19.83	72.97	7.20	1.1	gS
210	14.32	16.00	16.21	14.88	10.81	8.28	6.39	3.51	9.61	30.32	56.56	13.12	0.6	msG
215	26.58	12.75	11.79	11.11	9.00	7.77	6.27	3.68	11.04	39.33	45.94	14.72	0.6	msG
220	18.34	19.82	13.40	10.08	8.80	7.37	6.63	3.92	11.64	38.16	46.28	15.56	0.5	msG
225	15.04	19.50	14.35	12.26	8.36	6.75	6.13	3.83	13.79	34.54	47.84	17.62	0.4	msG
230	22.53	24.91	18.43	11.60	5.94	4.44	3.69	2.18	6.28	47.44	44.10	8.46	0.3	msG
235	3.92	19.53	18.18	16.42	11.28	8.45	6.62	3.72	11.89	23.45	60.95	15.61	0.3	gmS
240	24.13	17.76	12.06	12.00	8.98	6.77	5.76	3.35	9.18	41.89	45.58	12.53	0.4	msG
245	42.36	14.01	9.54	7.07	5.34	4.67	4.67	3.14	9.21	56.37	31.29	12.34	0.4	msG
250	42.75	12.71	8.60	6.09	8.54	4.57	4.57	2.85	9.33	55.46	32.36	12.18	0.3	msG
255	31.90	14.77	12.48	10.40	7.35	5.96	5.20	3.26	8.67	46.67	41.40	11.93	0.4	msG
260	2.77	12.73	14.22	14.65	12.09	11.02	9.82	5.26	17.43	15.50	61.81	22.69	0.4	gmS
265	2.17	15.98	16.63	16.27	11.79	9.83	9.47	5.21	12.65	18.15	63.99	17.86	0.4	gmS
270	43.87	11.72	10.05	7.64	6.50	5.36	4.49	2.41	7.97	55.59	34.03	10.38	0.4	msG
275	24.39	19.67	17.94	10.30	6.71	6.38	4.58	3.06	6.98	44.05	45.91	10.03	0.3	msG
280	10.44	15.46	16.75	16.54	10.78	7.73	7.05	3.39	11.86	25.90	58.85	15.25	0.4	gmS
285	9.38	22.03	23.45	17.77	9.74	5.47	3.91	1.99	6.25	31.41	60.34	8.24	0.5	msG
290	26.55	24.10	17.41	11.81	5.87	4.03	3.21	1.91	5.12	50.65	42.32	7.03	0.5	msG
295	20.48	33.58	20.28	10.61	4.16	2.89	3.02	1.75	3.22	54.06	40.97	4.97	0.5	msG
300	10.78	38.33	23.87	10.85	4.47	3.22	2.70	1.51	4.27	49.11	45.10	5.79	0.4	msG
305	2.18	8.44	24.00	37.02	13.31	5.75	3.42	1.53	4.36	10.62	83.49	5.89	0.5	gS
310	22.82	21.25	17.03	15.05	8.86	5.04	3.54	1.77	4.63	44.07	49.52	6.40	0.5	msG
315	2.32	7.51	31.42	30.94	10.59	5.33	4.51	2.05	5.33	9.84	82.79	7.38	0.3	(g)S
320	2.65	17.23	26.26	21.23	12.35	7.26	4.88	2.04	6.11	19.88	71.98	8.14	0.3	(m)gS
325	0.00	0.00	0.67	13.29	56.34	17.14	5.13	1.96	5.47	0.00	92.58	7.42	0.3	S
330	4.50	15.04	24.65	22.83	16.86	6.04	3.43	1.68	4.97	19.54	73.81	6.65	0.3	gS

Well 299-E25-30

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	2.6	3.2	9.7	12.0	9.1	13.7	15.8	9.5	24.4	5.7	60.3	33.9	2.8	(g)mS
10	17.0	7.3	26.3	30.3	9.5	4.2	2.3	0.9	2.1	24.3	72.7	3.0	0.5	gS
15	2.8	4.2	19.5	31.7	14.8	11.7	7.3	3.4	4.6	7.0	85.0	8.0	0.6	(g)S
20	4.9	2.3	14.2	53.5	14.4	4.5	2.6	1.1	2.6	7.2	89.1	3.7	0.6	(g)S
25	1.9	1.3	5.9	40.7	30.7	10.8	3.7	1.5	3.5	3.1	91.9	5.0	0.1	S
30	0.0	0.9	0.4	1.0	13.9	44.7	26.3	6.4	6.6	0.9	86.1	13.0	1.1	(m)S
35	4.1	0.8	2.7	28.7	33.1	13.6	7.8	2.6	6.5	4.9	85.9	9.2	1.2	S
40	0.0	0.7	0.3	5.1	44.6	24.4	12.6	4.3	8.0	0.7	87.0	12.3	1.2	(m)S
45	0.5	2.6	5.2	26.1	29.0	15.3	9.3	3.8	8.3	3.1	84.9	12.0	1.5	(m)S
50	0.1	0.5	2.5	21.6	32.7	17.3	10.8	4.7	9.9	0.5	84.9	14.6	0.9	(m)S
55	3.1	3.2	7.7	26.6	22.4	13.2	9.2	4.1	10.5	6.4	79.0	14.6	1.7	(m)(g
60	0.1	0.8	3.7	27.3	30.6	27.3	0.1	0.2	9.9	0.9	89.0	10.1	1.5	(m)S
65	0.2	0.1	2.8	22.3	37.5	16.2	9.4	2.7	8.9	0.3	88.1	11.6	1.2	(m)S
70	0.9	1.3	3.4	22.8	32.0	28.8	0.3	0.6	9.8	2.2	87.4	10.4	0.8	(m)S
75	1.1	1.2	3.8	23.1	35.1	14.1	8.6	3.8	9.2	2.3	84.7	13.0	1.2	(m)S
80	5.5	4.0	5.7	13.0	25.4	32.8	0.2	0.6	12.9	9.5	77.1	13.5	0.8	(m)(g
85	0.0	0.3	2.3	13.4	43.4	25.0	7.7	2.7	5.3	0.3	91.8	8.0	2.1	S
90	0.0	0.1	0.8	16.4	57.6	20.8	0.1	0.4	3.7	0.1	95.8	4.1	0.7	S
95	9.5	0.4	2.9	12.3	30.0	22.7	9.8	3.8	8.5	10.0	77.7	12.3	0.8	(m)(g
100	3.7	2.0	5.2	14.0	33.5	31.9	0.1	0.6	8.8	5.7	84.8	9.5	1.0	(m)(g
105	0.5	1.8	3.2	12.9	18.8	50.8	0.0	0.0	12.1	2.2	85.6	12.1	2.4	(m)S
110	0.2	0.9	5.0	21.4	41.3	15.4	7.1	2.9	6.0	1.0	90.1	8.8	1.4	S
115	0.1	1.0	4.0	18.1	48.4	17.0	6.0	2.2	3.4	1.0	93.4	5.6	1.6	S
120	0.1	1.2	4.9	15.4	41.5	24.2	7.0	2.1	3.6	1.3	93.0	5.7	1.5	S
125	0.4	1.5	4.6	17.1	38.3	33.2	1.2	0.9	2.8	1.9	94.4	3.7	1.1	S
130	0.1	0.3	0.8	4.5	29.9	41.4	12.7	3.7	6.6	0.4	89.3	10.3	2.1	(m)S
135	0.3	2.1	25.2	36.9	15.3	7.5	4.8	2.3	5.6	2.4	89.7	7.9	0.8	S
140	1.1	1.7	6.3	30.1	35.4	11.6	5.7	2.4	5.6	2.8	89.2	8.0	0.7	S
145	0.0	1.8	16.6	46.1	18.7	7.1	3.9	1.6	4.2	1.8	92.4	5.8	1.6	S
150	0.0	0.6	3.6	14.6	40.0	33.4	1.7	0.3	5.9	0.6	93.3	6.1	2.1	S
155	0.3	1.7	6.7	20.5	33.1	33.4	0.2	0.2	4.0	2.0	93.8	4.2	1.5	S
160	0.1	1.7	9.8	35.1	33.1	16.5	0.2	0.1	3.3	1.9	94.7	3.5	0.9	S
165	25.1	19.3	14.2	16.0	10.7	5.3	3.2	1.7	4.4	44.4	49.5	6.1	1.2	msG
170	31.9	27.3	19.4	10.8	4.0	1.9	1.4	1.3	2.0	59.2	37.5	3.3	1.3	sG
175	3.8	8.9	9.7	19.5	21.1	25.3	10.1	0.1	1.5	12.7	85.7	1.6	0.9	gS
180	25.0	20.8	18.7	13.8	6.8	4.6	3.5	1.7	5.0	45.9	47.4	6.7	0.6	msG
185	15.7	19.2	14.2	13.5	10.1	7.3	6.1	3.9	10.0	34.9	51.2	13.9	0.5	msG
190	19.6	17.1	14.7	11.9	9.6	15.7	4.8	1.0	5.6	36.8	56.6	6.6	0.6	msG
195	24.8	22.2	14.8	9.4	7.9	12.0	0.8	0.1	8.0	47.0	44.9	8.1	0.6	msG
200	10.0	15.3	18.9	18.2	14.8	9.5	4.9	2.1	6.3	25.3	66.3	8.4	0.4	(m)gS
205	22.1	25.2	18.2	9.8	5.8	5.4	4.5	2.4	6.7	47.3	43.6	9.1	0.1	msG
210	13.0	14.6	14.8	13.7	12.2	18.7	11.6	0.1	1.3	27.6	71.0	1.4	0.2	gS
215	35.4	16.5	11.0	7.6	6.6	6.1	5.5	3.3	7.9	52.0	36.8	11.2	0.3	msG
220	20.7	15.9	12.5	9.3	8.8	18.4	0.3	0.0	14.1	36.6	49.3	14.1	0.3	msG
225	12.2	15.9	14.5	13.0	11.7	18.9	0.4	0.0	13.6	28.0	58.4	13.6	0.3	(m)gS
230	8.2	17.0	17.6	16.4	11.9	17.0	9.5	0.0	2.3	25.2	72.5	2.3	0.4	gS
235	24.0	14.2	9.4	8.9	9.3	9.6	8.4	4.5	11.6	38.2	45.7	16.1	0.1	msG
240	32.0	13.3	9.3	9.1	7.1	7.6	7.2	3.7	10.8	45.3	40.2	14.5	0.2	msG
245	20.0	18.8	12.0	9.6	9.6	17.3	0.1	0.1	12.4	38.8	48.7	12.5	0.2	msG
250	13.3	13.3	12.5	12.5	11.9	10.2	8.9	4.8	12.5	26.6	56.1	17.3	0.2	gmS
255	13.6	16.2	14.6	11.5	8.9	19.2	0.0	0.0	16.0	29.8	54.2	16.0	0.2	gmS

Well 299-E25-30

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
260	8.5	14.7	16.3	13.5	12.2	19.9	0.3	0.1	14.4	23.2	62.2	14.6	0.3	(m)gS
265	5.5	19.4	15.7	12.6	11.4	9.9	8.1	5.1	12.4	24.8	57.7	17.5	0.3	gmS
270	2.3	7.2	16.4	16.9	14.5	24.3	4.6	0.1	13.6	9.5	76.8	13.7	0.2	(m)(g
275	1.5	4.5	12.2	18.1	15.9	27.7	3.2	0.1	16.7	6.0	77.2	16.8	NA	(m)(g
280	2.6	2.5	11.4	34.8	18.7	19.2	0.4	0.0	10.4	5.1	84.4	10.4	0.6	(m)(g
285	1.8	4.1	14.0	43.8	16.8	6.5	4.6	2.4	6.1	5.9	85.7	8.5	0.7	(g)S
290	0.3	2.2	10.2	46.2	21.9	8.3	4.7	1.9	4.3	2.5	91.3	6.2	0.7	S
295	0.0	1.5	8.5	36.2	22.8	19.7	1.8	0.3	9.2	1.5	89.1	9.4	0.6	S
300	3.2	2.4	8.7	37.4	23.7	10.9	5.9	2.4	5.5	5.7	86.5	7.8	0.4	(g)S
305	0.0	0.2	1.4	13.3	44.2	24.6	8.0	2.6	5.7	0.2	91.5	8.3	0.4	S
310	0.3	0.7	9.6	38.3	27.7	11.1	4.8	2.2	5.3	1.0	91.5	7.5	0.3	S
315	48.5	28.5	9.4	5.2	1.8	1.5	1.4	1.0	2.7	77.0	19.3	3.7	0.6	msG
323	18.0	12.1	16.8	21.4	13.4	13.1	0.7	0.5	4.1	30.0	65.3	4.7	0.3	sG
330	3.2	17.9	27.5	22.2	11.2	6.9	4.2	1.9	5.1	21.1	72.0	6.9	0.3	gS

Well 299-E25-31

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.40	1.45	7.47	24.65	21.94	15.53	13.09	4.56	10.91	1.85	82.68	15.47	1.1	(m)S
10	3.76	11.50	34.36	35.25	5.75	2.67	2.19	1.37	3.15	15.26	80.22	4.52	0.3	gS
15	1.95	8.90	45.38	34.95	4.17	1.11	1.04	0.63	1.88	10.84	86.66	2.50	0.5	gS
20	5.88	4.11	31.02	40.01	9.35	4.75	2.12	0.99	1.77	9.99	87.25	2.76	1.0	(g)S
25	4.92	11.20	34.63	36.27	7.51	2.87	1.37	0.48	0.75	16.12	82.65	1.23	1.4	gS
30	2.99	5.98	26.13	40.61	18.39	3.45	1.30	0.38	0.77	8.97	89.89	1.15	1.5	(g)S
35	7.29	2.43	6.44	38.76	32.81	5.71	3.04	1.46	2.07	9.72	86.76	3.52	0.6	(g)S
40	0.77	1.44	9.62	23.08	29.62	18.08	8.37	3.08	5.96	2.21	88.75	9.04	0.7	S
45	2.76	4.00	21.22	35.20	23.79	6.66	2.85	1.05	2.47	6.76	89.72	3.52	1.0	(g)S
50	3.73	1.33	10.20	43.12	31.23	5.68	2.04	0.89	1.77	5.06	92.28	2.66	0.8	(g)S
55	8.89	1.19	8.21	39.71	30.91	5.50	2.37	0.93	2.29	10.08	86.71	3.22	0.8	gS
60	0.61	1.63	3.74	28.37	43.95	13.13	4.69	1.70	2.18	2.24	93.88	3.88	1.0	S
65	0.00	0.35	1.82	23.55	55.36	12.82	3.15	1.05	1.89	0.35	96.71	2.94	1.0	S
70	0.00	0.13	3.36	21.17	41.73	21.71	6.38	2.08	3.43	0.13	94.35	5.51	1.0	S
75	0.53	0.87	5.28	25.05	39.01	15.76	6.48	2.67	4.34	1.40	91.58	7.01	1.6	S
80	0.00	0.71	3.33	24.61	46.45	13.90	5.60	1.91	3.48	0.71	93.90	5.39	1.4	S
85	0.00	0.34	1.84	13.96	41.96	23.16	9.67	3.20	5.86	0.34	90.60	9.06	2.5	S
90	1.03	1.16	5.20	19.56	35.36	19.77	9.10	3.56	5.27	2.19	88.99	8.82	2.6	S
95	0.41	0.68	7.01	35.37	26.33	15.31	9.39	3.06	2.45	1.09	93.40	5.51	1.0	S
100	2.03	3.71	4.19	16.88	36.06	20.19	8.78	3.24	4.93	5.74	86.09	8.17	1.1	(g)S
105	0.60	1.34	9.40	34.65	40.23	9.20	2.35	0.74	1.48	1.95	95.84	2.22	0.7	S
110	3.05	3.96	5.34	20.82	43.72	14.02	4.37	1.53	3.19	7.01	88.27	4.72	1.1	(g)S
115	2.99	5.83	22.74	28.43	23.31	9.88	3.20	1.35	2.27	8.81	87.56	3.62	1.2	(g)S
120	10.21	31.83	38.93	12.86	2.85	0.99	1.26	0.27	0.80	42.04	56.90	1.06	0.7	sG
125	1.35	8.33	24.24	44.28	15.03	3.32	1.29	1.15	1.02	9.68	88.15	2.17	0.7	(g)S
130	5.87	13.29	25.38	25.87	16.43	6.50	3.50	1.33	1.82	19.16	77.69	3.15	0.8	gS
135	6.13	13.80	30.98	35.42	10.37	1.68	0.67	0.27	0.67	19.93	79.12	0.94	1.3	gS
140	0.34	18.82	62.56	12.94	2.67	1.16	0.55	0.27	0.68	19.16	79.88	0.96	0.9	gS
145	1.21	7.37	34.43	40.52	11.59	2.48	1.00	0.40	1.00	8.57	90.02	1.41	1.0	(g)S
150	0.61	5.75	32.21	36.33	17.93	4.87	1.42	0.34	0.54	6.36	92.76	0.88	1.0	(g)S

Well 299-E25-31

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
155	0.00	8.55	42.62	35.64	8.98	2.64	0.86	0.29	0.43	8.55	90.73	0.71	0.9	(g)S
160	1.01	7.76	36.09	44.21	8.27	1.58	0.50	0.22	0.36	8.77	90.65	0.58	1.1	(g)S
165	2.77	11.07	37.31	40.28	6.55	1.08	0.40	0.20	0.34	13.83	85.63	0.54	1.0	gS
170	0.14	2.79	28.82	54.38	10.20	1.63	1.16	0.27	0.61	2.92	96.19	0.88	1.2	S
175	0.00	1.02	44.84	48.64	4.21	0.68	0.20	0.14	0.27	1.02	98.57	0.41	0.6	S
180	32.12	61.87	1.49	0.34	0.68	0.88	0.74	0.47	1.42	93.98	4.12	1.89	1.0	G
185	5.01	27.75	54.05	11.68	0.89	0.21	0.14	0.07	0.21	32.76	66.96	0.27	0.9	sG
190	20.54	23.57	37.04	13.13	3.03	1.28	0.61	0.27	0.54	44.11	55.08	0.81	0.8	sG
195	11.67	17.67	40.67	23.01	4.55	1.19	0.59	0.26	0.40	29.33	70.01	0.66	0.8	gS
200	5.30	6.55	39.95	27.31	7.53	4.52	2.88	1.44	4.52	11.85	82.19	5.96	0.6	gS
205	29.57	42.67	18.95	3.97	2.15	1.08	0.67	0.34	0.60	72.24	26.81	0.94	0.4	sG
210	40.29	23.93	21.14	10.71	2.14	0.57	0.36	0.21	0.64	64.21	34.93	0.86	0.4	sG
215	40.33	22.97	13.36	12.19	5.67	2.03	1.11	0.49	1.85	63.30	34.36	2.34	0.4	sG
220	10.47	14.04	55.91	13.84	2.03	0.88	0.88	0.54	1.42	24.51	73.53	1.96	0.3	gS
225	0.54	0.81	44.53	39.81	6.07	3.10	2.70	1.08	1.35	1.35	96.22	2.43	0.4	S
230	63.25	20.30	7.30	3.79	2.06	1.03	0.69	0.41	1.17	83.55	14.87	1.58	0.3	G
235	52.31	17.01	18.55	9.63	1.22	0.32	0.26	0.19	0.51	69.32	29.97	0.71	0.2	sG
240	76.47	10.92	9.66	1.43	0.42	0.34	0.25	0.17	0.34	87.39	12.10	0.50	NA	G
245	89.49	8.50	1.07	0.27	0.13	0.13	0.13	0.07	0.20	97.99	1.74	0.27	NA	G
250	81.51	13.16	3.68	1.18	0.20	0.07	0.07	0.07	0.07	94.67	5.20	0.13	NA	G
255	83.69	10.71	4.15	1.11	0.21	0.07	0.00	0.00	0.07	94.40	5.53	0.07	NA	G
260	74.72	12.41	7.61	3.07	0.93	0.47	0.33	0.13	0.33	87.12	12.41	0.47	0.6	G
265	83.55	11.12	3.73	1.16	0.19	0.06	0.06	0.06	0.06	94.67	5.21	0.13	NA	G
270	53.14	12.58	13.58	16.86	3.27	0.31	0.06	0.06	0.13	65.72	34.09	0.19	0.6	sG
275	31.59	12.90	24.06	25.07	5.24	0.67	0.20	0.07	0.20	44.49	55.24	0.27	0.7	sG
280	25.39	34.48	0.94	14.41	19.39	3.77	0.88	0.13	0.61	59.87	39.39	0.74	0.9	sG
285	55.00	27.04	11.95	4.96	0.72	0.07	0.07	0.07	0.13	82.04	17.77	0.20	0.8	G
290	31.28	22.35	29.56	14.15	1.79	0.33	0.20	0.07	0.26	53.64	46.03	0.33	0.6	sG
295	37.21	14.21	26.39	17.59	3.04	0.81	0.41	0.14	0.20	51.42	48.24	0.34	0.7	sG
298	4.21	33.24	57.26	1.83	1.76	1.29	0.27	0.07	0.07	37.45	62.42	0.14	0.7	sG

Well 299-E25-32

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
5	0.1	0.1	0.4	1.5	11.4	76.5	0.1	0.2	9.7	0.2	89.9	9.9	3.6	S
10	2.2	10.3	28.2	30.6	7.4	7.9	7.1	2.7	3.6	12.5	81.1	6.3	1.4	gS
15	6.4	22.3	36.1	26.5	5.2	2.5	0.0	0.0	0.9	28.7	70.3	0.9	0.7	gS
20	2.7	4.3	23.5	44.3	14.3	3.2	3.3	1.9	2.4	7.1	88.7	4.3	0.7	(g)S
25	8.1	8.6	21.4	27.1	13.6	8.6	5.0	1.8	5.9	16.6	75.6	7.7	1.0	gS
30	2.8	1.3	4.3	43.6	37.4	5.9	2.7	0.9	1.2	4.1	93.8	2.1	1.1	S
35	0.1	0.8	5.3	30.1	44.0	16.7	0.2	0.1	2.7	0.9	96.3	2.8	1.1	S
40	0.3	1.7	6.1	34.6	36.8	10.9	4.6	1.0	4.1	2.0	92.9	5.1	1.1	S
45	0.0	0.3	1.4	6.9	18.7	36.4	25.5	5.0	5.7	0.3	88.9	10.7	1.1	(m)S
50	0.3	5.3	17.8	32.9	22.7	18.1	0.1	0.1	2.7	5.5	91.6	2.9	1.2	(g)S
55	0.1	1.1	11.4	44.6	21.9	10.9	4.9	1.7	3.4	1.2	93.7	5.1	1.2	S
60	0.0	0.0	0.3	11.3	50.1	33.7	0.2	0.2	4.2	0.0	95.6	4.4	1.7	S
65	0.2	0.6	7.3	49.5	36.7	3.5	0.8	0.7	0.7	0.8	97.8	1.4	0.9	S
70	0.0	0.1	1.1	22.2	58.6	16.6	0.0	0.1	1.3	0.1	98.5	1.4	0.5	S

Well 299-E25-32

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
75	0.0	1.0	6.0	41.3	39.8	7.6	2.3	0.7	1.3	1.0	97.0	2.0	0.7	S
80	0.2	1.1	3.8	28.0	40.8	21.6	0.1	0.1	4.1	1.3	94.4	4.3	1.0	S
85	0.0	0.1	3.6	27.8	44.9	18.4	0.1	0.1	5.0	0.1	94.8	5.0	1.1	S
90	0.0	0.1	1.8	16.3	58.6	17.2	3.3	0.9	1.7	0.1	97.3	2.6	1.3	S
95	0.0	0.0	0.5	0.8	7.5	79.5	0.3	0.2	11.2	0.0	88.6	11.4	0.9	(m)S
100	0.0	0.0	0.3	1.6	14.9	42.2	23.0	6.2	11.8	0.0	82.0	18.0	0.7	(m)S
105	0.0	0.1	0.7	4.8	24.9	59.7	0.1	0.1	9.6	0.1	90.2	9.8	1.8	S
110	2.1	11.0	26.7	21.7	12.4	9.2	6.7	2.8	7.4	13.1	76.7	10.2	0.9	(m)gS
115	1.7	8.7	34.5	33.0	11.4	8.5	0.0	0.1	2.1	10.5	87.4	2.1	0.2	gS
120	1.3	7.4	26.4	32.9	20.4	6.2	2.6	0.9	1.8	8.7	88.6	2.7	0.8	(g)S
125	0.3	3.9	30.1	36.0	13.1	7.0	4.7	2.1	3.0	4.2	90.8	5.0	1.1	S
130	0.5	3.5	21.1	45.2	19.0	9.1	0.2	0.1	1.3	4.0	94.6	1.3	1.3	S
135	0.0	2.3	21.4	55.4	12.7	3.4	2.1	0.9	1.7	2.3	95.0	2.7	1.1	S
140	0.3	2.1	6.7	28.3	41.3	17.6	0.3	0.3	3.1	2.3	94.3	3.3	1.2	S
145	0.7	2.2	13.6	28.3	30.6	13.2	4.1	1.3	6.1	2.9	89.7	7.4	2.2	S
150	0.3	0.1	2.8	27.8	46.3	20.1	0.1	0.1	2.3	0.4	97.2	2.5	1.3	S
155	1.9	2.7	10.3	31.9	22.0	11.6	8.1	3.4	8.0	4.6	84.0	11.4	1.1	(m)S
160	13.4	15.3	17.9	18.7	11.8	17.9	1.1	0.4	3.5	28.7	67.4	3.9	0.8	gS
165	15.7	21.6	22.3	19.6	9.1	4.3	2.5	1.1	3.9	37.3	57.8	5.0	1.0	sG
170	15.8	23.5	27.1	15.2	6.3	7.9	1.0	0.3	2.9	39.4	57.4	3.2	1.0	sG
175	17.4	27.6	27.1	14.3	5.0	3.0	2.1	0.9	2.5	45.0	51.5	3.5	0.9	sG
180	22.3	22.1	25.2	12.8	5.0	7.0	1.3	0.8	3.5	44.4	51.3	4.3	0.5	sG
185	28.9	13.0	11.1	9.7	7.8	7.0	6.3	3.7	12.5	42.0	41.8	16.2	0.4	msG
190	23.0	20.4	16.6	10.4	7.9	12.4	4.3	1.0	3.9	43.4	51.6	4.9	0.5	sG
195	16.2	15.2	12.4	10.3	9.2	8.6	7.9	4.5	15.6	31.4	48.4	20.2	0.3	msG
200	10.5	11.1	12.4	11.7	11.1	23.1	19.2	0.5	0.4	21.6	77.5	0.9	0.2	gS
205	20.0	16.8	13.0	8.1	8.6	6.9	7.2	5.6	13.7	36.8	43.8	19.3	0.2	msG
210	14.4	15.8	18.1	18.8	12.0	9.1	6.0	2.1	3.6	30.2	64.1	5.7	0.2	sG
215	13.2	20.2	13.1	12.0	10.9	18.5	11.1	0.1	0.9	33.4	65.7	0.9	0.1	sG
220	15.1	15.5	12.5	12.1	11.3	9.0	7.7	4.4	12.4	30.6	52.6	16.8	0.2	msG
225	10.2	20.3	13.5	12.5	11.3	18.3	10.1	0.3	3.5	30.5	65.7	3.9	0.2	sG
230	7.9	17.0	13.4	12.2	11.3	9.8	8.8	5.7	14.0	24.9	55.5	19.6	0.1	gmS
235	18.2	15.4	12.3	11.3	11.9	15.4	11.1	1.3	3.1	33.6	62.1	4.3	0.2	sG
240	29.1	19.2	11.1	9.2	7.8	6.4	5.8	3.3	8.0	48.3	40.4	11.3	0.2	msG
245	15.1	14.7	12.3	11.7	16.9	10.9	7.0	3.5	7.9	29.9	58.7	11.4	0.6	(m)gS
250	14.7	13.7	8.6	7.9	21.2	23.1	6.6	0.3	3.9	28.4	67.5	4.1	0.8	gS
255	18.5	19.9	10.6	9.7	17.2	10.3	5.6	2.6	5.5	38.4	53.5	8.1	0.9	msG
260	34.6	20.0	10.6	7.2	10.3	11.7	1.9	0.4	3.4	54.6	41.7	3.8	0.9	sG
265	21.2	19.3	17.9	13.6	9.0	6.1	4.5	2.3	6.1	40.5	51.2	8.4	0.3	msG
270	4.3	7.6	7.6	12.9	29.8	30.3	1.8	0.5	5.2	11.9	82.4	5.7	0.3	gS
275	12.1	15.6	14.7	18.1	15.0	8.6	5.9	2.9	7.0	27.7	62.4	9.9	0.4	(m)gS
280	11.9	30.3	27.0	12.7	5.4	8.1	0.9	0.6	3.1	42.2	54.2	3.7	0.4	sG
285	0.2	3.3	9.9	23.6	27.8	29.5	1.8	0.3	3.7	3.5	92.6	4.0	0.2	S
290	0.1	2.1	10.1	23.8	33.6	18.1	6.8	1.9	3.5	2.1	92.4	5.4	0.4	S
295	14.7	22.8	29.9	20.2	7.4	4.2	0.1	0.1	0.7	37.5	61.7	0.7	0.5	sG
300	10.5	17.5	23.9	22.3	13.1	5.6	2.9	1.1	3.0	28.0	67.8	4.1	0.4	gS
305	1.4	10.1	31.0	34.7	20.4	2.4	0.1	0.1	0.0	11.5	88.5	0.1	0.2	gS
310	6.4	25.5	29.6	26.3	9.5	0.7	0.1	0.6	1.3	31.9	66.2	1.9	0.2	sG
315	4.2	28.5	31.9	16.1	8.2	8.8	0.5	0.1	1.7	32.7	65.5	1.8	0.2	sG
320	3.0	13.5	16.9	17.8	17.0	13.2	8.0	3.1	7.5	16.5	72.9	10.6	0.3	(m)gS
325	0.9	6.4	12.8	17.2	18.7	31.3	6.1	0.1	6.5	7.3	86.1	6.7	0.2	(g)S

Well 299-E25-32

Depth	%fp	%vfp	%vcs	%cs	%ms	%fs	%vfs	%silt	%<silt	gravel	sand	mud	CaCO3	Class
330	6.2	18.1	19.0	14.7	14.6	10.3	6.8	3.3	6.9	24.3	65.5	10.2	0.3	(m)gS
335	8.2	16.7	12.2	11.5	15.5	24.3	2.8	0.1	8.6	24.9	66.3	8.7	0.3	(m)gS
340	3.6	15.0	20.0	16.3	16.0	10.9	7.1	3.2	7.9	18.5	70.4	11.1	0.4	(m)gS
345	1.7	4.9	11.6	15.6	18.2	31.6	11.6	0.6	4.2	6.6	88.6	4.8	0.2	(g)S
350	0.8	4.3	11.0	18.6	18.4	15.2	12.2	5.8	13.7	5.1	75.3	19.5	0.2	(g)mS
354	3.1	8.6	18.6	20.9	19.4	23.2	1.7	0.6	3.9	11.7	83.8	4.5	0.6	gS

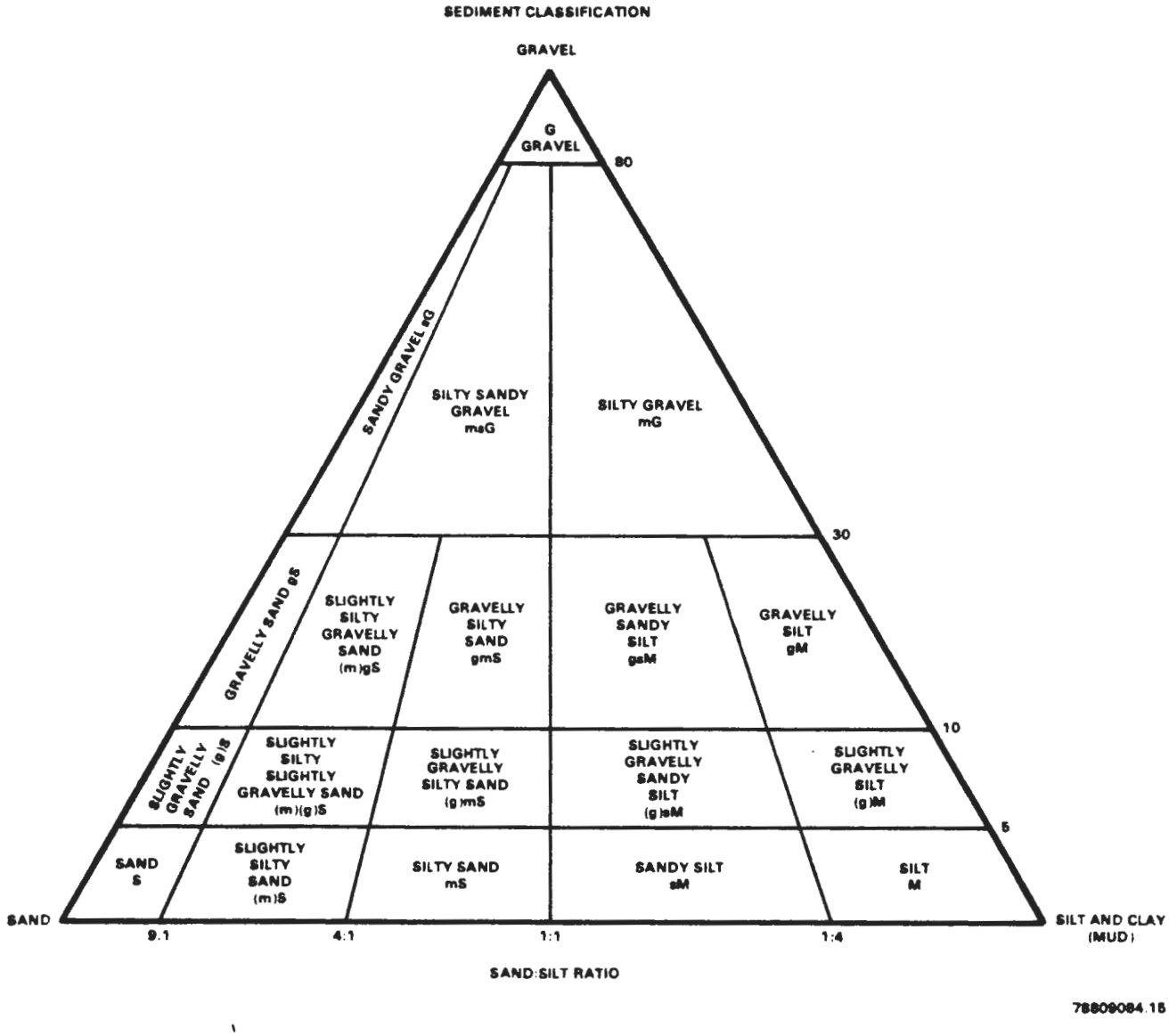


Figure 5A1-1. Sediment Classification Scheme (Tallman et al. 1979).

Sieve Analysis (Granulometric Analysis) Procedure

PURPOSE

This section describes the steps to be taken to measure the particle sizes of an uncontaminated sediment.

APPLICABLE STANDARDS

ASTM D422-63, Procedure 5 (ASTM 1972); ASTM C702 (ASTM 1987)

REQUIREMENTS

Equipment Required

1. Sieves, 8-in. dia.

Sieve mesh number	Sediment analysis form designation	Retained particles size (mm)
5	fp (fine pebbles)	>4.0
10	vfp (very fine pebbles)	2.0
18	vcs (very coarse sand)	1.0
35	cs (coarse sand)	0.5
60	ms (medium sand)	0.25
120	fs (fine sand)	0.25
230	vfs (very fine sand)	0.063
325	silt	0.043
PAN	silt and clay	<0.043

2. Balance. Sensitive to a minimum of 0.1 g.

3. Ro-Tap* shaker (ASTM D422-63, Procedure 5)(ASTM 1972). Equipped with a 15-min timer.

4. Drying oven.

5. Sample splitter (ASTM C702).

6. Brushes: wire for 60 mesh and coarser; nylon for finer than 60 mesh.

7. Drying trays, aluminum.

8. Leather mallet, larger rubber stopper, or wooden rolling pin.

*Ro-Tap is a trademark of W.S. Tyler, Incorporated.

Preparation of Sample--Transfer samples from original container to open trays labeled with well number and depth. Dry samples in an oven at 50 °C ± 20 °C until dry. Note the oven identification number on the sediment analysis form.

Method

1. Pour all of the dried sample through sample splitter and continue splitting until approximately 150 g remain. Return remaining sample to original container. Place particles that are too large to pass through splitter in the pan into which they would have fallen. Disaggregate dried samples using a leather mallet, by placing the sample in a size 18 mesh sieve and applying moderate pressure with a large rubber stopper, or by spreading the sample out on a piece of paper and using a wooden rolling pin to disaggregate the sediments. To ensure the most accurate results possible, as much of the aggregates should be broken up as is reasonably possible.

2. Weigh the sample to the nearest 0.1 g and record on the Sediment Analysis Form (Fig. 5A1-2). For reproducibility, all final entries are to be recorded in black ink.

3. Place weighed sample at the top of the clean sieve nest arranged with the coarsest sieve on top and decreasing to the smallest size and pan at the bottom.

4. Place sieve nest in Ro-Tap and shake for 15 min. Record the Ro-Tap and sieve identification numbers on the Sediment Analysis Form.

5. Starting at the top, check each sieve for aggregates. If aggregates are present, grind them with the rubber stopper, return them to the same sieve, and reshake for 15 min. Grind long enough only to disaggregate.

6. Weigh the contents of each sieve to the nearest 0.1 g.

7. Record weight onto the Sediment Analysis Form.

8. If calcium carbonate content is to be analyzed, transfer that portion of the sample that passed through the size 18 sieve to a separate labeled container and save. Return that portion of sample retained on the size 18 and coarser sieves to the original container. After calcium carbonate analysis has been performed, return any remaining sample to the original sample container.

9. If total weight after sieving is not within 2 percent of the starting weight, rerun the sample.

Quality Assurance--To provide quality assurance, the following steps should be observed.

1. The scale should be calibrated at least yearly to ensure accuracy.

SEDIMENT ANALYSIS

Analysis Performed by:	Date	
Reviewed and Approved by	Title	Date

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

		WELL #	FT	%CaCO3	DM	SPLIT	FP	VFP	VCS
1,0,5,0,1	MD								
				CS		MS	FS	VFS	
1,0,5,0,2	MD								
				SILT		PAN	TOTAL	•	COMMENTS
1,0,5,0,3	MD								

EQUIPMENT IDENTIFICATION

Balance _____

Oven _____

Ro-Tap _____

Sieve Set

Mesh No.	QA No.
5	
10	
18	
35	
60	
120	
230	
325	

A-6000-022 (R-5-83)

Figure 5A1-2. Sediment Analysis Form.

2. At the completion of every eight sample analyses, select one sample at random and rerun. These rerun samples are recorded on the Sediment Analysis Forms and are noted as reruns.

3. Submit a blind audit sample for at least every 100 samples. This is to be a sample already run but under new identification. Identification and results of blind samples should be recorded on the Sediment Analysis Forms.

4. Analyze a sediment standard at least every 300 samples to check for sieve wear. Results of this test are to be recorded on the Sediment Analysis Forms.

5. Clean sieves at the end of each sieving day and check for visible signs of sieve wear. Worn or damaged sieves are to be replaced.

REFERENCES

ASTM, 1972, *Standard Method for Particle Size Analysis*, ASTM D422, American Society for Testing and Materials, Philadelphia, Pennsylvania.

ASTM, 1987, *Standard Practice for Reducing Field Samples of Aggregate to Testing Size*, ASTM C702, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Calcium Carbonate Analysis Procedure

PURPOSE

The purpose of this section is to describe how to analyze for calcium carbonate in uncontaminated sediments.

APPLICABLE STANDARDS

Horowitz, W., ed., 1970, *Official Methods of Analysis of the Association of Official Analytical Chemists*, Association of Official Analytical Chemists, Washington, D.C., p. 139.

REQUIREMENTS

The Analytical Laboratories Department is responsible for acquiring and maintaining the following reagents and equipment.

Reagents

1. Hydrochloric Acid. 4M - Add 340 mL of concentrated reagent grade HCl to about 500 mL of deionized water. Dilute to 1 L and mix thoroughly.

2. Calibration Standard. Dry a quantity of reagent (or primary standard-grade sodium carbonate) for 2 h at 120 °C to 125 °C. Weigh out 31.80 ± 0.01 g of reagent, dissolve it in deionized water, and dilute it to 1 L. Store in a polyethylene bottle. This solution should be protected from evaporation and contamination and replaced each month. One mL is equivalent to 30 mg of $CaCO_3$.

3. Quality Assurance Standard. Use reagent grade calcium carbonate with a minimum assay of 99 percent. Dry overnight in an oven at a minimum temperature of 120 °C and store in a desiccator.

4. Displacement Solution. Dissolve 100 g of sodium sulfate decahydrate (Na_2SO_4, 10 H_2) in 500 mL of deionized water. Add about 1 g of sodium bicarbonate, $NaHCO_3$ and 2 mL of a 0.5 percent methyl orange solution. Add HCl (4 to 5 M) to make slightly acid (a definite pink color). Stir until CO_2 bubbles are no longer visible. This solution will be saturated with CO_2 and will not have a tendency to absorb CO_2 from the sample.

Equipment

1. Balance. Single pan, sensitive to a minimum of 0.01 g or less.

2. Gasometer. Shop made, consisting of gas tube, graduated gas buret, compensating tube, and leveling bulk (Figure 5A1-3).

3. Flasks. Pyrex*, 150 mL with 34/28 standard taper neck fitted with special acid buret (Figure 5A1-3).

4. Magnetic stirrer and stir bars.

5. Buret. (For dispensing calibration standard) 25 or 50 mL, graduated in 0.01-mL increments, fitted with a loose cap to exclude dust. This buret must be kept clean. If it does not drain smoothly (drops retained on walls), it should be cleaned with a warm solution of detergent or trisodium phosphate (5 g/L) and rinsed thoroughly.

Method

1. Weigh out approximately 5 g ± 0.01 g of sample, and transfer to a reaction flask. Add a stir bar to the flask. (For quality assurance standard, use 0.10 to 0.15 g weighed to 0.0001 g).

2. Fit the acid buret to the top of the flask and place flask on magnetic stirrer.

3. Close top of acid buret with a rubber stopper.

4. Turn three-way stopcock to vent gas tube and compensating tube to the air.

5. Adjust height of leveling bulb until liquid-level line if gas buret is at 0.

6. Turn three-way stopcock to connect gas tube to gas buret with outside vent tube closed.

7. Set timer for 3 min and open stopcock on acid buret. Turn on magnetic stirrer.

8. When the timer alarms, lower the leveling bulb until the liquid levels in the compensating tube and gas buret are the same. Record the volume reading on the gas buret. (Adjusting the levels in this way ensures that the gas in the buret is at atmospheric pressure.)

9. Rerun the sample (1) if a leak is suspected in the apparatus or (2) if the volume of gas measured is greater than the greatest gas volume used in the calibration. In such cases, rerun using a smaller sample.

10. Percent of calcium carbonate is determined using the method of Horowitz (1970).

---

*Pyrex is a trademark of Corning Glass Works.

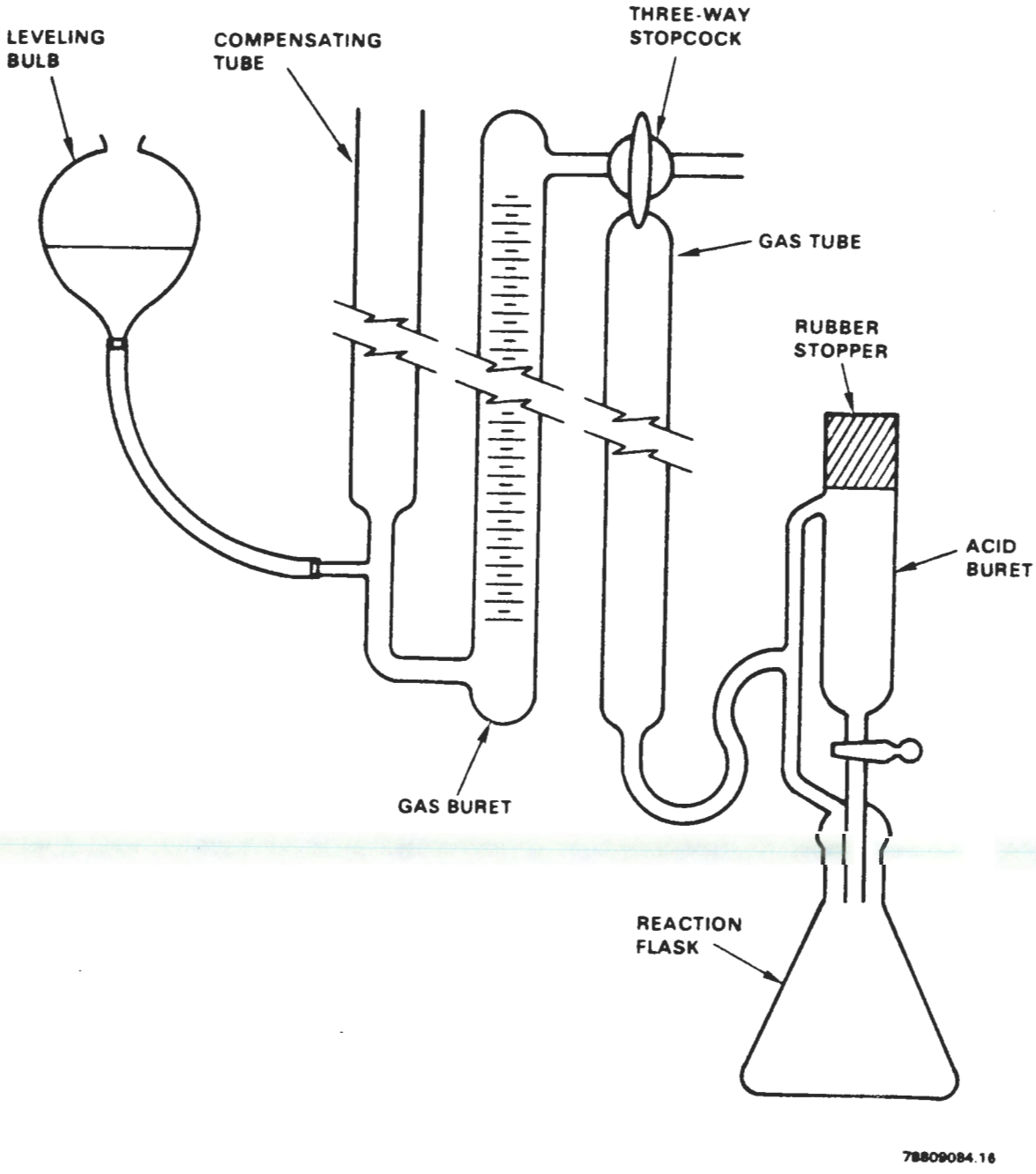


Figure 5A1-3. Gasometer Setup.

11. Return the unused portion of sample to original container in the Hanford Geotechnical Sample Facility.

12. Results of the analysis are to be forwarded to the cognizant scientist, who transfers the information onto the Sediment Analysis Form (Fig. 5A1-2, columns 18-21).

Quality Assurance--As quality assurance checks, the following should be performed.

1. Run calcium carbonate standard every 4 h. If the recovery is outside of 100 percent by ± 15 percent, run a new calibration curve. Rerun the calcium carbonate standard to verify the new calibration curve. Maintain records of the calibration curves and checks.

2. At the completion of every 10 sample analyses, select one of the samples at random and run. These data shall be included with the other results and marked as a rerun.

This page intentionally left blank.

9 0 1 1 7 8 6 1 4 3 8

APPENDIX 5A-2

CHEMICAL ANALYSES OF SEDIMENT SAMPLES

This page intentionally left blank.

APPENDIX 5A-2

CHEMICAL ANALYSIS OF SEDIMENT SAMPLES

Sediment chemical analyses from samples collected at or near the GTF are presented in Table 5A2-1. These analyses were performed by U.S. Testing Company, Richland, Washington. Their procedures are described in this appendix with the minimum detectable concentrations listed. Samples for analysis were collected from nine wells at various depths below ground surface. The well numbers, prefixed by 299-E25, include: 25 through 27 and 222 through 227 (the latter numbers are boreholes not completed as wells and generally drilled to a depth of not more than 50 ft). A total of 47 depth-discrete samples were analyzed for various chemical parameters.

UNITED STATES TESTING COMPANY, INC.
CHEMICAL ANALYSIS PROCEDURE SUMMARIES

DETERMINATION OF SPECIFIC CONDUCTIVITY

Conductivity is a measure of the salt content in the soil solution. Soil is saturated with H_2O until the surface glistens and the soil slowly runs from a beaker when turned sideways. After the mixture sits for 1 h, it is checked again to see if more water or soil is needed to meet the physical requirement for the conductivity analysis. Let stand four more hours, then suction off the liquid. Measure the conductance with a conductivity meter. Save the liquid for subsequent analyses. The minimum detectable conductance is 0.1 mmho/cm.

DETERMINATION OF ALKALINITY

A known volume of filtrate from the conductivity analysis is titrated with weak H_2SO_4, first with phenolphthalein as an indicator, then with methyl orange to its first endpoint to get $CO_3^{=}$ and HCO_3^-. The OH^- concentration is calculated from the relationship of OH^-, $CO_3^{=}$, and HCO_3^- ions to one another in the soil solution.

DETERMINATION OF SODIUM ABSORPTION RATIO

The sodium absorption ratio is calculated from the sodium, calcium, and magnesium content (determined by atomic absorption) of the solution. Sodium, calcium, and magnesium represent concentrations in milliequivalents per liter.

$$\text{Sodium absorption ratio} = \frac{Na}{\sqrt{(Ca + Mg)/2 \text{ in units of meq/L}}}.$$

A standard curve for sodium, magnesium, and calcium also is prepared.

DETERMINATION OF SOLUBLE SODIUM, CALCIUM, MAGNESIUM, AND POTASSIUM

Sodium, calcium, magnesium, and potassium concentrations are analyzed by atomic absorption on the supernatant from the conductivity determination. A standard curve is prepared for each element. The minimum detectable concentrations are 2, 2, 0.5, and 1 p/m for sodium, calcium, magnesium, and potassium, respectively.

DETERMINATION OF CATION EXCHANGE CAPACITY

Exchangeable cations are removed from the soils exchange complex by shaking with a readily exchangeable cation such as sodium. The excess (noncomplexed) sodium is removed by washing with ethyl alcohol. The

remaining sodium on the exchange complex is removed with the ammonium ion by shaking the soil with an ammonium acetate solution. The sodium is determined by atomic absorption. A standard curve also is run. The minimum detectable cation exchange capacity is 0.5 meq/100 g.

DETERMINATION OF EXCHANGEABLE CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM

Calcium, magnesium, potassium, and sodium are removed from the exchange complex by shaking with an ammonium acetate solution. The ammonium ion replaces calcium, magnesium, potassium, and sodium in the soil exchange complex , which then are measured by atomic absorption. A standard curve is prepared for each element. The minimum detectable concentrations are 2, 0.5, 1, and 2 p/m for calcium, magnesium, potassium, and sodium, respectively.

DETERMINATION OF CHLORIDE

Chloride is extracted by adding deionized H_2O to soil in a 1:1 (v:w) ratio and shaking for 1/2 h. The mixture is filtered, and chloride is determined in the filtrate using a specific ion electrode. A standard curve is run with the samples. The minimum detectable concentration is 1 p/m.

DETERMINATION OF FLUORIDE

Fluoride is analyzed on a 1:1 soil to water (w:v) ratio extract after shaking and filtering the sample. Fluoride is determined using a specific ion electrode. A standard curve also is run. The minimum detectable concentration is 0.1 p/m.

DETERMINATION OF ORGANIC MATTER

The oxidizable material in soil is oxidized by adding a known concentration of $CrO_7^{=}$ plus sulfuric acid. The excess $CrO_7^{=}$ is titrated with $FeSO_4$, and the organic matter is calculated. There are also distinct color changes that occur as the organic matter content increases. These color changes can be determined using a colorimeter. A standard curve is prepared from soil with known amounts of organic matter. The minimum detectable concentration is 0.5 percent.

DETERMINATION OF PHOSPHATE

For soils above 6.5 to 7.0 pH, phosphorous is extracted by shaking soil and sodium bicarbonate (0.5M at pH 0.5) together in a 1:20 ratio for 1/2 h and then filtering in the presence of carbon black. Phosphorous is determined on the filtrate by the intensity of the blue color that develops after the addition of ammonium molybdate and stannous chloride. A standard curve also is prepared. The minimum detectable concentration of phosphate is 0.5 p/m.

DETERMINATION OF SULFATE

Sulfate sulfur is determined on a soil solution after shaking equal parts of water and soil for 1/2 h. A seed solution containing a small amount of sulfate sulfur is added to the soil solution. Gum acacia is added to keep $BaSO_4$ in suspension, and then sized $BaCl_2$ crystals are added, causing $BaSO_4$ to form. The resulting turbidity is read in a colorimeter or turbidimeter. A standard curve is prepared with the samples. The minimum detectable concentration is 2 p/m.

DETERMINATION OF NITRATE

Nitrates are soluble in deionized H_2O and are extracted from soil by shaking soil and water in a 1:2.5 (w:v) ratio for 1/2 h. A small amount of silver sulfate is added to precipitate chloride, which interferes in the phenyldisulfonic acid method for nitrates. A small amount of copper sulfate is added to help flocculate the soil and aid filtering. After filtering, the filtrate is taken to dryness on a hot water bath, and the resulting residue is dissolved in phenyldisulfonic acid. First, water is added, then ammonium hydroxide until the yellow color of 6-nitrophenol-2:4-disulphonic acid is formed, then an excess of ammonium hydroxide is added. The intensity of the color is measured in a colorimeter. A standard curve is prepared with the samples. The minimum detectable concentration is 1 p/m nitrate.

DETERMINATION OF MOLYBDENUM

Molybdenum is extracted from soil with Tamm's reagent (a mixture of ammonium oxalate and oxalic acid). A 1:5 (w:v) ratio of soil to extracting solution is shaken overnight. The mixture is filtered or centrifuged and the filtrate is extracted with hexone. Molybdenum in the hexone fraction is measured by atomic absorption. A standard curve is prepared with the samples. The minimum detectable concentration is 0.2 p/m.

DETERMINATION OF ZINC, COPPER, IRON, MANGANESE, CADMIUM, COBALT, AND LEAD

Trace metals in soil can be extracted by 0.1N HCl or by diphenyl tetraacetic acid (DPTA). This is a measure of the readily available metals in the soil solution. Soil is shaken with either DPTA in a 1:2 soil to DPTA ratio (w:v) or a 1:10 ratio for soil to 0.1N HCl. The extractant is filtered, and the filtrate is analyzed by atomic absorption for the various metals. A standard curve is prepared for each metal.

Minimum detectable concentrations

Metals	p/m	Metals	p/m
Zinc	0.2	Copper	0.2
Iron	2	Manganese	1
Cadmium	0.2	Cobalt	0.5
Lead	1		

DETERMINATION OF pH

A 1:1 soil to deionized water (w:v) mixture is prepared, mixed, and allowed to stand for 1/2 h. The pH of the solution is measured with a pH meter. The minimum detectable pH is 0.2 pH units.

DETERMINATION OF ARSENIC AND SELENIUM

Arsenic and selenium are extracted from the soil with 30 percent nitric acid by heating at 70 °C for 1 h. Sodium borohydride is added to sample solution to reduce arsenic and/or selenium to volatile hydrides. The hydrides are carried with the hydrogen gas into a quartz absorbance cell, where the concentration of arsenic and/or selenium is measured. The minimum detectable concentration for arsenic and selenium is 0.003 p/m.

DETERMINATION OF MERCURY

Mercury in soil is converted to the ionic form by digesting with acid (aqua regia or a mixture of sulfuric and nitric acid) at 90 °C for 1 h. By adding potassium permanganate to the sample until a permanent purple color is reached, organic mercury also is converted to the ionic form. Mercury is vaporized by the addition of stannous chloride or sodium borohydride depending on the analysis system. The vapor is carried through a cold adsorption cell connected to an atomic absorption instrument. The minimum detectable concentration is 0.001 p/m.

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 1 of 10)

		Well 299-E25-25					
		Depth (ft)					
Parameter	Units	100	105	110	115	120	125
Alkalinity	p/m as $CaCO_3$	144	144	130	137	137	144
pH		8.13	8.33	8.29	8.34	8.22	8.25
Conductivity	mmho/cm	0.6	0.85	0.65	0.6	0.51	0.7
Sodium absorption ratio		5	4.25	4.35	4.53	4.15	4.05
Soluble Na	p/m	59.1	79.6	58.9	58	63.7	67.1
Soluble Ca	p/m	4	12.3	6.5	5.5	8.3	9.6
Soluble Mg	p/m	4	8.7	4.5	4.2	5.8	6.8
Soluble K	p/m	9.4	11.9	9.9	10.1	9.9	9.8
Cation exchange capacity	Meq/100 g	29.6	19.2	21.5	28	29.8	28.6
Exchange Na	p/m	168	122	130	144	174	172
Exchange Ca*	Meq/100 g	23.5	18.3	25.5	25.1	27.3	30.6
Exchange K	p/m	358	304	314	346	380	358
Exchange Mg*	Meq/100 g	3.95	3.21	3.71	3.72	4.72	4.76
Cl	p/ m	19.5	7.08	10.2	6.26	5.87	5.57
F	p/m	0.62	0.62	0.71	0.87	0.71	0.78
Organic matter	%	0.1	0.07	0.086	0.086	0.114	0.114
PO3P	p/m	3.65	2.58	2.85	2.85	2.85	3.65
SO3S	p/m	11.8	11	9.58	11	15.1	16
NO3N	p/m	2.16	2.23	1.31	1.51	2.46	1.58
Mo	p/m	0.14	0.12	0.13	0.1	0.19	0.2
Zn DPTA**	p/m	0.48	0.32	0.4	0.36	0.8	0.54
Cu DPTA	p/m	0.53	0.34	0.5	0.72	0.72	0.62
Fe DPTA	p/m	18.4	19.4	19.2	20.2	14.6	14
Mn DPTA	p/m	2.8	2.6	4	2.8	2.8	2.6
Cd DPTA	p/m	0.08	0.04	0.04	0.04	0.06	0.06
Co DPTA	p/m	0.25	0.16	0.25	0.25	0.25	0.25
Pb DPTA	p/m	0.62	0.38	0.62	0.62	0.76	0.76
As	p/m	2.08	1.97	1.86	1.82	1.63	1.86
Hg	p/m	<.006	<.006	<.006	0.006	0.006	0.006
Se	p/m	0.175	0.196	0.192	0.146	0.179	0.175
Zn 0.1N HCl	p/m	3.3	2.8	2.7	2.8	3.2	3
Cu 0.1N HCl	p/m	2.1	2.1	2.1	1.8	2.1	2.4
Fe 0.1N HCl	p/m	275	290	287	230	204	138
Mn 0.1N HCl	p/m	62	50	72	52	64	62
Cd 0.1N HCl	p/m	0.2	0.3	0.3	0.2	0.2	0.3
Co 0.1N HCl	p/m	2.5	1.9	1.9	1.9	1.9	2.5
Pb 0.1N HCl	p/m	3.1	2.5	3.8	3.8	3.8	5

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 2 of 10)

		Well 299-E25-26						
		Depth (ft)						
Parameter	Units	35	55	60	65	70	75	130
Alkalinity	p/m as $CaCO_3$	144	130	130	151	158	101	115
pH		8.56	8.46	8.47	8.4	8.31	8.43	8.48
Conductivity	mmho/cm	0.35	0.3	0.25	0.5	0.4	0.25	0.25
Sodium absorption ratio		3.14	3.22	1.89	2.57	2.35	1.5	4.25
Soluble Na	p/m	23	22.8	14.9	23	24.8	12.5	23.5
Soluble Ca	p/m	1.5	1.6	2.6	3.5	1.9	0.5	
Soluble Mg	p/m	15	1.4	1.9	2.1	3	2	1.1
Soluble K	p/m	6.5	6.1	6.2	7	8.6	6	6.4
Cation exchange capacity	Meq/100 g	11	11.6	9.9	18.6	18.8	6.3	4.8
Exchange Na	p/m	50	62	36	64	72	22	28
Exchange Ca*	Meq/100 g	12.6	17.8	15.2	25.6	29.4	11.5	8.3
Exchange K	p/m	202	230	182	256	304	106	92
Exchange Mg*	Meq/100 g	1.9	2.38	2.15	3.28	4.17	1.15	1.12
Cl	p/m	1.62	2.07	2.11	0.9	2.7	0.2	<0.1
F	p/m	0.41	0.43	0.52	0.42	0.5	0.42	0.54
Organic matter	%	0.057	0.1	0.086	0.086	0.1	0.086	0.1
PO3P	p/m	2.58	3.65	2.58	3.12	3.65	3.12	2.06
SO3S	p/m	4.58	3.48	2.43	2.95	4.02	2.43	2.69
NO3N	p/m	0.506	0.571	0.442	0.506	1.73	0.442	0.377
Mo	p/m	0.09	0.19	0.12	0.19	0.21	0.16	0.14
Zn DPTA**	p/m	0.3	0.5	0.38	0.58	2.7	0.56	1.3
Cu DPTA	p/m	0.34	0.5	0.44	0.44	0.78	0.28	0.28
Fe DPTA	p/m	14.6	14.2	13.8	15.2	14.4	8.4	7
Mn DPTA	p/m	1.7	2.4	2.6	3	2.6	2.6	2.8
Cd DPTA	p/m	0.06	0.04	0.04	0.04	0.06	0.04	0.04
Co DPTA	p/m	0.16	0.25	0.16	0.25	0.25	0.16	0.16
Pb DPTA	p/m	0.5	0.62	0.38	0.62	0.5	0.38	0.5
As	p/m	1.86	1.67	1.52	1.82	2.12	1.56	1.93
Hg	p/m	0.017	0.006	<.006	0.017	0.006	0.017	0.011
Se	p/m	0.255	0.225	0.196	0.2	1.96	0.233	0.217
Zn 0.1N HCl	p/m	1.8	2.8	2.7	3.2	5	3	2.9
Cu 0.1N HCl	p/m	2.4	2.4	2.4	2.4	2.6	1.8	2.4
Fe 0.1N HCl	p/m	320	343	282	202	228	267	235
Mn 0.1N HCl	p/m	47	52	59	69	77	81	70
Cd 0.1N HCl	p/m	0.2	0.2	0.2	0.4	0.4	0.3	0.2
Co 0.1N HCl	p/m	1.9	1.9	1.9	2.4	2.5	1.9	1.3
Pb 0.1N HCl	p/m	2.5	3.1	3.1	3.8	3.8	3.8	3.1

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 3 of 10)

		Well 299-E25-27				
		Depth (ft)				
Parameter	Units	5	10	85	90	95
Alkalinity	p/m as $CaCO_3$	252	270	130	144	115
pH		8.63	8.96	8.25	8.34	8.24
Conductivity	mmho/cm	1.15	2.4	0.7	0.6	0.7
Sodium absorption	ratio	10.8	22.8	3.49	4.11	3.93
Soluble Na	p/m	186.4	388	62.2	51.6	55.9
Soluble Ca	p/m	8.2	5	11.9	5.5	6.9
Soluble Mg	p/m	8.7	10.3	7.4	3.9	5.1
Soluble K	p/m	11.7	10.5	9.8	8.5	9.1
Cation exchange capacity	Meq/100 g	7.2	7.7	18.4	16.9	19
Exchange Na	p/m	172	342	144	108	128
Exchange Ca*	Meq/100 g	14.7	16.4	26.8	2	2.4
Exchange K	p/m	184	178	362	290	324
Exchange Mg*	Meq/100 g	2.3	2.87	4.54	3.33	3.95
Cl	p/m	12.5	33.3	2.9	1.72	2.23
F	p/m	0.67	1.68	0.8	0.72	0.76
Organic matter	%	0.24	0.23	0.086	0.129	0.086
PO3P	p/m	6.44	5.03	3.65	3.13	2.85
SO3S	p/m	15.5	27.4	12.6	7.57	9.58
NO3N	p/m	1.51	0.833	1.44	1.17	1.58
Mo	p/m	0.13	0.12	0.19	0.14	0.13
Zn DPTA**	p/m	0.66	0.48	0.62	0.4	0.4
Cu DPTA	p/m	0.88	0.78	0.44	0.38	0.5
Fe DPTA	p/m	10.4	9	17.6	18.4	17.8
Mn DPTA	p/m	2.4	1.8	2.4	2.4	2.4
Cd DPTA	p/m	0.06	0.02	0.03	0.04	0.04
Co DPTA	p/m	0.16	0.16	0.25	0.25	0.25
Pb DPTA	p/m	0.62	0.76	0.62	0.62	0.62
As	p/m	1.88	6.67	1.08	1.03	1.13
Hg	p/m	<.006	0.006	0.006	<.006	0.011
Se	p/m	0.266	0.287	0.171	0.167	0.2
Zn 0.1N HCl	p/m	2.7	2.7	3.1	2.6	2.7
Cu 0.1N HCl	p/m	2.6	2.4	2.1	1.8	2.9
Fe 0.1N HCl	p/m	212	233	278	311	233
Mn 0.1N HCl	p/m	46	49	61	74	59
Cd 0.1N HCl	p/m	0.2	0.2	0.2	0.3	0.3
Co 0.1N HCl	p/m	1.3	1.3	1.9	2.5	2.5
Pb 0.1N HCl	p/m	2.5	2.5	4.4	3.8	4.4

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 4 of 10)

		Well 299-E25-27 (cont)				
		Depth (ft)				
Parameter	Units	100	105	110	115	120
Alkalinity	p/m as CaCO3	101	126	144	130	117
pH		8.24	8.6	8.57	8.49	8.23
Conductivity	mmho/cm	0.75	0.45	0.5	0.5	1.3
Sodium absorption	ratio	3.54	8.01	13.7	8.84	4.18
Soluble Na	p/m	67.1	53.5	58.5	59.3	100
Soluble Ca	p/m	13.9	1.2	0.4	1.1	24
Soluble Mg	p/m	8.1	1.4	0.6	1.4	11.7
Soluble K	p/m	10	7.3	9.4	8.3	13.4
Cation exchange capacity	Meq/100g	17.6	10.8	12.9	12.1	17.7
Exchange Na	p/m	140	106	122	114	148
Exchange Ca*	Meq/100 g	2.2	14.5	16	15.1	22.3
Exchange K	p/m	324	238	264	250	304
Exchange Mg*	Meq/100 g	3.59	2.18	2.21	2.13	3.07
Cl	p/m	5.13	0.27	<0.1	0.61	4.5
F	p/m	0.73	0.68	0.78	0.6	0.61
Organic matter	%	0.114	0.114	0.07	0.043	0.1
PO3P	p/m	4.47	2.58	3.12	2.06	3.12
SO3S	p/m	15.1	5.43	6.33	6.94	22.3
NO3N	p/m	2.54	0.377	0.442	0.442	4.27
Mo	p/m	0.27	0.12	0.17	0.14	0.16
Zn DPTA**	p/m	0.3	0.38	1.24	0.9	1.96
Cu DPTA	p/m	0.34	0.44	0.38	0.56	0.88
Fe DPTA	p/m	17.8	12	12.2	11.8	12.6
Mn DPTA	p/m	2.4	1.7	1.5	1.6	1.8
Cd DPTA	p/m	0.06	0.04	0.06	0.04	0.04
Co DPTA	p/m	0.25	0.08	0.16	0.16	0.25
Pb DPTA	p/m	0.62	0.5	0.72	0.62	0.62
As	p/m	1.15	1.03	1.52	1.06	1.22
Hg	p/m	0.011	<.006	0.022	<.006	0.006
Se	p/m	0.158	0.154	0.079	0.182	0.211
Zn 0.1N HCl	p/m	2.8	3	4.2	2.8	4.4
Cu 0.1N HCl	p/m	2.4	2.4	2.6	3.2	3.8
Fe 0.1N HCl	p/m	278	333	396	348	338
Mn 0.1N HCl	p/m	64	64	62	55	60
Cd 0.1N HCl	p/m	0.3	0.1	0.3	0.3	0.3
Co 0.1N HCl	p/m	1.9	1.9	1.9	1.9	2.5
Pb 0.1N HCl	p/m	3.1	1.9	1.9	1.9	1.3

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 5 of 10)

		Well 299-E25-27 (cont)			
		Depth (ft)			
Parameter	Units	125	130	135	140
Alkalinity	p/m as $CaCO_3$	122	130	115	130
pH		8.24	8.48	8.38	8.32
Conductivity	mmho/cm	1.2	0.9	0.8	1.15
Sodium absorption	ratio	3.68	4	3.5	3.38
Soluble Na	p/m	79.7	75	61.8	76.9
Soluble Ca	p/m	17.9	13.4	10.1	19
Soluble Mg	p/m	10.7	8	8.2	12.3
Soluble K	p/m	10.4	8.5	7.7	7.3
Cation exchange capacity	Meq/100 g	18.4	7	8.3	9.3
Exchange Na	p/m	116	76	70	78
Exchange Ca*	Meq/100 g	23.5	14.7	16.7	20.9
Exchange K	p/m	222	118	148	132
Exchange Mg*	Meq/100 g	2.77	1.36	1.77	2.03
Cl	p/m	4.43	2.32	2.11	4.41
F	p/m	0.58	0.58	0.6	0.79
Organic matter	%	0.086	0.086	0.07	0.1
PO3P	p/m	3.65	3.65	3.65	3.38
SO3S	p/m	16	16.9	9.58	20.4
NO3N	p/m	3.24	1.44	1.44	2.38
Mo	p/m	0.19	0.17	0.11	0.17
Zn DPTA**	p/m	0.84	0.58	0.46	0.66
Cu DPTA	p/m	0.5	0.34	0.28	0.34
Fe DPTA	p/m	12	9	11.2	8.4
Mn DPTA	p/m	2.4	2.4	2.6	3.2
Cd DPTA	p/m	0.06	0.04	0.04	0.06
Co DPTA	p/m	0.25	0.34	0.25	0.34
Pb DPTA	p/m	0.62	0.62	0.5	0.72
As	p/m	1.82	1.88	1.77	1.23
Hg	p/m	0.11	<.006	0.011	0.011
Se	p/m	0.211	0.214	.193	0.211
Zn 0.1N HCl	p/m	3	3	3.5	3.1
Cu 0.1N HCl	p/m	2.9	2.1	2.1	2.4
Fe 0.1N HCl	p/m	196	342	243	225
Mn 0.1N HCl	p/m	66	80	60	90
Cd 0.1N HCl	p/m	0.3	0.1	0.2	0.2
Co 0.1N HCl	p/m	1.9	1.9	1.9	1.9
Pb 0.1N HC	p/m	3.1	1.9	2.5	2.5

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 6 of 10)

Parameter	Units	Well E25-222 Depth (ft) 3	42	55	Well E25-223 Depth (ft) 3	39	48
Alkalinity	p/m as $CaCO_3$	180	166	270	130	202	216
pH		7.6	8.61	8.51	7.82	8.61	8.49
Conductivity	mmho/cm	0.65	0.6	0.75	0.3	0.65	0.7
Sodium absorption ratio		0.43	2.8	3.34	0.6	2.7	2.7
Soluble Na	p/m	9.4	41.4	58	5.7	45.7	49.1
Soluble Ca	p/m	10.3	7.8	9.6	1.8	10.5	10.5
Soluble Mg	p/m	16.1	5.3	8	3	6.8	8.8
Soluble K	p/m	32.9	9.6	11.5	18.2	10.4	11.5
Cation exchange capacity	Meq/100 g	3.1	13.1	15.2	7.1	11.4	13.5
Exchange Na	p/m	14	84	92	10	60	70
Exchange Ca*	Meq/100 g	4	24.4	21.3	4.1	20.8	25.6
Exchange K	p/m	286	262	290	234	206	232
Exchange Mg*	Meq/100 g	1.41	2.67	2.69	1.23	1.79	2.33
Cl	p/m	3.31	1.54	0.56	<0.1	1.53	1.21
F	p/m	0.27	0.54	0.52	0.29	0.53	0.66
Organic matter	%	0.07	0.029	0.07	0.27	0.01	0.14
PO3P	p/m	9.39	7.6	5.59	8.19	3.65	3.65
SO3S	p/m	6.33	6.03	6.03	2.69	7.57	8.55
NO3N	p/m	0.833	0.636	0.701	0.442	0.506	0.506
Mo	p/m	0.11	0.14	0.16	0.1	0.15	0.14
Zn DPTA**	p/m	0.4	0.78	0.46	0.38	0.78	0.56
Cu DPTA	p/m	0.78	0.34	0.34	0.84	0.28	0.34
Fe DPTA	p/m	9.76	21.8	22.6	14.6	17	22.2
Mn DPTA	p/m	3.2	5	3.8	4.6	2.6	5
Cd DPTA	p/m	0.04	0.06	0.04	0.04	0.04	0.02
Co DPTA	p/m	0.08	0.34	0.16	0.08	0.16	0.25
Pb DPTA	p/m	0.5	0.76	0.62	0.62	0.5	0.5
As	p/m	1.65	1.71	1.46	2.1	1.71	1.86
Hg	p/m	0.022	0.017	0.028	0.028	0.017	0.022
Se	p/m	0.204	0.207	0.2	0.225	0.207	0.204
Zn 0.1N HCl	p/m	2	2.3	2.6	3	2.7	2.8
Cu 0.1N HCl	p/m	1.8	2.1	2.1	2.1	2.1	2.4
Fe 0.1N HCl	p/m	196	478	478	181	438	424
Mn 0.1N HCl	p/m	44	117	103	33	90	140
Cd 0.1N HCl	p/m	0.1	0.3	0.2	<0.1	0.2	0.3
Co 0.1N HCl	p/m	1.3	3.1	3.1	1.3	2.5	3.8
Pb 0.1N HCl	p/m	1.3	2.5	2.5	1.3	2.5	3.1

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 7 of 10)

		Well 299-E25-224		
		Depth (ft)		
Parameter	Units	3	45	51
Alkalinity	p/m as $CaCO_3$	137	144	137
pH		7.91	8.6	8.57
Conductivity	mmho/cm	0.8	0.6	0.65
Sodium absorption	ratio	0.62	2.4	2.41
Soluble Na	p/m	16.6	42.8	39.4
Soluble Ca	p/m	21.9	11.7	8.6
Soluble Mg	p/m	10.6	7.5	7
Soluble K	p/m	17.8	10.9	9.8
Cation exchange capacity	Meq/100 g	6.9	7.7	9.2
Exchange Na	p/m	16	48	54
Exchange Ca*	Meq/100 g	4.4	15.5	21.6
Exchange K	p/m	192	174	182
Exchange Mg*	Meq/100 g	1.33	1.49	1.84
Cl	p/m	11.8	1.42	0.5
F	p/m	0.36	0.51	0.53
Organic matter	%	0.27	0.1	0.09
PO3P	p/m	5.59	3.65	3.93
SO3S	p/m	9.58	10.3	11.1
NO3N	p/m	0.571	0.571	0.506
Mo	p/m	0.11	0.12	0.11
Zn DPTA**	p/m	0.38	0.34	0.44
Cu DPTA	p/m	0.66	0.38	0.44
Fe DPTA	p/m	7.4	20.8	16
Mn DPTA	p/m	2.4	5.4	2.8
Cd DPTA	p/m	0.04	0.04	0.02
Co DPTA	p/m	0.08	0.34	0.25
Pb DPTA	p/m	0.62	1.12	0.38
As	p/m	1.68	1.83	1.77
Hg	p/m	0.033	0.022	0.022
Se	p/m	0.218	0.218	0.193
Zn 0.1N HCl	p/m	2.2	2.9	2.4
Cu 0.1N HCl	p/m	2.4	2.4	2.1
Fe 0.1N HCl	p/m	139	496	424
Mn 0.1N HCl	p/m	32	96	98
Cd 0.1N HCl	p/m	<0.1	0.2	0.3
Co 0.1N HCl	p/m	0.6	1.9	2.5
Pb 0.1N HCl	p/m	0.6	2.5	1.9

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 8 of 10)

		Well 299-E25-225			
		Depth (ft)			
Parameter	Units	3	27	30	55
Alkalinity	p/m as $CaCO_3$	130	175	151	166
pH		8.11	8.67	8.82	8.75
Conductivity	mmho/cm	0.35	0.45	0.5	0.4
Sodium absorption	ratio	0.58	7.7	7.78	4.63
Soluble Na	p/m	5.7	55.5	58.4	38
Soluble Ca	p/m	2.2	1.3	1.3	1.8
Soluble Mg	p/m	3.1	1.6	1.8	2
Soluble K	p/m	10.9	8	8.2	8.1
Cation exchange capacity	Meq/100 g	7.1	13.3	11.5	12.6
Exchange Na	p/m	10	112	106	80
Exchange Ca*	Meq/100 g	5.1	25.4	25.1	20.4
Exchange K	p/m	176	236	226	270
Exchange Mg*	Meq/100 g	1.02	2.62	2.56	2.64
Cl	p/m	0.24	0.93	1.2	0.96
F	p/m	0.38	0.86	0.89	0.65
Organic matter	%	0.26	0.09	0.09	0.09
PO3P	p/m	4.47	4.2	4.2	4.2
SO3S	p/m	2.21	4.95	5.94	5.28
NO3N	p/m	0.636	0.442	0.377	0.571
Mo	p/m	0.18	0.14	0.14	0.17
Zn DPTA**	p/m	0.3	4.26	1.38	1.22
Cu DPTA	p/m	0.78	0.94	0.5	0.34
Fe DPTA	p/m	5.2	15.4	15.2	19.4
Mn DPTA	p/m	2.1	3	2.8	2.2
Cd DPTA	p/m	0.04	0.06	0.04	0.06
Co DPTA	p/m	0.25	0.25	0.25	0.16
Pb DPTA	p/m	0.38	0.62	0.62	0.5
As	p/m	2.29	1.31	1.65	1.01
Hg	p/m	0.011	0.011	0.011	0.017
Se	p/m	0.221	0.211	0.214	0.171
Zn 0.1N HCl	p/m	1.8	5.6	2.9	5.5
Cu 0.1N HCl	p/m	2.4	2.6	2.4	1.8
Fe 0.1N HCl	p/m	178	383	338	470
Mn 0.1N HCl	p/m	30	119	84	87
Cd 0.1N HCl	p/m	0.1	0.2	0.2	0.2
Co 0.1N HCl	p/m	1.3	3.1	2.5	2.5
Pb 0.1N HCl	p/m	1.9	3.8	3.1	3.1

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 9 of 10)

		Well 299-E25-226			
		Depth (ft)			
Parameter	Units	3	21	42	48
Alkalinity	p/m as $CaCO_3$	144	117	135	151
pH		7.86	8.49	8.58	8.51
Conductivity	mmho/cm	0.35	0.95	0.65	0.55
Sodium absorption	ratio	0.73	2.83	3.62	3.87
Soluble Na	p/m	8.7	58.4	51.4	53.6
Soluble Ca	p/m	2	19.4	5.9	6.1
Soluble Mg	p/m	4.6	7.8	5.7	5.1
Soluble K	p/m	12	11	9.7	9.9
Cation exchange capacity	Meq/100 g	8.2	13.2	13.2	13.8
Exchange Na	p/m	16	80	92	94
Exchange Ca*	Meq/100 g	4.9	26.3	23.4	18.5
Exchange K	p/m	200	216	252	256
Exchange Mg*	Meq/100 g	151	2.15	2.95	2.67
Cl	p/m	124	11	2.19	1.95
F	p/m	0.34	0.53	0.52	0.49
Organic matter	%	0.23	0.17	0.16	0.11
PO3P	p/m	7.02	4.47	3.65	3.12
SO3S	p/m	1.64	15.7	13.8	9.54
NO3N	p/m	0.506	0.506	0.899	0.506
Mo	p/m	0.14	0.21	0.2	0.19
Zn DPTA**	p/m	0.38	0.42	0.62	0.34
Cu DPTA	p/m	0.94	0.34	0.34	0.44
Fe DPTA	p/m	13.8	16	25.4	18.6
Mn DPTA	p/m	5.6	2.8	6	2.4
Cd DPTA	p/m	0.04	0.06	0.06	0.06
Co DPTA	p/m	0.25	0.25	0.34	0.16
Pb DPTA	p/m	0.5	0.62	0.76	0.5
As	p/m	2.04	1.34	1.28	1.2
Hg	p/m	0.006	0.011	0.017	0.017
Se	p/m	0.186	0.211	0.193	0.189
Zn 0.1N HCl	p/m	1.7	2.2	2.6	2.2
Cu 0.1N HCl	p/m	2.1	1.8	2.4	2.4
Fe 0.1N HCl	p/m	217	353	1494	475
Mn 0.1N HCl	p/m	43	97	181	79
Cd 0.1N HCl	p/m	0.1	0.3	0.2	0.1
Co 0.1N HCl	p/m	1.3	1.9	4.4	2.5
Pb 0.1N HCl	p/m	1.9	3.8	3.8	2.5

Table 5A2-1. Chemical Analysis of Sediment Samples. (sheet 10 of 10)

		Well E25-227		
		Depth (ft)		
Parameter	Units	3	30	55
Alkalinity	p/m as $CaCO_3$	126	168	144
pH		8.03	8.6	8.61
Conductivity	mmho/cm	0.4	0.6	0.5
Sodium absorption	ratio	0.45	6.09	3.75
Soluble Na	p/m	5	57.6	38.1
Soluble Ca	p/m	2	2.5	2.7
Soluble Mg	p/m	4.4	2.6	3.1
Soluble K	p/m	45.2	11.7	9.2
Cation exchange capacity	Meq/100 g	5.9	11	12.3
Exchange Na	p/m	10	84	72
Exchange Ca*	Meq/100 g	3.2	19.6	25.4
Exchange K	p/m	276	252	268
Exchange Mg*	Meq/100 g	1.23	1.85	2.82
Cl	p/m	1.34	9.14	1.78
F	p/m	0.19	0.77	0.66
Organic matter	%	0.46	0.11	0.15
PO3P	p/m	12.5	3.12	3.65
SO3S	p/m	5.61	4.63	6.28
NO3N	p/m	1.03	0.377	0.442
Mo	p/m	0.1	0.18	0.15
Zn DPTA**	p/m	0.62	0.7	0.68
Cu DPTA	p/m	0.53	0.34	0.38
Fe DPTA	p/m	11.4	13.4	31
Mn DPTA	p/m	2.6	2.4	9.2
Cd DPTA	p/m	0.04	0.06	0.06
Co DPTA	p/m	0.16	0.25	0.34
Pb DPTA	p/m	0.25	0.5	0.5
As	p/m	1.71	1.98	2.5
Hg	p/m	0.017	0.011	0.011
Se	p/m	0.179	0.221	0.204
Zn 0.1N HCl	p/m	3.2	3.4	3.1
Cu 0.1N HCl	p/m	1.8	2.4	2.6
Fe 0.1N HCl	p/m	166	458	755
Mn 0.1N HCl	p/m	33	90	165
Cd 0.1N HCl	p/m	0.1	0.2	0.3
Co 0.1N HCl	p/m	0.6	3.1	3.8
Pb 0.1N HCl	p/m	1.3	3.1	3.8

*The exchangeable calcium and magnesium may also contain significant amounts of soluble calcium and magnesium when free $CaCO_3$ and $MgCO_2$ exist in the soil.

**DPTA = Diphenyl tetraacetic acid.

This page intentionally left blank.

9 0 1 1 7 8 6 1 4 5 6

APPENDIX 5A-3

RADIONUCLIDE ANALYSES OF SEDIMENT SAMPLES

This page intentionally left blank.

APPENDIX 5A-3

RADIONUCLIDE ANALYSES OF SEDIMENT SAMPLES

This appendix contains the results of radionuclide analyses performed on sediment samples collected at or near the GTF. These analyses were performed by U.S. Testing Company, Richland, Washington, following their standard procedures. Samples for analyses were collected from 16 wells at various depths from the ground surface. The well numbers are all prefixed by 299-E25 and include: 25 through 27, 208, 210, 212 through 214, 217, and 221 through 227. A list of constituents including surface soil contamination limits and detection limits in picocuries per gram is presented in Table 5A3-1. Table 5A3-2 presents radionuclide constituent data by well and depth.

Except for ^{40}K and the natural uranium/thorium decay series radionuclides, nearly all analyses listed are near or below detection limits. The ^{40}K, uranium, thorium, and radium contents are consistent with crustal average values for similar lithologic materials. Thus, the radiological baseline for the vadose zone beneath the proposed vault locations should be at or near natural background (or detection limits for the artificial radionuclides).

REFERENCES

RHO, 1987, Environmental Protection Manual, RHO-MA-139, Rockwell Hanford Operations, Richland, Washington.

WHC, 1988, Environmental Compliance Manual, WHC-CM-7-5, Westinghouse Hanford Company, Richland, Washington.

Table 5A3-1. Surface Soil Contamination Limits and Detection Limits for Radionuclide Constituents.

Constituent (pCi/g)	Surface soil contamination limits[a]	Detection limits (pCi/g)
K-40	2.00 E+02	3.50 E-01
Co-60	3.00 E+02	2.00 E-02
Zn-65	2.00 E+03	4.00 E-02
Eu-152	8.00 E+02	1.10 E-01
Mn-54	1.00 E+03	2.00 E-02
Co-58	9.00 E+02	2.00 E-02
Nb-95	1.00 E+03	3.00 E-02
Zr-95	6.00 E+02	3.00 E-02
Cs-137	4.00 E+02	2.00 E-02
Cs-134	4.00 E+02	2.00 E-02
Ru-106	1.00 E+02	1.70 E-01
Ce-141	9.00 E+02	2.00 E-02
Ra-224	5.00 E+01	4.00 E-02
Ce-144	1.00 E+02	1.80 E-01
Eu-155	2.00 E+02	5.00 E-02
Eu-154	2.00 E+02	5.00 E-02
Ra-226	3.00 E+02	5.00 E-02
Th-232	6.20 E+01	4.00 E-02
Pu-239/40	6.00 E+01	6.00 E-04
Pu-238	6.00 E+01	6.00 E-04
U	2.50 E+02	1.00 E-02
Sr-89	3.00 E+02	2.50 E-01
Sr-90	4.00 E+02	2.50 E-02

[a]WHC (1988) [Information formerly contained in RHO (1987)].

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 1 of 9)

Well 299-E25-25						
Constituent (pCi/g)	Depth (ft)					
	100	105	110	115	120	125
K-40	1.28 E+01	1.12 E+01	1.10 E+01	1.05 E+01	1.19 E+01	1.31 E+01
Co-60	a	a	2.88 E-02	a	a	a
Zn-65	a	a	a	a	a	a
Eu-152	1.24 E-01	7.81 E-02	7.76 E-02	1.29 E-01	1.19 E-01	a
Mn-54	a	2.71 E-02	1.89 E-02	a	a	a
Co-58	a	a	a	a	a	6.44 E-02
Nb-95	a	a	a	a	a	a
Zr-95	a	a	a	a	a	a
Cs-137	a	a	a	a	a	a
Cs-134	a	3.03 E-02	3.64 E-02	a	4.89 E-02	4.98 E-02
Ru-106	a	a	a	a	a	a
Ce-141	a	a	a	7.47 E-01	a	a
Ra-224	6.53 E-01	6.78 E-01	5.98 E-01	5.06 E-01	6.58 E-01	6.57 E-01
Ce-144	a	a	a	a	a	a
Eu-155	a	a	a	a	a	a
Eu-154	a	a	a	a	a	a
Ra-226	5.37 E-01	4.39 E-01	4.90 E-01	4.23 E-01	4.67 E-01	4.70 E-01
Th-232	5.65 E-01	5.87 E-01	5.18 E-01	7.26 E-01	5.69 E-01	5.69 E-01
Pu-239/40	a	a	a	a	a	a
Pu-238	a	a	a	a	a	a
U	3.73 E-01	3.26 E-01	3.66 E-01	4.57 E-01	5.43 E-01	4.44 E-01
Sr-89	a	4.86 E-01	5.69 E-01	a	5.18 E-01	1.70 E-01
Sr-90	2.72 E-02	3.14 E-02	2.35 E-02	5.19 E-02	2.44 E-02	5.29 E-02

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 2 of 9)

Constituent (pCi/g)	Well 299-E25-26 Depth (ft) 35	55	60	65	70	75	130
K-40	1.11 E+01	1.32 E+01	1.37 E+01	1.37 E+01	1.33 E+01	1.60 E+01	1.69 E+01
Co-60	a	a	a	a	a	a	a
Zn-65	a	a	a	a	a	a	a
Eu-152	a	a	1.01 E-01	8.91 E-02	8.15 E-02	1.50 E-01	a
Mn-54	a	a	a	a	a	a	3.13 E-02
Co-58	a	a	a	a	a	a	a
Nb-95	a	a	a	a	a	a	a
Zr-95	a	a	1.63 E-01	a	a	a	1.49 E-01
Cs-137	1.25 E-02	a	a	a	a	a	a
Cs-134	3.80 E-02	a	a	4.94 E-02	6.47 E-02	a	3.47 E-02
Ru-106	a	a	a	a	a	a	a
Ce-141	a	a	a	a	a	9.50 E-01	a
Ra-224	6.49 E-01	6.13 E-01	6.58 E-01	7.18 E-01	7.90 E-01	8.75 E-01	9.78 E-01
Ce-144	a	a	a	a	a	a	a
Eu-155	6.51 E-02	a	a	9.67 E-02	a	a	a
Eu-154	a	9.00 E-02	a	a	a	a	5.87 E-02
Ra-226	4.76 E-01	5.04 E-01	4.27 E-01	4.63 E-01	5.55 E-01	5.25 E-01	5.78 E-01
Th-232	5.55 E-01	8.05 E-01	5.62 E-01	6.15 E-01	6.77 E-01	7.50 E-01	8.40 E-01
Pu-239/40	a	a	a	a	a	a	a
Pu-238	a	a	a	a	5.36 E-04	a	a
U	2.31 E-01	2.47 E-01	2.75 E-01	4.98 E-01	4.93 E-01	2.44 E-01	2.40 E-01
Sr-89	6.60 E-01	4.13 E-01	2.77 E-01	2.02 E-01	1.97 E-01	6.40 E-01	1.89 E-01
Sr-90	1.76 E-02	a	8.39 E-03	2.29 E-02	1.14 E-02	8.01 E-03	5.95 E-03

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 3 of 9)

Constituent (pCi/g)	Well 299-E25-27						
	Depth (ft)						
	5	10	85	90	95	100	105
K-40	1.35 E+01	1.27 E+01	1.19 E+01	1.21 E+01	1.06 E+01	1.15 E+01	1.25 E+01
Co-60	a	a	4.15 E-02	a	a	a	a
Zn-65	a	a	a	a	a		a
Eu-152	a	7.25 E-02	a	a	7.37 E-02	1.06 E-01	a
Mn-54	a	a	a	a	a	a	a
Co-58	a	a	a	a	a	a	a
Nb-95	a	a	2.18 E-01	2.36 E-01	a	a	a
Zr-95	a	a	2.32 E-01	1.46 E-01	a	a	a
Cs-137	1.86 E-01	7.98 E-02	a	a	a	a	a
Cs-134	3.83 E-02	2.05 E-02	a	a	4.16 E-02	3.32 E-02	2.82 E-02
Ru-106	a	a	a	3.86 E-01	a	a	a
Ce-141	a	a	a	a	a	a	a
Ra-224	9.67 E-01	8.46 E-01	5.88 E-01	6.07 E-01	6.51 E-01	6.55 E-01	7.54 E-01
Ce-144	a	a	a	a	a	a	a
Eu-155	7.35 E-02	6.67 E-02	a	a	a	a	a
Eu-154	a	a	a	a	a	a	a
Ra-226	6.77 E-01	5.95 E-01	4.31 E-01	4.45 E-01	4.51 E-01	4.17 E-01	4.75 E-01
Th-232	8.60 E-01	7.52 E-01	7.62 E-01	6.96 E-01	5.80 E-01	5.83 E-01	6.72 E-01
Pu-239/40	1.99 E-03	1.25 E-03	a	a	a	a	5.80 E-04
Pu-238	7.60 E-04	a	a	a	a	a	a
U	4.24 E-01	5.23 E-01	3.65 E-01	3.21 E-01	4.45 E-01	3.46 E-01	3.31 E-01
Sr-89	2.28 E-01	1.76 E-01	1.51 E-01	a	a	4.26 E-01	a
Sr-90	6.50 E-02	3.54 E-02	a	1.61 E-02	2.29 E-02	3.29 E-02	2.11 E-02

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 4 of 9)

Well 299-E25-27 (cont)							
Constituent (pCi/g)	Depth (ft)						
	110	115	120	125	130	135	140
K-40	1.23 E+01	1.27 E+01	1.39 E+01	1.28 E+01	1.58 E+01	1.43 E+01	1.49 E+01
Co-60	a	a	a	a	3.33 E-02	a	a
Zn-65	a	a	a	a	a	a	a
Eu-152	1.38 E-01	a	8.71 E-02	9.80 E-02	a	b	a
Mn-54	a	a	a	a	a	b	a
Co-58	a	a	a	a	a	a	a
Nb-95	a	a	a	a	a	a	a
Zr-95	a	a	9.93 E-02	8.93 E-02	4.31 E-01	a	a
Cs-137	a	a	a	a	3.00 E-02	a	a
Cs-134	a	3.07 E-02	3.10 E-02	2.50 E-02	a	a	4.54 E-02
Ru-106	a	a	a	a	a	a	a
Ce-141	a	a	a	a	a	a	a
Ra-224	5.96 E-01	7.70 E-01	8.84 E-01	8.31 E-01	1.24 E+00	6.18 E-01	8.70 E-01
Ce-144	a	a	a	a	a	a	a
Eu-155	a	a	a	5.57 E-02	a	a	b
Eu-154	8.16 E-02	a	a	a	a	a	a
Ra-226	5.38 E-01	4.63 E-01	6.02 E-01	5.52 E-01	6.21 E-01	4.32 E-01	5.88 E-01
Th-232	8.91 E-01	6.86 E-01	7.87 E-01	7.39 E-01	1.10 E+00	5.50 E-01	7.75 E-01
Pu-239/40	a	a	a	a	a	a	a
Pu-238	a	a	a	a	a	a	a
U	2.67 E-01	2.95 E-01	3.22 E-01	4.10 E-01	3.07 E-01	3.80 E-01	3.36 E-01
Sr-89	2.10 E-01	3.90 E-01	a	a	2.34 E-01	2.01 E-01	3.12 E-01
Sr-90	a	1.49 E-02	1.99 E-02	3.49 E-02	2.03 E-02	b	b

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 5 of 9)

Constituent (pCi/g)	Well 299-E25-208		Well 299-E25-210	Well 299-E25-212	
	Depth (ft)				
	20	25	24	20	25
K-40	1.17 E+01	1.16 E+01	1.04 E+01	1.16 E+01	1.15 E+01
Co-60	2.70 E-02	a	a	2.07 E-02	2.47 E-02
Zn-65	4.38 E-02	1.29 E-01	a	1.62 E-01	4.78 E-02
Eu-152	a	a	a	a	a
Mn-54	2.47 E-02	a	a	3.16 E-02	a
Co-58	6.43 E-02	6.00 E-02	4.46 E-02	2.27 E-01	6.53 E-02
Nb-95	1.83 E+00	6.53 E-01	1.28 E+00	8.61 E-01	1.89 E+00
Zr-95	4.06 E-02	8.37 E-02	3.99 E-01	2.03 E-01	2.55 E-01
Cs-137	a	a	2.67 E-02	a	a
Cs-134	3.91 E-02	a	3.03 E-02	2.51 E-02	5.06 E-02
Ru-106	a	a	a	2.81 E-01	a
Ce-141	8.64 E-01	3.76 E+00	1.18 E+00	2.59 E-01	4.30 E-02
Ra-224	7.12 E-01	6.22 E-01	6.45 E-01	5.12 E-01	5.71 E-01
Ce-144	a	a	a	a	a
Eu-155	8.29 E-02	a	a	a	a
Eu-154	a	5.32 E-02	a	a	a
Ra-226	5.01 E-01	4.49 E-01	4.04 E-01	3.93 E-01	3.98 E-01
Th-232	5.72 E-01	7.24 E-01	5.13 E-01	5.83 E-01	4.92 E-01
Pu-239/40	a	a	a	a	a
Pu-238	a	6.11 E-04	a	a	a
U	3.25 E-01	4.24 E-01	3.63 E-01	4.07 E-01	2.08 E-01
Sr-89	4.16 E+00	4.99 E+00	1.09 E+01	6.89 E+00	7.16 E+00
Sr-90	a	a	a	a	a

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 6 of 9)

Constituent (pCi/g)	Well 299-E25-213		E25-214	E25-217	E25-221
	Depth (ft)				
	17.5	22.5	21	24.5	14
K-40	1.08 E+01	1.05 E+01	1.25 E+01	1.21 E+01	1.21 E+01
Co-60	a	a	a	2.10 E-02	a
Zn-65	a	a	5.51 E-02	8.97 E-02	2.48 E-01
Eu-152	a	a	a	1.45 E-01	1.16 E-01
Mn-54	a	a	a	a	a
Co-58	1.05 E-01	5.94 E-02	5.72 E-02	a	3.10 E-02
Nb-95	1.72 E+00	4.73 E-01	4.46 E-01	1.30 E+00	4.07 E-01
Zr-95	1.71 E-01	3.46 E-02	1.89 E-01	5.46 E-02	4.93 E-01
Cs-137	1.31 E-01	3.49 E-02	a	a	9.03 E-02
Cs-134	3.84 E-02	a	3.64 E-02	5.34 E-02	a
Ru-106	a	a	a	a	a
Ce-141	4.25 E-01	1.48 E+00	9.50 E-01	1.43 E+00	6.44 E+00
Ra-224	6.58 E-01	6.42 E-01	7.56 E-01	8.36 E-01	5.54 E-01
Ce-144	a	a	1.19 E-01	a	4.74 E-01
Eu-155	a	7.95 E-02	a	a	1.06 E-01
Eu-154	a	a	7.26 E-02	a	a
Ra-226	4.11 E-01	4.01 E-01	4.33 E-01	4.75 E-01	4.55 E-01
Th-232	5.26 E-01	5.13 E-01	6.04 E-01	6.64 E-01	7.94 E-01
Pu-239/40	6.15 E-04	a	a	a	2.41 E-02
Pu-238	a	a	a	a	a
U	2.77 E-01	2.32 E-01	2.00 E-01	3.05 E-01	3.41 E-01
Sr-89	3.87 E+00	8.60 E+00	4.35 E+00	8.62 E+00	1.93 E+00
Sr-90	a	a	a	a	2.74 E-02

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 7 of 9)

Constituent (pCi/g)	Well 299-E25-222			Well 299-E25-223		
	Depth (ft)					
	3	42	55	3	39	48
K-40	1.55 E+01	1.09 E+01	1.12 E+01	1.55 E+01	1.15 E+01	1.19 E+01
Co-60	a	a	a	1.86 E-02	a	1.55 E-02
Zn-65	a	a	a	a	a	a
Eu-152	a	7.17 E-02	a	8.51 E-02	a	6.83 E-02
Mn-54	1.97 E-02	a	a	a	a	a
Co-58	a	a	a	a	a	a
Nb-95	a	a	a	a	a	a
Zr-95	4.04 E-02	3.81 E-02	a	a	2.93 E-02	a
Cs-137	1.28 E+00	4.29 E-02	1.57 E-02	3.37 E-01	1.26 E-02	4.20 E-02
Cs-134	4.52 E-02	a	1.71 E-02	2.79 E-02	2.96 E-02	3.29 E-02
Ru-106	1.73 E-01	a	a	a	a	a
Ce-141	a	a	a	a	a	a
Ra-224	9.27 E-01	5.83 E-01	5.28 E-01	9.40 E-01	5.74 E-01	6.11 E-01
Ce-144	a	a	a	a	a	a
Eu-155	8.36 E-02	a	a	a	a	a
Eu-154	a	a	a	4.92 E-02	a	a
Ra-226	7.38 E-01	4.81 E-01	4.73 E-01	6.71 E-01	3.90 E-01	4.31 E-01
Th-232	8.94 E-01	5.62 E-01	5.09 E-01	9.11 E-01	5.57 E-01	5.92 E-01
Pu-239/40	6.33 E-03	5.24 E-03	1.09 E-03	3.67 E-03	8.77 E-04	9.22 E-03
Pu-238	a	a	a	a	a	a
U	3.01 E-01	3.56 E-01	3.25 E-01	2.58 E-01	2.92 E-01	4.11 E-01
Sr-89	9.86 E-02	3.24 E-02	4.21 E-02	6.64 E-02	6.42 E-02	a
Sr-90	4.34 E-02	1.28 E-02	1.39 E-02	9.71 E-03	7.84 E-02	1.16 E-02

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 8 of 9)

Constituent (pCi/g)	Well 299-E25-224			Well 299-E25-225			
	Depth (ft)						
	3	45	51	3	27	30	55
K-40	1.49 E+01	1.16 E+01	1.12 E+01	1.46 E+01	1.20 E+01	1.20 E+01	1.15 E+01
Co-60	a	a	a	a	a	1.86 E-02	a
Zn-65	a	a	4.12 E-02	a	a	a	a
Eu-152	a	a	1.28 E-01	a	a	1.03 E-01	a
Mn-54	2.10 E-02	a	a	a	a	a	a
Co-58	a	a	a	a	a	a	a
Nb-95	a	a	a	a	a	a	a
Zr-95	a	a	a	a	a	a	a
Cs-137	2.14 E-02	1.26 E-02	a	1.94 E-02	a	a	1.77 E-02
Cs-134	3.28 E-02	2.83 E-02	3.59 E-02	2.15 E-02	2.69 E-02	1.94 E-02	1.92 E-02
Ru-106	a	a	a	a	a	a	a
Ce-141	a	a	a	a	a	a	a
Ra-224	8.47 E-01	5.32 E-01	5.00 E-01	9.61 E-01	6.87 E-01	6.47 E-01	5.89 E-01
Ce-144	a	a	a	a	a	a	a
Eu-155	7.02 E-02	a	a	a	1.16 E-01	a	4.81 E-02
Eu-154	a	a	a	a	a	6.25 E-02	a
Ra-226	6.79 E-01	4.14 E-01	3.74 E-01	7.07 E-01	4.71 E-01	4.68 E-01	4.06 E-01
Th-232	8.34 E-01	5.24 E-01	4.93 E-01	9.33 E-01	6.67 E-01	6.29 E-01	5.73 E-01
Pu-239/40	6.06 E-04	a	a	5.80 E-04	a	a	a
Pu-238	a	a	a	a	a	a	8.62 E-04
U	4.29 E-01	4.10 E-01	2.92 E-01	3.10 E-01	4.63 E-01	3.12 E-01	2.12 E-01
Sr-89	4.02 E-02	a	a	4.49 E-02	3.90 E-02	6.44 E-02	4.73 E-02
Sr-90	a	a	a	a	a	a	a

Table 5A3-2. Radionuclide Constituent Data by Well and Depth. (sheet 9 of 9)

Constituent (pCi/g)	Well 299-E25-226				Well 299-E25-227		
	Depth (ft)						
	3	21	42	48	3	30	55
K-40	1.57 E+01	1.16 E+01	1.28 E+01	1.20 E+01	1.60 E+01	1.22 E+01	1.10 E+01
Co-60	a	a	a	a	a	a	a
Zn-65	a	a	a	a	a	a	a
Eu-152	9.00 E-02	7.76 E-02	a	9.82 E-02	a	1.23 E-01	1.12 E-01
Mn-54	3.32 E-02	a	a	a	2.34 E-02	a	1.36 E-02
Co-58	a	a	a	a	a	a	a
Nb-95	a	a	a	a	a	a	a
Zr-95	a	a	a	a	a	a	2.81 E-02
Cs-137	2.36 E-02	a	2.88 E-02	a	2.09 E-02	a	a
Cs-134	4.85 E-02	3.63 E-02	2.53 E-02	3.15 E-02	4.41 E-02	a	a
Ru-106	a	a	a	a	a	a	a
Ce-141	a	a	a	a	a	a	a
Ra-224	9.38 E-01	6.45 E-01	6.52 E-01	6.04 E-01	8.46 E-01	6.96 E-01	5.61 E-01
Ce-144	a	a	a	a	a	a	a
Eu-155	a	7.70 E-02	a	a	a	4.76 E-02	a
Eu-154	a	a	a	a	a	a	a
Ra-226	6.65 E-01	4.62 E-01	4.47 E-01	4.47 E-01	6.99 E-01	5.07 E-01	4.46 E-01
Th-232	9.16 E-01	6.30 E-01	6.37 E-01	5.90 E-01	8.29 E-01	6.81 E-01	5.49 E-01
Pu-239/40	4.94 E-04	9.10 E-04	1.78 E-03	a	a	6.27 E-04	9.74 E-04
Pu-238	a	a	a	a	a	a	a
U	3.69 E-01	2.29 E-01	3.80 E-01	3.11 E-01	3.22 E-01	3.33 E-01	4.30 E-01
Sr-89	3.55 E-02	2.88 E-02	a	2.42 E-02	3.54 E-02	2.11 E-02	5.29 E-02
Sr-90	a	a	a	a	a	a	a

[a]Less than detection limit.

[b]Total error greater than 50% of the result value.

1 This page intentionally left blank.

APPENDIX 5A-4

SEDIMENT MOISTURE DATA

This page intentionally left blank.

APPENDIX 5A-4

SEDIMENT MOISTURE DATA

Moisture analyses calculated from samples collected during the drilling of selected boreholes in the vicinity of the Grout Treatment Facility are presented in Table 5A4-1. The wells, prefixed by 299-E25, include 222 through 227, 234, 235, 25 through 30, 32, and 33. Moisture samples were collected, dried, and weighed. Percent by weight water was calculated according to the procedure presented following Table 5A4-1.

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 1 of 10)

Borehole 299-E25-222

Depth (ft)	Moisture (wt%)	Comments
3	3.0	
6	3.2	
9	3.5	
12	3.1	
15	2.7	
18	3.1	
21	2.9	
24	3.1	
27	3.0	
30	3.9	
33	4.0	
38	4.9	
40	3.0	
42	4.4	
45	3.2	
48	4.4	
51	no data	
55	5.0	

Borehole 299-E25-223

Depth (ft)	Moisture (wt%)	Comments
3	1.1	
6	3.6	
9	3.4	
12	2.6	
15	2.9	
18	2.7	
21	2.8	
24	2.6	
27	3.1	
30	3.2	
33	3.0	
36	3.1	
39	4.1	
42	4.0	
45	3.9	
48	4.4	
51	3.5	
55	4.3	

Borehole 299-E25-224

Depth (ft)	Moisture (wt%)	Comments
3	3.4	
6	6.7	
9	2.9	
12	2.7	
15	2.4	
18	2.3	
21	2.1	
24	2.6	
27	2.5	
30	2.6	
33	2.4	
36	2.8	
39	2.8	
42	2.7	
45	3.2	
48	2.9	
51	3.2	
55	2.9	

Borehole 299-E25-225

Depth (ft)	Moisture (wt%)	Comments
3	2.1	
6	6.0	
9	4.3	
10	4.3	
12	4.0	
15	3.2	
18	4.1	
21	4.4	
24	4.1	
25.5	11.4	1 in. silty vf to fs lens
27	15.6	1 in. silty vf to fs lens
30	19.5	silty vfs lens
33	5.5	
36	7.3	
39	8.1	
42	6.7	
45	6.8	
48	7.0	
51	7.2	
55	7.9	

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 2 of 10)

Borehole 299-E25-226

Depth (ft)	Moisture (wt%)	Comments
3	2.2	
6	5.9	
9	2.8	
12	2.5	
15	2.8	
18	3.4	
21	4.3	
24	4.4	
27	3.9	
30	3.9	
33	3.4	
36	3.8	
39	3.5	
42	4.8	
45	3.6	
48	4.8	
51	3.4	
55	4.0	

Borehole 299-E25-227

Depth (ft)	Moisture (wt%)	Comments
3	4.0	
6	3.9	
9	4.7	
12	3.6	
15	2.6	
18	2.5	
21	2.6	
24	no data	
27	2.7	
30	5.4	
33	2.9	
36	2.6	
39	3.1	
42	3.5	
45	3.0	
48	3.3	
51	4.2	
55	4.5	

Borehole 299-E25-234

Depth (ft)	Moisture (wt%)	Comments	
17.30	12.5	low-value	sand [f]
22.70	6.0	low-value	silty sand [f]
29.10	6.0		silty sand [f]
39.00	45.5	high-value	sand [f] some clay
43.60	8.3		slightly silty sand [m-f]
51.50	5.5		sand [m-f]
58.50	4.4		silty sand [m-f]
63.20	5.8		sand [m-f]
75.40	18.2		thinly bedded silt
87.25	3.7		sand [m-f] some silt
97.20	4.9		sand [f]
106.20	4.8		sand [m]
121.60	4.7		sand [m]
130.25	6.0		sandy [m-f] gravel
139.20	4.8		silty sand [c]

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 3 of 10)

Borehole 299-E25-235

Depth (ft)	Moisture (wt%)	Comments
5	2.7	silty sand [f-vf]
10	3.7	slightly silty gravelly sand [vc-m]
15	3.0	slightly silty gravelly sand [vc-m]
20	2.9	sand [c-f]
25	3.0	sand [c-f]
30	3.5	sand [vc-f]
35	3.6	sand [c-f]
40	5.5	slightly silty sand [m-f]
45	3.6	sand [c-f]
50	3.1	sand [c-m]
55	4.1	sand [c-f]
60	5.2	sand [c-m]
65	2.9	sand [c-f]
70	4.9	sand [c-vf]
75	4.0	sand [c-f]
80	5.2	sand [c-f]
85	5.0	sand [c-f]
90	9.9	sand [c-f]
95	7.2	sand [c-f] mostly m-f
100	4.0	slightly silty sand [c-vf] mostly m-vf
105	4.8	sand [m-f]
110	11.0	slightly silty sand [m-vf]
115	23.8	sand [m-f] well bedded
120	9.4	slightly silty sand [c-vf] mostly m-f
125	10.9	sand [c-f] high CaCO3
130	2.6	sand [c-f]
135	2.2	sand [c-f]
140	2.3	sand [c-f]
145	1.9	slightly gravelly sand [vc-f]
150	2.3	sand [c-f]
155	1.5	sand [vc-f]
157	2.3	gravelly sand [vc-m]
160	2.1	slightly gravelly sand [vc-m]
165	1.5	sand [vc-f]
170	1.9	slightly silty sand [vc-f] mostly c-m
172.5	2.0	sandy [vc-f] gravel
174	1.7	silty sandy [vc-m] gravel

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 4 of 10)

Well 299-E25-25

Depth (ft)	Moisture (wt%)	Comments
5	9.6	sandy silt; 67% silt
10	3.2	
15	2.5	
20	2.5	
25	2.6	
30	2.6	
35	2.8	
40	2.9	
45	2.8	
50	3.7	
55	3.6	
60	3.8	
65	3.8	
70	4.8	
75	5.7	
80	6.4	
85	6.6	
90	6.5	
95	7.1	slightly silty sand [f-m]
100	12.7	slightly silty slightly gravelly [f-m] sand
105	7.9	sand [f-c]
110	7.9	slightly silty sand [f-c]
115	9.2	sand [f-c] w/vf-f sand lenses
120	8.9	silty [vf-f] sand lenses
125	10.2	sand w/silty vf-f sand lenses
130	3.2	
135	2.9	
140	3.5	
145	3.0	
150	2.8	
155	no data	
160	2.2	
165	2.5	
170	3.0	

Well 299-E25-26

Depth (ft)	Moisture (wt%)	Comments
5	no data	
10	no data	
15	no data	
20	no data	

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 5 of 10)

Well 299-E25-26 (cont)

Depth (ft)	Moisture (wt%)	Comments
25	no data	
26	7.4	sand [c-m]
30	5.2	
35	10.4	3-4-in. silt lens
40	6.1	
45	6.7	
50	7.9	sand [c-m] w/vf sand lenses
55	26.5	sand [f-c]
60	16.5	
65	12.3	55-75-ft numerous thin vf-f
70	16.2	sand lenses in m-c sand
75	9.8	
81	5.7	
85	3.4	
90	3.3	
95	3.6	
100	4.0	
103.5	22.3	thick silty lens
105	3.6	
110	3.8	
115	3.1	
120	3.5	
125	3.6	
130	10.5	3-in. silty sand [vf-f] lens
135	3.3	
140	2.9	
145	2.9	
150	2.9	
155	3.3	
160	2.6	

Well 299-E25-27

Depth (ft)	Moisture (wt%)	Comments
5	4.9	
10	4.1	
15	2.8	
20	2.8	
25	3.4	
30	3.5	
35	5.0	
40	4.1	

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 6 of 10)

Well 299-E25-27 (cont)

Depth (ft)	Moisture (wt%)	Comments
45	5.4	
50	4.5	
55	4.6	
60	5.2	
65	4.1	
70	4.8	
75	4.4	
80	4.2	
85	9.6	sand lens [f-m] in [m-c] sand
90	9.0	sand [m-c]
95	8.6	sand [f-c]
100	10.0	sand [f-m]
105	9.6	sand [vf-m]
110	9.2	slightly silty [vf-m] sand
115	9.9	slightly silty [vf-m] sand
117	27.4	1-2-in. silt lens
120	18.4	sand [vf-m]
125	9.9	slightly silty [vf-m] sand
130	17.8	2-3-in. silt lens
135	6.7	
140	24.6	sand lens [vf-f]
145	8.2	
150	6.8	
155	19.5	sand [f-m]

Well 299-E25-28

Depth (ft)	Moisture (wt%)	Comments
5	no data	
10	no data	
15	no data	
20	no data	
25	no data	
30	no data	
35	no data	
40	4.5	
45	5.1	
50	8.7	sand [m]
55	4.3	
60	9.2	numerous silt lenses
65	3.3	
70	3.6	

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 7 of 10)

Well 299-E25-28 (cont)

Depth (ft)	Moisture (wt%)	Comments
75	3.3	
80	3.4	
85	2.9	
90	2.5	
95	2.9	
100	4.9	
105	3.5	
110	2.7	
115	2.8	
120	2.7	
125	3.1	
130	2.8	
135	3.5	
140	2.6	
145	2.5	
150	2.5	
155	2.7	
160	2.3	
165	1.4	
170	2.4	
175	2.1	
180	2.2	
185	2.7	
190	2.2	
195	6.2	

Well 299-E25-29

Depth (ft)	Moisture (wt%)	Comments
5	5.7	low-value slightly silty sand [c-vf]
10	2.7	low-value gravelly sand [vc-vf]
45	4.1	low-value sand [c-m]
50	5.1	low-value sand [c-f]
70	7.4	low-value sand [c-f]
75	5.8	low-value sand [m-f]

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 8 of 10)

Well 299-E25-30

Depth (ft)	Moisture (wt%)	Comments
30	5.0	slightly silty sand [m-vf] (low value)
80	10.0	slightly silty slightly gravelly sand [c-f]
85	4.6	sand [c-f]
90	3.2	sand [c-f]
95	7.1	slightly silty slightly gravelly sand [c-f]
110	6.9	sand [c-f]
115	9.0	sand [c-f]
120	17.7	sand [c-f]
125	17.4	sand [c-f]
130	13.4	sand [m-vf]
135	9.3	sand [vc-m]
140	7.7	sand [c-f]
145	7.7	sand [vc-m]
150	17.5	sand [c-f]
155	23.4	sand [c-f] (sat. zone)
160	16.8	sand [vc-f]

Well 299-E25-32

Depth (ft)	Moisture (wt%)	Comments
5	NA	sand [m-f]
10	2.7	gravelly sand [vc-c]
15	3.0	gravelly sand [vc-c]
20	2.7	slightly gravelly sand [vc-m]
25	2.9	gravelly sand [vc-m]
30	3.2	sand [c-m]
35	3.6	sand c-f]
40	3.2	sand c-f]
45	4.4	slightly silty sand [m-vf]
50	4.9	slightly gravelly sand [vc-f]
55	4.4	sand [vc-f]
60	6.8	sand [c-f]
65	4.7	sand [c-m]
70	4.1	sand [c-f]
75	4.7	sand [c-m]
80	5.7	sand [c-f]
85	6.3	sand [c-f]
90	7.2	sand [c-f]
95	11.6	slightly silty sand [f]
100	15.6	slightly silty sand [m-vf]
105	13.9	sand [m-f]
110	2.6	slightly silty slightly gravelly sand [vc-f]

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 9 of 10)

Well 299-E25-32 (cont)

Depth (ft)	Moisture (wt%)	Comments
115	2.2	gravelly sand [vc-f]
120	2.7	slightly gravelly sand [vc-m]
125	3.1	sand [vc-m]
130	3.5	sand [vc-m]
135	3.2	sand [vc-m]
140	8.2	sand [c-f]
145	5.3	sand [vc-f]
150	2.0	sand [c-f]
155	2.0	slightly silty sand [vc-f]
160	1.9	gravelly sand [vc-f]
165	2.3	sandy [vc-m] gravel
175	2.3	sandy [vc-c] gravel

Well 299-E25-33

Depth (ft)	Moisture (wt%)	Comments
5	2.7	sand [vf-f]
10	2.5	slightly gravelly sand [vc-m]
15	3.0	sand [f]
20	6.4	slightly silty sand [f]
25	3.9	sand [m-f]
30	3.5	sand [c-m]
35	4.2	sand [m-f]
40	4.0	sand [m-f]
45	3.3	sand [m-f]
50	3.2	slightly silty sand [m-f]
55	3.5	sand [c-m]
60	1.2	sand [m-f]
65	4.8	sand [m-f]
68	16.6	silty sand [m-f]
70	9.5	sand [m-f]
75	11.7	slightly silty sand [[m-f]
80	11.7	sand [m-f] loosely consolidated
85	5.8	sand [m-f]
90	7.0	sand [m-f]
95	8.3	sand [m-f]
100	9.5	sand [c-m]
105	12.3	slightly silty slightly gravelly sand [vc-f]
110	4.0	slightly gravelly sand [c-vf]
115	4.0	sand [m-vf]
120	3.4	sand [vc-m]
125	3.6	slightly gravelly sand [vc-m]

Table 5A4-1. Sediment Moisture Data for Selected Boreholes in the Vicinity of the Grout Treatment Facility. (sheet 10 of 10)

Well 299-E25-33 (cont)

Depth (ft)	Moisture (wt%)	Comments
130	3.5	slightly gravelly sand [vc-m]
135	2.4	sand [vc-f]
140	2.8	sand [m-f]
145	2.6	sand [m-f]
150	2.6	sand [m-f]
155	2.4	sand [vc-f]
160	2.7	sand [vc-f]
165	8.4	sand [f-vf]
170	2.6	slightly silty slightly gravelly sand [vc-vf]
175	2.3	slightly silty slightly gravelly sand [vc-vf]

Moisture Content Measurement of Sediments

PURPOSE

This section covers the steps necessary to determine the moisture content of uncontaminated sediment samples. This applies to samples taken during drilling (except where water has been added) and during excavation of pits or surface sediments.

REQUIREMENTS

1. Samples from drilling operations should be taken as soon as possible after the sediments are brought to the surface. Sediments taken during the excavation of pits should be taken during the excavation. If this is not possible, the surface of the pit wall should be scraped away to expose sediments that have not changed in moisture content from being exposed to air.

2. Samples should be placed in soil moisture cans. The sample should be large enough to fill the can at least 3/4 full (preferably completely full). The lid should be set on the can, and the seam between the lid and the can should be taped shut. The well or pit number, depth of sample, and date should be written on the tape. The number marked on the moisture can should be noted on the geologic logs or in the geologist's notes along with the well or pit number, depth, and date.

3. Samples should be taken to the laboratory the same day if possible, and no later than 3 d after the sample is taken.

4. In the laboratory, remove the tape and the lid. Promptly weigh the can and lid and record the weight in grams. Place the can and lid in an oven set to 100 °C ± 50 °C and dry for 12 to 24 h. Reweigh the can and lid and record the weight, being careful not to spill any of the sediment. Dump out the sediments, wipe out the can and lid to remove any sediments adhering to their surface, weigh the empty can and lid, and record the weight.

5. Using the following equation, determine the percent moisture of the sample and record it.

$$\frac{(W_{WS} - W_{DS}) - (W_{DS} - W_C)}{W_{DS} - W_C} \times 100 = \% \text{ moisture}$$

where

W_{WS} = weight of the wet soil, can, and lid

W_{DS} = weight of the dry soil, can and lid

W_C = weight of the can and lid alone.

6. The lid ratings and calculations should be relocated in the geologist's log or on a suitable form developed for the purpose. The calculation should be reviewed by a peer.

1 This page intentionally left blank.

APPENDIX 5A-5

LITHOLOGIC SECTIONS FOR THE DETECTION MONITORING WELLS AND SITE BASELINE WELLS

This page intentionally left blank.

APPENDIX 5A-5

LITHOLOGIC SECTIONS FOR THE DETECTION MONITORING WELLS AND SITE BASELINE WELLS

Lithologic sections for groundwater monitoring wells constructed in 1984 through 1988 are presented in Figures 5A1-1 through 5A1-9. The lithologic section is an interpretation of the sediments in the subsurface based on field observations and laboratory analysis of samples obtained during drilling. For each well, the well number, ground surface elevation, total depth, total depth date, drill bit used, sample depth and elevation, graphic log, and lithologic description are presented.

The well number is based on the 200 East Area sheet system. Most of the wells are located on sheet map 25 of the 200 East Area. Ground surface elevation of all the wells is referenced to the 200 East Area datum, which is 0.37 ft below the National Geodetic Survey datum of 1929.

Total depth is the maximum depth, in feet, of the well boring. Total depth date is the date on which the borehole was completed to total depth. The temporary casings then were removed and the well screen and casings were emplaced.

Several methods of obtaining sediment samples were used at the GTF. All of the boreholes (except 299-E25-31) were drilled using cable tool techniques. The type of drill bit used to drill the hole is included in the column labeled 'samp int' (sample interval), which graphically shows where the sample was taken. An open circle indicates a drive barrel and a closed circle indicates a hard tool bit with the sample retrieved by a bailer. Borehole 299-E25-31 was drilled by the Odex method using foam to bring up the drill cuttings (see Appendix 5C-1). The sample intervals are shown with a diamond-shape symbol.

The graphic log denotes a symbolic representation of the sediments encountered during drilling. Three basic symbols are used for sand, gravel, and mud. Solid lines denote major lithologic changes (e.g., sand and gravel). Short lines separate sediments with discernable lithologic differences.

The lithologic description includes the sediment class name, a summary of information reported by the field geologist, and laboratory analyses, when possible. For brevity, some abbreviations are used in the description. These include: very course (VC), coarse (C), medium (M, fine (F), very fine (VF), angular (A), subangular (SA), subrounded (SR), rounded (R), moderately (MOD), reaction (RXN), dark (DK), light (LT), basalt (BAS), quartz (QTZ), hard tool (HT), driven barrel (DB), water level (WL), very (V), trace (TR), and pebbles (PEBS).

WELL DESIGNATION: 299-E25-25
GROUND SURFACE ELEVATION (ft ABOVE MSL): 666.84
TOTAL DEPTH (ft): 288
TOTAL DEPTH DATE: 4/9/85

* DRILL BIT USED
O DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft ABOVE MSL) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0	O		SANDY SILT: REACTS TO HCl
		O		SLIGHTLY SILTY SAND: FINE TO VF, SLIGHT RXN TO HCl
		O		SAND: MOSTLY COARSE TO MEDIUM, OCCASIONALLY SLIGHTLY SILTY, OCCASIONAL PEBBLES AND THIN STRINGERS OF SILT OR FINE SAND, GENERALLY UNCONSOLIDATED, NO TO SLIGHT RXN TO HCl, GRAY-BROWN
	50	O		
	600	O		SLIGHTLY SILTY SAND: MEDIUM TO FINE, GRAY-BROWN, V SLIGHT RXN TO HCl
		O		SAND: COARSE TO MEDIUM, GRAY-BROWN, NO TO V SLIGHT RXN TO HCl
		O		SAND: SLIGHTLY SILTY MEDIUM TO FINE, OCC. PEBBLES, LIGHT BROWN, MICACEOUS, NO TO SLIGHT RXN TO HCl
	100	O		
BLACK SAND		O		SAND: SLIGHTLY SILTY, COARSE TO MEDIUM, BLACK TO BROWN-BLACK, THIN LENSES OF SILT, SLIGHT RXN TO HCl, SLIGHT LIMONITE CEMENT(?)
	550	O		
		O		SAND: OCC. SLIGHTLY SILTY, MEDIUM TO FINE, YELLOW-BROWN TO TAN, SLIGHT RXN TO HCl TO 130 ft, THIN SILTY LENSES STRONGLY REACT TO HCl 130-140 ft
HT AFTER 150 ft SAMPLE TO ~157 ft		O		SAND: COARSE TO MEDIUM, SLIGHT RXN TO HCl
	150	●		GRAVELLY SAND: VERY COARSE TO COARSE SAND, SLIGHT RXN TO HCl
		O		SLIGHTLY SILTY SAND: COARSE TO FINE, SLIGHTLY GRAVELLY, TAN
	500	O		SLIGHTLY GRAVELLY SAND: COARSE TO MEDIUM, VARIABLE $CaCO_3$, SILTY SAND LAYER AT 168 ft
HT AFTER 169 ft SAMPLE TO END		●		SANDY GRAVEL: HIGHLY GROUND, COARSE TO MEDIUM SAND, GRAVEL >50% BASALT, BOULDER AT 180 ft and 185 ft, V SLIGHT RXN TO ACID
DRILLING SLOWS AT ~200 ft	200	●		SEEMS UNCEMENTED, NO TO V SLIGHT RXN TO ACID
DRILLING INDICATES BOULDERS AND VERY TRANSMISSIVE 220-230 ft	450	●		
HOLE WILL NOT STAY OPEN VERY MUCH	250	●		BASALT CONTENT DECREASES TO ~20-50%, STILL UNCONSOLIDATED, SLIGHT TO MODERATE RXN TO HCl 265 ft & BELOW
WL ▽		●		
	400	●		SAND 271-273 ft
SAND HEAVES INTO BOREHOLE		●		SLIGHTLY SILTY SLIGHTLY GRAVELLY SAND: COARSE TO MEDIUM, QUARTZITE FRACTION >BASALT
	300	●		
	350	●		

78809084.8

Figure 5A5-1. Lithologic Section for Well 299-E25-25.

WELL DESIGNATION: 299-E25-26
GROUND SURFACE ELEVATION (ft ABOVE MSL): 668.0
TOTAL DEPTH (ft): 290
TOTAL DEPTH DATE: 4/1/85

* DRILL BIT USED
O DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft ABOVE MSL) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0	O		SLIGHTLY SILTY SAND: MEDIUM TO VF, MOD RXN TO ACID
	650	O		SLIGHTLY SILTY SAND: COARSE TO MEDIUM, SLIGHTLY GRAVELLY, NO TO V SLIGHT RXN TO ACID, WELL SORTED BLACK SAND AT 20-22 ft
	50	O		SAND: COARSE TO MEDIUM, GRAVELLY AT 25.5 ft, THIN SILT LENSES, OCC. PEB, NO TO V SLIGHT RXN TO ACID
	600	O		SAND: MEDIUM TO FINE, UP TO 70% QTZ, NO TO V SLIGHT RXN TO ACID
		O		SLIGHTLY GRAVELLY SAND: V COARSE TO MEDIUM, NO TO SLIGHT RXN TO ACID
		O		SANDY GRAVEL: V COARSE TO COARSE, NO TO V SLIGHT RXN TO ACID, TAN FINES
	100	O		
	550	O		SLIGHTLY GRAVELLY SAND: V COARSE TO MEDIUM, UP TO 12% VF TO FINE, PEBBLES IN AREAS, SILTY CLAY LENSES AT 103.5, 112, AND 127 ft, NO RXN TO ACID
HT JUST BEFORE 160 ft	150	O		
		O		GRAVELLY SILTY SAND: V POORLY SORTED, NO RXN TO ACID
	500	●		SLIGHTLY SILTY SANDY GRAVEL: VC TO MED SAND, GENERALLY FINE PEBBLES, NO TO SLIGHT RXN TO ACID
		●		SLIGHTLY GRAVELLY SAND: MOSTLY SLIGHTLY SILTY, SLIGHTLY GRAVELLY, VC TO MEDIUM SAND, SLIGHT TO STRONG RXN TO ACID
	200	●		SLIGHTLY SILTY GRAVELLY SAND TO SANDY GRAVEL: V POORLY SORTED, INCREASE IN COBBLES AT 205 ft DOWNWARD, >50% BASALT CLASTS, NO TO V SLIGHT RXN TO HCl
	450	●		
V SLOW DRILLING 230-235 ft, DRILLER BELIEVES IS CONSOLIDATED		●		235-255 ft GRAVEL ≤50% BAS CLASTS, LOTS OF COBBLES, MORE SILT AT 250 ft, MODERTE RXN TO HCl
	250	●		
WL ▽		●		SLIGHTLY GRAVELLY SLIGHTLY SILTY SAND: MODERATE RXN TO HCl, UP TO 13% GRAVEL, GOLDISH MICAS BELOW 265 ft COMMON, SUBANG TO SUBRNDED SAND, QTZ RICH
	400	●		
		●		GRAVELLY SAND: SIMILAR TO ABOVE, MORE GRAVEL
		●		SAND: COARSE TO MED, FINES REACT STRONGLY TO HCl, QTZ PEBS
	300	●		
	350	●		

78809084.9

Figure 5A5-2. Lithologic Section for Well 299-E25-26.

WELL DESIGNATION: 299-E25-27
GROUND SURFACE ELEVATION (ft ABOVE MSL): 673.53
TOTAL DEPTH (ft): 300
TOTAL DEPTH DATE: 5/24/85

* DRILL BIT USED
○ DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft ABOVE MSL) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0	○		SLIGHTLY SILTY SAND: C TO VF, LT BROWN, TR PEBS, MOD TO STRONG RXN
		○		SLIGHTLY GRAVELLY SAND: MOSTLY VC TO C, UP TO 10% GRAVEL, SUBANGULAR TO SUBRNDED GRAINS, MOSTLY NO RXN TO ACID, GRAY
	650	○		
		○		SAND: COARSE TO MEDIUM, OCCASIONAL COBBLE OR PEBBLE, SOME LENSES OF BROWN MEDIUM TO FINE SAND, LESS THAN 10% SILT AND CLAY, GENERALLY WEAK TO MOD RXN TO HCl, 35-40 ft STRONG RXN TO HCl WITH WHITE AND ORANGE CEMENT, BROWN
	50	○		
		○		SAND: MEDIUM TO FINE, 5-20% SILT AND CALY, MICACEOUS, OCC. PEB, BROWN WEAK TO MOD RXN TO HCl
	600	○		
		○		SAND: COARSE TO MEDIUM, UP TO 6% GRAVEL, WEAK TO STRONG RXN TO HCl, MICA
		○		SAND: COARSE TO FINE, 5-12% SILT AND CLAY, WEAK TO MOD RXN TO HCl, MICACEOUS
	100	○		
HIGH MOIST ZONE		○		CLAYEY SILT LENS ABOUT 1-2 in. THICK, SECOND MOIST SAMPLE (117 ft) MORE REP OF ZONE
	550	○		SAND: COARSE TO MEDIUM, UP TO 6% GRAVEL, SOME SILTY LAYERS, BROWN, MOD RXN TO HCl, MICACEOUS
HIGH MOIST ZONE		○		SLIGHTLY SILT SAND: MED TO FINE, BROWN, MICACEOUS, MOD RXN TO HCl
		○		SAND: COARSE TO MEDIUM, UP TO 6% GRAVEL, WEAK TO STRONG RXN TO HCl, MICA
	150	○		
		●		SAND: COARSE TO FINE, 5-12% SILT AND CLAY, WEAK TO MOD RXN TO HCl, MICACEOUS
SWITCHED TO HT AT 157 ft SAMPLE		●		SLIGHTLY SILTY GRAVEL SAND: COARSE TO MED, 6-25% GRAVEL, MOD TO STRONG RXN TO HCl, 15-20% BAS
	500	●		
		●		SILTY SANDY GRAVEL: VC TO VF, MOSTLY VC TO C, VERY POORLY SORTED, 8-12% MUD, BOULDERS TO GRANULES, GRAY, NO RXN TO HCl
	200	●		
		●		SAND: COARSE TO MEDIUM, 1-3% GRAVEL, 10-13% MUD, NO RXN TO HCl
	450	●		
		●		SILTY SANDY GRAVEL: ROCSAN DATA SHOW 10-28% GRAVEL, DRILLING INDICATES HIGHER GRAVEL CONTENT, V POORLY SORTED, MAJOR SAND SIZE IS VC TO M, 8-19% MUD, VARIETY OF LITHOLOGIES, NO TO MOD RXN TO HCl
HOLE STAYED OPEN		●		
	250	●		
TENDS TO HEAVE INTO BOREHOLE	WL ▽	●		SLIGHTLY SILTY SAND: FINE, 2-4% GRAVEL, 13-14% MUD, 270-273 ft MOD RXN TO HCl
	400	●		
		●		SAND: COARSE TO MEDIUM, 1-4% GRAVEL, 9-13% MUD, SLIGHTLY SILTY, MOD RXN TO HCl
		●		SILTY SAND: COARSE TO VF, MOSTLY MED, 15-30% MUD, 1-4% GRAVEL, NO RXN TO HCl
	300	●		
	350			

78809084.1

Figure 5A5-3. Lithologic Section for Well 299-E25-27.

WELL DESIGNATION: 299-E25-28
GROUND SURFACE ELEVATION (ft ABOVE MSL): 660
TOTAL DEPTH (ft): 348
TOTAL DEPTH DATE: 3/19/86

* DRILL BIT USED
○ DRIVE BARREL
● HARD TOOL

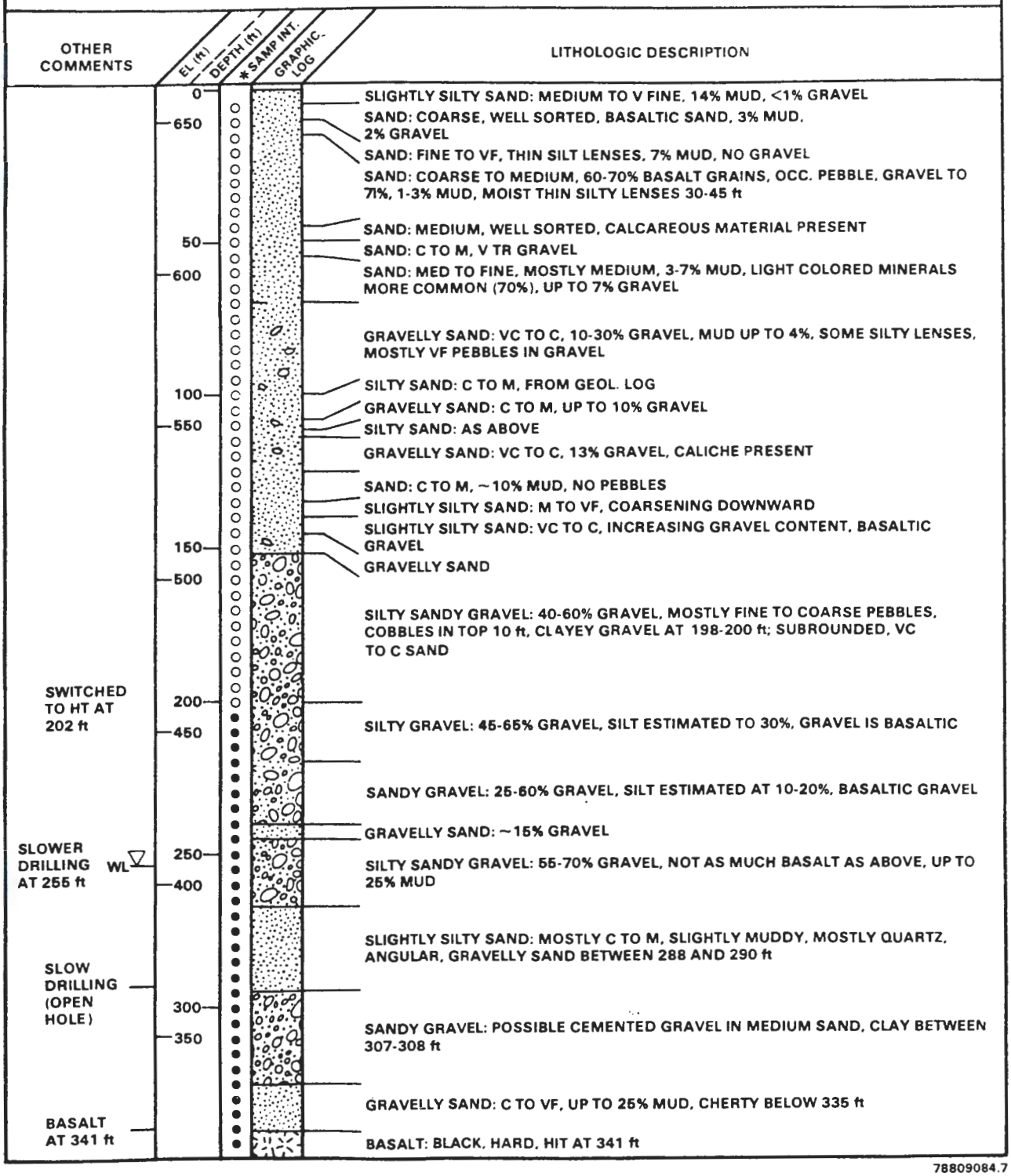


Figure 5A5-4. Lithologic Section for Well 299-E25-28.

WELL DESIGNATION: 299-E25-29
GROUND SURFACE ELEVATION (ft ABOVE MSL): 671.82
TOTAL DEPTH (ft): 330
TOTAL DEPTH DATE: 9/11/87

* DRILL BIT USED
O DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft ABOVE MSL) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
CHANGE TO HT AT 13 ft	0	O		SLIGHTLY SILTY SAND: C TO VF, 13% MUD, NO GRAVEL; SA TO SR, MOD SORTED, RXN TO HCl, BROWN
	650	●		GRAVELLY SAND: VC TO VF, 6-8% MUD, 7-20% GRAVEL; SA TO SR, MOD SORTED, BOULDER AT 13 ft; 80% BASALT OVERALL, GRAY
CHANGE TO DB BETWEEN 40 & 45 ft	50	O		SAND: C TO F, 2-13% MUD, 0-15% GRAVEL, SA TO SR, BASALT CONTENT DECREASES DOWNHOLE FROM 75-25%, GENERALLY WELL SORTED, GRAY TO BROWN GRAY, $CaCO_3$ PRESENT, LARGE MICA AT 80 ft AND TRACE AT OTHER DEPTHS
				15% GRAVEL
	600	O		
	100	O		13% MUD
				7% GRAVEL
	550	O		SLIGHTLY GRAVELLY SAND: AS ABOVE EXCEPT VC TO M, 7% GRAVEL, 1% MUD
				SILTY SAND: M TO VF, 37% MUD, 1% GRAVEL, MOD SORTED, 10-30% BASALT, YELLOWISH LT BROWN
	150	O		SAND: MOSTLY VC TO M, 1-4% MUD, 1-12% GRAVEL; SAND, SA TO SR, 20-50% BAS; GRAVEL, BAS AND QUARTZITE; WELL SORTED, GRAY
				12% GRAVEL
				11% GRAVEL
	500			SANDY GRAVEL: VC TO C SAND, 0-3% MUD, 26-63% GRAVEL; SAND, 45-55% BAS, SA TO SR; GRAVEL, SA TO R, BAS & QTZITE; MOD SORTED; GRAY
				SLIGHTLY GRAVELLY SAND: VC TO M, 1-2% MUD, 7-12% GRAVEL; SAND, SA TO SR, 40% BAS; WELL SORTED; GRAY
				GRAVELLY SAND: AS ABOVE, 3% MUD, ~25-30% GRAVEL, MOD SORTED
CHANGE TO HT AT 206 ft	200	●		GRAVELLY SAND: AS ABOVE, C TO F, 20% GRAVEL, LT BROWN GRAY, 7% MUD, 15% BAS
	450	●		SILTY SANDY GRAVEL: VC TO M SAND, 8 TO 18% MUD, 40-55% GRAVEL; POORLY SORTED, 75-80% BAS OVERALL
	250	●		SILTY SANDY GRAVEL: MOSTLY VC TO C SAND, 12% MUD, 45-50% GRAVEL; POORLY SORTED, 75-80% BAS OVERALL
				GRAVELLY SILTY SAND: VC TO VF, 15-18% GRAVEL, 18-23% MUD; POORLY SORTED, 70-75% BAS
WL ▽	400	●		SILTY SANDY GRAVEL: VC TO F SAND, 30-60% GRAVEL, 5-15% MUD; POORLY SORTED, 75-80% BAS
	300	●		GRAVELLY SAND TO SLIGHTLY SILTY GRAVELLY SAND: MOSTLY VC TO M SAND, 5-7% MUD, 9-40% GRAVEL; SAND, 50% BAS, MOD SORTED
	350	●		SAND: C TO F, 7% MUD, NO GRAVEL; SR TO R, WELL SORTED 30% BAS
				GRAVELLY SAND: VC TO F, 7% MUD, 20% GRAVEL, POORLY SORTED

78809084.4

Figure 5A5-5. Lithologic Section for Well 299-E25-29.

WELL DESIGNATION: 299-E25-30
GROUND SURFACE ELEVATION (ft ABOVE MSL): 667.0
TOTAL DEPTH (ft): 330
TOTAL DEPTH DATE: 9/23/87

* DRILL BIT USED
○ DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0			SILTY SAND: MUD TO F, TR M SAND, MOD TO WELL SORTED, LIGHT BROWN
				SAND: C TO F, TR GRAVEL, MINOR MUD, SOME LENSES OF M TO F SAND, MOD TO WELL SORTED, DARK GRAY, SUBANGULAR TO SUBROUNDED
	650			SAND: F TO MUD, WELL SORTED, LIGHT GRAY, SUBANGULAR TO SUBROUNDED
				SAND: M TO F, MINOR SILT, MOD-WELL SORTED, GRAY MAFIC 50-75%, QTZ 25-50%
	50			
				SAND: M TO F, TR SILT, TR CS, MOD SORTED, GRAY, 60-70% MAFIC, 0-10% FELDSPATHIC, 25-30% QTZ, SUBANGULAR TO SUBROUNDED
				FEW MICA FLAKES
	600			
				SAND: M TO F WITH MINOR CS TO MED PEBBLE, MOD TO SLI POOR SORTING, GRAY
	100			SAND: M TO F, MINOR SILT, MOD SORTED
				SAND: M, NO SILT, WELL SORTED, GRAY, SUBANGULAR TO SUBROUNDED, 75% MAFIC, 25% QTZ FELDSPATHIC
	550			SAND: M, SLIGHTLY SILTY, GRAY, DIORITE COBBLE, WELL SORTED, MAFIC 50%, QTZ FELD 50%
				SAND: C, WELL SORTED, GRAY, 30% MAFIC, 70% QTZ FELD, SUBANGULAR TO SUBROUNDED
	150			SAND: C TO M, MINOR FINE SAND TO SILT, GRAY
				SAND: C, CLEAN, WELL SORTED, GRAY, MAFIC 30%, QTZ FELD 70%
	500			SAND: M TO C, SMALL PEBBLES, MINOR FINE SAND, MAFIC 50-90% INCREASING WITH DEPTH, QTZ FELD 50-10% DECREASING WITH DEPTH
	200			GRAVELS: POSSIBLE BOULDERS, MAFIC 90, QTZ FELD 10%
	450			GRAVELLY SAND: C, LARGE PEBBLES & COBBLES, MAFIC 75-80%, QTZ FELD 20-25%, DARK GRAY, POORLY SORTED
	250			SLIGHTLY GRAVELLY SAND: C TO M, SMALL PEBBLES, POORLY TO MOD SORTED
WL				
	400			SAND: C TO M, MOD TO WELL SORTED, GRAY, SUBANGULAR TO SUBROUND, MAFIC DECREASING WITH DEPTH 70-40%, QTZ FELD INCREASING WITH DEPTH 30-60%
	300			SANDY GRAVEL: F TO VF PEBBLES, C TO M SAND, POORLY SORTED, SUBANGULAR TO WELL ROUNDED, GRAY
				GRAVELLY SAND: C TO M, M TO F PEBBLE, POORLY SORTED, GRAY
	350			SAND: C TO M, MOD SORTED, GRAY, SUBANGULAR TO SUBROUNDED, MAFIC 45%, QTZ FELD 55%

78809084.6

Figure 5A5-6. Lithologic Section for Well 299-E25-30.

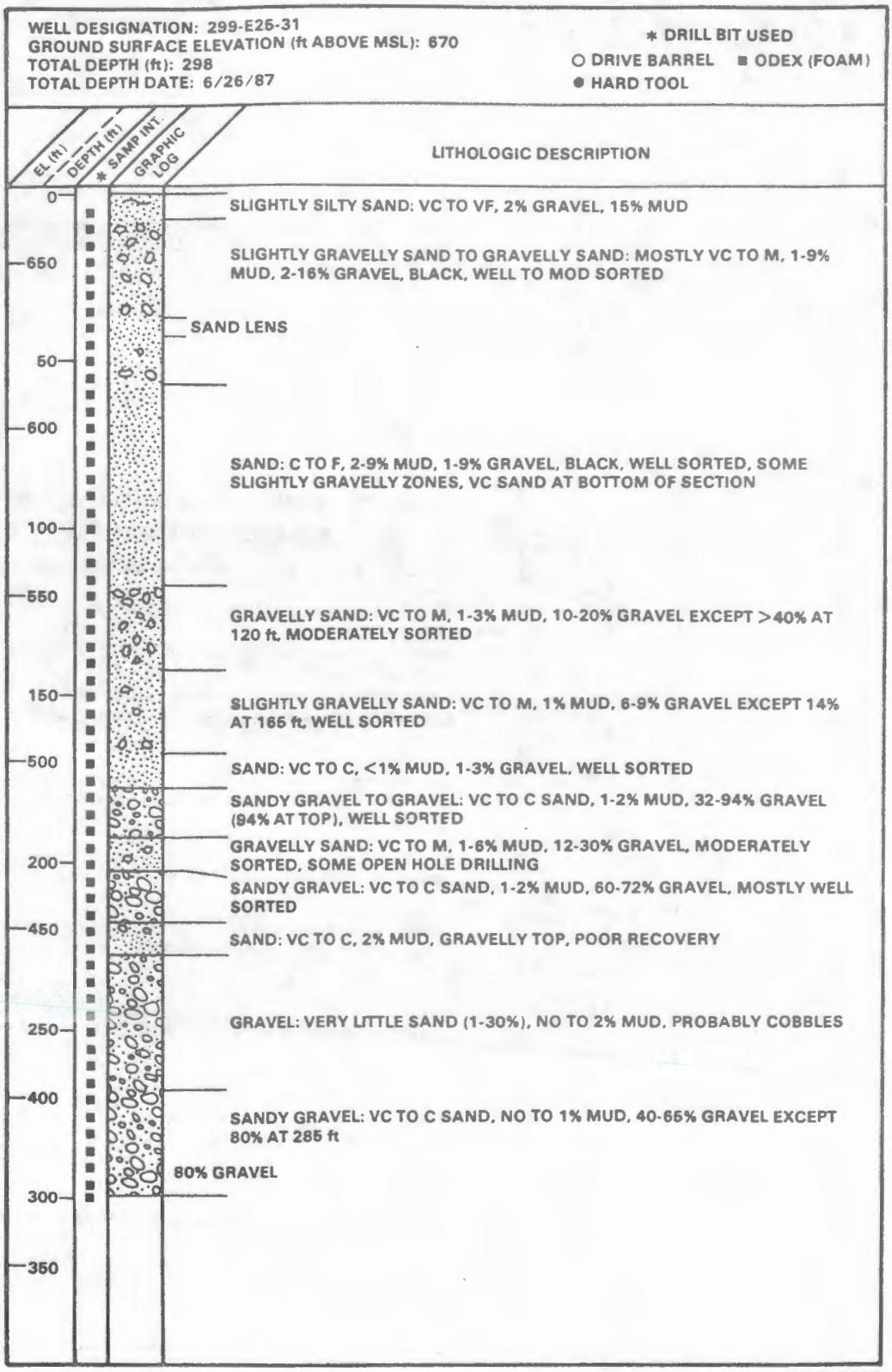


Figure 5A5-7. Lithologic Section for Well 299-E25-31.

WELL DESIGNATION: 299-E25-32
GROUND SURFACE ELEVATION (ft ABOVE MSL): 667.0
TOTAL DEPTH (ft): 354
TOTAL DEPTH DATE: 1/22/88

* DRILL BIT USED
O DRIVE BARREL
● HARD TOOL

OTHER COMMENTS	EL (ft) / DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0	O		SAND: M TO F, 10% MUD, ANG TO SUBANG, ~50% BASALT CONTENT, WELL SORTED, GRAYISH BROWN, STRONG RXN TO HCl
	650	O		SLIGHTLY GRAVELLY SAND TO GRAVELLY SAND: MOSTLY VC TO C SAND BECOMING MORE M & BOTTOM, 7-29% GRAVEL-LARGEST CLAST 90 mm, 1-8% MUD; WELL ROUNDED BASALTIC GRAVEL; SA TO SR BASALTIC SAND; MOD SORTING; GRAY BROWN (DRY); NO TO STRONG RXN TO HCl
	50	O		SAND: C TO F, M-VF LAST 5 ft, 0-4% GRAVEL, 2-11% MUD INCREASING w/DEPTH; SAND, 9 TO SR, 50-60% BAS, TR CALICHE, TR MICA; GRAVEL, MOSTLY ROUNDED NON-BASALT; WELL SORTED, LIGHT GRAY TO V DARK GRAY TO DARK GRAYISH BROWN, SLIGHT RXN TO HCl
	600	O		SLIGHTLY GRAVELLY SAND: VC TO F, 5-10% GRAVEL, 3-5% MUD; SAND, A TO SA, 80% BAS; GRAVEL, SA TO SR, 60% BAS; MOD SORTED; LT BROWNISH GRAY; MOD RXN TO HCL
		O		SAND: C TO F, 1-5% MUD, 0 TO 1% GRAVEL; SAND, A TO SA, 50-80% BASALT, WELL SORTED; VARIABLE COLOR, LT BROWNISH GRAY TO DARK GRAY; NO TO SLIGHT RXN TO HCl
	100	O		SLIGHTLY SILTY SAND: M TO VF, 10-18% MUD, NO GRAVEL, SA, 50% BAS, MOD TO WELL SORTED, GRAYISH BROWN, STRONG RXN TO HCl
	550	O		SLIGHTLY GRAVELLY SAND TO GRAVELLY SAND: VC TO M, 2-10% MUD, 4-13% GRAVEL, CLASTS TO 60 mm; GRAVEL & SAND, A TO SA, 65% BAS; MOD SORTED, LT GRAY, SLT TO MOD RXN TO HCl
	150	O		SAND: VC TO F, 1-11% MUD, 1-5% GRAVEL; SAN, A TO SA, 40-50% BAS, TR TO 5% CALICHE, TR MICA; GRAVEL, ROUNDED, BASALT; PALE BROWN TO LT GRAY, SLIGHT TO STRONG RXN TO HCl, MOD TO WELL SORTED
	500	O		SANDY GRAVEL: SAND MOSTLY VC TO C, 3-5% MUD, 30-45% GRAVEL; SAND, SA, 80% BAS; GRAVEL, SR TO R, BAS; MOD SORTED; LT GRAY (DRY), DK OLIVE GRAY (WET), NO TO SLT RXN TO HCl
SWITCHED TO HT BETWEEN 175 & 180 ft		●		
	200	●		GRAVELLY SILTY SAND TO SANDY GRAVEL: VC TO VF, 1-20% MUD, 22-43% GRAVEL; 80-85% BASALT OVERALL, POORLY SORTED, DK OLIVE GRAY (WET), NO RXN TO HCl
	450	●		GRAVELLY SILTY SAND TO SANDY GRAVEL: VC TO VF, 1-20% MUD, 25-34% GRAVEL; 80-85% BASALT OVERALL, POORLY SORTED, OLIVE TO OLIVE GRAY (WET), SIMILAR TO ABOVE, NO RXN TO HCl
	250	●		GRAVELLY SAND TO SANDY GRAVEL: VC TO VF, 4-11% MUD, 28-48% GRAVEL; 75% BASALT OVERALL, POORLY SORTED, OLIVE (WET), SIMILAR TO ABOVE, NO RXN TO HCl
~266 ft WL ▽		●		
DRILLING ON COBBLES	400	●		GRAVELLY SAND TO SANDY GRAVEL: VC TO VF, 4-10% MUD, 11-5% GRAVEL; 60% BASALT OVERALL, POORLY SORTED, OLIVE BROWN TO OLIVE GRAY (WET), NO RXN TO HCl
HEAVING		●		SANDY GRAVEL: VC TO C, 4% MUD, 42% GRAVEL; 30-65% BASALT IN SAND; GRAVEL, 40% BASALT, POORLY SORTED, LT YELLOWISH BROWN (WET), NO RXN TO HCl
HARD DRILLING AT 300 ft	300	●		SAND: VC TO F, 4-5% MUD, 2-4% GRAVEL; 50% BASLAT, OLIVE GRAY (WET), MOD SORTED, NO RXN TO HCl
		●		GRAVELLY SAND TO SANDY GRAVEL: VC TO M, 0-4% MUD, 12-38% GRAVEL; 50-60% BASALT OVERALL, MOD SORTED, NO RXN TO HCl
	350	●		SILTY SANDY GRAVEL: VC TO F, 2-11% MUD, GRAVEL CONTENT HIGHER THAN LAB ANALYSES INDICATES, 40-60% BASALT, NO RXN TO HCl, MOD TO POORLY SORTED
	350	●		BASALT: HIT FLOW TOP AT 349 ft, DENSE BASALT AT 354 ft, BLACK

78809084.10

Figure 5A5-8. Lithologic Section for Well 299-E25-32.

WELL DESIGNATION 299-E26-33
GROUND SURFACE ELEVATION (ft ABOVE MSL) 672.00
TOTAL DEPTH (ft): 400
TOTAL DEPTH DATE: 1/6/88

* DRILL BIT USED
C DRIVE BARREL
◇ SAND BAILER SAMPLE
● HARD TOOL

OTHER COMMENTS	EL (ft ABOVE MSL) / DEPTH (ft)	* SAMP INT	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	0			SAND: F TO VF, NO GRAVEL, SLIGHTLY SILTY, LT GRAY, MOD RXN TO HCl
				SLIGHTLY GRAVELLY SAND: VC TO M, 10% F PEBS, R TO SR, 70% BAS, LT BROWN GRAY
	650			SAND, M TO F, NO GRAVEL, 5-10% SILT, A TO SA, NO TO STRONG RXN TO HCl, LT BROWNISH GRAY TO GRAYISH BROWN, 40-60% BAS
				SAND: C TO M, 3% VF PEBS, POORLY SORTED, 65% BAS, V SLIGHT RXN TO HCl, LIGHT BROWNISH GRAY TO VSLT
	50			SAND M TO F, 1-2% F GRAVEL, A TO SA, NO RXN TO HCL WELL SORTED, LT BROWNISH GRAY TO DARK GRAYISH BROWN
				SAND: AS ABOVE, SLIGHTLY MORE SILT, ~2% VF PEBS, LT BROWNISH GRAY, 80% BAS
				SAND: C TO M, AS ABOVE, DK GRAYISH BROWN, NO RXN TO HCl
	600			SAND: M TO F, WELL SORTED, LENSES OF SILT & C & VC MATERIAL, NO TO MOD RXN TO HCl, GRAYISH BROWN, 80-60% BAS
				SAND: F TO VF, 5-10% SILT, 70-80% BAS, SOME LENSES OF MODERATELY CONSOLIDATED MATERIAL, MOD RXN TO HCl, TR CALICHE
	100			SAND: M TO F, 5-10% SILT, 45-70% BAS, LOOSELY CONSOLIDATED SILTY MATERIAL AT 80 ft, NO TO MOD RXN TO HCl (MOD RXN IN SILT), GRAYISH BROWN TO DK GRAYISH BROWN
				SAND: C TO M, 50% BAS, LT BROWNISH GRAY, MOD RXN TO HCl
	550			SLIGHTLY GRAVELLY SILTY SAND: M TO F, 10% C PEBS, A TO SA, LT OLIVE BROWN, 50% BAS, STRONG RXN TO HCl
				SAND: M TO VF, <5% PEBS, LT BROWNISH GRAY, 20-65% BAS, V WELL SORTED AND QUARTZ RICH AT 115 ft, MOD RXN TO HCl
	150			SAND: VC TO M, 4-5% F TO VF PEBS, LT BROWNISH GRAY TO LT YELLOWISH BROWN, 40% BAS, NO TO SLIGHT RXN TO HCl
				SAND: MOSTLY M TO F, <5% F TO VF PEBS, LT GRAY, 40% BAS, SOME SMALL GRAINS OF CALICHE AT 135 ft, A TO SA, STRONG TO MOD RXN TO HCl
	500			SAND: VC TO F, <5% F TO VF PEBS, <1% SILT, A, 50% BAS, LT OLIVE GRAY, MOD RXN
				SAND: MOSTLY F TO VF, LT YELLOWISH BROWN, A TO SA, 30% BAS, MOD RXN TO HCl
		◇		SAND: VC TO F, 5% F PEBS, 5% SILT, LT BROWNISH GRAY, A TO SA, 60% BAS, SOME CALICHE GRAINS, MOD RXN TO HCl
	200	●		GRAVELLY SAND: VC TO C, 30% F TO VF PEBS, DK GRAYISH BROWN (WET), 80% BAS, A, CLASTS TO 85 mm, V SLIGHT RXN TO HCl
		●		SANDY GRAVEL, 40% M TO F PEBS, VC TO F SAND, 5% VF SAND & SILT, 65% BAS, DK OLIVE GRAY (WET), NO RXN TO HCl
	450	●		SLIGHTLY GRAVELLY SAND: VC TO M, 8% C TO F PEBS, LT OLIVE BROWN (WET), 80% BAS NO RXN TO HCl
		●		SILTY SANDY GRAVEL, 50-60% PEBS, 10% SILT, OLIVE (WET), SAND IS A TO SA; 80% BAS, NO RXN TO HCl
		●		GRAVEL, 90% VC TO VF PEBS, 5% SILT, OLIVE GRAY (WET), 80% BAS, NO RXN TO HCl
	250	●		SILTY SANDY GRAVEL, 40-55% PEBS, 10% SILT, OLIVE GRAY (WET), 70-80% BAS; PEBS MOSTLY A SOME R; SAND A TO SA, NO RXN TO HCl
		●		SLIGHTLY SILTY SAND: M TO VF, 10% SILT, <5% VF PEBS, DK GRAYISH BROWN (WET), 40% BAS, A TO SA, SLIGHT RXN TO HCl
	400	●		GRAVELLY SAND: VC TO F, ~25 M TO VF PEBS, TR SILT, LT BROWNISH GRAY (WET), GRAVEL IS 30% BAS, NO RXN TO HCl
		●		SILTY SANDY GRAVEL: 50-70% M TO VF PEBS, 5-10% SILT, LT YELLOWISH BROWN (WET), GRAVEL IS 60-80% BAS, NO RXN
	300	●		GRAVELLY SAND: VC TO F, 20% F TO VF PEBS, 5% SILT, GRAYISH BROWN (WET), GRAVEL IS 40% BAS, NO RXN TO HCl
START OF CEMENTED GRAVELS		●		SANDY GRAVEL, 30-35% M TO F PEBS, <5% SILT, LT GRAYISH TO YELLOWISH BROWN
	350	●		SAND: VC TO M, TR SILT, DK GRAY OLIVE, 40% BAS, HEAVES
		●		SANDY GRAVEL, ~50% C TO VF PEBS, TR SILT, DK GRAY OLIVE, V POORLY SORTED, CEMENTED BY CALCITE OR SILICA
		●		SILTY SANDY GRAVEL, ~50% C TO VF PEBS, ~10% SILT, DK GRAY OLIVE TO OLIVE GRAY, CEMENT BY CALCITE OR SILICA, NO RXN TO HCl

78809084 J

Figure 5A5-9. Lithologic Section for Well 299-E25-33. (sheet 1 of 2)

WELL DESIGNATION: 299-E25-33
GROUND SURFACE ELEVATION (ft ABOVE MSL): 672.00
TOTAL DEPTH (ft): 400
TOTAL DEPTH DATE: 1/6/88

★ DRILL BIT
○ DRIVE BARREL
● HARD TOOL
▲ ROTARY

OTHER COMMENTS	EL (ft)	DEPTH (ft)	* SAMP INT.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	350				SILTY SANDY GRAVEL: 40% M TO RF PEBS, 15-20% SILT, OLIVE GRAY (WET); 40% BAS, "RUSTY" QUARTZ, TR MICA, NO RXN TO HCl, THIN CLAYEY GRAVEL LENSE BETWEEN 362 ft AND 363 ft
	300				
					BASALT: THIN GREEN CLAY BETWEEN 382 ft AND 383 ft; VESICULAR BAS FRAGMENTS AND SOME CLAY, >95% BASALT, DARK OLIVE GRAY TO V DARK GRAY; DENSE BASALT BEFORE 400 ft
	400				
	250				

78910170.1

Figure 5A5-9. Lithologic Section for Well 299-E25-33. (sheet 2 of 2)

1 This page intentionally left blank.

APPENDIX 5B

HYDROLOGIC DATA

5B-1 Liquid Effluent Discharge Volumes of Nearby Disposal Facilities, January 1985 Through December 1987

5B-2 Results of Shallow Borehole and Laboratory Permeability Tests for the Unsaturated Zone

5B-3 Hydrologic Test Data and Analyses

5B-4 Water-Level Elevation Data

5B-5 Baseline Water-Chemistry Data Collected Between September 1985 and July 1987

1 This page intentionally left blank.

APPENDIX 5B-1

LIQUID EFFLUENT DISCHARGE VOLUMES OF NEARBY DISPOSAL FACILITIES, JANUARY 1985 THROUGH DECEMBER 1987

1 This page intentionally left blank.

APPENDIX 5B-1

LIQUID EFFLUENT DISCHARGE VOLUMES OF NEARBY DISPOSAL FACILITIES, JANUARY 1985 THROUGH DECEMBER 1987

PUREX PROCESS CONDENSATE--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-10 crib
Waste Stream Description: PUREX Plant process condensate

Month	1985	1986	1987
January	6.4 E+06	5.9 E+06	6.5 E+06
February	2.5 E+06	5.2 E+06	Deactivated
March	3.2 E+06	6.0 E+06	"
April	1.2 E+07	5.8 E+06	"
May	8.9 E+06	9.9 E+06	"
June	2.6 E+06	7.9 E+06	"
July	1.8 E+07	1.4 E+07	"
August	1.6 E+07	1.1 E+07	"
September	1.2 E+07	5.8 E+06	"
October	3.6 E+06	2.2 E+06	"
November	9.3 E+06	2.4 E+05	"
December	7.3 E+06	2.6 E+05	"

PUREX STEAM CONDENSATE--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-30
Waste Stream Description: PUREX coil and steam condensate (67 percent of waste goes to A-30, 33 percent goes to A-37-2)

Month	1985	1986	1987
January	6.1 E+07	5.5 E+07	1.8 E+07
February	4.8 E+07	5.1 E+07	2.3 E+07
March	4.6 E+07	4.9 E+07	4.8 E+07
April	6.1 E+07	6.0 E+07	5.5 E+07
May	5.4 E+07	4.4 E+07	3.5 E+07
June	5.0 E+07	4.6 E+07	4.8 E+07
July	7.6 E+07	6.9 E+07	5.0 E+07
August	5.9 E+07	5.0 E+07	5.2 E+07
September	5.1 E+07	3.1 E+07	3.5 E+07
October	4.4 E+07	2.1 E+07	1.1 E+07
November	4.7 E+07	7.2 E+07	1.0 E+07
December	4.7 E+07	2.7 E+07	1.1 E+07

PUREX AMMONIA SCRUBBER--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-36B crib
Waste Stream Description: PUREX ammonia scrubber waste

Month	1985	1986	1987
January	7.2 E+06	3.8 E+06	0.0 E+00
February	5.0 E+06	6.2 E+06	0.0 E+00
March	5.4 E+06	8.4 E+06	2.0 E+06
April	5.7 E+06	8.8 E+06	2.3 E+06
May	4.2 E+06	5.3 E+06	2.4 E+06
June	3.6 E+06	6.5 E+06	1.3 E+06
July	1.0 E+07	1.0 E+07	8.4 E+06
August	8.7 E+06	7.5 E+06	6.4 E+06
September	4.8 E+06	0.0 E+00	5.4 E+06
October	5.2 E+06	0.0 E+00	INACTIVE
November	8.8 E+06	0.0 E+00	INACTIVE
December	6.8 E+06	0.0 E+00	INACTIVE

242-A PROCESS CONDENSATE--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-37-1
Waste Stream Description: 242-A Evaporator process condensate

Month	1985	1986	1987
January	6.5 E+06	5.4 E+06	4.2 E+05
February	2.1 E+06	2.0 E+06	4.1 E+06
March	NR[a]	6.2 E+06	4.1 E+05
April	5.0 E+06	1.7 E+06	0.0 E+00
May	4.0 E+06	8.2 E+06	0.0 E+00
June	NR[a]	4.5 E+06	3.1 E+06
July	7.0 E+06	1.6 E+06	5.2 E+06
August	2.5 E+06	5.7 E+05	7.7 E+06
September	6.5 E+06	1.3 E+06	3.1 E+06
October	1.2 E+06	6.3 E+06	2.7 E+05
November	5.9 E+06	8.7 E+06	0.0 E+00
December	7.6 E+06	4.1 E+06	2.7 E+05

PUREX STEAM CONDENSATE--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-37-2
Waste Stream Description: PUREX coil and steam condensate

Month	1985	1986	1987
January	2.0 E+07	2.7 E+07	9.1 E+06
February	1.6 E+07	2.6 E+07	1.2 E+07
March	1.5 E+07	2.4 E+07	2.4 E+07
April	2.0 E+07	3.0 E+07	2.7 E+07
May	1.8 E+07	2.2 E+07	1.7 E+07
June	1.7 E+07	2.2 E+07	2.4 E+07
July	2.5 E+07	3.4 E+07	2.5 E+07
August	2.0 E+07	2.5 E+07	2.6 E+07
September	1.7 E+07	1.6 E+07	1.7 E+07
October	2.2 E+07	1.1 E+07	5.6 E+06
November	2.3 E+07	3.6 E+06	5.0 E+06
December	2.3 E+07	1.3 E+07	5.5 E+06

PUREX PROCESS CONDENSATE--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-A-45 crib
Waste Stream Description: PUREX process condensate

Month	1985	1986	1987
January	0.0 E+00	0.0 E+00	0.0 E+00
February	0.0 E+00	0.0 E+00	0.0 E+00
March	0.0 E+00	0.0 E+00	5.7 E+06
April	0.0 E+00	0.0 E+00	8.9 E+06
May	0.0 E+00	0.0 E+00	5.0 E+06
June	0.0 E+00	0.0 E+00	7.6 E+06
July	0.0 E+00	0.0 E+00	8.4 E+06
August	0.0 E+00	0.0 E+00	3.0 E+06
September	0.0 E+00	0.0 E+00	4.8 E+06
October	0.0 E+00	0.0 E+00	0.0 E+00
November	0.0 E+00	0.0 E+00	0.0 E+00
December	0.0 E+00	0.0 E+00	1.4 E+06

B POND AND DITCHES--Monthly summary of liquid waste (volumes) discharged to ground (liters).

Disposal Site: 216-B-3 (Summary)
Waste Stream Description: PUREX chemical sewer and cooling water, B Plant cooling water, 241-A Tank Farm cooling water, 242-A Evaporator steam condensate and cooling water, 244-AR Vault cooling water, 283-E Filter backflush waste water, and 284-E Powerhouse cooling water

Month	1985	1986	1987
January	3.8 E+08	1.8 E+09	1.0 E+09
February	3.3 E+08	1.8 E+09	9.7 E+08
March	3.7 E+08	2.1 E+09	1.4 E+09
April	4.5 E+08	1.2 E+09	2.0 E+09
May	3.7 E+08	1.8 E+09	1.6 E+09
June	3.8 E+08	2.0 E+09	1.5 E+09
July	5.2 E+08	2.3 E+09	2.4 E+09
August	4.9 E+08	2.1 E+09	2.0 E+09
September	4.5 E+08	1.4 E+09	2.0 E+09
October	5.5 E+08	1.3 E+09	1.0 E+09
November	5.5 E+08	1.2 E+09	9.5 E+08
December	4.8 E+08	1.0 E+09	1.2 E+09

[a]NR = Not reported.

APPENDIX 5B-2

RESULTS OF SHALLOW BOREHOLE AND LABORATORY PERMEABILITY TESTS FOR THE UNSATURATED ZONE

This page intentionally left blank.

APPENDIX 5B-2

RESULTS OF SHALLOW BOREHOLE AND LABORATORY PERMEABILITY TESTS FOR THE UNSATURATED ZONE

Five boreholes were drilled by Dames and Moore in 1985 to evaluate some geotechnical properties at the Grout Treatment Facility (Dames and Moore 1986). Among the properties analyzed was the hydraulic conductivity (permeability). Both field and laboratory test results for hydraulic conductivity are described below.

Field Explorations/Laboratory Tests--Existing subsurface information in the vicinity of the waste management area was supplemented by drilling and sampling soils at the five boring locations shown on Plate 5-1 (Appendix 5E). Boring 85-3 was advanced to a depth of 60 ft, while the remaining four borings were terminated at a depth of 45 ft below the existing ground surface.

The field explorations were coordinated by Dames and Moore senior engineering technicians, who maintained detailed records of the subsurface soil conditions encountered, obtained representative soil samples for examination and subsequent laboratory testing, classified the soils by both visual and textural examination, and monitored the field permeability tests. Boring location grid coordinates and ground surface elevations were surveyed and staked by Kaiser Engineers Hanford before the start of the field explorations.

End-of-hole and open-hole falling head permeability tests were conducted at selected depths in each of the five borings drilled for the investigation. The field permeability tests were performed between the depths of 25 to 60 ft below the existing ground surface. Laboratory tests were performed on representative samples of the soils encountered to evaluate soil permeability. A description of the laboratory equipment and test procedures follow.

Field Test Methodology--Both end-of-hole and open-hole falling-head permeability tests were conducted at selected depths in each of the five borings. All end-of-hole permeability tests were run from the end of the 6-in. ID casing associated with the cable-tool drill rig. Before running the end-of-hole tests, the soils below the casing were saturated to the extent possible by allowing infiltration of water introduced into the casing for a minimum of 1/2 h.

All open-hole permeability tests were performed within the 5-ft zone directly below the depth of the end-of-hole test. After advancing the boring to the desired depth, pea gravel was introduced into the bottom of the hole to preclude caving of the sands into the boring as the casing was withdrawn to provide the desired 3- to 5-ft length of open hole. Before running the open-hole permeability tests, the soils surrounding the gravel-packed open hole were saturated to the extent possible by allowing infiltration of water introduced into the casing for a period of 15 to 30 min. Because of freezing weather conditions, warmed water was brought to the site at the start of

saturation for each end-of-hole test. Water in the tank was reported to have cooled to a near freezing condition by the time the open-hole tests were completed.

Laboratory Permeability Tests--Constant head permeability tests were performed on selected 3- or 6-in.-long saturated soil samples from each boring. The permeability tests were conducted in accordance with standard geotechnical test procedures.

Test Results--Results of the field and laboratory permeability tests performed for this investigation are presented in Table 5B2-1 and 5B2-2. The test depths presented for the field tests reflect the depth of the bottom of the test section of soil on which the falling-head permeability tests were conducted. It should be understood that the field tests provide an 'equivalent' or 'mean' permeability that is not specifically oriented in a horizontal or vertical direction; however, it is reasonable to generally assume that end-of-hole tests are influenced more by the vertical permeability of the soil being tested and that the open-hole tests are influenced more by the horizontal permeability of the soil surrounding the gravel-packed test section.

The equivalent hydraulic conductivities determined from the downhole falling-head permeability tests ranged from 1.5×10^{-3} cm/s to 2.9×10^{-1} cm/s, with a geometric mean value of 2.7×10^{-2} cm/s. The vertical hydraulic conductivities determined from the laboratory constant head permeability tests ranged from 1.2×10^{-4} cm/sec to 2.2×10^{-2} cm/s, with a geometric mean value of 2.0×10^{-3} cm/s.

REFERENCE

Dames and Moore, 1986, Report of Geotechnical Investigation, Proposed Shallow Land Disposal Site Hanford, Washington, Dames and Moore, Seattle, Washington.

Table 5B2-1. Field Permeability Test Results at Borings 85-1, 85-2, 85-3, 85-4, and 85-5, Conducted by Dames and Moore (modified after Dames and Moore 1986).

Boring number	Run number	Test depth (ft)	Type of test[a]	Equivalent hydraulic conductivity (cm/s)
85-1	1	30	EH	3.7×10^{-2}
85-1	2	35	OH	2.5×10^{-1}
85-1	3	35	OH	2.9×10^{-1}
85-2	1	35.5	EH	1.9×10^{-2}
85-2	2	40	OH	9.6×10^{-3}
85-2	3	40	OH	9.6×10^{-3}
85-3	1	55	EH	1.5×10^{-3}
85-3	2	60	OH	7.3×10^{-3}
85-4	1	25	EH	2.4×10^{-2}
85-4	2	30	OH	1.0×10^{-2}
85-4	3	30	OH	1.0×10^{-2}
85-5	1	40	EH	5.7×10^{-2}
85-5	2	45	OH	1.1×10^{-1}
85-5	3	45	OH	1.1×10^{-1}
				$\bar{K}_{eq} = 2.7 \times 10^{-2}$
				Range: 1.5×10^{-3} to 2.9×10^{-1}

[a]Falling head permeability test using 6-in.-ID drill casing.
EH = end-of-hole test.
OH = open-hole test with gravel pack to prevent caving.

Table 5B2-2. Laboratory Permeability Test Results for Borings 85-1, 85-2, 85-3, 85-4, and 85-5, Conducted by Dames and Moore (modified after Dames and Moore 1986).

Boring number	Sample depth (ft)	Material finer than No. 200 sieve (%)	Vertical hydraulic conductivity (cm/s)
85-1	20.5	5.5	5.3×10^{-3}
85-1	30.5	11.1	2.3×10^{-3}
85-1	33	16.7	4.9×10^{-4}
85-1	35.5	22.4	1.2×10^{-4}
85-1	40.5	12.1	1.5×10^{-3}
85-2	20.5	15.7	7.6×10^{-4}
85-2	35.5	9.4	2.5×10^{-3}
85-2	40.5	7.1	6.2×10^{-3}
85-3	20.5	7.8	3.4×10^{-3}
85-3	35.5	14.4	1.0×10^{-3}
85-3	45.5	22.7	4.0×10^{-4}
85-3	55.5	14.9	2.2×10^{-2}
85-4	25.5	8.8	1.6×10^{-3}
85-4	35.5	16.3	3.4×10^{-3}
85-5	25.5	7.3	4.5×10^{-3}
85-5	40.5	4.1	8.3×10^{-3}
			$\overline{K}_{eq} = 2.0 \times 10^{-3}$
			Range: 1.2×10^{-4} to 2.2×10^{-2}

APPENDIX 5B-3

HYDROLOGIC TEST DATA AND ANALYSES

This page intentionally left blank.

APPENDIX 5B-3

HYDROLOGIC TEST DATA AND ANALYSES

Four wells have been tested hydrologically at the Grout Treatment Facility since 1987: Wells 299-E25-22, 299-E25-32, and 299-E25-33. The types of tests conducted at these wells were step-drawdown and constant discharge. This appendix provides information about each test and discusses the test results.

The hydrologic tests were performed in wells that were constructed primarily for groundwater monitoring (water-level measurements) and groundwater sampling. This situation, coupled with the high transmissivities at the Grout Treatment Facility site, produced test results that were not optimum for quantifying aquifer properties. The well diameters were too small to accommodate pumps capable of creating the high flow rates needed for significant drawdowns. Drawdowns were generally less than 1 ft.

Discharge rates were measured by an in-line flowmeter or by timing the filling of a bucket of known volume. Drawdown and recovery data were measured and recorded with a transducer/data logger system and were verified regularly by electric or steel tape measurements. The transducers were 10 to 50 lbf/in^2 pressure transducers. The data loggers were Hermit SE1000s* marketed by In Situ, Inc.

Analyses for the aquifer test results were based on the Theis (1935) solution. The following basic assumptions apply to this method.

- The aquifer is infinite in areal extent.
- The aquifer is homogeneous, isotropic, and of uniform thickness.
- The potentiometric surface is horizontal before pumping.
- Water removed from storage is discharged instantaneously with a decline in head.
- The aquifer is pumped at a constant discharge rate.
- Well bore storage in the pumping well can be neglected.
- The pumping well screen fully penetrates the aquifer.

The assumptions of an isotropic aquifer and a fully penetrating well screen were not satisfied. Nevertheless, the analyses are still valuable in providing rough (conservative) estimates of the aquifer transmissivity.

The analyses were performed using the techniques presented in Lohman (1972). References to specific techniques presented by Lohman are given under each test.

---

*Hermit SE1000 is a trademark of In Situ, Incorporated.

AQUIFER TEST 299-E25-28

This test was conducted in March 1987. The diameter of the well (5 in.) limited the volume of discharge to about 50 gal/min. Drawdown from aquifer resistance was very small (virtually zero), which implies a relatively high transmissivity.

AQUIFER TEST 299-E25-22

Two types of tests were performed at the well; a step-drawdown test on August 28, 1987, and a constant discharge test on August 31, 1987 (Table 5B3-1). Recovery of water levels was monitored for the constant discharge test from August 31 to September 1, 1987 (Table 5B3-2). Insufficient drawdown for the step-drawdown test precluded analyzing the data to obtain a transmissivity value. The drawdown data during the pumping phase for the constant discharge test were influenced by well storage effects and, therefore, were not used for analysis.

Recovery data from the constant discharge test at well 299-E25-22 were analyzed for transmissivity. Background fluctuations that affected the data were removed by subtracting water-level fluctuations at well 299-E25-27 from the recovery data at well 299-E25-22. Pretest comparison of water-level changes in these two wells showed a close correspondence (Figure 5B3-1). Therefore, it was assumed that in-common groundwater trends and bariometric changes affecting water levels in well 299-E25-27 could be eliminated in well 299-E25-22 using this method.

The analysis results for the aquifer test only provided an estimate for aquifer parameters; i.e., the calculated transmissivity probably falls within an order of magnitude of the true value. The reason for an order-of-magnitude estimate is that several assumptions that are inherent in the analytical method were not satisfied. In particular, the aquifer is not homogenous and isotropic, the pumping well is partially penetrating rather than fully penetrating, the pumping rate varied during the test, and the rest results are affected by delayed yield. A number of these effects may be responsible for the change in slope in the data, as seen on Figure 5B3-2.

The pumping well was screened in the upper 25 ft of the unconfined aquifer and, therefore, was a partially penetrating well. The effect of the partial penetration was to increase the drawdown in the pumping well over what would occur for a well that was screened over the full saturated thickness of the aquifer. Calculating a transmissivity value using these data gives a value that is less than the true formation transmissivity. The drawdown curve from a partially penetrating well also may give the impression of a leaky semiconfined aquifer as a vertical flow component from the lower part of the aquifer becomes significant. The slope change seen on the drawdown curve may indicate this (Figure 5B3-2).

The effects of delayed yield may also be responsible for the change in slope in the recovery data about halfway through the test (Figure 5B3-2).

Table 5B3-1. Drawdown Data for the Constant Discharge Test at Well 299-E25-22 During the Pumping Phase on August 31, 1987. (sheet 1 of 2)

Discharge
(During Test)

Time (min)	Reading (gpm)
8:30	154
8:56	154.5
9:25	151.5
10:20	154
10:58	156.5

Test Data
(Pumping Phase)

(Time 0 begins on 08/31/87 at 07:40)

Elapsed Time (min)	Drawdown (ft)	Elapsed Time (min)	Drawdown (ft)	Elapsed Time (min)	Drawdown (ft)
0.0000	0.01	0.3166	1.30	5.0000	1.17
0.0033	0.01	0.3333	1.31	5.5000	1.17
0.0066	0.01	0.4167	1.31	6.0000	1.15
0.0099	0.01	0.5000	1.27	6.5000	1.15
0.0133	0.01	0.5833	1.23	7.0000	1.15
0.0166	0.01	0.6667	1.22	7.5000	1.17
0.0200	0.01	0.7500	1.21	8.0000	1.18
0.0233	0.01	0.8333	1.17	8.5000	1.16
0.0266	0.01	0.9167	1.17	9.0000	1.17
0.0300	0.01	1.0000	1.16	9.5000	1.18
0.0333	0.01	1.0833	1.13	10.0000	1.19
0.0500	0.01	1.1667	1.11	12.0000	1.17
0.0666	0.01	1.2500	1.13	14.0000	1.20
0.0833	0.01	1.3333	1.13	16.0000	1.20
0.1000	0.50	1.4166	1.14	18.0000	1.21
0.1166	0.79	1.5000	1.13	20.0000	1.22
0.1333	1.16	1.5833	1.13	22.0000	1.23
0.1500	1.39	1.6667	1.13	24.0000	1.25
0.1666	1.39	1.7500	1.16	26.0000	1.24
0.1833	1.38	1.8333	1.13	28.0000	1.25
0.2000	1.36	1.9167	1.15	30.0000	1.26
0.2166	1.34	2.0000	1.15	32.0000	1.27
0.2333	1.35	2.5000	1.15	34.0000	1.26
0.2500	1.33	3.0000	1.13	36.0000	1.26
0.2666	1.32	3.5000	1.13	38.0000	1.27
0.2833	1.31	4.0000	1.14	40.0000	1.28
0.3000	1.30	4.5000	1.16	42.0000	1.26

Table 5B3-1. Drawdown Data for the Constant Discharge Test at Well 299-E25-22 During the Pumping Phase on August 31, 1987. (sheet 2 of 2)

Elapsed Time (min)	Drawdown (ft)	Elapsed Time (min)	Drawdown (ft)	Elapsed Time (min)	Drawdown (ft)
44.0000	1.27	190.000	1.22	560.000	1.12
46.0000	1.27	200.000	1.23	570.000	1.11
48.0000	1.28	210.000	1.23	580.000	1.10
50.0000	1.27	220.000	1.22	590.000	1.13
52.0000	1.29	230.000	1.23	600.000	1.11
54.0000	1.27	240.000	1.21	610.000	1.13
56.0000	1.28	250.000	1.21	620.000	1.12
58.0000	1.28	260.000	1.22	630.000	1.12
60.0000	1.30	270.000	1.19	640.000	1.13
62.0000	1.28	280.000	1.19	650.000	1.13
64.0000	1.28	290.000	1.20	660.000	1.13
66.0000	1.30	300.000	1.19	670.000	1.14
68.0000	1.28	310.000	1.20	680.000	1.13
70.0000	1.29	320.000	1.18	690.000	1.13
72.0000	1.29	330.000	1.19	700.000	1.13
74.0000	1.27	340.000	1.18	710.000	1.14
76.0000	1.28	350.000	1.19	720.000	1.16
78.0000	1.30	360.000	1.17	730.000	1.17
80.0000	1.28	370.000	1.15	740.000	1.16
82.0000	1.28	380.000	1.16	750.000	1.16
84.0000	1.27	390.000	1.15	760.000	1.17
86.0000	1.28	400.000	1.17	770.000	1.17
88.0000	1.29	410.000	1.15	780.000	1.18
90.0000	1.30	420.000	1.18	790.000	1.18
92.0000	1.29	430.000	1.14	800.000	1.20
94.0000	1.28	440.000	1.16	810.000	1.18
96.0000	1.30	450.000	1.16	820.000	1.20
98.0000	1.30	460.000	1.13	830.000	1.20
100.000	1.29	470.000	1.14	840.000	1.19
110.000	1.27	480.000	1.13	850.000	1.20
120.000	1.26	490.000	1.15	860.000	1.23
130.000	1.25	500.000	1.13	870.000	1.24
140.000	1.25	510.000	1.12	880.000	1.25
150.000	1.26	520.000	1.13	890.000	1.22
160.000	1.23	530.000	1.12	900.000	1.22
170.000	1.24	540.000	1.14	910.000	1.21
180.000	1.22	550.000	1.13	920.000	1.22

Table 5B3-2. Recovery Data for the Constant Discharge Test at Well 299-E25-22 During the Pumping Phase on August 31, 1987. (sheet 1 of 2)

Discharge
(During Test)

Time (min)	Reading (gpm)
8:30	154
8:56	154.5
9:25	151.5
10:20	154
10:58	156.5

Test Data
(Recovery Phase)

(Time 0 begins on 08/31/87 at 23:10)

Elapsed Time (min)	Recovery (ft)	Elapsed Time (min)	Recovery (ft)	Elapsed Time (min)	Recovery (ft)
0.0000	1.20	0.3166	0.14	5.0000	0.08
0.0033	1.21	0.3333	0.14	5.5000	0.08
0.0066	1.20	0.4167	0.13	6.0000	0.08
0.0099	1.22	0.5000	0.13	6.5000	0.08
0.0133	1.21	0.5833	0.13	7.0000	0.08
0.0166	1.21	0.6667	0.13	7.5000	0.08
0.0200	1.21	0.7500	0.12	8.0000	0.08
0.0233	1.21	0.8333	0.12	8.5000	0.08
0.0266	1.22	0.9167	0.12	9.0000	0.08
0.0300	1.20	1.0000	0.12	9.5000	0.08
0.0333	1.21	1.0833	0.11	10.0000	0.07
0.0500	1.22	1.1667	0.11	12.0000	0.07
0.0666	1.23	1.2500	0.11	14.0000	0.07
0.0833	1.22	1.3333	0.11	16.0000	0.07
0.1000	0.73	1.4166	0.10	18.0000	0.07
0.1166	0.43	1.5000	0.10	20.0000	0.07
0.1333	0.19	1.5833	0.10	22.0000	0.07
0.1500	0.12	1.6667	0.10	24.0000	0.07
0.1666	0.14	1.7500	0.10	26.0000	0.07
0.1833	0.17	1.8333	0.10	28.0000	0.06
0.2000	0.17	1.9167	0.09	30.0000	0.06
0.2166	0.16	2.0000	0.09	32.0000	0.07
0.2333	0.15	2.5000	0.09	34.0000	0.06
0.2500	0.15	3.0000	0.09	36.0000	0.06
0.2666	0.14	3.5000	0.09	38.0000	0.06
0.2833	0.14	4.0000	0.08	40.0000	0.06
0.3000	0.14	4.5000	0.08	42.0000	0.06

Table 5B3-2. Recovery Data for the Constant Discharge Test at Well 299-E25-22 During the Pumping Phase on August 31, 1987. (sheet 2 of 2)

Elapsed Time (min)	Recovery (ft)	Elapsed Time (min)	Recovery (ft)	Elapsed Time (min)	Recovery (ft)
44.0000	0.06	72.0000	0.06	100.000	0.06
46.0000	0.06	74.0000	0.06	110.000	0.04
48.0000	0.06	76.0000	0.06	760.000	- 0.05
50.0000	0.06	78.0000	0.06	770.000	- 0.05
52.0000	0.07	80.0000	0.06	780.000	- 0.05
54.0000	0.06	82.0000	0.06	790.000	- 0.06
56.0000	0.07	84.0000	0.06	800.000	- 0.06
58.0000	0.06	86.0000	0.06	810.000	- 0.06
60.0000	0.06	88.0000	0.06	820.000	- 0.06
62.0000	0.06	90.0000	0.06	830.000	- 0.07
64.0000	0.06	92.0000	0.06	840.000	- 0.07
66.0000	0.06	94.0000	0.06	850.000	- 0.08
68.0000	0.06	96.0000	0.06	860.000	- 0.08
70.0000	0.06	98.0000	0.06	870.000	- 0.08

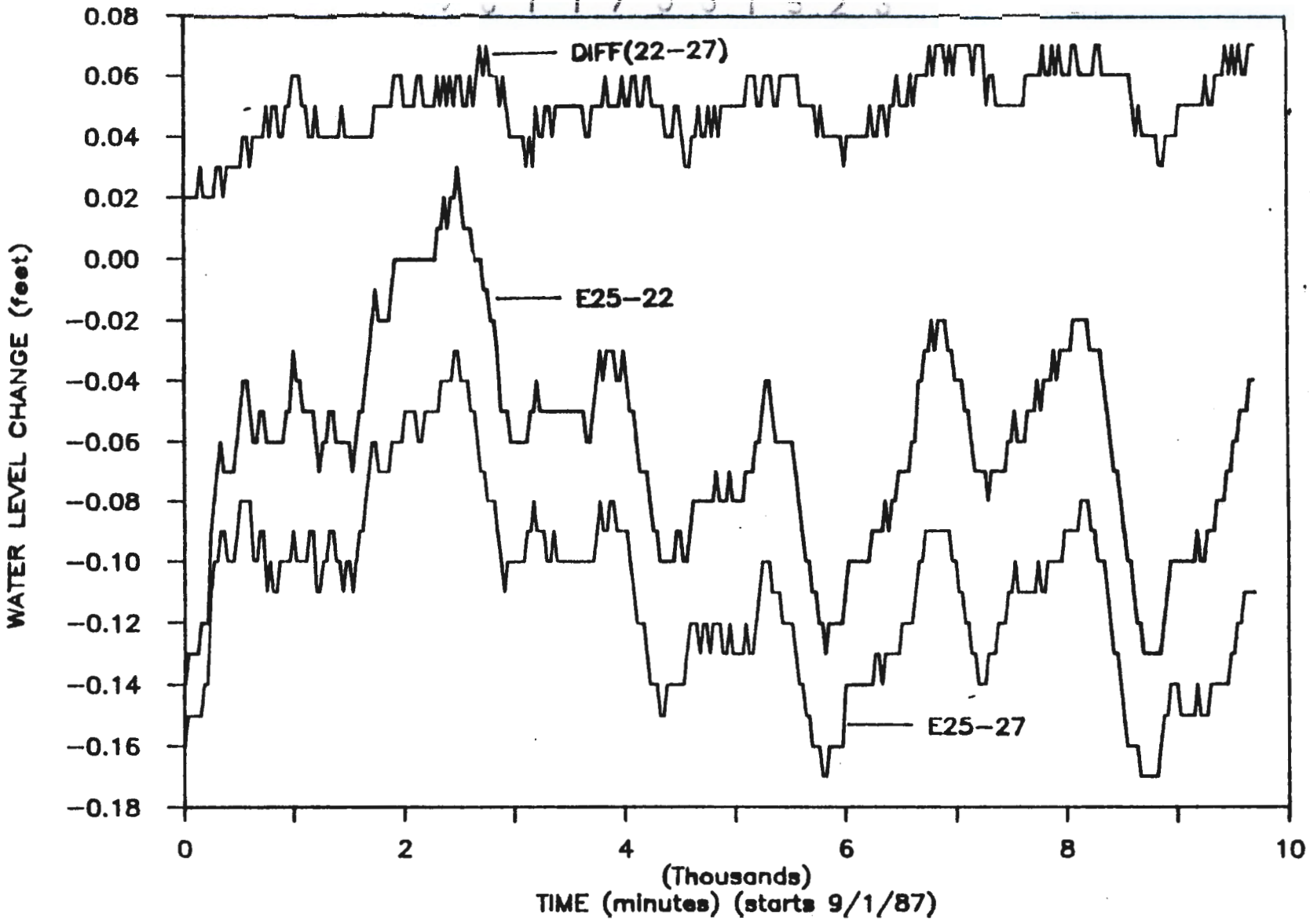


Figure 5B3-1. Graphical Representation of Comparison Between Background Water Levels in Wells 299-E5-22 Through 299-E25-27.

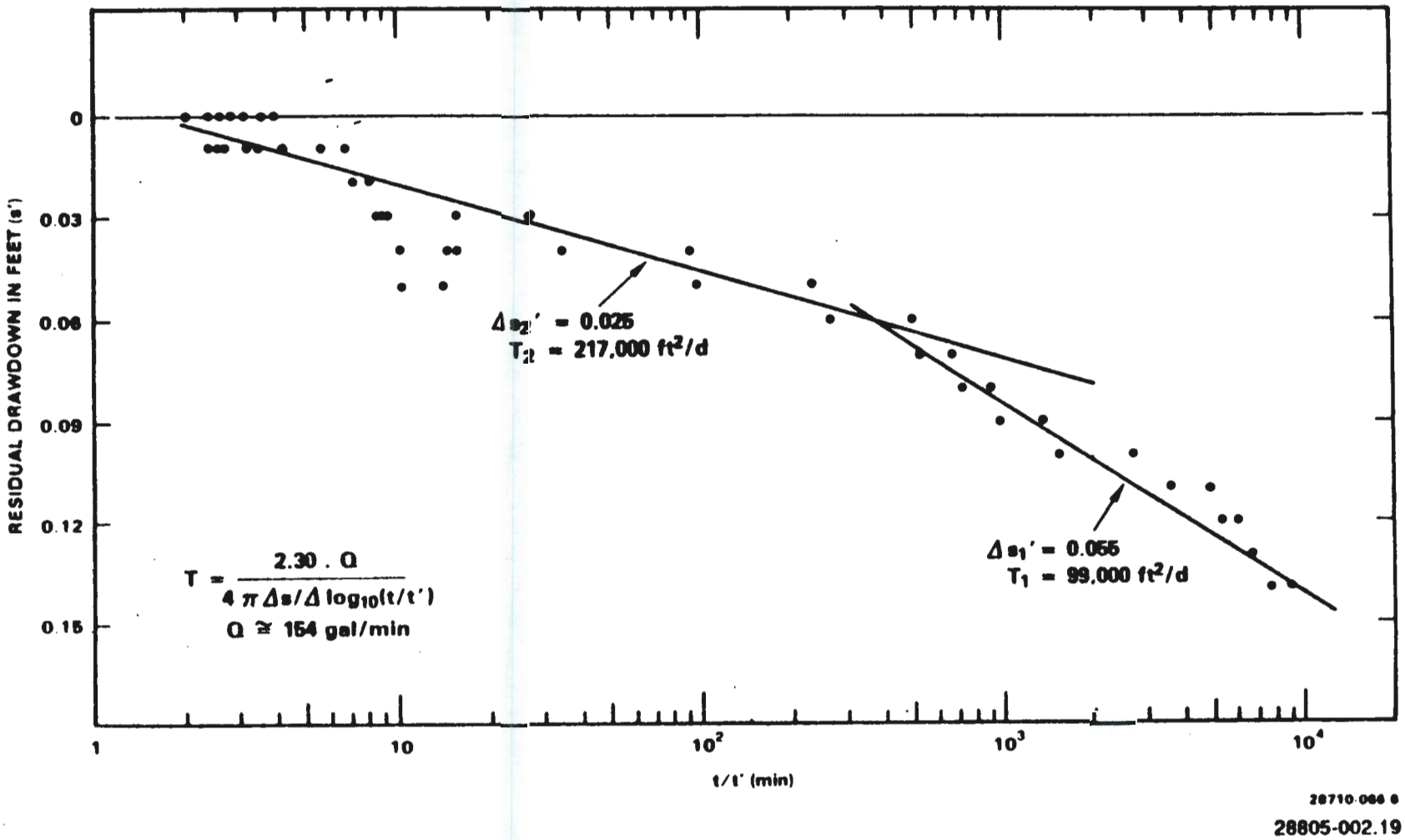


Figure 5B3-2. Corrected Recovery Data and Analysis from Well 299-E25-22 for Aquifer Test Conducted in Well 299-E25-22 from August 31 to September 1, 1987.

The decrease in slope may represent the intermediate phase of a delayed yield response.

The data also were affected by a variation in the rate of discharge during the test. This is especially evident when comparing Figure 5B3-3, which shows the drawdown data during the pumping phase, with Figure 5B3-4, which shows the variation in discharge with time. During the test the maximum variation in discharge was 10 gal/min. Some of the 'scatter' of the data around the match lines in Figure 5B3-2 is probably from discharge variability. This scatter also may be due to aquifer heterogeneities.

The actual 'raw' data are listed in Tables 5B3-1 and 5B3-2 for the drawdown and recovery periods for well 299-E25-22. Figures 5B3-3 and 5B3-5 show the drawdown for the pumping period. Figure 5B3-5 only shows the drawdown for the first minute. Table 5B3-3 lists the data used to compare diurnal fluctuations in the two wells. Figure 5B3-3 lists the data used to compare diurnal fluctuations in the two wells. Figure 5B3-1 shows this relationship graphically.

The recovery data were analyzed by applying the Cooper-Jacob straight-line method (Cooper and Jacob 1946) to the recovery data set. Residual drawdown was plotted against t/t' (Figure 5B3-2). Analysis of the data indicates that the transmissivity ranges from approximately 100,000 ft^2/d to 200,000 ft^2/day in the aquifer. Related test information is given in the following.

Pumping well:

Identification	Well 299-E-22
Open interval:	265 to 295 ft below surface
Screen:	8-in. telescoping 50 slot, 285 to 295 ft 10 slot, 265 to 285 ft
Static water level:	Approximately 268 ft below top of casing
Discharge rate:	Average 152 gal/min, ranging from 147 to 157 gal/min
Duration of pumping:	15.5 h
Pump:	30 hp submersible
Maximum drawdown:	1.2 to 1.3 ft.

Observation wells:

No quantifiable responses to pumping or recovery were recorded at the observation wells because of the influences of diurnal effects, and the

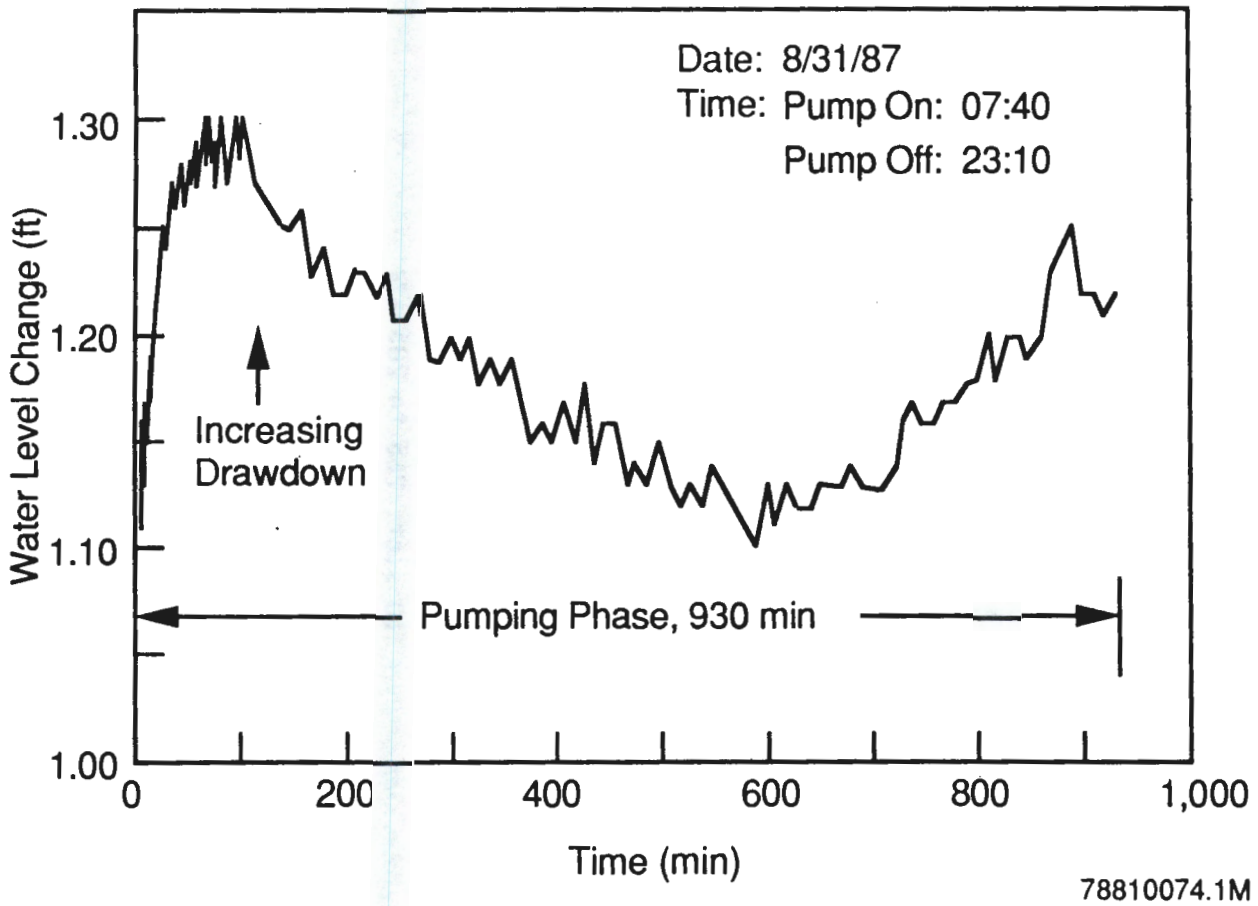


Figure 5B3-3. Water Level Changes at Well 299-E25-22 While Pumping This Well at 152 gal/min on August 31, 1987.

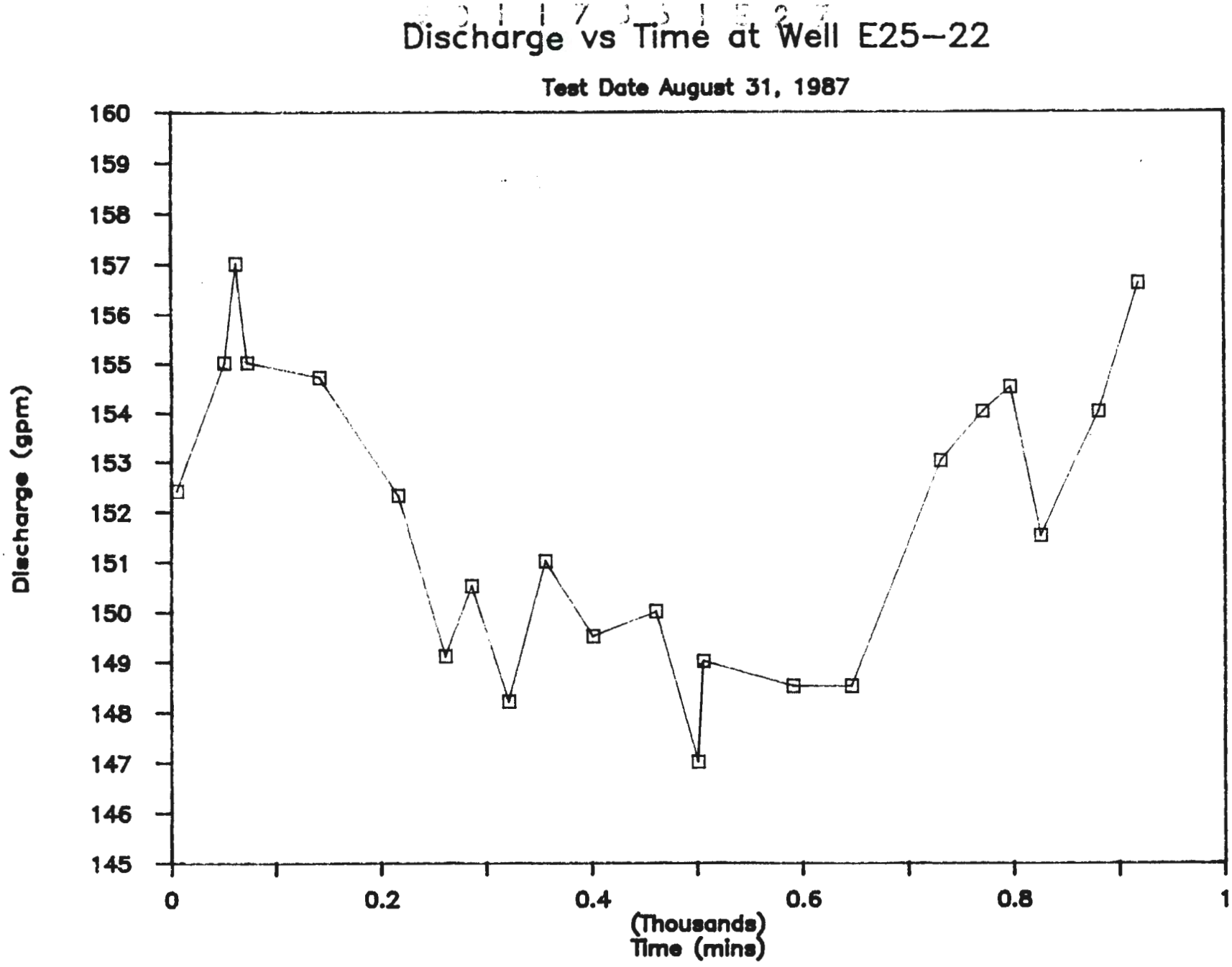


Figure 5B3-4. Drawdown Versus Time for Well 299-E25-22 During the August 31, 1987 Constant Discharge Test.

Table 5B3-3. Comparison Between Background Water Levels in Wells 299-E25-22 and 299-E25-27. (sheet 1 of 3)

Time 0 starts on 09/01/87 at 16:00

TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27
0	-0.14	-0.16	0.02	1290	-0.06	-0.1	0.04	2580	0.01	-0.04	0.05
30	-0.13	-0.15	0.02	1320	-0.05	-0.09	0.04	2610	0.01	-0.05	0.06
60	-0.13	-0.15	0.02	1350	-0.05	-0.09	0.04	2640	0	-0.05	0.05
90	-0.13	-0.15	0.02	1380	-0.06	-0.1	0.04	2670	0	-0.06	0.06
120	-0.13	-0.15	0.02	1410	-0.06	-0.1	0.04	2700	0	-0.07	0.07
150	-0.12	-0.15	0.03	1440	-0.06	-0.11	0.05	2730	-0.01	-0.07	0.06
180	-0.12	-0.14	0.02	1470	-0.06	-0.1	0.04	2760	-0.01	-0.08	0.07
210	-0.12	-0.14	0.02	1500	-0.06	-0.1	0.04	2790	-0.02	-0.08	0.06
240	-0.09	-0.11	0.02	1530	-0.07	-0.11	0.04	2820	-0.02	-0.08	0.06
270	-0.08	-0.1	0.02	1560	-0.06	-0.1	0.04	2850	-0.03	-0.09	0.06
300	-0.07	-0.1	0.03	1590	-0.05	-0.09	0.04	2880	-0.05	-0.1	0.05
330	-0.06	-0.09	0.03	1620	-0.05	-0.09	0.04	2910	-0.05	-0.11	0.06
360	-0.07	-0.09	0.02	1650	-0.04	-0.08	0.04	2940	-0.05	-0.1	0.05
390	-0.07	-0.1	0,03	1680	-0.03	-0.07	0.04	2970	-0.06	-0.1	0.04
420	-0.07	-0.1	0.03	1710	-0.02	-0.06	0.04	3000	-0.06	-0.1	0.04
450	-0.07	-0.1	0.03	1740	-0.01	-0.06	0.05	3030	-0.06	-0.1	0.04
480	-0.06	-0.09	0.03	1770	-0.02	-0.07	0.05	3060	-0.06	-0.1	0.04
510	-0.05	-0.08	0.03	1800	-0.02	-0.07	0.05	3090	-0.06	-0.1	0.04
540	-0.04	-0.08	0.04	1830	-0.02	-0.07	0.05	3120	-0.06	-0.09	0.03
570	-0.04	-0.08	0.04	1860	-0.02	-0.07	0.05	3150	-0.05	-0.09	0.04
600	-0.05	-0.08	0.03	1890	-0.01	-0.06	0.05	3180	-0.05	-0.08	0.03
630	-0.06	-0.1	0.04	1920	0	-0.06	0.06	3210	-0.04	-0.09	0.05
660	-0.06	-0.1	0.04	1950	0	-0.06	0.06	3240	-0.05	-0.09	0.04
690	-0.05	-0.09	0.04	1980	0	-0.06	0.06	3270	-0.05	-0.09	0.04
720	-0.05	-0.09	0.04	2010	0	-0.05	0.05	3300	-0.05	-0.1	0.05
750	-0.06	-0.11	0.05	2040	0	-0.05	0.05	3330	-0.05	-0.1	0.05
780	-0.06	-0.1	0.04	2070	0	-0.05	0.05	3360	-0.05	-0.09	0.04
810	-0.06	-0.11	0.05	2100	0	-0.05	0.05	3390	-0.05	-0.1	0.05
840	-0.06	-0.11	0.05	2130	0	-0.06	0.06	3420	-0.05	-0.1	0.05
870	-0.06	-0.1	0.04	2160	0	-0.06	0.06	3450	-0.05	-0.1	0.05
900	-0.06	-0.1	0.04	2190	0	-0.05	0.05	3480	-0.05	-0.1	0.05
930	-0.05	-0.1	0.05	2220	0	-0.05	0.05	3510	-0.05	-0.1	0.05
960	-0.05	-0.1	0.05	2250	0	-0.05	0.05	3540	-0.05	-0.1	0.05
990	-0.03	-0.09	0.06	2280	0	-0.05	0.05	3570	-0.05	-0.1	0.05
1020	-0.04	-0.1	0.06	2310	0.01	-0.05	0.06	3600	-0.05	-0.1	0.05
1050	-0.04	-0.1	0.06	2340	0.01	-0.04	0.05	3630	-0.05	-0.1	0.05
1080	-0.05	-0.1	0.05	2370	0.02	-0.04	0.06	3660	-0.06	-0.1	0.04
1110	-0.05	-0.1	0.05	2400	0.01	-0.04	0.05	3690	-0.06	-0.1	0.04
1140	-0.05	-0.09	0.04	2430	0.02	-0.04	0.06	3720	-0.05	-0.1	0.05
1170	-0.05	-0.09	0.04	2460	0.02	-0.03	0.05	3750	-0.04	-0.09	0.05
1200	-0.06	-0.11	0.05	2490	0.03	-0.03	0.06	3780	-0.03	-0.08	0.05
1230	-0.07	-0.11	0.04	2520	0.02	-0.04	0.06	3810	-0.04	-0.09	0.05
1260	-0.06	-0.1	0.04	2550	0.01	-0.04	0.05	3840	-0.03	-0.09	0.06

9 0 1 1 1 7 8 6 1 5 2 8

Table 5B3-3. Comparison Between Background Water Levels in Wells 299-E25-22 and 299-E25-27.
(sheet 2 of 3)

TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27
3870	-0.03	-0.08	0.05	5400	-0.06	-0.11	0.05	6930	-0.03	-0.09	0.06
3900	-0.03	-0.08	0.05	5430	-0.06	-0.12	0.06	6960	-0.03	-0.1	0.07
3930	-0.04	-0.09	0.05	5460	-0.06	-0.12	0.06	6990	-0.04	-0.1	0.06
3960	-0.04	-0.09	0.05	5490	-0.06	-0.12	0.06	7020	-0.04	-0.11	0.07
3990	-0.03	-0.09	0.06	5520	-0.06	-0.12	0.06	7050	-0.04	-0.11	0.07
4020	-0.04	-0.09	0.05	5550	-0.07	-0.13	0.06	7080	-0.05	-0.12	0.07
4050	-0.05	-0.1	0.05	5580	-0.08	-0.14	0.06	7110	-0.05	-0.12	0.07
4080	-0.05	-0.11	0.06	5610	-0.09	-0.14	0.05	7140	-0.06	-0.13	0.07
4110	-0.06	-0.12	0.06	5640	-0.1	-0.15	0.05	7170	-0.07	-0.13	0.06
4140	-0.07	-0.12	0.05	5670	-0.1	-0.15	0.05	7200	-0.07	-0.14	0.07
4170	-0.07	-0.12	0.05	5700	-0.11	-0.16	0.05	7230	-0.07	-0.14	0.07
4200	-0.07	-0.13	0.06	5730	-0.11	-0.16	0.05	7260	-0.07	-0.14	0.07
4230	-0.08	-0.14	0.06	5760	-0.12	-0.16	0.04	7290	-0.08	-0.13	0.05
4260	-0.09	-0.14	0.05	5790	-0.12	-0.17	0.05	7320	-0.07	-0.13	0.06
4290	-0.09	-0.14	0.05	5820	-0.13	-0.17	0.04	7350	-0.07	-0.13	0.06
4320	-0.1	-0.15	0.05	5850	-0.12	-0.16	0.04	7380	-0.07	-0.12	0.05
4350	-0.1	-0.15	0.05	5880	-0.12	-0.16	0.04	7410	-0.07	-0.12	0.05
4380	-0.1	-0.14	0.04	5910	-0.12	-0.16	0.04	7440	-0.07	-0.12	0.05
4410	-0.1	-0.14	0.04	5940	-0.12	-0.16	0.04	7470	-0.06	-0.11	0.05
4440	-0.1	-0.14	0.04	5970	-0.12	-0.16	0.04	7500	-0.06	-0.11	0.05
4470	-0.09	-0.14	0.05	6000	-0.11	-0.14	0.03	7530	-0.05	-0.1	0.05
4500	-0.09	-0.14	0.05	6030	-0.1	-0.14	0.04	7560	-0.06	-0.11	0.05
4530	-0.1	-0.14	0.04	6060	-0.1	-0.14	0.04	7590	-0.06	-0.11	0.05
4560	-0.1	-0.13	0.03	6090	-0.1	-0.14	0.04	7620	-0.06	-0.11	0.05
4590	-0.09	-0.12	0.03	6120	-0.1	-0.14	0.04	7650	-0.05	-0.11	0.06
4620	-0.08	-0.12	0.04	6150	-0.1	-0.14	0.04	7680	-0.05	-0.11	0.06
4650	-0.08	-0.12	0.04	6180	-0.1	-0.14	0.04	7710	-0.05	-0.11	0.06
4680	-0.08	-0.13	0.05	6210	-0.1	-0.14	0.04	7740	-0.04	-0.1	0.06
4710	-0.08	-0.12	0.04	6240	-0.09	-0.14	0.05	7770	-0.05	-0.11	0.06
4740	-0.08	-0.12	0.04	6270	-0.09	-0.13	0.04	7800	-0.04	-0.11	0.07
4770	-0.08	-0.13	0.05	6300	-0.09	-0.13	0.04	7830	-0.04	-0.1	0.06
4800	-0.08	-0.12	0.04	6330	-0.09	-0.14	0.05	7860	-0.04	-0.1	0.06
4830	-0.07	-0.12	0.05	6360	-0.08	-0.13	0.05	7890	-0.03	-0.1	0.07
4860	-0.08	-0.12	0.04	6390	-0.09	-0.13	0.04	7920	-0.04	-0.1	0.06
4890	-0.08	-0.13	0.05	6420	-0.08	-0.13	0.05	7950	-0.03	-0.1	0.07
4920	-0.08	-0.13	0.05	6450	-0.08	-0.13	0.05	7980	-0.03	-0.09	0.06
4950	-0.07	-0.12	0.05	6480	-0.07	-0.13	0.06	8010	-0.03	-0.09	0.06
4980	-0.08	-0.13	0.05	6510	-0.07	-0.12	0.05	8040	-0.03	-0.09	0.06
5010	-0.08	-0.13	0.05	6540	-0.07	-0.12	0.05	8070	-0.02	-0.09	0.07
5040	-0.08	-0.13	0.05	6570	-0.07	-0.12	0.05	8100	-0.02	-0.09	0.07
5070	-0.08	-0.13	0.05	6600	-0.06	-0.12	0.06	8130	-0.02	-0.08	0.06
5100	-0.07	-0.12	0.05	6630	-0.06	-0.11	0.05	8160	-0.02	-0.08	0.06
5130	-0.07	-0.13	0.06	6660	-0.04	-0.1	0.06	8190	-0.02	-0.08	0.06
5160	-0.07	-0.13	0.06	6690	-0.04	-0.1	0.06	8220	-0.03	-0.09	0.06
5190	-0.06	-0.12	0.06	6720	-0.03	-0.09	0.06	8250	-0.03	-0.09	0.06
5220	-0.06	-0.11	0.05	6750	-0.03	-0.09	0.06	8280	-0.03	-0.1	0.07
5250	-0.05	-0.1	0.05	6780	-0.02	-0.09	0.07	8310	-0.03	-0.1	0.07
5280	-0.04	-0.1	0.06	6810	-0.03	-0.09	0.06	8340	-0.04	-0.1	0.06
5310	-0.04	-0.1	0.06	6840	-0.02	-0.09	0.07	8370	-0.05	-0.11	0.06
5340	-0.05	-0.11	0.06	6870	-0.02	-0.09	0.07	8400	-0.06	-0.12	0.06
5370	-0.06	-0.11	0.05	6900	-0.02	-0.09	0.07	8430	-0.07	-0.13	0.06

Table 5B3-3. Comparison Between Background Water Levels in Wells 299-E25-22 and 299-E25-27. (sheet 3 of 3)

TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27	TIME (min)	E25-22 W.L. (ft)	E25-27 W.L. (ft)	E25-22 MINUS E25-27
8460	-0.07	-0.13	0.06	8880	-0.12	-0.15	0.03	9300	-0.09	-0.14	0.05
8490	-0.08	-0.14	0.06	8910	-0.11	-0.15	0.04	9330	-0.09	-0.14	0.05
8520	-0.09	-0.15	0.06	8940	-0.1	-0.14	0.04	9360	-0.08	-0.14	0.06
8550	-0.1	-0.16	0.06	8970	-0.1	-0.14	0.04	9390	-0.08	-0.14	0.06
8580	-0.1	-0.16	0.06	9000	-0.1	-0.14	0.04	9420	-0.08	-0.14	0.06
8610	-0.11	-0.16	0.05	9030	-0.1	-0.15	0.05	9450	-0.07	-0.14	0.07
8640	-0.12	-0.16	0.04	9060	-0.1	-0.15	0.05	9480	-0.07	-0.13	0.06
8670	-0.12	-0.16	0.04	9090	-0.1	-0.15	0.05	9510	-0.06	-0.13	0.07
8700	-0.13	-0.17	0.04	9120	-0.1	-0.15	0.05	9540	-0.06	-0.12	0.06
8730	-0.13	-0.17	0.04	9150	-0.1	-0.15	0.05	9570	-0.05	-0.12	0.07
8760	-0.13	-0.17	0.04	9180	-0.09	-0.14	0.05	9600	-0.05	-0.11	0.06
8790	-0.13	-0.17	0.04	9210	-0.1	-0.15	0.05	9630	-0.05	-0.11	0.06
8820	-0.13	-0.17	0.04	9240	-0.1	-0.15	0.05	9660	-0.04	-0.11	0.07
8850	-0.13	-0.16	0.03	9270	-0.09	-0.15	0.06	9690	-0.04	-0.11	0.07

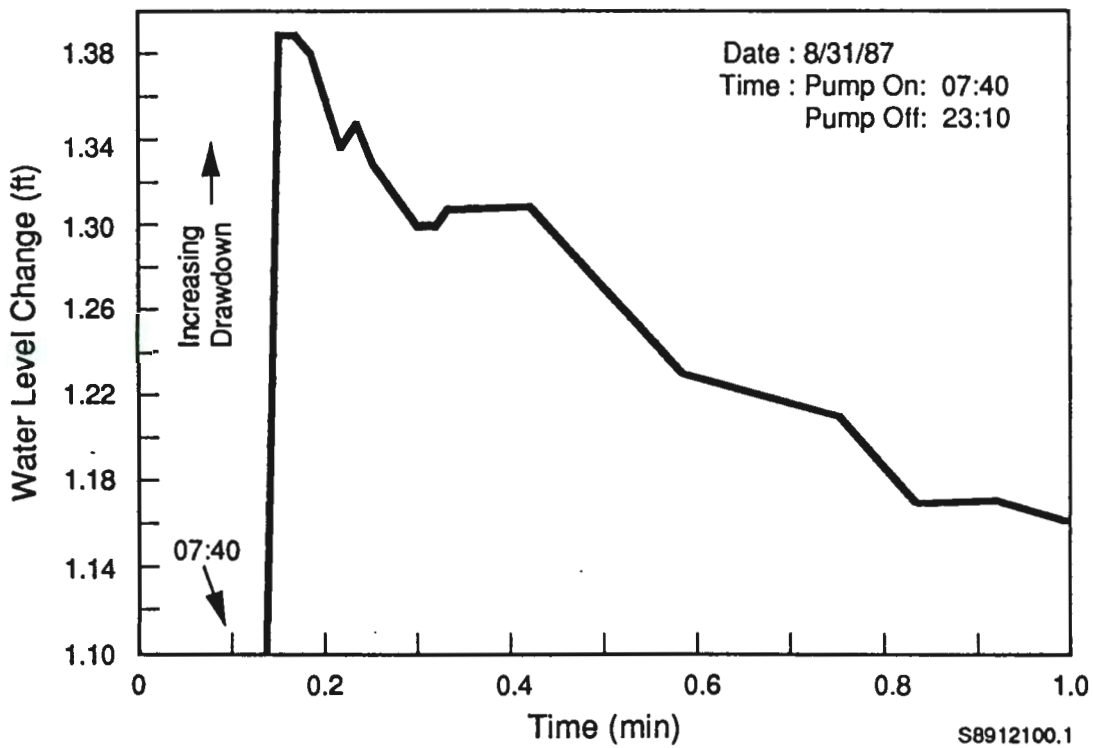


Figure 5B3-5. Water-Level Changes at Well 299-E25-22 For the First Minute While Pumping This Well on August 31, 1987.

distance of the wells from the pumping well; i.e., they were situated outside the cone of influence.

AQUIFER TESTS 299-E25-32 AND 299-325-33

Analyses from these aquifer tests are not yet complete. Qualitatively the results imply very high transmissivities. Drawdowns in wells 299-E25-32 and 299-E25-33 were about 1 ft while pumping at rates of 390 and 370 gal/min, respectively. Refer to Section 5.4.4.3 for further information. The preliminary results from these tests are planned to be completed by March 1, 1990.

REFERENCES

Cooper, H. H. and C. E. Jacob, 1946, "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History," *Transactions of the American Geophysical Union*, Vol. 27, No. 4, pp. 526-534.

Lohman, S. W., 1972, *Ground-Water Hydraulics*, Geological Survey Professional Paper 708, U.S. Geological Survey, Washington D.C.

Theis, C. V., 1935, "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage," *Transactions of the American Geophysical Union*, Vol. 16, pp. 519-524.

APPENDIX 5B-4

WATER-LEVEL ELEVATION DATA

This page intentionally left blank.

APPENDIX 5B-4

WATER-LEVEL ELEVATION DATA

Water levels were measured either with a steel tape, which has an accuracy of ± 0.02 ft, or with an electric tape, which has an accuracy of ± 0.05 ft. The casing elevations have been surveyed by Kaiser Engineers Hanford, licensed engineering surveyors.

Table 5B4-1. Water-Level Elevation Data. (sheet 1 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-03	689.73	20-May-86	289.98	399.75
		23-Jul-87	284.32	405.41
299-E25-04	659.39	20-May-86	252.35	407.04
		29-Dec-86	252.77	406.62
		17-Sep-87	252.05	407.34
		05-Nov-87	252.62	406.77
		11-Dec-87	252.99	406.40
		09-Feb-88	252.36	407.03
		29-Mar-88	252.51	406.88
		27-Apr-88	252.73	406.66
		30-Jun-88	252.41	406.98
		27-Jul-88	252.43	406.96
299-E25-06	658.31	20-May-86	252.18	406.13
299-E25-08	658.31	20-May-86	251.90	406.41
		21-Aug-86	252.09	406.22
299-E25-09	654.86	24-Mar-86	248.30	406.56
		29-Dec-86	248.94	405.92
		02-Apr-87	248.96	405.90
		23-Jul-87	248.20	406.66
		17-Sep-87	247.85	407.01
		05-Nov-87	248.77	406.09
		11-Dec-87	249.05	405.81
		09-Feb-88	248.58	406.28
		29-Mar-88	248.58	406.28
		27-Apr-88	248.92	405.94
		30-Jun-88	248.34	406.52
		27-Jul-88	248.43	406.43
299-E25-11	681.28	20-May-86	275.42	405.86
		23-Jul-87	275.61	405.67
		17-Sep-87	275.17	406.11
		09-Nov-87	275.78	405.50
		14-Dec-87	275.76	405.52
		09-Feb-88	275.38	405.90
		29-Mar-88	275.87	405.41
		27-Apr-88	275.67	405.61
		29-Jun-88	276.02	405.26
		27-Jul-88	275.61	405.67

Table 5B4-1. Water-Level Elevation Data. (sheet 2 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-18	679.05	24-Mar-86	273.22	405.83
		20-May-86	273.13	405.92
		11-Feb-87	274.04	405.01
		23-Jul-87	273.41	405.64
		17-Sep-87	273.00	406.05
		05-Nov-87	273.56	405.49
		14-Dec-87	273.71	405.34
		09-Feb-88	273.92	405.13
		29-Mar-88	273.52	405.53
		27-Apr-88	273.70	405.35
		29-Jun-88	273.65	405.40
		27-Jul-88	273.57	405.48
299-E25-19		20-May-86	271.37	405.83
299-E25-20	676.30	20-May-86	270.53	405.77
		11-Feb-87	271.43	404.87
		17-Sep-87	270.40	405.90
		05-Nov-87	270.99	405.31
		14-Dec-87	271.13	405.17
		09-Feb-88	271.31	404.99
		29-Mar-88	270.91	405.39
		27-Apr-88	270.95	405.35
		29-Jun-88	271.01	405.29
		27-Jul-88	270.95	405.35
299-E25-21		20-May-86	270.99	406.28
		30-Dec-86	271.46	405.81
		02-Nov-86	271.98	405.29
		04-Feb-87	271.47	405.08
		23-Jul-87	271.18	406.09
		14-Dec-87	271.61	405.66
299-E25-22	674.02	24-Mar-86	268.07	405.95
		20-May-86	268.19	405.83
		07-Oct-86	268.00	406.02
		11-Feb-87	269.08	404.94
		05-Nov-87	268.64	405.38
		14-Dec-87	268.78	405.24
		09-Feb-88	268.38	405.64
		29-Mar-88	268.53	405.49
		27-Apr-88	268.75	405.27
		30-Jun-88	268.48	405.54
		27-Jul-88	268.53	405.49

Table 5B4-1. Water-Level Elevation Data. (sheet 3 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-24	679.55	24-Mar-86	273.00	406.55
		20-May-86	273.00	406.55
		07-Nov-86	272.90	406.65
		11-Feb-87	274.12	405.43
		02-Apr-87	273.68	405.87
		23-Jul-87	273.25	406.30
		17-Sep-87	272.83	406.72
		05-Nov-87	273.74	405.81
		14-Dec-87	273.78	405.77
		09-Feb-88	273.86	405.69
		29-Mar-88	273.49	406.06
		27-Apr-88	273.67	405.88
		29-Jun-88	273.44	406.11
		27-Jul-88	273.45	406.10
299-E25-25	669.42	24-Mar-86	261.97	407.45
		20-May-86	262.03	407.39
		21-Aug-86	262.54	406.88
		09-Dec-86	262.84	406.58
		11-Feb-87	263.49	405.93
		02-Apr-87	262.54	406.88
		23-Jul-87	261.57	407.85
		17-Sep-87	261.72	407.70
		05-Nov-87	262.72	406.70
		10-Dec-87	262.78	406.64
		09-Feb-88	262.48	406.94
		27-Apr-88	262.89	406.53
		30-Jun-88	261.83	407.59
		27-Jul-88	262.18	407.24
299-E25-26	668.55	20-May-86	262.11	406.44
		21-Aug-86	262.26	406.29
		12-Feb-87	263.10	405.45
		23-Jul-87	261.98	406.57
		17-Sep-87	261.61	406.94
		05-Nov-87	262.40	406.15
		14-Dec-87	262.38	406.17
		09-Feb-88	262.44	406.11
		29-Mar-88	262.27	406.28
		27-Apr-88	262.55	406.00
		30-Jun-88	262.06	406.49
		27-Jul-88	262.14	406.41

Table 5B4-1. Water-Level Elevation Data. (sheet 4 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-27	676.10	24-Mar-86	269.62	406.48
		20-May-86	269.51	406.59
		21-Aug-86	269.74	406.36
		11-Feb-87	270.68	405.42
		02-Apr-87	270.15	405.95
		23-Jul-87	269.44	406.66
		17-Sep-87	269.03	407.07
		05-Nov-87	269.94	406.16
		14-Dec-87	269.98	406.12
		09-Feb-88	270.06	406.04
		29-Mar-88	269.82	406.28
		27-Apr-88	269.98	406.12
		30-Jun-88	269.59	406.51
		27-Jul-88	269.69	406.41
299-E25-28	662.44	24-Mar-86	260.60	401.84
		21-Aug-86	256.14	406.30
		02-Apr-87	256.29	406.15
		23-Jul-87	255.77	406.67
		17-Sep-87	255.43	407.01
		05-Nov-87	256.40	406.04
		10-Dec-87	256.56	405.88
		09-Feb-88	256.47	405.97
		29-Mar-88	256.21	406.23
		27-Apr-88	256.54	405.90
		30-Jun-88	255.98	406.46
		27-Jul-88	256.08	406.36
299-E25-29A	672.69	14-Oct-87	266.62	406.07
		16-Oct-87	266.71	405.98
		05-Nov-87	266.68	406.01
		10-Dec-87	266.98	405.71
		09-Feb-88	267.18	405.51
		29-Mar-88	266.67	406.02
		27-Apr-88	266.87	405.82
	672.84	30-Jun-88	266.89	405.95
		27-Jul-88	266.85	405.99

Table 5B4-1. Water-Level Elevation Data. (sheet 5 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-29B	672.62	14-Oct-87	266.55	406.07
		16-Oct-87	266.63	405.99
		05-Nov-87	266.78	405.84
		10-Dec-87	266.87	405.75
		09-Feb-88	267.08	405.54
		30-Jun-88	266.65	405.97
		27-Jul-88	266.69	405.93
299-E25-30A	678.02	14-Oct-87	271.92	406.10
		16-Oct-87	271.94	406.08
		05-Nov-87	272.19	405.83
		10-Dec-87	272.43	405.59
		09-Feb-88	272.31	405.71
	678.20	30-Jun-88	272.00	406.20
		27-Jul-88	272.10	406.10
299-E25-30B	677.93	14-Oct-87	271.89	406.04
		16-Oct-87	271.99	405.94
		05-Nov-87	272.14	405.79
		10-Dec-87	272.35	405.58
		09-Feb-88	272.23	405.70
		29-Mar-88	271.77	406.16
		27-Apr-88	272.22	405.71
	677.92	30-Jun-88	271.70	406.22
		27-Jul-88	271.83	406.09
299-E25-31	672.53	17-Sep-87	266.11	406.42
		05-Nov-87	266.78	405.75
		10-Dec-87	266.90	405.63
		09-Feb-88	266.93	405.60
		29-Mar-88	266.53	406.00
		27-Apr-88	266.90	405.63
		30-Jun-88	266.52	406.01
		27-Jul-88	266.51	406.02
299-E25-32A	669.19	30-Jun-88	262.15	407.04
		27-Jul-88	262.37	406.82
299-E25-32B	668.68	30-Jun-88	261.67	407.01
		27-Jul-88	261.89	406.79

Table 5B4-1. Water-Level Elevation Data. (sheet 6 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
299-E25-33	674.97	30-Jun-88	268.98	405.99
		27-Jul-88	269.03	405.94
299-E26-02	633.60	17-Sep-87	226.37	407.23
		05-Nov-87	227.38	406.22
		11-Dec-87	227.64	405.96
		09-Feb-88	227.55	406.05
		29-Mar-88	227.57	406.03
		27-Apr-88	227.54	406.06
		30-Jun-88	226.94	406.66
		27-Jul-88	227.00	406.60
699-37-43	690.58	24-Mar-86	284.54	406.04
		22-Jul-87	284.55	406.03
		05-Nov-87	284.30	406.28
		14-Dec-87	284.37	406.21
		09-Feb-88	284.58	406.00
		29-Mar-88	284.87	405.71
		27-Apr-88	284.36	406.22
		29-Jun-88	284.55	406.03
		27-Jul-88	284.38	406.20
699-39-39	536.65	20-Mar-86	117.11	419.54
		22-Jul-87	116.83	419.82
		08-Dec-87	124.03	412.62
		29-Jun-88	116.46	420.19
		27-Jul-88	121.31	415.34
699-42-40A	545.43	31-Dec-85	123.58	421.85
		20-Mar-86	120.54	424.89
		12-May-86	122.67	422.76
		05-Aug-86	121.20	424.23
		12-Dec-86	124.50	420.93
		22-Jul-87	120.28	425.15
		29-Jun-88	120.32	425.11
		27-Jul-88	121.66	423.77
699-42-40B	546.46	31-Dec-85	122.48	423.98
		20-Mar-86	122.19	424.27
		12-Dec-86	124.48	421.98
		22-Jul-87	121.64	424.82
		17-Sep-87	121.72	424.74
		05-Nov-87	124.08	422.38
		10-Dec-87	123.40	423.06
		09-Feb-88	121.17	425.29

Table 5B4-1. Water-Level Elevation Data. (sheet 7 of 7)

Well	Datum, ground level (ft above m.s.l.)	Date	Depth to water (ft below measuring point)	Elevation at water level (ft above m.s.l.)
699-42-40B (cont)		29-Mar-88	123.33	423.13
		27-Apr-88	123.69	422.77
		29-Jun-88	121.92	424.54
		27-Jul-88	122.71	423.75
699-43-42	564.48	19-Mar-86	143.61	420.87
		12-Dec-86	145.06	419.42
		22-Jul-87	143.10	421.38
		17-Sep-87	143.40	421.08
		05-Nov-87	144.59	419.89
		10-Dec-87	144.54	419.94
		09-Feb-88	143.64	420.84
		29-Mar-88	144.75	419.73
		27-Apr-88	144.98	419.50
		29-Jun-88	143.51	420.97
		27-Jul-88	144.14	420.34
699-45-42	577.33	19-Mar-86	158.92	418.41
		22-Jul-87	158.09	419.24
		08-Dec-87	158.76	418.57
		30-Jun-88	158.19	419.14
		27-Jul-88	157.90	419.43
699-47-46	580.14	19-Mar-86	173.42	406.72
		22-Jul-87	174.28	405.86
		08-Dec-87	173.56	406.58
		30-Jun-88	173.56	406.58
		27-Jul-88	173.39	406.75

APPENDIX 5B-5

BASELINE WATER-CHEMISTRY DATA COLLECTED BETWEEN SEPTEMBER 1985 AND JULY 1987

This page intentionally left blank.

9011735134

APPENDIX 5B-5

BASELINE WATER-CHEMISTRY DATA COLLECTED BETWEEN BETWEEN SEPTEMBER 1985 AND JULY 1987

Groundwater samples for an initial baseline and hydrochemical characterization were collected at the Grout Treatment Facility site by personnel from Pacific Northwest Laboratory through August 1987 from wells 299-E25-25 through 299-E25-28. All of these wells are referred to as baseline wells except 299-E25-25. This well is now one of the detection monitoring wells, even through it originally was constructed as part of the baseline system. Detection monitoring wells include 299-E25-25, 299-E25-29, 299-E25-31, 299-E25-32, and 299-E25-33. An additional well, 299-E25-30, was completed in October 1987 as part of the baseline system to monitor groundwater quality in the area of the cribs to the southwest of the waste management area. The detection monitoring wells were completed the last quarter of 1987 or the first and second quarters of 1988 (see Table 5-1 in Chapter 5.0). The baseline wells were completed in April or May 1985 except 299-E25-28 which was completed in April 1986, and 299-E25-30 as stated previously.

Three of the wells from the baseline and detection wells are dual-piezometer installations: 299-E25-29, 299-E25-30, and 299-E25-32. These wells are sampled from the 4-in. 'A' piezometer that is completed at the top of the uppermost aquifer. The 2-in. 'B' piezometer is completed at the bottom of the uppermost aquifer and is used primarily for water-level measurements.

Dedicated submersible pumps were used for purging and collecting groundwater samples from the baseline wells. In March 1988, a dedicated piston (Hydrostar*) pump replaced the submersible in 299-E25-25. Dedicated piston pumps were installed in all the detection monitoring wells. Dedicated submersible pumps were installed in the other baseline wells.

Laboratory analyses were conducted for all of the constituents in the following tables by U.S. Testing Company, except ^{99}Tc, which was analyzed by Pacific Northwest Laboratory. The tables in this appendix list groundwater sampling data available through August 1988. Tables 5B5-1 and 5B5-2 present summary information (pooled according to the constituent) for the baseline wells and the detection monitoring wells, respectively. In particular, these tables indicate which constituents exceeded the EPA drinking water standard if one is applicable. For many of the constituents, the EPA has not yet approved a drinking water standard.

Table 5B3-3 lists the well sampled, date of sampling, and concentrations of the constituent analyzed for constituent concentrations that exceeded the EPA drinking water standards. Some of the ^{106}Ru analysis results are listed as negative numbers. This occurred because a background value was subtracted from the measured concentration.

The dates that sampling occurred for the baseline and detection monitoring wells, through August 1988, are presented in Table 5B5-4.

---

*Hydrostar is a trademark of Instrumentation Northwest, Incorporated.

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 1 of 8)

Baseline Monitoring Wells

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
1,1,1,2-tetrachlorethane	PPB	10.0		3	3	0
1,1,1-trichloroethane	PPB	10.0	200.0	25	25	0
1,1,2,2-tetrachlorethane	PPB	10.0		3	3	0
1,1,2-trichloroethane	PPB	10.0		25	25	0
1,1-dichloroethane	PPB	10.0		3	3	0
1,1-dichloroethylene	PPB	10.0	7.0	3	3	3
1,1-dimethylhydrazine	PPB	3000.0		2	2	0
1,2,3,4-tetrachlorobenzene	PPB	10.0		15	15	0
1,2,3,5-tetrachlorobenzene	PPB	10.0		15	15	0
1,2,3-trichlorobenzene	PPB	10.0		15	15	0
1,2,3-trichloropropane	PPB	10.0		3	3	0
1,2,4,5-tetrachlorobenzene	PPB	10.0		15	15	0
1,2,4-trichlorobenzene	PPB	10.0		15	15	0
1,2-dibromo-3-chloropropane	PPB	10.0		3	3	0
1,2-dibromoethane	PPB	10.0		3	3	0
1,2-dichlorobenzene	PPB	10.0		15	15	0
1,2-dichloroethane	PPB	10.0	5.0	3	3	3
1,2-dichloropropane	PPB	10.0		3	3	0
1,2-dimethylhydrazine	PPB	3000.0		2	2	0
1,2-diphenylhydrazine	PPB	10.0		3	3	0
1,3,5-trichlorobenzene	PPB	10.0		15	15	0
1,3-dichlorobenzene	PPB	10.0		15	15	0
1,3-dichloropropene	PPB	10.0		3	3	0
1,4-dichloro-2-butene	PPB	10.0		3	3	0
1,4-dichlorobenzene	PPB	10.0		15	15	0
1,4-naphthoquinone	PPB	10.0		3	3	0
1-(o-chlorophenyl) thiourea	PPB	200.0		3	3	0
1-acetyl-2-thiourea	PPB	200.0		3	3	0
1-chloro-2,3-epoxypropane	PPB	10.0		3	3	0
1-naphthyl-2-thiourea	PPB	200.0		3	3	0
1-naphthylamine	PPB	10.0		3	3	0
2,3,4,6-tetrachlorophenol	PPB	10.0		3	3	0
2,4,5-T	PPB	2.0		3	3	0
2,4,5-TP silvex	PPB	2.0	10.0	15	15	0
2,4,5-trichlorophenol	PPB	50.0		3	3	0
2,4,6-trichlorophenol	PPB	10.0		3	3	0
2,4-D	PPB	2.0	100.0	15	15	0
2,4-dichlorophenol	PPB	10.0		3	3	0
2,4-dimethylphenol	PPB	10.0		3	3	0
2,4-dinitrophenol	PPB	50.0		3	3	0
2,4-dinitrotoluene	PPB	10.0		3	3	0
2,6-dichlorophenol	PPB	10.0		3	3	0
2,6-dinitrotoluene	PPB	10.0		3	3	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 2 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
2-acetylaminofluorene	PPB	10.0		3	3	0
2-chloroethyl vinyl ether	PPB	10.0		3	3	0
2-chloronaphthalene	PPB	10.0		3	3	0
2-chlorophenol	PPB	10.0		3	3	0
2-cyclohexyl-4,6-dinitrophenol	PPB	10.0		3	3	0
2-methyl-2-(methylthio) propio	PPB	10.0		3	3	0
2-methylaziridine	PPB	10.0		3	3	0
2-methyllactonitrile	PPB	10.0		3	3	0
2-naphthylamine	PPB	10.0		3	3	0
2-picoline	PPB	10.0		3	3	0
2-propyn-1-ol	PPB	8000.0		3	3	0
2-sec-butyl-4,6-dinitrophenol	PPB	10.0		3	3	0
3,3'-dichlorobenzidine	PPB	20.0		3	3	0
3,3'-dimethoxybenzidine	PPB	10.0		3	3	0
3,3'-dimethylbenzidine	PPB	10.0		3	3	0
3-chloropropionitrile	PPB	4000.0		3	3	0
3-methylcholanthrene	PPB	10.0		3	3	0
4,4'-methylenebis(2-chloroanil	PPB	10.0		3	3	0
4,6-dinitro-o-cresol and salts	PPB	10.0		3	3	0
4-aminobyphenyl	PPB	10.0		3	3	0
4-bromophenyl phenyl ether	PPB	10.0		3	3	0
4-nitrophenol	PPB	50.0		3	3	0
5-(aminomethyl)-3-isoxazolol	PPB	10.0		3	3	0
5-nitro-o-toluidine	PPB	10.0		3	3	0
7,12-dimethylbenz[a]anthracene	PPB	10.0		3	3	0
7H-dibenzo[c,g]carbazole	PPB	10.0		3	3	0
Acetone	PPB			2	0	0
Acetonitrile	PPB	3000.0		3	3	0
Acetophenone	PPB	10.0		3	3	0
Acrolein	PPB	10.0		3	3	0
Acrylamide	PPB	10000.0		3	3	0
Acrylonitrile	PPB	10.0		3	3	0
Aldrin	PPB	1.0		3	3	0
Allyl alcohol	PPB	3000.0		3	3	0
Alpha,alpha-dimethylphenethyla	PPB	10.0		3	3	0
Alpha-BHC	PPB	1.0	4.0	15	15	0
Aluminum	PPB	150.0		29	27	0
Aluminum, filtered	PPB	150.0		5	5	0
Americium-241	PCI/L	.1		4	4	0
Amitrole	PPB	10.0		3	3	0
Ammonium ion	PPB	50.0		28	25	0
Aniline	PPB	10.0		3	3	0
Antimony	PPB	100.0		28	28	0
Antimony, filtered	PPB	100.0		5	5	0
Aramite	PPB	10.0		3	3	0
Arochlor 1016	PPB	1.0		15	15	0
Arochlor 1221	PPB	1.0		15	15	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 3 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Arochlor 1232	PPB	1.0		15	15	0
Arochlor 1242	PPB	1.0		15	15	0
Arochlor 1248	PPB	1.0		15	15	0
Arochlor 1254	PPB	1.0		15	15	0
Arochlor 1260	PPB	1.0		15	15	0
Arsenic	PPB	5.0	50.0	29	10	0
Arsenic, filtered	PPB	5.0	50.0	5	1	0
Auramine	PPB	10.0		3	3	0
Barium	PPB	6.0	1000.0	29	0	0
Barium, filtered	PPB	6.0	1000.0	5	0	0
Benz[a]anthracene	PPB	10.0		3	3	0
Benz[c]acridine	PPB	10.0		3	3	0
Benzene	PPB	10.0	5.0	12	12	11
Benzene, dichloromethyl	PPB	10.0		3	3	0
Benzenethoil	PPB	10.0		3	3	0
Benzidine	PPB	10.0		3	3	0
Benzo[a]pyrene	PPB	10.0		3	3	0
Benzo[b]fluoranthene	PPB	10.0		3	3	0
Benzo[j]fluoranthene	PPB	10.0		3	3	0
Benzyl chloride	PPB	10.0		3	3	0
Berylliam	PPB	5.0		28	28	0
Beryllium, filtered	PPB	5.0		5	5	0
Beta-BHC	PPB	1.0	4.0	15	15	0
Bis(2-chloroethoxy) methane	PPB	10.0		3	3	0
Bis(2-chloroethyl) ether	PPB	10.0		3	3	0
Bis(2-chloroisopropyl)ether	PPB	10.0		3	3	0
Bis(2-ethylhexyl) phthalate	PPB	10.0		3	3	0
Bis(chloromethyl) ether	PPB	10.0		3	3	0
Bromide	PPB	1000.0		10	10	0
Bromoacetone	PPB	10.0		3	3	0
Bromoform	PPB	10.0	100.0	3	3	0
Butyl benzyl phthalate	PPB	10.0		3	3	0
Cadmium	PPB	2.0	10.0	28	28	0
Cadmium, filtered	PPB	2.0	10.0	5	5	0
Calcium	PPB	50.0		29	0	0
Calcium, filtered	PPB	50.0		5	0	0
Carbon disulfide	PPB	10.0		3	3	0
Carbon-14	PCI/L	20.0		4	0	0
Carbophenothion	PPB	2.0		3	3	0
Cesium-137	PCI/L	20.0	200.0	28	28	0
Chloral	PPB	3000.0		2	2	0
Chlordane	PPB	1.0		3	3	0
Chloride	PPB	500.0		28	0	0
Chlornaphazine	PPB	10.0		3	3	0
Chloroacetaldehyde	PPB	16000.0		3	3	0
Chloroalkyl ethers	PPB	10.0		3	3	0
Chlorobenzene	PPB	10.0		3	3	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 4 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Chlorobenzilate	PPB	100.0		5	5	0
Chloroform	PPB	10.0	100.0	16	16	0
Chloromethyl methyl ether	PPB	10.0		3	3	0
Chromium	PPB	10.0	50.0	29	26	2
Chromium, filtered	PPB	10.0	50.0	5	5	0
Chrysene	PPB	10.0		3	3	0
Citrus red	PPB	1000.0		3	3	0
Cobalt-60	PCI/L	22.5	100.0	28	28	0
Coliform bacteria	MPN	2.2	1.0	24	0	24
Conductivity, Laboratory	UMHO	1.0		4	0	0
Copper	PPB	10.0		28	28	0
Copper, filtered	PPB	10.0		5	4	0
Cresols	PPB	10.0		3	3	0
Crotonaldehyde	PPB	10.0		3	3	0
Cyanide	PPB	10.0		3	3	0
Cyanogen	PPB	3000.0		2	2	0
Cyanogen bromide	PPB	3000.0		2	2	0
Cyanogen chloride	PPB	3000.0		2	2	0
DDD	PPB	1.0		3	3	0
DDE	PPB	1.0		3	3	0
DDT	PPB	1.0		3	3	0
Delta-BHC	PPB	1.0	4.0	15	15	0
Di-n-butyl phthalate	PPB	10.0		3	3	0
Di-n-octyl phthalate	PPB	10.0		3	3	0
Di-n-propylnitrosamine	PPB	10.0		3	3	0
Dibenz[a,h]acridine	PPB	10.0		3	3	0
Dibenz[a,h]anthracene	PPB	10.0		3	3	0
Dibenz[a,j]acridine	PPB	10.0		3	3	0
Dibenzo[a,e]pyrene	PPB	10.0		3	3	0
Dibenzo[a,h]pyrene	PPB	10.0		3	3	0
Dibenzo[a,i]pyrene	PPB	10.0		3	3	0
Dibromomethane	PPB	10.0		3	3	0
Dichlorodifluoromethane	PPB	10.0		3	3	0
Dichloropropanol	PPB	3000.0		2	2	0
Dieldrin	PPB	1.0		3	3	0
Diethyl phthalate	PPB	10.0		3	3	0
Diethylarsine	PPB	10.0		3	3	0
Diethylstilbesterol	PPB	200.0		3	3	0
Dihydrosafrole	PPB	10.0		3	3	0
Dimethoate	PPB	5.0		3	2	0
Dimethyl phthalate	PPB	10.0		3	3	0
Dinitrobenzene	PPB	10.0		3	3	0
Dioxane	PPB	500.0		12	12	0
Dioxin	PPB	.1		1	0	0
Diphenylamine	PPB	10.0		3	3	0
Disulfoton	PPB	2.0		3	3	0
Endosulfan I	PPB	1.0		3	3	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 5 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Endosulfan II	PPB	1.0		3	3	0
Endrin	PPB	1.0	.2	15	15	14
Ethyl carbamate	PPB	5000.0		3	3	0
Ethyl cyanide	PPB	3000.0		3	3	0
Ethyl methacrylate	PPB	3000.0		3	3	0
Ethyl methanesulfonate	PPB	10.0		3	3	0
Ethylene glycol	PPB	10000.0		1	1	0
Ethylene oxide	PPB	3000.0		3	3	0
Ethyleneimine	PPB	10.0		3	3	0
Ethylenethiourea	PPB	200.0		3	3	0
Fluoranthene	PPB	10.0		3	3	0
Fluoride	PPB	500.0	4000.0	28	23	0
Fluoroacetic acid	PPB	3000.0		2	2	0
Formalin	PPB	500.0		12	12	0
Gamma-BHC	PPB	1.0	4.0	15	15	0
Glycidylaldehyde	PPB	3000.0		2	2	0
Gross alpha	PCI/L	4.0	15.0	24	23	0
Gross beta	PCI/L	8.0	50.0	24	12	0
Heptachlor	PPB	1.0		3	3	0
Heptchlor epoxide	PPB	1.0		3	3	0
Hexachlorobenzene	PPB	10.0		15	15	0
Hexachlorobutadiene	PPB	10.0		3	3	0
Hexachlorocyclopentadiene	PPB	10.0		3	3	0
Hexachloroethane	PPB	10.0		3	3	0
Hexachlorophene	PPB	10.0		15	15	0
Hexachloropropene	PPB	10.0		6	6	0
Hexone	PPB	10.0		1	1	0
Hydrazine	PPB	3000.0		3	3	0
Hydrazine, low DL	PPB	30.0		2	2	0
Hydrogen sulfide	PPB	10.0		3	3	0
Indeno(1,2,3-cd)pyrene	PPB	10.0		3	3	0
Iodine-129	PCI/L	15.0		4	4	0
Iodomethane	PPB	10.0		3	3	0
Iron	PPB	50.0		29	6	0
Iron, filtered	PPB	50.0		5	5	0
Isobutyl alcohol	PPB	3000.0		3	3	0
Isosafrole	PPB	10.0		3	3	0
Kerosene	PPB	10000.0		15	15	0
Lead	PPB	30.0		3	3	0
Lead (graphite furnace)	PPB	5.0	50.0	26	25	0
Lead, filtered	PPB	5.0	50.0	5	5	0
Magnesium	PPB	50.0		20	0	0
Magnesium, filtered	PPB	50.0		5	0	0
Maleic hydrizide	PPB	500.0		5	5	0
Malononitrile	PPB	10.0		3	3	0
Manganese	PPB	5.0		29	26	0
Manganese, filtered	PPB	5.0		5	5	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 6 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Melphalan	PPB	10.0		3	3	0
Mercury	PPB	.1	2.0	28	0	0
Mercury, filtered	PPB	.1	2.0	5	0	0
Methacrylonitrile	PPB	10.0		3	3	0
Methanethiol	PPB	10.0		3	3	0
Methapyrilene	PPB	10.0		3	3	0
Metholonyl	PPB	10.0		3	3	0
Methoxychlor	PPB	3.0	100.0	15	15	0
Methyl bromide	PPB	10.0		3	3	0
Methyl chloride	PPB	10.0		3	3	0
Methyl ethyl ketone	PPB	10.0		25	25	0
Methyl hydrazine	PPB	3000.0		2	2	0
Methyl methacrylate	PPB	10.0		3	3	0
Methyl methanesulfonate	PPB	10.0		3	3	0
Methyl parathion	PPB	2.0		3	3	0
Methylene chloride	PPB	10.0		16	16	0
Methylthiouracil	PPB	10.0		3	3	0
N,N-diethylhydrazine	PPB	10.0		3	3	0
N-nitroso-N-methylurethane	PPB	10.0		3	3	0
N-nitrosodi-n-butylamine	PPB	10.0		3	3	0
N-nitrosodiethanolamine	PPB	10.0		3	3	0
N-nitrosodiethylamine	PPB	10.0		3	3	0
N-nitrosodimethylamine	PPB	10.0		3	3	0
N-nitrosomethylethylamine	PPB	10.0		3	3	0
N-nitrosomethylvinylamine	PPB	10.0		3	3	0
N-nitrosomorpholine	PPB	10.0		3	3	0
N-nitrosonornicotine	PPB	10.0		3	3	0
N-nitrosopiperidine	PPB	10.0		3	3	0
N-phenylthiourea	PPB	500.0		3	3	0
N-propylamine	PPB	10000.0		3	3	0
Naphthalene	PPB	10.0		15	15	0
Nickel	PPB	10.0		29	26	0
Nickel, filtered	PPB	10.0		5	5	0
Nicotinic acid	PPB	100.0		5	5	0
Nitrate	PPB	500.0	45000.0	28	0	0
Nitrite	PPB	1000.0		10	10	0
Nitrobenzine	PPB	10.0		3	3	0
Nitrosopyrrolidine	PPB	10.0		3	3	0
O,O,O-triethyl phosphorothioat	PPB	10.0		3	3	0
O-toluidine hydrochloride	PPB	10.0		3	3	0
Osmium	PPB	300.0		24	24	0
Osmium, filtered	PPB	300.0		2	2	0
P benzoquinone	PPB	10.0		3	3	0
P-chloro-m-cresol	PPB	10.0		3	3	0
P-chloroaniline	PPB	10.0		3	3	0
P-dimethylaminoazobenzene	PPB	10.0		3	3	0
P-nitroaniline	PPB	50.0		3	3	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 7 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Paraldegyde	PPB	3000.0		3	3	0
Parathion	PPB	2.0		3	3	0
Pentachlorobenzene	PPB	10.0		15	15	0
Pentachloroethane	PPB	10.0		3	3	0
Pentachloronitrobenzene	PPB	10.0		3	3	0
Pentachlorophenol	PPB	50.0		3	3	0
Perchloroethylene	PPB	10.0		25	25	0
Phenacetin	PPB	10.0		3	3	0
Phenol	PPB	10.0		15	15	0
Phenol, low DL	PPB	10.0		2	2	0
Phenylenediamine	PPB	10.0		3	3	0
Phosphate	PPB	1000.0		28	27	0
Phthalic acid esters	PPB	10.0		3	3	0
Plutonium-238	PCI/L	17.0		3	3	0
Plutonium-239,240	PCI/L	17.0		3	3	0
Potassium	PPB	100.0		29	0	0
Potassium, filtered	PPB	100.0		5	0	0
Pronamide	PPB	10.0		3	3	0
Pyridine	PPB	500.0		12	12	0
Radium	PCI/L	1.0	5.0	24	24	0
Reserpine	PPB	10.0		3	3	0
Resorcinol	PPB	10.0		3	3	0
Ruthenium-106	PCI/L	172.5	30.0	28	28	5
Safrol	PPB	10.0		3	3	0
Selenium	PPB	5.0	10.0	28	28	0
Selenium, filtered	PPB	5.0	10.0	5	5	0
Silver	PPB	10.0	50.0	28	28	0
Silver, filtered	PPB	10.0	50.0	5	5	0
Sodium	PPB	100.0		29	0	0
Sodium, filtered	PPB	100.0		5	0	0
Specific conductance	UMHO	1.0		43	0	0
Strontium	PPB	300.0		29	29	0
Strontium, filtered	PPB	300.0		5	5	0
Strontium-90	PCI/L	5.0	8.0	3	3	0
Strychnine	PPB	50.0		5	5	0
Sulfate	PPB	500.0		28	0	0
Sulfide	PPB	1000.0		3	3	0
Suspended solids	MG/L	5.0		6	0	0
Sym-trinitrobenzene	PPB	10.0		3	3	0
Technetium-99	PCI/L	15.0	900.0	8	8	0
Tetrachloromethane	PPB	10.0	5.0	25	25	24
Tetraethylpyrophosphate	PPB	100.0		3	3	0
Thallium	PPB	10.0		6	6	0
Thallium, filtered	PPB	10.0		5	5	0
Thiofanox	PPB	10.0		3	3	0
Thiourea	PPB	200.0		3	3	0
Thiuram	PPB	10.0		3	3	0

Table 5B5-1. Summary of Analysis Results for Groundwater Samples Collected From Baseline Monitoring Wells 299-E25-26, 299-E25-27, and 299-E25-28 Through August 1988. (sheet 8 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Toluene	PPB	10.0		12	12	0
Toluenediamine	PPB	10.0		3	3	0
Total carbon	PPB	1000.0		19	0	0
Total dissolved solids	MG/L	5.0		15	0	0
Total organic carbon	PPB	1000.0		40	37	0
Total organic halogen	PPB	100.0		18	18	0
Total organic halogen, low DL	PPB	20.0		16	13	0
Toxaphene	PPB	1.0	5.0	15	15	0
Trans-1,2-dichloroethene	PPB	10.0		3	3	0
Tributylphosphoric Acid	PPB	10.0		1	1	0
Trichloroethylene	PPB	10.0	5.0	25	25	24
Trichloromethanethiol	PPB	10.0		3	3	0
Trichloromonofluoromethane	PPB	10.0		3	3	0
Trichloropropane	PPB	10.0		3	3	0
Tris(2,3-dibromopropyl) phosph	PPB	10.0		3	3	0
Tritium	PCI/L	500.0	20000.0	28	0	0
Uranium-234	PCI/L	.1		3	0	0
Uranium-235	PCI/L	.1		3	3	0
Uranium-238	PCI/L	.1		3	0	0
Vanadium	PPB	5.0		29	0	0
Vanadium, filtered	PPB	5.0		5	0	0
Vinyl chloride	PPB	10.0	2.0	3	3	3
Warfarin	PPB	10.0		3	3	0
Xylene-m	PPB	10.0		25	25	0
Xylene-o,p	PPB	10.0		25	25	0
Zinc	PPB	5.0		28	9	0
Zinc, filtered	PPB	5.0		5	1	0
pH, field		.1		35	0	0
pH, laboratory		.0		4	0	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 1 of 8)

Detection Monitoring Wells

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
1,1,1,2-tetrachlorethane	PPB	10.0		5	5	0
1,1,1-trichloroethane	PPB	10.0	200.0	13	13	0
1,1,2,2-tetrachlorethane	PPB	10.0		5	5	0
1,1,2-trichloroethane	PPB	10.0		13	13	0
1,1-dichloroethane	PPB	10.0		5	5	0
1,1-dichloroethylene	PPB	10.0	7.0	5	5	5
1,1-dimethylhydrazine	PPB	3000.0		1	1	0
1,2,3,4-tetrachlorobenzene	PPB	10.0		10	10	0
1,2,3,5-tetrachlorobenzene	PPB	10.0		10	10	0
1,2,3-trichlorobenzene	PPB	10.0		10	10	0
1,2,3-trichloropropane	PPB	10.0		5	5	0
1,2,4,5-tetrachlorobenzene	PPB	10.0		10	10	0
1,2,4-trichlorobenzene	PPB	10.0		10	10	0
1,2-dibromo-3-chloropropane	PPB	10.0		5	5	0
1,2-dibromoethane	PPB	10.0		5	5	0
1,2-dichlorobenzene	PPB	10.0		10	10	0
1,2-dichloroethane	PPB	10.0	5.0	5	5	5
1,2-dichloropropane	PPB	10.0		5	5	0
1,2-dimethylhydrazine	PPB	3000.0		1	1	0
1,2-diphenylhydrazine	PPB	10.0		4	4	0
1,3,5-trichlorobenzene	PPB	10.0		10	10	0
1,3-dichlorobenzene	PPB	10.0		10	10	0
1,3-dichloropropene	PPB	10.0		5	5	0
1,4-dichloro-2-butene	PPB	10.0		5	5	0
1,4-dichlorobenzene	PPB	10.0		10	10	0
1,4-naphthoquinone	PPB	10.0		4	4	0
1-(o-chlorophenyl) thiourea	PPB	200.0		4	4	0
1-acetyl-2-thiourea	PPB	200.0		4	4	0
1-chloro-2,3-epoxypropane	PPB	10.0		4	4	0
1-naphthyl-2-thiourea	PPB	200.0		4	4	0
1-naphthylamine	PPB	10.0		4	4	0
2,3,4,6-tetrachlorophenol	PPB	10.0		4	4	0
2,4,5-T	PPB	2.0		4	4	0
2,4,5-TP silvex	PPB	2.0	10.0	16	16	0
2,4,5-trichlorophenol	PPB	50.0		4	4	0
2,4,6-trichlorophenol	PPB	10.0		4	4	0
2,4-D	PPB	2.0	100.0	16	16	0
2,4-dichlorophenol	PPB	10.0		4	4	0
2,4-dimethylphenol	PPB	10.0		4	4	0
2,4-dinitrophenol	PPB	50.0		4	4	0
2,4-dinitrotoluene	PPB	10.0		4	4	0
2,6-dichlorophenol	PPB	10.0		4	4	0
2,6-dinitrotoluene	PPB	10.0		4	4	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 2 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
2-acetylaminofluorene	PPB	10.0		4	4	0
2-chloroethyl vinyl ether	PPB	10.0		5	5	0
2-chloronaphthalene	PPB	10.0		4	4	0
2-chlorophenol	PPB	10.0		4	4	0
2-cyclohexyl-4,6-dinitrophenol	PPB	10.0		4	4	0
2-methyl-2-(methylthio) propio	PPB	10.0		4	4	0
2-methylaziridine	PPB	10.0		4	4	0
2-methyllactonitrile	PPB	10.0		4	4	0
2-naphthylamine	PPB	10.0		4	4	0
2-picoline	PPB	10.0		4	4	0
2-propyn-1-ol	PPB	8000.0		4	4	0
2-sec-butyl-4,6-dinitrophenol	PPB	10.0		4	4	0
3,3'-dichlorobenzidine	PPB	20.0		4	4	0
3,3'-dimethoxybenzidine	PPB	10.0		4	4	0
3,3'-dimethylbenzidine	PPB	10.0		4	4	0
3-chloropropionitrile	PPB	4000.0		4	4	0
3-methylcholanthrene	PPB	10.0		4	4	0
4,4'-methylenebis(2-chloroanil	PPB	10.0		4	4	0
4,6-dinitro-o-cresol and salts	PPB	10.0		4	4	0
4-aminobyphenyl	PPB	10.0		4	4	0
4-bromophenyl phenyl ether	PPB	10.0		4	4	0
4-nitrophenol	PPB	50.0		4	4	0
5-(aminomethyl)-3-isoxazolol	PPB	10.0		4	4	0
5-nitro-o-toluidine	PPB	10.0		4	4	0
7,12-dimethylbenz[a]anthracene	PPB	10.0		4	4	0
7H-dibenzo[c,g]carbazole	PPB	10.0		4	4	0
Acetone	PPB			1	0	0
Acetonitrile	PPB	3000.0		5	5	0
Acetophenone	PPB	10.0		4	4	0
Acrolein	PPB	10.0		5	5	0
Acrylamide	PPB	10000.0		4	4	0
Acrylonitrile	PPB	10.0		5	5	0
Aldrin	PPB	1.0		4	4	0
Allyl alcohol	PPB	3000.0		4	4	0
Alpha,alpha-dimethylphenethyla	PPB	10.0		4	4	0
Alpha-BHC	PPB	1.0	4.0	16	16	0
Aluminum	PPB	150.0		23	19	0
Aluminum, filtered	PPB	150.0		15	14	0
Americium-241	PCI/L	.1		2	2	0
Amitrole	PPB	10.0		4	4	0
Ammonium ion	PPB	50.0		22	18	0
Aniline	PPB	10.0		4	4	0
Antimony	PPB	100.0		23	23	0
Antimony, filtered	PPB	100.0		15	15	0
Aramite	PPB	10.0		4	4	0
Arochlor 1016	PPB	1.0		9	9	0
Arochlor 1221	PPB	1.0		9	9	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 3 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Arochlor 1232	PPB	1.0		9	9	0
Arochlor 1242	PPB	1.0		9	9	0
Arochlor 1248	PPB	1.0		9	9	0
Arochlor 1254	PPB	1.0		9	9	0
Arochlor 1260	PPB	1.0		9	9	0
Arsenic	PPB	5.0	50.0	23	18	0
Arsenic, filtered	PPB	5.0	50.0	15	9	0
Auramine	PPB	10.0		4	4	0
Barium	PPB	6.0	1000.0	23	0	0
Barium, filtered	PPB	6.0	1000.0	15	4	0
Benz[a]anthracene	PPB	10.0		4	4	0
Benz[c]acridine	PPB	10.0		4	4	0
Benzene	PPB	10.0	5.0	9	9	5
Benzene, dichloromethyl	PPB	10.0		4	4	0
Benzenethoil	PPB	10.0		4	4	0
Benzidine	PPB	10.0		4	4	0
Benzo[a]pyrene	PPB	10.0		4	4	0
Benzo[b]fluoranthene	PPB	10.0		4	4	0
Benzo[j]fluoranthene	PPB	10.0		4	4	0
Benzyl chloride	PPB	10.0		4	4	0
Berylliam	PPB	5.0		23	23	0
Beryllium, filtered	PPB	5.0		15	15	0
Beta-BHC	PPB	1.0	4.0	16	16	0
Bis(2-chloroethoxy) methane	PPB	10.0		4	4	0
Bis(2-chloroethyl) ether	PPB	10.0		4	4	0
Bis(2-chloroisopropyl)ether	PPB	10.0		4	4	0
Bis(2-ethylhexyl) phthalate	PPB	10.0		4	4	0
Bis(chloromethyl) ether	PPB	10.0		5	5	0
Bromide	PPB	1000.0		14	14	0
Bromoacetone	PPB	10.0		5	5	0
Bromoform	PPB	10.0	100.0	5	5	0
Butyl benzyl phthalate	PPB	10.0		4	4	0
Cadmium	PPB	2.0	10.0	23	22	0
Cadmium, filtered	PPB	2.0	10.0	15	15	0
Calcium	PPB	50.0		23	0	0
Calcium, filtered	PPB	50.0		15	0	0
Carbon disulfide	PPB	10.0		5	5	0
Carbon-14	PCI/L	20.0		2	0	0
Carbophenothion	PPB	2.0		4	4	0
Cesium-137	PCI/L	20.0	200.0	19	19	0
Chloral	PPB	3000.0		1	1	0
Chlordane	PPB	1.0		4	4	0
Chloride	PPB	500.0		22	0	0
Chlornaphazine	PPB	10.0		4	4	0
Chloroacetaldehyde	PPB	16000.0		4	4	0
Chloroalkyl ethers	PPB	10.0		4	4	0
Chlorobenzene	PPB	10.0		5	5	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 4 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Chlorobenzilate	PPB	100.0		6	6	0
Chloroform	PPB	10.0	100.0	9	9	0
Chloromethyl methyl ether	PPB	10.0		5	5	0
Chromium	PPB	10.0	50.0	23	13	4
Chromium, filtered	PPB	10.0	50.0	15	14	0
Chrysene	PPB	10.0		4	4	0
Citrus red	PPB	1000.0		4	4	0
Cobalt-60	PCI/L	22.5	100.0	19	19	0
Coliform bacteria	MPN	2.2	1.0	19	0	19
Conductivity, Laboratory	UMHO	1.0		3	0	0
Copper	PPB	10.0		23	21	0
Copper, filtered	PPB	10.0		15	15	0
Cresols	PPB	10.0		4	4	0
Crotonaldehyde	PPB	10.0		5	5	0
Cyanide	PPB	10.0		4	4	0
Cyanogen	PPB	3000.0		1	1	0
Cyanogen bromide	PPB	3000.0		1	1	0
Cyanogen chloride	PPB	3000.0		1	1	0
DDD	PPB	1.0		4	4	0
DDE	PPB	1.0		4	4	0
DDT	PPB	1.0		4	4	0
Delta-BHC	PPB	1.0	4.0	16	16	0
Di-n-butyl phthalate	PPB	10.0		4	4	0
Di-n-octyl phthalate	PPB	10.0		4	4	0
Di-n-propylnitrosamine	PPB	10.0		4	4	0
Dibenz[a,h]acridine	PPB	10.0		4	4	0
Dibenz[a,h]anthracene	PPB	10.0		4	4	0
Dibenz[a,j]acridine	PPB	10.0		4	4	0
Dibenzo[a,e]pyrene	PPB	10.0		4	4	0
Dibenzo[a,h]pyrene	PPB	10.0		4	4	0
Dibenzo[a,i]pyrene	PPB	10.0		4	4	0
Dibromomethane	PPB	10.0		5	5	0
Dichlorodifluoromethane	PPB	10.0		5	5	0
Dichloropropanol	PPB	3000.0		1	1	0
Dieldrin	PPB	1.0		4	4	0
Diethyl phthalate	PPB	10.0		4	4	0
Diethylarsine	PPB	10.0		5	5	0
Diethylstilbesterol	PPB	200.0		4	4	0
Dihydrosafrole	PPB	10.0		4	4	0
Dimethoate	PPB	5.0		4	3	0
Dimethyl phthalate	PPB	10.0		4	4	0
Dinitrobenzene	PPB	10.0		4	4	0
Dioxane	PPB	500.0		9	9	0
Dioxin	PPB	.1		3	0	0
Diphenylamine	PPB	10.0		4	4	0
Disulfoton	PPB	2.0		4	4	0
Endosulfan I	PPB	1.0		4	4	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 5 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Endosulfan II	PPB	1.0		4	4	0
Endrin	PPB	1.0	.2	16	16	7
Ethyl carbamate	PPB	5000.0		4	4	0
Ethyl cyanide	PPB	3000.0		4	4	0
Ethyl methacrylate	PPB	3000.0		5	5	0
Ethyl methanesulfonate	PPB	10.0		4	4	0
Ethylene glycol	PPB	10000.0		3	3	0
Ethylene oxide	PPB	3000.0		5	5	0
Ethyleneimine	PPB	10.0		4	4	0
Ethylenethiourea	PPB	200.0		4	4	0
Fluoranthene	PPB	10.0		4	4	0
Fluoride	PPB	500.0	4000.0	22	17	0
Fluoroacetic acid	PPB	3000.0		1	1	0
Formalin	PPB	500.0		9	9	0
Gamma-BHC	PPB	1.0	4.0	16	16	0
Glycidylaldehyde	PPB	3000.0		1	1	0
Gross alpha	PCI/L	4.0	15.0	21	21	0
Gross beta	PCI/L	8.0	50.0	21	16	0
Heptachlor	PPB	1.0		4	4	0
Heptchlor epoxide	PPB	1.0		4	4	0
Hexachlorobenzene	PPB	10.0		10	10	0
Hexachlorobutadiene	PPB	10.0		4	4	0
Hexachlorocyclopentadiene	PPB	10.0		4	4	0
Hexachloroethane	PPB	10.0		4	4	0
Hexachlorophene	PPB	10.0		10	10	0
Hexachloropropene	PPB	10.0		7	7	0
Hexone	PPB	10.0		4	4	0
Hydrazine	PPB	3000.0		4	4	0
Hydrazine, low DL	PPB	30.0		1	1	0
Hydrogen sulfide	PPB	10.0		5	5	0
Indeno(1,2,3-cd)pyrene	PPB	10.0		4	4	0
Iodine-129	PCI/L	15.0		2	2	0
Iodomethane	PPB	10.0		5	5	0
Iron	PPB	50.0		23	0	0
Iron, filtered	PPB	50.0		15	13	0
Isobutyl alcohol	PPB	3000.0		4	4	0
Isosafrole	PPB	10.0		4	4	0
Kerosene	PPB	10000.0		10	10	0
Lead	PPB	30.0		3	3	0
Lead (graphite furnace)	PPB	5.0	50.0	19	16	0
Lead, filtered	PPB	5.0	50.0	13	13	0
Magnesium	PPB	50.0		18	0	0
Magnesium, filtered	PPB	50.0		15	0	0
Maleic hydrizide	PPB	500.0		6	6	0
Malononitrile	PPB	10.0		4	4	0
Manganese	PPB	5.0		23	6	0
Manganese, filtered	PPB	5.0		15	14	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 6 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Melphalan	PPB	10.0		4	4	0
Mercury	PPB	.1	2.0	19	0	0
Mercury, filtered	PPB	.1	2.0	10	0	0
Methacrylonitrile	PPB	10.0		5	5	0
Methanethiol	PPB	10.0		5	5	0
Methapyrilene	PPB	10.0		4	4	0
Metholonyl	PPB	10.0		4	4	0
Methoxychlor	PPB	3.0	100.0	16	16	0
Methyl bromide	PPB	10.0		5	5	0
Methyl chloride	PPB	10.0		5	5	0
Methyl ethyl ketone	PPB	10.0		13	13	0
Methyl hydrazine	PPB	3000.0		1	1	0
Methyl methacrylate	PPB	10.0		5	5	0
Methyl methanesulfonate	PPB	10.0		4	4	0
Methyl parathion	PPB	2.0		4	4	0
Methylene chloride	PPB	10.0		9	9	0
Methylthiouracil	PPB	10.0		4	4	0
N,N-diethylhydrazine	PPB	10.0		5	5	0
N-nitroso-N-methylurethane	PPB	10.0		4	4	0
N-nitrosodi-n-butylamine	PPB	10.0		4	4	0
N-nitrosodiethanolamine	PPB	10.0		4	4	0
N-nitrosodiethylamine	PPB	10.0		4	4	0
N-nitrosodimethylamine	PPB	10.0		4	4	0
N-nitrosomethylethylamine	PPB	10.0		4	4	0
N-nitrosomethylvinylamine	PPB	10.0		4	4	0
N-nitrosomorpholine	PPB	10.0		4	4	0
N-nitrosonornicotine	PPB	10.0		4	4	0
N-nitrosopiperidine	PPB	10.0		4	4	0
N-phenylthiourea	PPB	500.0		4	4	0
N-propylamine	PPB	10000.0		4	4	0
Naphthalene	PPB	10.0		10	10	0
Nickel	PPB	10.0		23	14	0
Nickel, filtered	PPB	10.0		15	14	0
Nicotinic acid	PPB	100.0		6	6	0
Nitrate	PPB	500.0	45000.0	22	0	0
Nitrite	PPB	1000.0		14	14	0
Nitrobenzine	PPB	10.0		4	4	0
Nitrosopyrrolidine	PPB	10.0		4	4	0
O,O,O-triethyl phosphorothioat	PPB	10.0		4	4	0
O-toluidine hydrochloride	PPB	10.0		4	4	0
Osmium	PPB	300.0		10	10	0
Osmium, filtered	PPB	300.0		1	1	0
P benzoquinone	PPB	10.0		4	4	0
P-chloro-m-cresol	PPB	10.0		4	4	0
P-chloroaniline	PPB	10.0		4	4	0
P-dimethylaminoazobenzene	PPB	10.0		4	4	0
P-nitroaniline	PPB	50.0		4	4	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 7 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Paraldegyde	PPB	3000.0		4	4	0
Parathion	PPB	2.0		4	4	0
Pentachlorobenzene	PPB	10.0		10	10	0
Pentachloroethane	PPB	10.0		5	5	0
Pentachloronitrobenzene	PPB	10.0		4	4	0
Pentachlorophenol	PPB	50.0		4	4	0
Perchloroethylene	PPB	10.0		13	13	0
Phenacetin	PPB	10.0		4	4	0
Phenol	PPB	10.0		10	10	0
Phenol, low DL	PPB	10.0		7	7	0
Phenylenediamine	PPB	10.0		4	4	0
Phosphate	PPB	1000.0		22	22	0
Phthalic acid esters	PPB	10.0		4	4	0
Plutonium-238	PCI/L	17.0		1	1	0
Plutonium-239,240	PCI/L	17.0		1	1	0
Potassium	PPB	100.0		23	0	0
Potassium, filtered	PPB	100.0		15	0	0
Pronamide	PPB	10.0		4	4	0
Pyridine	PPB	500.0		9	9	0
Radium	PCI/L	1.0	5.0	19	19	0
Reserpine	PPB	10.0		4	4	0
Resorcinol	PPB	10.0		4	4	0
Ruthenium-106	PCI/L	172.5	30.0	19	19	3
Safrol	PPB	10.0		4	4	0
Selenium	PPB	5.0	10.0	23	21	0
Selenium, filtered	PPB	5.0	10.0	15	15	0
Silver	PPB	10.0	50.0	23	23	0
Silver, filtered	PPB	10.0	50.0	15	15	0
Sodium	PPB	100.0		23	0	0
Sodium, filtered	PPB	100.0		15	0	0
Specific conductance	UMHO	1.0		75	0	0
Strontium	PPB	300.0		23	23	0
Strontium, filtered	PPB	300.0		15	15	0
Strontium-90	PCI/L	5.0	8.0	1	1	0
Strychnine	PPB	50.0		6	6	0
Sulfate	PPB	500.0		22	0	0
Sulfide	PPB	1000.0		4	4	0
Suspended solids	MG/L	5.0		3	0	0
Sym-trinitrobenzene	PPB	10.0		4	4	0
Technetium-99	PCI/L	15.0	900.0	12	12	0
Tetrachloromethane	PPB	10.0	5.0	13	13	9
Tetraethylpyrophosphate	PPB	100.0		4	4	0
Thallium	PPB	10.0		4	4	0
Thallium, filtered	PPB	10.0		5	5	0
Thiofanox	PPB	10.0		4	4	0
Thiourea	PPB	200.0		4	4	0
Thiuram	PPB	10.0		4	4	0

Table 5B5-2. Summary of Analysis Results for Groundwater Samples Collected From Detection Monitoring Wells 299-E25-29A, 299-E25-32A, and 299-E25-33 Through August 1988. (sheet 8 of 8)

CONSTITUENT			DRINKING WATER STANDARDS	NUMBER OF SAMPLES		
Name	Units	Detection Limit	Limit	Total	Below Detection	Above Limit
Toluene	PPB	10.0		9	9	0
Toluenediamine	PPB	10.0		4	4	0
Total carbon	PPB	1000.0		15	0	0
Total dissolved solids	MG/L	5.0		5	0	0
Total organic carbon	PPB	1000.0		81	43	0
Total organic halogen	PPB	100.0		33	33	0
Total organic halogen, low DL	PPB	20.0		48	31	0
Toxaphene	PPB	1.0	5.0	16	16	0
Trans-1,2-dichloroethene	PPB	10.0		5	5	0
Tributylphosphoric Acid	PPB	10.0		3	3	0
Trichloroethylene	PPB	10.0	5.0	13	13	9
Trichloromethanethiol	PPB	10.0		5	5	0
Trichloromonofluoromethane	PPB	10.0		5	5	0
Trichloropropane	PPB	10.0		5	5	0
Tris(2,3-dibromopropyl) phosph	PPB	10.0		4	4	0
Tritium	PCI/L	500.0	20000.0	19	5	6
Uranium-234	PCI/L	.1		1	0	0
Uranium-235	PCI/L	.1		1	1	0
Uranium-238	PCI/L	.1		1	0	0
Vanadium	PPB	5.0		23	0	0
Vanadium, filtered	PPB	5.0		15	4	0
Vinyl chloride	PPB	10.0	2.0	5	5	5
Warfarin	PPB	10.0		4	4	0
Xylene-m	PPB	10.0		13	13	0
Xylene-o,p	PPB	10.0		13	13	0
Zinc	PPB	5.0		23	2	0
Zinc, filtered	PPB	5.0		15	9	0
pH, field		.1		75	4	0
pH, laboratory		.0		3	0	0

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 1 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
1,1-dichloroethylene	PPB	2-E25-25	7/01/87	10.0	7.0	10.0
			3/29/88	10.0		
		2-E25-27	6/30/87	10.0		
		2-E25-28	6/30/87	10.0		
		2-E25-30	4/12/88	10.0		
		2-E25-31	4/13/88	10.0		
		2-E25-33	4/12/88	10.0		
1,2-dichloroethane	PPB	2-E25-25	7/01/87	10.0	5.0	10.0
			3/29/88	10.0		
		2-E25-27	6/30/87	10.0		
		2-E25-28	6/30/87	10.0		
		2-E25-30	4/12/88	10.0		
		2-E25-31	4/13/88	10.0		
		2-E25-33	4/12/88	10.0		
Benzene	PPB	2-E25-25	9/18/85	10.0	5.0	10.0
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			7/01/87	10.0		
			3/29/88	5.0		
		2-E25-26	9/20/85	10.0		
			2/07/86	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
		2-E25-27	9/18/85	10.0		
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			6/30/87	10.0		
		2-E25-28	6/04/86	10.0		
			6/30/87	10.0		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 2 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Benzene	PPB	2-E25-30	4/12/88	5.0	5.0	10.0
		2-E25-31	4/13/88	5.0		
		2-E25-33	4/12/88	5.0		
Chromium	PPB	2-E25-25	8/20/85	11.0	50.0	10.0
			9/18/85	10.0		
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/12/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			9/30/87	10.0		
			1/19/88	10.0		
			3/29/88	26.0		
			8/05/88	10.0		
		2-E25-26	9/20/85	10.0		
			2/07/86	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/15/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			10/01/87	10.0		
			3/28/88	10.0		
		2-E25-27	9/18/85	30.0		
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/05/86	10.0		
			3/12/87	10.0		
			6/30/87	10.0		
			9/29/87	10.0		
			3/30/88	10.0		
		2-E25-28	6/04/86	10.0		
			9/03/86	10.0		
			12/15/86	10.0		
			3/12/87	10.0		
			6/30/87	10.0		
			10/01/87	10.0		
			3/31/88	10.0		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 3 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Chromium	PPB	2-E25-29	7/08/88	169.0	50.0	10.0
		2-E25-30	4/12/88	260.0		
			4/12/88	429.0		
		2-E25-31	1/20/88	51.0		
			4/13/88	52.0		
			7/11/88	51.0		
		2-E25-32	8/11/88	18.0		
			8/11/88	26.0		
		2-E25-33	4/12/88	41.0		
			7/08/88	19.0		
Coliform bacteria	MPN	2-E25-25	8/22/85	3.0	1.0	2.2
			9/18/85	3.0		
			12/19/85	3.0		
			3/10/86	3.0		
			6/04/86	4.0		
			9/03/86	2.2		
			12/12/86	2.2		
			3/12/87	2.2		
			7/01/87	2.2		
			9/30/87	2.2		
			3/29/88	2.2		
			8/05/88	2.2		
		2-E25-26	9/20/85	3.0		
			2/07/86	3.0		
			3/10/86	3.0		
			6/04/86	3.0		
			9/03/86	2.2		
			12/15/86	2.2		
			3/12/87	2.2		
			7/01/87	2.2		
			10/01/87	2.2		
		2-E25-27	9/18/85	3.0		
			12/19/85	460.0		
			3/10/86	93.0		
			6/04/86	9.0		
			9/03/86	16.0		
			12/05/86	9.2		
			3/12/87	2.2		
			6/30/87	2.2		
			9/29/87	2.2		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 4 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Coliform bacteria	MPN	2-E25-28	6/04/86	28.0	1.0	2.2
			9/03/86	5.1		
			12/15/86	2.2		
			3/12/87	2.2		
			6/30/87	2.2		
			10/01/87	2.2		
		2-E25-29	7/08/88	2.2		
		2-E25-31	1/20/88	2.2		
			4/13/88	2.2		
			7/11/88	2.2		
		2-E25-32	8/11/88	2.2		
		2-E25-33	4/12/88	2.2		
			7/08/88	2.2		
Endrin	PPB	2-E25-25	8/20/85	1.0	.2	1.0
			9/18/85	1.0		
			12/19/85	1.0		
			3/10/86	1.0		
			6/04/86	1.0		
			9/03/86	1.0		
			7/01/87	1.0		
			3/29/88	.1		
			8/05/88	.1		
		2-E25-26	9/20/85	1.0		
			2/07/86	1.0		
			3/10/86	1.0		
			6/04/86	1.0		
			9/03/86	1.0		
		2-E25-27	9/18/85	1.0		
			12/19/85	1.0		
			3/10/86	1.0		
			6/04/86	1.0		
			9/03/86	1.0		
			6/30/87	1.0		
		2-E25-28	6/04/86	1.0		
			9/03/86	1.0		
			6/30/87	1.0		
		2-E25-29	7/08/88	.1		
		2-E25-30	4/12/88	.1		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 5 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Endrin	PPB	2-E25-31	1/20/88	.1	.2	1.0
			4/13/88	.1		
			7/11/88	.1		
		2-E25-32	8/11/88	.1		
		2-E25-33	4/12/88	.1		
			7/08/88	.1		
Ruthenium-106	PCI/L	2-E25-25	9/18/85	20.0	30.0	172.5
			12/19/85	-63.9		
			3/10/86	5.8		
			6/04/86	-17.1		
			9/03/86	17.1		
			12/12/86	-32.0		
			3/12/87	-40.7		
			7/01/87	-44.3		
			9/30/87	53.5		
			1/19/88	5.4		
			3/29/88	0.0		
			8/05/88	43.1		
		2-E25-26	9/20/85	-9.3		
			2/07/86	69.4		
			3/10/86	14.9		
			6/04/86	-88.9		
			9/03/86	-20.4		
			12/15/86	-11.0		
			3/12/87	8.6		
			7/01/87	-47.0		
			10/01/87	-63.7		
			3/28/88	14.5		
		2-E25-27	9/18/85	3.2		
			12/19/85	-47.7		
			3/10/86	21.3		
			6/04/86	41.5		
			9/03/86	41.2		
			12/05/86	4.4		
			3/12/87	-30.5		
			6/30/87	-10.6		
			9/29/87	23.2		
			3/30/88	-21.9		
		2-E25-28	6/04/86	-3.4		
			9/03/86	-10.5		
			12/15/86	25.7		
			3/12/87	37.0		
			6/30/87	-20.2		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 6 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Ruthenium-106	PCI/L	2-E25-28	10/01/87	13.9	30.0	172.5
			3/31/88	-23.7		
		2-E25-29	7/08/88	30.4		
		2-E25-30	4/12/88	47.3		
		2-E25-31	1/20/88	13.2		
			4/13/88	-2.8		
			7/11/88	-25.5		
		2-E25-32	8/11/88	-9.4		
		2-E25-33	4/12/88	0.0		
			7/08/88	16.0		
Tetrachloromethane	PPB	2-E25-25	9/18/85	10.0	5.0	10.0
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/12/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			9/30/87	10.0		
			3/29/88	5.0		
		2-E25-26	9/20/85	10.0		
			2/07/86	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/15/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			10/01/87	10.0		
		2-E25-27	9/18/85	10.0		
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/05/86	10.0		
			3/12/87	10.0		
			6/30/87	10.0		
			9/29/87	10.0		
		2-E25-28	6/04/86	10.0		
			9/03/86	10.0		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 7 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Tetrachloromethane	PPB	2-E25-28	12/15/86	10.0	5.0	10.0
			3/12/87	10.0		
			6/30/87	10.0		
			10/01/87	10.0		
		2-E25-30	4/12/88	5.0		
		2-E25-31	4/13/88	5.0		
		2-E25-33	4/12/88	5.0		
Trichloroethylene	PPB	2-E25-25	9/18/85	10.0	5.0	10.0
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/12/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			9/30/87	10.0		
			3/29/88	5.0		
		2-E25-26	9/20/85	10.0		
			2/07/86	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/15/86	10.0		
			3/12/87	10.0		
			7/01/87	10.0		
			10/01/87	10.0		
		2-E25-27	9/18/85	10.0		
			12/19/85	10.0		
			3/10/86	10.0		
			6/04/86	10.0		
			9/03/86	10.0		
			12/05/86	10.0		
			3/12/87	10.0		
			6/30/87	10.0		
			9/29/87	10.0		
		2-E25-28	6/04/86	10.0		
			9/03/86	10.0		
			12/15/86	10.0		
			3/12/87	10.0		
			6/30/87	10.0		
			10/01/87	10.0		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 8 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detection Limit
Trichloroethylene	PPB	2-E25-30	4/12/88	5.0	5.0	10.0
		2-E25-31	4/13/88	5.0		
		2-E25-33	4/12/88	5.0		
Tritium	PCI/L	2-E25-25	9/18/85	689.0	20000.0	500.0
			12/19/85	1540.0		
			3/10/86	721.0		
			6/04/86	582.0		
			9/03/86	807.0		
			12/12/86	534.0		
			3/12/87	433.0		
			7/01/87	413.0		
			9/30/87	408.0		
			1/19/88	558.0		
			3/29/88	486.0		
			8/05/88	270.0		
		2-E25-26	9/20/85	4200.0		
			2/07/86	2750.0		
			3/10/86	2290.0		
			6/04/86	2780.0		
			9/03/86	2650.0		
			12/15/86	2390.0		
			3/12/87	1640.0		
			7/01/87	1820.0		
			10/01/87	1940.0		
			3/28/88	3120.0		
		2-E25-27	9/18/85	1350.0		
			12/19/85	1370.0		
			3/10/86	1200.0		
			6/04/86	1770.0		
			9/03/86	7300.0		
			12/05/86	4020.0		
			3/12/87	3350.0		
			6/30/87	9520.0		
			9/29/87	9670.0		
			3/30/88	3120.0		
		2-E25-28	6/04/86	3100.0		
			9/03/86	3130.0		
			12/15/86	2490.0		
			3/12/87	2610.0		
			6/30/87	2350.0		
			10/01/87	1770.0		
			3/31/88	1690.0		

Table 5B5-3. Constituents that Exceeded the EPA Drinking Water Standard Concentrations. (sheet 9 of 9).

Constituent	Units	Monitoring Well	Sample Date	Analysis Result	Drinking Water Standard	Detect Limi
Tritium	PCI/L	2-E25-29	7/08/88	104000.0	20000.0	500
		2-E25-30	4/12/88	2160.0		
		2-E25-31	1/20/88	21400.0		
			4/13/88	20700.0		
			7/11/88	22700.0		
		2-E25-32	8/11/88	865.0		
		2-E25-33	4/12/88	23900.0		
			7/08/88	47300.0		
Vinyl chloride	PPB	2-E25-25	7/01/87	10.0	2.0	10
			3/29/88	10.0		
		2-E25-27	6/30/87	10.0		
		2-E25-28	6/30/87	10.0		
		2-E25-30	4/12/88	10.0		
		2-E25-31	4/13/88	10.0		
		2-E25-33	4/12/88	10.0		

Table 5B5-4. Sampling Dates for Baseline and Detection Monitoring Wells Through August 1988.

Monitoring well	Sample date
299-E25-25	08/20/85
	08/22/85
	09/18/85
	12/19/85
	03/10/86
	06/04/86
	09/03/86
	12/05/86
	12/12/86
	03/12/87
	07/01/87
	09/30/87
	01/19/88
	03/29/88
	08/05/88
299-E25-26	09/20/85
	02/07/86
	03/10/86
	06/04/86
	09/03/86
	12/15/86
	03/12/87
	07/01/87
	10/01/87
	03/28/88
299-E25-27	09/18/85
	12/19/85
	03/10/86
	06/04/86
	09/03/86
	12/05/86
	03/12/87
	06/30/87
	09/29/87
	03/30/88
299-E25-28	06/04/86
	09/03/86
	12/05/86
	12/15/86
	03/12/87
	06/30/87
	10/01/87
	03/31/88
299-E25-29	07/08/88
299-E25-30	04/12/88
	04/14/88
299-E25-31	01/20/88
	02/29/88
	04/13/88
	04/14/88
	07/11/88
299-E25-32	08/11/88
299-E25-33	04/12/88
	04/14/88
	07/08/88

This page intentionally left blank.

APPENDIX 5C

GROUNDWATER MONITORING PROGRAM INFORMATION

5C-1 Well Completion Information

5C-2 Analyses Performed To Justify Well Spacing, Detectability of Chromium, and Detectability of Technetium-99

This page intentionally left blank.

9011735157

APPENDIX 5C-1

WELL COMPLETION INFORMATION

9 0 1 1 7 3 5 1 5 7

This page intentionally left blank.

APPENDIX 5C-1

WELL COMPLETION INFORMATION

Included in this appendix is information on the construction of wells used to collect the existing water chemistry data and on wells proposed for the groundwater monitoring system. The general well construction is discussed with well-specific details and as-built diagrams provided.

The monitoring wells have been constructed according to *Minimum Standards for Construction and Maintenance of Wells*, WAC 173-160 (Ecology 1987). These wells are considered to be of high integrity, preventing intercommunication and contamination of aquifers, because of the construction methods/practices used and will allow representative samples to be collected from the screened interval. The procedures in the Sampling and Analysis Plan, Appendix 5D-1, provide further representative sampling. All of the wells used for detection monitoring at the Grout Treatment Facility share common characteristics. Every well has a factory-cleaned type-304 schedule 5S stainless steel continuous wire wrap screen with stainless steel plug and has been sealed to the ground surface. All wells were drilled by the cable-tool method except 299-E25-31, which was drilled by the ODEX* method described later. New schedule-40 carbon steel casings with carbon steel drive shoes were butt welded and used to prevent caving of the borehole. All carbon steel casings and drill equipment were cleaned prior to drilling. All temporary casings, except for 299-E25-25 through 299-E25-28 discussed later, were removed from the wells. Each well has been developed by bailing or by submersible pump. Wells are surveyed for vertical and horizontal coordinates by Kaiser Engineers Hanford after completion. An 'x' is stamped on the top of the casing as a reference point.

The general construction method for wells 299-E25-25, 299-E25-26, 299-E25-27, and 299-E25-28 are similar. The wells were drilled by Rockwell Hanford Operations personnel before May 1986. Drilling equipment was pre-cleaned (steam cleaned) prior to drilling. A 12-in. carbon steel starter casing was set to 20 ft. The hole was drilled to various depths (given for each well specifically) and 8-in. carbon steel casing was driven during drilling to prevent caving of the borehole. Perforations were made in the 8-in. casing at various locations before installation of the 6-in. casing. A 6-in. hole and carbon steel casing were advanced to the total borehole depth.

A stainless steel screen with stainless steel casing was telescoped into the 6-in. casing. The 6-in. casing was back pulled to above the water table so that only stainless steel materials were left beneath the water table. Cement grout slurry was pumped between the 6- and 8-in. casings anticipating that the grout would move through the perforations and into any annular space outside the 8-in. casing. The 12-in. starter casing was removed while the upper 20 ft were being grouted. The well was capped with a stainless steel

*ODEX is a trademark of Atlas Copco and Sandvik Rock Tools.

cap for the single piezometers or with a painted steel cap in the case of dual piezometers.

Well 299-E25-25--An as-built diagram of this well is shown on Figure 5C1-1. The construction duration was from March 11 through April 10, 1985. A drive barrel was used to a depth of 152 ft; a hard tool with water was used beyond that depth. The 8-in. casing was set to 150 ft; perforations were made at two cuts per round, one round per foot from 9 to 150 ft. The 6-in. casing was set to 288 ft, then pulled to 253 ft after the screen was set. The 4-in.-dia, 0.010-in. slot-size screen was set from 269 to 289 ft with 20 ft of stainless steel blank above that. The well was bailed for 5 h to develop it, and 486 gal of grout was used. The grout is a mixture of cement with 5 percent bentonite added.

Well 299-E25-26--An as-built diagram of this well is shown on Figure 5C1-2. The construction duration was from March 1 through April 4, 1985. A drive barrel was used to a depth of 155 ft; a hard tool with water was used beyond that depth. The 8-in. casing was set to 150 ft; perforations were made at four cuts per round, one round per foot from 0 to 150 ft. The 6-in. casing was advanced with drilling to 290 ft, then pulled to 254 ft after the screen was set. The 4-in. dia, 0.010-in. slot-size screen was set from 270 to 290 ft with 20 ft of stainless steel blank above that. The well was bailed for 8 h to develop it and 606 gal of grout were used. The grout is a mixture of cement with 5 percent bentonite added.

Well 299-E25-27--An as-built diagram of this well is shown on Figure 5C1-3. The construction duration was from April 10 through May 30, 1985. The 12-in. starter casing was set to 90 ft because of drilling conditions, and 80 ft were left in the hole. A drive barrel was used to a depth of 155 ft; a hard tool with water was used beyond that depth. The 8-in. casing was set to 160 ft; perforations were made at two cuts per round, one round per foot from 0 to 160 ft. The 6-in. casing was advanced with drilling to 294 ft, then pulled to 257 ft after the screen was set. The 4-in.-dia, 0.010-in. slot-size screen was set from 274 to 294 ft with 21 ft of stainless steel blank above that. The well was bailed for 5 h to develop it and 522 gal of grout were used. The grout is a mixture of cement with 5 percent bentonite added.

Well 299-E25-28--An as-built diagram of this well is shown on Figure 5C1-4. The construction duration was from February 24 through April 17, 1986. A temporary 10-in. casing was used in addition to the 12-in. casing and was set to 96 ft. All but 10 ft of this casing was removed. A drive barrel was used to a depth of 202 ft; a hard tool with water was used beyond that depth. The 8-in. casing was set to 220 ft; perforations were made at two cuts per round, one round per half-foot from 198 to 218 ft, and one round per foot from 148 to 198 ft. The 6-in. casing was advanced with drilling to 341 ft, (drilling proceeded to 348 ft) then pulled to 244 ft after the screen was set. The 5-in.-dia, 0.010-in. slot-size screen was set from 320 to 340 ft with 80 ft of stainless steel blank above that. The well was bailed for 3 h to develop it and 1,050 gal of grout were used. The grout is a mixture of cement with 5 percent bentonite added.

Well 299-E25-31--An as-built diagram of this well as constructed is shown on Figure 5C1-5. The drilling and construction duration was from

HANFORD WELL NUMBER 299-E25-25

HANFORD COORDINATES N41001.60, W43648.40

DATE COMPLETED 4/10/85

WELL CONSTRUCTION SUMMARY

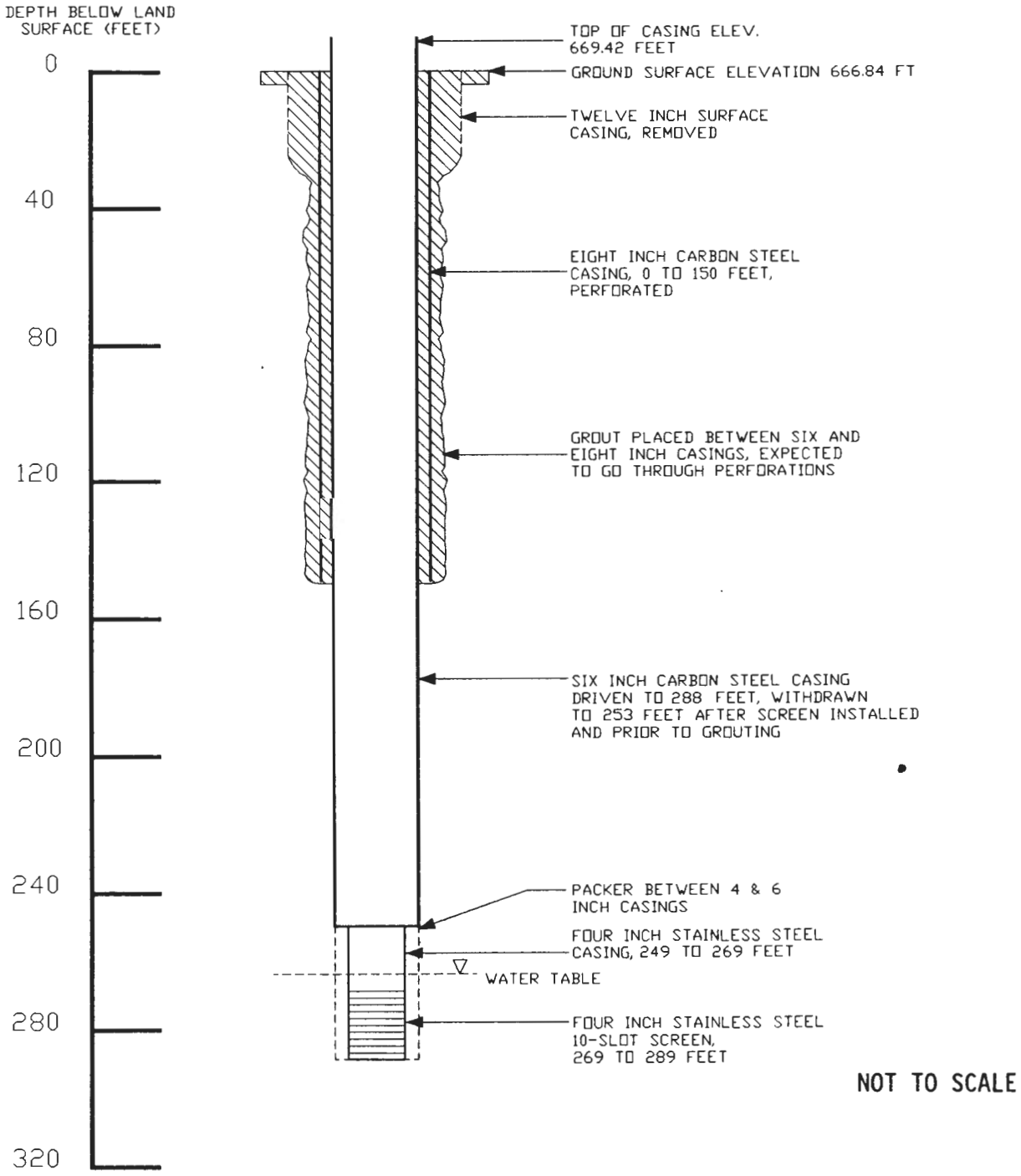


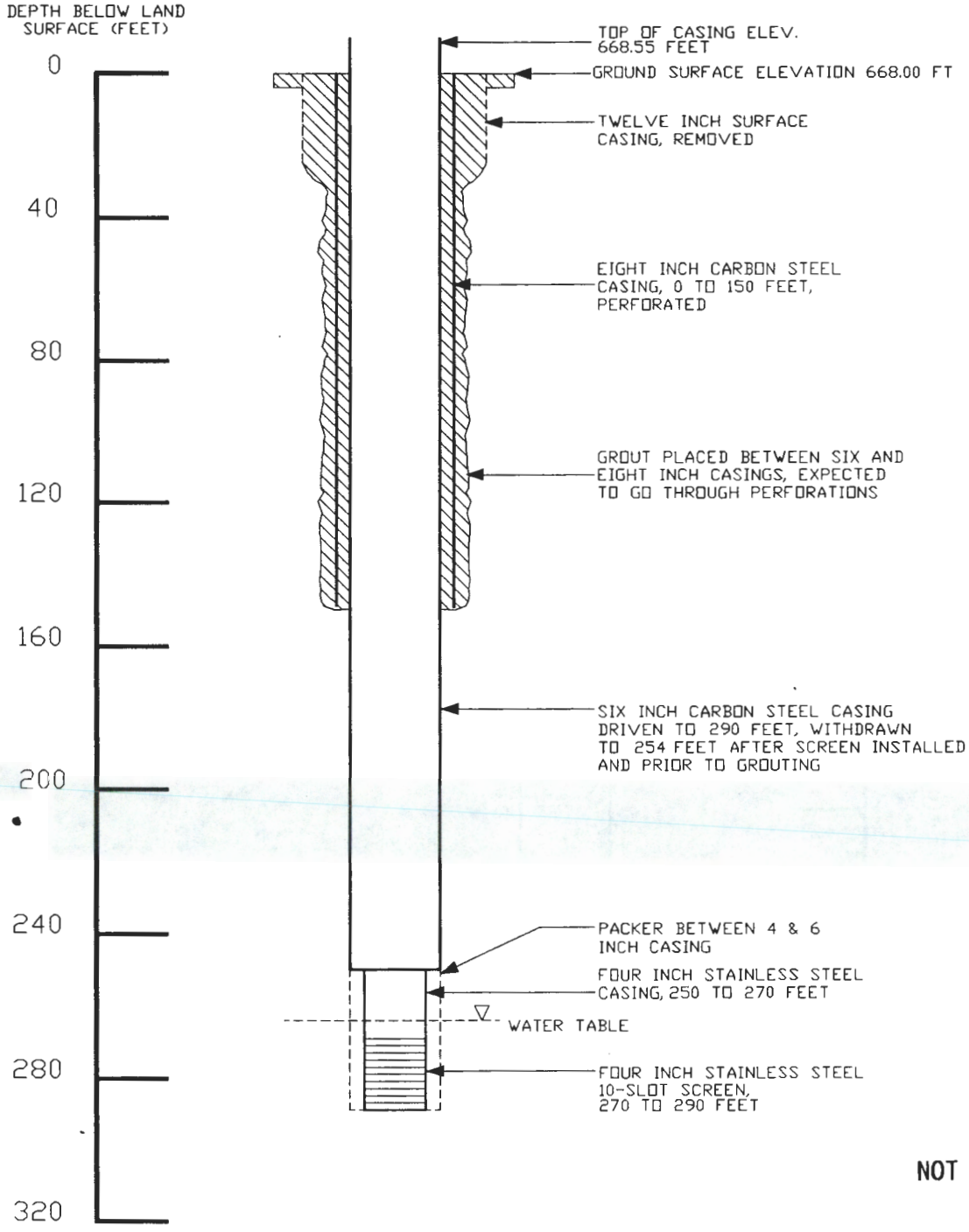
Figure 5C1-1. As-Built Diagram for Well 299-E25-25.

HANFORD WELL NUMBER 299-E25-26

HANFORD COORDINATES N40772.80, W45884.50

DATE COMPLETED 4/4/85

WELL CONSTRUCTION SUMMARY



NOT TO SCALE

Figure 5C1-2. As-Built Diagram for Well 299-E25-26.

HANFORD WELL NUMBER 299-E25-27

HANFORD COORDINATES N39855.00, W45136.00

DATE COMPLETED 5/30/85

WELL CONSTRUCTION SUMMARY

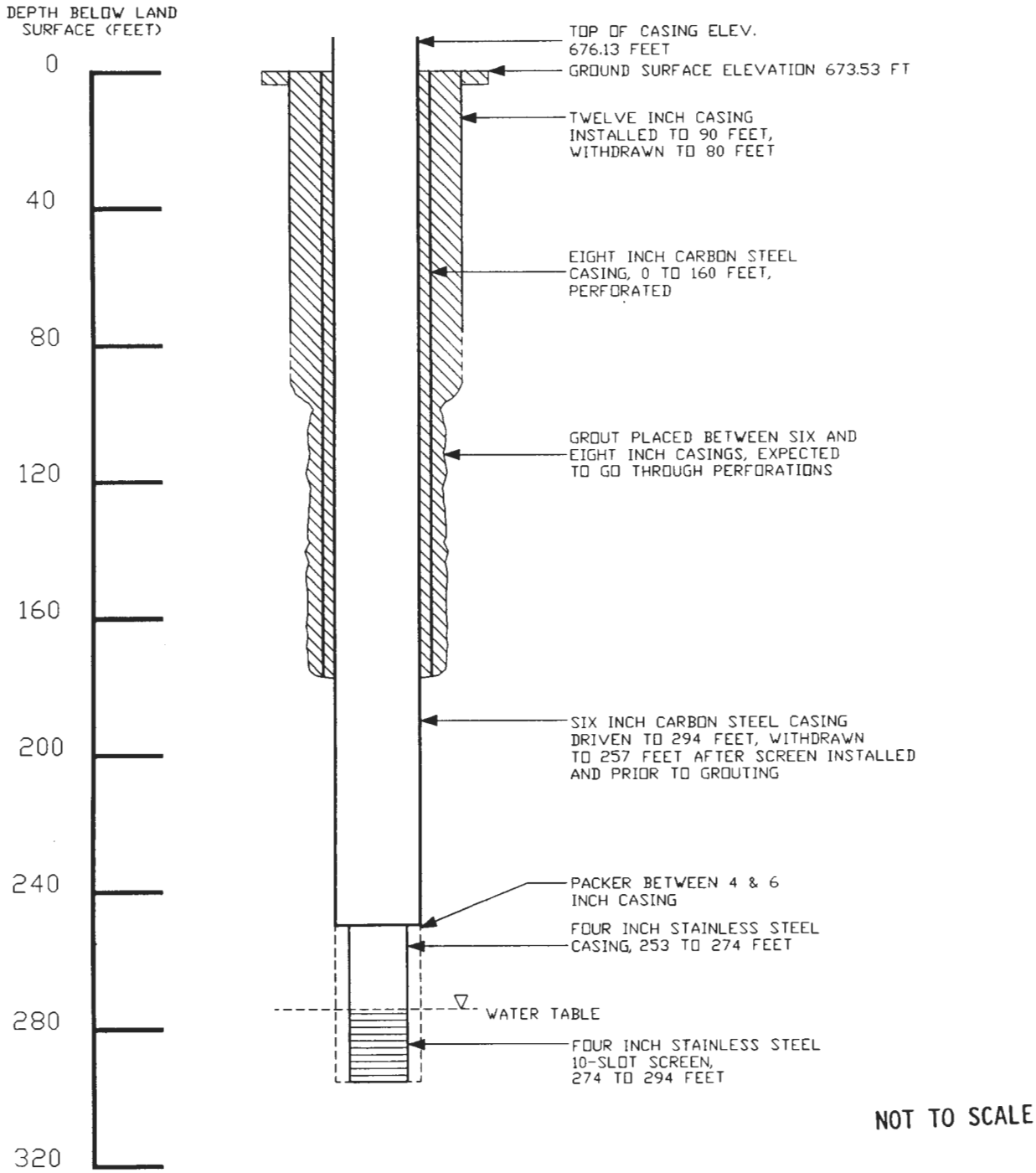


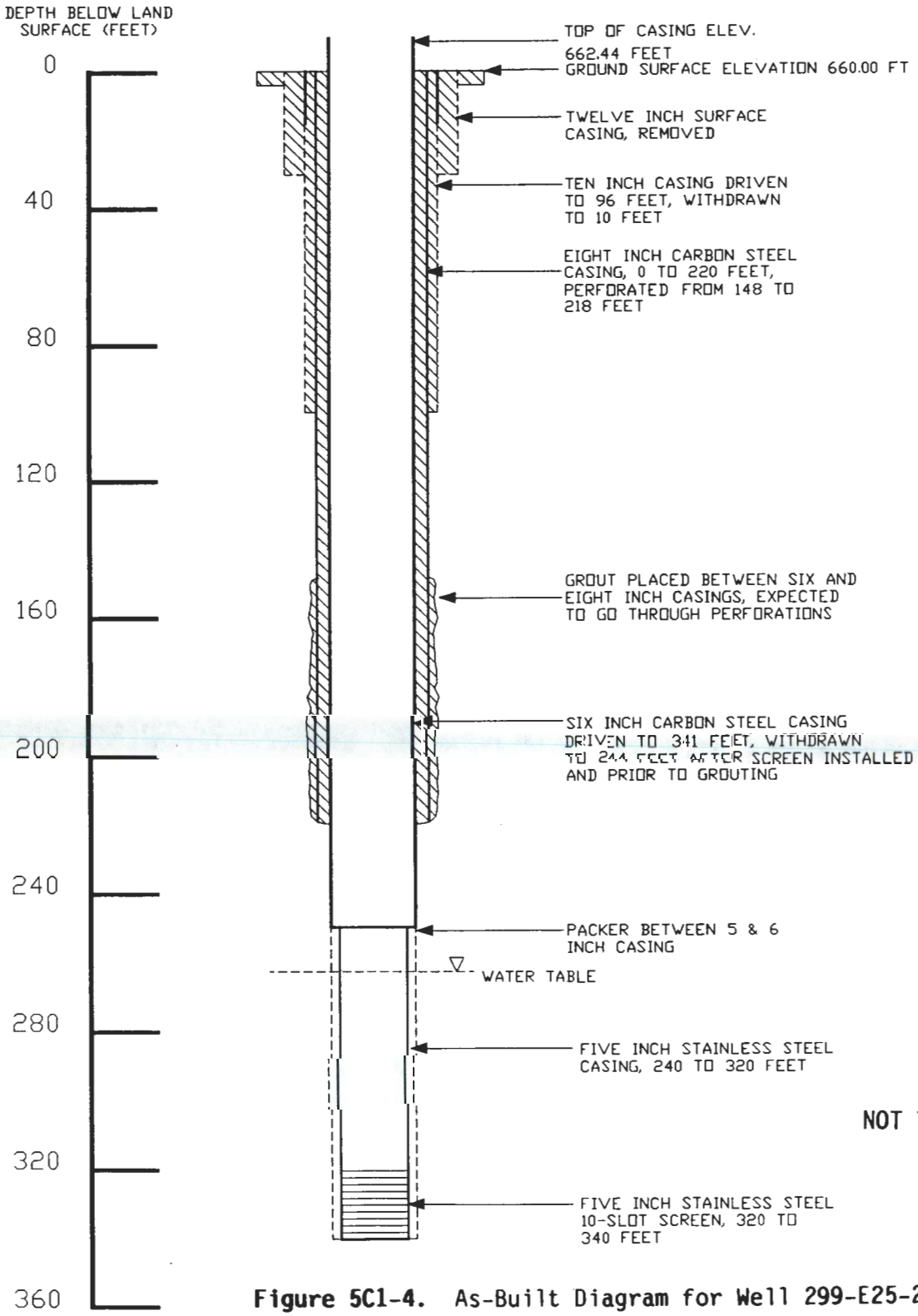
Figure 5C1-3. As-Built Diagram for Well 299-E25-27.

HANFORD WELL NUMBER 299-E25-28

HANFORD COORDINATES N41424.32, W45540.56

DATE COMPLETED 4/17/86

WELL CONSTRUCTION SUMMARY



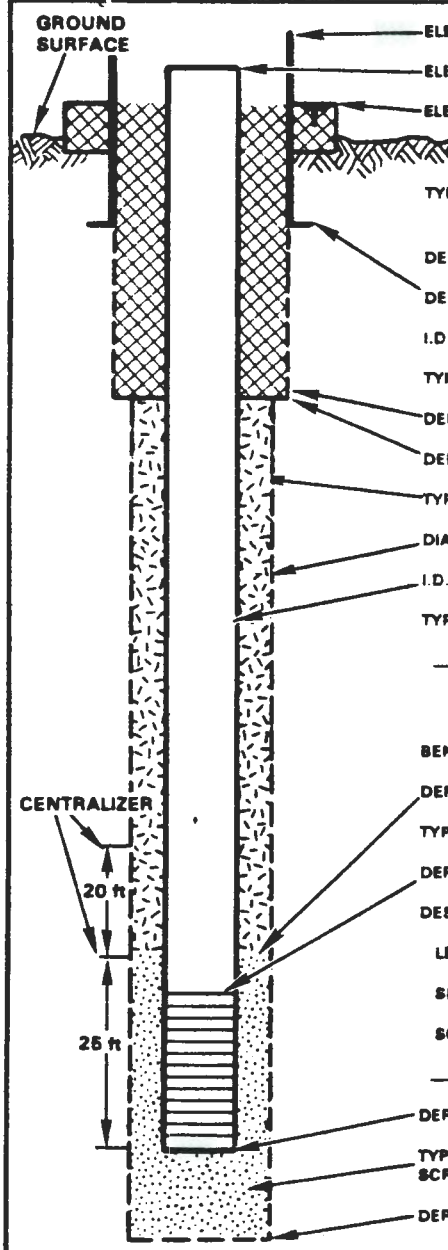
NOT TO SCALE

Figure 5C1-4. As-Built Diagram for Well 299-E25-28.

WELL DESIGNATION: 299-E25-31
HANFORD WELL NUMBER: 299-E25-31
HANFORD COORDINATES: N40311.2, W45752.9 (℄ CASING)
LAMBERT COORDINATES: --
DATE COMPLETED: 7/16/87

UNCONFINED WATER
WELL CONSTRUCTION SUMMARY

ALL DEPTHS ARE FROM GROUND SURFACE (NO SCALE GIVEN)



ELEVATION OF SURFACE CASING		NA
ELEVATION OF REFERENCE POINT		672.53 ft
ELEVATION OF SURVEYOR'S PIN		670.40 ft
GROUND SURFACE ELEVATION		670.00 ft
TYPE OF SURFACE SEAL	CEMENT GROUT	
DEPTH OF SURFACE SEAL		3 ft
DEPTH OF SURFACE CASING		NONE
I.D. OF ORIGINAL SURFACE CASING	SCH 40 CARBON STEEL	10 in.
TYPE OF SURFACE CASING	NA	
DEPTH OF ORIGINAL STARTER CASING		19 ft
DEPTH OF FILLER (SEAL)		3 ft
TYPE OF FILLER:	VOLCLAY GROUT SLURRY (3-249 ft)	
DIAMETER OF BOREHOLE		8 in.
I.D. OF RISER PIPE		4 in.
TYPE OF RISER PIPE:	TYPE 304 SCH 5S STAINLESS STEEL FLUSH JOINT THREADED	
BENTONITE PELLETS FROM 249-254 ft		
DEPTH OF TOP OF SAND PACK		254 ft
TYPE OF SAND PACK:	COLORADO SILICA SAND 20-30	
DEPTH OF TOP OF SCREEN		259 ft
DESCRIPTION OF SCREEN		
LENGTH: 20 ft	I.D. OF SCREEN SECTION	4 in.
SLOT SIZE	0.020 in.	
SCREEN CONSTRUCTION	TYPE 304 SCH 5S STAINLESS STEEL CONTINUOUS WIRE WRAP w/SS PLATE AT BOTTOM	
DEPTH OF BOTTOM OF SCREEN		279 ft
TYPE OF FILLER BELOW SCREEN:	COLORADO SILICA SAND 20-30	
DEPTH OF BOTTOM OF BOREHOLE		298 ft

WELL DRILLED USING ODEX AIR ROTARY WITH FOAM. TEMPORARY 8-in. SCH. 40 CARBON STEEL CASING EMPLACED TO 298 ft (EACH SECTION WELDED).

NOT TO SCALE

78809084.2

Figure 5C1-5. As-Built Diagram for Well 299-E25-31.

June 23 to July 16, 1987. This well was drilled by Nelson Drilling Company with a drill-through-the-casing, reverse-circulation air rotary method using a down-hole ODEX hammer. The ODEX bit under-reams the borehole, allowing the temporary casing to essentially follow the bit without being driven. This method is very rapid. A drilling additive, Quick Foam*, was used to assist in bringing drill cuttings to the surface.

Drilling materials and tools were cleaned with a high-pressure, hot water rinse before drilling began. Final completion materials were factory cleaned and kept in plastic wrap until they were placed in the borehole. A temporary 12-in.-dia surface casing was installed to a depth of 20 ft. An 8-in. temporary casing was installed to total depth, which was 298 ft.

Sand pack was placed in the borehole from 298 ft to 279 ft. The sand pack used in all portions of the borehole is 0.023 to 0.032-in.-dia, a rounded silica sand. A 4-in.-dia, 0.020-in. slot-size, type 304 stainless steel continuous wound screen was set from 259 to 279 ft (from approximately 15 ft below water table to 5 ft above water table). A 4-in.-dia, type 304 stainless steel schedule 5S flush-joint threaded casing was joined to the screen and set from 259 ft to 2 ft above land surface. Centralizers were placed at 25 and 45 ft above the bottom of the screen. Sand pack was installed around the screen and to 5 ft above the screen (to 254 ft). Bentonite pellets 1/4 in. in diameter were placed for 5 ft above the sand pack (from 254 to 249 ft). Volclay** grout was placed above the bentonite pellets to 3 ft below land surface. The above process was done while pulling back the temporary casings until they were out of the ground.

The remaining 3 ft of annular space was sealed with portland cement slurry. A 4-ft by 4-ft by 4-in. concrete pad was put around the well, and four guard posts were placed around the concrete pad. A brass surveyor's pin was set flush in the cement apron.

Wells 299-E25-29, 299-E25-30, 299-E25-32 and 299-E25-33--The design drawing for these wells is shown in Figures 5C1-6 to 5C1-9, This design is generic for the three multiple-completion wells; however, well 299-E25-32 has specific differences as noted below. Well 299-E25-33 is a single completion well.

Wells 299-E25-29 and 299-E25-30--These wells were completed in October 1987 and were drilled by the cable tool method. A 12-in. starter casing was installed to a depth of 20 ft in each well. All the drilling tools were high-pressure washed before the start of drilling. The casings were high-pressure washed before they were placed in the borehole, and final completion materials were factory cleaned and wrapped until they were placed in the borehole.

Well 299-E25-29--The duration of drilling and construction for well 299-E25-29 was from September 2 to October 7, 1987. Well 299-E25-29 was drilled by Basin and Range Drilling Company to a total depth of 330 ft, and 8-in. temporary casing was installed to 336 ft. Drive barrel samples were

*Quick Foam is a trademark of the Baroid Company.
**Volclay is a trademark of American Colloid Company.

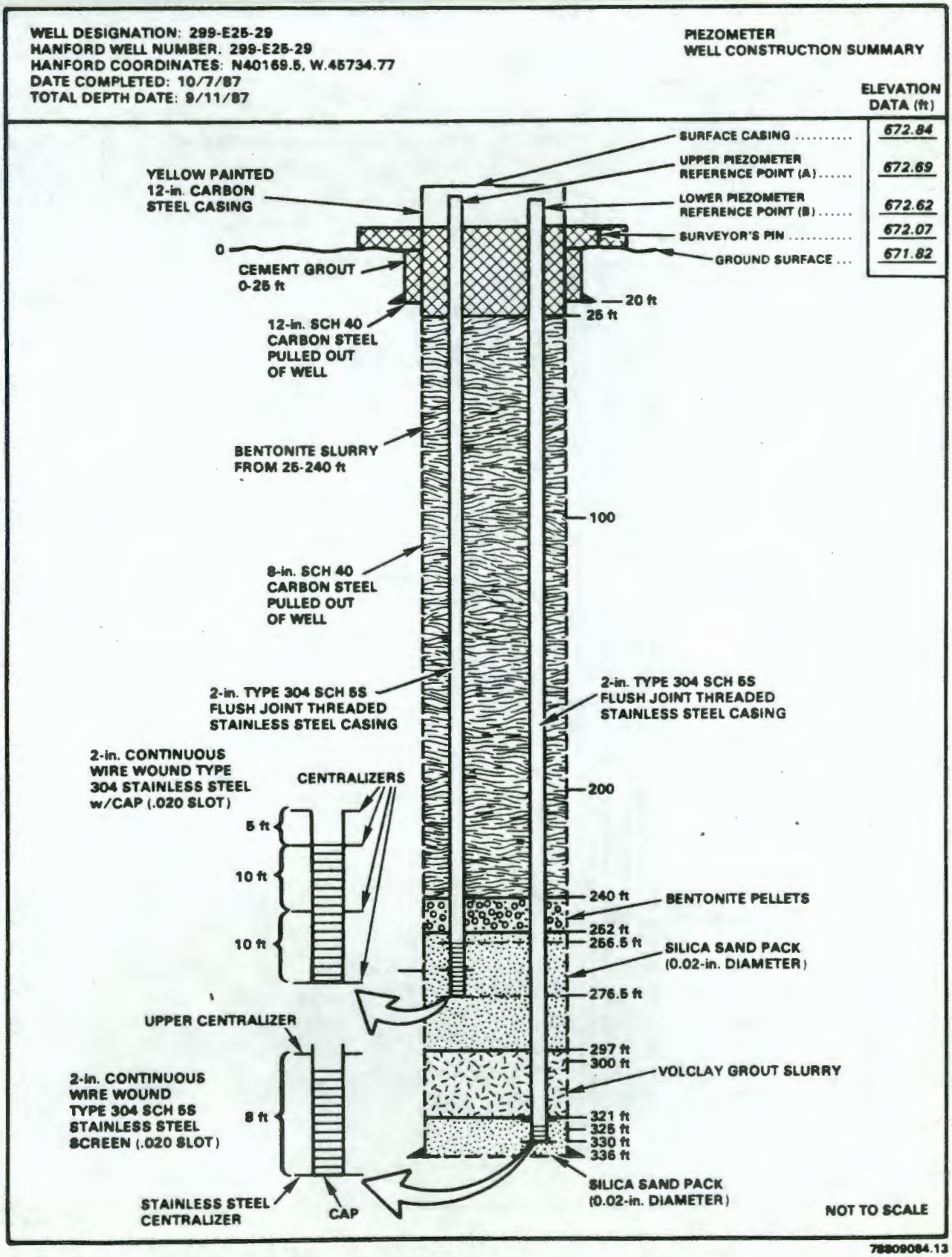


Figure 5C1-6. As-Built Diagram for Well 299-E25-29.

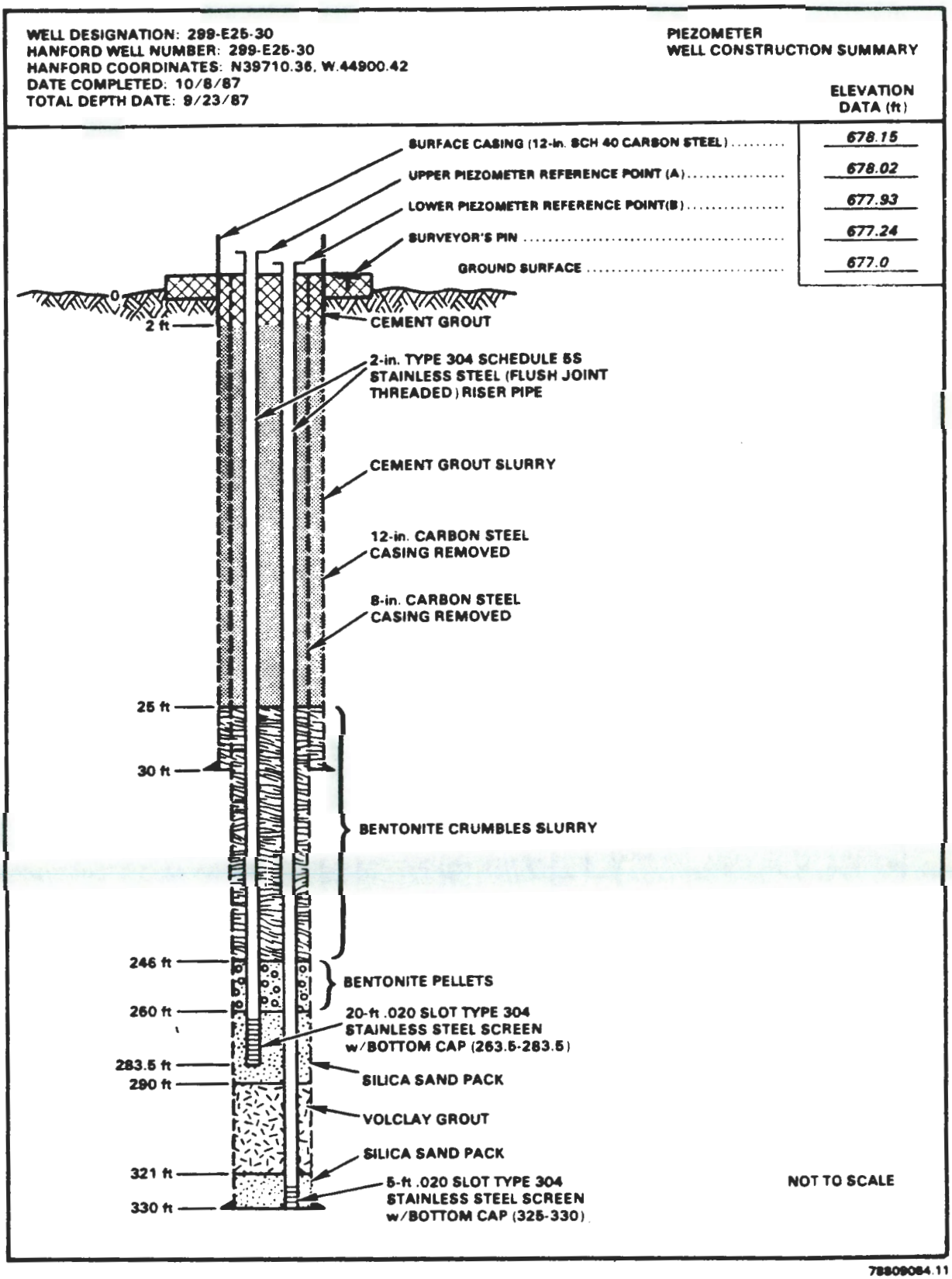


Figure 5C1-7. As-Built Diagram for Well 299-E25-30.

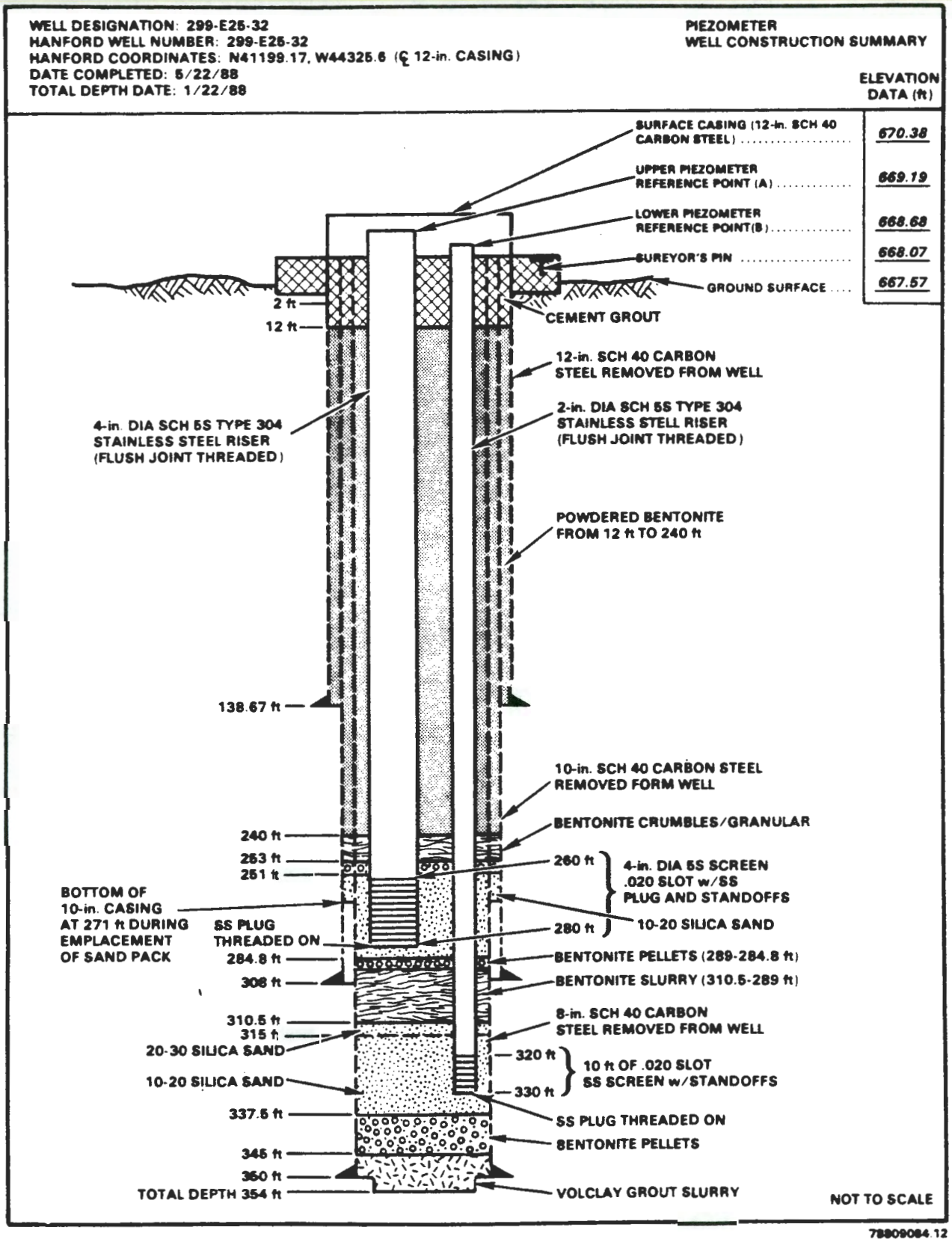
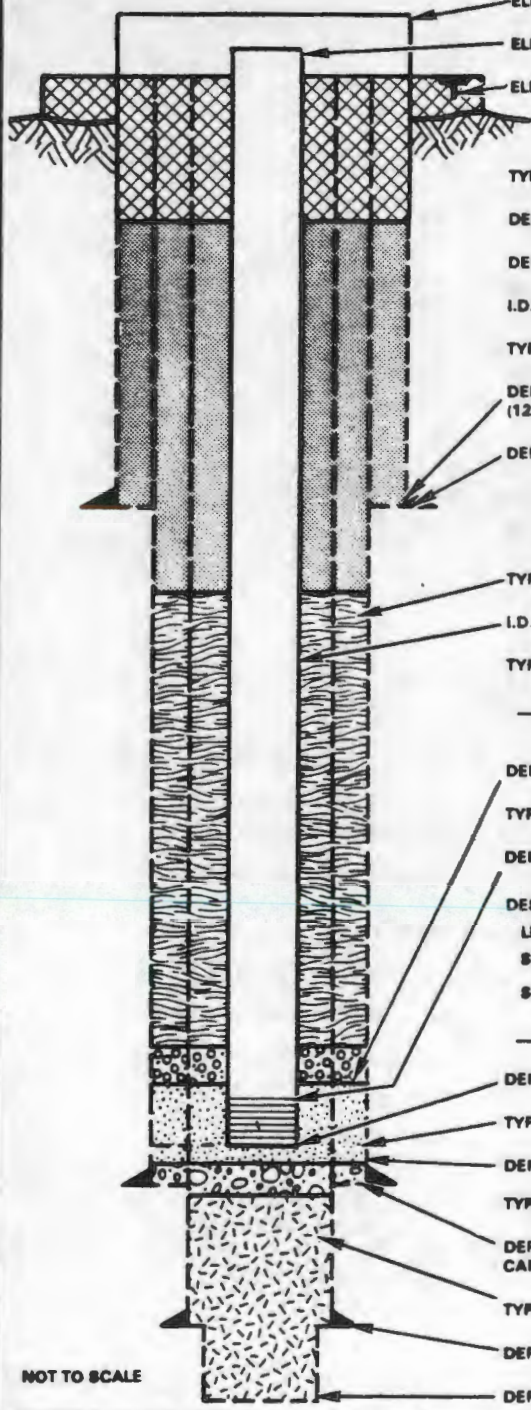


Figure 5C1-8. As-Built Diagram for Well 299-E25-32.

WELL DESIGNATION: 299-E25-33
HANFORD WELL NUMBER: 299-E25-33
HANFORD COORDINATES: N40116.4, W45609.0
DATE COMPLETED: 3/22/88
TOTAL DEPTH DATE: 1/6/88

WELL CONSTRUCTION SUMMARY

ALL DEPTHS ARE FROM GROUND SURFACE (NO SCALE GIVEN)



ELEVATION OF SURFACE CASING (NO SURFACE CASING USED)	NA
ELEVATION OF REFERENCE POINT (EL. OF STAINLESS STEEL PLATE)	674.97 ft
ELEVATION OF SURVEYOR'S PIN	672.35 ft
GROUND SURFACE ELEVATION	672.00 ft
TYPE OF SURFACE SEAL: CEMENT GROUT	
DEPTH OF SURFACE SEAL	20.5 ft
DEPTH OF SURFACE CASING	NA
I.D. OF SURFACE CASING	NA
TYPE OF SURFACE CASING: NA	
DEPTH OF ORIGINAL STARTER CASING (12-in. DIA SCH 40 CARBON STEEL)	125 ft
DEPTH OF FILLER (SEAL)	20.5 ft
TYPE OF FILLER: POWDERED BENTONITE 20.5-200 ft; GRANULAR BENTONITE 200-252 ft; BENTONITE PELLETS 252-257 ft	
I.D. OF RISER PIPE	4 in.
TYPE OF RISER PIPE: SCHEDULE 5S TYPE 304 FLUSH JOINT THREADED STAINLESS STE	
DEPTH OF TOP OF SAND PACK	257 ft
TYPE OF SAND PACK: 10-20 COLORADO SILICA S. D	
DEPTH OF TOP OF SCREEN	261.88 ft
DESCRIPTION OF SCREEN — LENGTH: 20.33 ft; SLOT SIZE: .020 in.	
I.D. OF SCREEN SECTION	4 in.
SCREEN CONSTRUCTION: TYPE 304 STAINLESS STEEL CONTINUOUS WIRE WOUND w/SS CAP	
DEPTH OF BOTTOM OF SCREEN	282.21 ft
TYPE OF FILLER BELOW SCREEN: 10-20 COLORADO SILICA SAND	
DEPTH OF BOTOM OF SAND PACK	288 ft
TYPE OF FILLER: SLOUGH 288-320 ft	
DEPTH OF BOTTOM OF 10-in. SCH 40 CARBON STEEL CASING (REMOVED)	318 ft
TYPE OF FILLER: VOLCLAY GROUT 320-400 ft	
DEPTH OF BOTTOM OF 8-in. SCH 40	383 ft
DEPTH OF BOTTOM OF BOREHOLE (8-in. DIA)	400 ft

NOT TO SCALE

78809084 14

Figure 5C1-9. As-Built Diagram for Well 299-E25-33.

collected to 13 ft, and from 40 to 205 ft; a hard tool was used between 13 and 40 ft, and from 205 to 330 ft. The lower screen (2-in., 0.020-in. slot size attached to 2-in. casing) was placed between 325 and 330 ft below ground surface. Stainless steel centralizers were placed at the bottom of the screen and 8 ft above the bottom of the screen. Silica sand pack (0.02-in. dia) was placed from 330 to 321 ft around and above the screen. Volclay grout was pumped into the borehole via tremie pipe from 321 to 297 ft. Silica sand pack (0.02-in. dia) was placed on the Volclay grout to 276.5 ft to provide adequate footing for the screen. A 20-ft, 2-in.-dia, 0.020-in. slot-size, stainless steel screen with plug was set at 276.5 to 256.5 ft. Stainless steel centralizers were placed at the bottom of the screen, 10 ft and 15 ft from the bottom. Silica sand pack was placed around the screen up to 252 ft. Bentonite pellets were placed above the sand pack to 240 ft, then bentonite crumbles slurry was poured to 25 ft. Cement grout was placed to ground surface, and a 4-ft by 4-ft by 7-in. cement apron was poured around the protective casing. All the temporary casings were removed. Each well was bailed using a 20-ft piece of 1-in. polyvinyl chloride pipe with check valve for approximately 10 h. The water was not turbid. Four protective posts were located around the apron.

Well 299-E25-30--The duration of drilling and construction for well 299-E25-30 was from September 2 to October 8, 1987. Well 299-E25-30 was drilled by Basin and Range Drilling Company to a total depth of 330 ft and 8-in. temporary casing was installed. Drive barrel samples were collected to 30 ft and from 75 to 170 ft; a hard tool with water added was used between 30 and 75 ft and from 170 to 330 ft. The lower screen (2-in., 0.020-in. slot size, attached to 2-in. casing) was placed between 325 and 330 ft below land surface. Sand pack (0.020 in.) was placed around the screen and to 321 ft. Volclay grout was placed between approximately 321 and 290 ft. Six and one-half ft of silica sand (0.020 in.) were placed in the borehole, and the upper screen (2-in., 0.020 in. slot size) were placed between 263.5 and 283.5 ft. Sand pack (0.020-in.) was placed around the screen and to 260 ft. Bentonite pellets were placed above the sand pack from 260 to 246 ft, and slurried bentonite crumbles were placed to 25 ft. A cement grout mixture was placed to the land surface, and a cement apron and protective casing were installed. The 8-in. and 12-in. casings were removed while the above construction activities were being performed . Each well was developed by bailing: the lower well for 5 h and the upper well for about 14 h.

Well 299-E25-32--The as-built diagram in Figure 5C1-8 shows the design for well 299-E25-32. This is a multiple completion hole consisting of a lower piezometer screen set at 320 to 330 ft and an upper piezometer screen set at 260 to 280 ft. Well drilling commenced on November 12, 1987, and the surface grout was poured on May 22, 1988. The well was drilled by Kaiser Engineers Hanford to a total depth of 354 ft in dense basalt and 8-in. casing driven to 350 ft. An aquifer test using a temporary screen was performed and is described in Appendix 5B-3. The lower screen is a 2-in., 0.020-in.-slot stainless steel with plug, connected to the riser which reaches to the surface. The upper screen is 4-in., 0.020-in.-slot stainless steel with plug, connected to the riser, which reaches to the surface. Stainless steel standoffs are attached at the top and bottom of both screens. Drive barrel samples were collected to 175 ft below ground surface; a hard tool with water added was used from about 175 ft to total depth.

The final completion consists of Volclay grout slurry from 354 to 345 ft, bentonite pellets from 345 to 337.5 ft, 10-20 silica sand from 337.5 to 315 ft, 20-30 silica sand from 315 to 310.5 ft, granular bentonite slurry from 310.5 to 289 ft, bentonite pellets from 289 to 284.8 ft, 10-20 silica sand from 284.8 to 254 ft, bentonite pellets from 254 to 240 ft, powdered bentonite from 240 to 12 ft, and cement grout slurry with 5 percent bentonite from 12 ft to ground surface. A 12-in. protective casing with cover was set to 2 ft below ground surface. A 4-ft by 4-ft by 6-in. cement apron was poured around the protective casing. The well was completed on May 22, 1988. Both piezometers were developed by submersible pump on June 27, 1988. The water was visually determined to be nonturbid. Currently, wells are quantitatively determined to be nonturbid when they have been developed to $\leq$5 nephelometric turbidity units. All temporary casings were removed from the borehole. All drilling tools and temporary casings were steam cleaned before being used.

Well 299-E25-33--The as-built diagram in Figure 5C1-9 shows the design for well 299-E25-33. The well was drilled by Kaiser Engineers Hanford between November 12, 1987, and March 22, 1988. On January 6, 1988, the maximum depth of 400 ft was reached by the 8-in. bit (8-in. casing driven to 383 ft) in dense basalt. A drive barrel was used to drill the borehole from ground surface to 185 ft; a hard tool with water added was used from 185 ft to total depth. A 4-in. dia, 0.020-in.-slot stainless steel screen with plug was set between 261.88 and 282.21 ft. An aquifer test using a temporary screen was performed between about 316 and 274 ft (see Appendix 5B-3 for details).

Volclay grout slurry was emplaced by tremie pipe from 400 to 320 ft, by formation slough from 320 to 288 ft, and by 10-20 silica sand from 288 ft to the bottom of the screen. The 10-20 silica sand was placed around the screen and to 257 ft. Bentonite pellets were placed from 257 to 252 ft with granular bentonite from 252 to 200 ft. Powdered bentonite was placed from 200 to 20.5 ft and cement grout with 5 percent bentonite was placed from 20.5 ft to ground surface. All temporary casings were removed and a 4-ft by 4-ft by 6-in. cement apron was poured around the stainless steel casing. The well was developed on March 24, 1988, using a 4-in. bailer for about 1 h. The water was nonturbid.

Other Future Wells--The as-built diagram for well 299-E25-31 (see Figure 5C1-5) shows the general conceptual design for future and postclosure groundwater monitoring wells. The boreholes are not expected to be over drilled. The drilling method for these wells has not yet been determined, but will be determined on a specific basis according to the data required from drilling and cost considerations. These wells will be 4 in. in dia, and the screen interval will extend from 15 ft below the water table to 5 ft above the water table. The casing material used for the future wells will be compatible with the sampled constituents. The current standard material used in well construction is stainless steel. The sealing method above the bentonite pellets will be hydrated granular bentonite or other materials that may be appropriate, based on advancements in sealing methods.

9011173615590

REFERENCES

Ecology 1987, *Minimum Standards for Construction and Maintenance of Wells*, Washington Administrative Code 173-160, Washington State Department of Ecology, Olympia, Washington.

9011178615591

1 This page intentionally left blank.

APPENDIX 5C-2

ANALYSES PERFORMED TO JUSTIFY WELL SPACING, DETECTABILITY OF CHROMIUM, AND DETECTABILITY OF TECHNETIUM-99

This page intentionally left blank.

APPENDIX 5C-2

ANALYSES PERFORMED TO JUSTIFY WELL SPACING, DETECTABILITY OF CHROMIUM, AND DETECTABILITY OF TECHNETIUM-99

This appendix contains models and calculations to verify that various constituents (chromium is the specific constituent analyzed) will be detected with a well spacing of 150 ft. Two types of models were used to determine the lateral spreading that might occur as the moisture plume reaches the water table, and then as the plume moves downgradient in the groundwater and reaches the detection monitoring wells. The overall intent of both models was to determine the total lateral spreading that might occur by the time a contaminant plume arrives at the downgradient wells.

The first model considered flow in the unsaturated porous media from the vaults in the excavated pit down to the water table. During this phase a constant leak rate of 72 gal/d was assumed. This is equivalent to a maximum recharge rate of about 10 cm/yr (refer to Section 5.2.4.1 in text) over the surface area of two vaults with dimensions of about 150 ft by 50 ft. The volume of run-off water is for two adjacent vaults recharging an area between them of 130 ft by 5 ft. The water encounters and mobilizes vault constituents, moving them downward to the water table by advective movement as a moisture plume. When flow conditions reached steady state, the actual and effective saturation were calculated to estimate spreading, and the results were plotted. A model entitled VADOSE (In Situ 1986) was used for this phase of modeling. The complete model setup is shown on Attachment 5C2-1. The 'critical' parameters used in the model are listed as follows:

- Unsaturated hydraulic conductivity for a fine sand
- A beta value for a fine sand from the Hanford Site
- The constant leak rate of 72 gal/d as described above
- A porosity equal to 0.42.

The second phase of modeling addressed transport of the constituents in the saturated zone (groundwater) to the downgradient detection monitoring wells. The parameters used for this analysis (and the vadose model) were the best known values for the sediment and aquifer conditions at the Grout Treatment Facility site. These values in general are considered to be conservative parameters and, therefore, should result in less spreading by the time the constituents reach the wells.

The following parameters were input into the WMPLUME model (Beljin 1985):

- The Darcy velocity (hydraulic conductivity times the hydraulic gradient). Hydraulic conductivity was taken from the results of the aquifer test at well 299-E25-22 (Appendix 5B-3). An aquifer thickness of 100 ft was assumed (Fig. 5-20). The hydraulic

gradient was estimated from the water table map (Plate 5-3). Given these inputs, the Darcy velocity was estimated to be 0.6 ft/d

- Effective porosity. Effective porosity was assumed to be 0.25, which is a typical value for the porosity in a sand

- The aquifer thickness, or in this case the thickness over which a constituent would disperse, assumed to be 30 ft

- A longitudinal dispersivity of 100 ft

- A transverse dispersivity of 10 ft.

Model Assumptions--A series of assumptions is inherent in any vadose zone or groundwater model that is used. These assumptions may introduce additional errors besides those associated with the input parameters for the model. For the particular models used in this study, the applicable inherent assumptions are given below.

VADOSE Model Assumptions--

- The unsaturated medium is homogeneous and isotropic. The effect of an anisotropic condition at the Grout Treatment Facility site, where the vertical hydraulic conductivity is estimated to be about one order of magnitude less than the horizontal value, would be to increase spreading of the moisture plume. This assumption is conservative, therefore, for the intent of this study.

- The effective saturation (Se) can be approximated as an exponential function of the capillary pressure (Pc) and an adjustable parameter, beta. Empirical studies in the professional literature indicate that this is generally an acceptable assumption.

- The hydraulic conductivity can be expressed as a power function of effective saturation (K = Ko * (Se**n)). As stated above, this is generally an acceptable assumption.

WMPLUME Model Assumptions--

- The aquifer is confined and uniformly porous.

- The aquifer is homogeneous, isotropic, infinite in areal extent, and of constant thickness.

- The solute injection well is fully penetrating.

- Recharge rates are negligible in relation to the uniform regional flow rate.

- Pollutants are distributed instantaneously to the entire aquifer thickness beneath the point source.

- Injection is continuous and constant.

Results--The width of a chromium plume after 180 d, located 140 ft downgradient from the nearest vault, is 160 ft. The concentration of chromium is 0.06 p/m, which is above the detection level by one order of magnitude (0.010 p/m). After interim status monitoring, the time interval between sampling events is equal to 180 d. Therefore, it appears that a well spacing of 150 ft is close enough to detect leakage from a vault. The results are listed on Attachment 5C2-2.

Minimum Leak Rate--An analysis was conducted to determine the minimum leak rate that can be detected when analyzing ^{99}Tc. This analysis was based on flow volumes estimated by Pacific Northwest Laboratory (Sewart et al. 1987) for two cases: (1) a vault situated with the long side (38 m) perpendicular to flow and (2) a vault situated with the short side (15 m) perpendicular to flow. Flow through a 50-m cross section of the aquifer is estimated to be 5.8 x 10 m^3/yr. The dilution volume in the worst case (38-m side) is 1.39 x 10^{-1} L/s, and in the best case (15-m side) it is 5.51 x 10^{-2} L/s.

Based on the estimated waste concentration for ^{99}Tc of 10^{-5} Ci/L, the minimum detectable leak rate for interim status is about 1.5 x 10^{-9} L/d (best case) and 4 x 10^{-9} L/d (worst case). For final status, the minimum detectable leak rate is about 1 x 10^{-9} L/d (best case) and 3 x 10^{-9} L/d (worst case). This analysis is detailed in Attachment 5C2-3. The analysis does not account for the movement and fate of constituents in the unsaturated zone.

REFERENCES

Beljin, M. S., 1985, *SOLUTE, A Program Package of Analytical Models for Solute Transport in Water*, IGWMC-BASI5, International Ground Water Modeling Center, Indianapolis, Indiana.

In Situ, 1986, VADOSE (computer program), Computer Technology Division, In Situ, Incorporated, Laramie, Wyoming.

Sewart, G. H., W. T. Farris, D. G. Huizenga, A. H. McMakin, G. P. Streile, and R. L. Treat, 1987, *Long-Term Performance Assessment of Grouted/Phosphate Waste From N Reactor Operations*, PNL-6152, Pacific Northwest Laboratory, Richland, Washington.

This page intentionally left blank.

9 0 1 1 7 8 6 1 5 9 8

Attachment 5C2-1

UNSATURATED ZONE MODEL SET UP AND RESULTS

9 0 1 1 7 8 6 1 5 9 9

V A D O S E V3.11

3-D Transient Unsaturated Flow

IN-SITU INC. SOFTWARE SERIES

Input data file name is C:VADGRTA.INP
Output data file name is C:VADGRTA.OUT
The plot file name is C:VADGRTA.PLT

Impact of Vault Leakage on Vadose Zone: Q=71.8 GPD

SOIL PROPERTIES

Capillary pressure at Effective Saturation of 1.0 (in. of fluid)	=	1.89
Exponential fit parameter for effective saturation (in.)	=	6.30
Major saturated hydraulic conductivity (ft/d)	=	1.2E+02
Minor saturated hydraulic conductivity (ft/d)	=	1.2E+02
Angle of major hydraulic conductivity (degrees)	=	.00
Ratio of vertical to mean horizontal hyd. conductivity	=	1.00
Porosity (%)	=	42.00
Maximum saturation (%)	=	95.20
Irreducible saturation (%)	=	22.60

PROJECT SITE DESCRIPTION

Drainfields

No.	Flow rate gal/day	Center X(ft)	Center Y(ft)	Depth ft	size ft		size ft	Orientation degrees
1	72.	.00	.00	50.00	130.	X	5.	90.00

Point leaks

Number of point leaks = 0

IMPERMEABLE BOUNDARIES

* Ground surface is not impermeable.

* No horizontal impermeable layer below the sources

* No vertical impermeable boundary. For all practical purposes soil formation is infinite in areal extent.

CALCULATIONS FOR A VERTICAL CROSS-SECTIONAL PLANE

X-coordinate of the NW or SW corner of the cross-sectional grid plane	=	-50.0 ft
Y-coordinate of the NW or SW corner of the cross-sectional grid plane	=	.0 ft
Angle of the cross-sectional grid w.r.t. X-axis	=	.0 degrees
Length of the cross-sectional grid	=	100.0 ft
Depth of the top of the grid	=	.0 ft
Depth of the bottom of the grid	=	220.0 ft
Number of horizontal grid points	=	10
Number of vertical grid points	=	17

K = Ko * (Se**3.0)

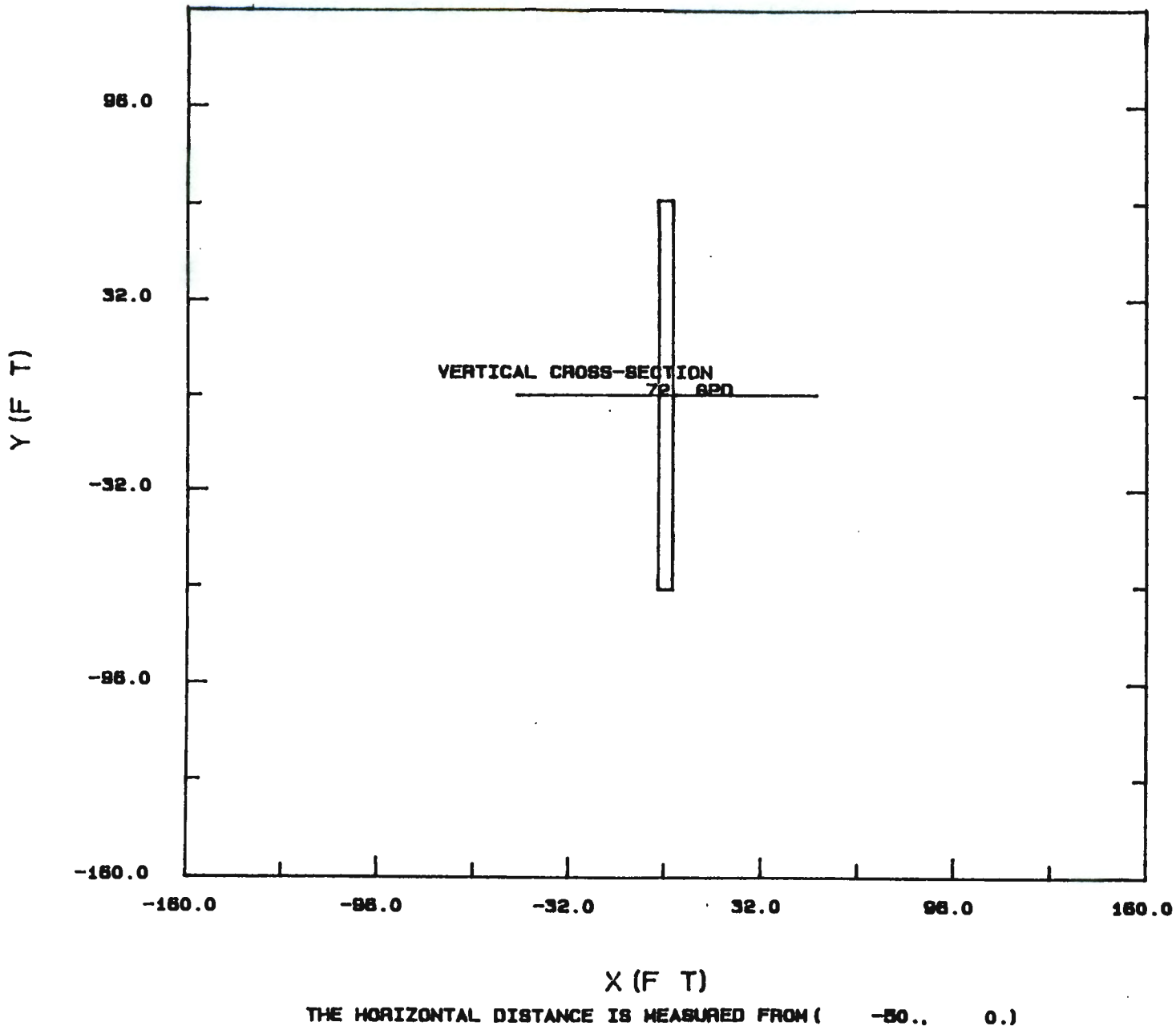
Steady state solution

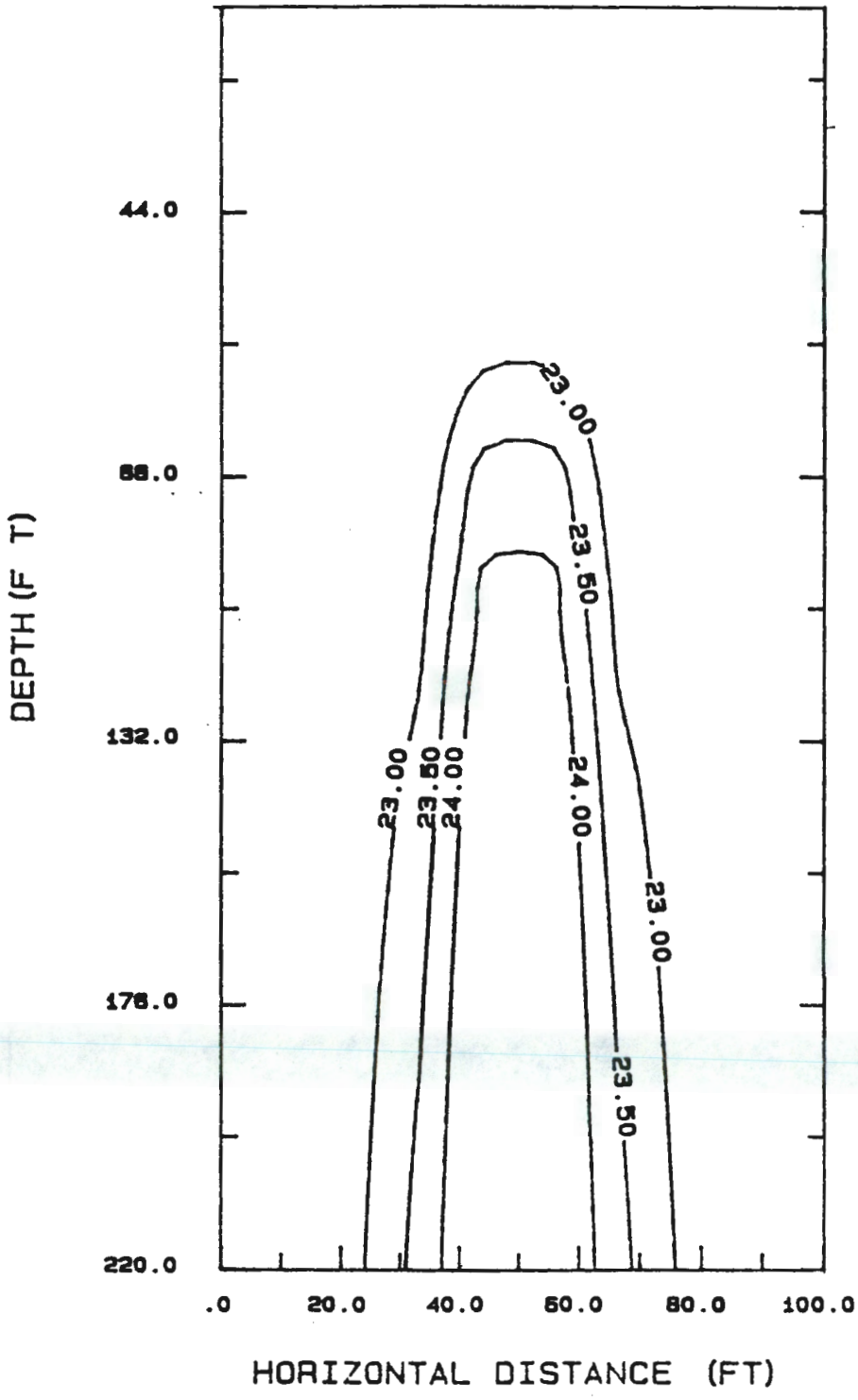
Depth (ft) — Effective Saturation (%)

X(ft)	-50.	-39.	-28.	-17.	-6.	6.	17.	28.	39.	50.
Y(ft)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
55.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
68.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
82.5	0.	0.	0.	0.	1.	1.	0.	0.	0.	0.
96.3	0.	0.	0.	0.	2.	2.	0.	0.	0.	0.
110.0	0.	0.	0.	0.	2.	2.	0.	0.	0.	0.
123.8	0.	0.	0.	1.	2.	2.	1.	0.	0.	0.
137.5	0.	0.	0.	1.	3.	3.	1.	0.	0.	0.
151.3	0.	0.	0.	1.	3.	3.	1.	0.	0.	0.
165.0	0.	0.	0.	1.	3.	3.	1.	0.	0.	0.
178.8	0.	0.	0.	1.	3.	3.	1.	0.	0.	0.
192.5	0.	0.	0.	1.	3.	3.	1.	0.	0.	0.
206.3	0.	0.	0.	1.	3.	3.	1.	0.	0.	0
220.0	0.	0.	0.	1.	3.	3.	1.	0.	0.	

Depth (ft) — Actual Saturation (%)

X(ft)	-50.	-39.	-28.	-17.	-6.	6.	17.	28.	39.	50.
Y(ft)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.0	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
13.8	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
27.5	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
41.3	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
55.0	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
68.8	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
82.5	23.	23.	23.	23.	23.	23.	23.	23.	23.	23.
96.3	23.	23.	23.	23.	24.	24.	23.	23.	23.	23.
110.0	23.	23.	23.	23.	24.	24.	23.	23.	23.	23.
123.8	23.	23.	23.	23.	24.	24.	23.	23.	23.	23.
137.5	23.	23.	23.	23.	24.	24.	23.	23.	23.	23.
151.3	23.	23.	23.	23.	25.	25.	23.	23.	23.	23.
165.0	23.	23.	23.	23.	25.	25.	23.	23.	23.	23.
178.8	23.	23.	23.	23.	25.	25.	23.	23.	23.	23.
192.5	23.	23.	23.	24.	25.	25.	24.	23.	23.	23.
206.3	23.	23.	23.	24.	25.	25.	24.	23.	23.	23
220.0	23.	23.	23.	24.	25.	25.	24.	23.	23.	2


VERTICAL CROSS-SECTION
72 GPD
96.0
32.0
-32.0
-96.0
-160.0
Y (F T)
-160.0
-96.0
-32.0
32.0
96.0
160.0
X (F T)
THE HORIZONTAL DISTANCE IS MEASURED FROM (-50., 0.)



THE HORIZONTAL DISTANCE IS MEASURED FROM (-50., 0.)

Attachment 5C2-2

SATURATED ZONE TRANSPORT MODEL SET UP AND RESULTS

```
*********************************************
*                                           *
*   SOLUTE TRANSPORT FROM POINT SOURCES     *
*                                           *
*     IN TWO-DIMENSIONAL  UNIFORM FLOW      *
*   MODEL: WMPLUME                          *
*                                           *
*********************************************
```

DATE: 10-14-87

INPUT DATA:

```
DARCY VELOCITY........................:    0.60 ft/d
EFFECTIVE POROSITY....................:     .25
AQUIFER THICKNESS.....................:   30.00 ft
LONGITUDINAL DISPERSIVITY.............:  100.00 ft
LATERAL DISPERSIVITY..................:   10.00 ft
RETARDATION FACTOR....................:    1.00
DECAY CONSTANT (lambda)...............:    0     1/d
NUMBER OF POINT SOURCES...............:    3
```

SOURCE DATA:

SOURCE NO. 1

```
X-COORDINATE OF THE SOURCE............:  200.00 ft
Y-COORDINATE OF THE SOURCE............:   90.00 ft
THE SOURCE STRENGTH...................:    0.01 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...:  180.00 d
```

SOURCE NO. 2

```
X-COORDINATE OF THE SOURCE............:  200.00 ft
Y-COORDINATE OF THE SOURCE............:  100.00 ft
THE SOURCE STRENGTH...................:    0.01 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...:  180.00 d
```

SOURCE NO. 3

X-COORDINATE OF THE SOURCE.....:	200.00 ft
Y-COORDINATE OF THE SOURCE.....:	110.00 ft
THE SOURCE STRENGTH.....:	0.01 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...:	180.00 d

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.....:	0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....:	0.00 ft
DISTANCE INCREMENT DELX.....:	10.00 ft
DISTANCE INCREMENT DELY.....:	10.00 ft
NUMBER OF NODES IN X-DIRECTION.....:	40
NUMBER OF NODES IN Y-DIRECTION.....:	20

********** RESULTS **********

+------> X-direction CONCENTRATION in mg/l (ppm)
|
v Y

	0.00 ft	10.00 ft	20.00 ft	30.00 ft	40.00 ft	50.00 ft	60.00 ft	70.00 ft	80.00 ft	90.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
50.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
60.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
70.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
80.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
90.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
100.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
120.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
130.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
140.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
150.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
170.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
180.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	100.00 ft	110.00 ft	120.00 ft	130.00 ft	140.00 ft	150.00 ft	160.00 ft	170.00 ft	180.00 ft	190.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
40.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
50.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
60.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
70.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
80.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
90.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
100.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
110.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
120.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
130.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
140.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
150.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
170.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
180.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

********** RESULTS **********

+------> X-direction CONCENTRATION in mg/l (ppm)
|
v Y

	200.00 ft	210.00 ft	220.00 ft	230.00 ft	240.00 ft	250.00 ft	260.00 ft	270.00 ft	280.00 ft	290.00 ft
0.00 ft	0.0240	0.0251	0.0263	0.0275	0.0286	0.0297	0.0308	0.0318	0.0328	0.0337
10.00 ft	0.0313	0.0329	0.0344	0.0359	0.0374	0.0387	0.0401	0.0413	0.0425	0.0436
20.00 ft	0.0410	0.0431	0.0451	0.0470	0.0488	0.0505	0.0521	0.0536	0.0549	0.0562
30.00 ft	0.0539	0.0566	0.0591	0.0615	0.0638	0.0658	0.0677	0.0694	0.0709	0.0722
40.00 ft	0.0713	0.0747	0.0780	0.0810	0.0837	0.0861	0.0882	0.0900	0.0915	0.0927
50.00 ft	0.0952	0.0998	0.1039	0.1075	0.1106	0.1132	0.1152	0.1168	0.1179	0.1185
60.00 ft	0.1298	0.1358	0.1409	0.1449	0.1480	0.1500	0.1512	0.1516	0.1514	0.1506
70.00 ft	0.1838	0.1918	0.1972	0.2002	0.2011	0.2005	0.1986	0.1958	0.1925	0.1887
80.00 ft	0.2854	0.2940	0.2928	0.2861	0.2769	0.2670	0.2570	0.2473	0.2380	0.2291
90.00 ft	-1.0000	0.5354	0.4427	0.3947	0.3608	0.3340	0.3119	0.2931	0.2767	0.2622
100.00 ft	-1.0000	0.5930	0.4937	0.4371	0.3952	0.3619	0.3346	0.3117	0.2922	0.2752
110.00 ft	-1.0000	0.5354	0.4427	0.3947	0.3608	0.3340	0.3119	0.2931	0.2767	0.2622
120.00 ft	0.2854	0.2940	0.2928	0.2861	0.2769	0.2670	0.2570	0.2473	0.2380	0.2291
130.00 ft	0.1838	0.1918	0.1972	0.2002	0.2011	0.2005	0.1986	0.1958	0.1925	0.1887
140.00 ft	0.1298	0.1358	0.1409	0.1449	0.1480	0.1500	0.1512	0.1516	0.1514	0.1506
150.00 ft	0.0952	0.0998	0.1039	0.1075	0.1106	0.1132	0.1152	0.1168	0.1179	0.1185
160.00 ft	0.0713	0.0747	0.0780	0.0810	0.0837	0.0861	0.0882	0.0900	0.0915	0.0927
170.00 ft	0.0539	0.0566	0.0591	0.0615	0.0638	0.0658	0.0677	0.0694	0.0709	0.0722
180.00 ft	0.0410	0.0431	0.0451	0.0470	0.0488	0.0505	0.0521	0.0536	0.0549	0.0562
190.00 ft	0.0313	0.0329	0.0344	0.0359	0.0374	0.0387	0.0401	0.0413	0.0425	0.0436

	300.00 ft	310.00 ft	320.00 ft	330.00 ft	340.00 ft	350.00 ft	360.00 ft	370.00 ft	380.00 ft	390.00 ft
0.00 ft	0.0345	0.0353	0.0360	0.0367	0.0373	0.0378	0.0382	0.0386	0.0389	0.0391
10.00 ft	0.0445	0.0454	0.0462	0.0469	0.0475	0.0481	0.0485	0.0488	0.0490	0.0491
20.00 ft	0.0572	0.0582	0.0590	0.0597	0.0603	0.0607	0.0610	0.0611	0.0612	0.0611
30.00 ft	0.0733	0.0742	0.0749	0.0755	0.0758	0.0760	0.0760	0.0759	0.0756	0.0752
40.00 ft	0.0935	0.0942	0.0945	0.0946	0.0945	0.0942	0.0937	0.0931	0.0923	0.0913
50.00 ft	0.1187	0.1186	0.1182	0.1175	0.1165	0.1154	0.1140	0.1125	0.1109	0.1091
60.00 ft	0.1493	0.1477	0.1458	0.1436	0.1413	0.1388	0.1361	0.1334	0.1306	0.1278
70.00 ft	0.1846	0.1803	0.1760	0.1716	0.1672	0.1628	0.1585	0.1542	0.1501	0.1459
80.00 ft	0.2207	0.2127	0.2051	0.1979	0.1911	0.1846	0.1784	0.1725	0.1669	0.1614
90.00 ft	0.2493	0.2377	0.2271	0.2174	0.2085	0.2002	0.1925	0.1853	0.1785	0.1720
100.00 ft	0.2604	0.2472	0.2354	0.2247	0.2149	0.2059	0.1976	0.1898	0.1826	0.1758
110.00 ft	0.2493	0.2377	0.2271	0.2174	0.2085	0.2002	0.1925	0.1853	0.1785	0.1720
120.00 ft	0.2207	0.2127	0.2051	0.1979	0.1911	0.1846	0.1784	0.1725	0.1669	0.1614
130.00 ft	0.1846	0.1803	0.1760	0.1716	0.1672	0.1628	0.1585	0.1542	0.1501	0.1459
140.00 ft	0.1493	0.1477	0.1458	0.1436	0.1413	0.1388	0.1361	0.1334	0.1306	0.1278
150.00 ft	0.1187	0.1186	0.1182	0.1175	0.1165	0.1154	0.1140	0.1125	0.1109	0.1091
160.00 ft	0.0935	0.0942	0.0945	0.0946	0.0945	0.0942	0.0937	0.0931	0.0923	0.0913
170.00 ft	0.0733	0.0742	0.0749	0.0755	0.0758	0.0760	0.0760	0.0759	0.0756	0.0752
180.00 ft	0.0572	0.0582	0.0590	0.0597	0.0603	0.0607	0.0610	0.0611	0.0612	0.0611
190.00 ft	0.0445	0.0454	0.0462	0.0469	0.0475	0.0481	0.0485	0.0488	0.0490	0.0491

1 This page intentionally left blank.

9 0 1 1 7 8 3 5 1 6 1 0

1
2
3
4

Attachment 5C2-3

CALCULATION OF LEAK DETECTION CAPABILITY

9 0 1 1 7 8 6 1 6 1 1

CALCULATION OF LEAK DETECTION CAPABILITY

Objective

Given a background level of ^{99}Tc in the groundwater at the Grout Treatment Facility (i.e., at wells 299-E25-25 and 299-E25-32), calculate the minimum detection leak rate from a grout vault.

Data

- Based on Sewart et. al (1987): flow through a 50-m cross section is 5.8×10^3 m^3/yr
- Vault dimensions: 15 m x 38 m x 10 m (WxLxD)
- The ^{99}Tc background concentration measurements per Table 5C2-1.

Two Scenarios

- Worst Case: leak on 38-m side, which is perpendicular to groundwater flow
- Best Case: leak on 15-m side, which is perpendicular to groundwater flow.

Table 5C2-1. Grout Treatment Facility Groundwater Monitoring Data.

Date	Well 299-E25-25 (pCi/L)	Well 299-E25-32 (pCi/L)
07/01/87	2.91 E-01	
09/30/87	1.47 E+00	
01/19/88	2.81 E-01	
01/19/88	3.40 E-01	
03/20/88	1.80 E-01	
08/05/88	6.62 E-01	
08/05/88	3.69 E-01	
08/11/88		6.40 E-01
08/11/88		7.60 E-01
10/19/88		2.75 E+00
01/03/89	1.00 E-01	
01/04/89		1.99 E+00
02/24/89		5.40 E-01
02/28/89	7.90 E-01	

NOTE: Position is upgradient; sample is ^{99}Tc.

Flow Rate Calculation:

- Worst Case:

$$\frac{5.8\ E{+}03\ m^3}{50\ m/yr} \times 38\ m \times \frac{1{,}000\ L}{m^3} \times \frac{1\ yr}{3.16\ E{+}07\ s} = \frac{1.39\ E{-}01\ L}{s}$$

- Best Case:

$$\frac{5.8\ E{+}03\ m^3}{50\ m/yr} \times 15\ m \times \frac{1{,}000\ L}{m^3} \times \frac{1\ yr}{3.16\ E{+}07\ s} = \frac{5.51\ E{-}02\ L}{s}$$

Detection Limits--Based on the statistical techniques outlined in Appendices 5D-2 and 5D-3, the groundwater will be considered uncontaminated if it is at the 99 percent level (interim status) and 95 percent level (final status) of significance. It can be stated that the upgradient ^{99}Tc concentration is equal to the downgradient ^{99}Tc concentration. The minimum detectable background shift is determined using the method detailed below.

Test for Normal Distribution--The student's t-statistic used for this analysis only applies to data that are normally distributed. Therefore, the background ^{99}Tc concentration data (Table 1) were tested for normality using the Lilliefors test (Conover 1980). The null hypothesis was that the background ^{99}Tc concentration data are normally distributed with an unspecified mean and variance. The t-statistic, T1, was found to be 0.2036, which is less than the 0.9 quantile of the Lilliefors test statistic of 0.242. Hence, it is concluded that there is no evidence that the data are not distributed normally.

Detectable Shift Calculations--The minimum detectable background shift is calculated using the following formula:

$$Xm - Xb = t \times Sb \times \sqrt{(1+1/Nb)}$$

where

Xm = mean background concentration
Xb = mean concentration from monitoring well
t = student's t-statistic, with significant alpha and Nb-1 degrees of freedom
Sb = background concentration standard deviation
Nb = number of background samples.

Case 1: Interim Status Standards (99% confidence level)

t = 2.7181
Sb = 0.82113 pCi/L
Nb = 12

$$Xm - Xb = 2.781 \times 0.82113 \text{ pCi/L} \times \sqrt{(1+1/12)}$$

$$Xm - Xb = 2.323 \text{ pCi/L minimum detectable background shift.}$$

Case 2: Final Status Standards (95% confidence level)

$t = 1.796$
$Sb = 0.82113$ pCi/L
$Nb = 12$

$$Xm - Xb = 1.796 \times .82113 \text{ pCi/L} \times \sqrt{(1+1/12)}$$

$$Xm - Xb = 1.535 \text{ pCi/L minimum detectable background shift.}$$

<u>Calculation of Minimum Detectable Leak Rate</u>

Case 1: Interim Status Standard (99% confidence level)

Minimum detectable concentration shift is 2.323 pCi/L

- Worst Case: (38-m side)

$$\frac{1.39 \text{ E-01 L}}{\text{s}} \times \frac{2.323 \text{ pCi}}{\text{L}} = 3.23 \text{ E-1 pCi/s (or 3.23 E-13 Ci/s).}$$

- Best Case: (15-m side)

$$\frac{5.51 \text{ E-02 L}}{\text{s}} \times \frac{2.323 \text{ pCi}}{\text{L}} = 1.28 \text{ E-1 pCi/s (or 1.28 E-13 Ci/s).}$$

Case 2: Final Status Standard (95% confidence level)

Minimum detectable concentration increase is 1.535 pCi/L

- Worst Case: (38-m side)

$$\frac{1.39 \text{ E-01 L}}{\text{s}} \times \frac{1.535 \text{ pCi}}{\text{L}} = 2.13 \text{ E-1 pCi/s (or 2.13 E-13 Ci/s)}$$

- Best Case: (15-m side)

$$\frac{5.51 \text{ E-02 L}}{\text{s}} \times \frac{1.535 \text{ pCi}}{\text{L}} = 8.46 \text{ E-02 pCi/s (or 8.46 E-14 Ci/s)}$$

Calculating the 95% confidence limit on ^{99}Tc concentration for the waste (Table 3-3) gives a concentration range of 9×10^{-5} to 6×10^{-5} pCi/L.

The leak detection capability can be calculated by dividing the minimum detectable concentration increase by the waste concentration. The results of this division are presented in Table 5C2-2 and show that a small amount of material released from a vault over a 1-yr period will produce a significant increase in ^{99}Tc concentration in the groundwater.

Table 5C2-2. Minimum Detectable Leak Rate.

Status	Best case (L/yr)	Worst case (L/yr)
Interim Status	4.4 E-02 - 6.43 E-02	1.1 E-01 - 1.6 E-01
Final Status	2.9 E-02 - 4.2 E-02	7.4 E-02 - 1.1 E-01

REFERENCE

Conover, W. J., 1980, *Practical Non-Parametric Statistics*, 2nd ed., John Wiley and Sons, Inc., New York, New York.

1 This page intentionally left blank.

APPENDIX 5D

DETECTION MONITORING PROGRAM

5D-1 Sampling and Analysis Plan

5D-2 Establishing Background

5D-3 Statistical Procedures for Evaluating Changes in Groundwater Parameters

5D-4 Quality Assurance Projects Plan

This page intentionally left blank.

APPENDIX 5D-1

SAMPLING AND ANALYSIS PLAN

1 This page intentionally left blank.

9 0 1 1 7 8 6 1 6 2 0

APPENDIX 5D-1

SAMPLING AND ANALYSIS PLAN

This plan introduces the procedures that will be used for sample collection (including well evacuation and sample withdrawal methods), field measurements, sample preservation and shipment, chemical analysis, chain of custody, and quality control.

All sampling activities are currently performed under contract by Pacific Northwest Laboratory. The U.S. Testing Company, Incorporated, currently conducts sample analyses for most constituents*.

5D1-1.0 SAMPLE COLLECTION PROCEDURES

5D1-1.1 INTRODUCTION

These procedures are intended for use in collecting groundwater samples that will be analyzed for hazardous chemicals. Sample collection at the Grout Treatment Facility site for the detection monitoring wells (299-E25-25, 299-E25-29A, 299-E25-31, 299-E25-32A, and 299-E25-33) is performed using a dedicated piston pump. The baseline monitoring wells (299-E25-26, 299-E25-27, and 299-E25-28) are sampled with dedicated submersible pumps.

5D1-1.2 EQUIPMENT

The following equipment may be needed in the field during sampling:

- Truck-mounted air compressor and generator
- Extra discharge line for submersible pump
- Teflon bailer
- pH and conductivity meter
- Digital thermometer
- Steel measuring tape
- Blue chalk
- Electrical tape
- Engineer's measurement tape

---

*The procedures identified in this appendix are in accordance with EPA standards.

- Stopwatch or watch with second hand
- Bucket or jug (for measuring flow rate)
- Distilled water
- Ziploc* bags
- Ice chests with ice
- Plastic gloves
- Aprons
- Towels
- Indelible marker
- Extra sample labels
- Sample seals
- A copy of all relevant procedures
- Sample containers with caps and liners (including extras)
- Field record forms
- Chain-of-custody forms
- Sample-analysis request forms.

5D1-1.3 SAMPLING PRECAUTIONS

Do not smoke, eat, or handle any objects not necessary for sampling while performing sampling procedures.

Do not sample downwind of any potential sources of volatile organics such as car exhausts or open fuel tanks. These could contaminate the sample. If any such sources are unavoidable, make a note of them on the field record forms.

Leave caps on the sample containers until just before filling.

Avoid handling the Teflon** bottle cap liners. Do not use any liner that falls out of the cap and onto the ground.

---

*Ziploc is a trademark of Dow Chemical Company.
**Teflon is a trademark of E.I. duPont de Nemours and Company, Incorporated.

Chemically inert sampling devices should be used for sampling activities unless a justification is provided to do otherwise.

Wear gloves when taking samples and when handling containers, especially those containers with preservatives added.

A radiation protection technician or equivalent shall monitor for radiation during sampling activities according to Hanford Site regulations, requirements, and standards.

5D1-1.4 Sample Collection Using Submersible Pump

Take water-level measurements according to the water-level measurement procedure (Section 5D1-1.9.1).

Check to see that the hose bib for the submersible pump is open.

CAUTION: Be sure the power switch on the 230-V outlets is turned off!

Plug the power cord into one of the 230-V outlets on the generator on the truck and into the outlet at the well head.

Start the electric generator.

Turn the power switch on to begin the pumping process. Be sure not to handle energized power cords. If the pump does not work properly, as indicated by a lack of airflow out the discharge hose or by failure of the generator to 'lug' down, turn the switch off immediately. After waiting a few seconds, turn the switch on and off several times rapidly, finally pausing in the ON position to determine if the pump has started to function properly.

After the water begins to flow from the outlet, pump the well until the pH, temperature, and specific conductivity have stabilized.

NOTE: Some wells pump down after a period of time. If the well pumps dry while purging, it does not generally mean that a sample cannot be collected. A sample can still be obtained by following these steps.

1. Turn off the submersible pump when the well pumps dry.

2. Wait for the well to recharge. This should be about 15 min, but may take as long as 30 min.

3. Measure the depth to water using the electrical tape. Make sure that the water level is above the pump intake.

4. Turn the submersible pump back on. Collect the samples that are designated for collection with the submersible pump.

Measure the pH, temperature, and specific conductivity of the discharged water at least three times during purging, according to the standard procedures for measuring pH and conductivity (explained in Section 5D1-1.9). The pH will be considered stable when two consecutive measurements agree within 0.2 pH units. Temperature will be considered stable when two consecutive measurements agree within 0.2 °C. Conductivity will be considered stable when two consecutive measurements agree within 10 µmhos. If pH, temperature, and conductivity do not stabilize within the calculated purging time, contact the technical supervisor before collecting samples.

Enter time, date, and your initials on all sample labels.

Record information on field record form as it becomes available. The information that must be recorded on the field record form is described in Section 5D1-2.1.

Check the labels on the sample containers to determine which ones can be filled using the submersible pump (a blue line on the right side of the sample label indicates that the submersible pump should not be used to fill that particular container).

Fill the appropriate sample containers as described under Section 5D1-1.8.

Attach a sample seal to each container and place it in a cooler or ice chest that has ice in it.

5D1-1.5 SAMPLE COLLECTION USING BLADDER PUMP

If the well has a dedicated bladder pump, turn on the air compressor and use the procedure described below. If the well does not have a bladder pump, use the procedures given for the Teflon bailer to collect the remaining samples.

1. Attach the air compressor to the bladder-pump pressure inlet on the face of the controller panel, using the female portion of the coupling supplied.

2. Connect either end of the controller's red air hose to the pump supply on the right side of the control panel. Connect the other end of the controller air hose to the quick-connect nipple located in the well cap assembly.

3. Attach the appropriately labeled extension line to the bladder-pump discharge line.

4. Five of the 15 pumping cycles are required to purge the air from the bladder pump and tubing. Full water flow from the sample supply tube should then begin. After water flows from the outlet tube, pump the well until the pH, temperature, and specific conductivity have

stabilized, (run the bladder pump for at least 5 min before taking samples).

5. To reduce the water-flow rate during sample collection, turn the throttle control on the left side of the control panel in the counter-clockwise direction. To increase the flow rate, turn the throttle control clockwise.

5D1-1.6 SAMPLE COLLECTION USING THE PISTON PUMP (HYDROSTAR*)

Upon arrival at the well head, immediately determine depth-to-water using the appropriate tapes, and record the values determined on the field record form.

Wear gloves when taking samples and when handling containers, especially those with preservatives added.

Attaching the Pneumatic Cylinder Assembly

1. Insert the support for the pneumatic cylinder into the column support on the well head assembly.**

2. Pull the cylinder rod down until it is fully extended and has stopped.

3. Align the eyelet on the top portion of the turnbolt with the clevis pin hole on the lower portion of the cylinder rod.

4. Align the hole on the cylinder support with the column support on the well head so that the turnbolt eyelet and clevis pin hole on the cylinder rod are aligned when the piston is fully extended.

5. Insert the clevis pin through one of the intersecting pairs of holes on the column support and clip a hitch pin into the holes in the small end of the clevis pin.

6. Check the alignment on the turnbolt eyelet with the hole on the cylinder rod. The alignment must be nearly perfect, neither too high nor too low.

7. Adjust by rotating the turnbolt clockwise or counter-clockwise.

---

*Hydrostar is a trademark of Instrumentation Northwest, Incorporated.

**When inserting the cylinder support into the column support on the pump assembly, at least two holes on the cylinder support must overlap with two holes on the column support. If less than two holes overlap, use the extension supplied with the Hydrostar pneumatic cylinder. Align the pumping system in the same manner as described above.

Operating the Pneumatic Cylinder

1. Attach either the purging hose (large diameter) or the Teflon sampling hose to the outlet on the discharge tee of the sampling pump.

2. Attach the quick-connect on the supply hose to the unattached end of the control valve on the pneumatic cylinder. The input air pressure should not exceed 120 lbf/in^2.

3. Turn on air supply to the control valve.

4. Turn on the control valve on the pneumatic cylinder. The piston will begin to operate.

5. Adjust stroke rate to no more than 60/min. (If the pneumatic cylinder assembly is not operating correctly, and the problems are not caused by the well or the pump in the well, the well may be hand pumped as described in "Manual Operations"). The stroke speed of the pneumatic cylinder can be adjusted with the control valve located on the top of the pneumatic cylinder. A stroke is defined as one downward and one upward extension.

6. Pump the well until the pH, temperature, and specific conductivity have stabilized.

Sampling With Pneumatic Piston Assembly

1. Slow down the pumping rate until the piston operates smoothly. This rate will be less than 10 strokes per minute.

2. Attach the Teflon sampling hose and purge at this rate for a minimum of 2 min.

3. Proceed with sampling all unfiltered samples.

4. Attach the filter assembly and purge the filter. If too much pressure is exerted across the filter the membrane will rupture, usually resulting in a popping noise. If this happens, replace the filter and restart the filtering procedure.

5. Dismantle the pneumatic pumping assembly as described below.

Removing the Pneumatic Pumping Assembly

1. Disconnect the air supply at the pneumatic cylinder.

2. Disassemble pneumatic cylinder in reverse order of steps 1 through 7 in the section "Attaching the Pneumatic Cylinder Assembly."

3. Replace well cap over top of well head.

Manual Operations

1. Insert the handle support into the column support on the pump head assembly so that at least two holes on the handle support overlap two holes on the column support.

2. Slide the clevis pin through one of the intersecting pairs of holes on the column support.

3. Clip the hitch pin into the hole in the small end of the clevis pin.

4. Remove the turnbolt on the top of the rod at the well head.

5. Attach the turnbolt on the end of the wire rope that is attached to the handle assembly onto the threaded rod at the top of the well head.

6. Lift the handle so that the flat edge of the cam nearest the shackle is approximately parallel with the ground.

7. Pull all the slack out of the wire rope.

8. Using either an adjustable or a 9/16-in. open-end wrench, tighten both nuts on the shackle until the sheath on the wire rope is compressed, remembering to keep all the slack out of the wire rope.

Manual Well Sampling

1. Attach either the purging hose (large diameter) or the Teflon sampling hose (small diameter) to the outlet on the discharge tee of the sampling pump.

2. Begin pumping the operating handle with smooth, even strokes. For best performance, use 20 to 45 strokes per minute for purging the well. Use less than 10 strokes per minute during sampling. When the filter assembly is attached, special attention is required to prevent rapid buildup of pressure across the filter. If too much pressure is exerted across the filter the membrane will rupture, usually resulting in a popping noise. If this happens, replace the filter and begin sampling for the filtered sample according to the written procedure.

3. When sampling is completed follow the direction below to disassemble the handle assembly from the well head.

Removing the Handle Assembly--Disassemble the handle assembly in reverse order of steps 1 through 8 in the section "Manual Operations."

5D1-1.7 SAMPLE COLLECTION USING TEFLON BAILER

Unclasp the metal bailer from the winch line and replace it with the Teflon bailer.

Disengage the winch clutch and slowly lower the bailer into the water.

Engage the winch clutch when the bailer strikes the water surface.

Allow about 30 s for the sample tube to fill.

Turn the electric winch and slowly raise the Teflon bailer to the surface.

Lower and rinse the bailer twice before collecting a sample.

Unscrew the cap of the sample container, being careful not to touch the lip of the bottle or the inside of the Teflon liner. Avoid touching the mouth of the Teflon bailer.

Unclasp the Teflon bailer.

Pour the water from the bailer into the sample container slowly to prevent trapping any air bubbles. Avoid splashing or agitating the water while the sample container is being filled.

5D1-1.7.1 Teflon Bailer Cleaning Procedure

Wash the inside and the outside of the bailer with a mild mixture of nonphosphate detergent soap and water.

Rinse the bailer with tap water and then distilled water.

Store the bailer in a sealable plastic bag between uses.

5D1-1.8 GENERAL SAMPLE COLLECTION PROCEDURE

Unscrew the cap from the sample container, being careful not to touch the lip of the bottle or the inside of the Teflon liner. Also avoid touching the mouth of the discharge line.

Fill the sample bottle slowly by placing the outlet tube against the inner side of the sample bottle to prevent trapping any air bubbles. Avoid splashing or agitating the water while the bottle is being filled.

NOTE: For those bottles requiring no headspace, the bottle should be filled completely so that a meniscus forms. Cap the bottle immediately, turn it upside down, tap it a few times, and check for air bubbles in the sample. If a bubble exists, discard the sample and repeat the

sampling procedures until an air-free sample is obtained. There is an exception to this if the bottle to be filled contains a preservative, in which case only one attempt will be made to obtain an air-free sample.

As each container is filled, attach a sample seal to it and place it in a cooler or ice chest.

Survey the sample container with a Geiger-Mueller instrument. If the count is greater than 200 c/min, record it on the field record form. Contact the Environmental Monitoring supervisor for instructions concerning where the sample is to be taken.

Turn off the air compressor.

Turn the power switch off and then turn the generator off. Unplug the power cord.

Complete the chain-of-custody and sample-analysis request forms.

Deliver the sample to the appropriate laboratory for analysis as soon as possible, following chain-of-custody procedures. If it cannot be delivered to the laboratory the same day, store the sample in a refrigerator located inside a locked building or within a secured area. The refrigerator must maintain a constant temperature of 4 °C (39 °F). Leave the cooler for use when the samples are delivered.

5D1-1.9 FIELD MEASUREMENTS

5D1-1.9.1 Water-Level Measurement Procedure

Water-level measurements are taken each time a well is sampled, before it is purged. These measurements are taken as depth to water from the top of the well casing, and are read to ±0.01 ft agreement. They must be subtracted from the surveyed elevation of the casing to obtain the elevation of the water table. The water table elevations obtained for all wells in the sampling network during a particular sampling episode can be used to produce a contour map showing the groundwater surface at the time that the measurements were made. These contour maps can be used to help characterize the groundwater flow system and to ensure that the sampling network is adequate.

Graduated steel measuring tapes are more accurate than electrical tapes and so should be used for official measurements, particularly in areas where a low hydraulic gradient exists such as the Grout Treatment Facility site. However, an electrical tape can be used to determine the approximate depth to water.

Equipment--The following equipment will be needed:

- Steel measuring tape with attached weight
- Blue carpenter's chalk
- Electrical tape
- Engineer's measuring tape
- Field record forms.

Graduated Steel Tape Method

1. Chalk the 1-ft section of steel tape below the zero reading point.

2. Find the elevation of the measuring point and the estimated water level from Hanford well information, or use an electric tape to find the approximate depth to water.

3. Lower the steel tape from the well's measuring point (marked with paint on the top of the casing) to the estimated water level. Note the amount of tape that is in the well by reading the tape at the measuring point. This value is referred to as the 'hold point.'

4. Remove the steel tape and check the wetted portion below the zero reading point.

NOTE: If the chalked portion is not wet, repeat the procedure, but allow more of the tape to go down the well (i.e., use a greater hold point).

5. Add the unwetted length of the chalked portion of the tape to the hold point value to obtain the depth-to-water measurement.

6. If the chalked portion is not wet, repeat until the water level is marked on the chalked portion of the tape.

7. Repeat the procedure until two steel tape measurements agree within ±0.02 ft.

8. Record the depth-to-water measurements, time of measurements, measuring device identifying number, and the name of the person taking the measurements on the field record form.

Electric Tape Method

1. Lower the electric tape from the measuring point into the borehole until the buzzer and the light indicate contact with the water.

2. Mark the electric tape at the measuring point and identify the nearest graduation on the electric tape.

9011178516 30

3. If the water level is deeper than the nearest graduation marked on the tape, add the difference to the depth identified to obtain the true depth to water.

4. If the water level is shallower than the nearest graduation marked on the tape, subtract the difference from the depth identified to obtain the true depth to water.

5. Record the depth to water measurements, time of measurements, measuring device, and the name of the person taking the measurements on the field record form.

NOTE: This measurement should be used only as an approximate depth to water, because the electric tape is less reliable than the steel tape.

5D1-1.9.2 Temperature Measurement Procedure

Temperature measurements are taken during and after purging of the well, just before sample collection. Measurements taken during purging are used to help ensure that the well bore has been sufficiently evacuated, as indicated by stabilization of the temperature (the pH and conductivity are measured at the same time for the same reason.) The temperature is considered stable when two consecutive measurements agree within 0.2 °C. The final temperature measurement is taken just before sampling and is recorded as an analytical value for the sample. The digital thermometers are checked regularly against a standard thermometer for accuracy.

Equipment--The following equipment will be needed:

- Digital thermometer
- Field record forms.

Temperature Measurement Procedure

1. Turn on the digital thermometer. Make sure that the switch is positioned so that the measurements will be in degrees centigrade.

2. Place the probe into the stream of water being discharged from the pump.

3. The temperature is indicated by a flashing display, which will normally fluctuate for a few seconds. Wait until fluctuation ceases (i.e., until the same temperature is indicated on three consecutive flashes) and then record the temperature on the field record form.

5D1-1.9.3 Conductivity Calibration and Measurement Procedures

Conductivity measurements are taken during and after purging of the well, just before sample collection. Measurements taken during purging are used to help ensure that the well bore has been sufficiently evacuated, as indicated by stabilization of the conductivity. The pH and temperature are measured at the same time for the same reason. Conductivity is considered stable when two consecutive measurements agree within 10 μmhos. The final conductivity measurement is taken just before sampling and is recorded as an analytical value for the sample. The conductivity meter should be calibrated daily, before it is taken to the field to begin sampling.

Equipment--The following equipment will be needed:

- Conductivity meter
- Distilled or deionized water
- Small screwdriver
- Standard solution
- Field record forms.

Conductivity Calibration Procedure--Internal Standard

1. Empty the sample cup on the meter. Rinse it out with distilled or deionized water. Dry the cup thoroughly.
2. Turn the range switch to TEST.
3. Press the OPERATE button.
4. Use the small screwdriver to adjust the CALIBRATE until the meter or display reads 8.

NOTE: This is to be done as a rough calibration or battery check.

Conductivity Calibration Procedure--Standard Solution

1. Empty the sample cup. Rinse it out with distilled or deionized water.
2. Fill the cup with standard solution.
3. Turn the MODE switch to conductivity.
4. Turn the RANGE selector switch to the correct range for the standard solution.
5. Press the OPERATE button.

9011178616 32

6. Use the small screwdriver to adjust the CALIBRATE until the meter or display reads the solution value.

NOTE: Do not return the conductivity standard solution to the container. Always discard it.

Conductivity Measurement Procedure

1. Check that the conductivity meter is properly calibrated by using the internal standard. Record the conductivity meter identifying number.

2. Remove the cap from the sample cup.

3. Rinse the cup several times with the water to be tested. Then fill the cup with the sample.

4. Turn the conductivity RANGE switch to the correct range.

	Range in µmhos
X1.	0 - 10
X10.	0 - 100
X100.	0 - 1,000
X1,000.	0 - 10,000

5. Turn the MODE switch to CONDUCTIVITY.

6. Press the OPERATE button on the side of the meter.

7. Read the conductivity on the digital display to the nearest µmho and record on field record form. Multiply the meter reading times the scale factor to obtain the correct placement of the decimal point.

8. After taking the reading, dump the sample and refill the cup with distilled water.

9. Replace the cap.

5D1-1.9.4 pH Calibration and Measurement Procedure

Measurements of the pH are taken during and after purging of the well, just before sample collection. Measurements taken during purging are used to help ensure that the well bore has been sufficiently evacuated, as indicated by stabilization of the pH (conductivity and temperature are measured at the same time for the same reason). The pH is considered stable when two consecutive measurements agree within 0.2 pH units. The final pH measurement is taken just before sampling and is recorded as an analytical value for the sample. The pH instrument is calibrated daily, before it is taken to the field for sampling.

Equipment--The following equipment will be needed:

- pH meter
- Distilled or deionized water
- Small screwdriver
- Buffer solutions
- Field record forms.

pH Calibration Procedure

1. Wash the meter's sample cup with distilled water.
2. Fill the cup with 4.0 buffer solution.
3. Turn the MODE switch to pH.
4. Press the OPERATE button. Use the small screwdriver to adjust the ZERO to make the display read 4.0 pH on the upper meter scale or on the digital display.
5. Discard the buffer solution. Wash the cup twice with distilled or deionized water.
6. Fill the cup with 10.0 buffer solution.
7. Adjust the SLOPE to make the display read 10.0 pH.
8. Rinse the cup again and refill it with 4.0 pH buffer solution. Recheck the 4.0 pH value and adjust the ZERO if necessary.

Single Buffer Calibration

1. After the SLOPE is calibrated the first time each day, it may be left alone for subsequent calibration. Recheck the slope as desired.
2. Calibrate with a buffer solution that is close to the range of interest. If the process pH is from 6.0 to 9.0, use a 7.0 buffer solution for single-point calibration.
3. With the buffer solution in the cup, recalibrate only the Standard (STD) to make the display read the desired value.

NOTE: Do not return buffer solutions to their containers. Always discard them.

pH Measurement Procedure

1. Ensure that the pH instrument is properly calibration.

2. Remove the cap from the sample cup.

3. Rinse the cup several times with the water to be tested. Then fill the cup with the sample.

4. Turn the MODE selector switch to pH.

5. Press the OPERATE button on the side of the meter.

6. Read the pH on the upper meter scale or on the digital display to the nearest tenth of a unit. Record the value on the field record form.

7. Dump the sample and refill the cup with distilled water.

8. Replace the cap.

5D1-2.0 CHAIN-OF-CUSTODY PROCEDURES

To ensure the integrity of the samples from the time of collection through data reporting, the history of the custody of each sample will be documented according to these procedures. A sample is considered to be under a person's custody if it is in any of the following stages: (1) in his physical possession; (2) in his view after he has taken possession; (3) secured by him so that no one can tamper with the sample; or (4) secured by him in an area that is restricted to authorized personnel. Anyone having custody of samples must comply with the procedures described below.

5D1-2.1 DELIVERY PROCEDURES

Sample Labels--Fill out and affix gummed paper labels to the sample containers before or at the time of sample collection. The well number noted on the label identifies the well location where the sample was collected. An example sample label is shown on Figure 5D1-1.

Sample Seals--Attach gummed paper seals to the samples immediately upon sample collection, before the samples leave your custody. Attach the seal in such a way that the sample cannot be opened without breaking the seal.

Field Record Form--Record (in black ink) all pertinent information about each sample collected on a field record form and insert into a logbook. It will be a bound book with consecutively numbered pages. An example field record form is shown in Figure 5D1-2.

Chain-of-Custody Form--A chain-of-custody form will accompany all samples from the time they are collected until they are disposed of after analysis and

(sample number) - company code (list of analyses)

(well number)

(bottle preparation)

SAMPLE SIZE: _____ LAB: _____

DATE/TIME: _____

COLLECTOR: _____

Figure 5D1-1. Sample Label.

Battelle
Pacific Northwest Laboratories

FIELD RECORD

Well Number _____ Date _____

Pumping Time: Precalculated _____
New _____

Submersible (Time On) _____
Bladder (Time On) _____

CALCULATIONS

SAMPLES COLLECTED

SAMPLE NO.	VOLUME	PUMP	COLLECTOR

FIELD MEASUREMENTS

WATER LEVEL

Time													
Meas				pH									
Wet				Temp									
(E - tape = _____) Level Below T.C.				Cond									

FIELD OBSERVATIONS _____

Data Recorded By _____ Data Checked By _____

Chain-Of-Custody Form No. _____ Laboratory Record Book No. _____

Page No. _____

BC 1500-113 5-86

Figure 5D1-2. Field Record Form.

reporting. A single form will be used for as many samples as possible. The form to be used is shown in Figure 5D1-3. Each person who handles the sample and signs the form will return a copy of the form to the company contact whose name appears on the top line.

Sample-Analysis Request Form--The U.S. Testing Company, Incorporated, requires that a sample-analysis request form accompany all samples delivered to the laboratory. The field portion of the form will be completed by the sample collector; the laboratory portion will be completed by laboratory personnel. An example sample-analysis request form is shown in Figure 5D1-4.

Normally, samples are delivered directly to the laboratory on the day of collection. If they cannot be delivered on the day of collection, they must be stored in a refrigerator in a locked building (no shipping of the samples will be necessary, because of the laboratory's proximity to the site). All samples will be accompanied by a chain-of-custody form and a sample-analysis request form. Deliver samples only to authorized laboratory personnel.

5D1-2.2 LABORATORY ACCEPTANCE PROCEDURES

The chain of custody does not end at the laboratory door; the laboratory must ensure the continuity of its record by following these procedures:

Receiving Department

1. Remove the sample cooler from the delivery vehicle and bring it into the receiving area.

2. Check the sample cooler for any obvious damage.

3. Sign the chain-of-custody and sample-analysis request forms.

4. If you transfer custody of the cooler to one or more intermediates before it is delivered to the sample custodian, the chain-of-custody form must reflect every change of custody.

Sample Custodian--When the sample cooler is delivered to you (or your designated alternate), sign the chain-of-custody form. Then return one copy to the sender and retain the remaining copies. The sample cooler is now your responsibility (or that of your designated alternate). You must now log in the samples.

1. Examine the sample coolers. On the sample log-in form (Figure 5D1-5), record the following:

   - Presence/absence of custody seal(s) on the samples and cooler

   - Condition of custody seal(s).

Battelle
Pacific Northwest Laboratories
P.O. Box [illegible]
Richland, Washington [illegible]

CHAIN OF CUSTODY

Rev. 1, 01/17/90

Company Contact _____ Telephone: _____

Samples Collected by: _____ Date: _____ Time: _____

Sample Location: _____

Ice Chest No.: _____ Field Logbook Page No.: _____

Remarks: _____

Method of Shipment: _____

Sample Identification

CHAIN OF POSSESSION

Relinquished by:	Received by:	Date/Time:
Relinquished by:	Received by:	Date/Time:
Relinquished by:	Received by:	Date/Time:
Relinquished by:	Received by:	Date/Time

BC-1200-345 (7-85)

Figure 5D1-3. Chain-of-Custody Form.

SAMPLE ANALYSIS REQUEST

Pacific Northwest Laboratory
P O Box 999
Richland WA 99352

United States Testing Company, Inc.
2800 George Washington Way
Richland WA 99352

Collector _____ Received by _____

Date /Time Sampled _____ Title _____

Company Contact _____ Date _____ Time _____

CHAIN OF CUSTODY NO. _____

SAMPLE ID _____

UST SAMPLE ID _____

COMMENTS

	CODE	CONSTITUENT	1	2	3	4	5	6	7	8	9	10	11	12
1	725	ICP METALS 6010												
2	726	ICP METALS 6010 ENHANCED												
3	A20	ARSENIC												
4	A21	MERCURY												
5	A22	SELENIUM												
6	A23	THALLIUM												
7	A24	THIOUREA 8330												
8	727	METHOD 8330 ENHANCED												
9	A51	LEAD BY GFAA												
10	739	PCB												
11	728	PESTICIDES 8080												
12	729	PESTICIDES 8080 ENHANCED												
13	730	VOA METHOD 8240												
14	731	VOA METHOD 8240 ENHANCED												
15	732	A/B/N 8270												
16	733	A/B/N 8270 ENHANCED												
17	734	PESTICIDES METHOD 8140												
18	C68	TOX												
19	C69	TOC												
20	C70	CYANIDE												
21	735	NITRATE, SULPHATE..... (IC)												
22	C77	PERCHLORATE												
23	C78	SULFIDE												
24	C80	AMMONIUM ION												
25	C81	ETHYLENE GLYCOL												
26	109	COLIFORM BACTERIA												
27	181	RADIUM												
28	112	ALPHA												
29	111	BETA												
30	C86	DIOXIN												
31	C87	CITRUS RED #2												
32	191	CONDUCTIVITY												
33	199	pH												
34	736	DIRECT AQUEOUS INJECTION												
35	738	HERBICIDE 2,4-D, 2,4,5-TP SILVEX												
36	737	HERBICIDE 8150 ENHANCED												

DR2:[7,9]66

Figure 5D1-4. Sample-Analysis Request Form.

9011178516 40

U.S. TESTING COMPANY-RD SAMPLE LOG-IN FORM

DATE:

TIME:

COOLER ID :
CLIENT SAMPLE ID :
UST[a]-RD ID :
NUMBER OF BOTTLES IN COOLER :
IS CHAIN OF CUSTODY FORM PRESENT? :
CHAIN OF CUSTODY NUMBER :
IS SAMPLE ANALYSIS REQUEST FORM PRESENT? :

* IS THE CUSTODY SEAL ON THE COOLER INTACT? :

* ARE THE CUSTODY SEALS ON THE BOTTLES INTACT? :

* DO THE SAMPLE LABELS AGREE WITH THE CHAIN OF CUSTODY SHEET?:

* DO THE SAMPLE LABELS AGREE WITH THE SAMPLE ANALYSIS REQUEST SHEET? :

---

* IF ANSWER IS 'NO', PLEASE EXPLAIN BELOW IN DETAIL.

SAMPLES LOGGED IN BY: _____

REVIEWED BY SAMPLE CUSTODIAN: _____

---

[a] = U.S. Testing Company

Figure 5D1-5. Sample Log-In Form.

2. Open the sample coolers, examine the sample documents, and record on the sample log-in form whether chain-of-custody form(s) are present.

3. Remove sample containers and record on sample log-in form the following:

   - Condition of samples (intact, broken, leaking, etc.)
   - Presence/absence of sample labels and sample seals
   - Any discrepancy with chain-of-custody form(s).

If discrepancies are found, contact the sender for clarification.

4. Once all samples have been properly logged in, send a copy of the sample log-in form to the company contact named on the chain-of-custody form.

5. Use an internal numbering system for identification of all samples.

6. Assign internal numbers to the samples and record the numbers on the sample log-in form alongside the corresponding sample number assigned by the collector.

7. Place the properly labeled sample containers in the secure storage area.

5D1-3.0 ANALYTICAL METHODS

This section includes the preservation techniques, analytical methods used, and the current detection levels for the following listed indicator constituents and parameters:

Constituent/parameter	Collection and preservation[a,b]	Methods[c]	Detection limit (p/b)
Total organic halogen	G, H_2SO_4 to pH<2	SW-846, #9020	20
Total organic carbon	AG, H_3PO_4 to pH<2	SW-846, #9060	1,000
Specific conductance	Field measurement	Described in Section 5D1-8.3	
pH	Field measurement	Described in Section 5D1-8.4	
Arsenic	P, HNO_3 to pH<2	SW-846, #7060	5

Constituent/parameter	Collection and preservation[a,b]	Methods[c]	Detection limit (p/b)
Chromium	P, HNO_3 to pH<2	SW-846, #6010	10
Selenium	P, HNO_3 to pH<2	SW-846, #7740	5

[a]P = Plastic, G = Glass, AG = Amber Glass.
[b]All samples will be cooled to 4 °C upon collection.
[c]SW-846 refers to *Test methods for the Evaluation of Solid Waste: Physical/Chemical Methods*, SW-846, 3rd ed., U.S. Environmental Protection Agency, Washington, D. C., revised November 1986.

Special Constituent--Technetium-99 is separated from the actinides, lanthanides, alkaline earths, transition metals, radium, lead, etc., by an iron hydroxide precipitation at pH = 10.0 followed by a carbonate precipitation. Technetium stays in the supernate as the TcO_4^- ion. The solution containing technetium is passed through Bio-Rad* 1x4 (100-200) mesh, anion-exchange resin (Cl-form) in 0.1M HNO_3. Technetium is adsorbed on the column, and all other interfering nuclides pass through. Technetium is finally eluted with 6M HNO_3, and the eluate is evaporated almost to dryness below 90 °C. Technetium is counted by liquid scintillation spectrometry.

5D1-4.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance--Quality Assurance (QA) for groundwater monitoring will be conducted in accordance with approved QA procedures. A QA plan describing the manner in which specific QA requirements are to be met will be prepared before work proceeds past the planning stages.

Quality Control--Quality Control (QC) will be conducted in accordance with approved QC procedures. The purpose of this effort is to determine and document the quality of the analytical results being produced by the laboratory and to institute corrective actions as needed. The QC effort has two main components: (1) routine internal checks performed by U.S. Testing Company, Incorporated, and (2) external checks conducted by Pacific Northwest Laboratory to independently evaluate U.S. Testing Company performance. The scope of these efforts is described in the following paragraphs.

U.S. Testing Company Internal and External Quality Control--Internal QC at U.S. Testing Company includes general practices applicable to a wide range of analyses, as well as specific procedures stipulated for particular analyses. Pacific Northwest Laboratory will use both interlaboratory comparisons and spiked, replicate, and blank samples in evaluating the accuracy of results from U.S. Testing Company. The purpose and scope of each of these are listed below.

*Bio-Rad is a trademark of Bio-Rad Laboratories.

Interlaboratory comparisons using field samples are conducted to determine if the results obtained by the primary laboratory, U.S. Testing Company, are comparable to those obtained from other laboratories. Comparisons currently are being conducted for anions, volatile organics, and metals. Each month, replicate samples from selected wells are delivered to different laboratories (usually within Pacific Northwest Laboratory), and the results are compared with the results from U.S. Testing Company.

Spiked samples are submitted to U.S. Testing Company to estimate the bias of analytical laboratory procedures and to determine when this bias exceeds control limits. Two types of spiked samples sometimes used are blind, spiked samples prepared by Pacific Northwest Laboratory and spiked samples prepared under an established multilaboratory comparison program. Blind, spiked samples containing metals, anions, herbicides, pesticides, and volatile organic compounds (e.g., halomethanes) have been submitted quarterly since January 1986. These samples were prepared by Pacific Northwest Laboratory with materials supplied by Environmental Resource Associates. Additional spiked samples prepared with materials supplied by the U.S. Environmental Protection Agency were added in June 1986. The constituents included are ammonium ion, cyanide, acid/base/neutral compounds, and an expanded number of pesticides and volatile organic compounds. The performance of various analyses, including analyses for semivolatile organics, thiourea, phosphoric pesticides, ethylene glycol, sulfide, and perchlorate, will be monitored. Numbers and types of spiked samples will be modified as needed to ensure that introduced biases are identified.

Replicate analyses of field samples are conducted sometimes to establish how much variability might be expected in the laboratory measurements performed on nearly identical samples. Trip blanks will be submitted to U.S. Testing Company to determine whether environmental conditions encountered during collection and transportation of samples have affected the results obtained by analysis. The trip blank is analyzed for volatile organics.

APPENDIX 5D-2

ESTABLISHING BACKGROUND

1 This page intentionally left blank.

9011175351644

APPENDIX 5D-2

ESTABLISHING BACKGROUND

The approach used for establishing background values consists of quarterly sampling of upgradient wells 299-E25-25 and 299-E25-32. The location of these wells is shown on Plate 5-1 (Appendix 5E). Sampling is conducted in March, June, September, and December during the background characterization period (a minimum of 1 yr) and semiannually thereafter. For each of the indicator parameters specified in Section 5.3.2.4, four replicate measurements are obtained from each sample collected from the two wells during each quarter and are submitted for chemical analysis. Results from each sampling period are placed in an electronic data base and presented in the format indicated by Figure 5D2-1.

Constituent code: xx Constituent name: xx Analysis units: xx Detection limit: x

Well number	Date	Sample #1	Sample #2	Sample #3	Sample #4	Mean	Variance	Coeff. of variation
xxx-xxx-xx	xx-xx-xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	xx.xx
etc.								

Constituent code: xx Constituent name: xx Analysis units: xx Detection limit: x

Well number	Date	Sample #1	Sample #2	Sample #3	Sample #4	Mean	Variance	Coeff. of variation
xxx-xxx-xx	xx-xx-xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	xx.xx
etc.								

Figure 5D2-1. Format for Reporting Results of Sample Analyses.

At least four quarters of data are used to establish background values. Quarterly background summary statistics (mean, variance, standard deviation, and coefficient of variation) are calculated for each well during each quarter of the background characterization period. The methodology for averaging the replicates depends on the distribution of data and whether any of the four replicate measurements are less than the detection limit values. At the end of the background characterization period, comparison background summary statistics will be established in a similar fashion by pooling all the quarterly arithmetic mean values from each well.

Because there is a potential for upgradient sources (i.e., the B Pond) to cause transient changes in groundwater quality, it may be necessary to continuously reevaluate and modify background values. After the background characterization period, sampling from the upgradient wells will be conducted semiannually throughout the active life of the facility and during the post-closure care period.

The historical background values will be compared with upgradient data collected subsequently using the appropriate t-test. If the t-test indicates a significant change (increase or decrease) in the concentration of an indicator parameter, then additional samples will be obtained from each well. Chemical analyses will be performed on each sample and the statistical comparisons with background values will be recalculated. One of two courses of action will result.

- If the differences can be attributed to laboratory or sampling error, continued monitoring of the upgradient wells will be performed on a semiannual frequency.

- If the differences cannot be attributed to either laboratory or sampling error (i.e., the statistical tests indicate a significant change in concentration in the upgradient wells), the sampling frequency will be increased from semiannually to quarterly or monthly.

If background values have changed significantly, then these concentrations may be modified since the historical data are unrepresentative of current upgradient conditions. The recommended method for modifying the background values is to combine the historical data and the recent data using a moving average. The specific methods for computing the moving average will be based on the site-specific hydrogeologic and engineering conditions.

5D2-1.0 CHECKING THE DISTRIBUTION

Different population distributions affect which particular method is used for calculating the background summary statistics. Therefore, it will be necessary to check the reasonableness of any assumptions concerning the distribution of data. It is probable that the data will be distributed normally, but this assumption will be verified. The validity of calculating background summary statistics (Cohen's method) and subsequent statistical testing (i.e., t-test) depends on this assumption.

Statistical goodness-of-fit tests generally require a data set with a substantial number of data values in order to have enough statistical power to discriminate among distributional types. The background data sets are not large enough for reasonable performance of a goodness-of-fit test. Thus, a graphical approach, which compares the empirical distribution of the data with a standard normal, will be used to examine the distributional shapes. If background data sets are large enough, the Shapiro-Wilk's W-statistic (Shapiro and Wilk 1965) will be used to test the null hypothesis that the data values are a random sample from a normal distribution with unspecified mean and variance.

5D2-2.0 CALCULATING QUARTERLY BACKGROUND SUMMARY STATISTICS

The method of calculating quarterly background summary statistics depends on the presence of any data value reported as less than (LT) the limit of detection (DL). Three possible cases and the references providing the necessary methods for calculating background summary statistics are provided. The symbols denoting these quarterly background summary statistics are given below:

$x_{b,ijk}$ = concentration measurement from the ith background well, the jth sampling period, and the kth replicate measurement, where $i = 1$ to n_b (the number of background wells), $j = 1$ to o_b (the number of sampling period), and $k = 1$ to p_b (the number of replicate measurements),

$\bar{x}_{b,ij}$ = average of the replicates ($x_{b,ijk}$) for the ith background well during j^{th} sampling period,

$s^2_{b,ij}$ = variance among the replicates for the ith background well during the jth sampling period, and

$CV_{b,ij}$ = coefficient of variation (expressed as %) among the replicates for the ith background well during the jth sampling period.

Note that the first subscript, b, denotes background.

5D2-2.1 NO 'LESS-THAN' VALUES

The first case is that none of the values are less than the limit of detection. This is the simplest case, and summary statistics are computed with the traditional methods for calculating sample mean, sample variance, and sample coefficient of variation from the replicate data. The formulas are given as:

$$\bar{x}_{b,ij} = \sum_k x_{b,ijk} / p_b$$

$$s^2_{b,ij} = \sum_k (x_{b,ijk} - \bar{x}_{b,ij})^2 / (p_b - 1)$$

$$CV_{b,ij} = (s_{b,ij} / \bar{x}_{b,ij}) * 100$$

5D2-2.2 ALL 'LESS THAN' VALUES

In the second case, all of the values measured for a particular parameter are below the limit of detection. In this situation, the distribution of the data is completely unknown, and there are no unbiased methods available for estimating the mean, variance, and coefficient of variation. Therefore, the

censored values are replaced by the detection limit value as the mean concentration from the ith background well sampled on the jth sampling period (i.e., $\bar{x}_{b,ij} = DL_{b,ij}$). Other summary statistics (variance, standard deviation, and coefficient of variation) will not be provided since their values will be zero.

Replacing censored values by the detection limit provides a biased estimate, and if this situation arises with an indicator parameter, an alternate parameter should be selected if possible.

5D2-2.3 SOME 'LESS THAN' VALUES

This case is by far the most complicated. Here, some of the data values are less than the detection limit, and some of the values are greater than the detection limit. If the data are distributed normally, Cohen's method (Cohen 1961) will be used to calculate the summary statistics. Otherwise, an underlying log-normal distribution will be assumed, and the summary statistics will be calculated using the log-normal maximum likelihood estimator method for censored data (Sarhan and Greenberg 1962). The log-normal distribution is the most reasonable assumption, next to the normal, for characterizing contaminants in the environment (Michels 1971; Waite and Denham 1974). The Sarhan and Greenberg method has been proven superior to other methods for estimating summary statistics from a non-normal population when some data below the limit of detection are present (Gilliom and Helsel 1986).

The following formulas describe the Cohen's method to obtain the quarterly summary statistics when the data are a mixture of values that are greater than or equal to a limit of detection and values that are less than a limit of detection.

(1) Calculate $\gamma_{b,ij}$ as follows:

$$\bar{x}'_{b,ij} = \sum_k x'_{b,ijk} / p'_b$$

$$s'^2_{b,ij} = \sum_k (x'_{b,ijk} - \bar{x}'_{b,ij})^2 / (p'_b - 1)$$

$DL_{b,ij}$ = detection limit for measurements from the ith background well sampled on the jth sampling period

where

$x'_{b,ijk}$ = measurements above or equal to detection limit

p'_b = number of measurements above or equal to the limit of detection

$$\gamma_{b,ij} = s'^2_{b,ij} / (\bar{x}'_{b,ij} - DL_{b,ij})^2$$

(2) Obtain values for $h_{b,ij}$ and $\lambda_{b,ij}$ as follows:

$h_{b,ij}$ = proportion of the replicate measurements below the detection limit at well i on sampling period j

$\lambda_{b,ij}$ = a parameter estimate obtained from entering Table 2 in Cohen (1961) with $\gamma_{b,ij}$ and $h_{b,ij}$.

(3) Compute the quarterly background mean, variance, and coefficient of variation as follows:

$$\bar{x}_{b,ij} = \bar{x}'_{b,ij} - \lambda_{b,ij} (\bar{x}'_{b,ij} - DL_{b,ij})$$

$$s^2_{b,ij} = s'^2_{b,ij} + \lambda_{b,ij} (\bar{x}'_{b,ij} - DL_{b,ij})^2$$

$$CV_{b,ij} = (s_{b,ij} / \bar{x}_{b,ij}) * 100$$

5D2-3.0 CALCULATING COMPARISON BACKGROUND SUMMARY STATISTICS

The statistics that are used for comparison to determine whether there has been a statistically significant increase (and decrease, in the case of pH) in any groundwater contamination indicator parameter in any well are referred to as comparison background summary statistics. These statistics are calculated at the end of the background characterization period using formulas similar to those described in Section 5D2-2.0. The only difference is that the input values used to compute these comparison background summary statistics are the quarterly background means from each of the upgradient wells (used to establish background values), whereas the quarterly background summary statistics use the replicate measurements (for the well, i, and sampling period, j) as input values.

The symbols used to denote these comparison background summary statistics are given below:

$\bar{x}_b$ = the comparison background sample mean

s^2_b = the comparison background sample variance

CV_b = the comparison background sample coefficient of variation.

Before calculating these comparison background summary statistics, it is important to plot the quarterly replicate averages over time to evaluate whether there appear to be seasonal or unusual events. If there are seasonal

fluctuations in the groundwater concentration measurements, two methods are available to reduce the adverse effects of seasonally influenced data.

The first method can be applied when background data for 1 yr are used in the analysis. This method simply calls for the seasonal effect to be included in the variance estimate (error term) used for the averaged replicate t-test. Therefore, comparisons of monitoring well data with the background data will not lead to inaccurate contamination assessments because the seasonal variability will have been accounted for in the error term. Under this method, the difference between the upgradient and downgradient mean must exceed the differences expected by seasonal change, to indicate contamination (NWWA 1986).

The other method requires that the upgradient wells have been monitored for more than 1 yr. Under this approach, the background and monitoring data are adjusted to reduce the tendency for the data values to become seasonally large or small, but retain their original error structure. Details are documented in NWWA (1986).

5D2-4.0 REFERENCES

Cohen, A. C., 1961, "Table for Maximum Likelihood Estimates: Singly Truncated and Singly Censored Samples, *Technometrics 3*, pp. 535-541.

Gilliom, R. J. and D. R. Helsel, 1986, "Estimates of Distributional Parameters for Censored Trace Level Water Quality Data - 1. Estimation Techniques," *Water Resources Research 22*, pp. 135-146.

Michels, D. E., 1971, "Log-Normal Analysis for Plutonium in the Outdoors," *Proceedings of the Environmental Plutonium Symp.*, LA-4756, Los Alamos National Laboratory, Los Alamos, New Mexico, pp. 105-11.

NWWA, 1986, *RCRA Ground Water Monitoring Technical Enforcement Guidance Document*, Appendix B, National Water Well Association, Dublin, Ohio, pp. B27-B29.

Sarhan, A. E. and B. G. Greenberg, 1962, *Contributions to Order Statistics*, Wiley, New York, New York.

Shapiro, S. S. and M. B. Wilk, 1965, "An Analysis of Variance Test for Normality (Complete Samples)," *Biometrika*, 52, 591-611.

Waite, D. A. and D. H. Denham, 1974, *Log-Normal Statistics Applied to the Planning, Collection and Analysis of Preoperational Environmental Surveillance Data*, BNWL-SA-4840, Battelle Northwest Laboratories, Richland, Washington.

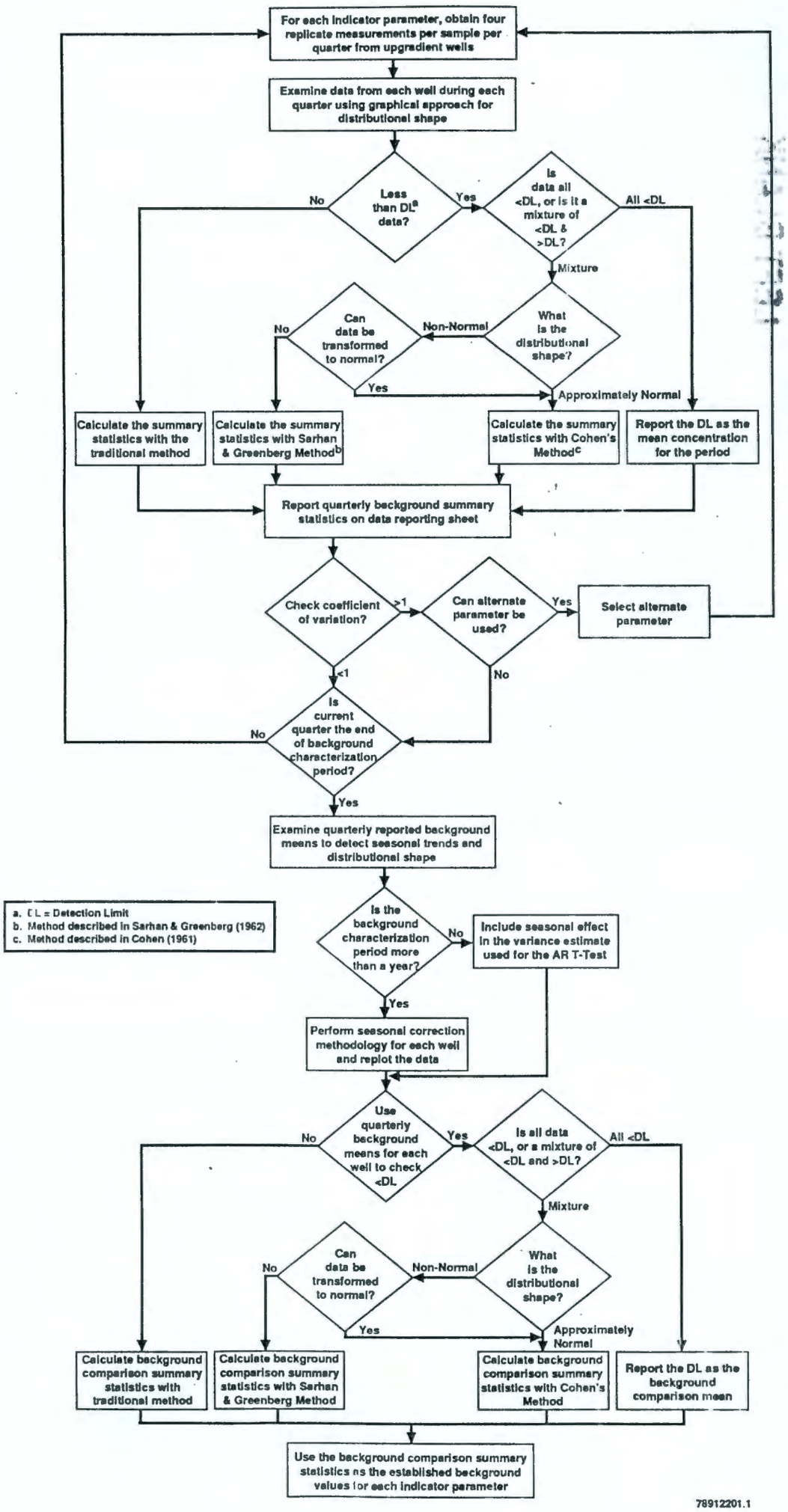


Figure 5D-2.2. Calculation of Background Summary Statistics.

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX 5D-3

STATISTICAL PROCEDURES FOR EVALUATING CHANGES IN GROUNDWATER PARAMETERS

This page intentionally left blank.

APPENDIX 5D-3

STATISTICAL PROCEDURES FOR EVALUATING CHANGES IN GROUNDWATER PARAMETERS

Because of the complex nature of the groundwater system and the likelihood for change in conditions, a multioption statistical methodology is used to detect changes in groundwater quality (Figure 5D3-1). This methodology ensures that the statistical test used for comparing monitoring well (upgradient and downgradient) data collected after characterization of the background groundwater quality is the best method for the existing conditions. The proposed statistical procedures provide a reasonable balance between the probability of falsely identifying a noncontaminating regulated unit (false positive) and the probability of failing to identify a contaminating regulated unit (false negative).

Subsequent to the establishment of the background groundwater concentrations, the entire monitoring well system is sampled semiannually, in March and September. The purpose is to determine whether any well in the monitoring system has concentrations that are larger than (or in the case of pH, different from) those established during the characterization of background groundwater quality. The interim status regulations [40 CFR 265 Subpart F (EPA 1988b)] require that a Student's t-test be used to determine whether there has been a statistically significant increase (and decrease, in the case of pH) in any groundwater contamination indicator parameter in any well. The t-test used in the analysis of interim status detection monitoring shall accommodate the data collected. The hypotheses that will be tested are described as:

(1) pH

- The null hypothesis (H_0) is that the upgradient (UG) value is equal to the downgradient (DG) value
- The alternative hypothesis (H_a) is that the UG value is not equal to the DG value (this is a 'two-tailed' test)

(2) Other parameters

- The H_0 is that the UG value is equal to the DG value
- The H_a is that the UG value is less than the DG value (this is a 'one-tailed' test).

Key assumptions of the t-test procedures are that the data are independently and normally distributed. Independent samples may be obtained by allowing an adequate amount of time to elapse (or a sufficient amount of water to be pumped) between samples so that the liquid in one sample does not influence the liquid in another sample. This appendix describes the methods for examining the distributional assumptions.

Note that other non-t-test statistical procedures, such as nonparametric tests, which are less dependent on distributional assumptions, generally do not satisfy the requirements for interim status detection monitoring. However, the permit regulations [40 CFR 264, Subpart F (EPA 1988a)] allow the use of nonparametric tests such as the Mann-Whitney test (Conover 1980) when comparing downgradient groundwater quality to that of background.

Checking for Normal Distribution--As mentioned above, an underlying assumption for the validity of all varieties of the t-test is that the data are normally distributed. This assumption is examined before proceeding with any of the t-tests. Approaches used to check the downgradient data distributional types are similar to those used for the background data (i.e., graphical presentation or, less likely, a statistical goodness-of-fit test). The details are described in Section 5D2-2.2 of Appendix 5D-2. The replicate averages tend to approach a normal distribution because of a fundamental statistical principle referred to as the central limit theorem. If the distribution should prove to be non-normal, transformations on the data are performed or a nonparametric test is used as an alternative to the t-tests within the requirements of the regulations.

Calculating Downgradient and Upgradient Summary Statistics--The method for calculating downgradient and upgradient summary statistics depends on the distribution of the data and whether or not any of the four replicate measurements are less than detection limit values. The methods are the same as that described in Appendix 5D-2. In addition, if the background data have been adjusted for the seasonal trend, the data from subsequent monitoring events must also be corrected in a similar fashion. The following symbols denote the summary statistics calculated after the background characterization period:

$\bar{x}_{m,i}$ = average of the replicates from the ith monitoring well during each of the subsequent sampling periods

$s^2_{m,i}$ = variance among the replicates for the ith monitoring well during each of the subsequent sampling periods

$CV_{m,i}$ = coefficient of variation among the replicated during each of the subsequent sampling periods.

Checking for Equal Variances--At this point, a standard F-test will be used to determine if the variance of the background data is comparable to that of the downgradient wells. This check is necessary to select the appropriate version of the t-test. The assumption of equal variances will be tested by calculating

$$F = \max(s_b^2, s_{m,i}^2) / \min(s_b^2, s_{m,i}^2).$$

That is, divide the larger of the two sample variances by the smaller of the two sample variances, where s_b^2 = the comparison background sample variance (calculated with the procedure described in Appendix 5D-2); and

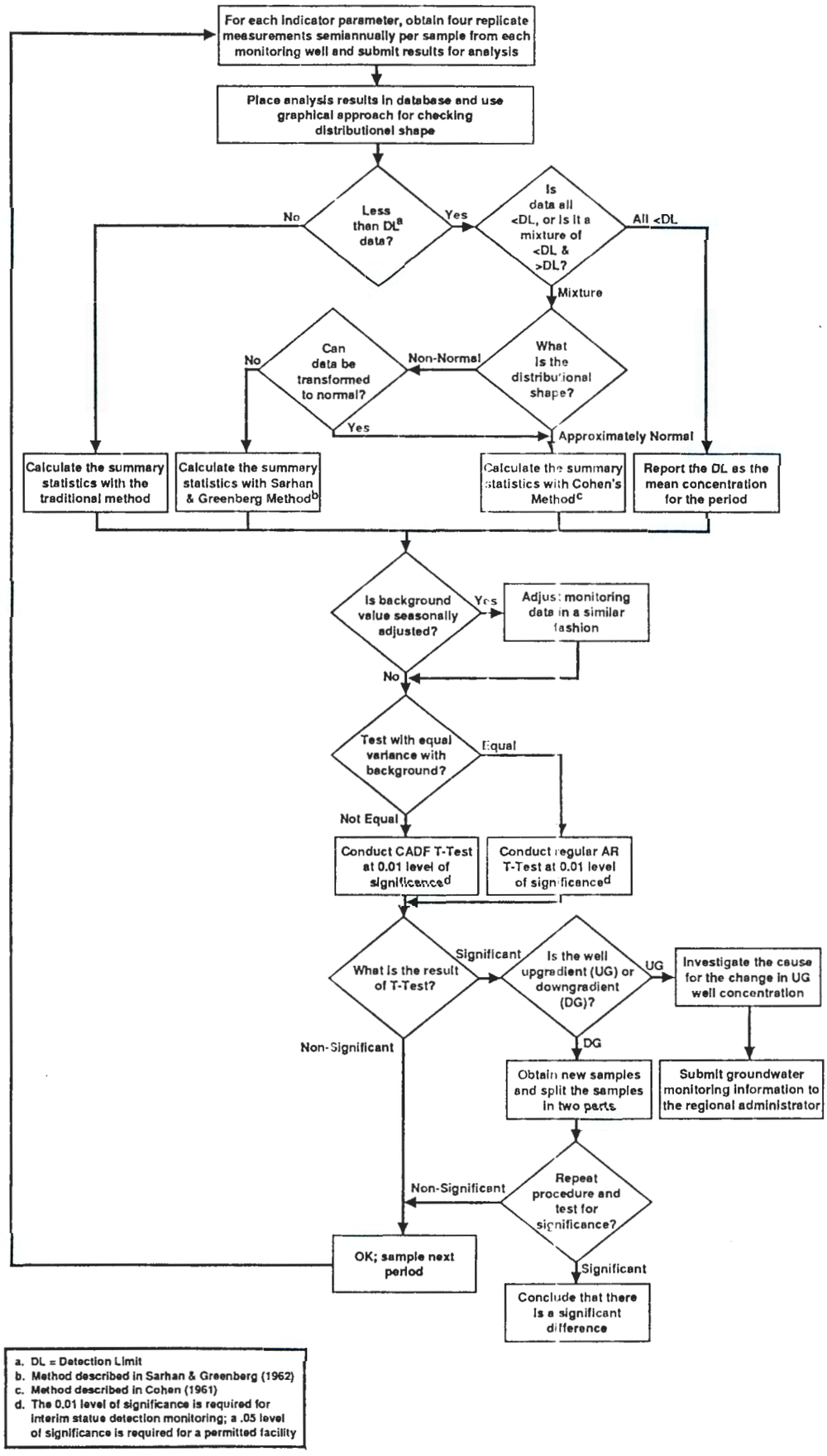


Figure 5D-3.1. Methodology for Evaluating Changes in Groundwater Quality.

THIS PAGE INTENTIONALLY
LEFT BLANK

$s^2_{m,i}$ = the sample variance among the replicates for the ith monitoring well (calculated with the same procedure as above).

If $s_b^2 > s^2_{m,i}$, let $k_1 = n_b - 1$, and $k_2 = n_m - 1$; and if $s_b^2 < s^2_{m,i}$, let $k_1 = n_m - 1$, and $k_2 = n_b - 1$, where n_b = number of background samples used in determining s_b^2, and n_m = number of replicate measurements (for the ith monitoring well) used in determining $s^2_{m,i}$.

The equality is rejected if F is larger than the tabulated value of F (Snedecor and Cochran 1980; F distribution, upper 2.5 percent points) with k_1 and k_2 degrees of freedom.

<u>The Averaged Replicate t-Test</u>--If the assumptions of normality and equal variances are not rejected, the averaged replicate (AR) t-test is used to examine whether there has been a statistically significant increase (and decrease, in the case of pH) in any groundwater contamination indicator parameter in any well. The AR t-test is a preferred test to apply to the interim status detection monitoring data because it helps to reduce statistically caused false positives. The AR t-statistic is calculated as

$$t^*_{m,i} = (\bar{x}_{m,i} - \bar{x}_b) / s_b \sqrt{1 + 1 / (n_b * o_b)}$$

where

$\bar{x}_{m,i}$ = average of the replicates from the ith monitoring well in each of the subsequent sampling period

$\bar{x}_b$ = the comparison background sample mean

s_b = the comparison background sample standard deviation

n_b = the number of background wells

o_b = the number of background sampling periods.

The value of $t^*_{m,i}$ is compared with critical values from the t-distribution that have been adjusted to control the overall false positive probability for the waste management facility. Critical values (t_c) based on Bonferroni t-statistics (Millikan and Johnson 1984) are used for each individual comparison to control the overall false positive rate at 1 percent for the entire facility [note that the 1 percent level of significance is required in the interim status detection monitoring by 40 CFR 265, Subpart F (EPA 1988b)]. The values of t_c depend on the total number of wells in the monitoring system and the number of degrees of freedom associated with the comparison background sample variance.

The test statistics (t^*) computed for each well are compared with the Bonferroni critical values (t_c) for an overall significance level of 1 percent, using the following decision rules.

(1) For pH, the null hypothesis is rejected if $| t^* |$ (absolute value of t^*) is larger than t_c, because there is a statistical indication that pH has changed.

(2) For other variables, the null hypotheses is rejected if t^* is larger than t_c, because there is a statistical indication that the concentrations are higher in the well under investigation.

<u>The CABF t-Test</u>--In the case of normally distributed data but unequal variances, Cochran's approximation to the Behrens-Fisher (CABF) t-test will be used to test for statistical significance (Ostle and Malone 1988).

All summary statistics are calculated according to previous defined procedures. The test statistic t^* is defined as:

$$t^*_{m,i} = (\bar{x}_{m,i} - \bar{x}_b) / \sqrt{(s^2_{m,i} / n_m) + (s^2_b / n_b)}$$

where

$\bar{x}_{m,i}$, $\bar{x}_b$, $s^2_{m,i}$, n_m, and n_b are the same as defined previously

and

s^2_b = the comparison background standard deviation.

This test statistic (t^*) is compared to a comparison statistic (t_c) that is calculated as follows.

First, for a 'two-tailed' test find t_b and t_m from the t-tables (Snedecor and Cochran 1980)

where

$$t_b = t_{(1 - \alpha/2),\ (n_b - 1)}$$

$$t_m = t_{(1 - \alpha/2),\ (n_m - 1)}$$

or, for a 'one-tailed' test,

$$t_b = t_{(1 - \alpha),\ (n_b - 1)}$$

$$t_m = t_{(1 - \alpha),\ (n_m - 1)}$$

and $\alpha = 0.01$ in a interim status detection monitoring program; but $\alpha = 0.05$ in a permitting monitoring program. Critical values based on Bonferroni

t-statistics are used for each individual comparison to control the false positive rate at 1 percent (or 5 percent) for the entire facility. This is accomplished by replacing $(1 - \alpha / 2)$ by $(1 - \alpha/ 2r)$ in a 'two-tailed' test, and replacing $(1 - \alpha)$ by $(1 - \alpha/ r)$ in a 'one-tailed' test where r = the total number of individual comparisons.

Then, the weights W_b and W_m are defined as

$$W_b = s_b^2 / n_b$$

and

$$W_m = s_m^2 / n_m$$

and the comparison t-statistic is

$$t_c = (W_b t_b + W_m t_m) / (W_b + W_m).$$

The null hypothesis of equality of means (monitoring well as compared with the background means) is rejected if

$$t^* \geq t_c \qquad \text{(for 'one-tailed' test)}$$

or if

$$| t^* | \geq t_c \qquad \text{(for 'two-tailed' test).}$$

<u>The Mann-Whitney Test for a Non-Normal Distribution</u>--The interim status regulations [40 CFR 265 (EPA 1988b)] require that a Student's t-test be used to determine whether there has been a statistically significant increase (and decrease, in the case of pH) in any groundwater contamination indicator parameter in any well. It is noted that parametric methods such as the t-test give robust to small departures from the normality assumption, particularly when the sample sizes are large.

However, the permit regulations [40 CFR 264 (EPA 1988a)] allow the use of alternative statistical procedures when the underlying distribution proves to be non-normal. One of the nonparametric alternatives to the two-sample t-test is the Mann-Whitney test (Conover 1980). The test is described as follows.

First, all the background observations are combined in a list with the observations from the monitoring well in question. Next, the combined observations are ranked from smallest to largest, using average ranks in case of ties. Let R_i, $i = 1, 2, \ldots, n$ $(n = n_b + n_m)$ denote the ranks, from the combined list of ranks, of the data from the background wells. The test statistic is

$$T = \Sigma R_i.$$

This test statistic is used when there are no ties, or just a few ties. If there are many ties, subtract the mean from T and divide by the standard deviation to obtain:

$$T_1 = [T-n_b\ (n+1)/2]/\sqrt{[n_b\ n_m\ * \Sigma R_i^2\ ]/[n(n-1)]-[n_b n_m (n+1)^2]/[4(n-1)]}.$$

Critical values (t_c) corresponding to 'too small' or 'too large' are tabulated in Conover (1980). Finally, the null hypothesis is rejected if

$T > t_c$ (too large) ('one-tailed' test)

or if

$T > t_c$ (too large) or
$T < -t_c$ (too small) ('two-tailed' test).

REFERENCES

Conover, W. J., 1980, *Practical Non-Parametric Statistics*, 2nd ed., John Wiley and Sons, Inc., New York, New York, pp. 216-223.

Ostle, B. and L. C. Malone, 1988, *Statistics in Research: Basic Concepts and Techniques for Research Workers*, 4th ed., The Iowa State University Press, Ames, Iowa, pp. 154.

Snedecor, G. W. and W. G. Cochran, 1980, *Statistical Methods*, 7th ed., The Iowa State University Press, Ames, Iowa, pp. 469, 480-488.

EPA, 1988a, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 264, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 265, U.S. Environmental Protection Agency, Washington, D.C.

Millikan, G. A. and D. E. Johnson, 1984, *Analysis of Messy Data, Volume I: Designed Experiments*, Lifetime Learning Publications, Belmont, California, pp. 33-34, 454-455.

19.0 PROCUREMENT CONTROL

19.1 Purchase Requisitions and Subcontracts

Procurements of items and subcontracted services are governed by PNL-MA-70 Administrative Procedure **PAP-70-401, Preparation, Review, and Approval of Purchase Requisitions.**

19.2 Work Orders and Work Package Authorizations

Work package authorizations (WPAs) or work orders (WOs) to individuals or groups outside the project organization must be generated and issued in accordance with PNL-MA-70 Administrative Procedure **PAP-70-404, Obtaining Services Via Work Orders.** As appropriate (as specified in PAP-70-404), a letter of instruction (LOI) or statement of work (SOW) must accompany each WO or WPA. A readiness review must be performed by a representative of the PNL Process Quality Department prior to work described in the SOW/LOI being initiated.

A Request for Analytical Services (RFAS) must accompany all samples submitted for analysis under a WO/WPA. The RFAS form is shown in PAP-70-404, Exhibit 6. An alternate, project-generated RFAS form, may be utilized provided that it contains equivalent information. The cognizant Quality Engineer must review and sign the first RFAS submitted under each SOW/LOI.

Project managers and task leaders have the option of preparing and maintaining the Work Order Log required in PAP-70-404 or allowing the log to be maintained at the group or section level by administrative staff.

9 0 1 1 7 8 6 1 7 0 3

20.0 STAFF TRAINING

Staff performing activities affecting quality shall be issued documented training assignments including applicable administrative and technical Procedures and this QA project plan.

20.1 Training Assignments

Staff shall be issued training assignments identifying specific training needs as specified in PNL-MA-70 Administrative Procedure **PAP-70-201, Indoctrination and Training, Exhibit 2 and Exhibit 3.** Alternate training assignment forms from those shown in PAP-70-201 may be used provided they contain equivalent information.

A copy of the staff member's Training Assignment form without completion of sign-offs does not need to be submitted to Laboratory Training at the time of being issued as specified in PAP-70-201, 4.4.2.

When each staff member has completed the assigned training, the training assignment(s) shall be returned to the cognizant Manager, or designee, who assigned the training. They will sign and date the bottom of the assignment indicating that assigned training has been completed, forward a copy to PNL Laboratory Training Coordination (LTC), and maintain the original as a project record.

20.2 Briefings and Formal Classroom Training

Briefings and formal classroom training must be documented using the Briefing Documentation Form and Training Attendance Form respectively. These forms are shown in PAP-70-201, Exhibit 2 and Exhibit 3.

21.0 SOFTWARE CONTROL

Computer code development, modification, and application activities are limited to those associated with the Hanford Ground-Water Data Base (HGWDB). These activities shall be performed in accordance with documented software Procedures for the Hanford Ground-Water Data Base.

Formal verification testing is required only for software classified as engineering/scientific.

21.1 Non-HGWDB Software Activities

If computer code development, modification, or application not associated with the HGWDB is to be performed (e.g., ground-water flow models), a documented assessment of the impact level of the activity based on the criteria contained in PNL-MA-70 Administrative Procedure **PAP-70-208, Impact Levels** shall be performed. If the impact level is determined to be Level I or II, the PNL-MA-70 software control Procedures (SCP-70-312 through -318) contained in Volume 1 of the PNL-MA-70 QA Manual shall be applied to the work. If the impact level is determined to be Level III, the minimum good practices for software development contained in the PNL Good Practices Standard, PNL-MA-70, Part 2, shall be applied.

22.0 NONCONFORMANCES AND DEFICIENCIES

For materials found to be in nonconformance with specifications, a Nonconformance Report (NCR) must be generated and the item(s) dispositioned in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1501, Nonconformance Reports.** The Westinghouse Hanford Company Projects cognizant engineer, Projects QA Representative, and Geosciences cognizant engineer must sign-off on the NCR. Nonconforming data are discussed in Section 11.

Unplanned deviations from Procedures, plans, specifications, or related documents shall be documented using a Deficiency Report (DR) in accordance with the requirements in PNL-MA-70 Administrative Procedure **PAP-70-1502, Controlling Deviations from QA Requirements and Established Procedures.** Potentially impacted data shall be segregated or flagged pending evaluation of the deficiency's impact on the data and final disposition of the DR.

See also Section 11 for handling suspect or unacceptable data and Section 16 for corrective actions.

9 0 1 1 7 8 6 1 7 0 6

23.0 DOCUMENT CONTROL

23.1 QA Project Plan Control

Distribution and control of this QA project plan shall be performed in accordance with PNL-MA-70 Administrative Procedure PAP-70-205, **Quality Assurance Plans**. Because of the large number of projects and staff using this plan, its distribution will be controlled by PNL Document Control.

Modifications to this QA project plan shall be made in accordance with Section 4.6 of PNL-MA-70 Administrative Procedure PAP-70-205, **Quality Assurance Plans**, that is, either by revision or by issue of an Interim Change Notice (ICN). Any PNL staff member may request an interim change to this QA project plan at any time by submitting a Document Change Request (DCR) to the Project Manager or Quality Engineer.

23.2 Technical Procedure Control

All technical Procedures referenced by this QA project plan are contained in PNL-MA-567, Procedures for Ground-Water Investigations. PNL-MA-567 is distributed and controlled by PNL Document Control. Modifications to any of the Procedures contained in PNL-MA-567 shall be performed in accordance with PNL-MA-70 Administrative Procedure PAP-70-602, **Procedure and Instruction Change Control and Change Request**. New technical Procedures, whether they will be included in PNL-MA-567 or not, must be developed in accordance with PNL-MA-70 Administrative Procedure PAP-70-1101, **Test Planning, Performance, and Evaluation** and controlled in accordance with Administrative Procedure PAP-70-601, **Document Control**. All technical Procedures shall be distributed and controlled by PNL Document Control.

24.0 MONITORING WELL INSTALLATION

Westinghouse Hanford Company (WHC) has contracted Kaiser Engineers Hanford (KEH) to provide drilling and procurement services related to well construction. WHC will provide the construction specification to be used for well installation. KEH will provide receiving inspection services for materials they procure.

24.1 Geologic Characterization and Inspection Documentation

Geologic sampling and inspection of well construction must be performed in accordance with PNL-MA-567, **DO-1 Collection and Documentation of Borehole Samples and Well Construction Data.** Initial receiving inspection of construction materials will be the responsibility of the organization procuring the materials. PNL will not provide such inspection.

Special sediment samples to be analyzed for chemical parameters or potentially contaminated sediments shall be sampled and characterized in accordance with PNL-MA-567, **DO-4 Contaminated Sediment Sampling.**

PNL-MA-567 Procedure **DO-2, Split-Barrel Auger Sediment Sampling,** shall be followed when performing sampling of sediments for geologic description, determination of physical and hydraulic properties, and/or chemical analyses using a split-barrel sampler.

24.2 Modifications to Well Technical Specifications

The construction specification(s) to be used for ground-water monitoring wells are developed, issued, and controlled by WHC. Any modifications to these specifications must be initiated by contacting the WHC Programs technical liaison and requesting that WHC change protocols be followed.

24.3 Geophysical Logging

Wells will be logged with a gross gamma-ray logging tool after placement of each casing, if a log is desired, and upon reaching total depth. If other geophysical logging is to be performed, the types of logging to be used will be specified in the PMP/WHC Statement of Work. All logging performed for WHC must be performed in accordance with PNL-MA-567 geophysical logging procedures previously approved by WHC.

24.4 Monitoring of Well Development

The monitoring of well suitability during well development for the purpose of collecting ground-water samples shall be performed in accordance with PNL-MA-567 Procedure **GC-7, Well Development.**

9011178617008

24.5 Sediment Sample Analysis

Physical analysis of sediment samples will be performed in accordance with the "SA" sediment analysis Procedures contained in PNL-MA-567.

24.6 SELECTION OF SCREEN AND FILTER PACK

The rationale for selection of screen slot size and filter pack sizes for wells must be documented by the Well-Site Geologist on the Drill Log form.

24.7 Hydrologic Testing

The following PNL-MA-567 Procedures will be used in performing hydrologic testing (as appropriate):

- AT-1, Setting and Instrumenting the Test Pump
- AT-2, Configuration of Surface Fittings and Monitoring Devices for Monitoring Well Development or Hydrologic Testing
- AT-3, Starting the Pump and Clearing the Borehole of Construction Fluids
- AT-4, Well Development
- AT-5, Constant Discharge Test
- AT-6, Aquifer Slug Injection and Withdrawal Test

Instrumentation used in aquifer testing shall be controlled in accordance with PNL-MA-70 Administrative Procedure PAP-70-1201, Calibration Control System, as indicated in Section 9.

24.8 Nonconformances or Unexpected Conditions

If unexpected conditions are encountered, or construction activities are not in conformance with the construction specifications, or the activities will not meet the fitness-for-use objective, the Well-Site Geologist is responsible for stopping work and contacting the WHC Projects cognizant engineer and the WHC Geosciences cognizant engineer.

See Section 22 for initiating Nonconformance Reports (NCRs).

This page intentionally left blank.

9 0 1 1 7 8 6 1 7 1 0

APPENDIX 5E

GROUNDWATER CHARACTERIZATION DRAWINGS

Appendix 5E contains the following groundwater characterization drawings:

Plate 5-1 Borehole Locations

Plate 5-2 Water-Table Surface

Plate 5-3 Environmental Monitoring

9011786172

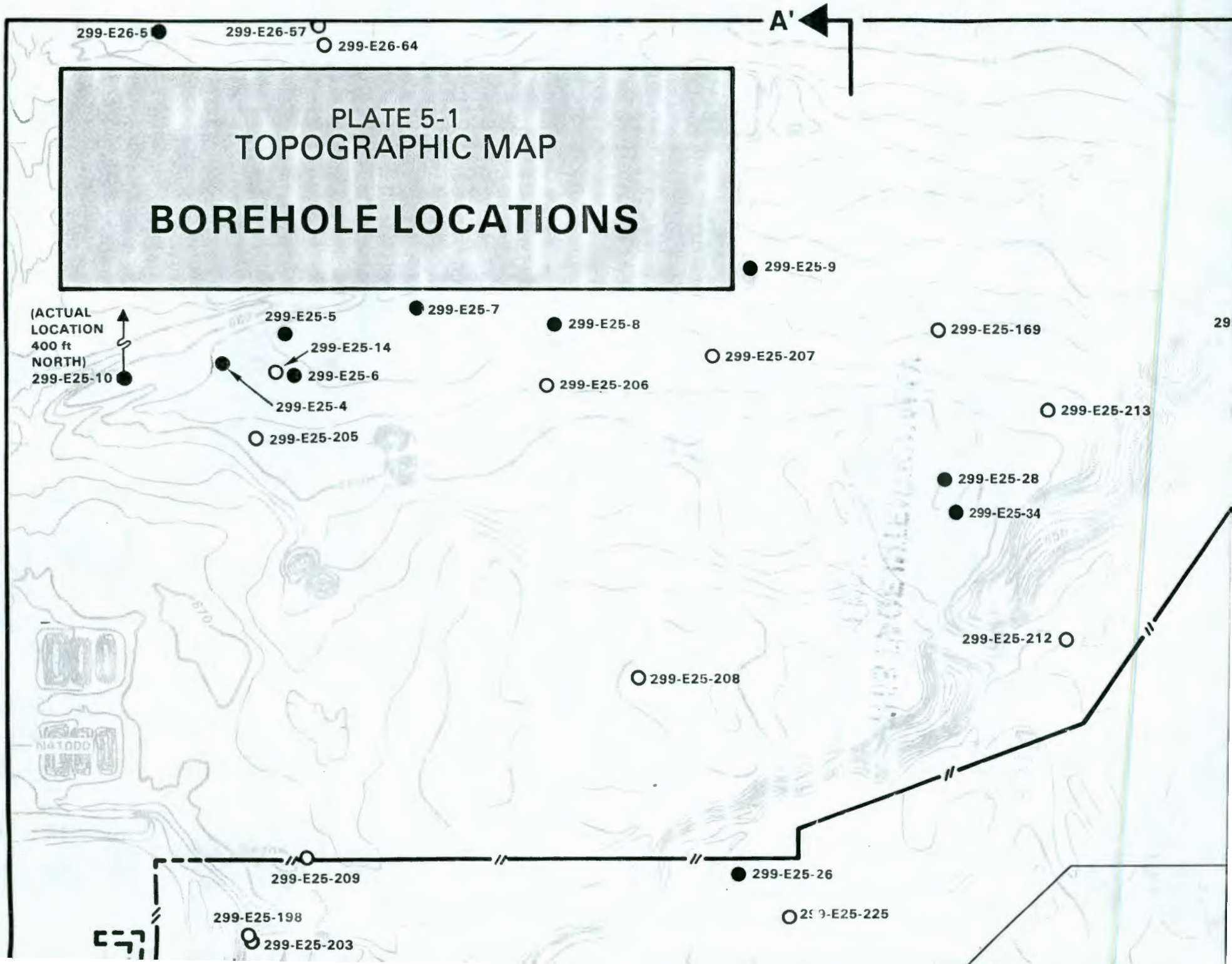


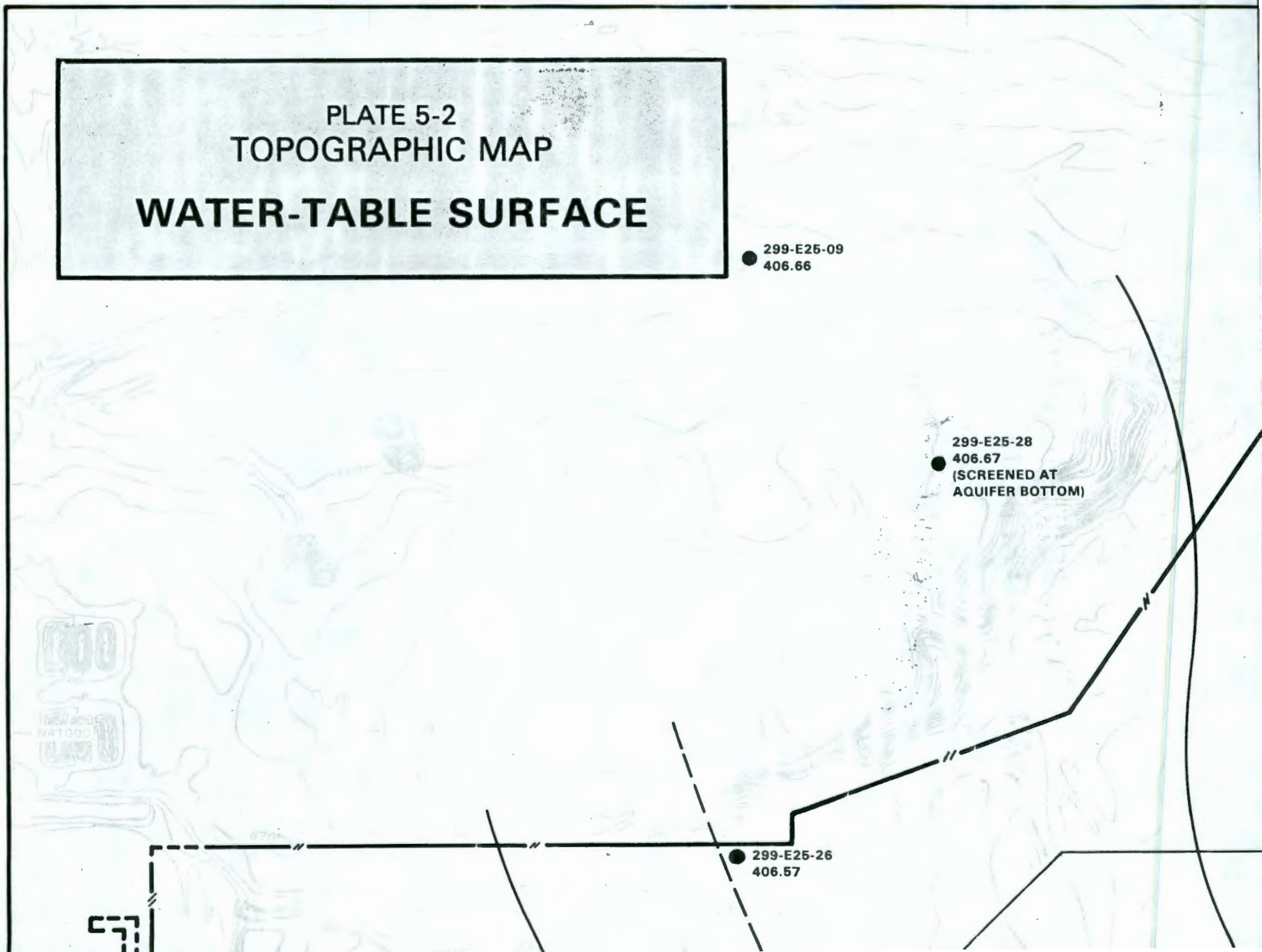
PLATE 5-1
TOPOGRAPHIC MAP
BOREHOLE LOCATIONS
A'
299-E26-5
299-E26-57
299-E26-64
299-E25-9
(ACTUAL LOCATION 400 ft NORTH)
299-E25-10
299-E25-5
299-E25-7
299-E25-8
299-E25-14
299-E25-6
299-E25-4
299-E25-169
299-E25-207
299-E25-206
299-E25-213
299-E25-205
299-E25-28
299-E25-34
299-E25-212
299-E25-208
299-E25-209
299-E25-26
299-E25-198
299-E25-203
299-E25-225

THIS PAGE INTENTIONALLY
LEFT BLANK

PLATE 5-2

TOPOGRAPHIC MAP

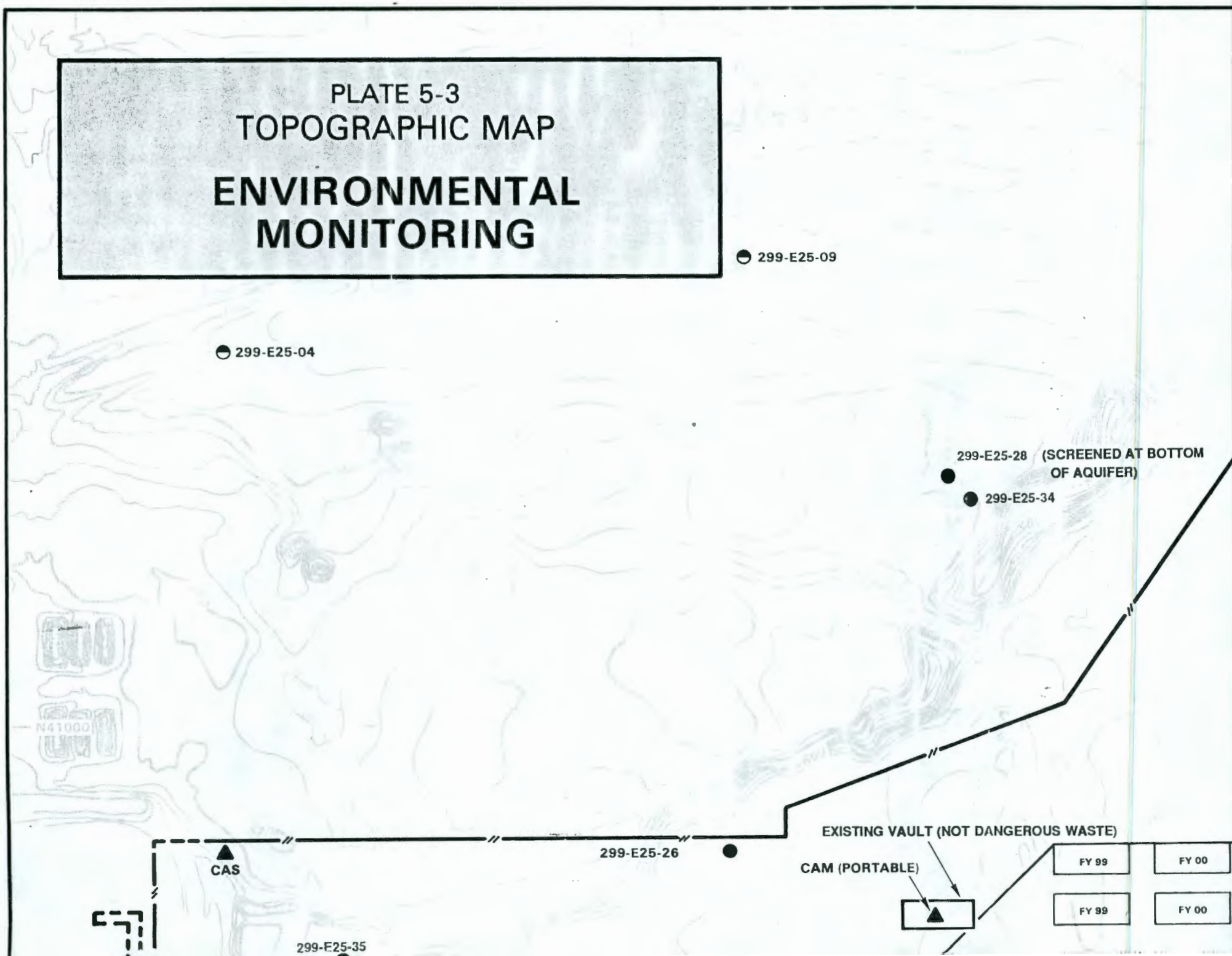
WATER-TABLE SURFACE



THIS PAGE INTENTIONALLY
LEFT BLANK

PLATE 5-3
TOPOGRAPHIC MAP

ENVIRONMENTAL MONITORING



THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX 7

CONTINGENCY PLAN

APPENDIX 7

CONTINGENCY PLAN

7A Response Action Plan for Grout Treatment Facility

RESPONSE ACTION PLAN

for

GROUT TREATMENT FACILITY

Prepared by

Westinghouse Northwest Environmental Center
7601 W. Clearwater, Suite 203
Kennewick, Washington 99336

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 DESCRIPTION OF THE FACILITY 1

2.1 General Description 1
2.2 Construction, Operation, and Vault Closure Phases 3
2.3 Waste Characterization 5

3.0 SOURCES OF FLUID WITHIN THE LDCRS 7

3.1 Construction Water 7
3.2 Dewatering of Concrete 8
3.3 Precipitation Events 9
3.4 Leakage from Inside the Vault 9

4.0 LEACHATE SUMP CAPACITY 9

5.0 ACTION LEAK RATE 11

6.0 RESPONSES 12

6.1 Flow Rate Less than the ALR (8 gpd) 12
6.2 Flow Rates Between the ALR (8 gpd) and RLL (800 gpd) 12
6.3 Flow Rates Greater than RLL (800 gpd) 13

APPENDICES

Appendix A - Calculations 14

1.0 INTRODUCTION

This document describes the response actions to be taken to address liquid in the Leachate Detection/Collection and Removal System (LDCRS) of a grout disposal vault. These actions may include modifying operating procedures and, when appropriate, notifying the United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (WSDOE).

2.0 DESCRIPTION OF THE FACILITY

This section provides a general description of the grout disposal vaults, discusses the vault construction, operation, and closure phases, and characterizes the waste placed in the vaults.

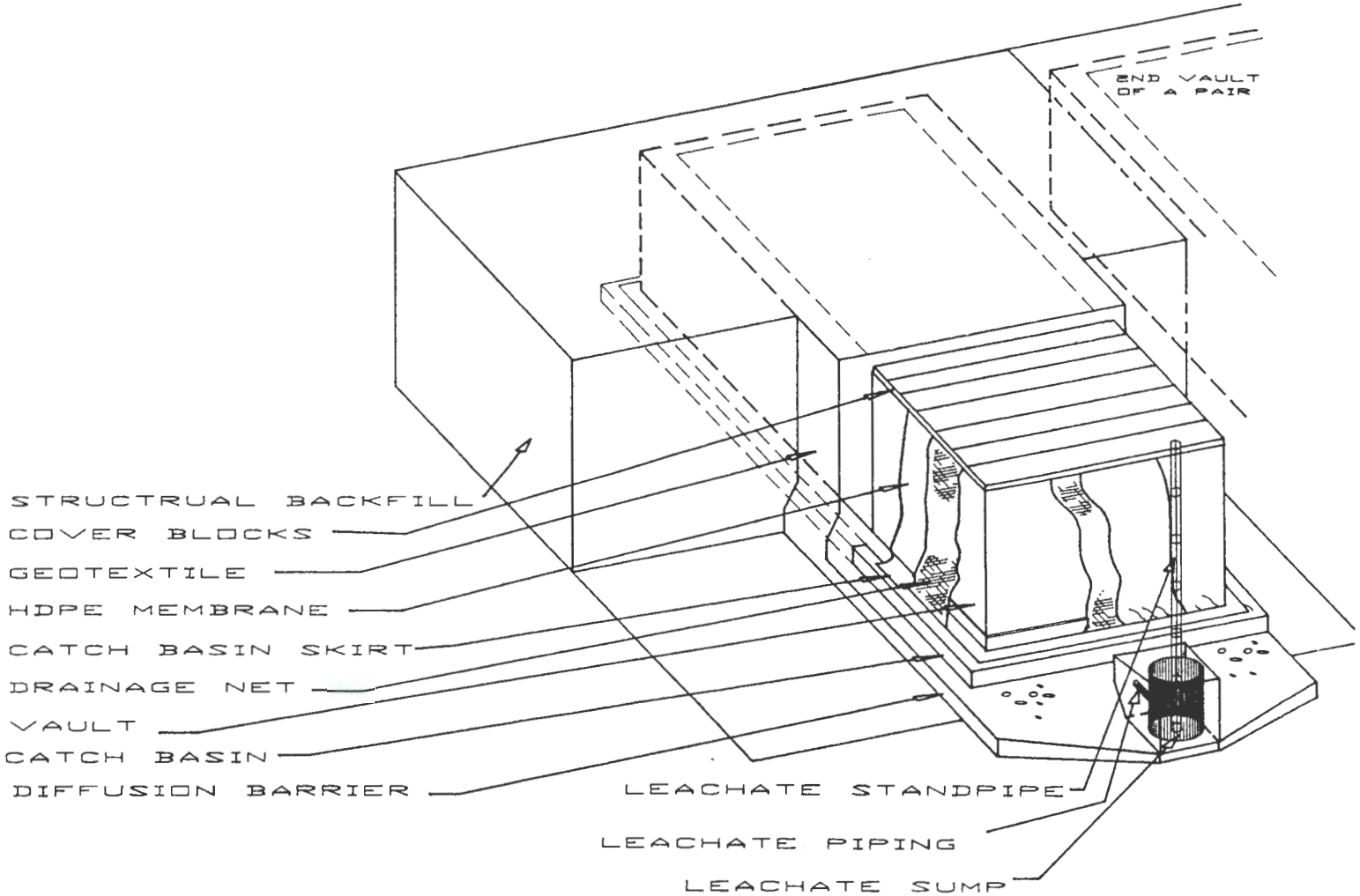
2.1 GENERAL DESCRIPTION

A total of 43 vaults are to be built in the Grout Treatment Facility (GTF). These vaults are subsurface concrete structures rectangular in shape as shown in Figure 1. Each vault is sized to hold 1.4 Mgal of grout and 0.2 Mgal of non-radioactive grout cap. The disposal system contains a double liner and a leachate detection/collection and removal system (LDCRS).

The upper composite liner consists of an elastomeric-asphalt coating on a reinforced concrete vault structure. Below the vault is the LDCRS which is located above a high density polyethylene (HDPE) lined concrete catch basin. This lined catch basin serves as the secondary liner. The LDCRS is comprised of a drainage gravel layer, collection pipe between the vault and catch basin, and a carbon steel sump to hold collected liquid for analysis, and removal.

An additional feature of the vault system is an exterior drainage path located on the exterior of the concrete vault. This drainage path consists of a HDPE liner and geogrid drainage path which serves two functions. The first function is to prevent any leachate that may permeate through the vault wall from migrating into the diffusion barrier or soil backfill. The second function is to prevent any liquid such as rainwater from entering the LDCRS.

Surrounding the vault on all sides is a diffusion barrier. This barrier is composed of asphalt-coated gravel. The diffusion barrier reduces diffusion of ionic contaminants.



DOE/RL 88-27
Rev. 1, 01/17/90

GROUT DISPOSAL VAULT	WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER	SCALE: NONE	DATE: 12/07/89
		JOB NO: NWAX03001	DRAWN: TRK
		FIG NO: 1	CHECKED: WJM

If liquid is detected in the LDCRS sump during active filling vault operations, it is sampled and can be pumped to the liquid collection tank located in the Transportable Grout Equipment (TGE) or other appropriate receiver tanks, through excess-water removal piping. After completion of vault filling, this LDCRS sump is monitored for any liquid. For a more detailed description of the GTF see Chapter 4, of the Part B Permit Application.

2.2 CONSTRUCTION, OPERATION, AND VAULT CLOSURE PHASES

This section discusses the construction, operation, and closure of grout disposal vaults.

2.2.1 Construction Phase

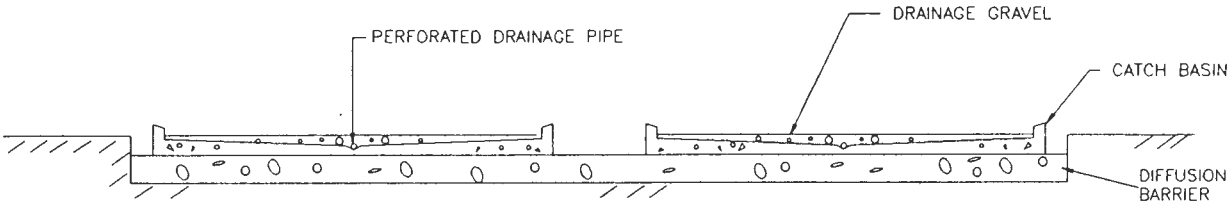
Each vault is built in a specific sequence as shown in Figure 2. First, a large excavation is made and the subgrade is compacted. The first layer of diffusion barrier is then placed over the compacted subgrade. Next, the concrete catch basin and steel sump are constructed over the diffusion barrier. A HDPE liner is installed over the catch basin, and piping for the leachate collection system is added. Next, drainage gravel required for the leachate collection system is placed over the HDPE liner. On top of this catch basin and leachate collection system the vault is constructed. The vault is constructed of reinforced concrete and is rectangular in shape.

An elastomeric-asphalt coating is sprayed on the vault interior. After curing and testing of the coating, the vault is hydrotested. Hydrotesting includes filling the vault with water while performing a visual examination of exterior vault walls for leakage. The leachate collection system is monitored for water discharge which could indicate leakage of the vault.

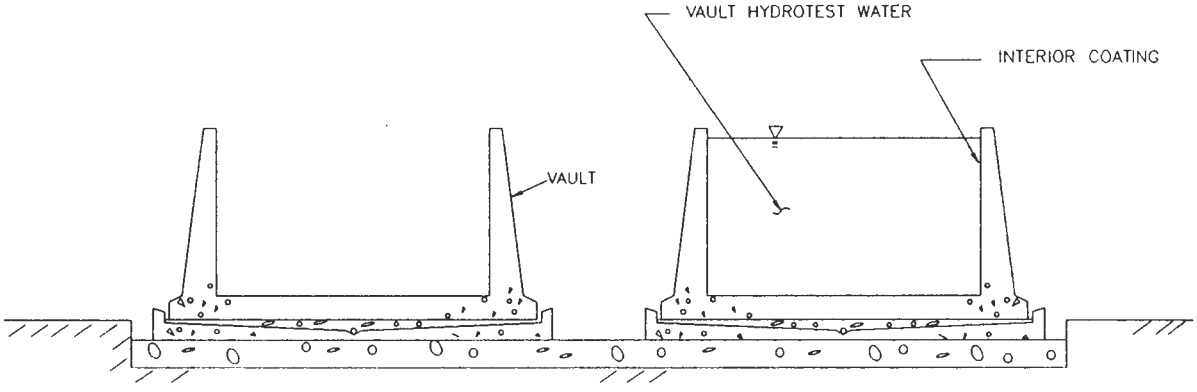
After passing the hydrotest which has a maximum allowable leak rate of 0.10 gallons per day and no visible leakage on the exterior vault walls, an exterior drainage path is placed on the outside of the vault. This exterior drainage path consists of a 60 mil HDPE liner and geogrid attached to the vault exterior.

The next phase of the construction is placement of the diffusion barrier and backfill around the vault. At this point in construction, the components of the vault such as the precast roof, piping, etc., are placed.

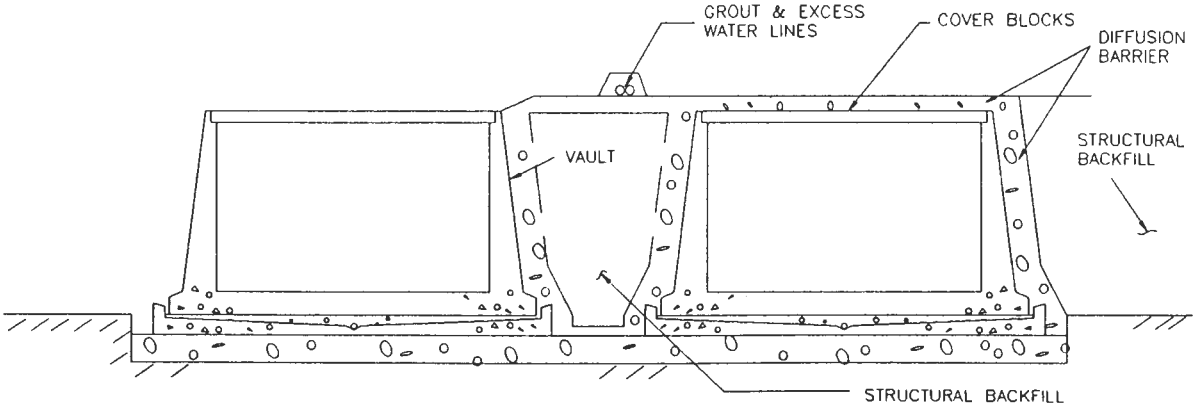
The final construction phase prior to operation of a vault is placement of 3 feet of diffusion barrier over the vault roof. On top of this diffusion barrier a protective geotextile is placed. At this point, the vault construction is completed and the vault is ready for filling, which is termed the operation phase.



INITIAL EXCAVATION, DIFFUSION BARRIER PLACEMENT, CATCH BASIN CONSTRUCTION, AND LDCRS CONSTRUCTION



VAULT CONSTRUCTION AND HYDROTEST



OPERATION COVER PLACEMENT

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER	SCALE: NONE	DATE: 12/07/89
	CONST. SEQUENCE	DRAWN: TRK
	FIG NO: 2	CHECKED: WJM

During the construction phase of each vault, liquid from construction water, precipitation, and hydrotest water may enter the LDCRS and then into the sump. This liquid is removed prior to starting the vault filling (operation phase).

A construction quality assurance (CQA) program is in place to ensure that all components of the vaults are constructed in accordance with applicable design criteria, drawings, and specifications. For further details of the CQA program, refer to Appendix 4G of the Part B Permit Application.

2.2.2 Operation Phase

After construction completion, the vault is ready for filling with grouted mixed waste. This grouted mixed waste is processed at the TGE and pumped to the vault.

After the grout cures, any excess water is pumped back to the TGE facility. Next, a nonhazardous grout is pumped into the void space between the grouted waste and roof bottom. Vault filling, excess water removal, equipment removal, and void space filling, is defined as the operation phase.

The LDCRS sump is monitored continuously during the operation phase to quickly detect any liquid rise indicating a potential leak in the vault. Sump liquid levels are compared on a daily basis to determine leakage rates.

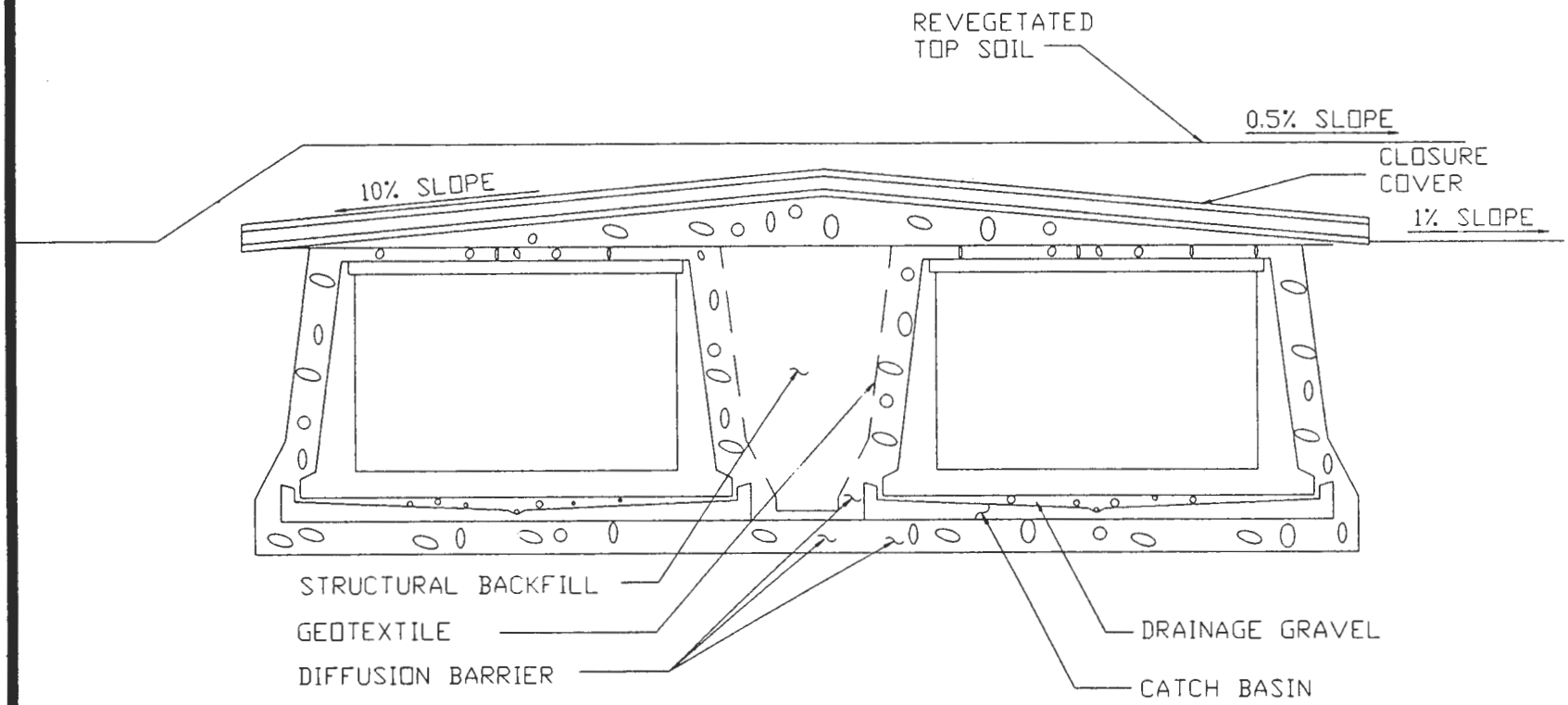
2.2.3 Closure Phase

After filling, excess water removal, equipment removal, and void space filling of the second vault of a pair of vaults, a closure cover is placed over the vault pair. The closure cover as shown on Figure 3 consists of layers of sand, clay, and liners to minimize the amount of water that can reach the contents of the vault.

The LDCRS sump monitoring following vault closure is less intense, as discussed in Chapter 11 of the Part B.

2.3 WASTE CHARACTERIZATION

The waste managed by the GTF is a concentrated salt solution produced by the evaporation of dilute wastes generated by the operating facilities in the 100, 200, 300, and 400 Areas of the Hanford Site. The waste streams from the operating facilities are transferred to the 200 East Area for interim storage in underground double-shell tanks (DST). Some of the wastes are concentrated to minimize waste volume.



CLOSURE COVER	WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER	SCALE: NONE	DATE: 12/07/89
		JOB NO: NWAX03001	DRAWN: TRK
		FIG NO: 3	CHECKED: WJM

The expected range of compositions for these wastes is determined based on the sample standard deviation and mean of the composition of three tanks of waste currently in storage that are potential grout feed material. The wastes stored in tanks 241-AN-103, 241-AN-106, and 241-AW-101 are believed to be representative of future grout waste feeds. Refer to Chapter 3 of the Part B for details of these tanks' waste compositions.

The DST waste is classified as an extremely hazardous waste (EHW) due to the characteristics of extraction procedure (EP) toxicity and toxicity (book method) as defined in WAC 173-303-101. The dangerous waste identification numbers associated with these classifications can be found in Chapter 3.0, Table 3-4 of the Part B.

The waste is characteristically corrosive due to the hydroxide concentration. The hydroxide concentration is high enough to cause the pH to exceed the designation limits of WAC 173-303-090(6).

The waste is characterized as EP toxic due to the concentrations of chromium, lead, cadmium, and silver. The concentrations of these materials exceed the designation limits of WAC 173-303-090(8) for EP toxicity.

The waste is characterized as toxic due to the high concentrations of nitrite and hydroxide ions. The book designation method of WAC 173-303-101 classifies this waste mixture as an EHW due to toxicity, as measured by equivalent concentration (EC) greater than 0.01 and the total weight. For further details, see Chapter 3.0 of the Part B.

3.0 SOURCES OF FLUID WITHIN THE LDCRS

Liquid from several sources and at different times may enter the LDCRS. Sources of liquid are water from construction, dewatering of the concrete, precipitation events and leakage from the vault. This liquid will flow in the leachate removal system to the sump. At the sump, the depth of any liquid will be measured and removed as necessary. The following sections describe the various sources of water, pathways, and prevention design features.

3.1 CONSTRUCTION WATER

This section discusses the potential for construction water from the vault construction and closure phases to enter the LDCRS.

3.1.1 During Vault Construction

During construction of a vault, water can enter the LDCRS and leachate sump from several sources. These sources include water used for moist curing of the concrete, precipitation falling on the vault structures, leakage into the LDCRS and leachate sump during the vault hydrotest, and water used for compaction of the backfill.

This water has many pathways in which it could reach the LDCRS and leachate sump prior to completion of protective features such as the exterior drainage path. Regardless of the source of water and pathway by which it may reach the vault, any pumpable liquid is removed from the leachate sump prior to operation.

3.1.2 During Construction of the Closure Cover

Construction of the closure cover will produce construction water. Construction of the closure cover requires the use of water during placement and compaction of the low permeability layers. This water may be a source of liquid that could be detected in the LDCRS.

Any excess water used during the compaction process may migrate downward through the cover layers to the roof of a vault. Liquid would run down the sloped roof and then down the exterior drainage path. Any water would then have to find a defect in the exterior drainage path to reach the LDCRS.

It is expected that the quantity of liquid reaching the LDCRS during closure would be a maximum of 5.5 gpd. See calculations in Appendix A.

3.2 DEWATERING OF CONCRETE

Concrete is composed of four major components: coarse aggregate, fine aggregate, portland cement, and water. When combined, a chemical process (hydration) takes place in which the portland cement sets and hardens into a solid mass.

Complete hydration of a given amount of portland cement requires an amount of water equal to about 25 per cent of the portland cement used, by weight. An additional 10 to 17 per cent must be present to provide mobility for the water in the cement paste during the hydration process. Any water remaining in the concrete matrix after the curing process is defined as the moisture content. This moisture content will vary depending upon the relative humidity of the surrounding air.

Since the interior of the vault has an asphalt coating and the exterior walls have the exterior drainage path, any excess water in the concrete may migrate through the pores in the concrete to either the exterior drainage path or the bottom of the vault.

It is expected that the maximum rate at which the concrete in the vault could release any liquid is 2.2 gpd given that the moisture migration rate of concrete is 0.3 grains/hr/ft^2. See Appendix A for calculations.

3.3 PRECIPITATION EVENTS

Historical weather records have shown that the maximum precipitation expected from a 24-hour, twenty-five year storm is 1.56 inches. Ditches have been designed for the facility to prevent storm water run-on from reaching the vaults (see Run-on/Run-off Engineering Report, Appendix 4G of the Part B Permit Application). The only precipitation that may reach the LDCRS is the water that falls directly above the vault.

During the operation period of the vault, a maximum of 31 gallons may find its way into the LDCRS after such a precipitation event. After vault closure, the multi-layered barrier over the vault will prevent any precipitation from percolating down into the vault. For further details, see calculations in Appendix A.

3.4 LEAKAGE FROM INSIDE THE VAULT

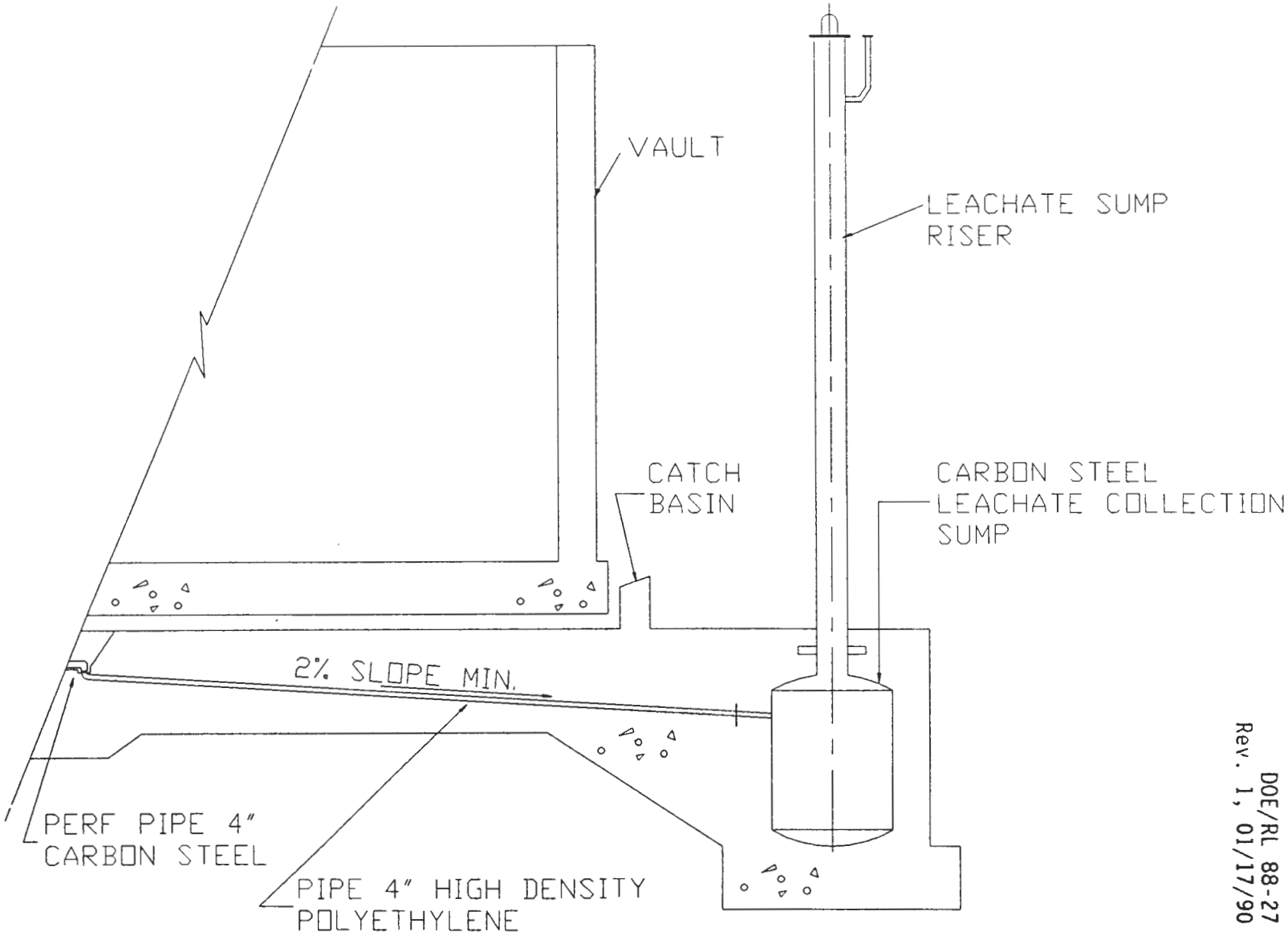
During the operation period, the vault will be filled with grout during a one to two month period. Liquid in the form of grouted waste and excess water will be present. After the vault is filled, any excess water is pumped backed to the TGE and handled as a waste.

Very small quantities of liquid are expected to permeate through the primary composite liner. Maximum quantity of flow should be on the order of 0.053 gpd. See Appendix A for calculations.

4.0 LEACHATE SUMP CAPACITY

A 4-inch perforated steel pipe lies on the sloped bottom of the catch basin. This pipe is connected to the leachate sump as shown in Figure 4. The sump is an 8-foot diameter steel vessel encased in concrete. The capacity of the leachate sump is 2,900 gallons.

Each 1-inch rise of liquid in the sump equals approximately 31 gallons of liquid. The precision of the level measuring instruments will be able to detect increases in excess of 20 gpd or 0.65 inches.



DOE/RL 88-27
Rev. 1, 01/17/90

LDCRS SYSTEM	Westinghouse Northwest Environmental Center	SCALE: 1" = 10'-0"	DATE: 12/07/89
		JOB NO: NWAX03001	DRAWN: TRK
		FIG NO: 4	CHECKED: WJM

5.0 ACTION LEAK RATE

The action leakage rate (ALR) selected for the vault represents a small leakage through the primary liner which would not affect overall performance of the liner system. This rate includes leakage which occurs through small defects in the coating or concrete of the primary liner.

The value selected for the ALR is based upon the EPA recommendation of 20 gpd per acre and the limits of precision of sump level instrumentation. The total surface area in which the grouted waste may come into contact is 18,069 square feet or 0.41 acres. Thus, the ALR was calculated to be 8 gpd for each vault.

The rate of liquid rise in the sump will be averaged over a 30 day period to determine leakage rates. If the leakage rate exceeds 8 gpd based on a 30 day average or 20 gallons on any one day, the responses for flows in excess of the ARL will be implemented. See Section 6.0 for responses.

The following expected leakage rates were calculated for various sources of liquid.

SOURCE	ESTIMATED QUANTITY (GPD)
Construction Water	Not Applicable (water removed prior to operation)
Precipitation from a 24-hour, 25-year storm	31
Concrete vault dewatering	2.2
Leakage through primary composite liner	0.053
During construction of closure cover, construction water	5.5
After closure	nil*

*See cover Design Report, Appendix 11A of the Part B Permit Application

6.0 RESPONSES

The actions required in response to various flow rates to the leachate sump located in the LDCRS are provided in this section. The sump will be monitored daily, and comparisons made with the previous day level to determine leak rates during the vault filling operation. After closure, monitoring will continue on a quarterly basis.

Pumpable quantities of leachate contained in the sump will be sampled, removed, and disposed of in accordance with site procedures.

Leak rates in excess of the ALR (8 gpd for a 30 day average or 20 gallons on any one day) will be responded to as described in this section. Responses are described for three leakage rate bands.

- Less than the ALR
- Above the ALR and less than the Rapid and Large Leakage (RLL) rate
- Above the RLL

6.1 FLOW RATE LESS THAN THE ALR (8 gpd)

Under normal operating conditions, flows in the leachate sump are expected to be less than 8 gpd, averaged over 30 days or 20 gallons on anyone day, the amount previously defined in the ALR. The actions required are as follows:

1. Perform daily comparisons of liquid levels in the leachate sump.
2. Sample, remove, and return liquids to the disposal vault if pumpable quantities are reached.

6.2 FLOW RATES BETWEEN THE ALR (8 gpd) AND RLL (800 gpd)

Flow rates between 8 gpd and 800 gpd indicate that an excess amount of liquid is entering the LDCRS. The required actions are listed below:

1. Notify WSDOE and EPA within 7 days if the flow to the leachate sump exceeds the ALR.
2. Sample and analyze leachate to determine source.
3. Pump leachate sump and return to the appropriate receiver tank for further processing.

6.3 FLOW RATES GREATER THAN THE RLL (800 gpd)

Flow rates greater than 800 gpd indicate that a major source of liquid is finding a path to the LDCRS and is defined as the RLL. The required actions are listed below:

1. Notify WSDOE and EPA within 24 hours if the flow to the leachate sump exceeds 800 gpd.

2. Immediately stop vault filling.

3. Remove excess water from vault.

4. Sample and analyze leachate to determine source.

5. Pump leachate sump and return to the appropriate receiver tank for further processing.

6. Evaluate alternatives and prepare response plans. Submit to WSDOE within 60 days.

APPENDIX A

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked 12/7/89 By OK

PURPOSE:

Estimate the potential Leakage through the Primary composite Liner.

ASSUMPTIONS

Grout or Excess water imposes a maximum 34 feet head on the vault.

REFERENCES

1. Fintel, M., Handbook of Concrete Engineering, Van Nostrand Reinhold Company, 1974, New York, New York.
2. Background Document on Bottom Liner Performance in Double-Lined Landfills and Surface Impoundments. EPA/530-SW-87-013, April 87.
3. Winter and Nilson, Design of Concrete Structures, 8th Edition, McGraw-Hill Book Company, 1972, New York, New York
4. Stone, W. A., Thorpe, J. M., Gifford, O. P., and Hoitink, D. J., "Climatological Summary for the Hanford Area." Battele Memorial Institute, Pacific Northwest Laboratory. PNL-4622, 1983.

RESULTS

The following quantities of liquid that may potentially reach the Leak Detection Collection Removal System (LDCRS) sump were estimated as follows:

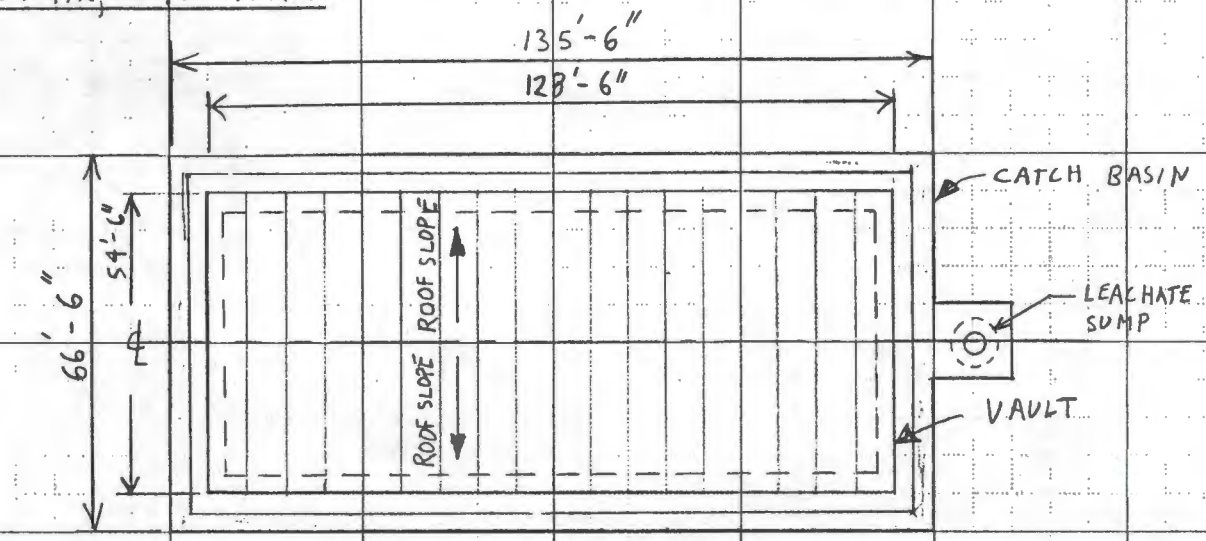
1. Precipitation from 24-hour, 25-year storm	33 gpd
2. Leakage through Primary Composite Liner	0.053 gpd
3. Concrete Dewatering (Vapor Phase)	2.2 gpd
4. Construction water during closure cover construction	5.5 gpd max

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX-0301-ES Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 10/23/89 By W.J. Magruder
Checked By

24-HR, 25-YR STORM



VAULT PLAN
NO SCALE

Expected precipitation of a 24-hour, twenty five year storm is 1.5 inches (Reference 3)

Total amount of precipitation over catch basin area = $135.5'(66.5')\left(\frac{1.5''}{12}\right)\left(7.48\ \frac{gals}{ft^3}\right) = 8,425$ gals

Since vault roof is sloped any precipitation will flow over the 2 long walls.

Total length of long walls = $2(128.5') = 257$ ft

Flow per foot = $\frac{8,425\ gals}{257\ ft} = 33\ \frac{gals}{ft}$

assume 1-1 ft long tears in exterior drainage liner, totally intercepts the precipitation flowing down the wall, in that 1 foot wide strip.

Max flow = 33 gals per day for a 24-hour, twenty five year storm

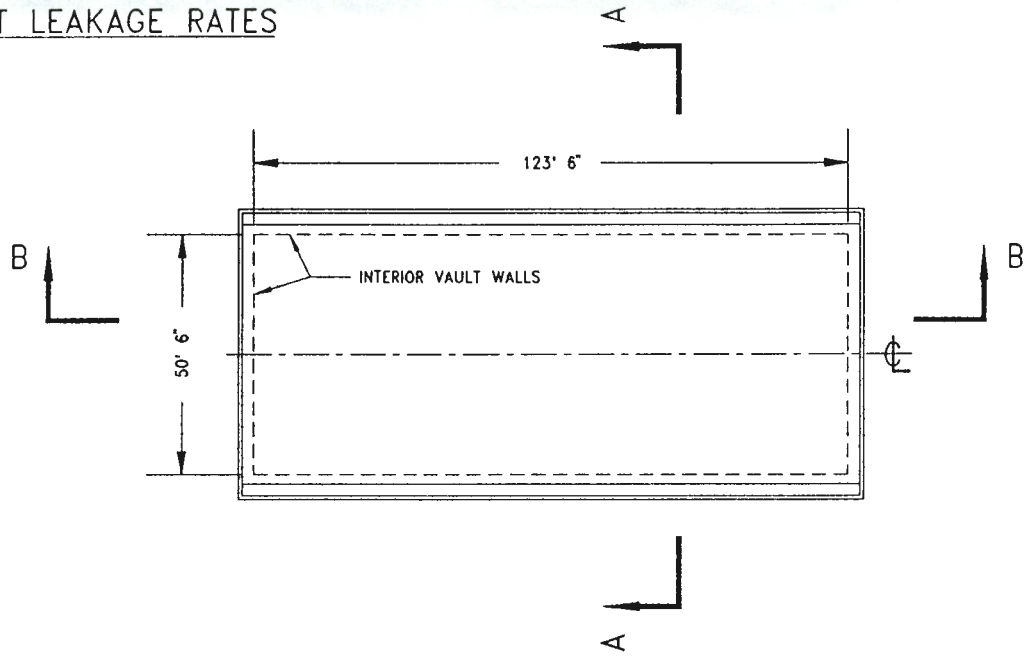
9011786173 5

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

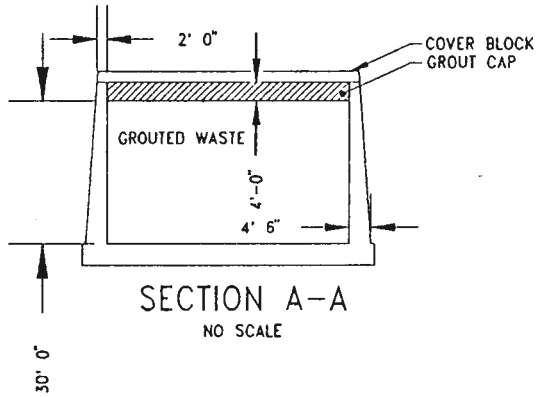
DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 10/31/89 By W. J. MAGRUDER
Checked _____ By _____

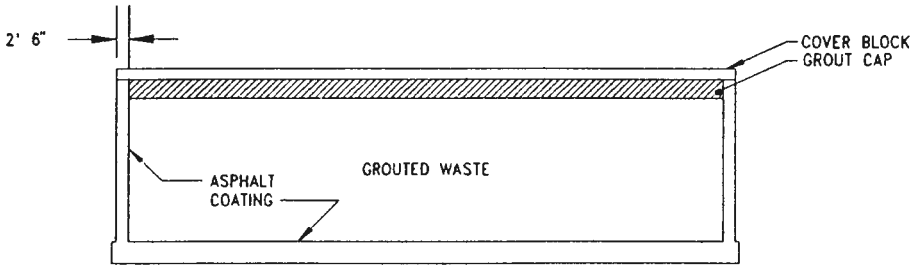
VAULT LEAKAGE RATES



VAULT PLAN
NO SCALE



SECTION A-A
NO SCALE



SECTION B-B
NO SCALE

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. Magruder
Checked By

VAULT LEAKAGE RATES

Grouted waste will contact the interior vault walls and floor up to a maximum depth of 34 feet. A 52 mil thick elastomeric asphalt urethane coating is applied to the interior walls and floor.

FLOOR AREA - 123'-6" long X 50'-6" = 6,237 ft^2

WALLS - 2(123'-6" + 50'-6")(34' high) = 11,832 ft^2

Permeability of Vault Components (Reference Supplement 1, Part VI Vault Design Report)

Primary Liner (Elastomeric Asphalt Urethane Coating) 2.56×10^{-14} cm/sec

Concrete 1×10^{-11} cm/sec

1. Determine Leakage rate through concrete if coating was removed

Using Darcy's equation $Q = AK(Z/t)$

Where Q = discharge (m^3/sec)

A = area (m^2)

K = coefficient of permeability (m/s) 1×10^{-13} m/s

t = thickness (m)

Z = depth below water level

a) Leakage Through Floor

$$Q = (6{,}237\ ft^2)(0.0929\ m^2/ft^2)(1 \times 10^{-13}\ m/s)\left(\frac{34' + \frac{1}{2}(4.5)}{3.280833\ ft/m}\right)\left(\frac{1}{(4.5)\,0.3048\ m/ft}\right)$$

$= 4.7 \times 10^{-10}\ m^3/sec$ or 0.011 GPD

9011786173 7

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked By

LEAKAGE RATE THROUGH CONCRETE WITH NO COATING

b.) Leakage through walls

Avg. Depth = 17 ft or 5.18 meters

Avg Wall thickness = $\frac{1}{2}(2+4.5) = 3.25'$ or 0.99 meters

$Q = 11{,}832 ft^2 (0.0929 \frac{m^2}{ft^2})(1 \times 10^{-13} m/s)(\frac{5.18 m}{0.99 m}) = 5.75 \times 10^{-10} \frac{m^3}{sec}$

or 0.013 gpd

Total leakage = 0.011 GPD + 0.013 GPD = 0.024 gpd

2. Determine Leakage Rate through coating, primary composite liner where T = 52 mils (Section 09885 of the B-714-62 construction specification)

52 mils = 0.052" (0.0254 $\frac{meters}{inch}$) = 0.0013 meters

$K = 2.56 \times 10^{-16}$ m/sec

a) Leakage through floor

$Q = 6{,}237 ft^2 (0.0929 \frac{m^2}{ft^2})(2.56 \times 10^{-16} m/sec)(\frac{34'(0.3048 m/ft)}{0.0013 m})$

$= 1.18 \times 10^{-9} \frac{m^3}{sec}$ or 0.027 gpd

b) Leakage through walls

Z = 5.18 m

$Q = 11{,}832 ft^2 (0.0929 \frac{m^2}{ft^2})(2.56 \times 10^{-16} m/sec)(\frac{5.18 m}{0.0013 m})$

$= 1.12 \times 10^{-9} \frac{m^3}{sec}$ or 0.026 gpd

Total Leakage Through asphalt coating = 0.027 gpd + 0.026 gpd
= 0.053 gpd

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked _____ By _____

Estimate leakage rate if coating has a "standard" defect of 1 cm^2 or $1 \times 10^{-4} m^2$

Assume excellent contact between coating and concrete

$Q = 0.7 a^{0.1} K_c^{0.88} h$ Equation B-28 from Background Document on Bottom Liner Performance in Double-Lined Landfills and Surface Impoundments USEPA, Apr 87

Where: Q = Leakage rate m^3/sec

a = area of hole (m^2)

K_c = Permeability of concrete 1×10^{-13} m/sec

h = 34 feet or 10.36m

$$Q = 0.7(1 \times 10^{-4} m^2)^{0.1}(1 \times 10^{-13} m/sec)^{0.88}(10.36m) = 1.05 \times 10^{-11} m^3/sec$$

or 0.0002 gpd per standard defect.

9011786173 9

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked By

CONCRETE DEWATERING FLOWRATE

Determine the potential flowrate of excess water in the vault structure.

Assume concrete used for vault construction is a 6 sack mix, or 6 sacks (94 lbs/sack) per yd^3 = 564 lbs portland cement per yd

Max water/cement = 0.42 (refer to subparagraph 2.1.2.5(d), section 03301 of B-714-C2 specifications)

Per ft^3 of concrete

a. Portland Cement = $\frac{1}{27}$(564 lbs) = 20.9 lbs

b. Max water used = 0.42(20.9 lbs) = 8.8 lbs water

Total amount of water allowed for mixing = 8.8 lbs/ft^3

For complete hydration 25% by weight of cement is used chemically or .25(20.9 lbs) = (−5.2 lbs/ft^3)
Ref. 2

Amount of uncombined water remaining Total 3.6 lbs/ft^3

Assume 3.6 lbs/ft^3 or $\frac{3.6 \text{ lbs}}{62.4 \text{ lbs/ft}^3}$ = 0.06 ft^3 of water per ft^3 of concrete remain in the concrete matrix.

Next determine the rate that this excess water may migrate to the outside of the vault.

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked By

CONCRETE DEWATERING FLOWRATE (CON'T)

Using Darcy's equation $Q = AK(z/t)$

Substituting $Q = VA$ $V\cancel{A} = \cancel{A}K(z/t)$ $V = K(z/t)$

Where V = velocity (m/s)

K = coefficient of permeability (m/s) = 1×10^{-13} m/s for concrete

z = depth below water level (assume a liquid level of 34' in the vault)

t = thickness (m)

a) Velocity Through Floor

$$V = 1 \times 10^{-13} \text{ m/sec} \left(\frac{34' + \frac{1}{2}(4.5')}{3.280833 \text{ ft/m}}\right)\left(\frac{1}{(4.5)(0.3048 \text{ m/ft})}\right)$$

$$V = 8.1 \times 10^{-13} \text{ m/sec}$$

b.) Average Velocity Through walls

Avg. Depth = 17' or 5.18 meters

Avg. wall Thickness = $\frac{1}{2}(2 + 4.5) = 3.25'$ or 0.99 meters

$$V = 1 \times 10^{-13} \text{ m/sec} \left(\frac{5.18 \text{ m}}{0.99 \text{ m}}\right) = 5.2 \times 10^{-13} \text{ m/sec}$$

Average velocity through floor and walls $= \frac{1}{2}(8.1 + 5.2)(1 \times 10^{-13})$
$= 6.7 \times 10^{-13}$ m/sec

Converting To English units

$$(6.7 \times 10^{-13} \text{ m/sec})(3.280833 \text{ ft/m}) = 2.2 \times 10^{-12} \text{ ft/sec}$$

$$2.2 \times 10^{-12} \text{ ft/sec} (60 \text{ secs/min})(60 \text{ min/hr})(24 \text{ hrs/day}) = 1.9 \times 10^{-7} \text{ ft/day}$$

9011178617 41

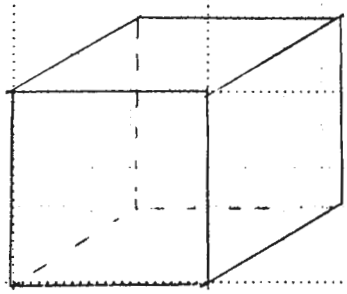
WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked _____ By _____

CONCRETE DEWATERING (CON'T)

$V_{Avg} = 1.8 \times 10^{-7}$ ft/day



1 ft^3 concrete contains 0.06 ft^3 water
" 0.94 ft^3 cement aggregate, etc.

The 0.06 ft^3 is assumed to be evenly distributed

The water is assummed to move 1.9×10^{-7} ft/day

the quanity of water per ft^2 = $(1.9 \times 10^{-7}\ ft)(1')(1')(0.06\ ft^3/ft^3\ conc.)$

$= 1.1 \times 10^{-8}\ ft^3$ per ft^2

or $1.1 \times 10^{-8}\ ft^3 (7.48\ gals/ft^3)$

$= 8.2 \times 10^{-8}$ gpd/ft^2

Bottom area of vault = $(61')(130') = 7{,}930\ ft^2$

Exterior area of walls = $34'(2(128.5') + 2(59.5') = 12{,}784\ ft^2$

Total = $20{,}714\ ft^2$

$20{,}714\ ft^2 (8.2 \times 10^{-8}\ gpd/ft^2) = 0.0017$ gpd

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/29/89 By W. J. MAGRUDER
Checked By

CONCRETE DEWATERING (Con't)

Check the amount of water that may migrate into the LDCRS in the form of water vapor.

Assume:

1. A pressure differential is present to drive the moisture into the LDCRS.
2. Enough excess water is present to be converted to vapor.
3. Vapor condenses into liquid at LDCRS.
4. Moisture migration through the concrete = 0.3 $\frac{grains}{hr \cdot ft^2}$

Reference: Fintel, M., Handbook of Concrete Engineering, pg. 175.

$$\text{Quanity of moisture} = 0.3 \frac{grains}{hr \cdot ft^2}\left(24 \frac{hrs}{day}\right)\left(\frac{1\ lb}{7{,}000\ grains}\right)\left(\frac{7.48 \frac{gals}{ft^3}}{62.4 \frac{lb}{ft^3}}\right)$$

$$= 1.23 \times 10^{-4} \frac{gallons}{ft^2 \cdot day}$$

Area of floor and walls = 6,237 ft^2 + 11,832 ft^2 = 18,069 ft^2
(See pg. 4 of these calcs)

$$\text{Quanity of moisture} = 18{,}069\ ft^2\left(1.23 \times 10^{-4} \frac{gallons}{ft^2\ day}\right) = \underline{2.2\ gpd}$$

Use 2.2 gpd as concrete dewatering rate

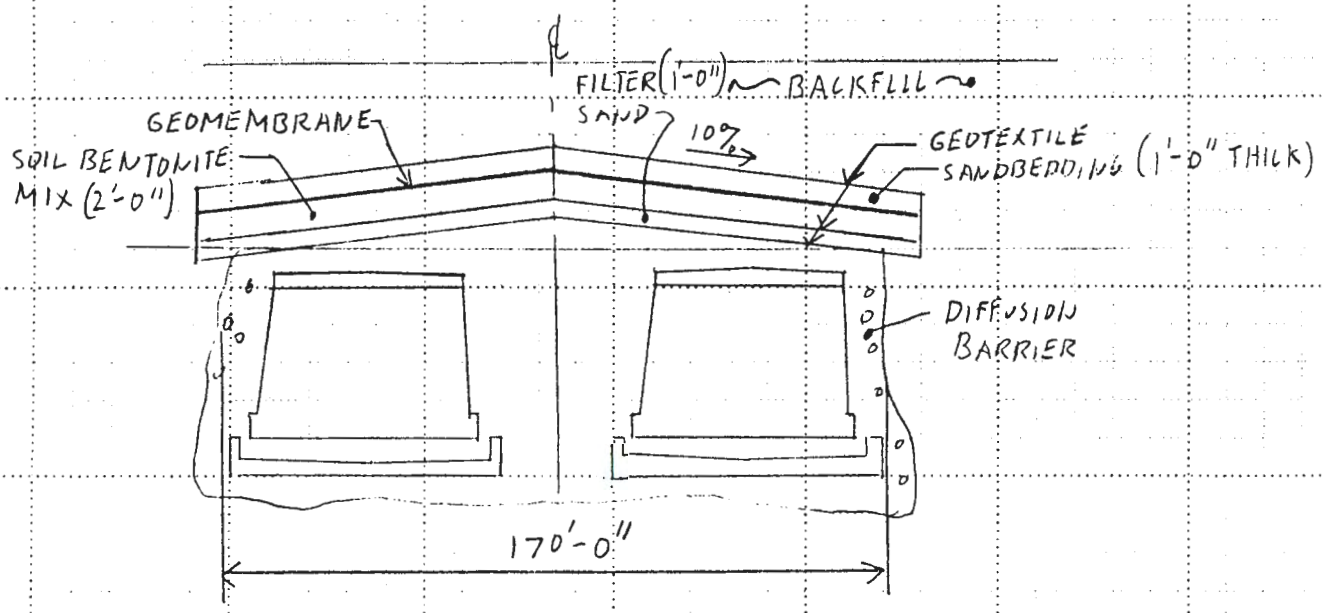
9011786174 3

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked By

CLOSURE COVER CONSTRUCTION WATER



CROSSECTION VAULT PAIR
NO SCALE

Size of closure cover - 170'-0" wide X 167'-6" long (Ref. Figure 1, Cover design, Supplement 1)

Assume geomembrane intercepts any moisture and 10% slope forces any water away from a vault pair.

Determine the amount of construction water that may find its way into the Leak Dection Collection Removal System (LDCRS)

SAND BEDDING

Assume - $w = 120$ lbs/ft³
- optimum moisture content required for compaction = 10%

Total quanity = $170'(167.5')(1') = 28{,}475\ ft^3$

Total quanity of water = $28{,}475\ ft^3 (120\ lbs/ft^3)(0.10) = 341{,}700$ lbs

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked ____ By ____

CLOSURE COVER (Con't)

$\frac{341,700 \text{ lbs } H_2O}{62.4 \text{ lbs/ft}^3} = 5476$ gallons for a pair of vaults

$\frac{5476 \text{ gallons}}{2 \text{ vaults}} = 2,738$ gallons per vault

SOIL BENTONITE MIX

Assume - $w = 110 \text{ lbs/ft}^3$

- Optimum moisture content required for compaction = 20%

Total quanity = $170'(167.5')(2') = 56950 \text{ ft}^3$

Total volume of water = $56,950 \text{ ft}^3 (110 \text{ lbs/ft}^3)(0.20) = 1,252,900$ lbs

$\frac{1,252,900 \text{ lbs}}{62.4 \text{ lbs/ft}^3} = 20,078$ gallons for a vault pair

$\frac{20,078 \text{ gallons}}{2 \text{ vaults}} = 10,040$ gallons per vault

Assume the moisture from the sand bedding can migrate downward over a 2 day construction period. Assume a 1 ft long tear in the exterior drainage in a similar fashion as a precipitation event.

Total length of long walls = $2(128.5') = 257'$

Flow per foot = $\frac{2,738 \text{ gallons}}{257'} = 11$ gallons max leakage into the LDCRS over a 2 day period

$\frac{11 \text{ gallons}}{2 \text{ days}} = 5.5$ gpd

9011786745

WESTINGHOUSE NORTHWEST ENVIRONMENTAL CENTER

DESIGN ANALYSIS

Job No. NWAX03001 Client/Project WHC
Location GROUT TREATMENT FACILITY
Date 11/7/89 By W. J. MAGRUDER
Checked By

CLOSURE COVER (CON'T)

For the soil bentonite layer assume only 25% of the water used for compaction could rapidly migrate downward due to the low permeability properties of the bentonite clay mixture. Assume this happens over a 4 day construction period.

(10,040 gallons per vault)(0.25) = 2,510 gallons

Flow per foot = $\frac{2,510 \text{ gallons}}{257'}$ = 9.8 gallons max leakage over 4 days

$\frac{9.8 \text{ gallons}}{4 \text{ days}}$ = 4.9 gpd

This page intentionally left blank.

APPENDIX 8

PERSONNEL TRAINING

APPENDIX 8

PERSONNEL TRAINING

8A Organizational Chart

8B Job Titles, Positions, and Descriptions

8C Sample Grout Facilities Employee Training Matrix

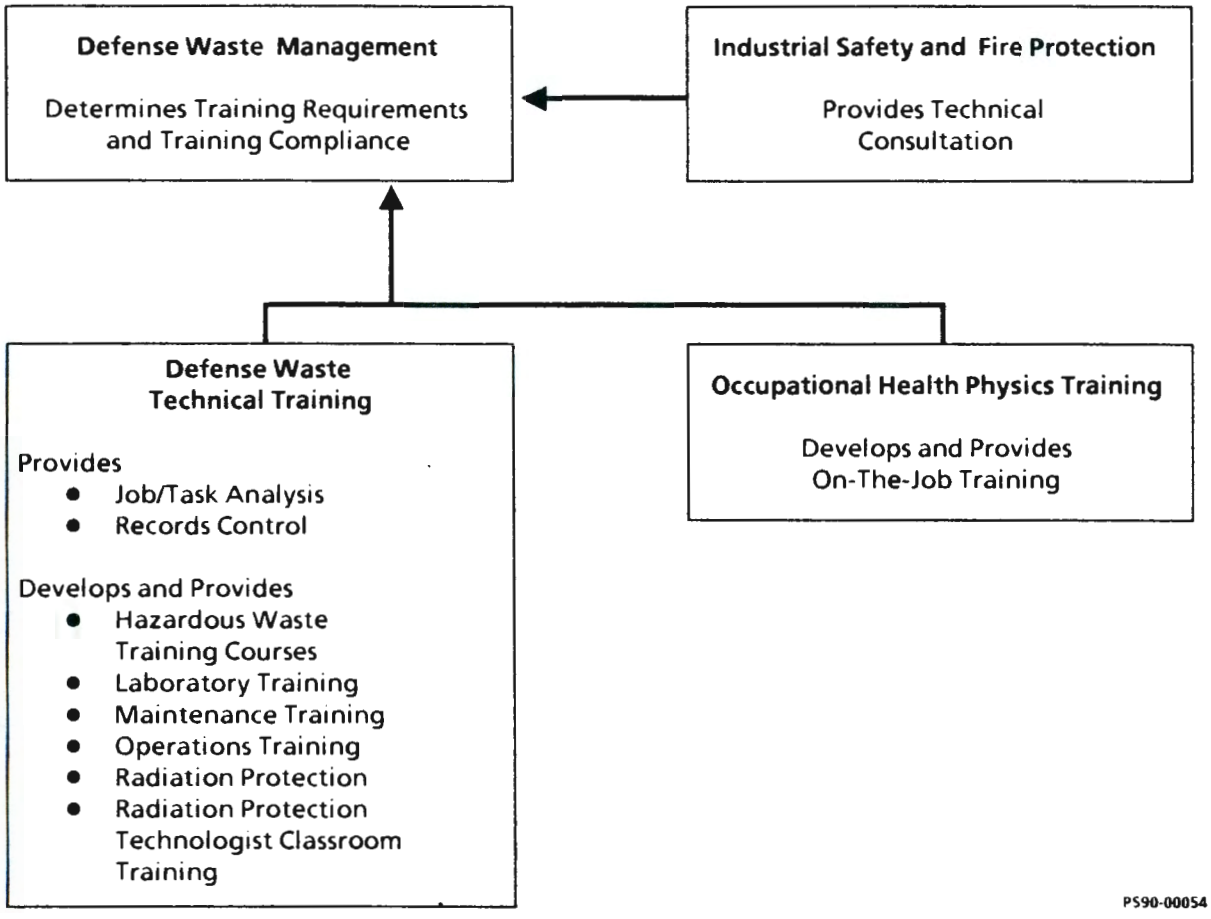
8D Environmental and Hazardous Material Safety Training Requirements

8E Sample Training Course Summaries

APPENDIX 8A

ORGANIZATIONAL CHART

This page intentionally left blank.



Appendix 8A. Grout Treatment Facility Training Organization Chart.

This page intentionally left blank.

APPENDIX 8B

JOB TITLES, POSITIONS, AND DESCRIPTIONS

This page intentionally left blank.

APPENDIX 8B

JOB TITLES, POSITIONS, AND DESCRIPTIONS

This appendix summarizes the job titles, positions, and descriptions for personnel associated with Grout Treatment Facility operations.

TANK FARMS

Managers, shift supervisors, and nuclear operators* within Tank Farm Grout Operations will operate the GTF.

Tank Farm Operations

Processing Shift Operations

- Nuclear operator--Computer Automated Surveillance System (CASS) certified
- Nuclear Operator--Routines certified.

Grout Operations

- Manager
- Supervisor
- Nuclear operator--GTF certified.

Tank Farm Services

Tank Farm East Area Operations

- Nuclear operator--Waste truck operations certified.

---

*Nuclear operator is a job category having three levels--nuclear process operator (NPO), nuclear operator (NO), and operator trainee (OT). The level, in conjunction with job category, facility, and assigned work, determines training requirements.

EAST TANK FARM MAINTENANCE

Designated managers, shift supervisors, plant engineer, and craftsmen from Tank Farms Maintenance will maintain the GTF.

- Manager
- Supervisor
- Plant engineer
- Electrician
- Instrument technician
- Millwright
- Pipefitter (plumber-steamfitter).

WASTE MANAGEMENT PLANT ENGINEERING

Managers and process engineers (i.e., senior and principal) will provide cognizant engineering support for the GTF.

- Unit manager
- Process engineer.

WASTE MANAGEMENT HEALTH PHYSICS

Operational Health Physics (OHP) supervisors and radiation protection technologists* (RPT) will provide radiological support services for GTF personnel.

<u>East Tank Farms</u>

- Supervisor
- The RPT.

---

* The RPT is a job category having three levels--junior radiation protection technologist (JRPT), RPT, and senior radiation protection technologist (SRPT). The level, along with job category and facility or area, determines training requirements.

POSITION: MANAGER, GROUT OPERATIONS

REPORTS TO: Manager, Tank Farm Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Supervise personnel
- Supervise emergency response and recovery actions
- Maintain administrative control
  - Review/revise operating safety documents
  - Review/revise plant operating procedures
  - Document study reviews
  - Review data sheets
  - Review inspection reports/housekeeping reports
  - Review/process event fact sheet/closeout
  - Develop activity reports (weekly--monthly--daily)
  - Process work authorization requests
  - Participate in readiness reviews
  - Critique reports
  - Daily operating reports
- Supervise procedure compliance
- Minimize injuries and/or equipment damage
- Ensure compliance to operating limits and specifications
- Minimize operating personnel radiation exposure and/or contamination.

QUALIFICATIONS:

A bachelor of arts (B.A.) degree or equivalent. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: SUPERVISOR

REPORTS TO: Manager, Grout Operations; Manager, Tank Farm Shift Operations; or Manager, Tank Farm Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Supervise personnel
- Supervise emergency response and recovery actions
- Maintain administrative control
  - Review/revise operating safety documents
  - Review/revise plant operating procedures
  - Document study reviews
  - Review data sheets
  - Review inspection reports/housekeeping reports
  - Review/process event fact sheet/closeout
  - Develop activity reports (weekly--monthly--daily)
  - Process work authorization requests
  - Participate in readiness reviews
  - Critique reports
  - Maintain time cards and records
  - Minimize absenteeism
  - Obtain overtime and maintain records
- Supervise procedure compliance
- Ensure that operators are trained
- Minimize injuries and/or equipment damage
- Assure compliance to operating limits and specifications
- Minimize operating personnel radiation exposure and/or contamination.

QUALIFICATIONS:

A B.A./bachelor of science (B.S.) degree or equivalent combination of education and/or experience. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

9011178617 59

JOB TITLE: NUCLEAR OPERATOR (Grout Treatment Facility)

REPORTS TO: Supervisor, Grout Shift Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Perform prestartup operations
  - Computer systems
  - Liquid waste system
- Pre-charge additive lines
- Start up instrument air system
- Start up process ventilation system
- Operate the transportable grout equipment/vault closed-circuit television system
- Operate the mixer and pump systems
  - Operate system/raw water
  - Operate system/waste feed
- Perform surveillance operations
  - Perform surveillance during operation
  - Maintain grout campaign operations log
  - Obtain sample number/monitor records
  - Stand by
- Transfer from truck to bin
- Sample dry blend
- Perform waste transfers
- Operate portable instrument house
- Perform liquid-collection tank operations
  - Sampling
  - pH adjustment
- Decontaminate systems
- Fill decontamination/additive module tank
- Operate flush and spray systems
- Bypass computer controls
- Shut down mixer pump
- Shut down/systems check
  - Emergency shutdown
  - Emergency stop
- Close/monitor vault
- Perform emergency plant and abnormal plant conditions activities.

QUALIFICATIONS:

Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: NUCLEAR OPERATOR (Waste Truck Operations)

REPORTS TO: Supervisor, Tank Farm East Area Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Inspect truck
- Ensure that truck has supplies
- Check procedures
- Load up dangerous waste
- Unload dangerous waste
- Pick up used laundry
- Stock shelves with laundry
- Complete daily logbook.

QUALIFICATIONS:

Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions. Physically able to lift containers and laundry bags.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: NUCLEAR OPERATOR (Tank Farm Routines)

REPORTS TO: Supervisor, Tank Farm Shift Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Record readings in the AP Farm
- Notify grout operations support supervisor of grout facility alarms.

QUALIFICATIONS:

Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Lift containers
- Lift laundry bags
- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: NUCLEAR OPERATOR (Computer Automated Surveillance System)

REPORTS TO: Supervisor, Tank Farm Shift Operations

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Monitor panelboards
- Notify grout operations support supervisor of grout facility alarms.

QUALIFICATIONS:

Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

POSITION: 200 EAST AREA MAINTENANCE MANAGER

REPORTS TO: Manager, Tank Farm Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Plan work schedules
- Organize work plan
- Provide direction/implementation of work authorization
- Maintain control/completion of work authorization.

QUALIFICATIONS:

A B.A. degree or equivalent. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: 200 EAST AREA MAINTENANCE PLANT ENGINEER

REPORTS TO: Manager, Tank Farm Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Plan work schedules
- Organize work plan
- Provide direction/implementation of work authorization
- Maintain control/completion of work authorization.

QUALIFICATIONS:

A B.S. degree or equivalent. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: MAINTENANCE SUPERVISOR

REPORTS TO: Manager, 200 East Area Tank Farm Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Plan work schedules
- Organize work plan
- Provide direction/implementation of work authorization
- Maintain control/completion of work authorization.

QUALIFICATIONS:

A B.A. Degree or equivalent. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: INSTRUMENT TECHNICIAN

REPORTS TO: Supervisor, Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Schedule maintenance of functioning systems
- Service functioning systems
- Repair functioning systems
- Upgrade functioning systems.

QUALIFICATIONS:

Journeyman status. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: ELECTRICIAN

REPORTS TO: Supervisor, Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried along with other duties associated with this position:

- Schedule maintenance of functioning systems
- Service functioning systems
- Repair functioning systems
- Upgrade functioning systems.

QUALIFICATIONS:

Journeyman status. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: PIPEFITTER (PLUMBER-STEAMFITTER)

REPORTS TO : Supervisor, Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to carried out along with other duties associated with this position:

- Remove equipment as required
- Repair equipment as required
- Replace equipment as required.

QUALIFICATIONS:

Journeyman status. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

JOB TITLE: MILLWRIGHT

REPORTS TO: Supervisor, Maintenance

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Remove equipment as required
- Repair equipment as required
- Replace equipment as required.

QUALIFICATIONS:

Journeyman status. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: MANAGER, GROUP, TANK FARM PLANT ENGINEERING

REPORTS TO: Manager, Department, Tank Farm Plant Engineering

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Coordinate grout engineering and support.

QUALIFICATIONS:

A B.S. degree in engineering. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: MANAGER, UNIT, TANK FARM PLANT ENGINEERING

REPORTS TO: Manager, Group, Tank Farm Plant Engineering

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Coordinate grout cognizant engineer support.

QUALIFICATIONS:

A B.S. degree in engineering. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: PROCESS ENGINEER

REPORTS TO: Unit Manager, Process Engineering

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Maintain facility expertise
  - Trouble-shooting
  - Engineering evaluations
  - Presentations
  - Tours
- Perform startup and maintenance activities
  - Process memos
  - Process engineering service and work requests
  - Process control plans
- Process weekly reports on facility operations
- Document calibrations/pisces forms
- Develop plant operating procedures
- Develop operability test procedure/operability test report
- Develop sample schedule
- Develop essential material specifications, sampling.

QUALIFICATIONS:

A B.S. degree in engineering. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

POSITION: OPERATIONAL HEALTH PHYSICS SUPERVISOR, EAST TANK FARMS

REPORTS TO: Manager, Waste Management Health Physics

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Administrative
  - Routines
  - Reports
- Emergency procedures and abnormal plant conditions.

QUALIFICATIONS:

A B.S. degree or equivalent. Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

9011178675

POSITION: RADIATION PROTECTION TECHNOLOGIST

REPORTS TO: Supervisor, Operational Health Physics

DUTIES ASSOCIATED WITH DANGEROUS WASTE:

The following duties are to be carried out along with other duties associated with this position:

- Survey and release personnel from radiation areas
- Survey radiological and nonradiological areas for contamination on a routine basis. Survey continuous air monitor (CAM) air samples and change on a routine basis
- Survey and release equipment from a radiation area. Survey equipment that work will be performed on
- Survey and release areas/buildings
- Set dose rates for personnel
- Set dose rates on equipment for personnel to work on, including gloveboxes
- Support radiological emergencies at the Grout Treatment Facility, which include CAM alarms and contamination spreads.

QUALIFICATIONS:

Completion of company-general, plant-specific, and job-specific training. Continued job-related experience. Knowledge of job requirements. Able to follow written/verbal procedures/instructions regarding normal operations and emergency conditions.

Physically able to:

- Work in changing weather conditions
- Ascend and descend stairs on the day bin tower
- Work in confined spaces
- Work in areas with limited access.

This page intentionally left blank.

APPENDIX 8C

SAMPLE GROUT FACILITIES EMPLOYEE TRAINING MATRIX

This page intentionally left blank.

9 0 1 1 7 8 6 1 7 7 9

APPENDIX 8C

SAMPLE GROUT FACILITIES EMPLOYEE TRAINING MATRIX

1. All personnel must complete Radiation Safety Training. Subsequent retraining is completed through the Radiation Safety Requalification with the exception of those in the Radiation Protection Technologist (RPT) Program (i.e., those in the RPT Program complete the retraining requirement through their certification courses).

2. New Employee Indoctrination is applicable only to those with payroll numbers 6C406 through 6D999 and any payroll number beginning with an 8.

3. Computer Security Awareness is not required for those in the Nuclear Operator Program because the only systems they operate are the programmable controllers, which are exempt from this course requirement.

4. The following courses are required for management-specified personnel only:

   - Basic Crane and Rigging Training
   - Computer Automated Surveillance System
   - Computer Security Awareness
   - On-the-Job Training Instructor Training
   - Tank Farm Routines
   - Waste Truck Operations.

R = Required training.

EXAMPLE

GIF EMPLOYEE TRAINING MATRIX

PAGE 1 OF 2

Org Code: | | | | | | |

Organization Title: TF PROCESSING

Manager's Signature: _____

Date: _____

EMPLOYEE NAME	JOB TITLE	PAYROLL NUMBER	RADIATION SAFETY TRAINING	RADIATION SAFETY REQUALIFICATION	NEW EMPLOYEE SAFETY ORIENTATION	GENERATOR HAZARDS SAFETY TRAINING	HAZARDS MATERIALS/WASTE JOB SPECIFIC TRAINING	GROUT FACILITIES ORIENTATION	TANK FARM FACILITY ORIENTATION	COMPREHENSIVE SECURITY BRIEFING	SECURITY REFRESHER BRIEFING	NEW EMPLOYEE INDOCTRINATION	COMPUTER SECURITY AWARENESS	OJT INSTRUCTOR TRAINING	BASIC CRANE AND RIGGING TRAINING	GRCO - NUCLEAR OPERATOR OPERATOR TRAINEE	GRCO - NUCLEAR OPERATOR 18 MONTH	GRCO - NUCLEAR OPERATOR 30 MONTH	GRCO - NUCLEAR OPERATOR 42 MONTH	GRCO - NUCLEAR PROCESS OPERATOR
	MANAGER/ SUPERVISOR		R[1]	R[1]	R	R	R	R	R	R	R	R[2]	R	R[4]	-	-	-	-	-	-
	NUCLEAR OPERATOR		R[1]	R[1]	R	R	R	R	R	R	R	R[2]	-[3]	R[4]	R[4]	R	R	R	R	R

REM

See previous numbered notes

VERIFIED BY:

EXAMPLE

GTF EMPLOYEE TRAINING MATRIX

Org Code: T 1 1 1 1

Organization Title: TF PROCESSING Manager's Signature: _____ Date: _____

EMPLOYEE NAME	JOB TITLE	PAYROLL NUMBER	TANK FARM PLANT SPEC. N.O. OPERATOR TRAINEE	TANK FARM PLANT SPEC. N.O. 18 MONTH	TANK FARM PLANT SPEC. N.O. 30 MONTH	TANK FARM PLANT SPEC. N.O. 42 MONTH	TANK FARM PLANT SPEC. NUCLEAR PROCESS OPER.	TANK FARM EP/APC NUCLEAR PROCESS OPER.	WASTE TRUCK OPERATIONS	COMPUTER AUTOMATED SURVEILLANCE SYSTEM	TANK FARM - PROCESS OPERATIONS MANAGER	TANK FARM EP/APC PROC. OPERATIONS MANAGER	TANK FARM OPERATOR GTF	TANK FARM ROUTINES
	MANAGER/ SUPERVISOR		-	-	-	-	-	-	-	-	R	R	-	-
	NUCLEAR OPERATOR		R	R	R	R	R	R	R[4]	R[4]	-	-	R	R[4]

REMARKS:

VERIFIED BY:
DATE:

This page intentionally left blank.

APPENDIX 8D

ENVIRONMENTAL AND HAZARDOUS MATERIAL SAFETY TRAINING REQUIREMENTS

This page intentionally left blank.

9011178615 85

ENVIRONMENTAL AND HAZARDOUS MATERIAL SAFETY INITIAL TRAINING REQUIREMENTS MATRIX

Employee category[a]	Course title and number														Total hours
	Hazardous Communication and Waste Orientation (1 hour)	Generator Hazards Safety Training (4 hours)	Hazardous Materials Waste Job-Specific Training[b]	Radiation Worker Training (8 hours)	Waste Site-Basic (16 hours)	Scott SKA-PAK[c] Training (2 hours)	Cardio-pulmonary Resuscitation (4 hours)	Fire Extinguisher Safety (1 hour)	Waste Site Advanced (24 hours)	Waste Site Field Experience (24 hours)	Hazardous Waste Shipment Certification (24 hours)	Certification of Hazardous Material Shipments (8 hours)	Hazardous Waste Site Supervisor/ Manager (8 hours)	Compliance Category[d]	
	02006B	02006G	02006H	020001	020101	020032	020123	02006F	020201	020202	02006S	020059	TBD		
All employees	X														1
General worker	X	X	X											1	5 + facility-specific training
General supervisor/manager	X	X	X											1	5 + facility-specific training
General nonradiological shipper	X	X	X								X			1,2	29 + facility-specific training
General hazardous material shipper	X	X	X									X		1,2	13 + facility-specific training
Hazardous waste site worker (known hazards)		X	X	X	X									1,3	28 + facility-specific training + field experience
Hazardous waste site worker (unknown hazards)	X	X	X	X		X	X	X	X	X				1,4	44 + facility-specific training + field experience
Hazardous waste site supervisor/ manager	X	X	X	X		X	X	X	X	X			X	1,5	52 + facility-specific training + field experience
Hazardous waste site shipper	X	X	X	X		X	X	X	X	X	X	X		1,2,4	76 + facility-specific training + field experience

PST90-00056-8B

[a]Definitions attached.
[b]Length varies for each facility.
[c]Scott SKA-PAK is a trademark of Figgie International, Incorporated.
[d]Compliance categories:
1 WAC 173-303 (Ecology 1989), 29 CFR 1910.1200 (OSHA 1988)
2 49 CFR 173 (DOT 1987)
3 29 CFR 1910.120 (24-hour requirement) (OSHA 1989)
4 29 CFR 1910.120 (40-hour requirement) (OSHA 1989)
5 29 CFR 1910.120 (40-hour plus 8-hour requirement) (OSHA 1989).

THIS PAGE INTENTIONALLY
LEFT BLANK

ENVIRONMENTAL AND HAZARDOUS MATERIAL SAFETY RETRAINING REQUIREMENTS MATRIX

Employee category[b]	Course title (length/frequency) and number				
	Generator Hazards Safety Training (4 hours/2 years)	Hazardous Materials Waste Job-Specific Training ([a]/1 year)	Hazardous Waste Site Retraining (8 hours/1 year)	Hazardous Waste Shipment Certification (24 hours/1 year)	Certification of Hazardous Material Shipments (8 hours/2 years)
	02006G	**02006H**	**020060**	**02006S**	**020059**
All employees (none required)					
General worker	X	X			
General supervisor/manager	X	X			
General nonradiological shipper	X	X		X	
General hazardous material shipper	X	X			X
Hazardous waste site worker (known hazards)	X	X	X		
Hazardous waste site worker (unknown hazards)	X	X	X		
Hazardous waste site supervisor/manager	X	X	X		
Hazardous waste site shipper	X	X	X	X	X

[a]Length varies for each facility.
[b]Definitions attached.

PST90-00056-8B

DEFINITIONS OF EMPLOYEE WORK CATEGORIES

Employee category	Definition
All employees	All Westinghouse Hanford Company employees and unescorted contract personnel.
General worker	Any employee who 'may be exposed' to hazardous chemicals in the work place. Such exposure is defined to include actual as well as potential exposure. Also, any employee who generates, packages, stores, or ships hazardous waste. This includes any employee who directly affects the management of hazardous chemicals/waste.
General supervisor/manager	A supervisor/manager who qualifies under the definition of general worker or who has employees that qualify as general workers.
General nonradiological dangerous waste shipper	An employee who qualifies under the definition of general worker and/or prepares and signs uniform hazardous waste manifests.
General hazardous material (radiological) shipper	An employee who qualifies under the definition of general worker and/or certifies the compliance of Hanford Site hazardous material shipments.

NOTE: For shipments of mixed waste, shipping course numbers 2006S and 20059, as indicated on the matrices, must be completed.

NOTE: The following definition of a hazardous waste site is used for the employee categories of hazardous waste site worker, hazardous waste site supervisor/manager, and hazardous waste site shipper:

> A 'hazardous waste site' is any site or operation defined in 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response" (OSHA 1989). These operations at the Hanford Site include, but are not limited to tank farms, cribs, grout, site characterization, chemical disposal and shock-sensitive chemical disposal, waste storage, and groundwater monitoring.

Hazardous waste site worker (known hazards)	Workers who are classified as requiring direct handling or involvement in the site or operation. Responsible for the safe operation of hazardous waste treatment, storage, and disposal facilities regulated under 40 CFR 264

Hazardous waste site worker (known hazards) (cont)	(EPA 1988a) and 40 CFR 265 (EPA 1988b) pursuant to the *Resource Conservation and Recovery Act of 1976*--provides for compliance with 29 CFR 1910.120 (24-hour training requirement) (OSHA 1989).
Hazardous waste site worker (unknown hazards)	Workers who are classified as requiring direct handling or involvement in the site or operation. Responsible for the safe initial site investigation and cleanup of *Comprehensive Environmental Response, Compensation and Liability Act of 1980* and *Resource Conservation and Recovery Act of 1976* hazardous waste sites--provides for compliance with 29 CFR 1910.120 (40-hour training requirement) (OSHA 1989).
Hazardous waste site supervisor/manager	Supervisors and managers who overview work or workers that require direct handling or involvement in the site or operation.
Hazardous waste site shipper	Employees who qualify under the definition of hazardous waste site worker and who certify shipments of hazardous waste, hazardous material (radiological), and/or mixed waste.

REFERENCES

DOT, 1988, *Hazardous Material Regulation of the Department of Transportation*, Title 49, Code of Federal Regulations, Part 173, U.S. Department of Transportation, Washington, D.C.

Ecology, 1989, *Dangerous Waste Regulations*, Washington Administrative Code WAC 173-303, Washington State Department of Ecology, Olympia, Washington.

EPA, 1988a, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 265, as amended, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 264, U.S. Environmental Protection Agency, Washington, D.C.

OSHA, 1988, *Occupational Safety and Health Standards*, Title 29, Code of Federal Regulations, Part 1910.1200, Occupational Safety and Health Administration, Washington, D.C.

OSHA, 1989, *Hazardous Waste Operations and Emergency Response*, Title 29, Code of Federal Regulations, Part 1910.120, Occupational Safety and Health Administration, Washington, D.C.

This page intentionally left blank.

APPENDIX 8E

SAMPLE TRAINING COURSE SUMMARIES

This page intentionally left blank.

APPENDIX 8E

SAMPLE TRAINING COURSE SUMMARIES

This appendix contains sample summaries of training courses for Grout Treatment Facility personnel.

8E.1 COMPANY-GENERAL COURSES

Title: Radiation Safety Training

Description: Instructs radiation workers in the fundamentals of radiation protection and the proper procedures for monitoring exposures.

Target Audience: Radiation workers

Delivery: Classroom

Assessment: Written test and practical dress/undress exercise

Length: 7 h

Frequency: 24 mo by completion of radiation safety requalification

---

Title: Radiation Safety Requalification

Description: Instructs radiation workers in the fundamentals of radiation protection and the proper procedures for monitoring exposures.

Target Audience: Radiation workers

Delivery: Classroom or computer-based training

Assessment: Written test and practical dress/undress exercise

Length: 7 h

Frequency: 24 mo

Title: New Employee Safety Orientation

Description: Course covers U.S. Department of Energy and Westinghouse Hanford regulations pertaining to employer and employee rights and responsibilities, general radiation training, hazardous communications and hazardous waste, fire prevention, personal protective equipment, safety regulations, accident reporting, avenues for addressing safety concerns.

Target Audience: All new employees

Delivery: Classroom

Assessment: N/A

Length: 3 h

Frequency: N/A

Title: Comprehensive Security Briefing

Description: Course is designed to acquaint individuals who are granted U.S. Department of Energy access authorization ("5" or "3") with their responsibilities concerning the classification, protection and control of classified information and materials, security regulations and reporting requirements. This includes escort training.

Target Audience: All new hire cleared employees and those receiving an upgrade clearance level, e.g., "0" to "5" or "3" and "5" to "3."

Delivery: Classroom

Assessment: N/A

Length: 1 h

Frequency: 12 mo by completion of security refresher briefing course.

Title: Security Refresher Briefing

Description: Intended to provide individuals who possess U.S. Department of Energy access authorizations with information on security regulations and information relating to their security responsibilities. It is expected to heighten individual security awareness, which tends to decline with time. Also includes escort training.

Target Audience: All employees with "5" or "3" clearances.

Delivery: Classroom

Assessment: N/A

Length: 1 h

Frequency: 12 mo

Title: New Employee Indoctrination

Description: New employee indoctrination is part of the new employee orientation program. Management must discuss and answer questions with new employees related to the content of topics listed on the Employee Indoctrination Checklist during each employee's first weeks on the job.

Target Audience: Company employees (new hires and updates, as needed, for all employees

Delivery: OJT

Assessment: N/A

Length: 3 h for new hires--time varies for all others.

Frequency: N/A

Title: Computer Security Awareness

Description: Covers procedures and user responsibilities for the protection of computer systems, including such topics as U.S. Department of Energy orders, definition of computer system, sensitive data and protective measures. Includes the six-minute video, "Computer Security Is You."

Target Audience: Personnel involved in the management, design, development, operation, maintenance, and use of computers or standalone processors.

Delivery: Classroom

Assessment: N/A

Length: 1 h

Frequency: 36 mo

Title: On-the-Job Training Instructor

Description: Instructional approach to the planning, implementation, and evaluation of on-the-job training. Includes role-model demonstration exercise and practice with critique.

Target Audience: Identified bargaining unit, exempt personnel.

Delivery: Classroom
Assessment: Practical exercise

Length: 12 h

Frequency: N/A

9011178517996

Title: Basic Crane and Rigging Training

Description: The course is designed to familiarize those who operate any type of lifting device who are not professional crane operators. The content includes principles of rigging and lifting as well as safety checks and practices.

Target Audience: Anyone who operates a lifting device.

Delivery: Classroom

Assessment: Written test

Length: Varies

Frequency: 24 mo

8E.2 PLANT-SPECIFIC COURSES

The scope and technique (delivery) for the annual review of initial training is still being reviewed.

Title: Grout Facilities Orientation

Description: Consists of a classroom presentation using structured notes and/or a videocassette. Topics to be presented in compliance with state and federal requirements include entry and exit requirements; location of organizational charts, administrative, and operating procedures; the person in charge of communications; potential hazards; restricted areas; potential emergencies, alarms, communications, responses and staging areas; location and use of emergency and equipment; identification of facilities; overview of the process; training requirements.

Target Audience: Unescorted personnel working at any of the grout facilities. (All others considered visitors and will be escorted.)

Delivery: Classroom or videocassette/self-study

Assessment: N/A

Length: 1 h

Frequency: N/A

Title: Facility Orientation--200 East/200 West Tank Farms

Description: Employees will be made aware of the type of radiation found in their work facility. They will become familiar with the types of instruments used to detect radiation. Employees will be aware of radiation areas at the facility and the signs used to identify the types of radiation areas. Radiation work permits along with the special work permit (SWP) procedures and dress requirements. Emergency signals and response to them will be discussed including evacuation routes. Employees will be instructed in self-survey for 200 Areas tank farm authorized personnel.

Target Audience: All personnel assigned to or perform work in the 200 Areas tank farms.

Delivery: Classroom

Assessment: N/A

Length: 1 h

Frequency: N/A

8E.3 JOB-SPECIFIC COURSES

Title: General Radio-Chemical Operator (GR-CO) Training

Description: Course consists of self-study, using a manual that covers the following topics in general terms for 200 Areas processing and waste management facilities:

- Introduction
- Mathematics
- Chemistry
- Security
- Industrial safety
- Emergency preparedness
- Radiation safety
- Environmental protection
- Criticality prevention
- Nuclear materials management
- Instrumentation
- Process and equipment.

Target Audience: Nuclear operators (i.e., operator trainee, 18-mo nuclear operator, 30-mo nuclear operator, 42-mo nuclear operator and nuclear process operator)

Delivery: Classroom or self-study

Assessment: Written test

Length: Varies

Frequency: 12 mo for operator trainee through nuclear operator 42-mo levels; 24 mo for nuclear process operator level.

Title: Tank Farm Processing and Services Plant-Specific Training

Description: Course consists of self-study, using a manual which covers the following topics about the 200 Areas tank farms:

- Introduction
- Emergency procedures
- Security
- Criticality and radiation safety
- Industrial safety
- Process and equipment.

Target Audience: Nuclear operators assigned to 200 Areas tank farms (i.e., operator trainee, 18-mo nuclear operator, 30-mo nuclear operator, 42-mo nuclear operator and nuclear process operator)

Delivery: Classroom or self-study

Assessment: Written test

Length: Varies

Frequency: 12-mo for operator trainee through nuclear operator 42-mo levels; 24-mo for nuclear process operator level.

Title: Tank Farm Processing Emergency Procedures and Abnormal Plant Conditions (EP/APC) Training for Nuclear Process Operators

Description: This course is designed to be a review of abnormal and emergency conditions that could occur in the tank farms, associated alarms and communications, and proper responses.

Target Audience: Nuclear process operators, beginning 12 mo after completion of GR-CO and plant-specific training

Delivery: Self-study

Assessment: Written test
Length: Varies

Frequency: 24 mo

SPECIAL NOTE: To comply with the U.S. Department of Energy training requirement for nonreactor nuclear facility operations personnel, nuclear process operators must complete emergency training at least annually. This course must be completed by nuclear operators at the nuclear process operators level in conjunction with the GR-CO and plant-specific requalification courses. In this way, the requalification courses will be completed one year, the EP/APC the next year, then the requalification courses, then the EP/APC, etc. In this way, nuclear process operators complete annual emergency training.

Title: Waste Truck Operations Training

Description: This course is designed to certify nuclear operators for transporting solid waste from various tank farm locations to the 200 East Area solid waste burial grounds. The course includes the following topics:

- Radioactive Packaging and Shipping Requirements for Laundry and Waste
- Radioactive Shipment Records
- Protective Clothing
- Cleanliness of Roadways and Interior Fencelines
- Regulated Waste and Soiled Laundry Pickup.

Delivery: Self-study and on-the-job training

Assessment: Written test and on-the-job training checklist

Length: Varies

Frequency: 24 mo

Title: Tank Farm Routines Training

Description: This course is designed to certify nuclear operators for routine work in all parts of the 200 Areas tank farms. The course includes the following topics:

- Surveillance
- Ventilation Systems
- Transfer and Routing Systems.

Delivery: Self-study and on-the-job training

Assessment: Written test and on-the-job training checklist

Length: Varies

Frequency: 24 mo

Title: Computer Automated Surveillance System (CASS) Training

Description: This course is designed to certify nuclear operators to monitor the CASS for the 200 Areas tank farms. The course includes the following topics:

- The CASS Operation
  - General troubleshooting
  - Troubleshooting
  - Shutdown/restart eclipse
  - Changing date/time
  - Changing backup to primary
- Emergency Response
  - Automatic temperature shutdown system/air Conditioner failure
  - Power outages
  - Fire alarm
- The CASS Routine Duties
  - Performance procedures
  - Receiving reports.

Delivery: Self-study and on-the-job training

Assessment: Written test and on-the-job training checklist

Length: Varies

Frequency: 24 mo

Title: Tank Farms Processing Operations Manager Certification

Description: This course covers the following topics:

- Administrative information
- Plant Technical information
- Facility safety analysis reports
- Operational safety requirements
- Radiation work procedures
- Jobs conducted in the area of assigned responsibility
- Processes
- Equipment.

Delivery: Self-study and on-the-job training

Assessment: Written test and on-the-job training checklist

Length: Varies
Frequency: 24 mo

Title: Tank Farms Processing Operations Manager Emergency Procedures and Abnormal Plant Conditions Training

Description: This course is designed to be a review of abnormal and emergency conditions that could occur in the 200 Areas tank farms, associated alarms and communications, and proper responses:

- General
- Plant
- Processes
- Equipment.

Delivery: Self-study and on-the-job training

Assessment: Written test

Length: Varies

Frequency: 12 mo

9011178502

Title: Grout Treatment Facility Training

Description: This course is designed to prepare and certify 200 Areas tank farms nuclear operators to operate the GTF. Operations managers/supervisors will complete the course only initially. The course consists of the following topics:

- Introduction

- Technology
  - Introduction
  - Major technology development activities
    - -- Waste characterization
    - -- Grout formulation
    - -- Performance assessment
    - -- Regulatory interface.

- Emergency procedures and abnormal plant conditions
  - Howler
  - Fire gong
  - Continuous air monitor
  - Steady siren
  - Wailing siren
  - Crash alarm
  - Bomb threat
  - Attack by hostile forces.

- Nonradioactive hazardous material emergency
  - Chemical hazards
  - Chemical safety
  - Dust hazards
  - Material safety data sheets
  - Loss of services
    - -- Electrical
    - -- Raw water
    - -- Ventilation
    - -- Process/instrument air system.

- Grout process
  - Function of system
  - System overview
  - Grout mixer
  - Surge tank
  - Grout pump
  - Product quality and control.

- Electrical and instrumental
  - Electrical component definitions
  - Power distribution
  - Instrumentation
  - Central processing units, redundant processing units
  - Software.

- Dry blend feed and dust collection system
  - Dry blend feed system
  - System operation on startup, shutdown
  - Truck off-loading/loading.
- Ventilation-radiation monitoring
  - Ventilation
  - Radiation monitoring
- Raw water
- Waste batch system (waste storage and feed/liquid-collection tank)
  - Waste feed system
  - Liquid-collection tank
- Waste treatment
  - Additive system
  - pH system
- Instrument air system
- Sample acquisition and handling
- Material/equipment removal/placement
- Decontamination system
- Grout line cleaning system
- System walkthrough
- Cold run training.

Target Audience: Nuclear operators assigned to the GTF and Grout Support Operations managers and supervisors.

Delivery: Classroom, self-study,and on-the-job training

Assessment: Written test and on-the-job training checklist

Length: Initial: 19 h of classroom; 120 h of on-the-job training--varies with recertification

Frequency: 24 mo

9011178618 04

Title: Phase I, Site-Generic Training

Description: Phase I certification training covers general information about nuclear processing operations. The following topics are covered: radiological controls, accident prevention standards, company policies, environmental protection, packaging and shipping of hazardous materials and radioactive waste, engineering procedures (configuration control, operating document control, and design media control), and selected quality assurance procedures.

Target Audience: Process engineers

Delivery: Classroom

Assessment: Written test

Length: Varies

Frequency: N/A

Title: Phase II, Plant-Specific Training

Description: Phase II certification training covers generic information for a specific operating facility, in this case 200 Areas tank farms. The following topics are covered: plant processes, plant utilities, etc.

Target Audience: Process engineers assigned to support 200 Areas tank farms

Delivery: Self-study

Assessment: Written test and oral walkthrough

Length: Varies

Frequency: 24 mo

Title: Phase III, Process-Specific Training

Description: Phase III certification training covers detailed information on specialized areas within a given facility or plant, in this case the GTF. Topics to be covered include details of the following:

- Process flowsheet
- Operating specifications
- Process equipment
- Operating procedures.

Target Audience: Process Engineers assigned to support the GTF

Delivery: Self-study

Assessment: Written test or oral walkthrough

Length: Varies

Frequency: 24 mo

Title: Tank Farm Plant Engineering Emergency Procedures and Abnormal Conditions Training

Description: This course is designed to prepare engineers to be able to recognize abnormal and emergency conditions that might occur in the 200 Areas tank farms, associated alarms and communications, and proper responses. The following topics are presented:

- Emergency procedures
- Abnormal conditions and responses
- Facility status
- Criticality prevention standards
- Desk instructions
- Facility/assigned area familiarity
- Operating procedures, operational specification Requirements, safety analysis reports for packaging, and instrument engineering flow diagrams
- Unusual/off-normal documentation.

Target Audience: Process engineers assigned to support 200 Areas tank farms

Delivery: Self-study

Assessment: Written test

Length: Varies

Frequency: 12 mo

Title: Junior Radiation Protection Technologist Certification

Description: Course consists of the following topics:

- Academics
- Radiation protection practices
- Emergency response
- Radiation safety
- Criticality safety
- Industrial safety
- Practical exercises
  - Dress/undress
  - Establishing radiation areas and control points
  - Surveying radiation generating machines
  - Release surveying
  - Estimating exposure
  - Detailed radiological survey.

Delivery: Classroom

Assessment: Written test

Length: Approximately 170 h

Frequency: N/A-The junior radiation protection technologist must complete the radiation protection technologist certification within 15 to 18 mo of this course completion.

Title: Junior Radiation Protection Technologist General On-the-Job Training

Description: Course includes the following topics:

- Manuals
- Records and reports
- Exposure control
  - Dosimetry
  - Survey techniques.

- Instrumentation
- Qualitative respirator fit
- Routine radiological control
- Job planning
  - Radiological postings
  - Hazards analysis.

- Abnormal conditions and emergencies
  - Criticality
  - Radiation area injuries

- Personnel decontamination
- Radioactive spills
- Area evacuation
- Continuous air monitor alarm response.

Delivery: On-the-job training

Assessment: On-the-job training checklist

Length: Up to 200 h

Frequency: 48 mo

Title: Junior Radiation Protection Technologist
200 East Area Tank Farms On-the-Job Training

Description: Course includes the following tasks:

- Decontamination and decommissioning
- 204 AR (tank car facility)
- 702A building (filter changes)
- Cars 33 and 38
- 242 A general monitoring and applicable routines
- Isolation and stabilization monitoring
- High efficiency particulate air (HEPA) filter change
- Tank farm construction coverage
- Routine tank farm coverage.

Delivery: On-the-job training

Assessment: On-the-job training checklist

Length: Up to 200 h

Frequency: 48 mo

Title: Radiation Protection Technologist Certification

Description: Course consists of the following topics:

- Academics
- Radiation protection practices
- Radiological work planning and briefing
- Radiation safety
- Criticality safety
- Emergency response
- Practical exercise--radiation detection Instrumentation.

Delivery: Classroom

Assessment: Written test

Length: Approximately 168 h

Frequency: N/A--The radiation protection technologist must complete the senior radiation protection technologist certification within 15 to 18 mo of this course completion.

Title: Radiation Protection Technologist General On-the-Job Training

Description: Course includes the following topics:

- Manuals
- Records and reports
- Exposure control
  - Dosimetry
  - Survey techniques.
- Instrumentation
- Qualitative respirator fit
- Routine radiological control
- Job planning
  - Radiological postings
  - Hazards analysis.

- Abnormal conditions and emergencies
  - Criticality
  - Radiation area injuries
  - Personnel decontamination
  - Radioactive spills
  - Area evacuation
  - Continuous air monitor alarm response.

Delivery: On-the-job training

Assessment: On-the-job training checklist

Length: Up to 200 h

Frequency: 48 mo

Title: Radiation Protection Technologist
200 East Area Tank Farms On-the-Job Training

Description: Course includes the following task:

- Monitoring for rigging crew activities

Delivery: On-the-job training

Assessment: On-the-job training checklist

Length: Up to 200 h

Frequency: 48 mo

Title: Senior Radiation Protection Technologist Certification

Description: Course consists of the following topics:

- Academics
- Radiation protection practices
- Emergency response
- Radiation safety
- Criticality safety
- Radiological problem solving
- Practical exercises.

Delivery: Classroom

Assessment: Written test

Length: Approximately 168 h

Frequency: 24 mo

9011178610

Title: Senior Radiation Protection Technologist General On-the-Job Training

Description: Course includes the following topics:

- Manuals
- Records and reports
- Exposure control
  - Dosimetry
  - Survey techniques.

- Instrumentation
- Qualitative respirator fit
- Routine radiological control
- Job planning
  - Radiological postings
  - Hazards analysis.

- Abnormal conditions and emergencies
  - Criticality
  - Radiation area injuries
  - Personnel decontamination
  - Radioactive spills
  - Area evacuation
  - Continuous air monitor alarm response.

Delivery: On-the-job training

Assessment: On-the-job training checklist

Length: Up to 200 h

Frequency: 48 mo

Title: Radiation Protection Technologist On-the-Job Training--Emergency Procedures and Abnormal Plant Conditions

Description: The course alternates from year-to-year between classroom training and testing, and on-the-job training and on-the-job training checklist. The topics include:

- Continuous air monitor alarm
- Contamination spread
- Personnel decontamination
- Criticality alarm
- Chemical spill or problem
- General emergencies (e.g., fire).

Delivery: Classroom or on-the-job training

Assessment: Written test or on-the-job training checklist

Length: Varies

Frequency: 12 mo

Title: Grout Equipment Checklist for Maintenance Personnel

Description: The course consists of a walkthrough, which is designed to acquaint designated maintenance personnel with the facilities, equipment, instrumentation, and other items so they will be able to locate, identify and be able to provide proper maintenance support for the grout facilities.

Target Audience: Maintenance personnel assigned to support the GTF

Delivery: Physical walkthrough

Assessment: N/A

Length: Varies

Frequency: N/A

Title: Texas Instrument 520/530 Programmable Controller Orientation

Description: The course consists of an overview of programmable controller and process interface, components of a programmable controller and the function of each component.

Target Audience: Electricians, instrument technicians, maintenance managers, supervisors, and plant engineers assigned to support the GTF.

Delivery: Classroom and video

Assessment: N/A

Length: 4 to 8 h

Frequency: N/A

Title: Uninterruptible Power Supply (UPS) Orientation

Description: Course consists of an overview which will identify the location of the GTF UPS system, why a UPS system is essential, and identification of the components of the UPS system.

Target Audience: Electricians, instrument technicians, maintenance managers, supervisors, and plant engineers assigned to support the GTF

Delivery: Classroom

Assessment: N/A

Length: 1 h

Frequency: N/A

Title: Variable-Speed Drive Orientation

Description: Course consists of an overview of the components of and various applications of the Westinghouse Accutrol 300 Vari-Speed Drive Unit.

Target Audience: Electricians, instrument technicians, maintenance managers, supervisors, and plant engineers assigned to support the GTF.

Delivery: Classroom

Assessment: N/A

Length: 2 h

Frequency: N/A

Title:	Lock and Tag Orientation for Tank Farms Maintenance Personnel
Description:	Two lock and tag procedures are reviewed with identified 200 Areas tank farms maintenance personnel: • Westinghouse Hanford procedures • Plant-specific procedures.
Delivery:	Classroom
Assessment:	N/A
Length:	1 h
Frequency:	N/A

9 0 1 1 7 8 6 1 8 1 4

ENVIRONMENTAL AND HAZARDOUS MATERIAL

SAFETY TRAINING

Course name	Course number	Course description
Hazard Communication and Waste Orientation	02006B	This course provides an overview of the federal and Westinghouse Hanford Company hazard communication programs and hazardous waste disposal. Note: The requirements for this training also are satisfied by course number 02006A or 02006G.
Generator Hazards Safety Training	02006G	This course provides the hazardous material/waste worker with the fundamentals for use and disposal of hazardous materials.
Hazardous Materials/ Waste Job-Specific Training	02006H	This course provides specific information on hazardous chemicals and waste management at the employees' facility.
Initial Radiation Worker Training	020001	This course provides radiation workers with the fundamentals of radiation protection and the proper procedures for maintaining exposures as low as reasonably achievable.
Waste Site-Basic	020101	This course provides required information for the safe operation of hazardous waste treatment, storage, and disposal facilities regulated under 40 CFR 264 (EPA 1988a) and 40 CFR 265 (EPA 1988b) pursuant to the *Resource Conservation and Recovery Act of 1976*.

Scott "SKA-PAK" Training-SKA	020032	This class is designed to instruct employees in the proper use of the Scott "SKA-PAK" for entry, exit, or work in conditions immediately dangerous to life and health and to instruct employees to recognize and handle emergencies.
Cardiopulmonary Resuscitation (CPR)	0200123	This American Heart Association course provides certification in CPR for the single rescuer (Heartsaver Course).
Fire Extinguisher Safety	02006F	This course is a videocassette presentation that covers types of portable fire extinguishers and the proper use for each.
Waste Site-Advanced	020201	This course provides employee and environmental safety information for *Resource Conservation and Recovery Act of 1976* and/or *Comprehensive Environmental Response, Compensation and Liability Act of 1980* operations and sites. Topics include regulations and acronyms, occupational health and safety, chemical hazard information, toxicology, personal protective equipment and respirators, site safety, decontamination, and chemical monitoring instrumentation.
Waste Site Field Experience	020202	This course provides 3 days of field experience under the direct supervision of a trained, experienced supervisor.
Hazardous Waste Shipment Certification	02006S	This course takes an in-depth look at federal, state, and company requirements for nonradioactive hazardous waste management and transportation.

Certification of Hazardous Material Shipments	020059	This course provides training in the U.S. Department of Transportation hazardous material regulations, as required by law, to those who certify the compliance of Hanford Site hazardous material shipments. The main focus will be on the proper preparation and release of radioactive material shipments.
Hazardous Waste Site Supervisor/Manager	TBD	This course provides specialized training for operation/site management and supervision in the following Westinghouse Hanford Company programs: safety and health, employee training, personal protective equipment, spill containment, and health hazard monitoring procedures and techniques.

REFERENCES

EPA, 1988a, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 265, as amended, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Title 40, Code of Federal Regulations, Part 264, U.S. Environmental Protection Agency, Washington, D.C.

1 This page intentionally left blank.

APPENDIX 5D-4

QUALITY ASSURANCE PROJECT PLAN

This page intentionally left blank.

RCRA GROUND-WATER MONITORING PROJECTS

QUALITY ASSURANCE PROJECT PLAN

PREPARED BY

PACIFIC NORTHWEST LABORATORY
P.O. BOX 999
RICHLAND, WASHINGTON 99352

Issue Date:

Approvals:

PNL Environmental Assessment Department, Site Characterization Section — P G Dectar — 12-22-89 Date

PNL Office of Hanford Environment, Ground-Water and Compliance Monitoring — Roy Thurston for MS Hanson — 12/22/89 Date

PNL Process Quality Department, Quality Engineering Group — Jeff W. Smith — 12/22/89 — 12/22/89 Date

QA Project Plan OHE-18, Revision 1

2.0 TABLE OF CONTENTS

Section Number	Section Title	Pages
1.	TITLE PAGE	1
2.	TABLE OF CONTENTS	2
3.	QUALITY ASSURANCE PROGRAM	1
4.	PROJECT DESCRIPTION	3
5.	PROJECT ORGANIZATION AND RESPONSIBILITIES	4
6.	QA OBJECTIVES FOR MEASUREMENT DATA	6
7.	SAMPLING PROCEDURES	2
8.	SAMPLE CUSTODY AND FIELD DOCUMENTATION	1
9.	CALIBRATION PROCEDURES AND FREQUENCY FOR TEST EQUIPMENT	2
10.	ANALYTICAL PROCEDURES	1
11.	DATA REDUCTION, VALIDATION AND REPORTING	3
12.	INTERNAL QUALITY CONTROL CHECKS	2
13.	AUDITS AND SURVEILLANCES	1
14.	PREVENTIVE MAINTENANCE	1
15.	SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY AND COMPLETENESS	1
16.	CORRECTIVE ACTION	1
17.	QUALITY ASSURANCE REPORTS TO MANAGEMENT	1
18.	RECORDS	5
19.	PROCUREMENT CONTROL	1
20.	STAFF TRAINING	1
21.	SOFTWARE CONTROL	1
22.	NONCONFORMANCES AND DEFICIENCIES	1
23.	DOCUMENT CONTROL	1
24.	MONITORING WELL INSTALLATION	2

Modifications or revisions to this QA Project Plan are discussed in Section 23, Document Control.

QA Project Plan OHE-18, Rev. 1 Controlled Distribution

PNL

SP Airhart
DL Alamia
GL Andersen
DJ Bates
LL Belt
BN Bjornstad
JV Borghese
KL Bray
RW Bryce
MA Chamness
WE Cronin
DR Dahl
DD Dickinson
JC Evans
PM Fangman
RM Fruland
TJ Gilmore
DW Glover
SM Goodwin
RH Gray
SH Hall
PR Heller
EL Hilty
EJ Jensen
JL Julya
SP Juracich
MR Kerns
KJ Klingler
GV Last
SP Luttrell
DL Mackliet
JP McDonald
VL McGhan
DL Merril
DR Newcomer
KB Olsen
JT Rieger
R Schalla
DL Stewart
SS Teel
BA Walker
EJ Westergard

WHC

KR Fecht
LW Vance

QA Project Plan OHE-18, Revision 1

3.0 QUALITY ASSURANCE PROGRAM

This quality assurance (QA) project plan applies to Pacific Northwest Laboratory (PNL) Resource Conservation and Recovery Act (RCRA) ground-water monitoring projects staffed by members the Environmental Assessment Department of the Earth and Environmental Sciences Center. The PNL Office of Hanford Environment programmatically oversees the work. The QA program described here was developed to address both U.S. Environmental Protection Agency (EPA) QAMS-005/80, Interim Guidelines for Preparing Quality Assurance Project Plans, and DOE Orders 5700.1A and 5700.6B. It also addresses QA requirements specified in Article 30 of the Hanford Federal Facility Agreement and Consent Order. This QA Project Plan refers to PNL's Quality Assurance Manual, PNL-MA-70, and associated administrative procedures contained in the manual. PNL-MA-70 is based on the 18 elements for a QA program presented in ANSI/ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facilities.

United States Testing Company, Incorporated (UST) will serve as the primary analytical laboratory. UST's QA Program is documented in UST-RD-QA, QA Manual, and UST-RD-QC, QC Manual.

4.0 PROJECT DESCRIPTION

This QA project plan is intended to address all of the various types of activities that PNL RCRA ground-water monitoring projects might potentially perform. Not all projects will necessarily perform all the activities. A detailed description of each specific ground-water monitoring project must be included in the respective Project Management Plan (PMP) or Ground-Water Monitoring Plan (GWMP).

The PNL RCRA ground-water monitoring projects have been developed as described at 40 CFR 265, Subpart F, and Washington Administrative Code (WAC) 173-303-400 to establish interim status ground-water monitoring programs. Applicable elements of the EPA RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD) are incorporated.

4.1 Objectives

The objectives of PNL RCRA ground-water monitoring projects are to

- characterize the stratigraphy and the horizontal and vertical ground-water flow components beneath specified sites, focusing on the uppermost unconfined aquifer, and determine the rate of ground-water flow
- determine if any statistically significant amounts of hazardous waste constituents that originate at the specified sites are detectable in the ground water.

4.2 Approach

The technical approach for meeting the objectives of Section 4.1 shall be documented in each specific PMP or GWMP as previously indicated.

Typically, new ground-water monitoring wells must be constructed. The functional design and construction standards for these wells meet the minimum requirements of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells, Part Three-Resource Protection Wells". These standards are implemented through well construction specifications, which are issued by Westinghouse Hanford Company.

Subsurface soil samples are obtained during drilling at each location for determination of stratigraphy. Selected samples are submitted to a PNL laboratory for analyses to determine physical and chemical parameters. The method or reason for selecting specific samples for additional physical or chemical analysis must be described in the PMP or GWMP. Selection should ensure sample representativeness and avoid bias.

Ground water samples will be collected and analyzed quarterly for 1 year from all new and from selected existing monitoring wells. Samples will be collected and analyzed semiannually after the first year.

Statistical evaluation of the sample analyses will provide an indication of whether hazardous constituents are significantly affecting the ground water. As a minimum, the requirements of 40 CFR 265.93(b) must be applied to determine if statistically significant increases take place. Other methods may also be used at the discretion of the PNL Statistician.

4.3 Monitoring Parameters

As a minimum, samples will be collected and analyzed for the constituents listed in Exhibit 4.1, as required by 40 CFR 265, Subpart F, by the following schedule. Unless otherwise noted in project planning documents (i.e., PMP, groundwater monitoring plan), samples to be analyzed for all of these constituents will be collected quarterly for the first year of monitoring. Following the first year of monitoring, the ground-water contamination indicators will be analyzed semiannually and ground-water quality parameters annually. Additional site specific parameters to be analyzed for shall be identified in the PMP or GWMP.

EXHIBIT 4.1. Ground-Water Sampling Parameters

Interim Drinking Water Standards	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Toxaphene
Chromium	2,4-D
Fluoride	2,4,5-TP Silvex
Lead	Radium
Mercury	Gross alpha
Nitrate	Gross beta
Selenium	Turbidity (surface water)
Silver	Coliform bacteria
Endrin	

Ground-Water Quality Parameters	
Chloride	Iron
Manganese	Phenols
Sodium	Sulfate

Ground-Water Contamination Indicator Parameters	
pH	Specific conductance
Total organic carbon	Total organic halogen

QA Project Plan OHE-18, Revision 1

4.4 Change Control (Scope, Schedule, Budget)

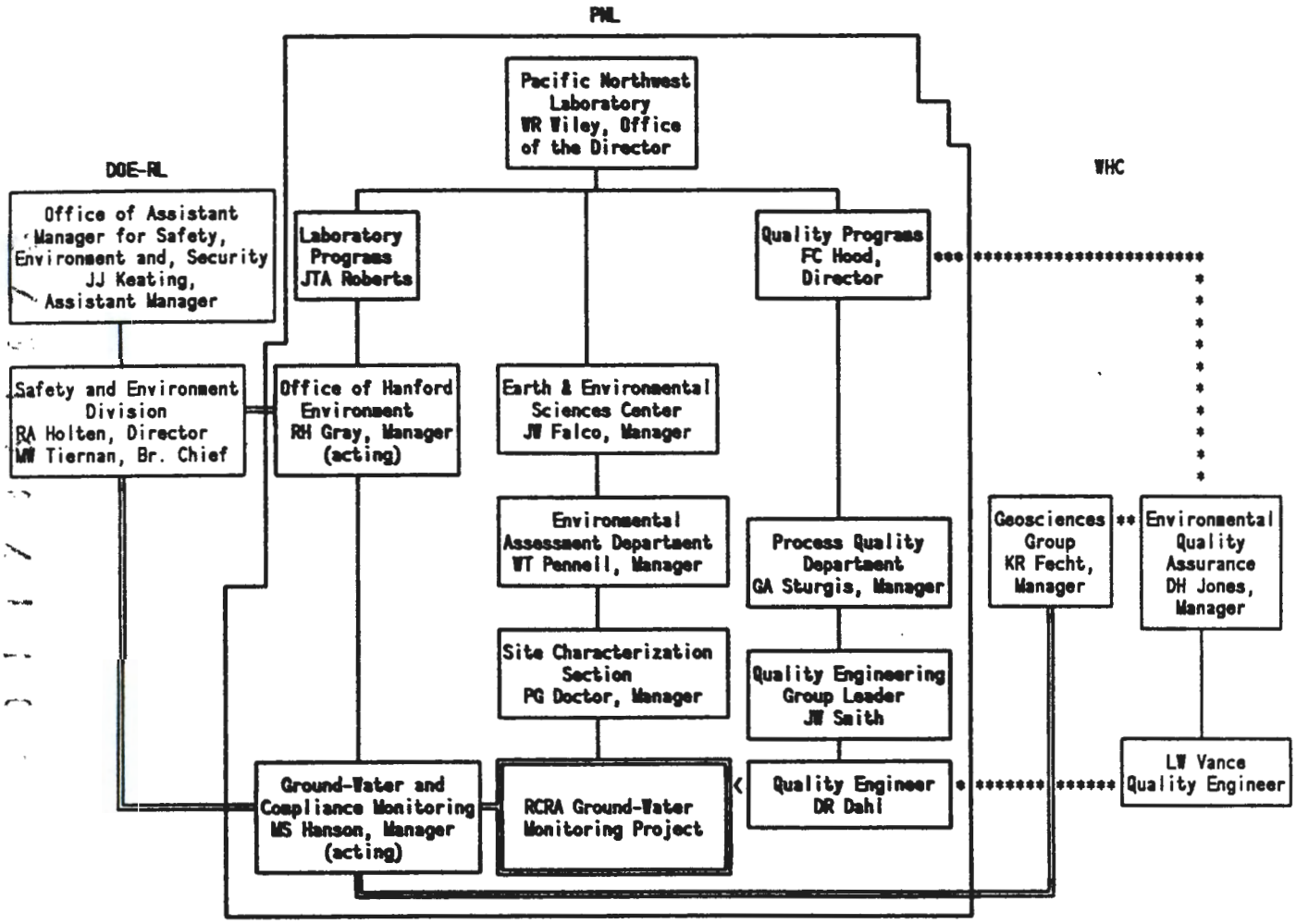
Requests for changes in project scope, schedule or budget from that in the PMP (other than changes in the sampling site, frequency, or parameters) must be formally made by letter. A Change Request/Record and Change Control Log must be used by the project manager to document changes in scope, schedule, or budget. Changes in the sampling site, frequency of sampling, or parameters to be analyzed for are discussed in Section 7.5 of this QA project plan.

5.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Line authority, quality assurance authority and support within PNL, and interfaces with Westinghouse Hanford Company (WHC) and the U.S. Department of Energy, Richland Operations Office (DOE-RL), are shown in Exhibit 5.1. The responsibilities of key PNL personnel are summarized in Table 5.1.

Changes to organizational/interface structures shown in Exhibit 5.1 that do not reflect a change in the overall scope of the activities or a change of requirements will not require a QA project plan revision but will be incorporated in the next required revision of the QA Project Plan.

EXHIBIT 5.1. Project Interfaces



_____ Line Management Guidance

********** WHC QA Interface

<<<<<<<< PNL Project QA Support

═══ Formal Client Technical Interface

TABLE 5.1. Responsibilities of Key Personnel

Personnel	Responsibilities
Office of Hanford Environment (OHE), Ground-Water and Compliance Monitoring Manager	Provides the formal interface between the PNL Project Manager and both the DOE-RL Program Monitor and the WHC Geosciences Manager. Also manages and integrates cost, scope, and schedule.
Site Characterization Section and Environmental Assessment Department Mgrs.	Provide management review of project. Assure appropriate and qualified staff are available.
Project Manager	Provides overall direction of the project at PNL and day-to-day activities necessary to accomplish all project objectives. Ensures that the QA project plan is prepared and adhered to and that data, QA information, and reports are produced in a timely manner. Has direct contact with the PNL Quality Engineer.
Quality Engineering Group Manager	Provides for independent quality assurance reviews, surveillances, and data quality and traceability audits. Is responsible for reviewing and has sign-off authority for QA project plans.
PNL Site Geologists/ Hydrologists	Support well construction activities, characterize sediment samples, perform inspection function, document well construction and completion, perform and document aquifer tests and sampling pump installation.
Field Sampling Staff	Perform sampling and testing activities in accordance with methods in PNL-MA-567 and this QA project plan.
Data Management Task Leader	Ensures correct entry of data into the Hanford Ground-Water Data Base (HGWDB) and maintains the database.
Quality Control (QC) Task Leader	Coordinates all QC activities including the scheduling, preparation, and submittal of QC samples to UST and various PNL laboratories, and evaluates the results. Interacts with the Project Statistician, and Sample Analysis and Data Handling Task Leaders to investigate suspect results. Monthly, prepares a report of the QC Task activities for each Project Manager.

TABLE 5.1 (continued)

Personnel	Responsibilities
Sample Analysis and Coordination Task Leader	Coordinates and implements ground-water monitoring sample and analysis plans. Is responsible for maintaining document files (chains-of-custody, sample analysis requests, analytical report data), and facilitating data reviews as needed. Acts as liaison with PNL subcontract administration and between PNL and subcontract laboratory.
Sample Collection Task Leader	Manages all field aspects of sample collection, ensures sample collection personnel are kept current in the procedures, investigates suspect results, and reviews field records.
Sample Preparation Task Leader	Is responsible for procuring sample containers and preservatives, preparing the containers, labelling the containers, and preparing chain-of-custody and Field Record sheets.
Project Statistician	Ensures that required interim status detection monitoring statistical analyses are performed. Provides statistical support to other personnel as needed. Reviews chemistry data as it comes in for consistency with other pertinent data and information.
Quality Engineer	Provides QA support in such areas as QA requirement interpretation, external audit preparation, QA project plan development or revision, document review, and interfacing with client QA personnel. Also provides independent oversight to verify project activities are being performed consistent with applicable requirements identified in this QA project plan.

6.0 QA OBJECTIVES FOR MEASUREMENT DATA

The characteristics used to define data quality are accuracy, precision, completeness, comparability, and representativeness. The definitions used for accuracy and precision terms are those contained in EPA QAMS-005/80, Appendix A. The completeness definition to be used will be:

$$\text{Completeness, \%} = \frac{\text{Number of Valid Data Points Acquired}}{\text{Total Number of Data Points Planned}} \times 100$$

Data quality objectives (DQOs) for accuracy, precision, and completeness are shown in Tables 6.1 and 6.2. Water chemistry accuracy objectives are expressed in terms of an acceptable range of recovery and precision objectives in terms of percent relative precision (except where noted). Any DQOs for project-specific constituents not included in the tables must be included in the PMP or GWMP.

Representativeness and comparability of data must be discussed, when appropriate, in deliverable reports.

The precision and accuracy objectives specified in Table 6.2 are based on standard method performance information, when available, and historical laboratory performance. For some methods, this information was not available; an N/A is marked in the summary tables. As additional analytical results are compiled this information will be completed.

TABLE 6.1. Data Quality Objectives for Sampling

Measurement Parameter	Accuracy	Precision	Completeness
Water Chemistry	See Table 6.2	See Table 6.2	90%
Hydrologic Testing			
• flow rate	± 10 %	± 10 %	80% per log cycle
• depth to water (testing)	± 0.25 ft	± 0.04 ft	80% per log cycle
• well diameter	± 0.01 ft	± 0.01 ft	100 %
• distance between wells	± 5 %	± 5 %	100 %
• well depth	± 1 ft	± 0.1 ft	100 %
• time	<10 min ± 5 sec >10 min ± 1 %	± 5 sec	100 %
Depth to Water (sampling)(a)	± 0.02 ft	± 0.02 ft	100 %
Well Development:			
• turbidity	± greater of 20 % or 1 NTU/100mL	± greater of 10 % or 0.5 NTU/100 ml	N/A
Surveyed Casing Elevation(a)	± 0.04 ft	± 0.02 ft	100%
Sediment Analyses:			
• scale(s)	± 0.02 g	± 1 % (b)	100%
• caliper(s)	± 0.025 mm	± 1 % (b)	100%
• pressure gauge	± 0.01 bar	± 1 % (b)	100%
• hydrometer	± 1g colloids/L	± 2 % (b)	100%

(a) relative to National Geodetic Survey or Hanford facility datum
(b) of full scale

TABLE 6.2

DESCRIPTION	LAB CODE	REFERENCE METHOD(a)	DATA QUALITY OBJECTIVES RANGE OF RECOVERY %	RELATIVE PRECISION	REFERENCE	SAMPLE SIZE	BOTTLE TYPE(b)	NUMBER BOTTLES	PRESERVATIVE
1 METALS									
ICP Metals	726	6010 SW	75-125	±20%	6010 SW	1L	PWC	1	HNO_3
ICP Metals(f)	741	6010 SW	75-125	±20%	6010 SW	1L	PWC	1	HNO_3
Arsenic	A20	7060 SW	75-120	±15%	206.2 EPA/H	1L	PWC	1	HNO_3
Mercury	A21	7470 SW	75-125	±15%	245.1 EPA/H	500mL	GC	1	HNO_3
Selenium	A22	7740 SW	75-115	±15%	270.2 EPA/H	1L	PWC	1	HNO_3
Thallium	A23	7841 SW	75-125	±30%	H	1L	PWC	1	HNO_3
Lead (GF)	A51	7421 SW	75-125	±15%	239.2 EPA/H	1L	PWC	1	HNO_3
Arsenic(f)	H37	7060 SW	75-115	±15%	206.2 EPA/H	1L	PWC	1	HNO_3
Mercury(f)	H38	7470 SW	75-125	±15%	245.1 EPA/H	500mL	GC	1	HNO_3
Selenium(f)	H39	7740 SW	75-115	±15%	270.2 EPA/H	1L	PWC	1	HNO_3
Thallium(f)	H40	7841 SW	75-125	±30%	H	1L	PWC	1	HNO_3
Lead(f)	H41	7421 SW	75-125	±15%	239.2 EPA/H	1L	PWC	1	HNO_3
Chromium VI	P11	7196/7197 SW	85-115	±10%	218.4 EPA		G	1	
2 PESTICIDES & HERBICIDES									
Pesticides	728	8080 SW	See Below		8080 SW/H	2L	GA	1	
Matrix Spikes									
Endrin (A33)			50-140						
g-BHC (A38)			50-125						
Surrogates									
DBC (X10)			60-146	(at least one of the					
TCMX (X16)			44-125	criteria must be met)					
Pesticides (enhanced)	729	8080 SW	See Below		8080 SW/H	2L	GA	1	
Matrix Spikes									
Endrin (A33)			50-145						
g-BHC (A38)			50-125						
DDT (A42)			50-130						
Heptachlor (A43)			50-110						
Dieldrin (A46)			50-130						
Aldrin (A47)			50-115						
Surrogates									
DBC (X10)			70-146	(at least one of the					
TCMX (X16)			44-115	criteria must be met)					
Phosphorus Pesticides	734	8140 SW	See Below		8140 SW/H	4L	GA	1	
Matrix Spikes									
Dimethoate (C65)			75-120						
Herbicides	737	8150 SW	See Below		8150 SW/H	4L	GA	1	
Matrix Spikes									
2,4-D (H13)			70-100						
2,4,5-T,P (silvex) (H14)			63-101						
2,4,5-T (H15)			65-107						

TABLE 6.2

DESCRIPTION	LAB CODE	REFERENCE METHOD(a)	DATA QUALITY OBJECTIVES RANGE OF RECOVERY %	RELATIVE PRECISION	REFERENCE	SAMPLE SIZE	BOTTLE TYPE(b)	NUMBER BOTTLES	PRESERVATIVE
Surrogate									
2,4-DB (X14)			75-120						
3 VOLATILE ORGANICS GC/MS									
Volatile Organics (VOA's)	730	8240 SW	See Below		8240 SW/H	40mL	GA/S	2	
Matrix Spikes									
Benzene (A62)			50-125						
Toluene (A66)			65-140						
Tricene (A69)			71-140						
Chlorobenzene (A78)			50-145						
Dicethy (A92)			5-150						
Surrogates									
12DCAD4 (X07)			76-114						
TOLUD8 (X08)			88-110						
BFB (X09)			86-115						
VOAs Targeted (730) + non Targeted	731	8240 SW	See Below		8240 SW/H	40 mL	GA/S	2	
Matrix Spikes									
Benzene (A62)			50-125						
Toluene (A66)			65-140						
Tricene (A69)			71-140						
Chlorobenzene (A78)			50-145						
Dicethy (A92)			5-150						
Surrogates									
12DCAD4 (X07)			76-114						
TOLUD8 (X08)			88-110						
BFB (X09)			86-115						
VOAs Additional Targeted + non-Targeted Cmpds.	750	8240 SW	See Below		8240 SW/H	40 mL	GA/S	2	
Matrix Spikes									
Benzene (A62)			50-125						
Toluene (A66)			65-140						
Tricene (A69)			71-140						
Chlorobenzene (A78)			50-145						
Dicethy (A92)			5-150						
Surrogates									
12DCAD4 (X07)			76-114						
TOLUD8 (X08)			88-110						
BFB (X09)			86-115						

TABLE 6.2

DESCRIPTION	LAB CODE	REFERENCE METHOD(a)	DATA QUALITY OBJECTIVES RANGE OF RECOVERY %	RELATIVE PRECISION	REFERENCE	SAMPLE SIZE	BOTTLE TYPE(b)	NUMBER BOTTLES	PRESERVATIVE
4 VOLATILE ORGANICS by GC									
VOA by GC	749	8010 SW	See Below		8010 SW/H	40 mL	GA/S	4	
Matrix Spikes									
Chloroform (L34)			60-130						
1,1-DCL (L36)			47-115						
Triceln (L43)			50-130						
5 SEMI VOLATILES									
A/B/Ns	732	8270 SW	See Below		8270 SW/H	2L	GA	1	
Matrix Spikes									
P-Chloro-m-cresol (B46)			50-125						
2-Chlorophenol (B49)			45-120						
Di-n-butyl Phthalate (B60)			25-110						
p-Dichlorbenzene (B63)			20-115						
2,4-Dinitrotoluene (B80)			40-130						
Di-n-propylnitrosamine (B85			20-185						
p-nitrophenol (C13)			5-130						
Pentachlorophenol (C28)			30-140						
1,2,4-Trichlorobenzene (C43			44-130						
Phenol (C57)			35-110						
Acenaphthene (I29)			47-120						
Pyrene (I32)			58-115						
Surrogates									
2FLPHEN (X01)			48-106						
PHEND6 (X02)			35-110						
NITBN2 (X03)			35-114						
2FLBIPH (X04)			43-116						
246TRI (X05)			10-123						
TERD14 (X06)			33-141						
A/B/Ns Targeted (732) + non-Targeted Cmpds.	733	8270 SW	See Below		8270 SW/H	2L	GA	1	
Matrix Spikes									
P-Chloro-m-cresol (B46)			50-125						
2-Chlorophenol (B49)			45-120						
Di-n-butyl Phthalate (B60)			25-110						
p-Dichlorbenzene (B63)			20-115						
2,4-Dinitrotoluene (B80)			40-130						
Di-n-propylnitrosamine (B85			20-185						
p-nitrophenol (C13)			5-130						
Pentachlorophenol (C28)			30-140						
1,2,4-Trichlorobenzene (C43			44-130						
Phenol (C57)			35-110						
Acenaphthene (I29)			47-120						
Pyrene (I32)			58-115						

TABLE 6.2

DESCRIPTION	LAB CODE	REFERENCE METHOD(a)	DATA QUALITY OBJECTIVES RANGE OF RECOVERY %	RELATIVE PRECISION	REFERENCE	SAMPLE SIZE	BOTTLE TYPE(b)	NUMBER BOTTLES	PRESERVATIVE
Surrogates									
2FLPHEN (X01)			48-106						
PHEND6 (X02)			35-110						
NITBN2 (X03)			35-114						
2FLBIPH (X04)			43-116						
246TRI (X05)			10-123						
TERD14 (X06)			33-141						
A/B/Ns Additional Targeted + non-Targeted Capds.	751	8270 SW	See Below		8270 SW/H	2L	GA	1	
Matrix Spikes									
P-Chloro-m-cresol (B46)			50-125						
2-Chlorophenol (B49)			45-120						
Di-n-butyl Phthalate (B60)			25-110						
p-Dichlorbenzene (B63)			20-115						
2,4-Dinitrotoluene (B80)			40-130						
Di-n-propylnitrosamine (B85			20-185						
p-nitrophenol (C13)			5-130						
Pentachlorophenol (C28)			30-140						
1,2,4-Trichlorobenzene (C43			44-130						
Phenol (C57)			35-110						
Acenaphthene (I29)			47-120						
Pyrene (I32)			58-115						
Surrogates									
2FLPHEN (X01)			48-106						
PHEND6 (X02)			35-110						
NITBN2 (X03)			35-114						
2FLBIPH (X04)			43-116						
246TRI (X05)			10-123						
TERD14 (X06)			33-141						
6 MISC. ORGANICS									
Thiourea(enh)	727	8330 SW	80-105	±20%	H	40 mL	GA/S	1	
PCBs	739	8080 SW	See Below		8080 SW/H	2 L	GA	1	
Surrogates									
DBCPCB (X15)			70-146						
TCMX (X16)			70-135						
TCMXPCB (X17)			44-125						
Ethylene Glycol	C81	-	75-125	±20%	H	40 mL	G	1	
Hydrazine (LDL)	H62	D1385 A	65-105	±10%	D1385 ASTM	250 mL	GA/S	2	HCl
PCDD's etc.	752	8280 SW	See Below		8280 SW/H				
Surrogates									
CHLOR037 (X11)			40-140						
Thiourea	A24	8330 SW	80-105	±20%		40 mL	GA/S	1	

TABLE 6.2

DESCRIPTION	LAB CODE	REFERENCE METHOD(a)	DATA QUALITY OBJECTIVES RANGE OF RECOVERY %	RELATIVE PRECISION	REFERENCE	SAMPLE SIZE	BOTTLE TYPE(b)	NUMBER BOTTLES	PRESERVATIVE
7 INORGANIC									
Anions by IC	742	300 EPA	80-135	±35%	300 EPA	125 mL	P	1	
Nitrate(HDL)	H65	9200 SW	N/A	N/A	N/A	125 mL	P	1	
Cyanide	C70	9010 SW	85-102	±15%	335.2 EPA	1 L	P	2	NaOH
Perchlorate	C77		80-110	±25%	H	125 mL	P	1	
Sulfide	C78	9030 SW	90-105	±15%	H	500 mL	P	2	NaOH, Zn Acetate
Ammonium Ion	C80	D1426-D A	75-125	±20%	H	500 mL	GC	1	H_2SO_4
Fluoride(LDL)	H63	D1179-80-B	90-105	±10%	D1179-80-B	250 mL	P	1	
Ferrocyanide	P09	N/A	N/A	N/A	N/A	1 L	P	1	
Oxalate	P10	N/A	N/A	N/A	N/A	125 mL	P	1	
8 MISC.									
Conductance(lab)	088	D1125A A	N/A	N/A	D1125A A	250 mL	P	1	
Coliform	109	9131 SW	N/A	N/A	N/A	120 mL	P	2	sterile
Coliform	P19	9132 SW	N/A	±40%	H	120 mL	P	2	sterile
TOC	C69	9060 SW	75-120	±10%	H	250 mL	G	1	H_3PO_4
Citrus Red	C87		N/A	N/A	N/A	40 mL	GA/S	1	
Total Carbon	H16	D2579A/B A*	80-125	±10%	H	250 mL	G	1	
Total Dis. Sol.	H17	209B A	N/A	N/A	N/A	500 mL	P	1	
Total Organic Halogen (LDL)	H42	9020 SW	75-125	±30%	9020 SW	250 mL	GA/S	2	H_2SO_4
Alkalinity (method B)	H58	D1067B A	N/A	N/A	N/A	250 mL	P	1	
Total Organic Halides, Extractable	L61	600/4-84-00 USEPA	75-125	±25%	H				
Alkalinity (method A)	P14	D1067A A	N/A	N/A	N/A	250 mL	P	1	
pH (lab)	207	D1293 A	±0.5% Bias	±0.1SD	9040 SW	250 mL	P	1	
9 RAD ANALYSES				Allowed Uncertainty					
Gross Beta	111	9310 SW	95-105	±30%	H & 9310 SW	1 L	PBC	1	HNO_3
Alpha(HDL)	112	9310 SW	80-120	±30%	H & 9310 SW	1 L	PBC	1	HNO_3
Radium	181	9315 SW	90-110	±30%	H	1 L	PBC	1	HNO_3

(a) Reference Method:

H = Determined based on historical laboratory information.
SW = EPA SW-846, Test Methods for Evaluating Solid Waste, 3rd ed.
A = Annual Book of ASTM Standards, Volume 11.01, 1986
A* = Annual Book of ASTM Standards, Volume 11.02, 1986
EPA = EPA 600/4-79-020, Methods for Chemical Analysis of Water and Wastes, 1983.

(b) Bottle Type:

G = glass
GA = amber glass
GC = clear glass
S = septum cap
P = plastic (polyethylene)
PWC = plastic, white cap (precleaned)
PBC = plastic, black cap (non precleaned)

7.0 SAMPLING PROCEDURES

7.1 Sample Containers and Preservation

Bottle type and preservative for each specific parameter analyzed are shown in Table 6.2. This information must be included in the PMP or GWMP for project-specific parameters not included in Table 6.2.

Precleaned sample containers must be used to collect ground-water samples that will be analyzed for hazardous chemical constituents. Coliform sample containers shall be sterile. Containers used for the collection of groundwater to be analyzed for radiochemical constituents do not have to be precleaned to EPA protocols by the manufacturer.

Certifications or chemical analytical reports attesting to the cleanliness of precleaned containers are required except for radiological and sterile (coliform) sample containers. This documentation must be received and found to be acceptable by the PNL Quality Control Group before container use. Pending receipt of this documentation and its acceptance, affected sample containers must be segregated to prevent inadvertent use. Certifications and chemical analytical reports received for precleaned containers must be maintained in Sample Preparation Task files.

A log of preservatives used must be maintained. The log, as a minimum, must identify the preservative, manufacturer, lot or batch number (if available), and date bottle was opened.

The purchase order number must be stamped on boxes containing precleaned sample containers upon initial receipt. Precleaned bottles must be kept in these stamped boxes until use unless each individual bottle is labeled with the lot or purchase order number.

See also Section 19.1.

7.2 Water-Level Measurement Before Sampling

Before purging wells, the static water level must be measured in accordance with PNL-MA-567 procedure **WL-1, Water-Level Measurement Procedure** (provided the well is not instrumented with an automatic water-level measurement device). For instrumented wells see WL-1.

7.3 Ground-Water Sample Collection

Ground-water samples shall be collected in accordance with PNL-MA-567 Procedure **GC-1, Ground-Water Sample Collection Procedure.** Ground-water samples requiring filtration, as indicated on the sample container label (see PNL-MA-567 procedure GC-1, Figure 1) shall be filtered during sampling in accordance with PNL-MA-567 Procedure **GC-2, In-Line Sample Filtration Procedure.**

7.4 Sediment Sample Collection During Drilling Operations

Sediment samples shall be collected in accordance with PNL-MA-567 Procedure **DO-1, Collection and Documentation of Borehole Samples and Well Construction Data** and/or PNL-MA-567 Procedure **DO-2, Split-Barrel Auger Sediment Sampling.**

7.5 Changes to the Monitoring Program

Planned changes to the sampling and analysis schedules must be verbally agreed upon by the PNL project manager and the Westinghouse Hanford Company (WHC) contact for the facility. The change must be documented, including as a minimum 1) the effective date of change and 2) the reason for the change, on Contact Memorandum forms. These forms shall be included in the monthly report. Justification for modifications to monitoring programs shall be documented.

The PNL Sample Analysis and Coordination Task Leader must be notified of changes in the ground-water monitoring program in accordance with PNL-MA-567 Procedure **AD-3, Modifications to Field Sampling Program.**

8.0 SAMPLE CUSTODY AND FIELD DOCUMENTATION

8.1 Water Sample Chain-of-Custody

The chain-of-custody of ground-water and quality control samples submitted for analysis shall be controlled in accordance with PNL-MA-567 Procedure **AD-2, Ground-Water Sample Chain-of-Custody Procedure.**

8.2 Sediment Sample Chain-of-Custody

The chain-of-custody of sediment samples submitted for radionuclide and hazardous constituent analysis shall be controlled in accordance with PNL-MA-567 Procedure **AD-4, Sediment Sample Chain-of-Custody Procedure.**

8.3 Field Record Form

A Field Record Form shall be completed for each well sampled for ground-water monitoring during each sampling event. This excludes predevelopment samples collected upon reaching the water table during drilling. The form to be used is shown in Figure 4 of PNL-MA-567 Procedure **AD-2, Ground-Water Sample Chain-of-Custody Procedure.**
The completed Field Record Form shall be reviewed by the Radiation Protection Technologist (RPT) Supervisor (or designee) for completeness, reasonableness, and reference to necessary maintenance. This review shall be documented by signature or initials of the reviewer and date of review on the bottom of the form.

8.4 Sample Pump Installation Documentation

Installation of sampling pumps in newly constructed monitoring wells shall be documented by the Well-Site Geologist in accordance with PNL-MA-567 Procedure **DO-3, Documentation of Sampling Pump Installation.**

8.5 Corrections to Documentation

If an error is made on any field or laboratory documentation, an individual may correct the error by drawing a line through the error and entering the correct information. The error shall not be obliterated. All non-editorial corrections shall be initialed and dated.

9.0 CALIBRATION PROCEDURES AND FREQUENCY

All measurement and test equipment (M&TE), for which PNL is responsible, must be controlled in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1201, Calibration Control System.**

Category 1 M&TE is calibrated by an approved metrology organization. All organizations providing Category 1 calibration services must be evaluated by the PNL Process Quality Department in accordance with PNL-MA-70 Quality Assurance Procedure **QAP-70-701, Preaward Evaluations/Surveys**, before being utilized.

Category 2 M&TE is calibrated by the user. Requirements for documenting user calibration of Category 2 M&TE are included in PNL-MA-70 Administrative Procedure **PAP-70-1201, Calibration Control System.**

Category 3 M&TE is not calibrated and is for indication only.

9.1 pH Meter Calibration

pH meters used by PNL field personnel must be calibrated daily before use in accordance with PNL-MA-567 Procedure FA-3, **Calibration of pH Meter and Measurement of Field pH.** The calibration must be documented on the pH Meter Calibration Record form. A calibration check must be performed as specified in FA-3 before taking pH measurements at each sampling site. If it is found during the check that the criteria specified in FA-3 aren't met, the pH meter shall be recalibrated before use.

9.2 Conductivity Meter Calibration

Conductivity meters used by PNL field personnel must be calibrated daily before use in accordance with PNL-MA-567 Procedure **FA-2, Calibration of Conductivity Meter and Measurement of Field Conductivity.** The calibration must be documented in the Conductivity Meter Calibration Record.

9.3 Digital Thermometer Calibration Check

A digital thermometer calibration check must be performed daily before using the thermometer by comparison to a Category 1 calibrated mercury thermometer as specified in PNL-MA-567 Procedure **FA-1, Temperature Measurement Procedure.** This calibration check must be documented in the Digital Thermometer Calibration Log.

9.4 Electrical Tapes Used to Estimate Water Level

Electrical tapes are used only for estimates of water level. They are classified as Calibration Category 3, For Indication Only. As such, calibration is not required.

9.5 Steel Tapes

Steel tapes used for water-level measurements must be standardized quarterly in accordance with PNL-MA-567 Procedure **WL-2, Procedure for Standardizing Steel Tapes**, against Category 1 standard steel tapes.

- Steel tapes deviating less than 0.10 foot from the Category 1 tape may be used for water-level measurements.
- Steel tapes deviating from the Category 1 tape more than 0.10 foot but less than 0.25 foot may not be used for water-level measurement but may be used for tagging during well construction.
- Steel tapes deviating from the Category 1 tape more than 0.25 foot may not be used for water-level measurement or tagging and are for indication only.

9.6 Flow Meters

Flow meters used in hydrologic testing activities are provided by Westinghouse Hanford Company (WHC) or Kaiser Engineers Hanford (KEH). WHC or KEH are responsible for calibration of the flow meters. It is the responsibility of the PNL staff using the flow meters to verify their calibration status and obtain documentation of calibration in the form of a calibration report before use.

9.7 Turbidimeters

Turbidimeters are classified as Category 2. They must be calibrated periodically by users in accordance with the manufacturer's instructions. This calibration must be documented on the Well Development Log form as specified in PNL-MA-567 Procedure **GC-7, Well Development**.

9.8 Pressure Transducers

Pressure transducers classified as Category 1 shall be calibrated by comparison to a nationally recognized standard by a calibration agency evaluated and approved by the PNL Process Quality Department, Quality Control Group, before calibration.

9.9 Geophysical Logging Probes

A calibration check on probes used in performing geophysical logging must be done by the user before use as specified in the PNL-MA-567 procedures governing the logging activities. A total system calibration shall be performed on natural gamma logging probes and associated instrumentation annually by a metrology organization evaluated and approved by the PNL QC Group. Calibration and calibration check activities must be referred to or provided on the log headers.

10.0 ANALYTICAL PROCEDURES

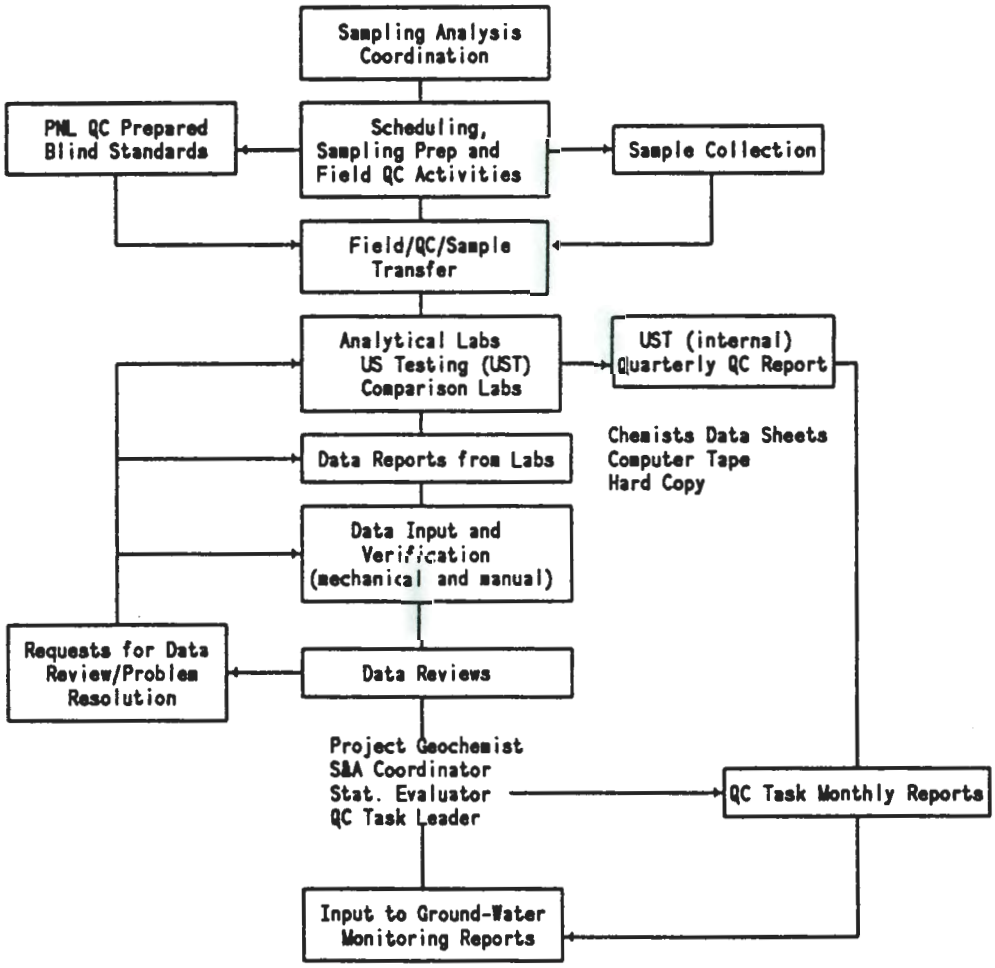
Potential chemical constituents to be analyzed for, as well as the corresponding standard analytical methods on which the primary analytical laboratory bases its procedures are shown in Table 6.2. The PMP or GWMP must identify which specific constituents will be analyzed. If there are project-specific constituents that aren't included in Table 6.2, they must be identified in the PMP or GWMP and the associated Procedure(s) referenced cited.

Unless specified in the project specific PMP or GWMP, detection-level terms shall be defined and calculated as in EPA SW-846, Test Methods for Evaluating Solid Waste, latest edition (or applicable standard method being used if different from SW-846).

11.0 DATA REDUCTION, VALIDATION, AND REPORTING

Exhibit 11.1 presents the data reduction, validation, review, and reporting process in flow-chart format. The following sections briefly describe the data reduction, validation, and reporting Procedures that shall be used. Also, some specific data validation methods are described in Section 12 as part of the required internal QC.

EXHIBIT 11.1. Data Flow Scheme



11.1 Data Management Procedures

Analytical results must be managed in accordance with PNL-MA-567 Procedure **DM-1, Analytical Data Handling and Verification Procedure.** Water-level data must be managed in accordance with PNL-MA-567 Procedure **DM-2, Water Level Data Handling and Verification Procedure.** These Procedures specify the methods for entry of data into the Hanford Ground-Water Data Base (HGWDB), including verification and validation of the data.

11.2 Process for Handling Suspect or Unacceptable Data

When the initial data review identifies suspect data, that data must be investigated to establish whether it reflects true conditions or an error. The investigation must be documented using a Request for Data Review (RDR) (Exhibit 11.2). The Sample Analysis and Coordination Task Leader shall issue RDR numbers and maintain a log of all RDRs generated identifying their status (i.e., date issued, and date closed). If the data value is determined to be in error, the source of the error must be investigated, the correct value established if possible, and the erroneous value replaced with the correct value. If the investigation concludes that the data are suspect (possibly in error) but a correct value cannot be determined, the data must be flagged to indicate its suspect status.

If the source of the error was noncompliance with an established requirement or Procedure, a Deficiency Report (DR) must be generated in accordance with PNL-MA-70 Administrative Procedure PAP-70-1502, **Controlling Deviations from QA Requirements and Established Procedures.** If the source of error was due to the nonconformance of an item, then a Nonconformance Report (NCR) must be generated in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1501, Nonconformance Reports.** As a minimum, the Project Manager, Program Manager, Sample Analysis and Coordination Task Leader, and the Quality Engineer must be copied on the data investigation documentation (RDR).

11.3 Standard Units

The standard units used to report data are

• water chemistry parameters (nonrad)	ppb
• radium, gross alpha, and gross beta	pCi/L
• turbidity	NTU (a)
• coliform bacteria (b)	MPN(c)/100 mL or Number/100 mL
• pH	pH units
• specific conductivity	μmho/cm
• elevation	ft above mean sea level
• temperature	°C

(a) NTU = nephelometric turbidity unit (b) Units dependent on method used.
(c) MPN = most probable number.

Exhibit 11.2, Request for Data Review (RDR) Form

REQUEST FOR DATA REVIEW

RDR Tracking Number: _____
YYMMDD-sequent (assigned by Sample Analysis Task Leader)

Originator: _____ Date Submitted: _____

Data to be reviewed

Reason for review
(attach any documentation)

Project: _____

UST Number: _____

Well Name or Code: _____

Collection Date: _____

Report Date: _____

Duplicate Sample Number: _____

Constituent: _____

Present Value: _____

Data Review Results

Reviewer: _____ Date Completed: _____

__ Non-Conforming Data (UST or PNL NCD form or attached)

__ No change, review has found no problems (documentation attached)

__ No change, problems could not be documented, but data should be flagged as questionable (documentation attached)

Database Update Verification

Updated by: _____ Date Completed: _____

__ Data was changed in database, RDR tracking number added to database

__ Data was not changed, RDR tracking number added to database

__ Data was not changed, RDR tracking number added to database, Data flagged as questionable and brief comment added to database

Return completed copy to originator, Project Manager, and others

12.0 INTERNAL QUALITY CONTROL CHECKS

A summary of PNL QC checks is presented in TABLE 12.1 below. Additionally, the primary analytical laboratory has instituted an internal laboratory QC program that is implemented through the laboratory's analytical Procedures.

TABLE 12.1. Summary of Quality Control Checks

Data Characteristic Evaluated	Sample Type	Frequency
Field/Transport Contamination	Field Blank	1 per 20 samples or per sample event
Field/Transfer Contamination	Field Blank	1 per 20 samples or per sample event
Laboratory Contamination	Lab Blank	1 per batch or per sample event
Laboratory Accuracy	Blind Standards	See Table 12.2
Precision (field variability)	Field Duplicates	1 per 20 samples or per sample event
Precision (lab variability)	Lab Replicates	1 per batch
Container Contamination	Empty Container	1 per lot

12.1 Interlaboratory Comparisons

Interlaboratory comparisons between PNL and the primary analytical laboratory will be approximately 1 per 20 field samples (with duplicate).

Interlaboratory blind standard comparisons will also be performed. These comparisons are discussed further in Section 12.2.

12.2 Blind Standards

The frequency at which blind standards are submitted to the primary analytical laboratory depends on 1) constituents that are detected at or above drinking water standard (DWS) or screening levels, 2) constituents that are detected, but at levels below DWS or screening levels, and 3) constituents that may be present, based on disposal records, but have not been detected. The frequency of testing for the constituent and the complexity of the analysis method are also considered. Table 12.2 shows the types of blind standard analyses performed and the frequency.

12.3 Acceptable Limits/Results Requiring Action

The acceptance limit for blind standards is ±2 standard deviations (s.d.). In interlaboratory comparisons using actual field samples, difference between laboratory results of 2.8 s.d is allowed. This criterion is based on the reproducibility limit, with 95% confidence that random error is not responsible for the difference.

When results of blind standards, or interlaboratory comparisons fall outside the acceptance limits specified above, the cause must be investigated in accordance with Section 11.2. Additional samples may be directed to the laboratory to determine or check the adequacy of corrective action. See also Section 11.2.

12.4 Reporting

The Quality Control Task Leader will provide the Project Manager with a monthly report of results including all above elements.

TABLE 12.2. Blind Standards

Analyses	Approx. Frequency
Volatile Organic Constit.	Monthly
Metals	Quarterly
As, Se, Pb	Quarterly
Hg	Quarterly
Anions	Quarterly
Ammonium	Semiannually
Cyanide	Quarterly
Sulfide	Annually
Thallium	Annually
ABN enh	Quarterly
Thiourea enh	Semiannually
Pesticides (enhanced)	Semiannually
Herbicides (enhanced)	Semiannually
Phosphorus Pesticides	Semiannually
Ethylene Glycol	Semiannually

13.0 PERFORMANCE AND SYSTEM AUDITS

Compliance, real-time, and data traceability surveillances are performed by the cognizant Quality Engineer. Compliance surveillances are performed to ensure that a specific requirement, or set of requirements, is being implemented. Real-time surveillances are performed during the work or analytical process to ensure that specific standardized Procedures are being implemented. Data traceability surveillances are performed to ensure that the resultant project data are traceable back through the analytical process, through sample handling and transportation, back to the date, time, location, staff, and technique used to collect the sample. Surveillances are performed in accordance with PNL-MA-70 Quality Assurance Procedure **QAP-70-1001, Planning and Performing Surveillance.** Quarterly surveillance plans will be developed identifying the requirements of this QA project plan and supporting project planning documents and specifications to be verified.

System audits, or simply audits, are performed by the PNL Quality Verification Department on a periodic basis. Audits are planned and performed in accordance with PNL-MA-70 Quality Assurance Procedure **QAP-70-1801, Internal Audits.** Quality assurance audit personnel are qualified in accordance with PNL-MA-70 Quality Assurance Procedure **QAP-70-204, QA Audit Personnel Qualification.**

Performance audits, checks on the performance of the analytical system, are in the form of check/audit samples prepared by the QC Task Leader and are submitted to the primary analytical laboratory. Periodic source surveillances and audits are also performed on the contracted primary analytical laboratory in accordance with PNL-MA-70 Procedures **PAP-70-704, Source Inspections, Tests, and Surveillances,** and **QAP-70-704, Supplier and Other Hanford Contractor Audits.**

The results of surveillances and audits will be made available to project and line management as well as to individuals contacted.

14.0 PREVENTIVE MAINTENANCE

Routine equipment and facility maintenance and instrument services ensure the timely and effective completion of a measurement effort.

14.1 Well Maintenance

Well maintenance needs must be documented in a memo to the Environmental Field Services Group of the Westinghouse Hanford Company (WHC) Environmental Engineering and Technology Function (Environmental Division). Upon completion of repairs, the PNL Sample Analysis and Coordination Task Leader will be notified by WHC that the repairs have been completed. Sample collection teams should not be sent to wells identified for maintenance until this notification has been received.

14.2 Spares Needed During Ground-water Sampling

Spares necessary during regular ground-water sampling are identified in the "Equipment" section of the specific PNL-MA-567 technical Procedure when such spares are necessary.

14.3 Field Equipment Maintenance

Field equipment maintenance (limited primarily to calibration and calibration check activities) is the responsibility of the Radiation Protection Technologist Supervisor.

15.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, AND COMPLETENESS

Because of the nature of environmental measurements, it is difficult or impossible to know the "true" value of the measured parameter. The accuracy of the measured value must instead be inferred through the use of QC samples of known composition. PNL uses this method to verify that the data quality objectives (DQOs) established in Tables 6.1 and 6.2 have been met.

The water quality DQOs specified in Table 6.2 are stated in the terms used by the primary analytical laboratory to report its internal QC analyses on a quarterly basis. The performance charts supplied by the laboratory must be visually reviewed quarterly by comparison to the DQOs specified in Table 6.2. The results of the review must be documented in the QC Task Leader's monthly report. Laboratory results falling outside any DQO boundary must be investigated (see Section 11.2).

Completeness will be calculated on a quarterly basis by the Sample Analysis Coordination Task Leader, with Project Statistician input, using the following formula.

$$\text{Completeness, \%} = \frac{\text{Number of Valid Data Points Acquired}}{\text{Total Number of Values Planned}} \times 100$$

The result should be compared against the completeness DQO established in Table 6.1, and reported in the quarterly report. Any discrepancies must be investigated (see Section 11.2).

16.0 CORRECTIVE ACTION

Corrective action must be initiated by the Project Manager or cognizant Task Leader when unplanned deviations from procedural, contractual, regulatory requirements, or construction specifications occur. The need for corrective action may be revealed by observations of measurement system response, during data reasonableness checks (brief comparison of newly collected data against observed historical trends), when discrepancies are noted during instrument calibration, or during data analysis.

16.1 Measuring and Test Equipment (M&TE) Calibration Discrepancies

Instruments or equipment found to be operating outside acceptable operating ranges (as specified in the applicable technical procedure or manufacturer's instructions) must be investigated. A Calibration Discrepancy must be initiated in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1201, Calibration Control System**, when it is determined that M&TE is not within calibration and that data have been collected after the calibration expired.

16.2 Deviations from Procedures or Requirements

Unplanned deviations from procedural, contractual, or regulatory requirements must be documented by completing a Deficiency Report (DR) in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1502, Controlling Deviations from QA Requirements and Established Procedures**. The DR must identify the requirement deviated from, the cause of the deviation, whether any results were effected, and corrective action needed to remedy the immediate problem and to prevent recurrence.

A copy of the DR must be transmitted to the client through the Program Office Manager within 10 days of when the deficiency was identified.

Planned deviations, documented (including justification) and approved by the Project Manager or Task Leader in advance, do not constitute a deficiency as defined in PAP-70-1502 and do not require development of a DR.

16.3 Corrective Action for Significant Conditions Adverse to Quality

When significant conditions adverse to quality are identified, the cause of the conditions and the corrective action taken to preclude repetition will be documented and reported to immediate management for review and assessment by a Corrective Action Request (CAR) in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1602, Corrective Action**. "Significant" conditions are identified in Section 4.2.1.1 of PAP-70-1602.

17.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

Significant QA aspects of project activities must be regularly reported in monthly RCRA Ground-Water Monitoring and Characterization Activities status reports. Deviations from this QA project plan, as well as the results of surveillances and audits, must be documented and described in the reports. Quality-assurance-related information in the reports must be reviewed by the cognizant PNL Quality Engineer.

Significant problems uncovered by project personnel must be reported to line management immediately for resolution. Significant problems involving data quality, sample integrity, or well construction must be thoroughly documented.

Line management must be included on the distribution of all audit reports. Significant problems encountered in day-to-day operations must be reported to line management immediately by the Project Manager.

18.0 RECORDS

18.1 Records Control

Project records must be controlled in accordance with PNL-MA-70 Administrative Procedure **PAP-70-1701, Records System.** A Records Inventory and Disposition Schedule (RIDS) must be prepared and submitted for review and approval by the Records Specialist and Quality Engineer. Records retention schedules shall be based on DOE Order 1324.2A, Records Disposition, and applicable regulatory requirements.

18.2 Records Checkout

When records identified on the RIDS are removed from their specified location, a check-out card identifying who removed the document, the document's title or identification, and when the document was removed, must be placed in the file from which the document was removed. Upon the return of the document the check-out card is removed and the borrower's name lined through.

18.3 Turnover of Records To WHC

All PNL generated record copy, quality affecting documents shall be transmitted to WHC at the frequency specified in the governing statement of work utilizing the process described below. These activities must be coordinated through the PNL Records Specialist.

18.3.1 Technical Review

- The Project Manager must assure that documents are reviewed for technical adequacy, accuracy, and completeness to verify that the documents support fitness for use of the facility (well) and conformance to specifications and procedures.

- Any problems or deficiencies noted in the records must be properly resolved and documented in accordance with PNL's deficiency/nonconformance system (see Section 22).

Following this review, the Project Manager should make 2 photocopies of the documents intended to be transferred to WHC. The record copy and 1 photocopy of the documents along with the appropriate RIDS shall be sent to the PNL Records Specialist who will be responsible for performing the remaining actions described in Sections 18.3.2 through 18.3.4 below.

18.3.2 Administrative Review

- Review documents to assure they are paginated and complete.
- Assure that documents are authenticated by personnel authorized to authenticate records. An authentication list shall be maintained identifying the signatures and initials of personnel authorized to authenticate records.
- Verify that the documents are legible, identifiable to a task or activity, and reproducible and microfilmable.

18.3.3 Objective Evidence of Reviews

Objective evidence of the reviews described in Sections 18.3.2 shall be provided. The review must be documented by placing a mark on the top sheet of each multipage record in a location that will not obliterate the data, thus signifying that the review is complete and is ready for further processing.

18.3.4 Transmittal of Document Copies to WHC

Provide the record copy and 1 photocopy of the documents to WHC. Transmit the record copy to the WHC Environmental Data Management Center (EDMC) on an EDMC Item Transmittal (Exhibit 18.1). Transmit the photocopy to the WHC Geosciences Group for use as a working copy.

18.4 Revision of RIDS

Following transfer of the records to permanent storage the RIDS shall be revised to reflect the location of the stored records and a retention time of Lifetime, to satisfy NQA-1, plus 10 Years after termination of the Hanford Federal Facility Agreement and Consent Order, to satisfy the Tri-Party Agreement.

EXHIBIT 18.1, WHC EDMC Item Transmittal Form

Transmittal No. (1)

ENVIRONMENTAL DATA MANAGEMENT CENTER
ITEM TRANSMITTAL

Date Submitted (2)

TO: Westinghouse Hanford Company
EDMC 114-51
P.O. Box 1970
Richland, WA 99352

PREPARED BY: NAME: (3)
ADDRESS: (4) MSIN:
CITY/STATE: PHONE: (5)
ORG. CODE NUMBER: (6) AREA: (7)

TO BE COMPLETED BY SENDER

ITEM	DATE	DOC. NO.	TITLE/DESCRIPTION	OU	TSD
(8)	(9)	(10)	(11)	(12)	(13)

EDMC USE ONLY

KEYWORD	DIC. NO.	FN
(14)	(15)	(16)

COMMENTS/REMARKS: (17)

The signature below certifies that the documents submitted by this transmittal have been reviewed and are complete.
SIGNATURE (18) DATE

PROCESSED BY: (19) DATE:

EXHIBIT 18.1 (continued), Instructions for Completing EDMC Item Transmittal

TRANSMITTAL INSTRUCTIONS

1. TRANSMITTAL NUMBER - Pre-numbered transmittal form.

2. DATE SUBMITTED - Date transmitted to EDMC.

3. NAME - Printed or typed name of person preparing transmittal.

4. ADDRESS - Correct mailing address of preparer (Includes area and Mail Stop Identification Number (MSIN).

5. PHONE NUMBER - Number where the preparer can be reached during the day.

   NOTE: If a box is not applicable to the item being submitted, then the box should be marked N/A.

6. ORGANIZATION CODE NUMBER - Number of the originating organization if applicable.

7. WORK AREA - Hanford Site Area.

8. ITEM NUMBER - Sequential number of each item being transmitted.

9. DOCUMENT COMPLETION DATE - The final completion date of the document.

10. DOCUMENT NUMBER - Document identifying number.

11. TITLE/DESCRIPTION - Correct title or description of the documenting being submitted.

    NOTE: This field is used for data entry. The more concise the title/description, the better the retrievability of computerized search.

12. OU - The Operable Unit that the document pertains to. If the document applies to all or a portion of the OU's indicate "ALL" in this column. (Refer to Appendices B and C of the Action Plan for Applicable OU's.

13. TSD - The treatment, storage and disposal group that the document pertains to. If the document applies to all or a portion of the TSD's indicate "ALL" in this column. (Refer to Appendices B and C of the Action Plan for applicable TSD numbers.)

14. KEYWORD - To be completed by EDMC. Keyword assignments for retrievability.

15. DIC NUMBER - To be completed by EDMC. Document identification code assignments for retrievability.

EXHIBIT 18.1 (continued), Instructions for Completing EDMC Item Transmittal

16. FILE NUMBER - To be completed by EDMC. EDMC file number assignment for retrievability.

17. COMMENTS/REMARKS - To be used by preparer to show references or any additional information that might be useful. (This box may be used by Project/Unit Managers to identify Administrative Records.)

18. SIGNATURE AND DATE - Certification that submitted documents have been reviewed for compliance with appropriate procedures and requirements.

19. PROCESSED BY - To be completed by EDMC. EDMC personnel signature and data closing out processing of the item.

APPENDIX 9

EXPOSURE INFORMATION REPORT

APPENDIX 9

EXPOSURE INFORMATION REPORT

9A Overview of the Hanford Site Grout Performance Assessment

9B Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste From N Reactor Operations

9C Land Use and Zoning Map

9011178618 20

APPENDIX 9A

OVERVIEW OF THE HANFORD SITE GROUT PERFORMANCE ASSESSMENT

This page intentionally left blank.

APPENDIX 9A

OVERVIEW OF THE HANFORD SITE GROUT PERFORMANCE ASSESSMENT

1.0 INTRODUCTION

The grout disposal program is a comprehensive program to develop the technology and facilities required for the disposal of dangerous liquid wastes at the Hanford Site. Long-term protection of the public and the environment is a principal goal of the grout disposal program. The disposal system (in this document the disposal system is defined as the waste form, the concrete vault, the gravel-diffusion barrier, and the protective barrier) has been designed such that projected releases will meet the U.S. Environmental Protection Agency (EPA) *National Primary Drinking Water Regulations* (EPA 1988a) in a downgradient compliance well. To determine whether projected performance of the disposal system will be within applicable regulations, a performance assessment is conducted. The performance assessment models expected system performance and projects the impact of the disposal initiative. The impacts can then be compared to regulations to determine whether the projected performance of the disposal system lies within regulatory limits. The following sections discuss the key elements in the performance assessment and provide preliminary projected exposure levels for dangerous chemicals.

2.0 RELEASE RATE

Dangerous chemicals can be released from the grout disposal system via two pathways: through a leak in the vault and catch basin before the curing of the grout or through molecular diffusion through the grout, concrete vault, and gravel-diffusion barrier. The design of the grout disposal system precludes the escape of quantities of liquid that would result in exceeding drinking water standards at a downgradient compliance well. The major release mechanism is molecular diffusion through the grout, concrete vault, and gravel-diffusion barrier. The balance of this section discusses the release mechanisms and rates of dangerous constituents from the grout disposal system.

2.1 RELEASE RATE FROM THE GROUT

The effective diffusivity of dangerous chemicals in the grout is determined by the American Nuclear Society leachability procedure (ANS 1986). The procedure calls for immersing a cylindrical sample of the waste form in a volume of leachate (deionized water and local groundwater have been used)

equal to 10 times the surface area of the sample. The sample is removed at specified time intervals, and the leachate is analyzed for dangerous chemicals of interest. A knowledge of the starting inventory of dangerous chemicals in the sample and the amount in the leachate at each interval provides the information required to determine the effective diffusivity of the dangerous chemicals of interest. Table 1 provides effective diffusivities of dangerous chemicals as measured in actual waste (also see Chapter 3.0, Appendix 3D). The criterion set by the grout disposal program for acceptability relative to leaching is that dangerous chemicals must have an effective diffusivity of less than 1×10^{-7} cm^2/s. For many chemicals, however, effective diffusivities have been measured in the range of 10^{-9} cm^2/s.

Table 1. Effective Diffusivities for Selected Hazardous Chemicals in Tank 106-AN Waste.

Hazardous chemical	Effective diffusivity (cm^2/s)
Nitrate	4.6×10^{-9}
Nitrite	5.8×10^{-9}
Chloride	8.9×10^{-9}
Fluoride	4.1×10^{-9}
Sodium	5.7×10^{-9}
Molybdenum	$<3 \times 10^{-9}$
Nickel	$<5 \times 10^{-10}$
Chromium	$<1 \times 10^{-12}$

Some of the species in the grout form precipitate in the pore liquid or in the groundwater. These species are identified as being solubility limited in their release. The relative amount of such contaminants that could be found in the groundwater is limited because of the solubility control mechanism.

2.2 RELEASE RATE THROUGH THE CONCRETE VAULT

The release rate of contaminants through the concrete vault is not a critical parameter in the modeling of the disposal system because the diffusivity of contaminants through the concrete is expected to be greater than that through the grout. Effective diffusivities have been measured at another U.S. Department of Energy facility (Savannah River Plant) and a value of 5×10^{-8} cm^2/s has been measured (Wilhite 1987). This value has been used in the evaluations to date, although the actual value has been shown to not be of significance in long-term release modeling.

2.3 RELEASE RATE THROUGH THE GRAVEL-DIFFUSION BARRIER

The asphalt-coated gravel- (gravel-) diffusion barrier is a minimum 3 ft of crushed, graded and asphalt-coated gravel sized between 0.2 and 2.54 cm. It is designed to minimize fines infiltration during and after construction. The gravel-diffusion barrier also has been designed to reduce the rate at which contaminants will diffuse out of the disposal system and minimize the infiltration of water into the disposal system by serving as a capillary break. Contaminants in the disposal system only diffuse through the connected water path within the grout, vault, and gravel. The gravel selected has both a low internal and a low external moisture content, providing a tortuous path length for any contaminants that diffuse out of the grout and vault. The gravel also serves as a capillary (hydraulic) break to keep external moisture from infiltrating the disposal system as long as the adjacent soils remain unsaturated. Given the low precipitation (Stone et al. 1983) at the Hanford Site and the low permeability and wicking layers that will be placed over the gravel-diffusion barrier, the soil is projected to remain unsaturated. This occurrence has been supported by modeling.

The effective diffusivity of gravel was determined through the use of an electrical conductivity technique. The method is well established as a technique for measuring the diffusivity of ionic species in soils at a given moisture content. The plan developed involved fixing the moisture content of the gravel at the expected level (based on analysis of Hanford Site soils by computer modeling, the moisture content is expected to range from 0.8% to 2%) and then determining the diffusivity through electrical conductivity of the sample. Moisture content was varied to determine a range of effective diffusivities. The effective diffusivity used for the gravel selected is 1×10^{-10} cm^2/s. This value will be revised as additional information is obtained on the sensitivity as a function of moisture content, fines content, and temperature.

3.0 TRANSPORT THROUGH THE SOIL PATHWAY AND GROUNDWATER

Once the dangerous chemicals have diffused through the disposal system, they are transported through the soil pathway to the unconfined aquifer. Transport through the soil will be by a combination of two mechanisms: diffusion through soil moisture and transport by advecting water. These processes are modeled in flow and transport models of the soil pathway. The TRACR3D computer code (Travis 1984) is used to model the flow, and the S301 computer code (Wikramaratna and Farmer 1987) is used to model the transport of dangerous chemicals from the grout disposal site to the groundwater. Inputs to these models are the release rates through the disposal system, characterization of soils at the grout disposal site, diffusivities of contaminants in the grout site soils, and a knowledge of the expected climatic conditions, which determines the amount of advecting water available for moving dangerous chemicals through the soil.

The soils characterization information required for the flow and transport models includes soil gradation, moisture content, moisture characteristic curve, density, and unsaturated hydraulic conductivity. This information is required as a function of depth from the grout disposal system to the aquifer. Soil cores have been taken within the grout site and have been analyzed for the required information (see Chapter 5.0, Appendix 5A).

Studies have shown that some of the contaminants in the grout will sorb to Hanford Site soils. The sorption process tends to retard the movement of contaminants through the soil, resulting in a longer travel time to the groundwater and less potential exposure to the population. Sorption is not assumed for any of the dangerous chemicals in the grout. In addition, no sorption is assumed for highly mobile radioactive species such as ^{99}Tc and ^{129}I.

As mentioned previously, some of the species within the grout are limited in concentration in the groundwater because of solubility. Dangerous chemicals exhibiting this characteristic include barium, cadmium, copper, lead, manganese, and zinc. A more detailed description of the controlling reactions for solubility can be found in Serne et al. (1987).

Prediction of the actual amount of precipitation that will fall at the Hanford Site can be estimated by evaluating prior climatic cycles (Stone et al. 1983) and projecting the trends forward. The current average rainfall at the Hanford Site is 16 cm/yr. Evapotranspiration, run-off, evaporation, and other processes limit the amount of precipitation available for transporting hazardous chemicals to the groundwater to 0.5 cm/yr of recharge water. In addition, a hypothetically wetter climate has been evaluated where 30 cm/yr of precipitation occurs, and the recharge to the groundwater is 5.0 cm/yr. The addition of a protective barrier over the waste form will further reduce the precipitation available as recharge water to 0.05 cm/yr. The ability of the protective barrier to reduce recharge water is discussed in Section 4.0.

4.0 DESCRIPTION OF THE PROTECTIVE BARRIER

The protective barrier scheduled for construction over the grout disposal site is the same barrier described in DOE (1987). The barrier is designed to minimize the infiltration of water to the waste form and to minimize the occurrence of plant, animal, and human intrusion into the waste form. Water infiltration is minimized through uptake of water by plants and selection of a soil that holds sufficient quantities of precipitation before drainage. Intrusion into the waste form is minimized by the use of a gravel/riprap layer and a marker system. Similar to the gravel-diffusion barrier, the riprap layer also serves as a capillary break. Water will not drain out of the fine soils layer until the interface between the fine soils and the riprap becomes saturated. The interface between the fine soils and the riprap is graded such that fine soils will not infiltrate the riprap layer and diminish its performance as a capillary break.

A plan has been developed (Adams and Wing 1987) to address the steps required to defend the performance of the Hanford Site protective barrier. Natural analogues have been used to defend its operation for long time periods (up to 10,000 yr). Lysimeters are being used to finalize the design of the protective barrier (fine soil selection, riprap size distribution, fine soil and riprap layer thicknesses, plant selection, etc.). The results of the lysimeter evaluations will be used to calibrate and verify model predictions of barrier performance (Fayer 1987) and to serve as the required validation of the performance of the protective barrier.

5.0 RESULTS OF PERFORMANCE ASSESSMENT

Each of the various features in the disposal system was selected based on the 'isolation credit' relative to reduction in the peak concentration of contaminants observed in a hypothetical downgradient water well. In each case, the relative reduction is compared to the option of disposing of the grout monolith in bare soil. (The grout monolith provides a reduction of 100 to 1,000 p/b in the peak concentration relative to disposal of the waste directly to the soil). The reinforced concrete vault provides a reduction of 2 p/b in the peak concentration. The protective barrier provides a reduction of 20 p/b in the peak concentration. The gravel diffusion barrier provides a reduction of 1,000 p/b in the peak concentration. The combination of a protective barrier and a gravel diffusion provides a reduction of 2,000 p/b in the peak concentration.

Table 2 provides the projected maximum increases in hazardous chemicals in the drinking water and compares the results to EPA (1988a, 1988b). The projected maximum increases are all below the drinking water standards. The release of contaminants from the disposal system is minimized by the presence of the gravel-diffusion barrier. The Hanford Site protective barrier serves to decrease the amount of recharge available for carrying contaminants to the unconfined aquifer, which increases the resultant travel time to the groundwater. The peak concentrations of ^{99}Tc and ^{129}I in the groundwater also are below drinking water standards.

Table 2. Projected Maximum Increases in Contaminant Levels for Hazardous Chemicals.

Chemical constituent	Drinking water standard (p/b)	Fraction of standard
Arsenic	50	0.06
Barium	1,000	0.0002[a]
Cadmium	10	0.004[a]
Chloride	250,000[b]	0.00004
Chromium	50	0.02
Copper	1,000[b]	0.00008[a]
Fluoride	4,000	0.001
Iron	300[b]	0.02
Lead	50	0.002[a]
Manganese	50[b]	0.0001[a]
Mercury	2	0.00004
Nitrate	45,000	0.006
Nitrite	33,000	0.004
Selenium	10	0.02
Silver	50	0.0004
Sulfate	250,000[b]	0.00016
Zinc	5,000[b]	0.000014[a]

[a]Solubility limited.
[b]Secondary drinking water standards.

6.0 REFERENCES

Adams, M. R. and N. R. Wing, 1987, *Protective Barrier and Warning Marker System Development Plan*, RHO-RE-PL-35 P, Rockwell Hanford Operations, Richland, Washington.

ANS, 1986, *Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure*, ANS 16.1, American Nuclear Society, La Grange Park, Illinois.

DOE, 1987, *Final Environmental Impact Statement-Disposal of Hanford Defense High-Level, Transuranic and Tank Waste, Hanford Site, Richland, Washington*, DOE/EIS-0113, 5 vol., U.S. Department of Energy, Washington, D.C.

EPA, 1988a, *National Primary Drinking Water Regulations*, Title 40, Code of Federal Regulations, Part 141, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, *National Secondary Drinking Water Standards*, Title 40, Code of Federal Regulations, Part 143, U.S. Environmental Protection Agency, Washington, D.C.

Fayer, M. J., 1987, *Model Assessment of Protective Barrier Designs: Part II*, PNL-6297, Pacific Northwest Laboratory, Richland, Washington.

Serne, R. J., W. J. Martin, S. B. McLaurine, S. P. Airhart, V. L. LeGore, and R. L. Treat, 1987, *Laboratory Leach Tests of Phosphate/Sulfate Waste Grout and Leachate Adsorption Tests Using Hanford Sediment*, PNL-6019, Pacific Northwest Laboratory, Richland, Washington.

Stone, W. A., J. M. Thorp, O. P. Gifford, and D. J. Hoitink, 1983, *Climatological Summary for the Hanford Area*, PNL-4622, Pacific Northwest Laboratory, Richland, Washington.

Travis, B. J., 1984, *TRACR3D: A Model of Flow and Transport in Porous/Fractured Media*, LA-9667-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Wikramaratna, R. S. and C. L. Farmer, 1987, *The S301 High Resolution Miscible Displacement Simulator 2-D Version With User Specified Velocities*, S302-2/1, Winfrith Atomic Energy Establishment, Dorset, England.

Wilhite, E. L., 1987, "Concept Development for Saltstone and Low Level Waste Disposal," *Waste Management '87*, Tucson, Arizona, March 1-5, 1987.

This page intentionally left blank.

9 0 1 1 7 8 5 1 8 3 0

APPENDIX 9B

LONG-TERM PERFORMANCE ASSESSMENT OF GROUTED PHOSPHATE/ SULFATE WASTE FROM N REACTOR OPERATIONS

APPENDIX 9B

LONG-TERM PERFORMANCE ASSESSMENT OF GROUTED PHOSPHATE/ SULFATE WASTE FROM N REACTOR OPERATIONS

NOTE: Since the performance assessment for this waste stream was prepared, design modifications to the disposal system have been evaluated and are being implemented. The design shown in this document is only applicable to the nondangerous wastes currently being disposed of. This document provides background information for the preparation of a performance assessment. The performance assessment for double-shell tank waste will be prepared in a similar fashion.

This appendix (Stewart, G. H., W. T. Farris, D. G. Huizenga, A. H. McMakin, G. P. Streile, and R. L. Treat, 1987, *Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste from N Reactor Operations*, PNL-6152, Pacific Northwest Laboratory, Richland, Washington) contains 106 pages.

9011178613832

Hanford Grout Technology Program

Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste From N Reactor Operations

G. H. Sewart
W. T. Farris
D. G. Huizenga
A. H. McMakin
G. P. Streile
R. L. Treat

April 1987

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

PNL-6152

9 0 1 1 7 8 6 1 8 3 4

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government of any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or Battelle Memorial Institute.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

LONG-TERM PERFORMANCE ASSESSMENT OF GROUTED PHOSPHATE/SULFATE WASTE FROM N REACTOR OPERATIONS

G. H. Sewart
W. T. Farris
D. G. Huizenga
A. H. McMakin
G. P. Streile
R. L. Treat

April 1987

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

ABSTRACT

The long-term performance of the grout disposal system for Phosphate/Sulfate Waste (PSW) was analyzed. PSW is a low-level liquid generated by activities associated with N Reactor operations. The waste will be mixed with dry solids and permanently disposed of as a cementitious grout in sub-surface concrete vaults at Hanford's 200-East Area. Two categories of scenarios were analyzed that could cause humans to be exposed to radionuclides and chemicals from the grouted waste: contaminated groundwater and direct intrusion. In the groundwater scenario, contaminants are released from the buried grout monoliths, then eventually transported via the groundwater to the Columbia River. As modeled, the contaminants are assumed to leach out of the monoliths at a constant rate over a 10,000-year period. The other category of exposure involves intruders who inadvertently contact the waste directly, either by drilling, excavating, or gardening.

Long-term impacts that could result from disposal of PSW grout were expressed in terms of incremental increases of 1) chemical concentrations in the groundwater and surface waters, and 2) radiation doses. None of the calculated impacts exceeded the corresponding regulatory limits set by Washington State, the Department of Energy, or the Nuclear Regulatory Commission.

SUMMARY

The long-term performance of the grout disposal system for Phosphate/Sulfate Waste (PSW) was analyzed. This report documents the performance assessment, which served as input to the Environmental Assessment for the Grouting and Near-Surface Disposal of Low-Level Radioactive Phosphate/Sulfate Waste from N Reactor Operations (U.S. DOE 1986a). The long-term performance of the PSW grout disposal system was evaluated in terms of 1) potential incremental increases of regulated *chemicals* in groundwater and in the Columbia River, and 2) potential incremental *radiation doses* to a person who either intrudes directly into a grout monolith or uses groundwater contaminated by long-term release of PSW radionuclides.

PSW GROUT DISPOSAL SYSTEM

The Phosphate/Sulfate Waste discussed in this report is a low-level radioactive waste generated by activities associated with operation of the N Reactor on the Hanford Site near Richland, Washington. Contaminants in the waste include radionuclides, and nonradioactive chemicals that are regulated by federal and state drinking water standards. The waste will be mixed with grout-forming materials (cement, fly ash, and clays) and then pumped as a slurry into sub-surface concrete vaults on the Hanford Site for hardening and permanent disposal.

The PSW grout disposal site is located in the 200-East area of the Hanford Site. The currently projected volume of PSW will require the use of approximately 12 rectangular vaults made of reinforced concrete. Each vault will be 10.4 m deep, 15.24 m wide, 38.1 m long, and lined on the inside with high-density polyethylene. Each vault will be covered with concrete cover blocks and soil backfill, then filled with radioactive grout up to about 90% of the vault's volume. The remaining 10% of each vault will be filled up to the concrete cover with nonradioactive grout. Finally, an overburden of soil and rock will be placed over the vaults.

MODEL OF GROUT DISPOSAL SYSTEM AND APPROACH OF PERFORMANCE ASSESSMENT

In this performance assessment, we used environmental pathway models to project transport of contaminants from the disposed waste form to points of human access. The transport may be the result of natural release mechanisms (e.g., diffusion) or a consequence of inadvertent disruptive intrusion.

Over very long periods of time (hundreds or thousands of years), the vault and liners are expected to degrade and allow some degree of contaminant migration into the soil layers around and below the vault (vadose zone). Water percolating down through the vadose zone could carry contaminants down to the groundwater and subsequently to uncontrolled areas such as the Columbia River, where humans could be exposed to the contaminants. In addition, because institutional control of the Hanford Site cannot be ensured indefinitely, an inadvertent intruder could conceivably move onto the grout disposal site and be exposed to the grout contaminants by drilling, excavating, or gardening.

The physical transport processes that could result in contamination of the groundwater were modeled using a number of simplifying assumptions. An intact grout monolith was assumed to be in direct contact with the surrounding soil; no isolation credit was taken for the liners, vault, water-shedding cap, or barrier. In this model, the monolith was assumed to be bathed with incoming water and all the contaminants leached out of the monolith at a constant rate over a 10,000-year period. (Laboratory leach tests on small cylinders of simulated grout, in conjunction with the assumption of a diffusional release mechanism and a subsequent release model that can be scaled up to describe field-scale release, indicate that total release from an uncracked monolith would actually occur over a much longer period than 10,000 years; the constant-release model used here is more conservative than the assumed actual release model would be.) Once contaminants enter the vadose zone, they were modeled as traveling to the groundwater via vertical, one-dimensional transport. Some radionuclides travel through the vadose zone more slowly than water, because they are sorbed on the soil. Some of the nonradiological contaminants form

precipitates in the soil, and hence their transport in the vadose zone is solubility-limited. The remainder of the contaminants were modeled as having the same travel time as water.

The amount of water available to carry contaminants through the vadose zone is a fraction of the amount of precipitation. Therefore, the analysis was performed for two recharge rates: one represents an estimate of current climatic conditions, and the other encompasses the effects of a hypothetical wetter climate.

The second means by which humans could become exposed to contaminants from the grout site is by direct intrusion. Active controls of the grout disposal site were assumed to cease 100 years after disposal (although this situation is extremely unlikely). A suite of inadvertent-intruder scenarios was postulated (drilling, excavating, and gardening), and the resulting radiological doses were calculated.

Calculations of radiological dose to humans are directly related to a number of parameters specific to each radionuclide: sorption in the vadose zone, rate of radioactive decay, and effect of the radionuclide on various organs in the human body. Two computer codes were used to calculate the doses associated with various exposure scenarios: the ONSITE/MAXI1 code (Napier et al. 1984) and the DITTY code (Napier, Peloquin and Strenge 1986).

9 0 1 1 7 8 6 1 8 3 9

RESULTS

Long-term impacts that could result from disposal of PSW grout are expressed in terms of incremental increases of 1) chemical concentrations in the groundwater and surface waters, and 2) radiation doses. The impacts are then compared to correspondent regulations.

Nonradiological Chemical Impacts

Projected incremental increases in concentrations of regulated chemicals are listed in Table S.1. The concentrations were calculated for two locations: at a hypothetical well 5 km downgradient from the PSW grout disposal site, and in the Columbia River. Although the groundwater below the Hanford

TABLE S.1. Calculated Increase in Concentrations of Regulated Chemicals in a Hypothetical 5-km Well and in the Columbia River, mg/L

	In 5-km Well Water		In Columbia River Water		Washington State Drinking Water Limit
	Recharge Rate, cm/yr				
	0.5	5.0	0.5	5.0	
Primary Contaminants					
Arsenic	2×10^{-2}	1×10^{-2}	7×10^{-10}	7×10^{-10}	0.05
Barium	6×10^{-4}	4×10^{-3}	3×10^{-11}	2×10^{-10}	1.0
Cadmium	3×10^{-5}	2×10^{-4}	1×10^{-12}	1×10^{-11}	0.01
Chromium	1×10^{-3}	1×10^{-2}	4×10^{-11}	6×10^{-10}	0.05
Fluoride	3×10^{-2}	2×10^{-1}	1×10^{-9}	1×10^{-8}	2.0
Lead	4×10^{-3}	3×10^{-2}	2×10^{-10}	2×10^{-9}	0.05
Mercury	1×10^{-4}	9×10^{-5}	5×10^{-12}	5×10^{-12}	0.002
Nitrogen	3×10^{-1}	3×10^{-1}	1×10^{-8}	1×10^{-8}	10.0
Selenium	1×10^{-3}	8×10^{-4}	5×10^{-11}	5×10^{-12}	0.01
Silver	1×10^{-3}	8×10^{-3}	4×10^{-11}	5×10^{-10}	0.05
Secondary Contaminants					
Chloride	3×10^{-1}	3×10^{-1}	2×10^{-8}	2×10^{-8}	250
Copper	8×10^{-4}	7×10^{-3}	4×10^{-11}	4×10^{-10}	1.0
Iron	3×10^{-4}	3×10^{-3}	1×10^{-11}	2×10^{-10}	0.3
Manganese	3×10^{-4}	2×10^{-3}	1×10^{-11}	1×10^{-10}	0.05
Sulfate	3×10^{1}	2×10^{1}	1×10^{-6}	1×10^{-6}	250
Zinc	3×10^{-4}	2×10^{-3}	1×10^{-11}	1×10^{-10}	5.0

Site does not constitute a public water supply, Washington State limits (as given in the Washington Administrative Code) are listed for comparison (WAC 1985). All calculated concentrations are below these limits established for drinking water.

The Hanford Reach of the Columbia River is governed by Class A water quality standards for the State of Washington (WAC 1984). These standards do not list specific concentration limits for inorganic chemicals, but they do include limits on biological waste, turbidity, thermal waste (heat), and aesthetic qualities of the river. The incremental increases of chemicals in

9 0 1 1 7 8 5 1 8 4 0

Columbia River water from disposal of PSW grout are projected to be very low and will comply with all Class A water quality standards.

Radiological Impacts

A summary of calculated radiological impacts is provided in Table S.2; these values represent incremental increases in dose. Correspondent regulatory limits are also listed for comparison. Maximum dose to an intruder is compared to limits established in DOE Order 5480.1A (U.S. DOE 1981a) and by the Nuclear Regulatory Commission for shallow-land disposal of commercial low-level wastes (U.S. NRC 1982a). Maximum dose from the drinking water scenario is compared to Washington State limits for a public water supply (WAC 1985). In the short term, strontium-90 and cesium-137 dominate the intruder impacts. The long-term radiological impacts result primarily from uranium-238.

TABLE S.2. Summary of Maximum Radiological Impacts

Scenario	Dose, mrem/yr Total Body/ Critical Organ	Regulatory Dose Limit, mrem/yr Total Body/ Critical Organ	Dominant Radionuclide
Drinking Water, 0.5 cm/yr recharge	0.02/0.3	4/4[a]	^{238}U
Full Garden, 5.0 cm/yr recharge	0.05/0.4	25/75[b]	^{238}U
River, both recharges	$4 \times 10^{-9}/3 \times 10^{-8}$	25/75[b]	^{238}U
Intruder (residential home garden)	60/200	500/1500[b,c]	^{90}Sr, ^{137}Cs

(a) WAC (1985).
(b) U.S. NRC (1982a).
(c) U.S. DOE (1981a).

PURPOSE AND CONCLUSIONS OF PERFORMANCE ASSESSMENT

This performance assessment was prepared as input to the environmental assessment for PSW grout. An environmental assessment "means a concise public document...that serves to briefly provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement or a finding of no significant impact" (U.S. EPA 1985a). Thus, an environmental assessment is a scoping document written to assist decisionmakers.

Environmental assessments, and other such documents described by the National Environmental Policy Act (NEPA) of 1969, typically include a "bounding analysis" to help foster what NEPA calls "excellent decisions." A bounding analysis is performed with a set of data, modeling assumptions, and accidental release scenarios, the total of which is sufficiently conservative so that there is a high degree of confidence that as a result of the compounded conservatisms, the calculated (predicted) environmental impacts will exceed those expected in practice. Individual parameters are not necessarily extreme values. They may be mean values in cases where ample data warrants such a choice, or values well on the conservative side of the expected mean for parameters with highly uncertain ranges of values. Furthermore, when uncertainties exist regarding modeling assumptions, the assumptions are made on what is considered to be the side of conservatism. Finally, accident scenarios are chosen, within the bounds of credibility, to describe the most serious incidents (i.e., those with the greatest impacts) that could reasonably occur. (For this performance assessment, "accident scenarios" were the scenarios of inadvertent intrusion into the grout disposal site.)

To support the environmental assessment for grout disposal of PSW, the authors of this long-term performance assessment used models and the best available data to provide what is believed to be a "bounding analysis" such as that described above. The results can then be used as input for determining whether to prepare an environmental impact statement or a finding of no significant impact.

To assist decisionmakers, calculated impacts were compared to potentially applicable regulations. It is not precisely known what regulations will apply to the Hanford Site and surrounding areas during the post-operational period of disposal. Regulatory requirements were conservatively assumed to apply for a period of 10,000 years following disposal. None of the calculated impacts exceeded the regulatory limits that were reviewed and provided for comparison. Therefore, the results of this performance assessment indicate that grout disposal of PSW can provide long-term protection of public health and safety.

9011178618 42

ACKNOWLEDGMENTS

The authors thank all those who contributed to the preparation of this performance assessment. In particular, we would like to thank peer reviewers R. J. Serne, A. E. Reisenauer, and B. A. Napier (Pacific Northwest Laboratory); L. C. Brown, R. G. Richmond, D. E. Bowers, and R. C. Baca (Rockwell Hanford Operations); and for programmatic review, S. L. Stein, M. S. Hanson, W. F. Bonner, P. E. Bramson, and J. E. Van Beek.

This program was funded by the Department of Energy's Waste Management Division as administered by Rockwell Hanford Operations under the name Grout Disposal Program.

CONTENTS

ABSTRACT iii
SUMMARY v
ACKNOWLEDGMENTS xi
1.0 INTRODUCTION 1.1
2.0 PHILOSOPHY OF PERFORMANCE ASSESSMENT 2.1
2.1 GENERAL DISCUSSION OF PERFORMANCE ASSESSMENTS . . . 2.1
2.2 APPROACH TO PERFORMANCE ASSESSMENT IN THIS REPORT . . . 2.2
2.2.1 Overall Procedure 2.3
2.2.2 Expected Performance Versus Modeled Performance . . 2.4
3.0 DESCRIPTION OF WASTE AND GROUT DISPOSAL SYSTEM 3.1
3.1 ORIGIN OF PSW WASTE 3.1
3.2 VOLUME AND COMPOSITION OF PSW STREAM 3.2
3.3 DISPOSAL STRUCTURE 3.4
4.0 SOURCE TERM 4.1
4.1 CALCULATING THE WASTE INVENTORIES 4.1
4.1.1 Chemical Inventory 4.1
4.1.2 Radionuclide Inventory 4.6
4.2 RELEASE OF WASTE FROM GROUT MONOLITH 4.7
4.2.1 Constant-Release Model 4.7
4.2.2 Solubility-Controlled Release 4.11
5.0 TRANSPORT OF CONTAMINANTS VIA GROUNDWATER 5.1
5.1 GROUNDWATER SCENARIO--OVERALL CONCEPTUAL MODEL . . . 5.1
5.2 MIGRATION THROUGH THE VADOSE ZONE 5.3
5.2.1 Water Flow Through the Vadose Zone 5.3
5.2.2 Contaminant Transport Through the Vadose Zone . . 5.8
5.3 MIGRATION THROUGH THE UNCONFINED AQUIFER 5.12
5.3.1 Water Flow Through the Unconfined Aquifer . . . 5.12
5.3.2 Contaminant Transport Through the Unconfined Aquifer . 5.17
5.4 NONRADIOLOGICAL RESULTS 5.19
6.0 RADIOLOGICAL ASSESSMENT 6.1
6.1 POSTULATED EVENTS 6.1
6.2 CALCULATIONAL METHODS 6.2
6.2.1 Dosimetry 6.2

9011178518844

6.2.2 Method for Calculating Groundwater Doses 6.4
6.2.3 Method for Calculating Intruder Doses 6.5
6.3 GROUNDWATER IMPACTS 6.7
6.3.1 Drinking Well Water 6.9
6.3.2 Full-Garden Scenario 6.9
6.3.3 Radionuclide Migration to the Columbia River . . 6.12
6.4 INTRUDER IMPACTS 6.16
6.4.1 Drilling 6.20
6.4.2 Excavation 6.20
6.4.3 Residential Home Garden 6.22
6.4.4 Post-Drilling Habitation 6.24
6.4.5 Post-Excavation Habitation 6.24
6.5 SUMMARY OF RADIOLOGICAL IMPACTS 6.27
6.5.1 Regulatory Review 6.27
6.5.2 Comparison to Regulations 6.30
7.0 GLOSSARY 7.1
8.0 REFERENCES 8.1

FIGURES

1.1 Progression and Organization of Long-Term Performance Assessment 1.2

2.1 Procedure for a Performance Assessment 2.2

2.2 Conceptual Model for Grout Disposal System and Potential Exposure Pathways 2.3

2.3 Comparison of Modeled Grout Disposal System to Actual System 2.5

3.1 Preliminary Design of a PSW Grout Disposal Vault 3.5

4.1 Scaled Curve of Fraction of Contaminant Released from Grout Monolith as a Function of Time, Showing Extrapolation Method for Constant Release Approximation 4.10

5.1 Conceptual Model for Contaminant Migration 5.2

5.2 Conceptual Model of the Vadose Zone and Associated Water Flow and Contaminant Transport 5.4

5.3 Schematic of Soil Profile Identifying Soil Types Using Available Data. 5.6

5.4 Simulated Groundwater Contours and Streamlines from the 200-Area Plateau, 0.5 cm/yr Recharge Rate 5.13

5.5 Simulated Groundwater Contours and Streamlines from the 200-Area Plateau, 5.0 cm/yr Recharge Rate 5.14

5.6 Conceptual Model for Contaminant Transport in the Unconfined Aquifer Along Water Flow Pathlines 5.18

6.1 Use of Computer Models to Calculate 10,000-year Integrated Population Doses from Contaminant Release to Groundwater . . 6.5

6.2 Concentrations of Key Radionuclides in Groundwater at 5-km Well, 0.5 cm/year Recharge Rate 6.8

6.3 Concentrations of Key Radionuclides in Groundwater at 5-km Well, 5.0 cm/year Recharge Rate 6.8

6.4 10,000-year Release to Columbia River, 0.5 cm/yr Recharge Rate 6.15

6.5 10,000-year Release to Columbia River, 5.0 cm/yr Recharge Rate 6.15

9011178846

TABLES

S.1 Calculated Increase in Concentrations of Regulated Chemicals in a Hypothetical 5-km Well and in the Columbia River, mg/L . viii

S.2 Summary of Maximum Radiological Impacts ix

3.1 Typical Dry Solids Blend 3.2

3.2 Concentrations of Chemicals and Radionuclides Present in PSW Streams 3.3

4.1 Nonradiological Regulated Chemicals in PSW Grout 4.2

4.2 Concentrations of Chemicals in Dry Grout-Forming Solids . . 4.4

4.3 Concentrations of Chemicals in Centralia Fly Ash 4.5

4.4 Radionuclides in PSW Grout 4.6

4.5 Solubility-Limited Concentrations as Calculated by MINTEQ . . 4.12

5.1 Textural Description of Soil Samples Collected from 241-AP Tank Farm Excavation 5.7

5.2 Soil Profiles to the Water Table and Travel Times Through a 64-m Depth 5.8

5.3 Radionuclide Travel Times in the Vadose Zone for Recharge Rates of 0.5 and 5.0 cm/yr 5.11

5.4 Calculated Increase in Concentrations of Regulated Chemicals in a Hypothetical 5-km Well and in the Columbia River . . . 5.20

6.1 Postulated Events Leading to Radiological Impacts . . . 6.1

6.2 Comparison of Radiation Dose for the Drinking Water Scenario Using ICRP-2 and ICRP-26/30 Methods 6.4

6.3 Calculated Maximum Radiation Doses to Individuals from the Drinking Water Scenario, mrem (Annual Doses) 6.10

6.4 Calculated Maximum Doses to Individuals from the Drinking Water Scenario, mrem (Lifetime Doses) 6.11

6.5 Calculated Maximum Radiation Doses to Individuals from the Full-Garden Scenario, mrem (Annual Doses) 6.13

6.6 Calculated Maximum Radiation Doses to Individuals from the Full-Garden Scenario, mrem (Lifetime Doses) 6.14

6.7 Calculated Potential Maximum Radiation Doses to Individuals from Radionuclide Migration to the Columbia River, mrem (Annual Doses) 6.17

6.8 Calculated Potential Maximum Radiation Doses to Individuals from Radionuclide Migration to the Columbia River, mrem (Lifetime Doses) 6.18

6.9 10,000-year Cumulative Population Doses from Radionuclide Migration to the Columbia River, person-rem 6.19

6.10 Calculated Maximum Radiation Doses to Individuals Resulting from the Drilling Scenario (Annual Doses) 6.21

6.11 Calculated Maximum Radiation Doses to Individuals Resulting from the Excavation Scenario (Annual Doses) 6.23

6.12 Calculated Maximum Radiation Doses to Individuals Resulting from the Residential Home Garden Scenario (Annual Doses) . . 6.25

6.13 Calculated Maximum Radiation Doses to Individuals Resulting from the Post-Drilling Scenario (Annual Doses) 6.26

6.14 Summary of Maximum Radiological Impacts 6.27

1.0 INTRODUCTION

This report documents the long-term performance assessment that is described in DOE/EA-0312, Environmental Assessment for the Grouting and Near-Surface Disposal of Phosphate/Sulfate Waste from N Reactor Operations (U.S. DOE 1986a).

The Environmental Assessment (EA) was prepared for the Grout Disposal Program, which is managed by Rockwell Hanford Operations (Rockwell). The EA applies specifically to Phosphate/Sulfate Waste from N Reactor Operations (PSW), a low-level radioactive waste stream scheduled for grout disposal. In this application, grout is a mixture of liquid wastes and grout-forming solids (portland cement, fly ash, and various clays) that will be pumped as a slurry to sub-surface reinforced concrete vaults where it will subsequently harden into a solid matrix that immobilizes the waste. The primary purpose of the performance assessment (PA) contained in the EA was to investigate whether the grout disposal system for PSW grout could provide long-term protection of public health and safety. To accomplish this goal, Pacific Northwest Laboratory (PNL) researchers investigated the pathways and mechanisms by which wastes could conceivably be transported to the biosphere. The results of the study were then compared with potentially applicable federal and state regulatory requirements.

This report begins with a discussion on the rudiments of a PA (Chapter 2.0). The progression and organization of the remainder of the report are shown in Figure 1.1. Chapter 3.0 describes the PSW waste stream and the grout disposal system. Chapter 4.0 describes the inventories of contaminants (radionuclides and inorganic chemicals as regulated by drinking water standards) in the PSW grout and how we model the release of contaminants from grout. Chapter 5.0 describes the simulated transport of contaminants in the soil surrounding the PSW grout disposal site and the subsequent movement of the contaminants in Hanford groundwater to points of access by humans. Chapter 6.0 describes the method of calculating radiological doses projected to result from hypothetical transport of radionuclides to the biosphere. For the reader's convenience, technical terms are defined in Chapter 7.0.

9011178349

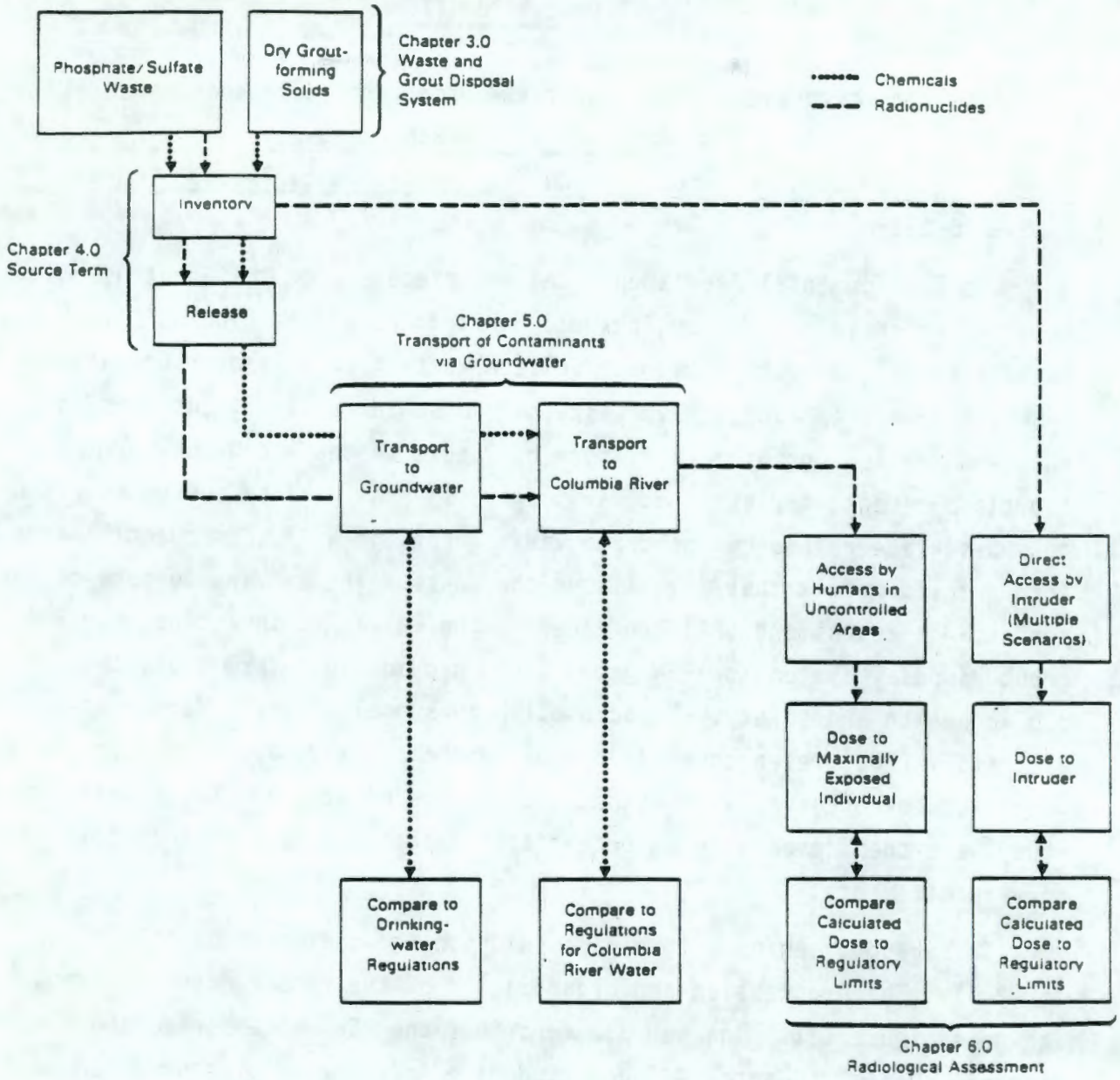


FIGURE 1.1. Progression and Organization of Long-Term Performance Assessment

2.0 PHILOSOPHY OF PERFORMANCE ASSESSMENT

This chapter begins by discussing the purpose of PAs, typical steps in the PA process, and how the results of a PA can be used. Section 2.2 gives an overview of how the PA process was used to evaluate a specific application: the performance of the disposal system for PSW grout.

2.1 GENERAL DISCUSSION OF PERFORMANCE ASSESSMENTS

Performance assessment is a multidisciplinary exercise aimed at predicting a system's response to reasonably projected conditions over a designated period of time. The primary purpose of a PA is to estimate whether a system, as designed, will comply with applicable regulations. Typically, long-term performance assessments are conducted for a range of performance conditions. Scenarios are selected that represent the expected behavior of the system as well as performance under stressed or partially failed conditions. Because researchers often lack quantitative data pertaining to the long-term durability of the system, conservative estimates are selected in an attempt to produce a bounding analysis (i.e., a prediction of performance under less than optimal conditions).

The steps of a PA are shown in Figure 2.1. First the system and its environmental setting are defined. Applicable regulations dictate the level of detail necessary to define the system. Second, a set of scenarios is developed to postulate reasonably foreseeable stresses on the system. Next, the physical responses of the system to the scenarios are modeled. Last, the consequences of the scenarios are calculated and compared to applicable regulations and design goals. If the consequences are acceptable, system planning may proceed.

Although the procedure for a PA is simple in concept, applying the approach to actual situations can be very difficult. This is particularly true for cases in which the engineered system is poorly defined, the environmental setting is not well known, or when the system's performance must be projected over extended time periods. Where unknowns or uncertainties exist, estimates must be made. As previously mentioned, conservative

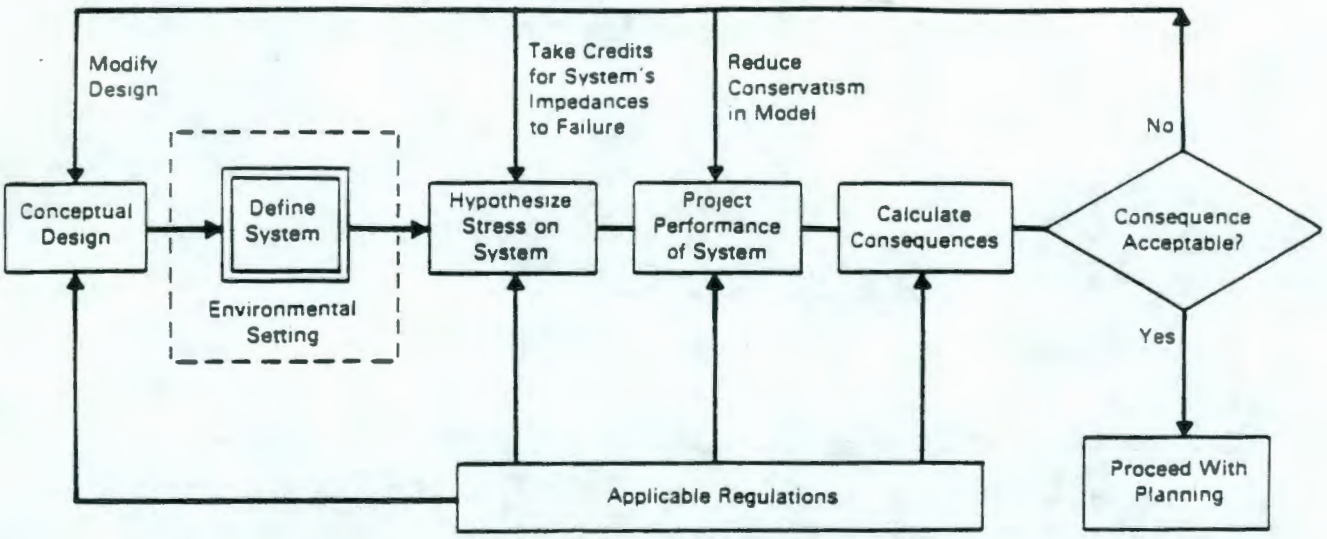


FIGURE 2.1. Procedure for a Performance Assessment

estimates are often used to ensure that the analysis will represent the upper range of credible impacts. For example, if we know that the rate of release for a certain contaminant is between x and y, with y representing the most rapid release, we model the release of the contaminant using the release rate y, so long as other model parameters are compatible with the release rate y.

Most PAs performed for waste disposal systems overestimate potential consequences in order to compensate for inherent uncertainties. Examples of these uncertainties are 1) waste characteristics, system design parameters, and waste form performance; 2) the understanding of contaminant transport; and 3) the selection of the reasonable intrusion scenarios to be analyzed.

2.2 APPROACH TO PERFORMANCE ASSESSMENT IN THIS REPORT

The purpose of this PA is to support the EA by investigating whether the PSW grout disposal system can adequately provide long-term protection of public health and safety. The PA contains a number of simplifying assumptions, as well as a level of uncertainty that cannot be quantified at this time. When the PSW grout disposal system and associated applicable regulations become more clearly defined, a "retroactive" PA could be conducted in order to more defensibly project regulatory compliance.

9 0 1 1 7 8 6 1 8 5 2

2.2.1 Overall Procedure

In this PA, we model the transport of contaminants from the waste form to points of human access. Following the general procedure that was shown in Figure 2.1, the PSW grout disposal system and its environmental setting were defined as shown in Figure 2.2. (A detailed description of the PSW grout disposal system is given in Section 3.3 of this report.) Because it is not yet possible to quantify the degree of protection afforded by the grout vault structure (i.e., cement walls and liners), the monolith was modeled as directly contacting the soil.

A number of scenarios were postulated to occur over a 10,000-year period following disposal of PSW grout. The scenarios identify pathways by which contaminants could be transported from the monoliths to humans. Two types of pathways were postulated: 1) migration of contaminants into the groundwater and then to the Columbia River, and 2) inadvertent intrusion into the grout site after a hypothetical loss of institutional (government) control. The first pathway (groundwater) applies both to radionuclides and nonradiological

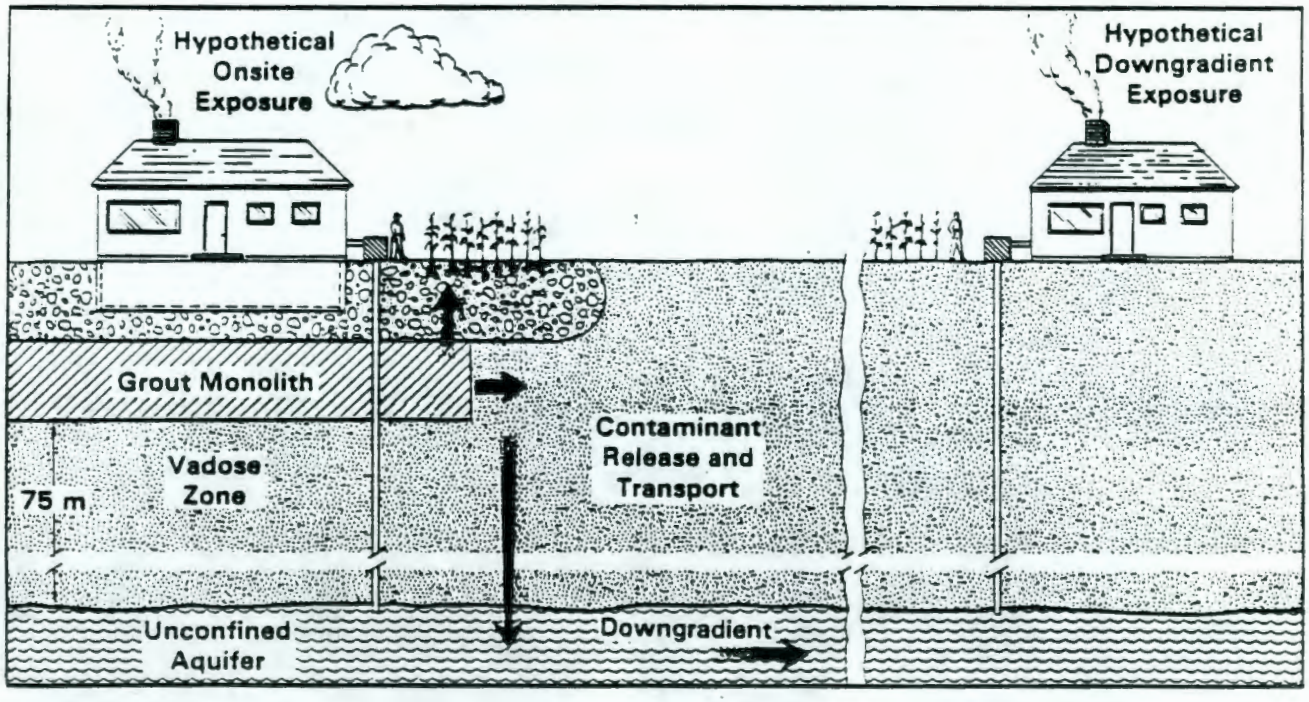


FIGURE 2.2. Conceptual Model for Grout Disposal System and Potential Exposure Pathways

chemicals. Contaminant transport via groundwater is described in Chapter 5.0. Calculated concentrations of chemical contaminants in groundwater and in the Columbia River were compared to corresponding regulations. However, concentrations of radionuclides must be translated to human radiation doses in order to compare them to regulations that limit radiation exposure to humans. Consequently, calculated concentrations of radionuclides in the groundwater and Columbia River were used as input for dose models, as described in Chapter 6.0. Chapter 6.0 also describes the second major pathway of contaminant transport: inadvertent intrusion into the grout disposal site. Calculated doses to an inadvertent intruder are presented.

2.2.2 Expected Performance Versus Modeled Performance

The model of the grout disposal system differs from the actual system in several ways. Figure 2.3 compares the system as modeled to the actual system. Detailed descriptions of the grout disposal system and modeling approach are contained in Chapters 3.0 through 6.0. However, a few general differences are noted here.

As designed, the grouted waste will be poured into plastic-lined, steel-reinforced concrete vaults. Each vault will be equipped with a leachate collection system. About 4 feet of nonradioactive grout will be poured on top of the radioactive grout. Above the grout will be a water-shedding cap and shielding material up to ground level. Over long periods of time, the liners and vault may fail, allowing contaminants to diffuse out of the vault and into the soil where they could be carried down into the aquifer by advecting water. Some contaminants would move more slowly because of geochemical interactions. The contaminants would become dispersed before and after reaching the aquifer, resulting in reduced concentrations. The monolith itself could also crack and crumble with age, potentially providing additional surface area from which contaminants could be leached.

As modeled, the grout monolith is bathed with incoming water. Because it is not yet possible to specify how or when its containment structures will fail, no containment credit was taken for the liners or vault. However, the monolith is assumed to remain intact (uncracked) over the long term. As

9011178518 54

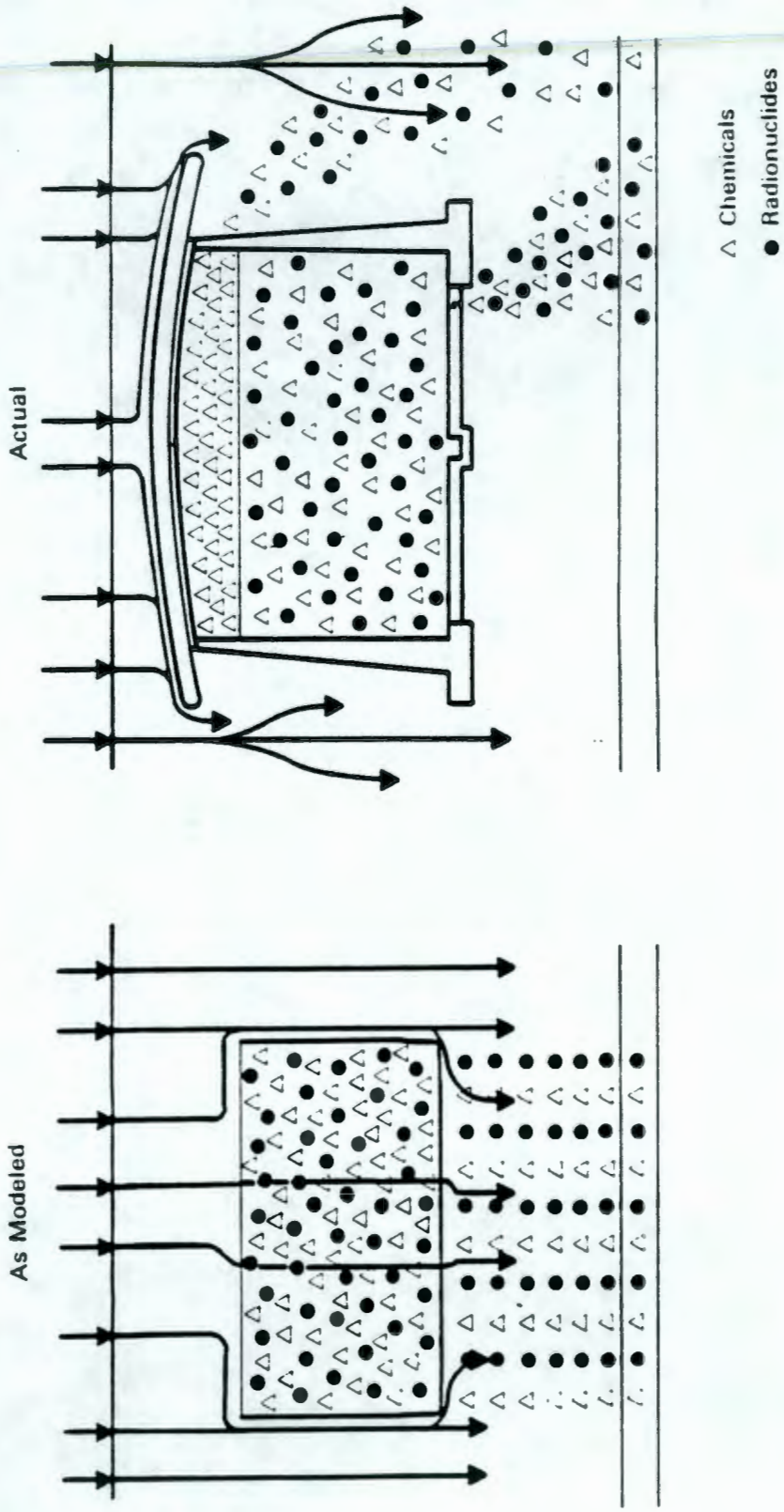


FIGURE 2.3. Comparison of Modeled Grout Disposal System to Actual System

modeled, the contaminants are uniformly distributed throughout the grout monolith, and the entire inventory is released at a constant rate into the soil below. No credit was taken for reduced concentrations due to dispersion. The contaminants are modeled as traveling directly down to the aquifer and then horizontally to a hypothetical well and on to the Columbia River.

3.0 DESCRIPTION OF WASTE AND GROUT DISPOSAL SYSTEM

A variety of low-level liquid wastes (LLW) can be immobilized by grouting. The specific low-level waste stream discussed in this report is called Phosphate/Sulfate Waste from N Reactor Operations (PSW). Section 3.1 discusses the nature and source of the waste streams that compose PSW. Section 3.2 identifies the estimated volumes of the waste before and after grouting, and the composition of the grouted waste. Section 3.3 describes the disposal system planned for the grouted waste.

3.1 ORIGIN OF PSW WASTE

Phosphate/Sulfate Waste is composed of three waste streams that originate at the N Reactor in 100-N Area of the Hanford Site. (The N Reactor produces special nuclear materials, and its byproduct steam is used to generate electricity.) The waste streams are designated as phosphate waste, sulfate waste, and sandfilter backwash.

Phosphate waste is produced during periodic reactor decontamination using a commercial decontamination agent that contains phosphoric acid, citric acid, and trace amounts of other chemicals. The resulting waste is a dilute aqueous solution of trisodium phosphate and citrate, containing trace amounts of inorganic chemicals and radioactive elements (radionuclides) of varying half-lives.

The two other waste streams that make up PSW--sulfate waste and sandfilter backwash--are produced during periodic cleanup of the water in N Reactor's spent-fuel storage basin. Ion-exchange resins remove radionuclides from recirculated storage basin water. Sulfuric acid is used to regenerate the cation exchange resin; sodium hydroxide is used to regenerate the anion exchange resin. Extensive rinsing of the resins produces a dilute sodium sulfate waste solution. The acidic solution is adjusted to a pH of 12 with sodium hydroxide to limit corrosion of the carbon-steel storage tanks. Also present in the basin-water cleanup system is a sandfilter for removing entrained solids from the water. Periodic flushing of the filter with water generates sandfilter backwash waste in the form of a dilute slurry.

3.2 VOLUME AND COMPOSITION OF PSW STREAM

The volume of PSW to be grouted is projected to be about 43,000 cubic meters. These 43,000 cubic meters are expected to be composed of 2.45×10^4 cubic meters of sulfate waste and 1.14×10^4 cubic meters of phosphate waste, which are then diluted with 7.2×10^3 cubic meters of flush water. (The sandfilter backwash sludge is included in the volume of sulfate waste.) For each gallon of PSW, approximately 7.5 pounds of grout-forming solids (cement, fly ash, and clay) will be added. The volume of the grouted waste will be approximately 56,000 cubic meters; the density will be about 12 lb/gal (1.44×10^3 kg/m^3). The proportions of each component in the dry solids blend are shown in Table 3.1.

Concentrations of radionuclides and chemicals present in PSW are listed in Table 3.2. Not all radionuclides are significant in the assessment of the long-term performance of disposed grout. Certain radionuclides have sufficiently short half-lives such that they do not affect the results of the PA. Other species can be considered "key" radionuclides because of their concentrations, longevity, and mobility. The chemicals listed here are those inorganic species regulated by the Washington State Department of Social and Health Services (WAC 1985).

Nitrogen is regulated when it exists in the form of nitrate (NO_3). However, Table 3.2 includes nitrogen from ammonia (NH_3). Nitrite and organic

TABLE 3.1. Typical Dry Solids Blend[a]

Material	Amount (wt%)
Type I-II-LA portland cement	41
Centralia, WA ASTM Class F, fly ash	40
Attapulgite-150 drilling clay	11
Indian Red pottery clay	8

(a) Based on the formulation developed at Oak Ridge National Laboratory.

converted to nitrate, and, therefore, all sources of combined nitrogen (particularly organic nitrogen and ammonia) should be considered as potential nitrate sources" (U.S. EPA 1985b).

The state drinking water standards do not apply directly to the groundwater beneath the Hanford Site because it is not a continuous source of public drinking water. However, the chemical species evaluated in this PA were selected from those regulations for comparison purposes. Comparison with these values provides an indication of the grout system's performance under the most restrictive of standards.

3.3 DISPOSAL STRUCTURE

The slurry will be pumped into subsurface disposal vaults, where it will harden into a solid matrix that immobilizes the waste. A preliminary design of the disposal vault is shown in Figure 3.1. Each vault will be 10.4 m deep, 15.24 m wide, and 38.1 m long. The walls and floor will be made from steel-reinforced concrete. Each vault will be lined with a high-density polyethylene liner which will prevent dewatering of the grout during setting and curing. An additional liner will provide redundant protection. Two leachate collection systems will be installed: one to remove leachate from the base of the grout monolith; the other from between the two liners at the bottom of each vault (to remove any leachate that may penetrate the primary liner). A concrete cover and a clay or asphalt cap will then be placed over the vault, and the remaining volume above the cap will be filled in with shielding backfill up to grade.

Each vault will hold approximately 5,000 cubic meters of radioactive grouted waste. The unfilled volume of the vault (about 1,000 cubic meters) will be filled with nonradioactive grout to prevent subsidence. Hence, the radioactive grout will be about 9 m thick, and the nonradioactive grout will be about 1.5 m thick. The final distance from ground level down to the top of the radioactive grout will be 5 m.

Final closure of the PSW grout disposal site will include emplacement of an interim surface barrier over the vaults.

TABLE 3.2. Concentrations of Chemicals and Radionuclides Present in PSW Streams[a]

Chemical	Concentration in Sulfate Stream, moles/L	Concentration in Phosphate Stream, moles/L	Concentration in Sandfilter Backwash, µg/g
Arsenic (As)	6.7×10^{-8}	6.7×10^{-8}	0.08
Barium (Ba)	$<4.0 \times 10^{-7}$	6.3×10^{-7}	4
Cadmium (Cd)	$<2.2 \times 10^{-6}$	3.6×10^{-8}	1.6
Chromium (Cr)	$<6.0 \times 10^{-7}$	4.7×10^{-5}	1.3
Fluoride (F)	$<1.4 \times 10^{-4}$	1.0×10^{-3}	2.5
Lead (Pb)	$<3.9 \times 10^{-6}$	3.6×10^{-7}	32
Mercury (Hg)	1.0×10^{-7}	4.8×10^{-8}	0.5
Selenium (Se)	6.3×10^{-8}	6.3×10^{-8}	0.5
Silver (Ag)	$<9.0 \times 10^{-7}$	1.9×10^{-7}	32
Chloride (Cl)	1.1×10^{-3}	1.0×10^{-3}	2.5
Copper (Cu)	$<5.0 \times 10^{-7}$	1.8×10^{-6}	5.9
Iron (Fe)	$<1.6 \times 10^{-6}$	5.6×10^{-3}	1,320
Manganese (Mn)	$<3.6 \times 10^{-5}$	6.5×10^{-4}	8.2
Sulfate (SO_4)	2.4×10^{-2}	1.3×10^{-3}	25
Zinc (Zn)	$<8.0 \times 10^{-7}$	1.8×10^{-5}	31
Nitrate (NO_3)	2.2×10^{-4}	$<2.0 \times 10^{-3}$	---
Ammonia (NH_3)	---	$<8.7 \times 10^{-2}$	---

Radionuclide[a]	Concentration in Sulfate Stream, Ci/L	Concentration in Phosphate Stream, Ci/L	Concentration in Sandfilter Backwash, Ci/kg
Carbon-14	9.9×10^{-14}	6.0×10^{-8}	8.4×10^{-15}
Cobalt-60	2.0×10^{-6}	1.6×10^{-4}	6.2×10^{-1}
Strontium-90	3.3×10^{-5}	2.2×10^{-10}	2.8×10^{-6}
Technetium-99	4.0×10^{-9}	4.0×10^{-9}	4.2×10^{-8}
Iodine-129	7.0×10^{-14}	1.1×10^{-15}	5.9×10^{-15}
Cesium-137	5.0×10^{-5}	9.3×10^{-7}	3.8×10^{-2}
Uranium-238	1.1×10^{-9}	1.8×10^{-11}	1.1×10^{-12}
Plutonium-239	2.4×10^{-7}	5.2×10^{-9}	1.0×10^{-7}
Amercium-241	3.3×10^{-10}	1.2×10^{-8}	6.2×10^{-7}

(a) Source: U.S. DOE (1986a).

nitrogen are not present in the waste streams. Including all sources of nitrogen in the inventory is consistent with the Environmental Protection Agency's (EPA's) Proposed Rule for National Primary Drinking Water Regulations, which states, "Most nitrogeneous materials in natural waters tend to be

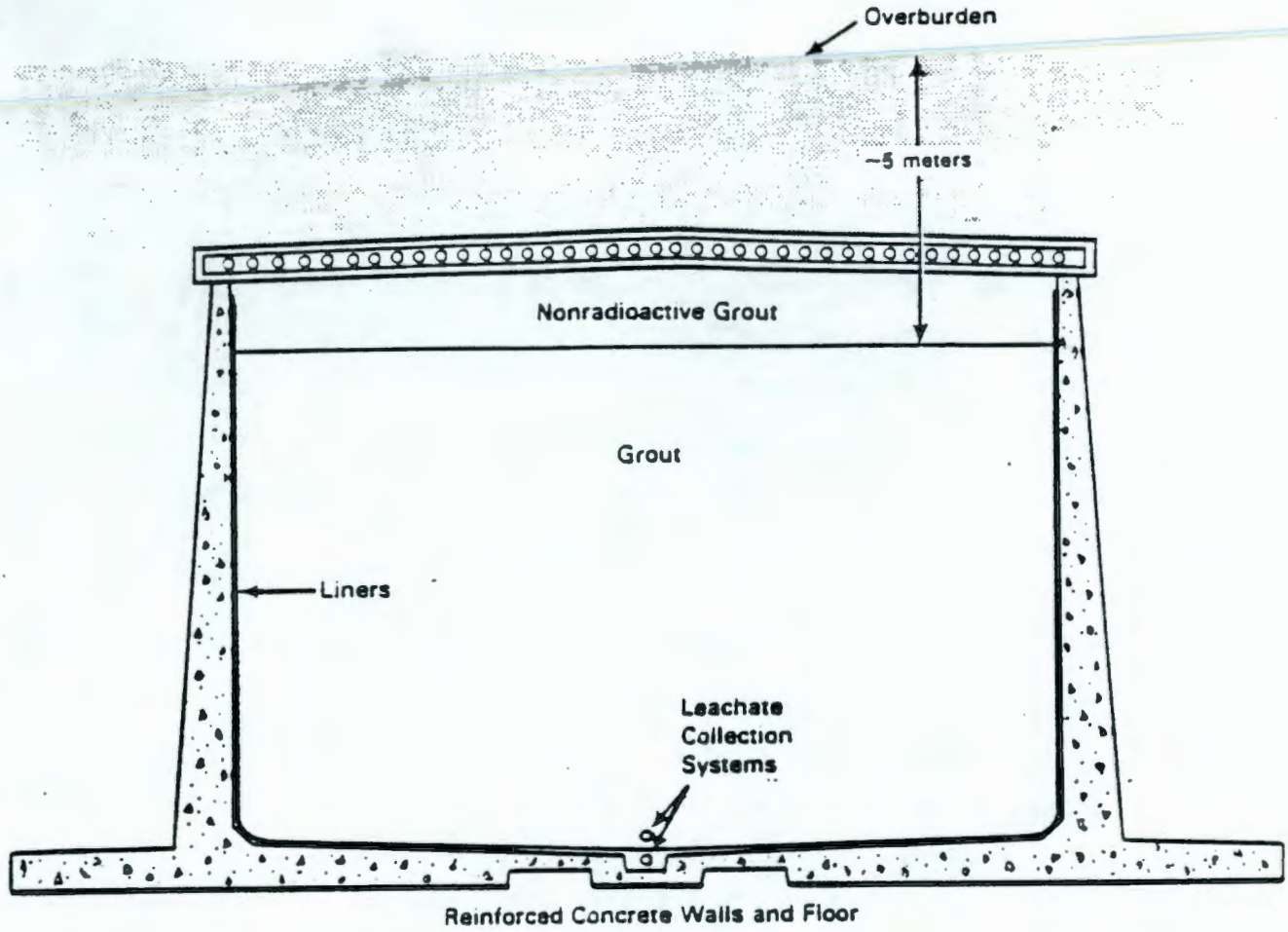


FIGURE 3.1. Preliminary Design of a PSW Grout Disposal Vault

4.0 SOURCE TERM

To quantitatively project a contaminant's movement out of a grout monolith and through the environment, the source term of each contaminant in the grout monolith must be defined. In this context, "source term" refers not only to the inventory of contaminants in the grout monolith, but also to the amount released from the monolith and hence available for transport. This chapter describes how the source terms for specific contaminants were calculated for the PA for PSW grout.

Section 4.1 discusses the inventories for the radionuclides and the regulated nonradioactive chemicals. Section 4.2 describes the calculation of the fraction of waste released from the monolith as a function of time.

4.1 CALCULATING THE WASTE INVENTORIES

The inventories of specific chemicals and radionuclides in the PSW streams are based on analyses of actual waste samples. The dry grout-forming solids added to the waste also contribute to the total inventory of regulated nonradioactive contaminants. Estimates of the dry solids' contribution to this inventory are based on quantitative analyses of various dry solids components. Sections 4.1.1 and 4.1.2 describe how the inventory of each chemical and radionuclide was calculated.

4.1.1 Chemical Inventory

As stated in Section 3.2, the nonradioactive chemicals in PSW grout that were evaluated in the PA were those listed in state drinking-water standards (WAC 1985). The primary and secondary standards are included. The inventory of all regulated inorganic chemicals in PSW grout (Table 4.1) includes contributions from the three waste streams, the dry grout-forming solids, and any processing additives such as de-aerating agents. The contributions from the waste streams are projected to be the same as those measured in actual waste samples. The chemical concentrations in PSW streams shown in Table 3.2 were multiplied by the total volume of each waste stream to produce the data shown

TABLE 4.1. Nonradiological Regulated Chemicals in PSW Grout, kg

Chemical	Source: From Phosphate Stream[a]	From Sulfate Stream[a]	From Sandfilter Backwash[a]	Subtotal	From Dry Solids[b]	Total[b]
Arsenic	0.057	0.123	0.0001	0.180	680	680
Barium	0.980	1.35	0.005	2.3	54,000	54,000
Cadmium	0.046	6.06	0.002	6.1	64	70
Chromium	88	0.764	0.0016	29	4,300	4,300
Fluoride	223	65.1	0.003	290	---	290
Lead	0.843	19.8	0.038	21	45	66
Mercury	0.109	0.49	0.0006	0.61	4.5	5.1
Selenium	0.057	0.122	0.0006	0.18	45	46
Silver	0.230	2.38	0.038	2.6	45	48
Chloride	412	955	0.003	1,400	14,000	15,000
Copper	1.3	0.780	0.007	2.1	2,000	2,000
Iron	3,550	2.19	1.58	3,600	1,900,000	1,900,000
Manganese	408	48.5	0.010	460	21,000	21,000
Sulfate	1,400	56,500	0.030	58,000	1,100,000	1,200,000
Zinc	13.5	1.28	0.037	15	5300	5,300
Nitrogen	14,000[c]	75	0	14,000	---	14,000

(a) Source: U.S. DOE 1986(a).
(b) Includes chemicals in the 1.5-m layer of nonradioactive grout.
(c) Essentially all in the form of ammonia.

in Table 4.1. These volumes were 25,500 cubic meters of sulfate waste, 11,400 cubic meters of phosphate waste, and 1,200 kilograms of sandfilter backwash.

Chemicals in the Dry Solids

The remainder of this section describes how the chemical contributions from the dry grout-forming solids were calculated. Contributions from the dry solids were estimated from three sources: 1) analyses of the four dry solids, 2) a separate analysis of the Centralia fly ash, and 3) measurements of chemicals in an actual sample of grout. In the last set of measurements, the waste stream used to make the grout sample was 60% actual phosphate waste and 40% simulated sulfate waste (Serne et al. 1986). The processing additive for PSW, tributyl phosphate, is not a regulated chemical and hence does not contribute to the calculated inventory of chemicals.

The chemical contributions from the dry solids were calculated as follows. When more than one measurement of a chemical was available, the higher value was used. Certain chemicals were not detected in the samples, and hence their detection limits were used in calculating the total inventory. Using detection limits is conservative because it can result in the calculated inventory being higher than the actual inventory.

The total amount of dry solids in PSW grout is calculated in Equation (1):

$$\left(43{,}000\ m^3\ \text{waste}\right)\left(\frac{7.5\ \text{lb solids}}{\text{gal waste}}\right)\left(\frac{1\ \text{gal}}{0.00378\ m^3}\right)\left(\frac{0.454\ \text{kg}}{\text{lb}}\right) = \begin{matrix}3.88 \times 10^7\ \text{kg}\\ \text{solids in}\\ \text{PSW grout}\end{matrix} \qquad (1)$$

The dry solids in the 1.5 m of nonradioactive grout to be placed over the 9-m-thick PSW grout must also be accounted for. Assuming the nonradioactive grout will be made from the same solids that will be used to produce the waste grout, we added it to the PSW grout volume: $(3.88 \times 10^7\ \text{kg})(10.5\ \text{m}/9\ \text{m}) = 4.5 \times 10^7$ kg dry solids.

An analysis of the four dry solids included measurements of arsenic, barium, chromium, iron, manganese, sulfur, and zinc (Table 4.2). These values were multiplied by their weight fractions in the dry blend for grout (see

TABLE 4.2. Concentrations of Chemicals in Dry Grout-Forming Solids

Element	Cement	Fly Ash	Attapulgite Clay	Pottery Clay
Arsenic (ppm)	6.3 ± 2.5	23 ± 2	<2	15.5 ± 1.5
Barium (ppm)	970 ± 85	1540 ± 90	330 ± 100	600 ± 100
Chromium (ppm)	<80	75 ± 20	120 ± 20	90 ± 20
Iron (wt%)	3.48 ± 0.17	4.73 ± 0.23	2.09 ± 0.10	4.38 ± 0.20
Manganese (ppm)	365 ± 15	590 ± 20	375 ± 10	203 ± 8
Sulfur (wt%)	1.1 ± 0.4	0.28 ± 0.1	<0.03	<0.03
Zinc (ppm)	50 ± 6	180 ± 10	82 ± 5	85 ± 5

Table 3.1), and then multiplied by the total kilograms of dry solids. The calculation of arsenic is reproduced here as an example:

$$[(8.8 \text{ ppm arsenic in cement})(0.41) + (25 \text{ ppm in flyash})(0.40) + (2 \text{ ppm in attapulgite})(0.11) + (17 \text{ ppm in pottery clay})(0.08)] \times 10^{-6} \times 4.5 \times 10^{7} \text{ kg solids} = 680 \text{ kg arsenic in dry solids} \quad (2)$$

Inventory of Sulfate. In the PA, the total amount of elemental sulfur measured in the dry solids was conservatively assumed to be in the form of sulfate (SO_4), which is a regulated chemical. Using the same procedure, approximately 1×10^6 kg of sulfate is calculated to exist in all PSW grout; the dry solids contribute about 95%. In a separate analysis, 11,000 to 22,000 ppm of sulfate were measured in a grout sample (Serne et al. 1986). The higher measurement in that analysis yields the same mass of sulfate as was predicted from the measurement of sulfur in dry solids:

$$\left(\frac{22{,}000 \text{ kg sulfate}}{10^6 \text{ kg dry grout}}\right)\left(\frac{1 \text{ kg dry grout}}{2 \text{ kg wet grout}}\right)\left(56{,}000 \text{ m}^3 \text{ grout}\right) \quad (3)$$

$$\left(\frac{1.44 \times 10^3 \text{ kg grout}}{\text{m}^3 \text{ grout}}\right)\left(\frac{10.5 \text{ m nonradioactive grout + waste grout}}{9 \text{ m waste grout}}\right) = 1 \times 10^6 \text{ kg sulfate in PSW grout}$$

Therefore, because two independent calculation methods yielded the same value, we have greater confidence that the calculated value is accurate.

Inventory of Chloride. Chloride is assumed to exist in the dry solids in a concentration of <300 ppm, based on a measurement of chloride in the grout sample (Serne et al. 1986). This assumption is conservative because it does not discount the amount of chloride contributed by the PSW. The calculation of chloride is parallel to the calculation of sulfate in Equation (3).

Database. A sample of Centralia fly ash was also analyzed by California Analytical Laboratories, Inc. The results of this analysis are shown in Table 4.3. These data were used to enhance the database of chemical concentrations in fly ash. When the database contained more than one measurement of a certain chemical, the higher value was used in subsequent calculations.

No data were available for the concentrations of cadmium, lead, mercury, selenium, silver, or copper in the other dry solids (cement, attapulgite clay,

TABLE 4.3. Concentrations of Chemicals in Centralia Fly Ash[a]

Element	Concentration, ppm
Arsenic	<2
Barium	290
Cadmium	1.4
Chromium (Total)	25
Lead	<1
Mercury	<0.1
Selenium	1
Silver	<1
Copper	43
Zinc	41

(a) Letter, D. J. Leu (Department of Health Services, State of California) to T. A. Fox (Pozzolanic International, Mercer Island, Washington), August 20, 1984.

and Indian Red pottery clay). However, the concentrations of these trace elements are not expected to exceed their concentrations in fly ash. Therefore, the concentrations of these elements as measured in fly ash were assumed to be present in all 4.5×10^7 kilograms of dry solids to be used in PSW grout.

No data were available on the concentrations of fluoride or nitrogen in the four dry solids. However, a higher concentration of fluoride in PSW grout would not change the projected concentrations of fluoride in groundwater because fluoride is assumed to reach a maximum concentration in the vadose zone[a] due to solubility constraints (see Section 4.2.2). Therefore, any additional fluoride would form precipitates rather than dissolving in the groundwater. The calculated inventory of nitrogen is thought to be conservative because it includes nitrogen actually present as ammonia in addition to nitrogen in its regulated form, nitrate.

4.1.2 Radionuclide Inventory

The radionuclides addressed in this long-term PA are only those that have significant half lives and significant environmental impacts. Using the concentrations listed in Table 3.2, the total curies in PSW grout were calculated as shown in Table 4.4. The calculations are based on 24,500 cubic meters of

TABLE 4.4. Radionuclides in PSW Grout[a]

Radionuclide	Sulfate, Ci	Phosphate, Ci	Sandfilter Backwash, Ci	Total Ci	Concentration in Grout, Ci/m^3
Carbon-14	2.4×10^{-6}	6.8×10^{-1}	1.0×10^{-11}	6.8×10^{-1}	1.2×10^{-5}
Cobalt-60	4.9×10^{1}	1.9×10^{3}	7.4×10^{2}	2.7×10^{3}	4.8×10^{-2}
Strontium-90	8.1×10^{2}	2.5×10^{-3}	3.4×10^{-3}	8.1×10^{2}	1.4×10^{-2}
Technetium-99	9.8×10^{-2}	4.5×10^{-2}	5.1×10^{-5}	1.4×10^{-1}	2.6×10^{-6}
Iodine-129	1.7×10^{-6}	1.2×10^{-8}	7.1×10^{-12}	1.7×10^{-6}	3.1×10^{-11}
Cesium-137	1.2×10^{3}	1.1×10^{1}	4.6×10^{1}	1.3×10^{3}	2.3×10^{-2}
Uranium-238	2.7×10^{-2}	2.0×10^{-4}	1.3×10^{-9}	2.7×10^{-2}	4.8×10^{-7}
Plutonium-239	5.9×10^{0}	5.9×10^{-2}	1.2×10^{-4}	5.9×10^{0}	1.1×10^{-4}
Americium-241	8.1×10^{-3}	1.4×10^{-1}	7.4×10^{-4}	1.5×10^{-1}	2.6×10^{-6}

(a) 5.66×10^4 m^3 of disposed grout. Source: U.S. DOE 1986(a).

(a) The vadose zone is the unsaturated region of soil between the ground surface and the water table.

9 0 1 1 7 8 6 1 8 6 7

sulfate waste, 11,400 cubic meters of phosphate waste, and 1,200 kilograms of sandfilter backwash. The final concentrations are also based on the current projection of 5.66×10^4 cubic meters of grout at final disposal.

Radionuclides could also be present in fly ash, one of the dry grout-forming solids. Measurable levels of potassium-40 and radium-226 are known to be present in certain certain fly ashes (up to 26 pCi/g of ^{40}K and up to 10 pCi/g of ^{226}Ra), as reported by the Electric Power Research Institute (EPRI 1983). However, we did not attempt to quantify the radiological contribution, if any, from Centralia fly ash in this analysis. A radiochemical assay of Centralia fly ash is planned, and if the activity is found to differ significantly from that naturally present in soil, the results could be used to modify this analysis.

4.2 RELEASE OF WASTE FROM GROUT MONOLITH

Release from the grout monoliths was modeled in two ways dependent upon the chemical speciation of the contaminant under consideration. Contaminants that are not limited by solubility constraints were modeled as being released at a constant rate while the less soluble contaminants were assumed to be released according to their solubility limits and the annual volume of water available for transport. The subsequent transport of the contaminants in the vadose zone and in the groundwater is described in Chapter 5.0.

4.2.1 Constant-Release Model

Contaminant movement downward from the PSW grout disposal site was modeled as constant across a horizontal cross-section beneath the disposal site. This implies a uniform release per horizontal area of soil in the grout site. We assume that the grout monoliths are uniformly spaced throughout the grout site, and that the composition of each monolith is the same. For the soluble contaminants, the release rate for each monolith is modeled as a single constant value, unaffected by the water flow rate or water chemistry. The constant release continues until the total radionuclide and chemical inventory in the monolith has been leached.

Calculating the Period of Total Release

The model calculations use 10,000 years as the release time interval for release of all radionuclides and chemicals from a PSW grout monolith (with the exception of those chemicals with solubility-controlled releases). This release interval was calculated using laboratory data from PNL leaching experiments conducted on small PSW grout cylinders. The following equation, which is supported by the American Nuclear Society (ANS 1984), describes a fractional release from cylindrical monoliths that is controlled by diffusion of contaminants through the grout (Huizenga et al. 1986):

$$FR = 2\ (A/V)\ (D_e\ t/\pi)^{1/2} \qquad (4)$$

where FR = fraction released
A = geometric surface area of the cylinder (cm^2)
V = geometric volume of the cylinder (cm^3)
D_e = effective diffusion coefficient of the contaminant in grout (cm^2/sec)
t = time (sec)

It is assumed that the contaminants are initially homogeneously dispersed in the cylinder, so that the release rate of any contaminant from any part of the surface of the cylinder is the same. It is also assumed that the release from a cylinder of finite size can be approximate by the release from a semi-infinite slab (which never completely depletes), and that the leached contaminants are swept away rapidly such that the solution concentration at the grout surface is always zero for each contaminant. These assumptions maximize the concentration gradient between the monolith and the surrounding soil, and, as a result, maximize the projected rate of diffusional release.

Data from the PNL laboratory studies (Serne et al. 1986) were plotted as fraction released versus time, and a value for the effective diffusion coefficient (D_e) was estimated from a best fit of Equation (4) to the data. A D_e value of approximately 10^{-9} cm^2/sec was obtained for the most mobile species. It was then assumed that the model could be applied to release of contaminants from buried grout monoliths by using the same D_e and scaling the time axis based on differences in the surface-area-to-volume ratio of the two grout

matrices. The surface-area-to-volume ratio for the large monolith (10.4 m x 15.24 m x 38.1 m) is 3.8×10^{-3} cm^{-1}.

Although the geometry of the lab tests differs from that of the actual monoliths, (elongated rectangles rather than cylinders), scaling diffusional release based on the surface-area-to-volume ratio has been shown to be a close approximation when less than 20% of the total inventory has been released. As discussed below, the release rates in this PA were based on the fraction released during the first 70 years after disposal. This fraction is 0.7%, which is significantly below the 20% upper bound. Contaminant release that is controlled strictly by diffusion is not constant with time; rather, it is faster at the beginning of release when the concentration gradient is the highest. For this PA, the release rate was based on an estimation of the amount of a contaminant that would be released from a grout monolith during a person's average lifetime (70 years). Because the concentration gradient is highest initially, the fastest release would occur during the first 70 years after disposal.

The rate of contaminant release was estimated by using Equation (4) with a D_e of 10^{-9} cm^2/sec and a surface-area-to-volume ratio for the large grout monolith of 3.8×10^{-3} cm^{-1}. As mentioned above, the total amount of contaminant that would be released by diffusion in the first 70 years is approximately 0.7% of the inventory. This 70-year average release rate was used to extrapolate a constant release curve from zero to the 100% released limit (FR = 1) as shown in Figure 4.1. This limit was reached at approximately 10,000 years. (The initial parts of the curves are not drawn to scale, in order to show the detail at the 70-year point.) Throughout this analysis, an average release rate of approximately 0.01% per year was assumed, based on the initial 70-year time period of diffusioned release.

Release Rate and Monolith Cracking

The assumed constant release rate does not take into account a change in the rate of release caused by cracking of the grout monolith. It is difficult to project how cracking may affect contaminant migration. Models can be postulated to project how cracking may be detrimental or beneficial. For example, impedances to contaminant diffusion may develop as a result of dry

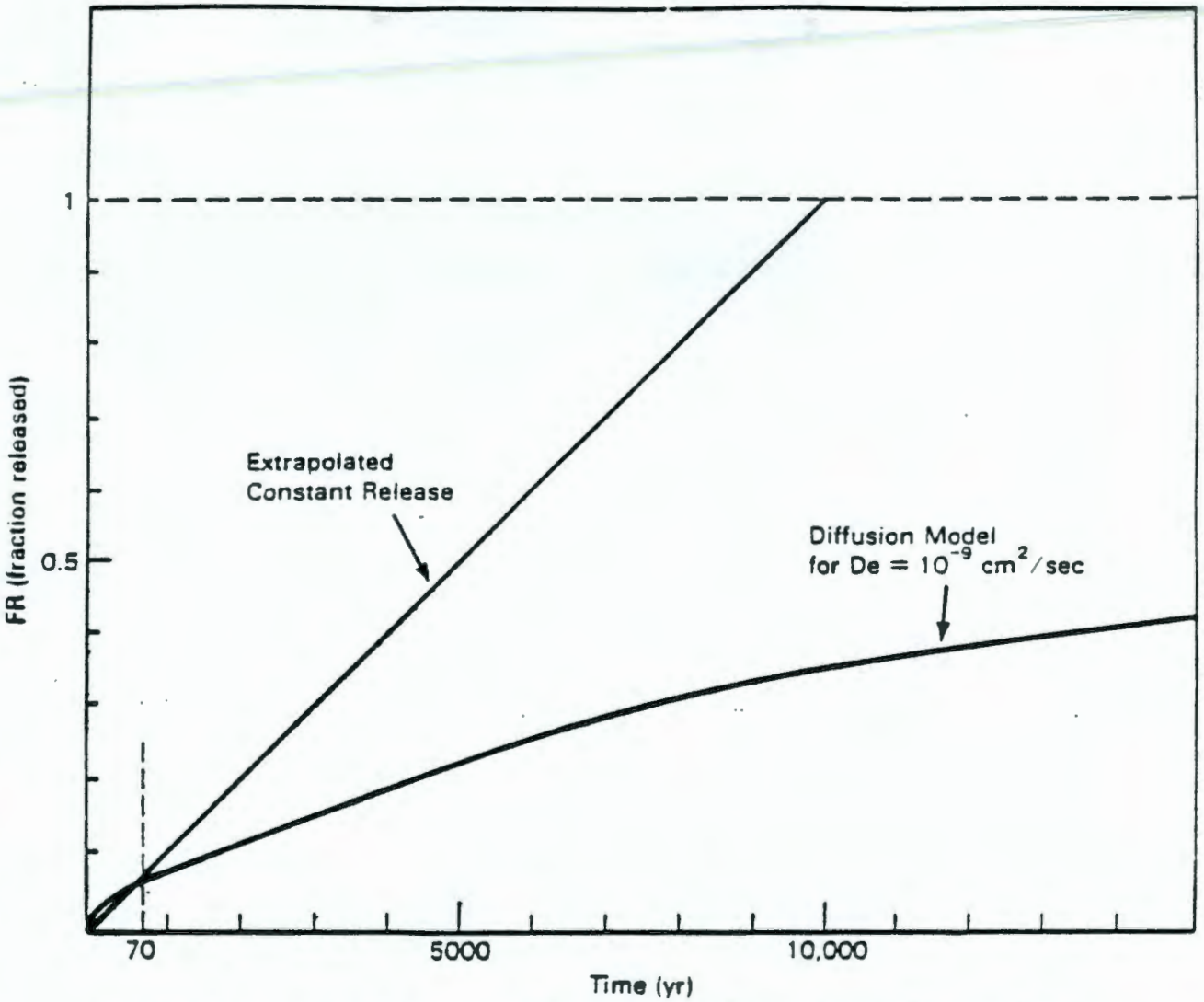


FIGURE 4.1. Scaled Curve of Fraction of Contaminant Released from Grout Monolith as a Function of Time, Showing Extrapolation Method for Constant Release Approximation

inner cracks within the monolith. On the other hand, if water were to penetrate the grout vault and flow between the cracks, migration of contaminants would be enhanced because leach rates are directly related to the surface-area-to-volume ratio. Preliminary leach tests performed on crushed grout samples indicate a disproportionately low rate of release based on scaling up Equation (4) by the surface-area-to-volume ratio (Serne et al. 1986). At this point, it is not possible to ascertain the reason for this anomaly. The boundary conditions of the crushed grout experiments are not consistent with

those used when developing Equation (4); therefore, it is not strictly a valid expression for describing release from the crushed grout by passive diffusion. Another possible explanation for the lower-than-expected release of contaminants from crushed grout is that release is not strictly caused by passive diffusion in the grout pore water. It is possible that chemical reactions occur on the internal surfaces of the grout or in the pore water, thus altering contaminant transport. Such chemical reactions have been evidenced by the presence of a heavy calcium carbonate precipitation on the crushed grout samples. Studies are continuing in an attempt to validate models that predict release in cases where the waste form is stressed and cracked. As this information becomes available, it can be used to update this and future analyses.

4.2.2 Solubility-Controlled Release

Solubility constraints are expected to limit the rates of release of certain chemical contaminants from the grout matrix to the water in the vadose zone. To determine which of the chemicals in PSW grout are solubility-controlled, site-specific parameters of the soil pore water outside of the grout vaults were used as input to the geochemical computer code MINTEQ (Felmy, Girvin and Jenne 1984). Based on the results, ten of the PSW chemical species regulated in WAC-248-54 (WAC 1985) were assumed to have solubility-controlled release rates: barium, cadmium, chromium, copper, iron, lead, manganese, silver, fluoride, and zinc. The solubility limits (maximum predicted concentrations in the vadose-zone water) and underlying parameters are shown in Table 4.5.

Concentrations of these elements in the groundwater system were estimated to be at their maximum solubilities in the vadose-zone water. Then, as contaminants in the soil water percolated downward and mixed with water flowing in the unconfined aquifer beneath the PSW grout disposal site, concentrations of contaminants were reduced by the dilution.

TABLE 4.5. Solubility-Limited Concentrations as Calculated by MINTEQ

Element	Controlling Solid	Maximum Predicted Concentration, mg/L
Manganese	$MnHPO_4$	0.02
Iron	$Fe_3(OH)_8$	0.025
Chromium	$Cr(OH)_3$	0.09
Copper	CuO (tenorite)	0.06
Barium	$BaSO_4$ (barite)	0.04
Zinc	Zn_2SiO_4 (willemite)	0.02
Cadmium	$CdCO_3$ (otavite)	0.002
Silver	AgCl (cerargyrite)	0.075
Lead	$PbCO_3$ (cerussite)	0.29
Fluoride	CaF_2 (fluorite)	2.04

Assumed Parameters

pH, 8.1
Eh, 295 mV
Potassium, 7.8 mg/L
Sodium, 25 mg/L
Magnesium, 14.4 mg/L
Calcium, 56 mg/L
Chloride, 22 mg/L
Sulfate, 85 mg/L
H_4SiO_4, 54 mg/L
total carbonate, 86 mg/L

5.0 TRANSPORT OF CONTAMINANTS VIA GROUNDWATER

This chapter presents the conceptual model of the groundwater scenario, and describes the mathematical theory on which it is based. Numerical values of input parameters required by the model are presented, as well as assumptions and approximations that were made when actual physical data was unavailable. Section 5.1 gives an overview of the model. Sections 5.2 and 5.3 explain the two submodels used to simulate the groundwater scenario: water flow and contaminant transport in the vadose zone and in the unconfined aquifer, respectively.

5.1 GROUNDWATER SCENARIO--OVERALL CONCEPTUAL MODEL

Figure 5.1 illustrates the overall conceptual model for the groundwater scenario. In this scenario, impacts to members of the general public are postulated to occur through the following pathway: contaminants (mobile radionuclides and nonradioactive regulated chemicals) migrate out of the grout vaults over a period of time. No credit is taken for vault containment. The contaminants are assumed to enter the soil solution (moisture present in the soil) by the mechanisms described in Section 4.2. The contaminants then move downward through the vadose zone to the unconfined aquifer beneath the grout site.[a] Some radionuclides sorb to the porous materials in the ground and decay into insignificant quantities as they move downward. Solubility-limited chemicals are postulated to exist in their maximum concentrations in the vadose zone. Upon entering the unconfined aquifer, the radionuclides and chemical contaminants move into the groundwater that is flowing under the grout site. The contaminants are modeled as migrating along with the groundwater as it moves past the location of a hypothetical well and then finally on to the Columbia River.

(a) Contaminants in this scenario are assumed to have vapor pressures so low that vapor phase transport is negligible. The scenario further assumes that there are no mechanisms by which contaminants may migrate upward and be lost to the atmosphere through volatilization, or be removed from the site by soil erosion or water runoff. Exposure via a direct air pathway is addressed, however, by the inadvertent intrusion scenarios described in Chapter 6.0. The impacts resulting from inhalation of resuspended contaminants that were mixed directly with the soil are expected to be bounded by the scenarios in Chapter 6.0.

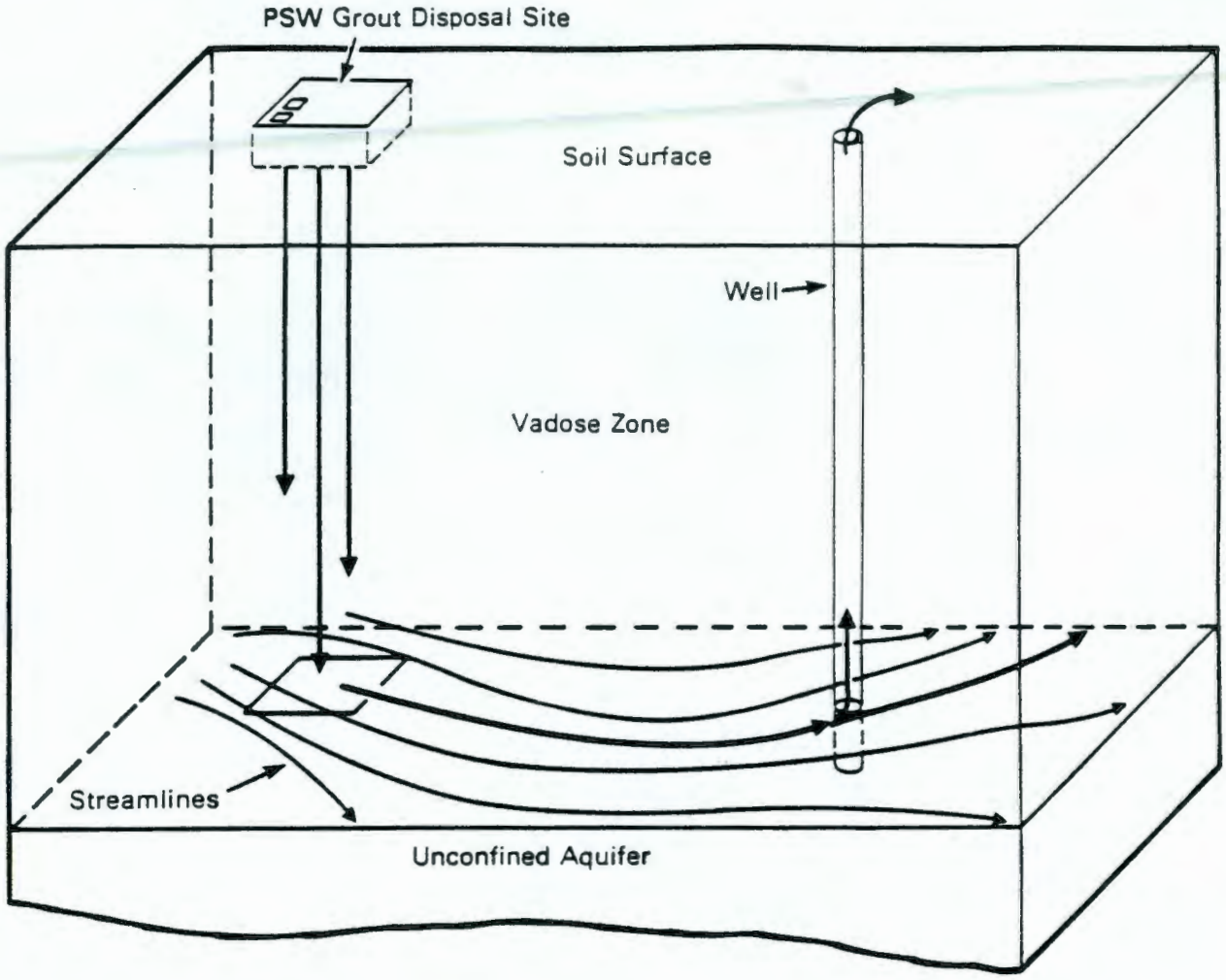


FIGURE 5.1. Conceptual Model for Contaminant Migration

As a basis for evaluating long-term performance, concentrations of regulated nonradioactive chemical species are compared to drinking water standards in Section 5.4 at both the groundwater well and in the Columbia River. To measure the long-term radiological impacts, exposure to the public is calculated based on ingesting the contaminated water from the hypothetical well, either through drinking the water directly from the well, or through eating crops and animals that were irrigated/fed with the contaminated water. Additionally, exposure is calculated (Section 6.3) as a result of drinking or using hypothetically contaminated Columbia River water.

5.2 MIGRATION THROUGH THE VADOSE ZONE

Water flow and contaminant transport through the vadose zone are simulated by two models that are separate but linked. The details and assumptions of each are discussed separately.

5.2.1 Water Flow Through the Vadose Zone

This section describes the vadose zone model and explains how values were calculated for the model parameters (e.g., physical properties of the vadose zone and the travel time of water through the zone).

The vadose zone below the future grout site is assumed to be composed of several horizontal layers of different thicknesses that have abrupt interfaces. Preliminary investigations of the vadose zone near the future grout site (observations of stratified soil columns) indicate that a vertical variation in soil properties does exist, and a number of distinct regions were identified. Figure 5.2 illustrates this conceptual model of the vadose zone. The properties of each layer (e.g., water content, hydraulic conductivity as a function of water content, sorption distribution coefficient) are assumed to be homogeneous throughout each layer. However, different layers may have different properties.

Water movement through the vadose zone is assumed to be steady-state, one-dimensional (vertically downward), and described by Darcy's law for unsaturated flow driven by a unit hydraulic gradient (i.e., other forces are assumed negligible compared to gravitational forces). Thus, the water flux (equal to the recharge rate for our considerations) is equal in magnitude to the hydraulic conductivity

$$q = K(\Theta) \tag{5}$$

where q = magnitude of steady-state water flux (recharge rate)

Θ = water content

$K(\Theta)$ = hydraulic conductivity at water content Θ

Because the water flux is assumed constant throughout all layers of the vadose zone, it follows from Equation (5) that the hydraulic conductivity of

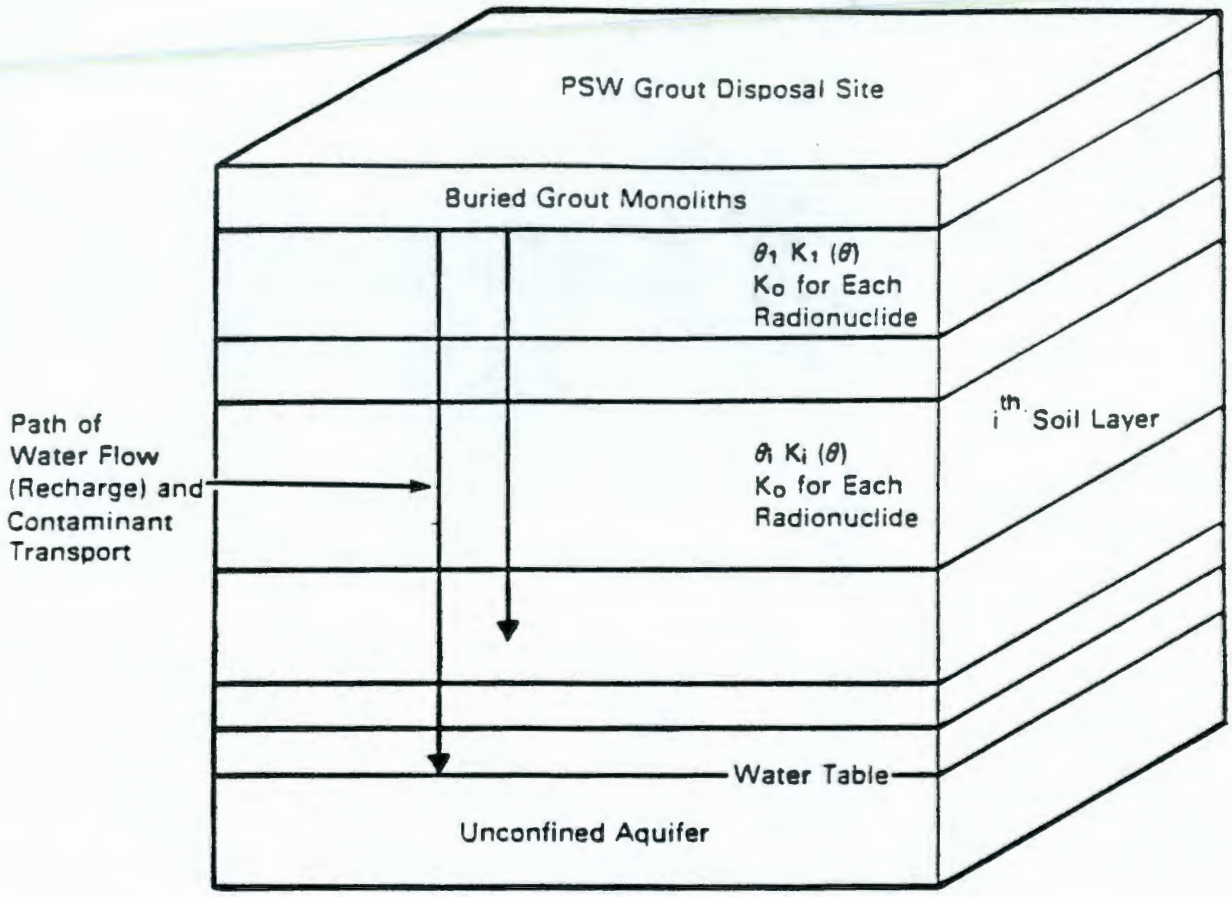


FIGURE 5.2. Conceptual Model of the Vadose Zone and Associated Water Flow and Contaminant Transport

all layers must be the same. If the layers have different hydraulic properties, the water content of a given layer must have a value (Θ_i for the ith layer) such that

$$K_i(\Theta_i) = q \qquad (6)$$

where $K_i(\Theta)$ is the hydraulic conductivity function for the ith soil layer.

The travel time of water through a given layer is calculated as the layer thickness divided by the average pore water velocity. The average pore water velocity is calculated as the water flux divided by the average water content.

The total travel time for water through the entire vadose zone is calculated by summing the travel times through individual layers:

$$t_w = \sum_{i=1}^{n} t_{wi} = \left(\sum_{i=1}^{n} \theta_i(q)\, T_i\right)/q \qquad (7)$$

where t_w = total travel time of water through vadose zone
t_{wi} = travel time of water through the ith layer
n = number of soil layers
T_i = thickness of the ith soil layer

and where the water content of the ith layer has been written to show that it depends of the water flux, q. Unstable flow and viscous "fingering" caused by the abrupt layer interfaces or by preferential paths through the porous media are assumed not to occur.

The number of soil layers and the corresponding thicknesses used in the calculations of water travel time were taken from a hypothetical soil profile thought to be representative of the stratification at a location under the grout disposal site. This representative soil profile was generated by interpolating data (Fecht, Last and Marratt 1979) from soil profiles (extending to the water table) taken below the 216-A-8 and 216-A-37 cribs, which are located on the north and south sides of the 241-AP tank farm and the grout disposal site. Figure 5.3 is a schematic diagram of this stratified column.

Hydraulic conductivity functions (factors that affect the rate of water flow) for materials in these layers were not available. Instead, the hydraulic conductivity functions were estimated by assuming that they would be the same as those for materials with similar particle sizes and geologic soil types. Particle size distributions, saturated hydraulic conductivities, and water retention characteristics had been previously determined for six soil samples taken from a 15-m-deep excavation at the 241-AP tank farm at the Hanford Site. One sample was taken from each major horizon observed in this excavation. A textural description of these samples is given in Table 5.1. These data were used to obtain approximate hydraulic conductivity functions for model calculations.

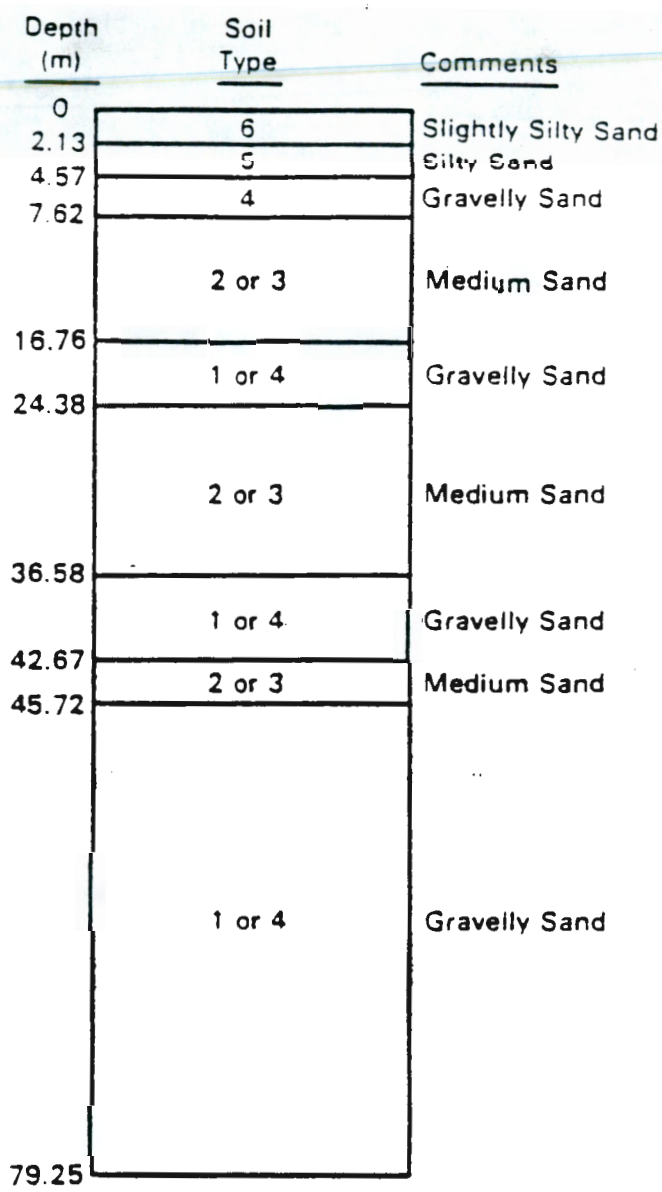


FIGURE 5.3. Schematic of Soil Profile Identifying Soil Types Using Available Data

Figure 5.3 shows which of the six 241-A soil samples were used to approximate the properties of each layer.

Table 5.2 presents the soil profile data used to generate Figure 5.3 along with the travel times to the unconfined aquifer through various combinations of soils. The numbers under columns A to D represent the combinations of soil types selected to represent each layer. By using predominantly

TABLE 5.1. Textural Description of Soil Samples Collected from 241-AP Tank Farm Excavation

Soil Sample Number and Type		Description
1	Sandy gravel	Unconsolidated, horizontally bedded, very coarse sand with very fine to very coarse pebbles
2	Sand	Well-consolidated, horizontally bedded, medium to coarse sand
3	Sand	Horizontal beds of well-consolidated fine to medium sand, to coarse sand
4	Gravelly sand	Very unconsolidated coarse sand with pebbles and small cobbles
5	Silty sand	Very well-consolidated horizontally bedded, very fine sand and silt
6	Slightly silty sand	Fine to very fine sand loess

coarse or fine media, one can establish bounds on the travel times associated with the uncertainty due to soil types. The data below 15 m were used to determine the travel time from the level of the proposed grout monoliths to the water table. The distance from the bottom of the monoliths to the water table was 64 meters. The travel times listed at the bottom of columns A through D are considered representative of the existing soil column. No major fine sand, silt, or clay layers were indicated above the water table in the stratigraphic cross sections beneath the 216-A-8 and 216-A-37 cribs in the 200-East Area. However, to show the effect of a fine sand layer (such as occurs at the surface), a 3.05-m thick layer was included in columns E and F. The resultant travel time of column E should be compared to that of column D, and the travel time of column F should be compared to column A. These results indicate that for a 5.0 cm/yr steady-state recharge rate, minimum and maximum travel times are 99 and 143 years, respectively. These are the lower and upper bounds of the travel times for these soil data; other soil combinations will result in travel times that fall between these times. An infiltration rate of 0.5 cm/yr results in minimum and maximum travel times of 784 and

TABLE 5.2. Soil Profiles to the Water Table and Travel Times Through a 64-m Depth

Depth from Top to Bottom of Layer, m	Thickness of Layer, m	Soil Assignments A	B	C	D	E	F
15.25 to 16.76	1.51	3	2	3	2	2	3
16.76 to 24.38	7.62	1	1	4	4	4	1
24.38 to 36.58	12.20	3	2	3	2	2	3
36.58 to 42.67	6.09	1	1	4	4	4	1
42.67 to 45.72	3.05	3	2	3	2	6[a]	6[a]
45.72 to 79.25 (water table)	33.53	1	1	4	4	4	1
Travel time in years							
for q = 5.0 cm/yr		99	118	124	143	149	109
for q = 0.5 cm/yr		784	936	957	1110	1166	862

(a) Substituted fine layer.

1,110 years, respectively. For calculations in this report, 925 and 100 years were selected as the travel times to be used in the transport model for the 0.5 and 5.0 cm/yr recharge rates, respectively.

5.2.2 Contaminant Transport Through the Vadose Zone

Contaminant transport through the vadose zone was modeled using the TRANSS solute transport code (Simmons, Kincaid and Reisenauer 1986). This code models one-dimensional, vertical transport of contaminants by an analytical solution of the convection-dispersion equation, including first-order radioactive decay and linear equilibrium sorption, and assuming a local-scale dispersion coefficient.

The remainder of this section describes the process for determining the quantity of each radionuclide that is sorbed within the layers of the vadose zone, and consequently, how long it takes sorbed radionuclides to travel through the vadose zone.

The linear equilibrium sorption coefficient (distribution coefficient), K_d, for a given radionuclide is assumed to be constant in all soil layers and for any water chemistry and flow rate. Specifically, this implies that when

several radionuclides are migrating simultaneously, the sorption of any one of them is still governed by its individual K_d value (i.e., there is no competitive sorption). Because the K_d value for a specific radionuclide depends on the chemical species in which the radionuclide occurs, this implies that the radionuclide exists in only one form.

Numerical values of K_d for each radionuclide, with the exception of strontium-90, were taken from a study related to single-shell tank contents (Delegard and Barney 1983). The composition of the liquid waste containing the radionuclides included organic complexants, and so the K_d values calculated from this study would be different than the K_d values for the radionuclides leaching from grout along with the primarily aqueous PSW constituents. Because the presence of organic complexants should act to reduce K_d values, it is conservative to use the values from the single-shell tank study. In addition, the salt content of single-shell tank liquid is much higher than that in the grout leachate, and higher salt content often translates into a lower K_d. Because of the lack of specific data on sorption of non-radioactive hazardous chemicals, K_d values for all non-radioactive hazardous chemicals were assumed to be zero.

The K_d value for strontium-90 was experimentally determined by leaching simulated PSW grout and running a batch K_d test with leachates that contained strontium-90. The values measured were approximately 91 and 31 (Serne et al. 1986). In this PA, a K_d of 31 was used. There is no effective difference between using a K_d of 31 or 91, because with either K_d value, the strontium-90 decays to an insignificant quantity while traveling in the vadose zone.

Sorption tends to retard the movement of solution-phase chemicals in time relative to the travel time of water (t_w). In the assumed theory, mean travel times for sorbed chemicals can be related to the water travel time, t_w, by

$$t_c = R\ t_w = (1 + \rho_b K_d/\theta)\ t_w = [1 + \rho_p(1 - \theta_s)K_d/\theta]\ t_w \qquad (8)$$

where t_c = travel time of the contaminant
R = retardation factor
ρ_b = bulk density of the porous material

ρ_p = average particle density of the soil solids
θ_s = saturated water content (equal to the porosity)

As stated above, the K_d value for a given contaminant is assumed constant for all soil layers; however, because the bulk density and water content differ between layers, the retardation factor will be different for each layer. Because using a different retardation factor for each layer would complicate the calculations (and because there is disagreement on the proper water content value to use in calculations of advective transport in unsaturated soils), a conservative constant value of R was used. In this case, the conservative approximation is the one that results in the fastest movement of the contaminant through the vadose zone; namely, the approximation that results in the smallest value of R. According to the determination of R given in Equation (8), this smallest value of R is achieved if the largest value of water content is used, i.e., the saturated water content.

The mean travel time of a radionuclide through one layer (the ith layer), t_{rni}, is given by $t_{rni} = R_i t_{wi} = [1 + \rho_b K_d/\theta_i]\, t_{wi}$, according to Equation (8). Furthermore, the mean total travel time of a radionuclide through the vadose zone, t_{rn}, is given by

$$t_{rn} = \sum_{i=1}^{n} R_i t_{wi} = \sum_{i=1}^{n} (1 + \rho_b K_d/\theta_i)\, t_{wi} \qquad (9)$$

If, as argued above, we assume that $\theta_i = \theta_s$ for all layers, R_i becomes a constant for all layers and we have

$$t_{rn} = R \sum_{i=1}^{n} t_{wi} = R t_w = (1 + \rho_b K_d/\theta_s)\, t_w \qquad (10)$$

Here, t_{rn} represents the conservative approximation of the mean total travel time of the radionuclide. Because K_d has been assumed to be zero for non-radioactive hazardous chemicals, R_i would equal one, and the mean total travel time for these chemicals would just be equal to t_w. Note that the travel times as calculated are mean travel times, not actual ones. Several phenomena

(e.g., dispersion) will create a range in actual travel times of contaminant molecules moving through the vadose zone, rather than a single constant travel time for all molecules.

Table 5.3 presents half-lives, K_d values, retardation factors, and vadose zone radionuclide travel times for each significant radionuclide and for two recharge scenarios. The climate of the site, soil characteristics, and vegetation affect the rate at which meteoric water percolates deep enough into the vadose zone to become recharge to the aquifer and carry contaminants to the unconfined aquifer. To quantify the effect of the groundwater recharge rate on the performance of the grout disposal system, two average annual recharge rates were analyzed. Values of 0.5 and 5.0 cm/yr were chosen to "bridge" expected recharge rates under drier and wetter conditions at the disposal site. The lower end of this range represents recharge rates considered to be typical of present-day dry climatic conditions (15 cm/yr precipitation), while the upper end represents a hypothetical wetter climate (30 cm/yr precipitation) (Kirkham and Gee 1983).

TABLE 5.3. Radionuclide Travel Times in the Vadose Zone for Recharge Rates of 0.5 and 5.0 cm/yr

Nuclide	Half-life, yr	Distribution Coefficient (K_d)	Retardation Factor (R)[a]	Radionuclide Travel Time, yr	
				0.5 cm/yr Recharge	5.0 cm/yr Recharge
Carbon-14	5.7×10^3	0	1	925	100
Strontium-90	2.8×10^1	31[b]	170	157,000	17,000
Technetium-99	2.1×10^5	0	1	925	100
Iodine-129	1.6×10^7	0	1	925	100
Uranium-238	4.5×10^9	0	1	925	100
Plutonium-239	2.4×10^4	21[c]	115	106,000	11,500
Americium-241	4.3×10^2	5.6[c]	31.5	29,000	3,150

(a) Assuming $\Theta_s = 0.33$ and $\rho_b = 1.8$ g/cm^3.
(b) Serne et al. (1986).
(c) Delegard and Barney (1983).

9011178618 84

5.3 MIGRATION THROUGH THE UNCONFINED AQUIFER

As with the vadose zone, water flow and contaminant transport through the unconfined aquifer were simulated by two models that are separate but linked. The details and assumptions of each are discussed separately.

5.3.1 Water Flow Through the Unconfined Aquifer

Water flow through the unconfined aquifer was modeled using the VTT groundwater flow code. Details of the theory, assumptions, and limitations of this code are given in the draft environmental impact statement (EIS) for the disposal of Hanford defense waste (U.S. DOE 1986b), as well as in the code documentation report (Reisenauer 1979a,b,c).

The code determines kinematic pathlines and streamtubes for two-dimensional, steady-state, vertically averaged water flow in an aquifer of variable thickness. The aquifer is also assumed to be isotropic (the hydraulic conductivity or transmissivity at a point does not depend on the direction of water flow at that point) and horizontally heterogeneous (with respect to saturated hydraulic conductivity or transmissivity). The water flow model in VTT is based on the Boussinesq equation for incompressible fluid flow through a saturated, rigid porous media with a free-surface boundary condition. Vertical velocities, flow in the capillary fringe, and seepage between aquifers are assumed negligible. The numerical solution algorithm uses a finite difference approximation to the differential equation of flow, and solves the resulting set of algebraic equations with a Newton iteration technique.

Figures 5.4 and 5.5 show groundwater contours and streamlines near the 200-Area waste sites, as calculated by VTT, using recharge rates of 0.5 and 5.0 cm/yr, respectively (U.S. DOE 1986b).

Obtaining Values for the Transmissivity Field

The model assumes a spatially varying transmissivity field that is piecewise constant with transmissivity values constant over a finite region associated with each node. Numerical values representing the transmissivity field, which are required as inputs to the model, were obtained by calibrating the model with data of water potential surface for the unconfined aquifer. These data were collected during periods of Hanford Site operations, and

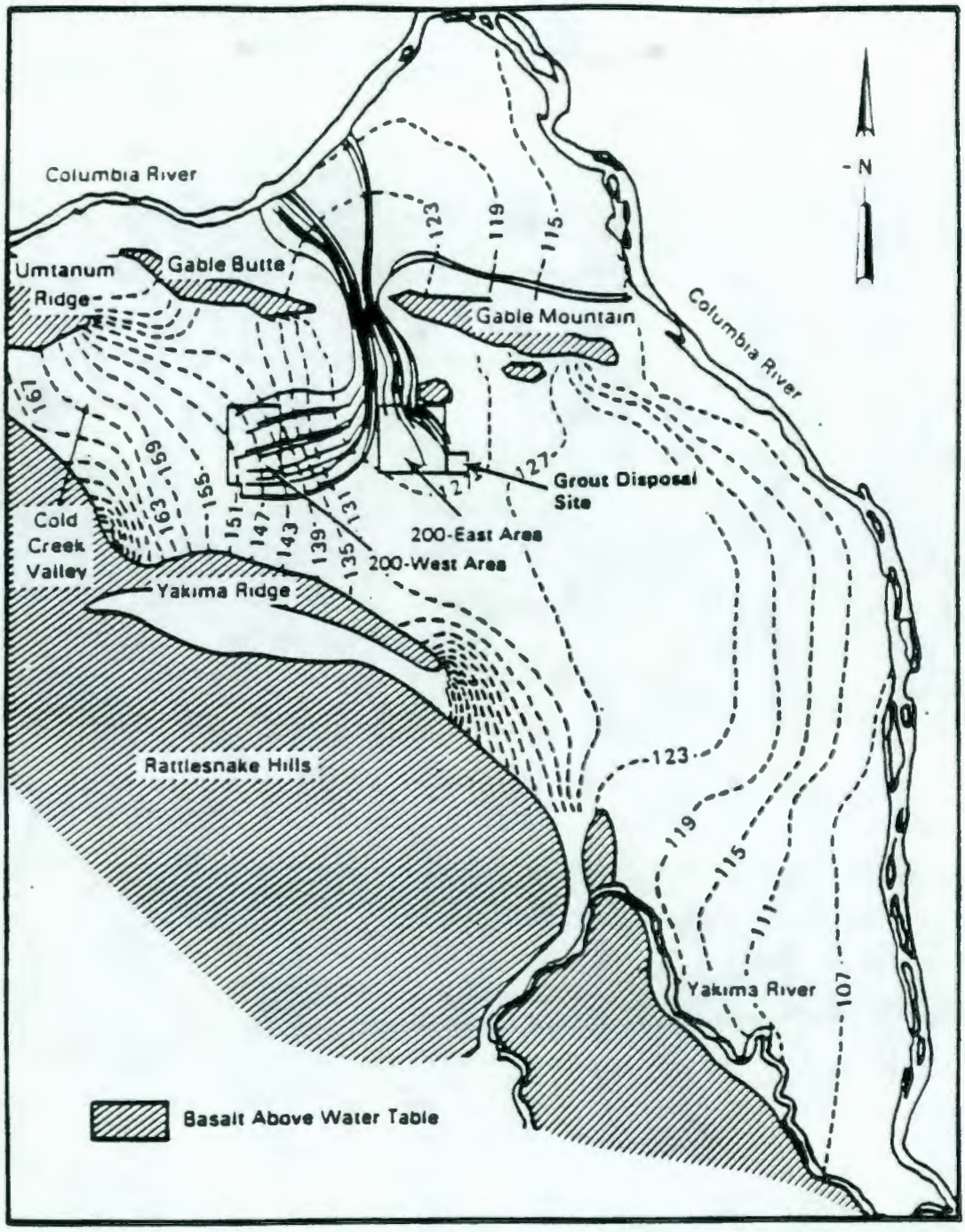


FIGURE 5.4. Simulated Groundwater Contours (in meters above mean sea level) and Streamlines from the 200-Area Plateau, 0.5 cm/yr Recharge Rate

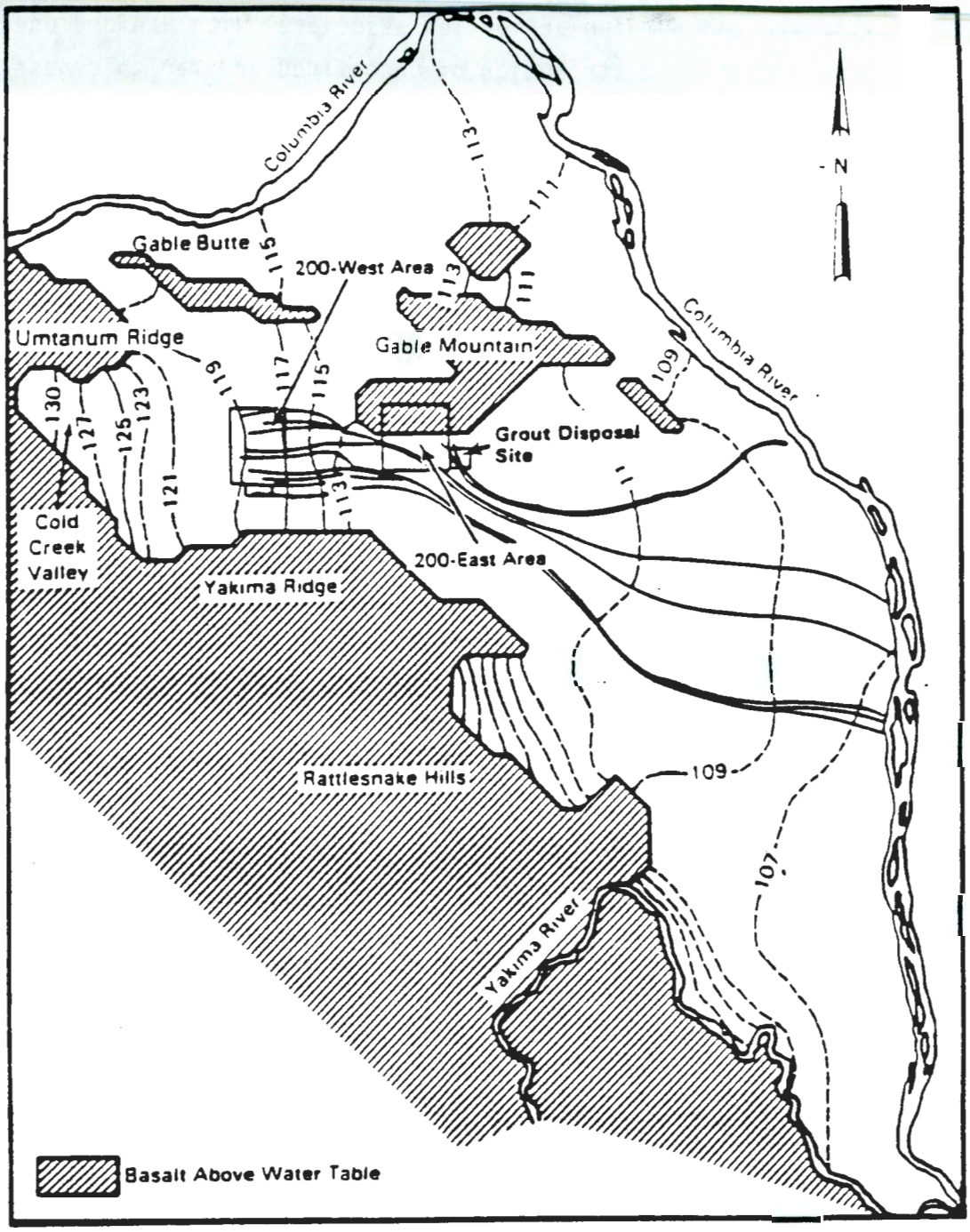


FIGURE 5.5. Simulated Groundwater Contours (in meters above mean sea level) and Streamlines from the 200-Area Plateau, 5.0 cm/yr Recharge Rate

therefore represent water table elevations that have been affected by various water infiltration and pumping activities associated with Hanford operations. Knowledge of the spatial distribution of unconfined aquifer thickness was used to obtain values of vertically averaged, saturated hydraulic conductivity from these calibrated transmissivity values. These resulting values of hydraulic conductivity were used in the VTT model for the simulations of the groundwater contours shown in Figures 5.4 and 5.5. In other words, each value of transmissivity required as input to VTT was obtained as the product of a value of the aforementioned hydraulic conductivity field and the not-yet-calculated thickness of the aquifer at that location. The simulations of the 0.5 and 5.0 cm/yr recharge scenarios have shown that the water table elevations (and hence, the aquifer thicknesses) predicted to exist in these scenarios are not substantially different than the measured elevations that were used for calibration. For this reason, it is assumed that only slight error may exist in predictions of future groundwater flow characteristics (i.e., when the water infiltration and pumping activities associated with Hanford operations have ceased) when using properties obtained by calibration with data taken during periods of Hanford activity.

Calculating the Annual Dilution Volume

Contaminants entering the unconfined aquifer directly below the PSW grout disposal site are assumed to mix with the flowing groundwater. The concentration of contaminants flowing in the groundwater is a function of the rate at which the groundwater flows beneath the disposal site. The greater the volume of water into which the released contaminants are mixed, the lower their concentrations in the groundwater.

There are two hypothetical cases to be considered when calculating the ultimate dilution volume in the unconfined aquifer. In one case, the amount of dilution is calculated as the product of four parameters: 1) the stream-tube intercept width, 2) an assumed mixing depth, 3) the porosity of the aquifer, and 4) the groundwater velocity. These parameters are discussed in detail in the following subsections. The resulting value is used as the annual dilution volume in cases in which the downgradient user of groundwater is assumed to pump less water per year than this dilution volume. In this

9 0 1 1 7 8 6 1 8 8 8

instance, the well is only drawing part of the contaminated water that is passing by, and the conservative assumption is that all of the water drawn is contaminated at a concentration governed by the dilution volume in the aquifer.

The second case occurs when more water is used than the aquifer dilution volume described above. In this case, the conservative assumption is that the well draws in all of the contaminated water passing by. However, to supply the needs of the user, it must also draw in uncontaminated water as well. Therefore, the concentrations of contaminants in the water used are further diluted by the extra uncontaminated water pumped.

Streamtube Intercept Width. Figure 5.1 can be referred to again to illustrate the transport scenario for the unconfined aquifer that is used to calculate the volume of water into which a yearly release of a contaminant mixes. The streamtube intercept is the dimension of the vertical projection of the grout site that is perpendicular to the water flow direction. The smaller the streamtube intercept width, the less dilution occurs. Hence, it is conservative to assume that the intercept is equal to the smallest plan dimension of the grout disposal site. The smallest plan dimension of the PSW grout disposal site, 50 m, is therefore used in the calculations.

Mixing Depth. By the time a contaminant is drawn up into a well, it has mixed downward through a certain depth below the water table. The VTT model is based on a vertically averaged set of equations, hence it does not calculate vertical flow. It is assumed that any well beyond the PSW grout disposal site that may take up water will penetrate the unconfined aquifer with a screened casing extending from the water table to 5 m below it. If the true mixing depth is less than 5 m, uncontaminated water will simultaneously be drawn into the well, and mixing will occur in the well in a manner such that the resulting radionuclide concentration is the same as that calculated by assuming 5 m for the mixing depth. If the true mixing depth is greater than 5 m, the radionuclide is already more dilute at the well than with a 5-m assumed mixing depth, and so this assumption is conservative. The present calculation could be less than conservative if the actual future well had a screen of less than 5 m in length and if the true mixing depth were less than

5 m. However, the 5-m mixing depth was chosen because it is the minimum depth of penetration that would accommodate the submergence necessary for operation of pumps using current technology.

Aquifer Porosity and Groundwater Velocity. The product of the streamtube intercept and the mixing depth gives the cross-sectional area of the aquifer that is perpendicular to the direction of flow (50 m x 5 m = 250 m^2). Multiplying this by two factors--the annual distance of flow of water passing through this area (which is equal to the groundwater velocity when expressed on a per-year basis) and the effective porosity of the soil in this area--gives the annual dilution volume. The velocity of the water passing under the site is assumed to be an average of the velocities across the streamtube, as calculated by the VTT code. This value is 182 or 230 m/yr for recharge rates of 0.5 or 5.0 cm/yr, respectively (U.S. DOE 1986b). To be consistent with past modeling, the effective porosity of the Hanford unconfined aquifer was assumed to be 0.1 (Bierschenck 1959).

Annual Dilution Volume: The Resulting Values. Using the parameter values described above, the annual dilution volume would be 4.6 x 10^3 cubic meters at the recharge rate of 0.5 cm/yr, and 5.8 x 10^3 cubic meters at the recharge rate of 5.0 cm/yr for the case where this volume is greater than that required each year by a downgradient user.

However, the value for the annual dilution volume must be selected to be compatible with the groundwater exposure scenarios. At present, the radiological exposure model assumes that the downgradient user farms a 20,000 m^2 parcel of land with an irrigation rate of 150 L/m^2-month during a 6-month-per-year irrigation period (Napier, Peloquin and Strenge 1986). The groundwater-use exposure scenario requires an annual volume of 1.8 x 10^4 cubic meters per year, which is greater than both values calculated above. Hence, 1.8 x 10^4 cubic meters was used as the annual dilution volume for the radiological exposure analysis presented in Chapter 6.0.

5.3.2 Contaminant Transport Through the Unconfined Aquifer

The VTT water flow model generates pathlines that can be used to represent two-dimensional advective solute transport in the unconfined aquifer.

9011178618900

(For steady-state conditions, these pathlines are the same as the streamlines of water flow.) Contaminants are assumed to enter the unconfined aquifer through an area of the water table that is the vertical projection of the PSW grout field onto the saturated flow field. The contaminants are subsequently transported by the groundwater flowing between the pathlines that enclose the projected area. Figure 5.6 illustrates this scenario. A leached contaminant is assumed to remain entirely within the streamtube bounded by these two pathlines, i.e., no transverse dispersion of radionuclides is assumed. The width of the streamtube is determined by the dimension of the vertical projection of the grout field that is perpendicular to the flow direction. Longitudinal dispersion is assumed to occur solely because of variations in advective velocities and pathlengths associated with pathlines within the streamtube.

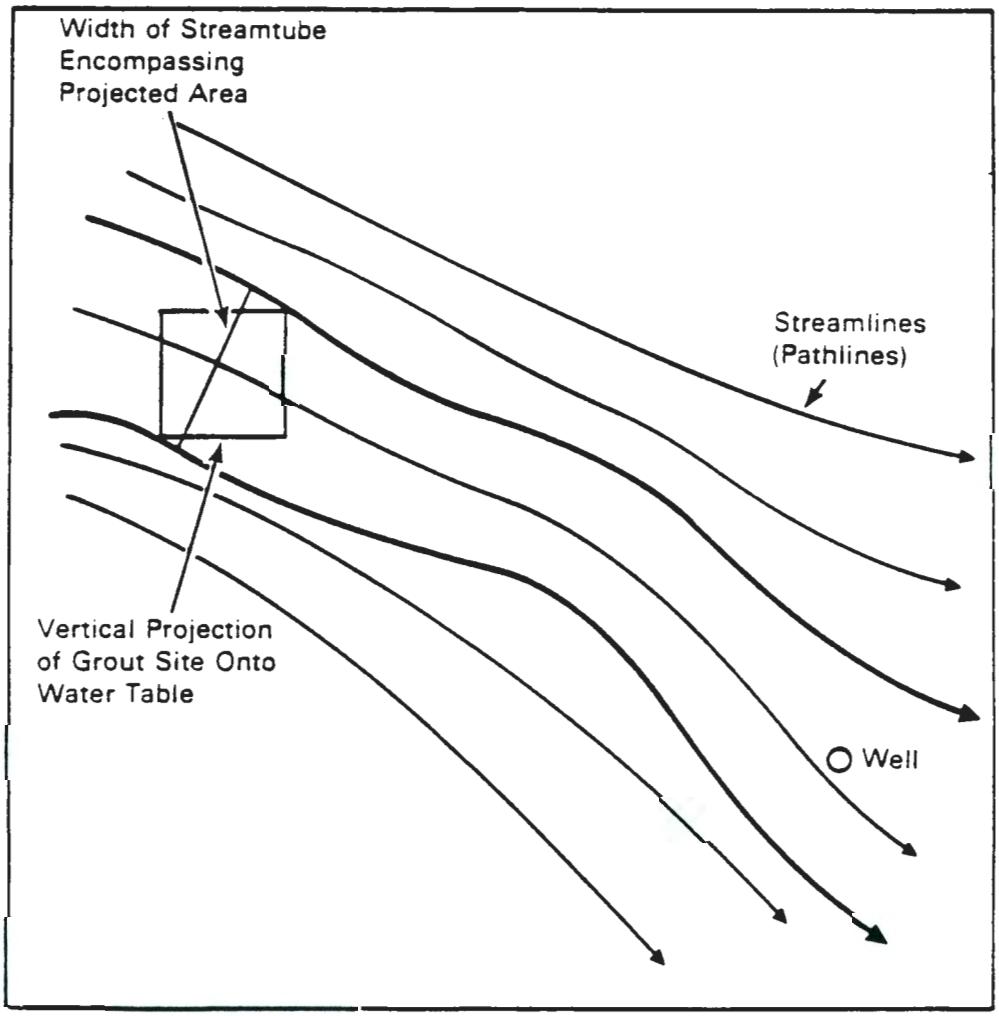


FIGURE 5.6. Conceptual Model for Contaminant Transport in the Unconfined Aquifer Along Water Flow Pathlines

The TRANSS computer code, which was used to model contaminant transport to the vadose zone, was also used to model contaminant transport along the one-dimensional streamtube in the unconfined aquifer. Radioactive decay and sorption are accounted for, and the same K_d values (one for each radionuclide) that TRANSS used for the vadose zone model are used in the unconfined aquifer. The associated assumptions are also the same.

5.4 NONRADIOLOGICAL RESULTS

The long-term ability of the grout disposal system to contain nonradioactive regulated chemicals can be measured by direct comparison to concentration standards at two locations: 1) the hypothetical well located 5 km downgradient from the grout monoliths, and 2) the Columbia River. Chemical concentrations in the well and river, based on the projected inventories and the release and transport assumptions described above, are listed in Table 5.4. The values in Table 5.4 represent incremental increases, which should be added to the existing level of contamination from other sources to obtain the absolute value of the actual contaminant concentration.

As previously mentioned, although the Hanford groundwater does not constitute a public water supply, drinking water limits are listed in Table 5.4 for comparison. All calculated incremental concentrations are below the limits at both the well and the river. The Hanford Reach of the Columbia River is governed by Class A water quality standards for the State of Washington (WAC 1984). These standards do not list specific limits for these inorganic chemicals, but they do include limits on biological waste, turbidity, thermal waste (heat), and aesthetic qualities of the river. The incremental increases of chemicals postulated to occur in Columbia River water as a result of disposed PSW are very low, and will comply with all Class A water quality standards.

Radionuclide concentrations must be translated to resulting doses before being compared to regulatory limits. Therefore the radionuclide concentrations are not listed here, but are used as input for the groundwater exposure scenarios described in Chapter 6.0. The resulting doses are provided in Chapter 6.0, Section 6.3.

9011178618922

TABLE 5.4. Calculated Increase in Concentrations of Regulated Chemicals in a Hypothetical 5-km Well and in the Columbia River, mg/L

	In 5-km Well Water		In Columbia River Water		Washington State Drinking Water Limit[a]
	Recharge Rate, cm/yr				
	0.5	5.0	0.5	5.0	
Primary Contaminants[a]					
Arsenic	2×10^{-2}	1×10^{-2}	7×10^{-10}	7×10^{-10}	0.05
Barium	6×10^{-4}	4×10^{-3}	3×10^{-11}	2×10^{-10}	1.0
Cadmium	3×10^{-5}	2×10^{-4}	1×10^{-12}	1×10^{-11}	0.01
Chromium	1×10^{-3}	1×10^{-2}	4×10^{-11}	6×10^{-10}	0.05
Fluoride	3×10^{-2}	2×10^{-1}	1×10^{-9}	1×10^{-8}	2.0
Lead	4×10^{-3}	3×10^{-2}	2×10^{-10}	2×10^{-9}	0.05
Mercury	1×10^{-4}	9×10^{-5}	5×10^{-12}	5×10^{-12}	0.002
Nitrogen	3×10^{-1}	3×10^{-1}	1×10^{-8}	1×10^{-8}	10.0
Selenium	1×10^{-3}	8×10^{-4}	5×10^{-11}	5×10^{-12}	0.01
Silver	1×10^{-3}	8×10^{-3}	4×10^{-11}	5×10^{-10}	0.05
Secondary Contaminants[a]					
Chloride	3×10^{-1}	3×10^{-1}	2×10^{-8}	2×10^{-8}	250
Copper	8×10^{-4}	7×10^{-3}	4×10^{-11}	4×10^{-10}	1.0
Iron	3×10^{-4}	3×10^{-3}	1×10^{-11}	2×10^{-10}	0.3
Manganese	3×10^{-4}	2×10^{-3}	1×10^{-11}	1×10^{-10}	0.05
Sulfate	3×10^{1}	2×10^{1}	1×10^{-6}	1×10^{-6}	250
Zinc	3×10^{-4}	2×10^{-3}	1×10^{-11}	1×10^{-10}	5.0

(a) Per Washington State standards for public water supplies (WAC 1985).

6.0 RADIOLOGICAL ASSESSMENT

This chapter presents the long-term radiological impacts from the disposal of grouted PSW. Radiation doses are calculated for members of the general public who receive exposure by either directly contacting the grouted waste form or by being exposed to radionuclides that have migrated from the grout into the groundwater. Calculated doses represent incremental increases. Both natural and human-induced events that could lead to contact with the disposed radionuclides have been addressed. The dosimetry models, pathway models, calculational method, and the resulting calculated impacts are presented below.

6.1 POSTULATED EVENTS

Table 6.1 lists events that past PAs have postulated to lead to significant releases of radionuclides from waste disposed near the ground's surface at Hanford.

TABLE 6.1. Postulated Events Leading to Radiological Impacts[a]

- Residential Home Garden
- Drilling
  - Resource Exploration
  - Water well
- Post-drilling Habitation
- Excavation
- Climate State
  - Present
  - Drier
  - Wetter
- Irrigation
  - Onsite
  - Offsite
- Contaminated Water Supply
- Glacial Flooding
- Other Surface Flooding
  - 100-Year Flood
  - Dam Failure
- Wind Erosion
- Magmatic Activity
- Seismic Activity
- Criticality
- Terrorism
- Warfare

(a) Source: U.S. DOE 1986(b).

9011178619 4

Of these events, eight were judged to have sufficient probability and/or consequence for grout disposal to warrant further detailed analysis:

- contaminated water supply
- irrigation
- changing climate
- drilling
- excavation
- residential garden
- post-drilling habitation
- post-excavation habitation.

A suite of exposure scenarios was established based on assumptions specific to the analysis of long-term performance of the PSW grout system. The radiological impacts associated with these scenarios are presented in Section 6.3 (Groundwater Impacts) and Section 6.4 (Intruder Impacts). Methods for calculating radiation doses are presented in Section 6.2.

6.2 CALCULATIONAL METHODS

This section describes the dose model used, then discusses the methods for calculating groundwater doses and doses to intruders.

6.2.1 Dosimetry

The dose model used in this report is derived from that originally endorsed by the International Commission on Radiological Protection (ICRP 1959) in Publication 2 for body burden and maximum permissible concentration. Effective decay energies for radionuclides are calculated using the ICRP model. This model is based on the assumption that the entire quantity of a given radionuclide is located at the center of a spherical organ with an appropriate effective radius (Soldat 1976). Metabolic parameters for the standard man are used (ICRP 1975); some of the parameters are updated from later ICRP publications.

Several radionuclides are handled as special cases. For the radionuclides tritium and carbon-14, the accumulated dose for the organs, total body,

and bone are calculated as described above. Because these radionuclides distribute evenly in the rest of the body, the doses for all the other organs are set equal to that for total body.

The model for the gastrointestinal (GI) tract is as follows. The GI tract--stomach, small intestine (SI), upper large intestine (ULI), and lower large intestine (LLI)--is modeled as a four-compartment system with a plug flow. Because no long-term storage or retention of radionuclides occurs in the GI tract, the dose to the GI tract in any one year is equal to the dose commitment for that year. The portions of the GI tract are assumed to be irradiated by radionuclides that are uniformly distributed in the material passing through each compartment.

The internal distribution of radionuclides following inhalation adds a degree of complexity because of radionuclide retention in the lungs. The model of the respiratory tract adopted by the ICRP Task Group on Lung Dynamics (ICRP 1966) forms the general basis for the mathematical models developed to calculate the dose from inhalation of radionuclides.

A new dosimetry model has recently been developed and recommended by the ICRP in ICRP-26 (ICRP 1977) and applied in ICRP-30 (ICRP 1979). The new model is based on more recent human metabolic parameters and applies a more realistic approach for uptake and retention of radionuclides in body organs. For example, the contribution to organ dose resulting from decay of radionuclides in other organs ("crossfire") is now accounted for. Rather than report the individual organ doses, the concept of an "effective whole-body dose" (the sum of the product of each organ dose multiplied by its appropriate weighting factor) is used. The effective whole-body dose is then used for comparison to a stochastic dose limit. Stochastic in this context means that impact is proportional to dose; i.e., no threshold is assumed. The stochastic effective dose equivalent limit recommended for an individual in the general public, according to ICRP-26, is 500 mrem/yr. In addition, ICRP-26 states that when prolonged exposures are expected, the annual dose limit should be 100 mrem/yr.

As mentioned, the dosimetry used in this report is based on the ICRP-2 model. An environmental assessment code using the more recent ICRP 26/30

9011178618996

dosimetry model is being developed at PNL but is not yet available for use. However, to determine whether the calculated doses in our PA would have varied greatly if the ICRP-26/30 dose model were used, the dose results calculated for the drinking water scenario (Section 6.3.1) were compared using ICRP-2 and ICRP-26/30 methods. The ICRP 26/30 doses were estimated using hand calculations for this comparison.

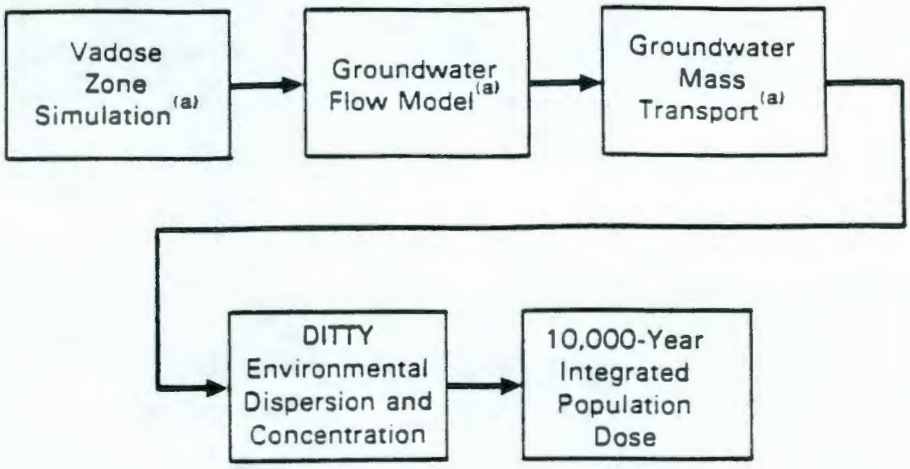
As shown in Table 6.2, the radiological impacts from the drinking water scenario calculated using ICRP-2 methods result in doses of 0.02 mrem/yr to the total body and 0.3 mrem/yr to the critical organ (bone). Using the newer ICRP 26 and 30 methodology, the calculated effective dose equivalent is 0.09 mrem/yr. Hence, the ICRP-26/30 dose is approximately three times below that of the ICRP-2 critical organ dose.

TABLE 6.2. Comparison of Radiation Dose for the Drinking Water Scenario Using ICRP-2 and ICRP-26/30 Methods, mrem/yr

Radionuclide	ICRP-2 Total Body	ICRP-2 Bone	ICRP-26/30 Effective Dose Equivalent
^{14}C	5.6×10^{-3}	2.7×10^{-2}	2.0×10^{-2}
^{238}U	1.4×10^{-2}	2.3×10^{-1}	7.0×10^{-2}
^{99}Tc	8.0×10^{-5}	2.1×10^{-4}	2.0×10^{-3}
^{129}I	2.0×10^{-7}	7.3×10^{-8}	6.2×10^{-6}
	2.0×10^{-2}	3.0×10^{-1}	9.0×10^{-2}

6.2.2 Method for Calculating Groundwater Doses

The computer program DITTY (Napier, Peloquin and Strenge 1986) estimates the time integral of collective dose over a period up to 10,000 years for time-variant radionuclide releases to surface waters, wells, or the atmosphere. The computer program was initially developed to determine the collective dose from high-level waste geologic repositories resulting from groundwater pathways, but other pathways are included as well. The relationship of DITTY to the hydrogeologic models described in Chapter 5.0 is shown in Figure 6.1.



(a) See Chapter 5.0 for details.

FIGURE 6.1. Use of Computer Models to Calculate 10,000-year Integrated Population Doses from Contaminant Release to Groundwater

Source terms for DITTY may be defined for releases to the atmosphere, to groundwater, to water wells, and to surface water via groundwater. The actual release rates are specified in an input file as the curies per year released for selected years following the start time of the calculation.

The DITTY code calculates a dose for any 10,000-year period. This period is broken into 143 periods of 70 years each. The average release during each period is calculated from the source-term data provided. The total-population dose to selected organs is determined for the population present in each period. The radioactivity present during any period is the sum of material uniformly released over that period and residual material in the environment from releases in previous periods. The dose is calculated for all contributing pathways of exposure, including external exposure, inhalation, and ingestion of contaminated water and foods.

6.2.3 Method for Calculating Intruder Doses

The ONSITE/MAXI computer program (Napier et al. 1984) is used to calculate a maximum annual dose to an individual from residual surface contamination. Exposure pathways that can be modeled include direct external

exposure to contaminated soil or building surfaces, inhalation of resuspended material, and ingestion of contaminated foods and aquatic products. The ONSITE/MAXI code calculates the time of the maximum dose rate to specific organs of reference and gives an annual dose for that organ. Special options are available to tailor the program to simulate a variety of decommissioned facilities such as reactors, low-level waste burial grounds, or other facilities for handling nuclear material.

As described in Section 6.4 of this document, the onsite scenarios are postulated to occur at a future date following the hypothetical loss of active institutional control of the Hanford Site. While warning markers, land-use records, and protective overburdens over the grout vaults should render intrusion events less likely, it is impossible to accurately predict human behavior over the long term; a determined individual can ignore, circumvent, or destroy any potential barrier. Thus, an individual could potentially receive a wide range of exposures depending on the magnitude of disruption of a site. Consequently, a suite of scenarios has been used that spans the range from negligible to significant site disruption.

The scenarios evaluated in this performance assessment include drilling, excavation, and residential gardening activities that hypothetically occur directly over the PSW grout disposal site. Drillers or diggers are assumed to penetrate areas of the highest radioactivity. The probability, or relative unlikelihood, of a scenario occurring is not factored into the calculations; the intrusions are assumed to occur and the results are presented.

For the scenarios involving farming, roots from all types of plants, including food crops, are assumed to penetrate to a depth of at least 5 m with a small percentage contacting the grouted wastes. Because the intrusion events are localized, the individuals receiving maximum doses are the intruders themselves. While the scenarios chosen for analysis represent a range of potential conditions, the parameters used for each scenario are selected to ensure conservatism.

6.3 GROUNDWATER IMPACTS

As described in Chapters 4.0 and 5.0, once the radionuclide contaminants are released from the grout vault, they migrate downward through the vadose zone. From the vadose zone they mix with the unconfined aquifer below the grout disposal site. Once in the aquifer, the radionuclides are transported away from the grout disposal site and may eventually reach the Columbia River, depending on their specific half-lives and adsorption characteristics.

Similar to the calculation of concentrations of regulated chemicals presented in Chapter 5.0, incremental concentrations of radionuclides in the unconfined aquifer and in the Columbia River were calculated as input for the dose assessment code for the groundwater exposure pathway. The time-dependent concentrations of key radionuclides in groundwater are shown in Figures 6.2 and 6.3 for recharge rates of 0.5 and 5.0 cm/yr, respectively.

To calculate radiological impacts, one must postulate locations at which humans could contact the contaminated groundwater. As mentioned, one assumed location is a hypothetical domestic well located between the PSW grout disposal site and the Columbia River. The location of this well was chosen so as to draw water from the maximally contaminated portion of the aquifer. The radiological impacts calculated for using water from this well are almost independent of distance from the PSW grout disposal site because conservative assumptions were made concerning the ability of contaminants to disperse in the aquifer. Hence a well located 10 km downgradient from the PSW grout disposal site is modeled as having essentially the same radionuclide concentrations as would a well located 100 m downgradient. Because the well scenarios described in the following sections are assumed to occur immediately after the loss of active institutional control, the well could conceivably be located anywhere from 0 km to 10 km from the disposal site. However, the most likely location for people to resettle many years into the future would be some distance from the 200-Area Plateau. Therefore, the well is assumed to be 5 km from the PSW grout disposal site.

Because contaminants may eventually reach the Columbia River, radiological impacts were also assessed downriver from the Hanford Site.

9011173519900

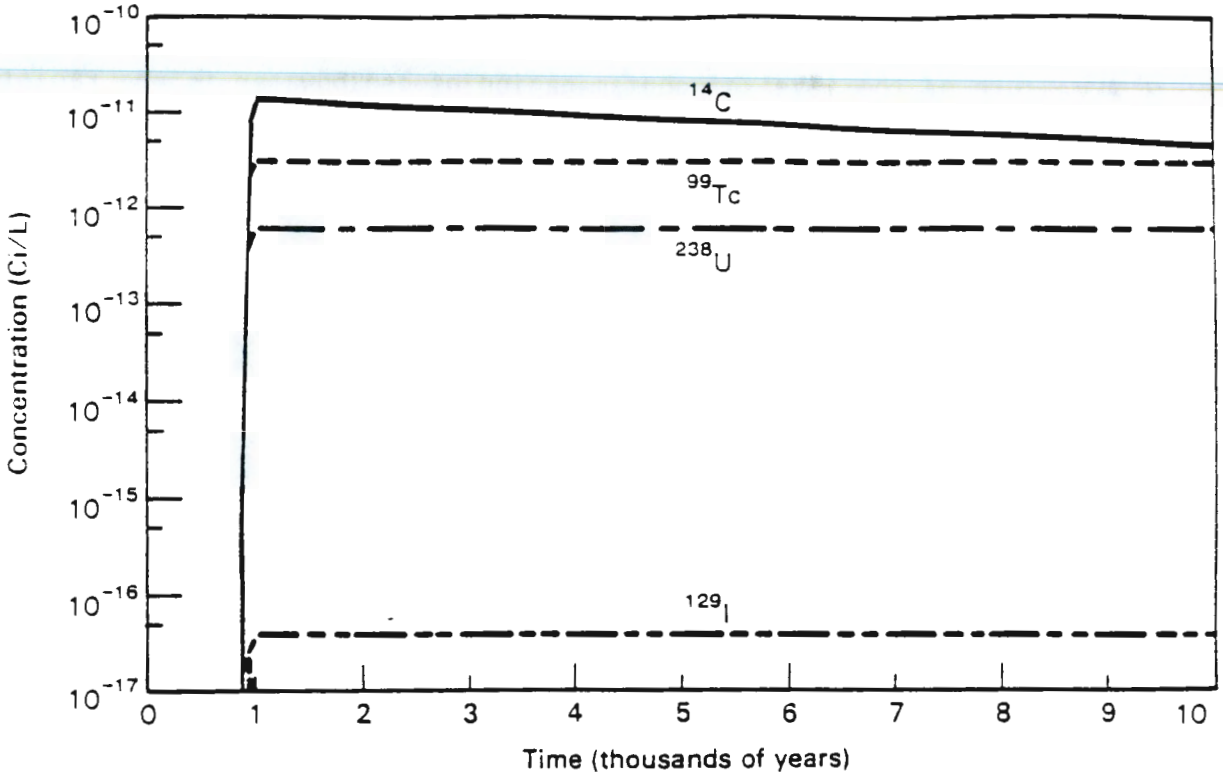


FIGURE 6.2. Concentrations of Key Radionuclides in Groundwater at 5-km Well, 0.5 cm/yr Recharge Rate

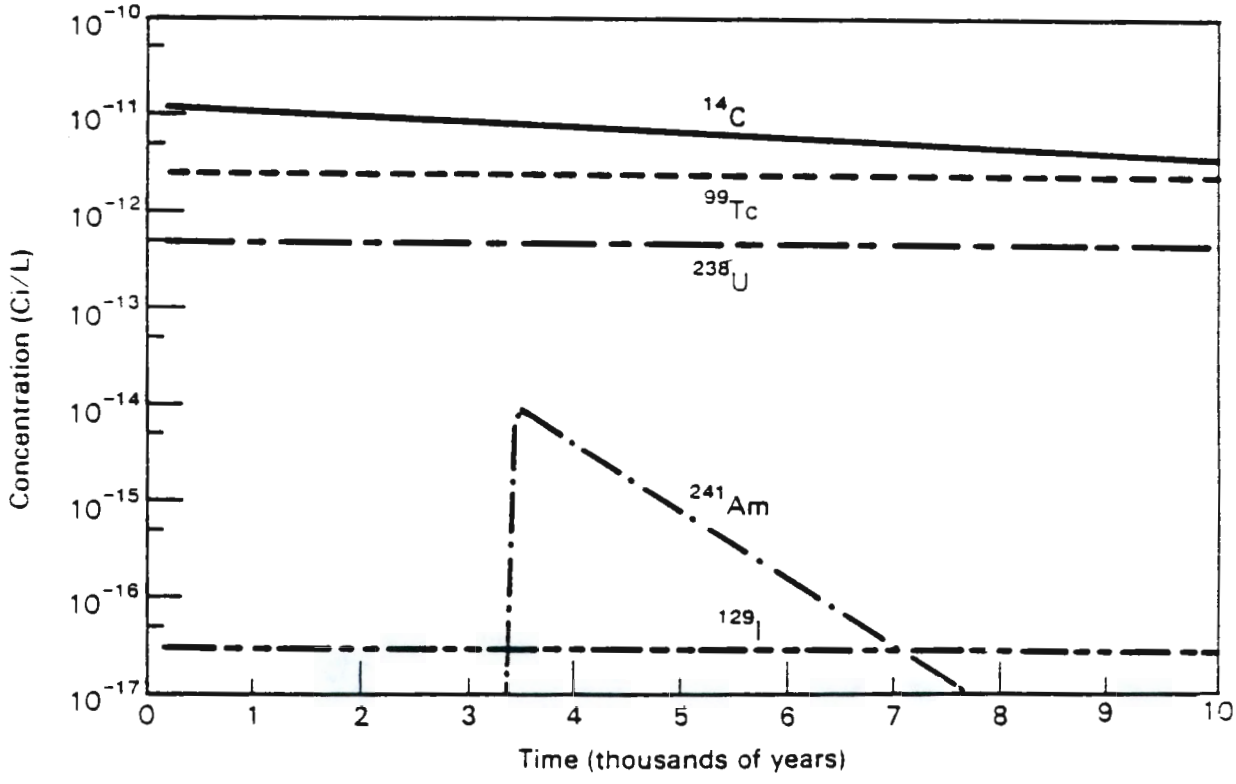


FIGURE 6.3. Concentrations of Key Radionuclides in Groundwater at 5-km Well, 5.0 cm/yr Recharge Rate

6.3.1 Drinking Well Water

A measure of the level of contamination of groundwater is the radiation dose caused by drinking the water. Annual and lifetime doses to an individual drinking water from the hypothetical 5-km well are given in Tables 6.3 and 6.4. The maximally exposed hypothetical individual evaluated was a person who consumes 2 liters of water per day, as defined by the Nuclear Regulatory Commission (U.S. NRC 1977). Total-body and critical-organ doses are presented in these two tables as a function of recharge rate. The time at which the maximum doses are projected to occur is shown to be dependent on the assumed recharge rate. The maximum doses occur 600 years and 1600 years following disposal for the 5.0 and the 0.5 cm/yr recharge rates, respectively. The doses presented are the maximum doses expected to occur within a 10,000-year period. The dominant radionuclides in this scenario are uranium-238 (which contributes 89% of the dose) and carbon-14.

Because leach rate data specific to uranium is unavailable, the release rate of uranium from within the grout monolith to the surrounding soils was modeled as being congruent with the diffusional release rates of mobile ions such as nitrite and sodium. This assumption may overestimate the release rate for uranium, because it may be solubility-controlled and slower than diffusional release. Additional laboratory studies are being conducted to quantitatively measure the leach rate of uranium-238 from PSW grout. Because uranium-238 controls the dose rate under the current set of assumptions, a reduction in release rate could significantly reduce the projected doses for this scenario.

6.3.2 Full-Garden Scenario

Contaminated well water could be used for irrigation and livestock water, as well as for human drinking water. A full-garden scenario was postulated wherein an individual grows a large percentage of his food using the well for irrigation, as might occur on a small, 2-ha (5-acre) family farm. In addition to drinking contaminated water, the individual is exposed to radionuclides deposited on the soil via irrigation water and also to radioactivity accumulated in crops and animal products. Dietary parameters for this scenario are

TABLE 6.3. Calculated Maximum Radiation Doses to Individuals from the Drinking Water Scenario, mrem (Annual Doses)

0.5 cm/yr Recharge Rate (maximum exposure 1600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	5.6×10^{-3}	28	2.7×10^{-2}	10	5.6×10^{-3}	99	5.6×10^{-3}	97	5.6×10^{-3}	16
Uranium-238+D	1.4×10^{-2}	71	2.3×10^{-1}	89	0	0	0	0	1.9×10^{-2}	53
Technetium-99	8.0×10^{-5}	<1	2.1×10^{-4}	<1	2.6×10^{-5}	<1	0	0	1.1×10^{-2}	31
Iodine-129	2.0×10^{-7}	<1	7.3×10^{-8}	<1	0	0	1.6×10^{-4}	3	1.1×10^{-8}	<1
TOTAL	2×10^{-2}		3×10^{-1}		6×10^{-3}		6×10^{-3}		4×10^{-2}	

5.0 cm/yr Recharge Rate (maximum exposure 600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	4.7×10^{-3}	30	2.3×10^{-2}	11	4.7×10^{-3}	100	4.7×10^{-3}	97	4.7×10^{-3}	17
Uranium-238+D	1.1×10^{-2}	70	1.8×10^{-1}	89	0	0	0	0	1.5×10^{-2}	50
Technetium-99	6.3×10^{-5}	<1	1.6×10^{-4}	<1	2.0×10^{-5}	<1	0	0	8.6×10^{-3}	30
Iodine-129	1.6×10^{-7}	<1	5.8×10^{-8}	<1	0	0	1.3×10^{-4}	3	8.8×10^{-9}	<1
TOTAL	2×10^{-2}		2×10^{-1}		5×10^{-3}		5×10^{-3}		3×10^{-2}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

TABLE 6.4. Calculated Maximum Doses to Individuals from the Drinking Water Scenario, mrem (Lifetime Doses)

0.5 cm/yr Recharge Rate (maximum exposure 1600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	3.9×10^{-1}	28	1.9×10^{0}	11	3.9×10^{-1}	100	3.9×10^{-1}	97	3.9×10^{-1}	16
Uranium-238+D	9.7×10^{-1}	71	1.6×10^{1}	89	0	0	0	0	1.3×10^{0}	53
Technetium-99	5.6×10^{-3}	<1	1.5×10^{-2}	<1	1.8×10^{-3}	<1	0	0	7.6×10^{-1}	31
Iodine-129	1.4×10^{-5}	<1	5.1×10^{-6}	<1	0	0	1.1×10^{-2}	3	7.8×10^{-7}	<1
TOTAL	1×10^{0}		2×10^{1}		4×10^{-1}		4×10^{-1}		2×10^{0}	

5.0 cm/yr Recharge Rate (maximum exposure 600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	3.3×10^{-1}	30	1.6×10^{0}	11	3.3×10^{-1}	100	3.3×10^{-1}	97	3.3×10^{-1}	17
Uranium-238+D	7.7×10^{-1}	70	1.3×10^{1}	89	0	0	0	0	1.0×10^{0}	50
Technetium-99	4.4×10^{-3}	<1	1.1×10^{-2}	<1	1.4×10^{-3}	<1	0	0	6.0×10^{-1}	30
Iodine-129	1.1×10^{-5}	<1	4.0×10^{-6}	<1	0	0	8.8×10^{-3}	3	6.1×10^{-7}	<1
TOTAL	1×10^{0}		2×10^{1}		3×10^{-1}		3×10^{-1}		2×10^{0}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

presented in Napier, Peloquin and Strenge (1986). In addition, other parameters were required to estimate the dose to this individual. For example, it was assumed that the individual spends 50% of his time exposed to contaminated soil. It was also assumed that irrigation occurs for 6 months of the year at a rate of 150 L/m^2/month. Soil-to-plant concentration ratios and meat concentration ratios are from Napier, Peloquin and Strenge (1986).

Radiation doses to individuals for this scenario were estimated for the same well-water concentrations as shown in Figures 6.2 and 6.3. Tables 6.5 and 6.6 show the calculated annual and lifetime doses, respectively. As with the drinking water scenario, the radionuclide that makes the major dose contribution (75%) is uranium-238.

6.3.3 Radionuclide Migration to the Columbia River

Radionuclides and other contaminants that are leached into the groundwater could eventually reach the Columbia River. The rate at which radionuclides enter the river depends on five factors: 1) the rate at which they enter the groundwater, 2) their radioactive decay, 3) their adsorption characteristics, 4) the linear flow rate of the aquifer, and 5) distance to the river. The highly mobile radionuclides (e.g., iodine-129 and technetium-99) could reach the Columbia River within a few hundred years after the initiation of waste leaching. The less mobile radionuclides, e.g., cesium-137 and strontium-90, were shown to decay before ever reaching the water table. The rate of radionuclide release to the river is shown in Figures 6.4 and 6.5, at recharge rates of 0.5 and 5.0 cm/yr, respectively. It is assumed that the flow rate of the river past Hanford is 120,000 cubic feet per second (U.S. DOE 1986b).

The Columbia River is currently used for drinking, irrigation, and recreation by many people living downstream of Hanford. These uses are assumed to increase in the future. Currently, only a small fraction of the river's flow below Hanford is used for irrigation and drinking. (Water for the large irrigation projects in the area is primarily obtained from the Columbia River upstream of Hanford.) Within 80 km of Hanford, 2,000 people are currently estimated to eat food grown using irrigation water from the Columbia River, 70,000 people drink water from the river, and about

TABLE 6.5. Calculated Maximum Radiation Doses to Individuals from the Full-Garden Scenario, mrem (Annual Doses)

0.5 cm/yr Recharge Rate (maximum exposure 1600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	1.1×10^{-2}	22	5.5×10^{-2}	16	1.1×10^{-2}	30	1.1×10^{-2}	33	1.1×10^{-2}	11
Uranium-238+D	3.9×10^{-2}	77	2.9×10^{-1}	84	2.6×10^{-2}	69	2.3×10^{-2}	66	4.5×10^{-2}	44
Technetium-99	3.3×10^{-4}	1	8.6×10^{-4}	<1	1.1×10^{-4}	<1	2.9×10^{-14}	<1	4.5×10^{-2}	45
Iodine-129	6.9×10^{-7}	<1	4.0×10^{-7}	<1	2.4×10^{-7}	<1	3.5×10^{-4}	1	2.6×10^{-7}	<1
TOTAL	5×10^{-2}		3×10^{-1}		4×10^{-2}		3×10^{-2}		1×10^{-1}	

5.0 cm/yr Recharge Rate (maximum exposure 600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	1.3×10^{-2}	25	6.2×10^{-2}	18	1.3×10^{-2}	33	1.3×10^{-2}	36	1.3×10^{-2}	12
Uranium-238+D	3.8×10^{-2}	75	2.9×10^{-1}	82	2.5×10^{-2}	66	2.2×10^{-2}	63	4.4×10^{-2}	43
Technetium-99	3.3×10^{-4}	<1	8.7×10^{-4}	<1	1.1×10^{-4}	<1	3.0×10^{-14}	<1	4.5×10^{-2}	45
Iodine-129	6.9×10^{-7}	<1	4.0×10^{-7}	<1	2.4×10^{-7}	<1	3.5×10^{-4}	1	2.6×10^{-7}	<1
TOTAL	5×10^{-2}		4×10^{-1}		4×10^{-2}		4×10^{-2}		1×10^{-1}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

TABLE 6.6. Calculated Maximum Radiation Doses to Individuals from the Full-Garden Scenario, mrem (Lifetime Doses)

0.5 cm/yr Recharge Rate (maximum exposure 1600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	7.9×10^{-1}	22	3.9×10^{0}	16	7.9×10^{-1}	30	7.9×10^{-1}	33	7.9×10^{-1}	11
Uranium-238+D	2.7×10^{0}	77	2.0×10^{1}	84	1.8×10^{0}	69	1.6×10^{0}	66	3.1×10^{0}	44
Technetium-99	2.3×10^{-2}	1	6.0×10^{-2}	<1	7.4×10^{-3}	<1	2.1×10^{-12}	<1	3.1×10^{0}	45
Iodine-129	4.8×10^{-5}	<1	2.8×10^{-5}	<1	1.7×10^{-5}	<1	2.5×10^{-2}	1	1.8×10^{-5}	<1
TOTAL	4×10^{0}		2×10^{1}		3×10^{0}		2×10^{0}		7×10^{0}	

5.0 cm/yr Recharge Rate (maximum exposure 600 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	8.9×10^{-1}	25	4.4×10^{0}	18	8.9×10^{-1}	33	8.9×10^{-1}	36	8.9×10^{-1}	12
Uranium-238+D	2.7×10^{0}	75	2.0×10^{1}	82	1.8×10^{0}	66	1.6×10^{0}	63	3.1×10^{0}	43
Technetium-99	2.3×10^{-2}	<1	6.1×10^{-2}	<1	7.5×10^{-4}	<1	2.1×10^{-12}	<1	3.2×10^{0}	36
Iodine-129	4.8×10^{-5}	<1	2.8×10^{-5}	<1	1.7×10^{-7}	<1	2.5×10^{-2}	1	1.8×10^{-5}	<1
TOTAL	4×10^{0}		2×10^{1}		3×10^{0}		2×10^{0}		7×10^{0}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

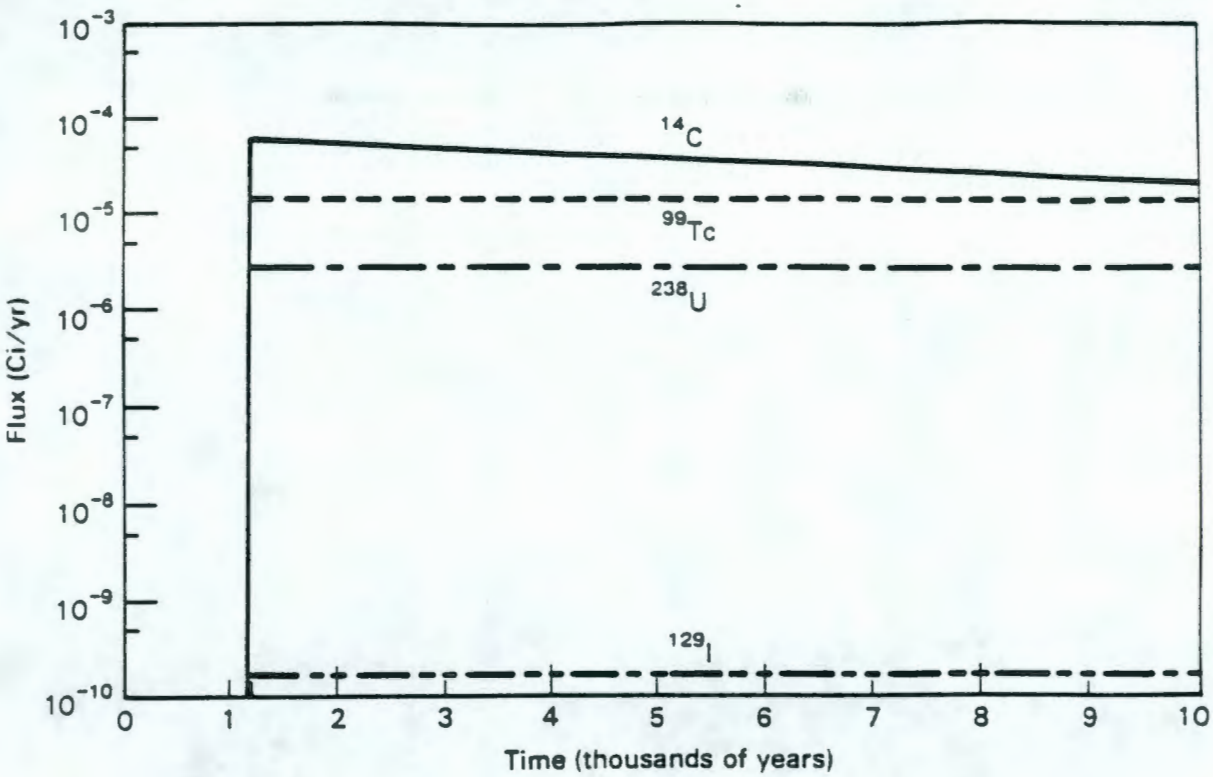


FIGURE 6.4. 10,000-year Release to Columbia River, 0.5 cm/year Recharge Rate

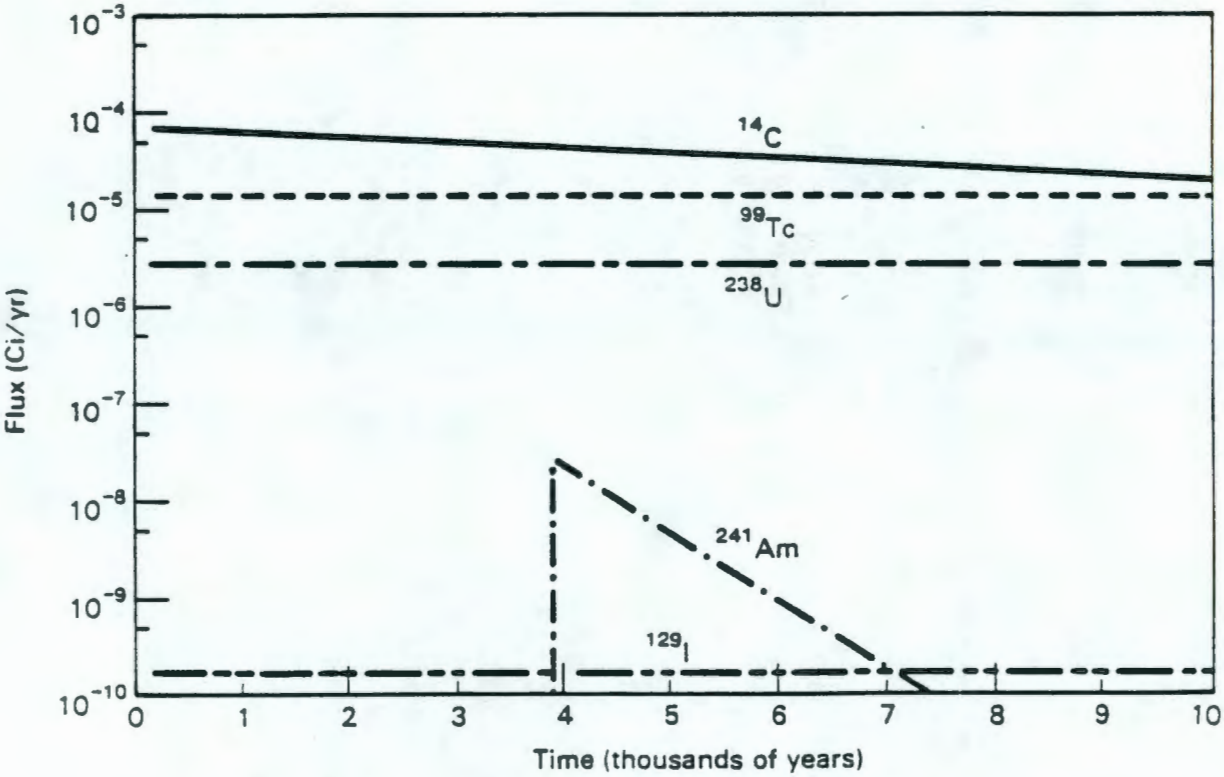


FIGURE 6.5. 10,000-year Release to Columbia River, 5.0 cm/year Recharge Rate

125,000 people swim or boat in the river (McCormack, Ramsdell and Napier 1984). It is assumed that a maximum of 5 million affected individuals will live at any point in time downstream along the Columbia River between Hanford and the river's mouth during the next 10,000 years. For this many people to be affected, a very large increase in the amount of irrigated land in both Washington and Oregon would be required, concurrent with a large increase in overall population. Thus, about 410 million people are assumed to live along the Columbia River over the 10,000-year period. The total dose that a group this size would receive from naturally occurring background sources is nearly 3 billion person-rem.

People who live along the Columbia River downstream of Hanford could be subject to doses resulting from the release of radionuclides from the grout. The gradual release of contaminants to the river would cause a slow increase in dose rate to a peak, followed by a gradual decline. There could be more than one peak, separated in time from the others, caused by the different mobilities of the radionuclides released from grout. The total dose to all people living over the next 10,000 years depends mostly on the total activity of each radionuclide (curies) released, but the rate of release controls the dose rate to any one individual.

Tables 6.7 and 6.8 show the doses that people living downriver of the Hanford Site would receive from PSW grout. Ten-thousand-year population doses are given in Table 6.9. As in the previous scenarios, the dominant radionuclide is uranium-238.

6.4 INTRUDER IMPACTS

In accordance with NRC guidelines (U.S. NRC 1981), active institutional controls cannot be relied upon for environmental protection for more than 100 years after disposal. After that time, passive institutional controls, such as markers, monuments, and public records, are the only mechanisms to inhibit intrusion into the waste. For this PA, intrusion events were analyzed at 100 years when active institutional control is assumed to cease at the Hanford Site. In addition, intrusion was also postulated at 400, 1,000, and 10,000 years after disposal. Radiological impacts were estimated at these

TABLE 6.7. Calculated Potential Maximum Radiation Doses to Individuals from Radionuclide Migration to the Columbia River, mrem (Annual Doses)

0.5 cm/yr Recharge Rate (maximum exposure 3000 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	4.1×10^{-10}	9	2.0×10^{-9}	7	4.1×10^{-10}	12	4.1×10^{-10}	14	4.1×10^{-10}	4
Uranium-238+D	4.0×10^{-9}	90	2.6×10^{-8}	93	3.0×10^{-9}	88	2.6×10^{-9}	85	4.5×10^{-9}	47
Technetium-99	3.4×10^{-11}	1	8.9×10^{-11}	<1	1.1×10^{-11}	<1	2.8×10^{-16}	<1	4.6×10^{-9}	49
Iodine-129	8.0×10^{-14}	<1	4.7×10^{-14}	<1	2.8×10^{-14}	<1	4.1×10^{-11}	1	3.1×10^{-14}	<1
TOTAL	4×10^{-9}		3×10^{-8}		3×10^{-9}		3×10^{-9}		1×10^{-8}	

5.0 cm/yr Recharge Rate (maximum exposure 2000 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	4.1×10^{-10}	9	2.0×10^{-9}	7	4.1×10^{-10}	12	4.1×10^{-10}	14	4.1×10^{-10}	4
Uranium-238+D	4.0×10^{-9}	90	2.6×10^{-8}	93	3.0×10^{-9}	88	2.6×10^{-9}	85	4.5×10^{-9}	47
Technetium-99	3.4×10^{-11}	1	8.9×10^{-11}	<1	1.1×10^{-11}	<1	2.8×10^{-16}	<1	4.6×10^{-9}	49
Iodine-129	8.0×10^{-14}	<1	4.7×10^{-14}	<1	2.8×10^{-14}	<1	4.1×10^{-11}	1	3.1×10^{-14}	<1
Americium-241	2.6×10^{-14}	<1	7.7×10^{-14}	<1	4.3×10^{-14}	<1	2.4×10^{-14}	<1	2.6×10^{-14}	<1
TOTAL	4×10^{-9}		3×10^{-8}		3×10^{-9}		3×10^{-9}		1×10^{-8}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

TABLE 6.8. Calculated Potential Maximum Radiation Doses to Individuals from Radionuclide Migration to the Columbia River, mrem (Lifetime Doses)

0.5 cm/yr Recharge Rate (maximum exposure 3000 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	2.9×10^{-8}	9	1.4×10^{-7}	7	2.9×10^{-8}	12	2.9×10^{-8}	14	2.9×10^{-8}	4
Uranium-238+D	2.8×10^{-7}	90	1.8×10^{-6}	93	2.1×10^{-7}	88	1.8×10^{-7}	85	3.2×10^{-7}	47
Technetium-99	2.4×10^{-9}	1	6.2×10^{-9}	<1	7.6×10^{-10}	<1	2.0×10^{-14}	<1	3.2×10^{-7}	49
Iodine-129	5.6×10^{-12}	<1	3.3×10^{-12}	<1	1.9×10^{-12}	<1	2.9×10^{-9}	1	2.1×10^{-12}	<1
TOTAL	3×10^{-7}		2×10^{-6}		2×10^{-7}		2×10^{-7}		7×10^{-7}	

5.0 cm/yr Recharge Rate (maximum exposure 2000 years after disposal)

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[a]	Percent Contribution
Carbon-14	2.9×10^{-8}	9	1.4×10^{-7}	7	2.9×10^{-8}	12	2.9×10^{-8}	14	2.9×10^{-8}	4
Uranium-238+D	2.8×10^{-7}	90	1.8×10^{-6}	93	2.1×10^{-7}	88	1.8×10^{-7}	85	3.2×10^{-7}	47
Technetium-99	2.4×10^{-9}	1	6.2×10^{-9}	<1	7.6×10^{-10}	<1	2.0×10^{-14}	<1	3.2×10^{-7}	49
Iodine-129	5.6×10^{-12}	0	3.3×10^{-12}	<1	1.9×10^{-12}	<1	2.9×10^{-9}	1	2.1×10^{-12}	<1
Americium-241	1.8×10^{-12}	<1	5.4×10^{-12}	<1	3.0×10^{-12}	<1	1.7×10^{-12}	<1	1.8×10^{-12}	<1
TOTAL	3×10^{-7}		2×10^{-6}		2×10^{-7}		2×10^{-7}		7×10^{-7}	

(a) GI-LLI = gastrointestinal tract - lower large intestine.

TABLE 6.9. 10,000-year Cumulative Population Doses from Radionuclide Migration to the Columbia River, person-rem[a]

0.5 cm/yr Recharge Rate

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[b]	Percent Contribution
Carbon-14	1.8×10^{-2}	15	9.0×10^{-2}	11	1.8×10^{-2}	17	1.8×10^{-2}	20	1.8×10^{-2}	8
Uranium-238+D	1.0×10^{-1}	84	7.0×10^{-1}	88	8.5×10^{-2}	82	7.2×10^{-2}	79	1.0×10^{-1}	46
Technetium-99	9.6×10^{-4}	1	2.5×10^{-3}	<1	3.1×10^{-4}	<1	7.9×10^{-9}	<1	1.0×10^{-1}	46
Iodine-129	2.2×10^{-6}	<1	1.3×10^{-6}	<1	7.7×10^{-7}	<1	1.3×10^{-3}	1	8.5×10^{-7}	<1
TOTAL	1×10^{-1}		8×10^{-1}		1×10^{-1}		9×10^{-2}		2×10^{-1}	

5.0 cm/yr Recharge Rate

Radionuclide	Total Body	Percent Contribution	Bone	Percent Contribution	Lung	Percent Contribution	Thyroid	Percent Contribution	GI-LLI[b]	Percent Contribution
Carbon-14	1.9×10^{-2}	16	9.5×10^{-2}	11	1.9×10^{-2}	18	1.9×10^{-2}	20	1.9×10^{-2}	9
Uranium-238+D	1.0×10^{-1}	83	8.0×10^{-1}	89	8.7×10^{-2}	82	7.4×10^{-2}	78	1.0×10^{-1}	46
Technetium-99	9.9×10^{-4}	1	2.6×10^{-3}	<1	3.2×10^{-4}	<1	8.1×10^{-9}	<1	1.0×10^{-1}	46
Iodine-129	2.3×10^{-6}	<1	1.3×10^{-6}	<1	7.7×10^{-7}	<1	1.2×10^{-3}	1	8.5×10^{-7}	<1
Americium-241	1.5×10^{-4}	<1	6.7×10^{-4}	<1	2.2×10^{-4}	<1	1.3×10^{-4}	<1	1.6×10^{-4}	<1
TOTAL	1×10^{-1}		9×10^{-1}		1×10^{-1}		9×10^{-2}		2×10^{-1}	

(a) Cumulative population dose received by the local population over 10,000 years with an assumed 70-yr individual lifetime.
(b) GI-LLI = gastrointestinal tract - lower large intestine.

times of intrusion and are described below. Radionuclide concentrations used in the following scenarios were presented in Table 4.4.

6.4.1 Drilling

Drilling, either for water wells or for mineral exploration, is a potential mechanism for moving buried waste directly to the earth's surface with little indication that the waste has been encountered. Monuments, barriers, and markers may reduce the likelihood of drilling, but they cannot preclude it.

In the drilling scenario, a well 30 cm in diameter is bored through the grout. The grout vault is 7 m thick; hence, 0.5 m^3 of grout is brought to the surface. Drilling through the waste form itself is assumed to take 1 hour. During this time, the driller breathes contaminated dust with a mass loading of 1×10^{-4} g/m^3 of air. The drill tailings are assumed to be spread over a 100-m^2 area.

The drillers are assumed to spend 40 hours working in the immediate vicinity of the tailings. (The maximum annual dose includes that from external radiation received during drilling, plus the longer-term dose that results from inhalation of radionuclides in the contaminated dust.)

Maximum annual total-body radiation doses to members of the drill crew are presented in Table 6.10. The doses are dominated by external exposure to cesium-137 at early times and after disposal, uranium-238 at longer time periods.

6.4.2 Excavation

Several plausible excavation events that involve major disturbances of the grout site can be postulated. These include construction projects required for highway or canal building, or, on a smaller scale, for residential basements. In these cases, workers operating heavy machinery can be assumed to be in a "hole in the ground," essentially surrounded by contaminated soil. The hole could range from relatively small (for a basement) to quite large (for a canal), but the direct exposure source and the contaminated dust concentration would be about the same in either case. The workers in the

TABLE 6.10. Calculated Maximum Radiation Doses to Individuals Resulting from the Drilling Scenario (Annual Doses)

Time, yr	Organ	Individual Maximum Annual Dose, mrem/yr	Dominant Pathway	Dominant Nuclide
100	Total Body	4×10^{-1}	External	^{137}Cs
	Bone	4×10^{-1}	External	^{137}Cs
	Lung	4×10^{-1}	External	^{137}Cs
	Thyroid	4×10^{-1}	External	^{137}Cs
	LLI[a]	4×10^{-1}	External	^{137}Cs
400	Total Body	4×10^{-4}	External	^{137}Cs
	Bone	4×10^{-4}	External	^{137}Cs
	Lung	4×10^{-4}	External	^{137}Cs
	Thyroid	4×10^{-4}	External	^{137}Cs
	LLI[a]	4×10^{-4}	External	^{137}Cs
1000	Total Body	3×10^{-6}	External	^{238}U
	Bone	5×10^{-6}	External	^{238}U
	Lung	2×10^{-5}	Inhalation	^{239}Pu
	Thyroid	3×10^{-6}	External	^{238}U
	LLI[a]	3×10^{-6}	External	^{238}U
10,000	Total Body	2×10^{-6}	External	^{238}U
	Bone	4×10^{-6}	External	^{238}U
	Lung	1×10^{-5}	Inhalation	^{239}Pu
	Thyroid	2×10^{-6}	External	^{238}U
	LLI[a]	2×10^{-6}	External	^{238}U

(a) LLI = lower large intestine.

hole would be exposed to direct radiation from radionuclides in the soil and to resuspended dust from the construction activity.

An individual operating heavy equipment is assumed to work in the contaminated area for 80 hours. A contaminated dust loading of 1×10^{-2} g/m^3 of

9011178619 14

air is assumed. The excavated waste is assumed to be uniformly mixed with soil that has a density of 1.7×10^6 g/m^3.

Maximum annual whole-body radiation doses to workers who excavate into the grout at various future times are presented in Table 6.11. Again, maximum annual total-body radiation doses are dominated by external exposures from cesium-137 and uranium-238.

6.4.3 Residential Home Garden

The resettlement of the Hanford Site is assumed to occur following the cessation of active institutional control of the Site. It is believed that hypothetical resettlement would occur first along parts of the Hanford Site relatively close to the Columbia River because of the availability of water from both the river and groundwater at shallow depths. However, for the sake of conservatism, potential future occupancy is also assumed near or at locations of disposed waste. For waste sites in the 200-Area plateau (where PSW grout is planned to be disposed), this type of resettlement is believed to be applicable only to a few individuals, rather than a systematic settlement.

Without active institutional controls, and with disregard of passive institutional controls such as permanent markers and public records, waste disposal areas could possibly be used for residential purposes. People could build homes and conduct routine subsistence activities over buried waste sites. Food crops, for either domestic or animal consumption, could be grown. (Individuals in this scenario are assumed to use uncontaminated well water. For impacts directly resulting from use of contaminated well water, see Section 6.3.2.) The resident would consequently be exposed to low levels of direct radiation from the buried grout and also to radionuclides via ingestion of contaminated crops grown in the site. Crop contamination is a function of the depth of the grout, the ability of the grout vault to prevent root intrusion, and the overall surface area used for gardening.

Exposure pathways for the residential home garden scenario are ingestion of contaminated food and external radiation.

TABLE 6.11. Calculated Maximum Radiation Doses to Individuals Resulting from the Excavation Scenario (Annual Doses)

Time, yr	Organ	Individual Maximum Annual Dose, mrem/yr	Dominant Pathway	Dominant Nuclide
100	Total Body	4×10^{1}	External	^{137}Cs
	Bone	4×10^{1}	External	^{137}Cs
	Lung	4×10^{1}	External	^{137}Cs
	Thyroid	4×10^{1}	External	^{137}Cs
	LLI[a]	4×10^{1}	External	^{137}Cs
400	Total Body	4×10^{-2}	External	^{137}Cs
	Bone	5×10^{-2}	External	^{137}Cs
	Lung	8×10^{-2}	Inhalation	^{239}Pu
	Thyroid	4×10^{-2}	External	^{137}Cs
	LLI[a]	4×10^{-2}	External	^{137}Cs
1000	Total Body	7×10^{-4}	Inhalation	^{239}Pu
	Bone	2×10^{-2}	Inhalation	^{239}Pu
	Lung	6×10^{-2}	Inhalation	^{239}Pu
	Thyroid	3×10^{-4}	External	^{238}U
	LLI[a]	3×10^{-4}	External	^{238}U
10,000	Total Body	5×10^{-4}	Inhalation	^{239}Pu
	Bone	1×10^{-2}	Inhalation	^{239}Pu
	Lung	5×10^{-2}	Inhalation	^{239}Pu
	Thyroid	2×10^{-4}	External	^{238}U
	LLI[a]	2×10^{-4}	External	^{238}U

(a) LLI = lower large intestine.

Dietary parameters represent the vegetable diet of the "Hanford maximum individual" (McCormack, Ramsdell and Napier 1984). The individual in this scenario is assumed to grow 25% of his diet in the contaminated soil. The garden is postulated to be located directly above a PSW grout vault.

One percent of the crop roots are in contact with the waste. For external radiation, the individual is exposed to the contaminated soil for 8,770 hours per year.

Calculated maximum annual whole-body radiation doses to individuals resulting from the residential home garden scenario are listed in Table 6.12. Individual maximum annual radiation doses are dominated by the ingestion pathway. Strontium-90 and cesium-137 control the doses for 400 years, while carbon-14 and technetium-99 control the doses after 1,000 years.

6.4.4 Post-Drilling Habitation

The doses to people who directly contact the buried wastes represent only a portion of the impact of intrusion into the grout site. Drilling results in waste being physically disturbed and distributed in the local environment. This contamination could represent a source of radiation exposure to people living on or near the site of the original disturbance long after the original redistribution. As in the example of the residential home garden scenario, people who live on or near the waste would be exposed to direct radiation from contamination in the soil, and to ingestion of garden foods grown in the contaminated soil.

In the post-drilling habitation scenario, waste brought to the surface by the drilling scenario is assumed to be further distributed throughout a 15-cm plow layer in a garden that is 2,500 square meters in area. Twenty-five percent of the individual's vegetable intake is assumed to come from this garden. The individual is assumed to spend 2,000 hours per year outside, exposed to resuspended dust and to surface contamination.

Calculated maximum annual doses to individuals living on the grout site are presented in Table 6.13. Total-body doses are dominated by strontium-90 ingestion at 400 years, carbon-14 ingestion at 1,000 years, and inhalation of plutonium-239 at 10,000 years.

6.4.5 Post-Excavation Habitation

The post-excavation habitation scenario follows directly from the excavation activities described in Section 6.4.2. As in the post-drilling scenario,

TABLE 6.12. Calculated Maximum Radiation Doses to Individuals Resulting from the Residential Home Garden Scenario (Annual Doses)

Time, yr	Organ	Individual Maximum Annual Dose, mrem/yr	Dominant Pathway	Dominant Nuclide
100	Total Body	6×10^{1}	Ingestion	^{90}Sr
	Bone	2×10^{2}	Ingestion	^{90}Sr
	Lung	2×10^{-2}	Ingestion	^{137}Cs
	Thyroid	2×10^{-6}	Ingestion	^{129}I
	LLI[a]	7×10^{-0}	Ingestion	^{90}Sr
400	Total Body	6×10^{-2}	Ingestion	^{90}Sr
	Bone	2×10^{-1}	Ingestion	^{90}Sr
	Lung	3×10^{-5}	Ingestion	^{137}Cs
	Thyroid	2×10^{-6}	Ingestion	^{129}I
	LLI[a]	2×10^{-2}	Ingestion	^{14}C
1000	Total Body	1×10^{-2}	Ingestion	^{14}C
	Bone	7×10^{-2}	Ingestion	^{14}C
	Lung	4×10^{-6}	Ingestion	^{99}Tc
	Thyroid	2×10^{-6}	Ingestion	^{129}I
	LLI[a]	1×10^{-2}	Ingestion	^{14}C
10,000	Total Body	4×10^{-3}	Ingestion	^{14}C
	Bone	3×10^{-2}	Ingestion	^{14}C
	Lung	4×10^{-6}	Ingestion	^{99}Tc
	Thyroid	2×10^{-6}	Ingestion	^{129}I
	LLI[a]	5×10^{-3}	Ingestion	^{14}C

(a) LLI = lower large intestine.

people were postulated to live in a home constructed at the site and to consume food grown in an adjacent small garden. However, it was considered to be extremely unlikely that excavation activities would bring materials to the

TABLE 6.13. Calculated Maximum Radiation Doses to Individuals Resulting from the Post-Drilling Scenario (Annual Doses)

Time, yr	Organ	Individual Maximum Annual Dose, mrem/yr	Dominant Pathway	Dominant Nuclide
100	Total Body	1×10^{1}	Ingestion	^{90}Sr
	Bone	4×10^{1}	Ingestion	^{90}Sr
	Lung	2×10^{0}	External	^{137}Cs
	Thyroid	2×10^{0}	External	^{137}Cs
	LLI[a]	3×10^{0}	External	^{137}Cs
400	Total Body	1×10^{-2}	Ingestion	^{90}Sr
	Bone	6×10^{-2}	Ingestion	^{90}Sr
	Lung	1×10^{-2}	Inhalation	^{239}Pu
	Thyroid	2×10^{-3}	External	^{137}Cs
	LLI[a]	5×10^{-3}	Ingestion	^{14}C
1000	Total Body	4×10^{-3}	Ingestion	^{14}C
	Bone	4×10^{-2}	Inhalation	^{239}Pu
	Lung	9×10^{-3}	Inhalation	^{239}Pu
	Thyroid	1×10^{-5}	External	^{239}Pu
	LLI[a]	2×10^{-6}	Ingestion	^{14}C
10,000	Total Body	2×10^{-3}	Inhalation	^{239}Pu
	Bone	3×10^{-2}	Inhalation	^{239}Pu
	Lung	7×10^{-3}	Inhalation	^{239}Pu
	Thyroid	9×10^{-6}	External	^{238}U
	LLI[a]	9×10^{-4}	Ingestion	^{14}C

(a) LLI = lower large intestine.

surface for redistribution from depths greater than 5 m, and therefore, no impacts were projected to be associated with the reference 5-m depth of soil overburden.

6.5 SUMMARY OF RADIOLOGICAL IMPACTS

Table 6.14 summarizes the long-term radiological impacts associated with the disposal of grouted PSW at Hanford. The maximum dose calculated for each type of scenario is shown. The major types of scenarios represent impacts from drinking water at a downgradient well, using a full garden at this same well, using water from the downgradient river, and intruding directly into the grouted waste. The summary doses are compared to various radiological standards as a means of measuring the effectiveness of the grout disposal system. Correspondent regulations are also listed for comparison.

TABLE 6.14. Summary of Maximum Radiological Impacts

Scenario	Dose, mrem/yr Total Body/ Critical Organ	Regulatory Dose Limit, mrem/yr Total Body/Critical Organ	Dominant Radionuclide
Drinking Water, 0.5 cm/yr recharge	0.02/0.3	4/4[a]	^{238}U
Full Garden, 5.0 cm/yr recharge	0.05/0.4	25/75[b]	^{238}U
River, both recharges	$4 \times 10^{-9}/3 \times 10^{-8}$	25/75[b]	^{238}U
Intruder (residential home garden)	60/200	500/1500[b,c]	^{90}Sr, ^{137}Cs

(a) WAC (1985).
(b) U.S. NRC (1982a).
(c) U.S. DOE (1981a).

6.5.1 Regulatory Review

The current body of radiological regulations and guidelines pertaining to the protection of public health and the environment were reviewed to provide a way to measure the long-term performance of the PSW grout system. Included in this review, for direct applicability and indirect guidance, were DOE orders and federal and state regulations, including those promulgated by the EPA, the NRC, and the State of Washington.

The regulatory review indicated that regulations pertaining to the permanent disposal of both DOE and commercial LLW are currently developing and changing. In 1983, the EPA published an advanced notice of public rulemaking for LLW disposal (U.S. EPA 1983). These regulations are being developed and

9011178619920

are expected to be promulgated as LLW standards in the Code of Federal Regulations as 40 CFR 193. After promulgation, these regulations would be expected to apply to the disposal of future PSW grout; however, the schedule for final issuance is currently unknown.

Although the DOE is not legally bound to comply with NRC requirements, it is useful to inspect performance criteria that have been established for land disposal of commercial LLW, particularly because they are the result of a lengthy environmental impact study that included the incorporation of public comments (U.S. NRC 1982b). The NRC issued regulations for disposal of commercial radioactive wastes in shallow-land facilities as contained in 10 CFR 61 (U.S. NRC 1982a). The regulations established procedures, terms, criteria and conditions upon which the NRC will issue a license for the disposal of wastes containing byproduct, source, and special nuclear materials.

Requirements to protect the general population from releases of radioactivity are established in 10 CFR 61.41 (U.S. NRC 1982a). According to these requirements, concentrations of radionuclides transported through all pathways, including groundwater, surface water, air, soil, plants, or animals must not result in an annual dose to an individual exceeding

- 25 mrem to the whole body
- 75 mrem to the thyroid
- 25 mrem to any other organ.

Additionally, the regulation stipulated that "design, operation, and closure of the land-disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed" (U.S. NRC 1982a).

The NRC approach to ensuring the long-term protection of the inadvertent intruder was to establish maximum waste concentrations for a series of disposal systems of increasing stability and expected long-term performance. To determine the limits, the NRC evaluated the expected performance of each disposal system, using several hypothetical exposure scenarios, and using an annual dose limit of 500 mrem to the whole body or bone and 1500 mrem/yr to

9011786192 1

any other critical organ. The inadvertent intruder scenarios evaluated in our performance assessment closely parallel the NRC scenarios; therefore, the impacts of inadvertently intruding into the PSW disposal site are "benchmarked" against the design criteria of 500/1500 mrem/yr.

In lieu of specific EPA and NRC regulations pertaining to permanent disposal of DOE LLW, other regulations were examined. In particular, the following DOE orders, as applied during the operational phase of disposal, were reviewed for guidance:

- Order 5480.2, "Radioactive Waste Management" (U.S. DOE 1984)
- Order 5480.1A, "Environmental Protection, Safety and Health Protection Programs for DOE Operations" (U.S. DOE 1981a).

Regulations specific to the management of radioactive waste are contained in DOE Order 5820.2, "Radioactive Waste Mangement" (U.S. DOE 1984). Chapter III of DOE Order 5820.2, "Management of Low-Level Waste," established DOE policy and guidelines for management and disposal of LLW. This order established the policy that LLW generated by DOE operations shall be disposed ". . . where practical, by shallow land burial or greater confinement disposal. Site-specific requirements for waste acceptance and disposal, site selection, site design, site operation, and site closure/post-closure shall be developed and implemented by field organizations . . .". No quantitative performance objectives are included in the order; however, additional guidance is being prepared.

The DOE Order 5480.1A, "Environmental Protection, Safety and Health Protection Programs for DOE Operations," established an overall framework of program requirements for safety and environmental and health protection (U.S. DOE 1981a). The order set forth radiation protection standards for operating DOE facilities. Chapter XI of DOE Order 5480.1A includes the dose limits for members of the general public in unrestricted areas in the vicinity of DOE facilities. The exposure limits were maximum annual dose equivalents of 500 mrem to the whole body, gonads, or bone marrow, and 1500 mrem to any other organ. Calculation of compliance with these limits must include an analysis of all potential pathways including groundwater, air, and direct exposure as well as consumption of contaminated foodstuffs (U.S. DOE 1981b).

9011785192 2

These standards apply to routine DOE operations, defined as normal planned operations, and do not include actual or potential accidents or unplanned releases.

The DOE is in the process of revising its radiation standards for protection of the public in the vicinity of DOE facilities. In 1985, DOE issued guidance supplanting the dose limits outlined above with new dose limits based on the latest concepts and dosimetry of the International Commission on Radiological Protection (ICRP 1977, 1979). Interim standards, effective July 1, 1985, limit the continuous dose to any member of the public to 100 mrem/yr from all routine DOE operations at a DOE site.

This dose must be calculated using the dosimetry models of ICRP 26/30. As discussed in Chapter 6.0, Section 6.2.1, the capability to calculate long-term impacts using the newer dosimetry is being developed at this time. However, because the doses presented in this analysis are calculated using ICRP 2 dosimetry, they must be compared to dose limits that are based on ICRP 2 models.

Finally, federal and state drinking water standards were reviewed for guidance concerning the radiological protection of the groundwater. The Safe Drinking Water Act (SDWA) was enacted in 1974 to protect the nation's drinking water. Under the authority of SDWA, the EPA issued National Interim Primary Drinking Water Regulations in 40 CFR 141 (U.S. EPA 1984). The 40 CFR 141 regulations set forth radiological standards. The State of Washington has adopted the EPA standards as drinking water limits in WAC 248-54 (WAC 1985). The radionuclide standards for Washington State drinking water supply systems are established such that "the maximum contaminant level for beta particle and photon radioactivity from man-made radionuclides is that the average annual concentration shall not produce an annual dose equivalent to the total body or any internal organ greater than four millirem/year" (WAC 1985).

6.5.2 Comparison to Regulations

The long-term radiological impacts resulting from migration of radionuclides in groundwater are dominated by uranium-238. At 100 years after disposal of PSW, the intruder impacts are dominated by strontium-90 and cesium-137; after 400 years, the impacts are approximately 1000 times less.

The calculated release of radionuclides from PSW grout to the Columbia River results in extremely low incremental increases of radioactivity. The 10,000-year cumulative impact from PSW is less than 1 person-rem. This can be compared to the dose from natural background radiation that the downriver population would receive over 10,000 years: 3 billion person-rem.

7.0 GLOSSARY

active institutional control - in this document, active institutional control means continued federal control of the Hanford Site along with maintenance and surveillance of facilities and waste sites

advection - the transport of a substance solely by the bulk phase movement of a fluid such as water

aquifer - an underground bed or stratum of earth, gravel, or porous stone that contains water. The water can be pumped to the surface through a well or it can emerge naturally as a spring

barrier - any medium that retards the movement of emplaced radioactive or nonradioactive material or reduces the probability of human access to the material. (Examples are engineered features, including waste containers, waste form, or backfill material; a natural geologic medium; or institutional site access and use restrictions.)

conservative - conservative choices of parameters or assumptions are those that would tend to overestimate rather than underestimate impacts

constant release rate - a rate of release (amount released/time) that does not vary over time

diffusion-controlled release rate - a rate of release (amount released/time) dependent on the rate of diffusion of the released substance from inside the source to the surface of the source

disposal system - combination of waste preparation steps, engineered and natural barriers, performance verification methods, and in situ marking systems that contain and isolate waste after disposal

distribution coefficient (K_d) - the ratio of the concentration of a solute sorbed by solids in a porous media to the concentration of solute remaining in solution

dose - the term "dose" is used throughout this report as a shorthand notation where the term dose-equivalent (calculated in mrem) is intended

dose equivalent - the product of absorbed dose, quality factor, distribution factor, and other modifying factors necessary to evaluate the effects of irradiation received by exposed persons, so that the different characteristics of the exposure are taken into account

effective dose equivalent - the sum of the products of the dose equivalent to individual organs and tissues and appropriate weighing factors representing the risk of health relative to that for an equal dose to the whole body

evapotranspiration - the combined loss of water from soil by evaporation and by transpiration from the surfaces of plant structures

exposure - the condition of being made subject to the action of radiation; a measure, in roentgens, of the ionization produced in air by x-ray or gamma radiation

fingering - the formation and downward propagation of (finger-shaped) regions of preferential flow caused by viscosity differences between fluids occupying the pore space of a porous solid

flux - quantity of substance moving past a unit area (perpendicular to flow direction) per unit time

groundwater - water below the land surface in a zone of saturation

grout - a slurry mixture of cement, water, fly ash, and clay that sets up as a solid mass and is used for waste fixation or immobilization

half-life - the time required for a radionuclide's activity to decay to half its value, used as a measure of the persistence of radioactive materials; each radionuclide has a unique half-life

hazardous waste - a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical or infectious characteristics may:

a) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

b) pose a substantial present or potential hazard to human health or the environmental when improperly treated, stored, transported, or disposed of, or otherwise managed.

hydraulic conductivity - the parameter relating the volumetric flux to the driving force in flow through a porous medium (particularly water through soil); a function of both the porous medium and the properties of the fluid

inadvertent intrusion - human activity, such as home excavation, resource mining, and well digging, that accidentally breaches a waste site

institutional control - see active institutional control or passive institutional control

intruder - a person who violates site and marker boundaries to disturb a waste site

isotope - one of several different species of a given chemical element; different isotopes are distinguished by different numbers of neutrons in the atomic nucleus

9011178619926

K_d - see distribution coefficient

leach - to dissolve out the soluble components of a solid by contact with water or other solvent

low-level waste (LLW) - radioactive waste not classified as high-level waste, transuranic waste, or spent nuclear fuel

model - a conceptual or mathematical representation of the chemical, physical, and biological behavior in the natural environment; the computational implementation of which often requires a computer code

parameters - constant or variable factors (mathematical variables) contained in a mathematical model which, when given different numerical values, will result in different values of some desired output variable

passive institutional control - period following closure and deactivation of a disposal site during which public access and use is restricted by continued government ownership and restrictions on either land or resource area by the use of markers to delineate boundaries and potential health hazards to intruders and the use of public records, archives, and other methods to preserve information about the location, design, and contents of the disposed system

pathway - the movement of materials from the source to locations of interest

performance assessment - an analysis that identifies the events and processes that might affect the waste disposal system, examines their effects upon its natural and engineered barriers, and estimates the probabilities and consequences of those events and processes

Phosphate/Sulfate Waste from N Reactor Operations - a combination of two liquid low-level waste streams generated by the N Reactor at the Hanford Site, comprised of one stream generated periodically during decontamination activities, another semi-continuously as a result of back-flushing ion exchange resins used to purify the water in the spent-fuel storage basin

piecewise constant - constant within a discrete piece of a region of interest; with different pieces of the region having different constant values

radionuclide - any nuclide that emits radiation

recharge - the net process of water entering a saturated aquifer at the water table after having percolated downward through the soil profile. Recharge is a fraction of the annual rainfall; the remainder is evaporated from the bare surface or transpired by plants.

sorb - to adsorb onto a solid surface or to become absorbed into the body of a solid material

sorption - a general term used to encompass the processes of physical and chemical absorption or adsorption, ion exchange, and dialysis

9011786192 7

standards - a quantitative measure of criteria satisfaction, or prescriptive norms established to govern action, established from the perspective of criteria; can govern such things as radiation exposure, water quality, barrier and waste form design, and releases from a waste site

steady-state - constant with respect to time

streamlines - in a steady-state flow model, the paths that particles would move along if passively flowing along with the moving water; a line that is everywhere parallel to the direction of fluid flow at a given instant

stream tube - water flowing between two streamlines (two-dimensional); an imaginary tube whose wall is generated by streamlines passing through a closed curve

transmissivity - a coefficient relating the volumetric flow through a unit width of groundwater to the driving force (hydraulic potential); a function of the porous medium, fluid properties, and saturated thickness of the aquifer

unconfined aquifer - an aquifer that has a water table or surface at a atmospheric pressure

vadose zone - the unsaturated region of soil between the ground surface and the water table

vault - in the context of this report, a concrete disposal structure for containing grouted waste

9011178619928

8.0 REFERENCES

American Nuclear Society (ANS). 1984. "Measurement of the Leachability of Solidified Low-Level Radioactive Wastes." ANS 16.1, Champaign, Illinois.

Bierschenck, W. H. 1959. Aquifer Characteristics and Groundwater Movement at Hanford. HW-60601, Hanford Atomic Products Operation, Richland, Washington.

Delegard, C. H., and G. S. Barney. 1983. Effect of Hanford High-Level Waste Components on Sorption of Cobalt, Strontium, Neptunium, Plutonium, and Americium on Hanford Sediments. RHO-RE-ST-1P, Rockwell Hanford Operations, Richland, Washington.

Electric Power Research Institute (EPRI). 1983. Physical-Chemical Characteristics of Utility Solid Wastes. EPRI EA-3236, Electric Power Research Institute, Palo Alto, California.

Fecht, K. R., G. V. Last and M. C. Marratt. 1979. Stratigraphy of the Late Cenozoic Sediments Beneath the 216-A Crib Facilities. RHO-LD-71, Rockwell Hanford Operations, Richland, Washington.

Felmy, A. R., D. C. Girvin and E. A. Jenne. 1984. MINTEQ--A Computer Program for Calculating Aqueous Geochemical Equilibria. EPA-600/3-84-032; NTIS PB 84-a57148, U.S. Environmental Protection Agency, Athens, Georgia.

Huizenga, D. G., W. T. Farris, R. L. Treat and A. H. McMakin. 1986. "Sensitivity Analysis of Long-Term Performance of the Grout System for the Disposal of a Low-Level Radioactive Waste Stream at Hanford." PNL-SA-13386, In Proceedings of Waste Management '86 Symposium, March 2-6, 1986, Tucson, Arizona.

International Commission on Radiological Protection (ICRP). 1959. "Report of ICRP Committee II on Radiological Protection." ICRP Publication 2, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1966. "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract." Health Physics 12:173.

International Commission on Radiological Protection (ICRP). 1975. "Report of the Task Group on Reference Man." ICRP Publication 23, Pergamon Press, Oxford.

International Commission on Radiological Protection (ICRP). 1977. "Recommendations of the International Commission on Radiological Protection." ICRP Publication 26, Annals of the ICRP, 2, No. 3.

International Commission on Radiological Protection (ICRP). 1979. "ICRP Publication 30, Limits for Intakes of Radionuclides by Workers:" Part 1 (1979) Annals of the ICRP, 2, No. 3/4:1-62. Supplement to Part 1 (1979) Annals of the ICRP, 3:84, 202, 236, 414, 456. Supplement to Part 2 (1981) Annals of the ICRP, 5:195. Supplement A to Part 3 (1982) Annals of the ICRP, 7:17.

Kirkham, R. R. and G. W. Gee. 1983. "Measurement of Unsaturated Flow Below the Root Zone at an Arid Site." PNL-SA-11629, Pacific Northwest Laboratory, Richland, Washington.

McCormack, W. D., J. V. Ramsdell and B. A. Napier. 1984. Hanford Dose Overview Program: Standardized Methods and Data for Hanford Environmental Dose Calculations. PNL-3777, U.S. Nuclear Regulatory Commission, Washington, D.C.

Napier, B. A., R. A. Peloquin, W. E. Kennedy, Jr. and S. M. Neuder. 1984. Intruder Dose Pathway Analysis for the ONSITE/MAXI Computer Program. NUREG/CR-3620 (PNL-4054), Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin and D. L. Strenge. 1986. DITTY - A Computer Program for Calculating Population Dose Integrated Over Ten Thousand Years. PNL-4456, Pacific Northwest Laboratory, Richland, Washington.

Reisenauer, A. E. 1979a. Variable Thickness Transient Groundwater Flow Model: Volume 1, Formulation. PNL-3160-1, Pacific Northwest Laboratory, Richland, Washington.

Reisenauer, A. E. 1979b. Variable Thickness Transient Groundwater Flow Model: Volume 2. User's Manual. PNL-3160-2, Pacific Northwest Laboratory, Richland, Washington.

Reisenauer, A. E. 1979c. Variable Thickness Transient Groundwater Flow Model: Volume 3. Program Listings. PNL-3160-3, Pacific Northwest Laboratory, Richland, Washington.

Safe Drinking Water Act, PL 93-523 (December 16, 1974).

Serne, R. J. et al. 1986. Laboratory Leach Tests of HFW Grout and Leachate Absorption Tests Using Hanford Sediment. PNL-6017, Pacific Northwest Laboratory, Richland, Washington.

Soldat, J. K. 1976. "Radiation Doses from Iodine-129 in the Environment." Health Physics 30:61-70.

Simmons, C. S., C. T. Kincaid and A. E. Reisenauer. 1986. A Simplified Model for Radioactive Transport: The TRANSS Code. PNL-6029, Pacific Northwest Laboratory, Richland, Washington.

9011178519 30

U.S. Department of Energy (U.S. DOE). 1981a. "Environmental Protection, Safety and Health Protection Programs for DOE Operations." DOE Order 5480.1A, Chapter XI, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (U.S. DOE). 1981b. "Environmental Protection, Safety, and Health Protection Information Reporting Requirements." DOE Order 5484.1, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (U.S. DOE). 1984. "Radioactive Waste Management." DOE Order 5820.2, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy - Richland Operations (U.S. DOE). 1986a. Environmental Assessment for the Grouting and Near-Surface Disposal of Phosphate/Sulfate Hanford Facilities Waste. DOE/EA-0312, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (U.S. DOE). 1986b. Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes--Draft Environmental Impact Statement, DOE/DEIS-0113, U.S. Department of Energy, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 1983. "Advanced Notice of Proposed Rulemaking: Environmental Radiation Protection Standards for Low-Level Radioactiev Waste Disposal." (48 FR 39563), W. D. Ruckelshaus, Administrator, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 1984. "National Interim Primary Drinking Water Regulations." Code of Federal Regulations, Title 40, Part 141. U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 1985a. "Environmental Assessment." Code of Federal Regulations, Title 40, Part 1508.9(a)(1), Chapter V - Council on Environmental Quality, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA). 1985b. "National Primary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms, Proposed Rule." 40 CFR Part 141. Federal Register (November 13, 1985), U.S. Environmental Protection Agency, Washington, D.C.

U.S. Nuclear Regulatory Commission (U.S. NRC). 1977. Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I. Regulatory Guide 1.109, Rev. 1. U.S. Nuclear Regulatory Commission, Washington. D.C.

U.S. Nuclear Regulatory Commission (U.S. NRC). 1981. Draft Environmental Impact Statement on 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." NUREG-0782, Vols. 1-4, Washington, D.C.

U.S. Nuclear Regulatory Commission (U.S. NRC). 1982a. "10 CFR Parts 2, 19, 20, 21, 30, 40, 51, 61, 70, 73, and 170: Licensing Requirements for Land Disposal of Radioactive Waste." Federal Register 47:248.

9011178619 31

U.S. Nuclear Regulatory Commission (U.S. NRC). 1982b. Final Environmental Impact Statement on 10 CFR 61, Licensing Requirements for Land Disposal of Radioactive Waste, NUREG-0945, U.S. Nuclear Regulatory Commission, Washington, D.C.

Washington Administrative Code (WAC). 1984. WAC-173-201, "Water Quality Standards for the Water of the State of Washington." Washington State Department of Ecology, Olympia, Washington.

Washington Administrative Code (WAC). 1985. "Maximum Contamination Levels," WAC-248-54-175 (in WAC 248-54, "Public Water Supplies,"). Washington State Department of Social and Health Services, Olympia, Washington.

9011178619 32

APPENDIX 9C

LAND USE AND ZONING MAP

This page intentionally left blank.

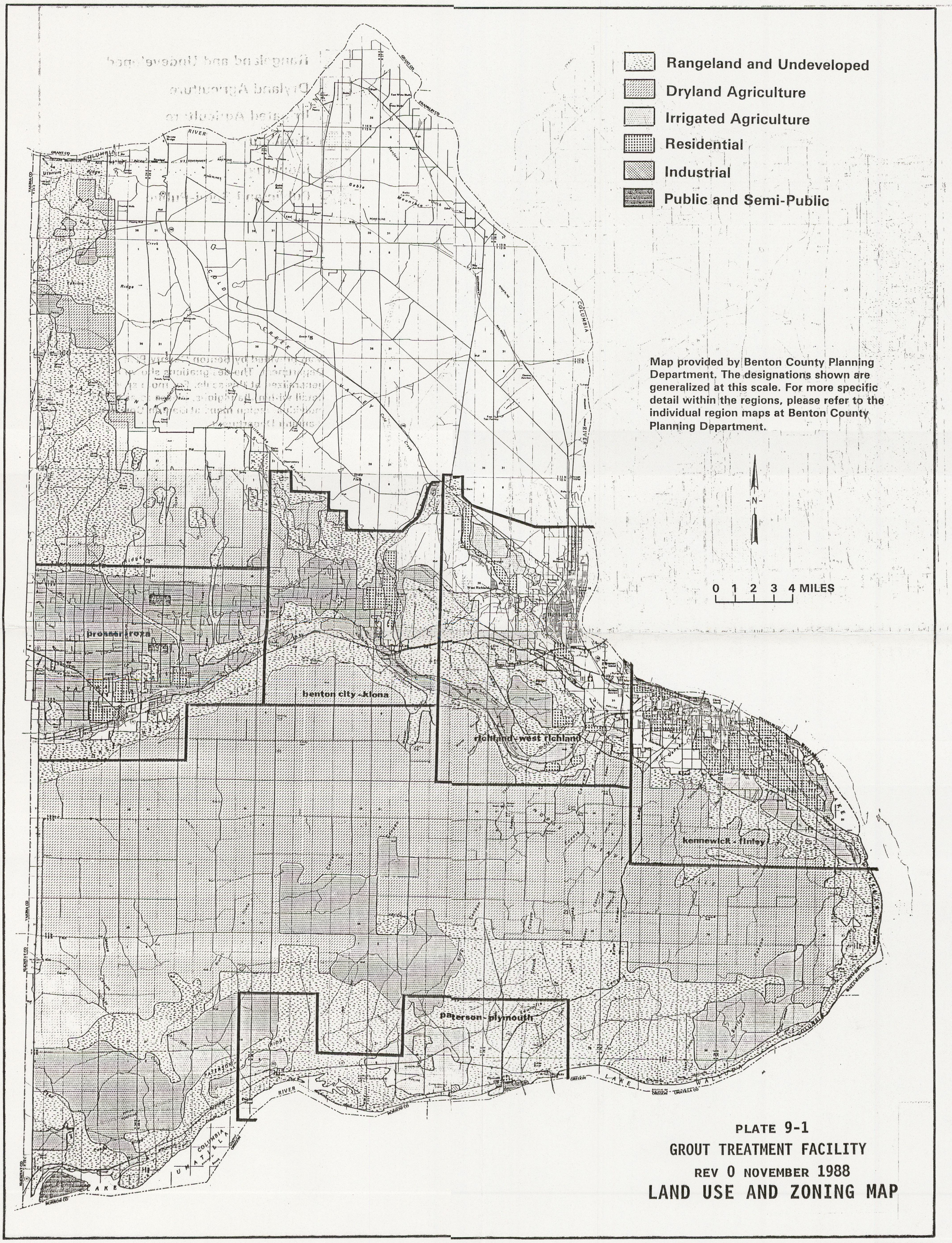


PLATE 9-1

GROUT TREATMENT FACILITY

REV 0 NOVEMBER 1988

LAND USE AND ZONING MAP

28710-007.8

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX 11

CLOSURE/POSTCLOSURE REQUIREMENTS

APPENDIX 11

CLOSURE/POSTCLOSURE REQUIREMENTS

11A Cover Design Engineering Report

11B Closure Plan Drawing

11C Clay Liners (Admixtures) in Semiarid Environments

APPENDIX 11A

COVER DESIGN ENGINEERING REPORT

1 This page intentionally left blank.

DOE/RL 88-27
Rev. 1, 01/17/90

ENGINEERING REPORT

COVER DESIGN

Prepared for

WESTINGHOUSE HANFORD COMPANY

September 1989

For the U.S. Department of Energy
Contract DE-AC06-87RL10900

Prepared by

KAISER ENGINEERS HANFORD COMPANY
Richland, Washington

KEH-88-29
ER9089

KAISER ENGINEERS
HANFORD

9011178519 40

KEH-88-29

ENGINEERING REPORT

FOR

COVER DESIGN

9011178619 41

Prepared by

KAISER ENGINEERS HANFORD COMPANY
Richland, Washington

for

WESTINGHOUSE HANFORD COMPANY

William J. Magnuson Principal Lead Engineer	8/15/89 2/10/89 Date	S O McCleary Technical Documents	8/15/89 2/10/89 Date
L H Smith Safety	8/16/89 2/10/89 Date	J H Ray Environmental	8/16/85 2/10/89 Date
[illegible] Chief Design Engineer	8/16/89 2-22-89 Date	[illegible] Quality Engineering	8/16/89 2/16/89 Date
Project Manager	9/15/89 Date		

Westinghouse Hanford Company

L R Bunger — 9/15/89 Date

TABLE OF CONTENTS

Page

I. INTRODUCTION 1

II. SUMMARY 1

III. PURPOSE 3

IV. DESCRIPTION 3

A. Protection of Membrane 3
B. Low Permeability Layers 7
C. Laboratory Analysis 8
D. Lateral Drainage 10
E. Gas Vents 10
F. Slope Stability 10
G. Liquid Migration Analysis 10
H. Maintenance Requirements 13
I. Erosion Potential 13
J. Settlement and Subsidence 15
K. Infiltration 16
L. Freeze/Thaw Effects 17
M. Waste Stabilization 17

V. CONCLUSIONS AND RECOMMENDATIONS 18

A. Slope Stability 18
B. Liquid Migration Analysis 18
C. Erosion Potential 19

VI. REFERENCES 19

APPENDICES

Appendix A Hydrologic Evaluation of Landfill Performance (HELP) Model Results
Appendix B Soil Loss Calculations

ENGINEERING REPORT
COVER DESIGN

I. INTRODUCTION

Grout vaults will be constructed in pairs at the Grout Treatment Facility (GTF). A closure cover will be constructed over each pair of vaults after filling operations are completed. The closure cover is designed to prevent infiltration from precipitation, roots, and burrowing animals from reaching the waste. This report contains an evaluation of the cover design for the GTF.

II. SUMMARY

The design of the closure cover is based mainly on the results of the liquid migration analysis performed by computer (ref 2). The cover configuration chosen was carefully checked to ensure it met all requirements of the Technical Guidance Document, "Final Covers on Hazardous Waste Landfills and Surface Impoundments" (ref 5).

The cover system chosen is nearly identical to the Environmental Protection Agency (EPA) recommended design. The following is a description of each cover layer beginning at the top:

- The surface will be revegetated with perennial grasses to prevent erosion.

- A layer of topsoil with a 3 ft 9 in. minimum thickness will support the grasses, prevent their roots from reaching the low permeability layers, and prevent freeze-thaw damage of the lower layers.

- A 1 ft 0 in. thick lateral drainage layer will effectively transport infiltration to the edges of the cover where it will be safely transferred into the native soil.

9 0 1 1 7 8 6 1 9 4 3

- A 60-mil geomembrane will act as a barrier to the infiltration. The slope of the geomembrane will promote lateral drainage in the layer above.

- The 2-ft 0-in. thick layer of soil-bentonite mix with a minimum hydraulic conductivity of E^{-7}cm/S will impede the downward movement of precipitation should any breaches occur in the geomembrane. This soil mixture, along with the geomembrane, form the composite barrier layer.

- A 1-ft 0-in. thick layer of filter sand will prevent migration of particles from the soil-bentonite layer into the gravel below.

The computer analysis using the Hydrologic Evaluation of Landfill Performance (HELP) program shows that an average of 94% of annual precipitation is removed by evapotranspiration. The remaining precipitation that infiltrates the cover is partially retained in the topsoil and the rest drains laterally off the geomembrane overlying the soil-bentonite layer.

The computer analysis was also used to predict the expected volume of run-off from precipitation on the surface area of the cover. Run-off occurs only when 24-hr storms exceed 1 in. and the volume produced is small (refer to appendix A).

Settlement analysis in Section J4, indicated that settlement up to 3.2 in. could occur at the cover base. The cover layers are of sufficient thickness to continue to perform as designed with this settlement. Periodic inspection and maintenance of the surface will ensure that ponding is prevented.

Wind and water erosion analysis of the surface showed that erosion is negligible. Straw mulch anchored in place with a straw roller will help prevent erosion during the first few seasons and establishment of the wheatgrasses will prevent erosion for the long term.

9011178619944

III. PURPOSE

The cover prevents infiltration from precipitation from reaching the vault structure or the concrete catch basin.

IV. DESCRIPTION

Closure covers will be constructed over a pair of vaults. The precipitation infiltrating the topsoil will drain laterally through a sand layer across the 10% slope of the barrier layer and into the subsoil between vault pairs. The barrier layer is a composite of a geomembrane overlying a layer of soil/bentonite mix. This composite is beneath more than 3.5 ft of soil to prevent damage from frost action, roots, and burrowing animals (refer to figures 1, 2, and 3).

A. Protection of Membrane

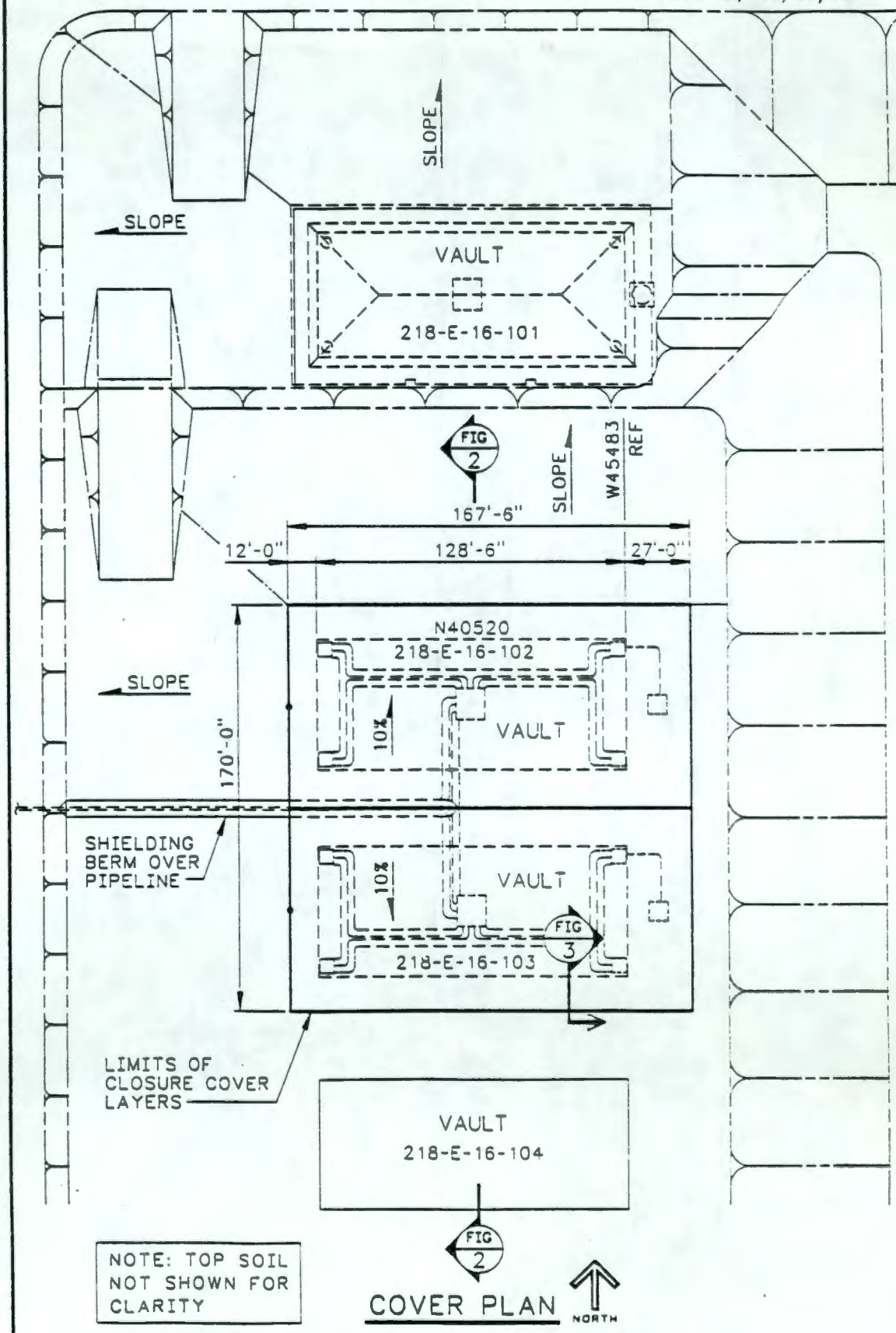
1. Sand Bedding Layer

The sand bedding layer will offer protection from above for the geomembrane. The layer will be constructed from stockpiled materials which are no coarser than sand (SP) as designated by the Unified Soil Classification System (USCS). The layer thickness of 12 in. is more than adequate to prevent damage from sharp objects in the overlying topsoil.

2. Soil/Bentonite Mix Layer

The soil/bentonite mix layer will underlie the geomembrane providing protection from below. The soil material in the mix is sandy silt (ML), as designated by the USCS, and is available onsite. The material will be screened and the lifts compacted and rolled smooth before placement of the geomembrane.

9011178619 45



COVER PLAN

FIGURE 1

9 0 1 1 7 8 6 1 9 4 5

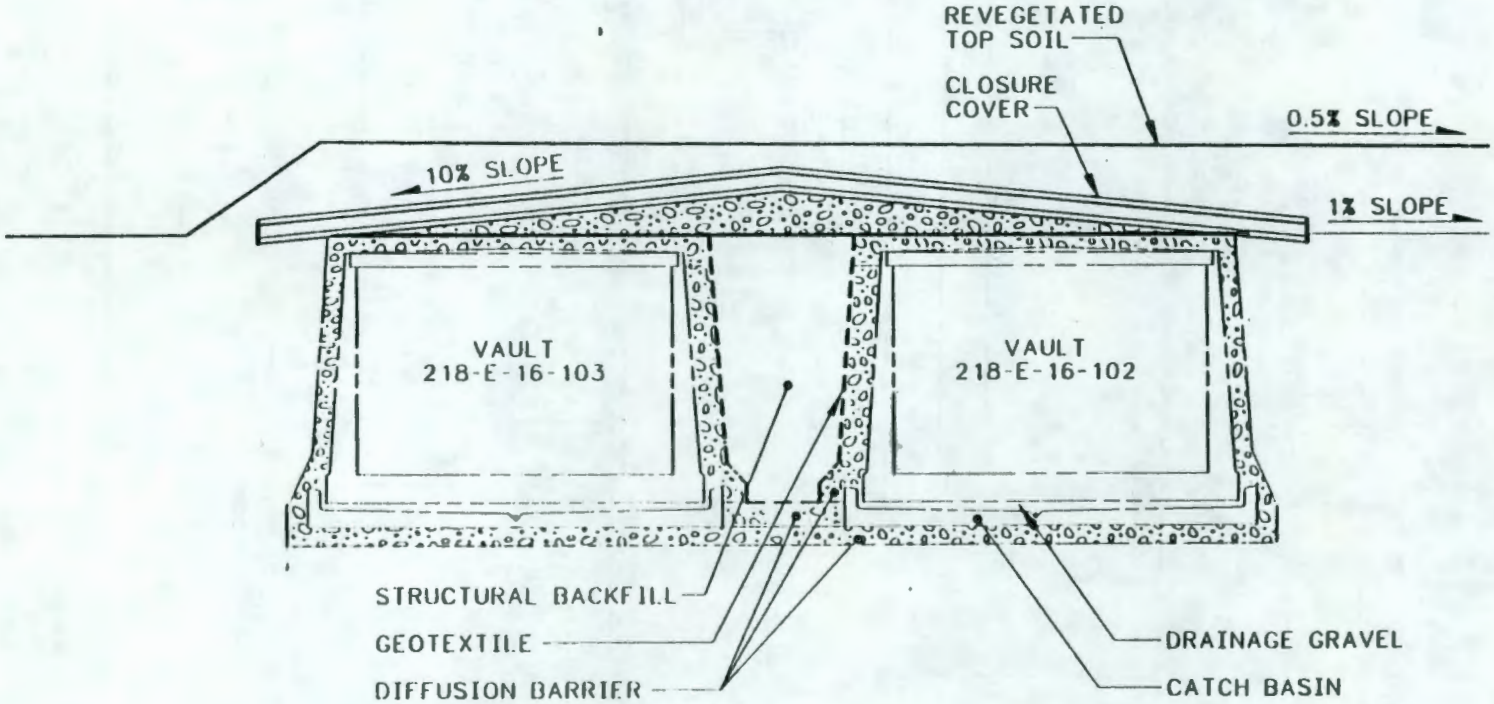

REVEGETATED
TOP SOIL
CLOSURE
COVER
0.5% SLOPE
10% SLOPE
1% SLOPE
VAULT
218-E-16-103
VAULT
218-E-16-102
STRUCTURAL BACKFILL
GEOTEXTILE
DIFFUSION BARRIER
DRAINAGE GRAVEL
CATCH BASIN

FIGURE 2

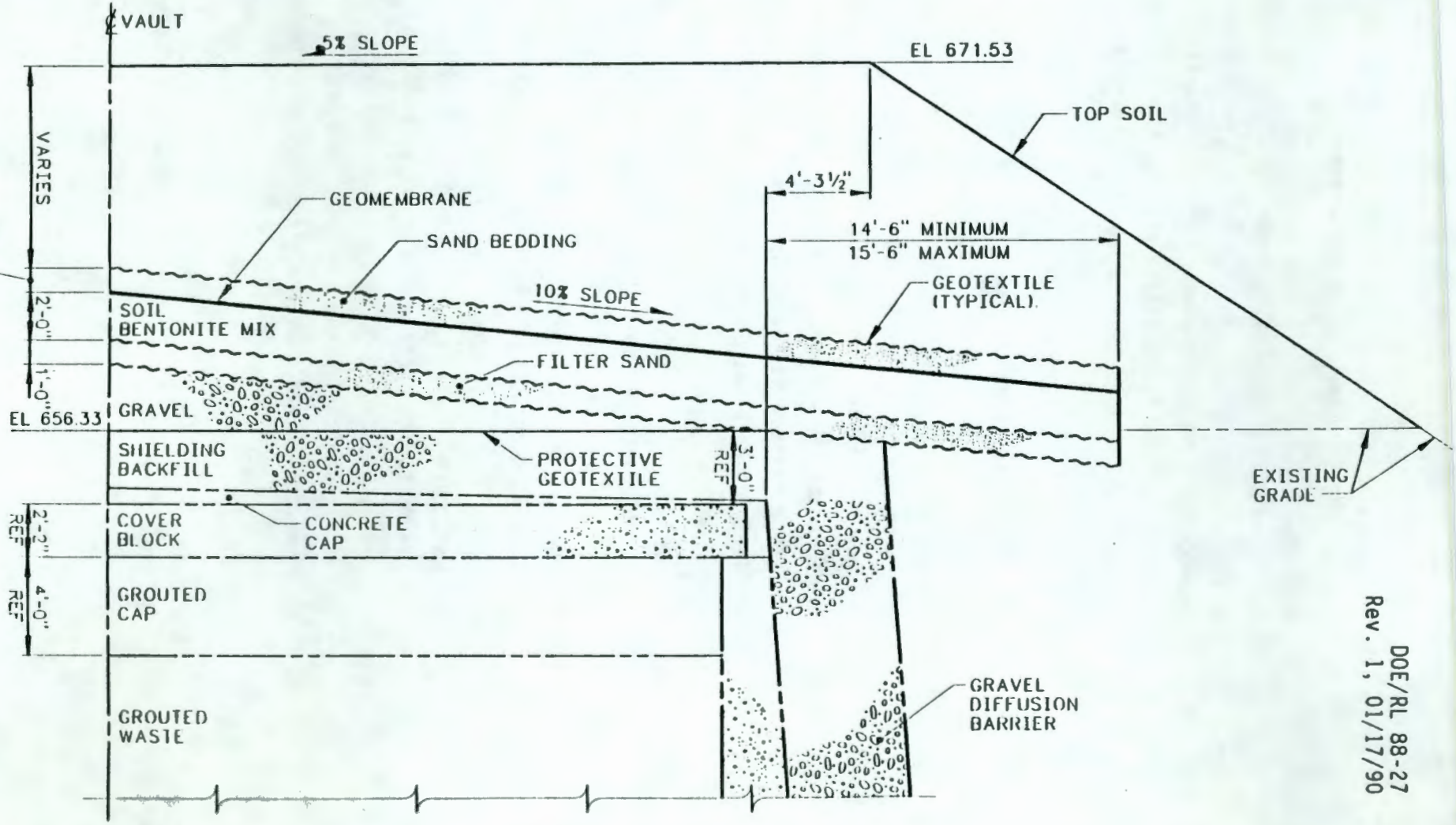

VAULT
5% SLOPE
EL 671.53
TOP SOIL
VARIES
1'-0"
2'-0"
1'-0"
GEOMEMBRANE
SAND BEDDING
4'-3½"
14'-6" MINIMUM
15'-6" MAXIMUM
10% SLOPE
GEOTEXTILE (TYPICAL)
SOIL BENTONITE MIX
FILTER SAND
EL 656.33
GRAVEL
SHIELDING BACKFILL
PROTECTIVE GEOTEXTILE
3'-0" REF
EXISTING GRADE
2'-2" REF
COVER BLOCK
CONCRETE CAP
4'-0" REF
GROUTED CAP
GROUTED WASTE
GRAVEL DIFFUSION BARRIER

FIGURE 3

B. Low Permeability Layers

1. Geomembrane

The geomembrane material chosen is 60 mil, high density polyethylene (HDPE). This material is identical to the geomembrane used in the secondary liner system. Using the same material and installation procedures will ensure that the permeability of the cover is equal to that of the secondary liner.

2. Soil/Bentonite Layer

The spread of any liquid passing through breaches in the geomembrane will be slowed by a 2-ft thick layer of soil/bentonite mix. A pug mill will be used to thoroughly blend the mix and ensure consistent results. The layer will be compacted to 95% maximum dry density at a mix ratio that will achieve a maximum permeability of E^{-7} cm/sec. Specification B-714-C5 includes methods of construction to be used.

a. Soil

A geotechnical report (ref 1) investigated candidate soils for use in the low-permeability layer. Laboratory tests yielded results indicating that a sandy silt USCS (ML) available onsite will perform satisfactorily.

b. Bentonite

The bentonite portion of the mix will be sodium montmorillonite. Laboratory tests indicate that a mix of 10 to 20% bentonite, depending on the method of mixing, compaction, etc., will achieve the required permeability.

9011786194 9

C. Laboratory Analysis

A laboratory testing program was conducted to determine physical and engineering characteristics of soil samples obtained at the project site. Following is an excerpt from ref 1 which describes the laboratory analysis on the soil samples:

"The program consisted of index property tests such as moisture content, density, particle size, and Atterberg Limits tests. Specific tests to determine compaction characteristics, strength, deformability, permeability, and shrinkage characteristics were also conducted and are described below.

"Particle size (sieve) analysis tests were conducted on samples from the excavation face, a borehole at the proposed vault location, and the stockpile soils in order to assist in classifying the soils, and to provide a basis for estimating engineering performance such as strength, deformability, collapse potential, and erodibility. This data is also useful for estimating permeability.

"Strength parameters for foundation soils were obtained using both direct-shear and triaxial-compression tests performed on slightly disturbed samples. Direct-shear tests were conducted on samples from shallow depths to provide data for the analysis of the stability of natural slopes, as well as for the analysis of foundation bearing capacity. Samples were tested in triaxial compression primarily to provide deformability estimates for the analysis of foundation settlements. The tests were conducted under consolidated drained conditions at the natural moisture content of the sample, and included several unload-reload cycles to better define the true elastic modulus.

9011178619 50

"Strength parameters were obtained for stockpile soils in order to assess the stability of future compacted fill slopes. Direct-shear tests were conducted on samples compacted to 90% of the maximum dry density as determined by ASTM D 1557 and permitted to air dry to a moisture content more representative of the in-situ conditions.

"Compaction characteristics of the stockpile soils were examined by conducting both standard and modified Proctor compaction tests. This information was obtained to provide a basis for compacted fill recommendations, estimates of loads applied by compacted backfill, estimates of earth pressures, and evaluation for possible use in the vault closure-cover system.

"The closure cover soil analysis also required that compaction tests be conducted on both stockpile sand and silt mixed with various percentages of bentonite. The resulting data was used to guide the preparation of samples for permeability testing.

"Constant head permeability tests were conducted on soils under consideration for use in the closure-cover system. A rigid wall compaction mold permeameter was employed in this testing. Pressure heads for 2 to 20 psi were used, with most testing conducted at 15 psi. The soils investigated were mixed with as much as 20% by weight of bentonite, in order to achieve the target laboratory permeability of 1×10^{-8} cm/sec. One set of samples, including stockpile sand and sandy silt, was first desiccated by drying to 160°F over a 12-day period, then tested for permeability using the procedure above.

"Shrinkage performance of soils under consideration for use in the closure cover was examined by conducting

9 0 1 1 7 8 6 1 9 5 1

shrinkage tests on cylindrical samples and by mapping shrinkage cracks in permeability samples that were desiccated by drying to 160°F in 13°F increments over a 12-day period."

Results of the laboratory analysis are found in ref 1.

D. Lateral Drainage

The sand bedding layer, placed directly above the geomembrane, will allow infiltrating liquid to migrate laterally out of the cover and into the surrounding soil. The sand USCS (SP) is spread to a compacted thickness of 12 in. The grain size distribution selected yields a typical hydraulic conductivity of $1E^{-1}$ cm/sec (ref 12).

E. Gas Vents

Gas generation studies have not been completed. Gas venting, if required, will be designed at a later date.

F. Slope Stability

Construction of the cover requires temporary slopes of 1.5 horizontal to 1.0 vertical as detailed in figures 2 and 3. The slopes are temporary and will be backfilled to a level condition as adjacent vault excavations are backfilled. A maintenance schedule will be implemented to repair any eroded areas until adjacent covers are placed. The results of the slope stability analysis are presented in the geotechnical report (ref 1).

G. Liquid Migration Analysis

The HELP software, developed by Schroeder et al (ref 2) for the EPA, was used to model water movement through the cover design. The HELP model uses a maximum of 20 yr of precipitation data. Precipitation data has been recorded at the Hanford townsite and

9011178619 52

the Hanford Meteorology Station from 1912 to the present (figure 4). The average annual precipitation rate, excluding years of incomplete data, is 6.42 in. (ref 3). The climatological history of the Hanford Site from the year 1981 through 1987 was used as input for daily precipitation and temperatures. These 7 yr of data were chosen because of their higher-than-average annual precipitation rate of 7.21 in. This period also included the third highest annual precipitation recorded (11.03 in.) (ref 4).

The HELP model results (refer to appendix A) show that an average of 94% of the annual precipitation is removed by evapotranspiration. This percentage is probably conservative because the HELP program does not include calculations for evaporation caused by wind. No run-off from precipitation on the surface area of the cover is produced by the model, even though the data includes a storm of 0.93 in. in 24 hr.

The rainfall for the 24-hr, 25-yr storm was inserted in the precipitation data to evaluate the cover design performance for the worst case single event (refer to appendix A).

The precipitation which infiltrates the cover is partially retained in the topsoil. Less than 4% of the average annual precipitation will drain laterally off the geomembrane of the composite barrier layer and into the soil between vault pairs. No water penetrates the composite barrier layer of the cover according to the model. Also, the model predicts no head (saturated soil) on the surface of the composite barrier layer. (See appendix A for details assumed for the geomembrane.)

The HELP program was also used to analyze the EPA recommended cover design. The only difference between the two designs is the amount of topsoil. The EPA design requires only 2 ft of topsoil. The topsoil over the vaults varies between 3.75 and 11.5 ft. The greater thickness of topsoil provides more water retention capacity, so less water reaches the composite barrier layer.

9011178619553

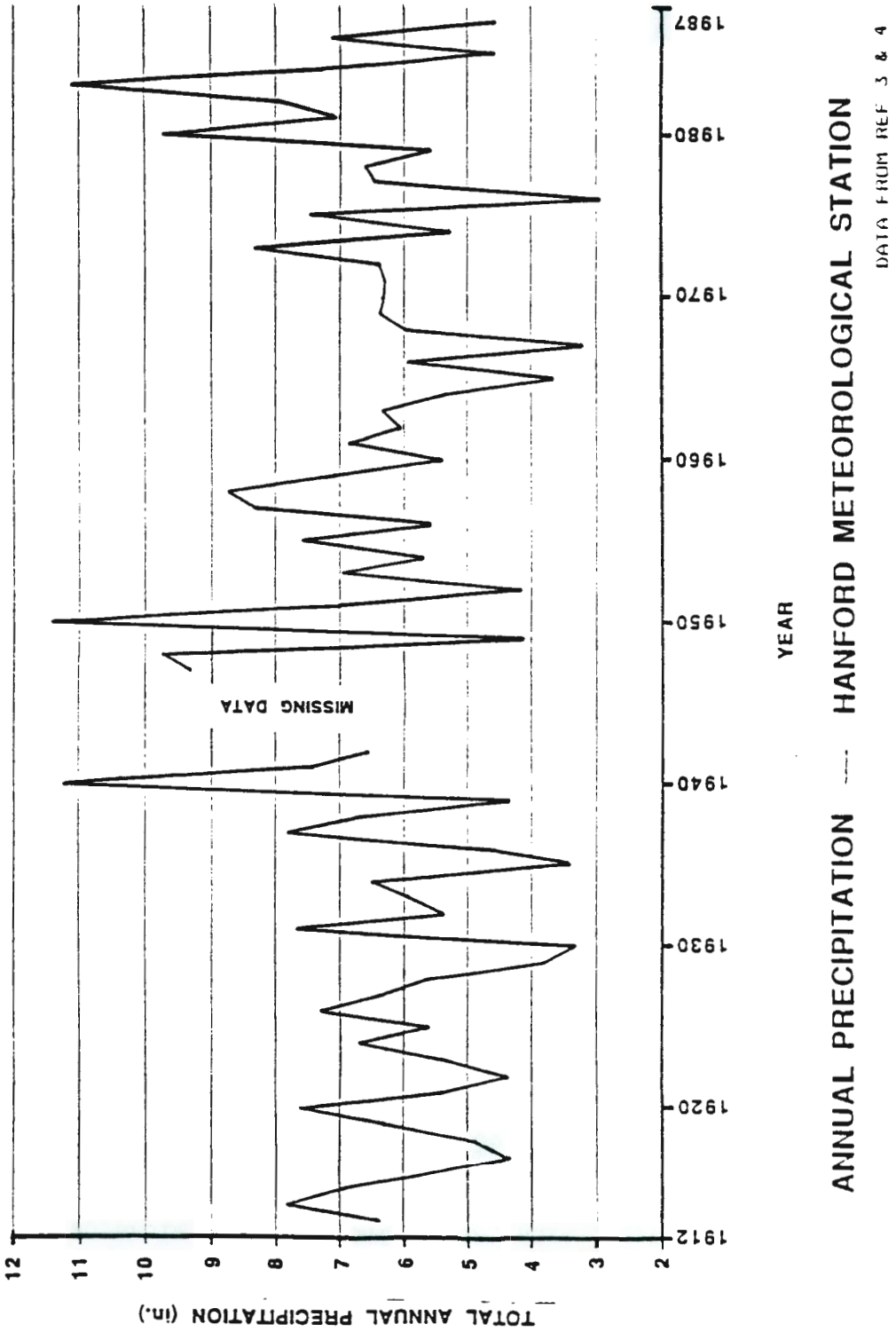

ANNUAL PRECIPITATION — HANFORD METEOROLOGICAL STATION
DATA FROM REF 3 & 4
YEAR
1912
1920
1930
1940
1950
1960
1970
1980
1987
MISSING DATA
TOTAL ANNUAL PRECIPITATION (in.)
12
11
10
9
8
7
6
5
4
3
2

FIGURE 4

H. Maintenance Requirements

The closure cover will require maintenance as identified by the quarterly inspections. Maintenance action could include:

- Erosion damage repair
- Correction of settlement and subsidence
- Vegetative cover maintenance
- Animal activity repair

The Inspection and Maintenance Plans, contained in the permit application, describe scheduled inspection and maintenance action for the cover.

I. Erosion Potential

1. Surface Erosion

Erosion damage may occur as a result of flooding, precipitation, or wind. Because the flow in the Hanford reach of the Columbia River is controlled by the Priest Rapids Dam, the probability of erosion damage to the site from floods is low. The vault site lies in an area completely above the 100-yr floodplain. The combination of arid climate, high evapotranspiration rate, and the 0.5% slope of the cover surface makes damage at the site from storms unlikely.

A potential for erosion from wind exists, particularly during the period of vegetative establishment. Mulching practices, which will be implemented during closure, are quite effective at minimizing wind erosion prior to establishment of a perennial grass cover. A stable vegetative cover will reduce possible damage due to wind and water erosion. A mixture of Thickspike wheatgrass (Agropyron dasytachyum) and a Siberian wheatgrass (Agropyron sibericum) will be seeded in the topsoil. Thickspike wheatgrass is a rhizomatous native grass of the Pasco Basin and well suited for wind erosion control on deep sandy soils (ref 7). Siberian wheatgrass is the most abundant

of the perennial grasses seeded on the Hanford Site for stabilization purposes and has been noted to competitively limit a variety of less-desirable plant species. The Russian wheatgrasses develop a much larger root density than native wheatgrasses and thus more effectively extract water from the soil profile (ref 8). The wheatgrasses are planted in the fall whenever practicable. If, due to scheduling, cover construction requires a spring planting, an annual cereal ryegrass is specified to quickly stabilize the surface, followed by planting of perennial wheatgrasses in the fall. The grass roots are expected to penetrate throughout and stay within the fine topsoil, as water is retained preferentially in this layer rather than the sand bedding layer directly below the topsoil. Soil permeabilities and rainfall intensities at Hanford are such that water-induced erosion will be very minor on the relatively flat area surrounding the vaults. However, slopes created by the placement of the topsoil and run-on/run-off control structures during closure and the channeling of run-off water may lead to localized increases in erosion.

The HELP model analysis indicated precipitation run-off would occur when 24-hr storms exceeded 1 in. Since daily precipitation has equalled or exceeded 1 in. only twice during the period from 1946 through 1987 (ref 3), there is little potential for run-off to cause erosion.

2. Piping and Seepage Erosion

The geotechnical investigation (ref 1) indicates that recompacted soils are expected to perform well under erosive conditions. Geosynthetic materials placed between each layer will prevent interlayer mixing during construction. The particle size distribution for each layer was designed to prevent migration between layers.

3. Drainage System

Due to the infrequent and low volume of run-off, the cover is sloped uniformly so that all run-off will travel to the north and be drained away from the site. Intermediate collection ditches are not necessary. Additional run-on/run-off features may be found in the Engineering Report for Run-on/Run-off Control System Design.

J. Settlement and Subsidence

The bottom of the vault will be placed about 57-ft below existing grade. The subgrade will undergo an upward heave movement due to excavation unloading, and will subsequently experience downward settlements as construction and vault filling progresses. Settlement at the cover surface will be the sum of settlements in the following:

- Subsoil
- Vault structure (including lining systems)
- Grouted waste

1. Subsoil Settlement

The subsoil consists of relatively dry sands making settlements immediate in nature. The addition of the closure cover is expected to cause a settlement of around 0.2 in. The cumulative settlement of the subsoil during construction is given in the geotechnical report (ref 1).

2. Vault Structure Settlement (Including Lining Systems)

The vault structure consists of:

- Spray-on coating
- Concrete vault with structural cover
- Gravel drainage media

- Flexible membrane liner (FML)
- Concrete basin
- Gravel diffusion barrier

The spray-on coating and FML are relatively thin and any compression in these elements will be insignificant. The gravel is a graded layer, and settlement after initial compaction will be negligible. The solid mass of the concrete is essentially incompressible at these pressures and will contribute nothing to the cover settlement.

3. Grouted Waste Settlement

After filling operations are complete, a nonradioactive grout fill will be placed over the waste to fill any void space between the grouted waste surface and the vault ceiling and any open voids caused by grout shrinkage. Local voids of 3 in. or less in depth could be left in the surface of the clean grout cap. A performance specification for void space filling will be written at a later date.

4. Total Settlement

The additive result of these settlements is

$$0.2 + 0 + 3 = 3.2 \text{ in.}$$

This assumes that at some point the structural vault cover fails and collapses into a 3-in. void in the clean grout cap. A 3-in. local failure at the top of the vault level will have little disruptive effect on the cover layers some 5 ft above. The layer thickness and slope are sufficient to allow the cover to continue to perform as designed to minimize infiltration during and after settlement.

K. Infiltration

The HELP model results indicate that no liquid from the design storm infiltrates through the low-permeability layers of the

cover. If, for any reason, some liquid does infiltrate through the cover, it would be shed by the sloped and sealed cover blocks. Directly below the cover blocks is the grout cap (figure 3) which gives additional protection against infiltration. Upon closure, the vault will be completely filled leaving minimum void space thereby eliminating areas for liquid to collect should any penetrate the barriers above.

L. Freeze/Thaw Effects

Freeze/thaw effects have been considered in the grout vault cover design. The maximum frost penetration depth as recorded at the Hanford Meteorological Station is 3-ft belowgrade. The average number of annual freeze/thaw cycles is 93 with a range of 25 to 168 (ref 3). A freeze/thaw cycle is defined as a day where the minimum temperature is below freezing and the maximum temperature is above freezing.

Water from capillary rise must be considered for freeze-thaw evaluation. Capillary rise is typically a few inches to several feet depending on the pore size of the soil (ref 9). Ground water monitoring wells nearby indicate that the water table is 205 ft below the disposal vault bottom elevation. This water table elevation, coupled with the subsurface soils of the Hanford formation, indicate that capillary rise from the water table to the cover is not a problem.

In summary, considerations of freeze/thaw effects on the cover have been evaluated, and the cover has been adequately designed to prevent deterioration due to freeze/thaw cycling by being placed a minimum of 3.5-ft belowgrade.

M. Waste Stabilization

Cement, fly ash, slag, and other materials will be mixed with the liquid waste to form a slurry. The slurry will setup in the vault to form a stable grout mass. Minimum design compressive strength is 50 psi. The total weight of the waste and all earth

9011786195 9

loads from above yields a compressive stress of 38 psi. This represents a minimum ultimate safety factor of 1.33, therefore waste will remain stable under expected loads.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Slope Stability

The Bishop modified method of slices (ref 10) was used to determine the slope stability. The input parameters include slope topography, piezometric levels, soil parameters, surcharge load conditions, earthquake acceleration coefficients, and search limits for locating possible failure surfaces.

The stability of slopes constructed at inclinations of 1 horizontal to 1 vertical, 1.3 horizontal to 1 vertical, and 1.5 horizontal to 1 vertical were analyzed. Site conditions have indicated that the piezometric level is far below the excavation floor (elevation 621), therefore, water was not considered in the analysis.

Slope geometries 1.3 to 1 and 1.5 to 1 indicate that these slopes, composed of native soil or compacted backfill material, are stable under static loading conditions. The 1.5 to 1 slope has a factor of safety of 1.01 under dynamic loading conditions, which produces a horizontal acceleration of 0.1 g and a factor of safety of 1.27 under static conditions.

B. Liquid Migration Analysis

The HELP model analysis showed that the cover design will prevent liquids from infiltrating to the vaults containing the waste. Most of the precipitation will be evapotranspirated because of the low precipitation and low humidity at the site. The precipitation that will infiltrate the cover will be partially retained by the soil. Less than 4% of the average annual precipitation will reach the barrier layer and will drain laterally from the cover into the surrounding backfill.

C. Erosion Potential

The universal soil loss equation developed by the U.S. Department of Agriculture (ref 11) was used to estimate the soil loss due to water erosion. The input parameters include rainfall erosion index, soil erodability factor, length and steepness of slope, vegetative cover factor, and erosion control practice factor.

The results show 0.22 ton/acre will be lost due to erosive action the first year, and 0.96 ton/acre will be lost annually thereafter. The flatness of the cover and the low annual rainfall were the most instrumental factors influencing the low results. The soil loss calculations are included in appendix B.

The wind erosion equation (ref 6) was used to estimate the soil loss from wind erosion. The input parameters included soil erodibility index, soil ridge roughness factor, climatic factor, field length, and quantity of vegetative cover.

The results indicate an annual loss of .915 ton/acre due to wind erosion.

Total calculated erosion is .96 + .915 = 1.88 tons/acre/yr. This figure is below the EPA recommended 2 tons/acre/yr maximum (ref 5). Periodic inspection and maintenance is required during the post closure monitoring period to ensure that erosion does not threaten the integrity of the cover.

VI. REFERENCES

1. "Geotechnical and Corrosion Investigation - Grout Vaults, Hanford, Washington," prepared by Dames and Moore for Kaiser Engineers, Inc., Document No. 10805-282-016, October 10, 1988.

2. Schroeder, P. R., "Hydrologic Evaluation of Landfill Performance," HELP Version 2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 1988.

3. Stone, W. A., Thorpe, J. M., Gifford, O. P., and Hoitink, D. J., "Climatological Summary for the Hanford Area," Battelle Memorial Institute, Pacific Northwest Laboratory, PNL-4622, 1983.

4. Hanford Meteorology Station, Climatological Data - Monthly Records. Battelle Memorial Institute, Pacific Northwest Laboratory, 1981-1987.

5. Technical Guidance Document, "Final Covers on Hazardous Waste Landfills and Surface Impoundments," EPA/530-SW-89-047, July 1989.

6. Lutton, R. J., Regan, G. L., and Jones, L. W., "Design and Construction of Covers for Solid Waste Landfills," EPA, August 1979.

7. Brown, G. A. and Wiesner, L. E., "Selected Species for Revegetation - A Guide for Disturbed Land in the Western Coal Region," Special Publication No. 3, Montana Agriculture Experiment Station, Bozeman, Montana, 1984.

8. Cadwell, M. M., Dean, T. J., Nowak, R. S., Dzurec, R. S., and Richards, J. H., "Bunchgrass Architecture, Light Interception, and Water Use Efficiency: Assessment by Fiber Optic Point Quadrants and Gas Exchange," Oecologia, Vol. 59, pp. 178-1984, 1983.

9. Linsey, R. K., Jr., Kohler, M. A., and Paulhus, J. L., "Hydrology For Engineers," 3rd Edition, 1982.

10. Bishop, A. W., "Use of the Slip Circle in the Stability Analysis of Slopes," Geotechniques, V.I., March 1955.

9011178619 62

11. Wischmeier, W. H. and Smith, D. D., "Predicting Rainfall Erosion Losses from Cropland East of the Rocky Mountains," Agriculture Handbook No. 282, U. S. Department of Agriculture, Washington, D.C., 1965.

12. George B. Sowers and George F. Sowers, "Introductory Soil Mechanics and Foundations," 3rd Edition, MacMillan Publishing Company, 1970.

APPENDIX A

Hydrologic Evaluation of Landfill Performance (HELP) Model Results

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL RESULTS

The Hydrologic Evaluation of Landfill Performance (HELP program), by P.R. Schroeder et al, 1988, models water movement across, into, through and out of landfills. This program contains solution techniques for surface storage, runoff, infiltration, evapotranspiration, vertical percolation, lateral drainage and soil moisture storage. Data required by the program can be manually input, synthetically generated and/or retrieved from files of default data.

Input and results of the liquid migration analysis of the cover designs are contained in the following pages. Three models were created: 1) the cover design for the grout vault pairs, 2) the EPA cover design and 3) the final cover over five vaults for the runoff evaluation. These evaluations were produced using the daily precipitation and temperature data from the years 1981 through 1987 (this data was obtained from the Hanford Meteorology Station and input manually). These years were chosen because of their greater than average precipitation and the wide range of temperatures. The solar radiation values were synthetically generated. Default data from Yakima was used to obtain a range of values for leaf area indices and evaporative zone depths.

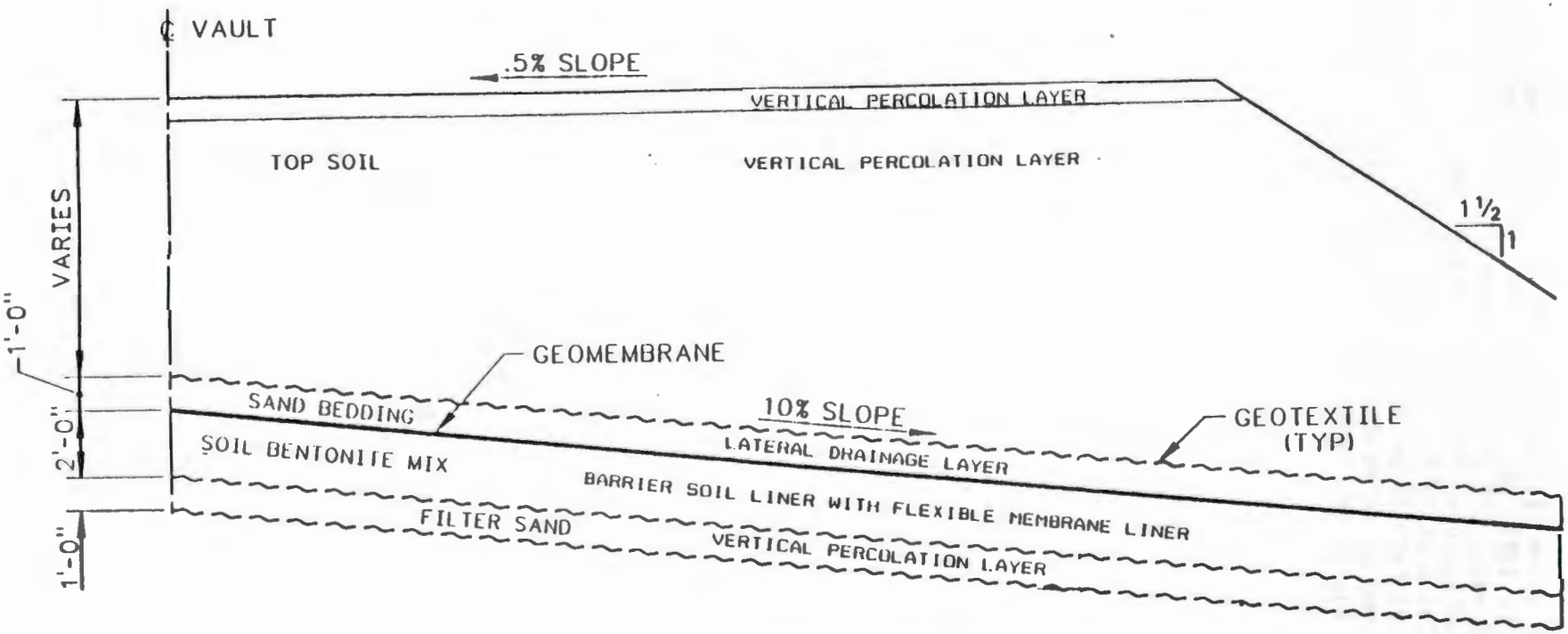
The HELP program provides default soil data for unvegetated, uncompacted soil. This data is correlated with the Unified Soil Classification System (USCS). The soil characteristics used to model the cover design were obtained by choosing default data that closely approximated the information from the soil tests performed by Dames & Moore and EPA's recommendations for cover design. The tests by Dames & Moore are documented in "Geotechnical and Corrosion Investigation - Grout Vaults, Hanford, Washington", October 10, 1988. These characteristics include hydraulic conductivity, porosity, field capacity (amount of water soil retains after gravity drainage ceases) and initial soil water content. The program adjusts the data for compacted soils.

The topsoil layer of the closure cover design was divided into a lower compacted portion and a 6 inch layer at the surface of uncompacted silty, fine sand to support the vegetation (see diagram, p. A-4). The vegetation, according to the HELP model classification, was poor grass with an evaporative zone depth of 20 inches. The model computes both decaying plant density and actively transpiring plant density as a function of ambient temperature and soil temperature, so the model also requires information about the growing season.

To model water movement through the composite barrier layer (layer 4), the program requires a value for the fraction of the area of the soil bentonite layer that drains from leaks in the geomembrane. The results showing no percolation from the composite barrier layer were modelled with a leakage factor of 0.00001 (values must be between 0 and 1, recommended range between 0.01 and 0.000001). When the model was run with a leakage factor of 0.01, the results showed an average annual total percolation through the composite barrier of three cubic feet.

9011178619 65

The 25-yr, 24-hr storm (Stone, W. A. et al, Climatological Summary of the Hanford Area, PNL, 1983) was inserted into the portion of the precipitation data which would model the greatest amount of runoff from the cover. The runoff evaluation included the entire area of the final cover over five vaults (161200 ft^2). The 1.56 inches of rainfall was added to the data of late January in the heaviest winter (1985-1986) of the 7 years of input data. All the snow had melted followed by three days of rainfall that totalled about a half inch. The addition of the 25-yr, 24-hr storm on the fourth day produced 0.165 inch of runoff (2211 ft^3).



SECTION THROUGH GROUT VAULT COVER

TABLE 4. DEFAULT UNVEGETATED, UNCOMPACTED SOIL CHARACTERISTICS

SOIL TEXTURE HELP	SOIL TEXTURE USDA	SOIL TEXTURE USCS	POROSITY (VOL/VOL)	FIELD CAPACITY (VOL/VOL)	WILTING POINT (VOL/VOL)	SAT. HYD. CONDUCTIVITY (CM/SEC)
1	CoS	GS	0.417	0.045	0.018	1.0E-02
2	S	SW	0.437	0.062	0.024	5.8E-03
3	FS	SM	0.457	0.083	0.033	3.1E-03
4	LS	SM	0.437	0.105	0.047	1.7E-03
5	LFS	SM	0.457	0.131	0.058	1.0E-03
6	SL	SM	0.453	0.190	0.085	7.2E-04
7	FSL	SM	0.473	0.222	0.104	5.2E-04
8	L	ML	0.463	0.232	0.116	3.7E-04
9	SiL	ML	0.501	0.284	0.135	1.9E-04
10	SCL	SC	0.398	0.244	0.136	1.2E-04
11	CL	CL	0.464	0.310	0.187	6.4E-05
12	SiCL	CL	0.471	0.342	0.210	4.2E-05
13	SC	CH	0.430	0.321	0.221	3.3E-05
14	SiC	CH	0.479	0.371	0.251	2.5E-05
15	C	CH	0.475	0.378	0.265	1.7E-05
16	Liner Soil		0.430	0.366	0.280	1.0E-07
17	Liner Soil		0.400	0.356	0.290	1.0E-08
18	Mun. Waste		0.520	0.294	0.140	2.0E-04
19	USER SPECIFIED SOIL CHARACTERISTICS					
20	USER SPECIFIED SOIL CHARACTERISTICS					

from

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE by P.R. Schroeder et al, 1988

POOR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	6.00 INCHES
EVAPORATION COEFFICIENT	=	5.100 MM/DAY**0.5
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1907 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0007200000691 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	54.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	0.3610 VOL/VOL
FIELD CAPACITY	=	0.1643 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1643 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000359999976 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	=	12.00 INCHES
EVAPORATION COEFFICIENT	=	3.417 MM/DAY**0.5
POROSITY	=	0.3178 VOL/VOL
FIELD CAPACITY	=	0.0350 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0350 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.1000000014901 CM/SEC
SLOPE	=	10.00 PERCENT
DRAINAGE LENGTH	=	85.0 FEET

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC

LAYER 5

VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
EVAPORATION COEFFICIENT	=	3.417 MM/DAY**0.5
POROSITY	=	0.3178 VOL/VOL
FIELD CAPACITY	=	0.0350 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0350 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.1000000014901 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	79.58
TOTAL AREA OF COVER	=	28475. SQ FT
EVAPORATIVE ZONE DEPTH	=	20.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	4.417 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	7.7720 INCHES
INITIAL VEG. STORAGE	=	3.4444 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR HANFORD WASHINGTON

MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	96
END OF GROWING SEASON (JULIAN DATE)	=	294

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.60	38.70	44.00	51.10	60.50	70.20
76.10	74.40	66.30	52.60	39.40	32.80

AVERAGE ANNUAL TOTALS (AND STD. DEVIATIONS) FOR 81 THROUGH 87

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	7.21	(2.016)	17116.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	6.824	(1.641)	16193.	94.61
LATERAL DRAINAGE FROM LAYER 3	0.2207	(0.2173)	524.	3.06
PERCOLATION FROM LAYER 4	0.0000	(0.0000)	0.	0.00
PERCOLATION FROM LAYER 5	0.0116	(0.0000)	27.	0.16

PEAK DAILY VALUES FOR 81 THROUGH 87

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	2206.8
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 3	0.0023	5.6
PERCOLATION FROM LAYER 4	0.0000	0.0
HEAD ON LAYER 4	0.0	
PERCOLATION FROM LAYER 5	0.0002	0.5
HEAD ON LAYER 5	0.0	
SNOW WATER	1.15	2733.4

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2586

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0849

EPA COVER
HANFORD, WASHINGTON
11/22/88

POOR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	6.00 INCHES
EVAPORATION COEFFICIENT	=	5.100 MM/DAY**0.5
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1907 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0007200000691 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	13.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	0.3610 VOL/VOL
FIELD CAPACITY	=	0.1643 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1643 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000359999976 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	=	12.00 INCHES
EVAPORATION COEFFICIENT	=	3.417 MM/DAY**0.5
POROSITY	=	0.3178 VOL/VOL
FIELD CAPACITY	=	0.0350 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0350 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.1000000014901 CM/SEC
SLOPE	=	10.00 PERCENT
DRAINAGE LENGTH	=	85.0 FEET

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC

LAYER 5

VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
EVAPORATION COEFFICIENT	=	3.417 MM/DAY**0.5
POROSITY	=	0.3178 VOL/VOL
FIELD CAPACITY	=	0.0350 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0350 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.1000000014901 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	79.58
TOTAL AREA OF COVER	=	28475. SQ FT
EVAPORATIVE ZONE DEPTH	=	20.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	4.417 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	7.7720 INCHES
INITIAL VEG. STORAGE	=	3.4444 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR HANFORD WASHINGTON

MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	96
END OF GROWING SEASON (JULIAN DATE)	=	294

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.60	38.70	44.00	51.10	60.50	70.20
76.10	74.40	66.30	52.60	39.40	32.80

AVERAGE ANNUAL TOTALS (AND STD. DEVIATIONS) FOR 81 THROUGH 87

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	7.21	(2.016)	17116.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	6.824	(1.641)	16193.	94.61
LATERAL DRAINAGE FROM LAYER 3	0.4265	(0.5201)	1012.	5.91
PERCOLATION FROM LAYER 4	0.0000	(0.0000)	0.	0.00
PERCOLATION FROM LAYER 5	0.0116	(0.0000)	27.	0.16

PEAK DAILY VALUES FOR 81 THROUGH 87

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	2206.8
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 3	0.0258	61.3
PERCOLATION FROM LAYER 4	0.0000	0.0
HEAD ON LAYER 4	0.0	
PERCOLATION FROM LAYER 5	0.0002	0.5
HEAD ON LAYER 5	0.0	
SNOW WATER	1.15	2733.4

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2586

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0849

MONTHLY TOTALS FOR 86

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	3.31	1.08	0.76	0.00	0.30	0.34
	0.21	0.02	0.96	0.14	0.60	1.77
RUNOFF (INCHES)	0.165	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	0.584	1.458	0.962	0.413	0.712	1.160
(INCHES)	0.210	0.020	0.341	0.116	0.122	0.187
LATERAL DRAINAGE FROM	0.0223	0.0322	0.0937	0.1174	0.1686	0.1674
LAYER 3 (INCHES)	0.1656	0.1504	0.1296	0.1132	0.1003	0.0914

ANNUAL TOTALS FOR 86

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	5.31	11216.	100.00
RUNOFF	0.165	348.	3.10
EVAPOTRANSPIRATION	4.267	9026.	80.51
LATERAL DRAINAGE FROM LAYER 3	1.347	2851.	25.42
PERCOLATION FROM LAYER 4	0.0000	0.	0.00
PERCOLATION FROM LAYER 6	0.0053	11.	0.10
SOIL WATER AT START OF YEAR	20.73	43826.	
SOIL WATER AT END OF YEAR	21.46	45371.	
SNOW WATER AT START OF YEAR	0.60	2066.	

APPENDIX B

Soil Loss Calculations

DESIGN ANALYSIS

Client Westinghouse Hanford Company	WO/Job No. ER9089		
Subject Grout Treatment Facility Closure Cover	Date 01-25-89	By RG Hollenbeck	
Universal Soil Loss Equation	Checked	By	
Location 218-E-16	Revised	By	

OBJECTIVE

Determine annual soil loss of the closure cover due to erosion using the Universal Soil Loss Equation (USLE).

CRITERIA

Maximum annual soil loss permitted for a disposal site is 2T/acre. (Ref 4).

REFERENCES

1. Design and Construction of Covers for Solid Waste Landfills. R. J. Lutton, G. L. Regan, and L. W. Jones. U.S. Environmental Protection Agency. August, 1979.

2. Report of Geotechnical and Corrosion Investigation. Dames & Moore. October 10, 1988.

3. Erosion and Sediment Control Handbook. S. J. Goldman, K. Jackson Taras Bursztynsky

4. Draft Guidance Document: Landfill Design, Liner Systems. and Final Covers. U.S. Environmental Protection Agency. July, 1982.

ASSUMPTIONS

Straw mulch will be tacked down over the cover for the first year. Perennial grasses will be seeded in the late fall at the end of the first year.

CONCLUSIONS

First year soil loss is 0.22 T/acre and 0.96 T/acre for each year thereafter. These values are far below the RCRA maximum of 2 T/acre.

CALCULATIONS

Universal Soil Loss Equation

A = RKLSCP

where A = average soil loss, in tons per acre, for the time period used for factor R (e.g., annual)
R = rainfall and runoff erosivity index
K = soil erodibility factor
L = slope-length factor
S = slope-steepness factor
C = cover/management factor
P = practice factor

R = 15 (Ref 1, Fig 59)
% sand (.10 to 2 mm) = 8% (Ref 2, Plate B-7)
% silt and very fine sand (>.1 mm) = 92% (Ref 2, Plate B-7)
% organics = 1% (typically <2% for this area)
soil structure rating = 2 (fine granular, Ref 1, Fig 60)
permeability rating = 5 (1.3×10^{-5}, Ref 2, Plate B-3)
K = .675 (Ref 1, Fig 60)
LS = .11 (first year), .19 (after first year) (Ref 1. Table 28)
C = .2 (first year straw mulch), .5 (after first year. 20% wheatgrass coverage) (Ref 3 Page 5.23)
P = 1 (Ref 1, Table 30)

A = 15 x .675 x .11 x .2 x 1 = .22 Tons/Acre (first year)
A = 15 x .675 x .19 x .5 x 1 = .96 Tons/Acre (after first year)

DESIGN ANALYSIS

Client	Westinghouse Hanford Company	WO/Job No.	ER9089		
Subject	Grout Treatment Facility Closure Cover	Date	01-25-89	By	RG Hollenbeck
	Wind Erosion Equation	Checked		By	
Location	218-E-16	Revised		By	

OBJECTIVE

The closure cover is placed over the grout vaults soon after filling operations are completed. The closure cover must remain intact to minimize the generation of leachate from infiltration thereby reducing long-term discharge of pollutants to the groundwater. These calculations will estimate annual loss of soil in the cover from wind force.

CRITERIA AND SOURCE

Wind Erosion Equation

GIVEN

Hanford Climate
Wheatgrass cover

ASSUMPTIONS

No wind barriers will be present

METHODS TO BE USED

Hand calculation of the Wind Erosion Equation

REFERENCES AND SOURCES

1. Design and Construction of Covers for Solid Waste Landfills. R. J. Lutton, G. L. Regan, and L. W. Jones. U.S. Environmental Protection Agency. August 1979.

2. Draft Guidance Document. Landfill Design, Liner Systems, and Final Covers. U.S. Environmental Protection Agency. July 1982.

3. Geotechnical and Corrosion Investigation, Grout Vaults, Hanford, WA. Dames & Moore, October 1988.

4. H-1-77589 Sh 1, Rev. 0, Closure Cover Plan and Sections.

9011786196

5. H-1-77574 Sh 1, Rev. 0, Site Plan.

6. How to Control Wind Erosion, Agriculture Information Bulletin No. 354. U.S. Department of Agriculture, Washington DC, 1972.

7. Protective Barrier Materials Analysis: Fine Soil Site Characterization. G. V. Last, M. A. Glennon, M. A. Young, and G. W. Gee. Pacific Northwest Laboratories, November 1987.

CALCULATIONS

Wind Erosion Equation

$$A' = f(K', C', L', T', V')$$

where
- K' = a soil erodibility index
- T' = a soil ridge roughness factor
- C' = a climatic factor
- L' = the field length along the prevailing wind erosion direction
- V' = an equivalent quantity of vegetative cover

K' Soil Erodibility Index

Fraction > .84 mm = 1% (Conservative) (Ref 7)
Erodibility Factor = 250 T/acre (Ref 1, Fig 69)
Windward knoll slope = 0.5% (Ref 4)
Soil loss = 100% (Ref 1, Fig 70)
K' = 250 T/acre x 100% = 250 T/acre

C' Climatic Factor = 25% (March)
9% (Oct) (Ref 1, Fig 68)

T' Soil Ridge Roughness Factor

Soil ridge roughness - 1"
T' = .6 (Ref 1, Fig 71)

L' Field Length Factor
Worst case length is diagonal length of cover over all vaults = 1600 ft (Ref 5)

$A'_1 = K' = 250$
$A'_2 = A'_1\ T' = 250 \times .6 = 150$
$A'_3 = A'_2\ C' = 150 \times .25 = 37.5$ (March)
$A'_3 = A'_2\ C' = 150 \times .09 = 13.5$ (Oct)
$A'_4 = A'_3\ f(L') = 37.5$ (March) (Ref 1, Fig 72)
$A'_4 = A_3\ f(L') = 13.5$ (Oct) (Ref 1, Fig 72)

V' Vegetative Cover Quantity

Actual cover = 750 lb/acre (Ref 6)
V' = 6000 lb/acre (Ref 1, Fig 73, standing stubble)
$A'_5 = A' = A'_4\ f(V')$
A' = 1.6 T/acre/year (March) (Ref 1, Fig 74)
A' = 0.23 T/acre/year (Oct) (Ref 1, Fig 74)

yearly soil loss due to wind = .5(1.6 + 0.23) = 0.92 T/acre

The sum of wind and water erosion is:

0.92 + .22 = 1.14 T/acre for first year
0.92 + .96 = 1.88 T/acre/year after first year

FINDINGS AND CONCLUSIONS

EPA recommended maximum allowable erosion loss is 2 ton/year. Calculated soil loss from wind and water erosion is $\frac{1.88}{2.00}$ = 94% of allowable.

From Fig 69 of Ref 1 it is clear that a small change in the fraction < .84 mm results in a large change in soil loss. A conservative value for the fraction < .84 mm was used, therefore actual soil loss should be much less than the calculated value.

9011178619 81

B-714-C5

CONSTRUCTION SPECIFICATION FOR

VAULT CLOSURE COVER

FOR
GROUTED WASTE DISPOSAL FACILITIES

GROUT VAULT PAIR (218-E-16)

Work Order ER9090

CAUTION
NOT COMPLETE WITHOUT
CURRENT STATUS OF OUTSTANDING
ECNS FROM DATA BASE

SEP 13 1989

SECTION 01300

SUBMITTALS

PART 1 - GENERAL

1.1 DESCRIPTION

1.1.1 This Section summarizes submittals required in Part 1 of each section of this Specification. It explains type of submittals required, and describes procedures for submittals and review.

1.1.2 Submittals required in Part 1 of each section are summarized in Schedule of Submittals. Each submittal is identified by Submittal Number, Reference Section, and Title. Submittals are required for either Review and Approval or Review for Record.

1.1.2.1 Submittals requiring Review and Approval are those which shall receive approval before procurement, fabrication, or construction is started.

1.1.2.2 Submittals requiring Review for Record are those which Contractor may proceed with procurement, fabrication, construction, or acceptance testing, but acceptance is contingent upon compliance with Drawings and Specifications.

1.1.3 Supplemental Submittals are initiated by Contractor in accordance with Section 01630 for consideration of substitute products or corrective procedures and require Review and Approval.

1.2 SUBMITTAL PROCEDURES

1.2.1 Transmit submittals to KEH by Data Transmittal form.

1.2.2 Identify each submittal by Submittal Number, Reference Section, and Title noted in the Schedule of Submittals. Number of copies required for retention by KEH are shown in Schedule and include 2 copies to be returned to Contractor. Additional copies required for Contractor uses shall be added.

1.2.3 Review each submittal for completeness, compliance with Contract Documents, and proper identification before sending to KEH. Submittal data shall either be stamped showing review process has taken place or Data Transmittal form may be signed with statement of "Reviewed for Compliance." Submittals not stamped or signed to show review will be returned without consideration.

1.2.4 Submittals requiring Review and Approval will be stamped by KEH and marked "Approved", "Approved with Exception," or "Not Approved, Revise and Resubmit." Approval of submittals does not relieve Contractor of responsibility for errors which may be contained therein.

9011178619883

1.2.4.1 Approved submittals are identified by submittal stamp with "Approved" or "Approved with Exception" box checked. "Approved" signifies general concurrence to achieve conformance with design concept of Project and compliance with requirements of Contract Documents. "Approved with Exception" signifies general concurrence with noteworthy comments or clarifications. Approval of submittals does not relieve Contractor of responsibility for errors contained therein. Approval of specific item shall not be construed as approval of system or assembly of which item is a component.

1.2.4.2 A submittal which is not approved is identified as "Not Approved, Revise and Resubmit." Submittal is considered by KEH to be technically deficient or incomplete and therefore, unacceptable. Resubmittal is required, hence fabrication, procurement, or performance of procedures shall not proceed.

1.2.4.3 Upon receipt of deficient submittal data, Contractor shall make corrections noted on transmittal and resubmit data to KEH within 10 calendar days.

1.2.5 Materials and equipment fabricated or installed without required approved submittals, or which differ from approved Drawings or vendor data are subject to rejection and replacement at Contractor's expense.

1.2.6 Delays arising out of Contractor's failure to submit in timely manner required Drawings and other related data described in Contract Documents shall not constitute excusable delays for extensions, unless excusable under other provisions of Contract. Contractor shall allow 15 calendar days for KEH review and disposition of submittals, including shop drawings and vendor information, required to be furnished by Contractor. Time period will be measured from date of receipt of submittal in KEH's office to date of return mailing to Contractor.

1.2.7 Contractor is responsible for dimensions to be confirmed and correlated at worksite.

1.2.8 Submittals for Review and Record will be reviewed and filed. Incomplete or inaccurate data will be returned to Contractor marked "Resubmit" with appropriate comments, and items procured or work performed shall be corrected.

1.2.9 Supplemental Submittals shall contain sufficient data required in Section 01630 to show substantial compliance with Drawings and Specifications. Substitute product submittals shall contain as minimum, outline dimensions, operating clearances, and engineering data. Identify each submittal by Specification Section number and Paragraph number or referenced Drawing number and detail. Improperly identified or incomplete submittals will be returned without consideration.

1.2.10 Procedures for performing certain items of work are required to be submitted for Review and Approval before work is commenced. Those work

procedures which have been approved by KEH for work similar to that to be accomplished on Project may not need to be reapproved. Forward 1 copy of previously approved procedure to KEH by Data Transmittal form and identify by Submittal Number, Reference Section, Title, and either Contractor's procedure number or project number for which procedure was approved. Submittal will be reviewed by KEH and if acceptable retained for record. If previously approved procedure is not acceptable submittal will be returned with requirements for resubmittal.

1.3 SCHEDULE OF SUBMITTALS

Submittal Number	Submittal Title	Quantity	Review and Approval	Review For Record
CONTRACT GENERAL CONDITIONS				
55.2	Safety Program and Job Safety Analysis	5	5 days before start of work	
55.3	Industrial Injury/ Illness Experience	5		5 days before start of work and each month
55.5.1	OSHA Form No. 200 Report	5		5th working day, each month
55.6	Equipment Certification	5		2 days before bringing equipment onsite
PROGRESS SCHEDULES				
01310/1.2.1	Progress Schedule	5	10 days after notice of award	
CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS				
01500/1.2.1	Anchoring and Enclosure Methods	10	Before placing field office	
EARTHWORK				
02200/1.2.1	Method to Prevent Damage During Excavation	10	Before excavation	
02200/1.2.2	Gravel Laboratory Reports	10	Before delivery	

Submittal Number	Submittal Title	Quantity	Review and Approval	Review For Record
EARTHWORK (Continued)				
02200/1.2.3	Method of Mixing Soil/ Bentonite	10	Before mixing	
02200/1.2.4	Test Fill Reports	10	Before placing soil/bentonite mix in cover	
02200/1.2.5	Manufacturer's Data	10	Before fabrication	
02200/1.2.6	Certificate of Conformance	10		At time of delivery
PLASTIC MEMBRANE LINERS				
02754/1.2.1	Installation Drawings	10	Before delivery	
02754/1.2.2	Installation Procedures	10	Before installation	
02754/1.2.3	Manufacturer's Data	10	Before fabrication	
02754/1.2.4	Samples	10		Upon completion of fabrication
02754/1.2.5	Certified Material Test Reports (CMTR)	10	Before delivery	
02754/1.2.6	Care and Repair Instructions	10		Before acceptance
02754/1.2.7	Certificates of Experience	10	Before notice to proceed	
02754/1.2.8	Manufacturer's Quality Control Plan	10	5 days after notice of award	
02754/1.2.9	Certification	10		Before acceptance

PART 2 - PRODUCTS

Not Used

PART 3 - EXECUTION

Not Used

END OF SECTION

SECTION 01720

PROJECT RECORD DOCUMENTS

PART 1 - GENERAL

1.1 REFERENCES: Not Used

1.2 SUBMITTALS: Not Used

1.3 RECORD REQUIREMENTS

1.3.1 The nature of work at the Hanford Site requires certain documents, defined herein, be held to record construction process and administration of the Contract. KEH will assemble pertinent data for final disposition. Contractor shall prepare, preserve, and deliver project record documents to KEH required by this Contract. Documents are in addition to submittals required in Section 01300.

1.3.2 Mark project record documents to identify copies for record and to prevent use for construction. Keep record copies of construction documents in field office and make available to KEH during the progress of the Work.

1.3.3 Some data required for project records shall be delivered to KEH during course of construction and contract administration, while other shall be assembled after completion of construction for delivery to KEH. Document delivery by retaining copy of reports delivered during course of work until construction completion, retaining copy of letter of transmittal itemizing delivered items, or other means acceptable to KEH.

1.4 PROJECT RECORD DOCUMENTS

1.4.1 General: Documents required for project records are itemized herein. Identify complete documents by Title or Number. Notes or markings added by hand shall be legible utilizing permanent nonsmearing marking media, such as ink or felt tip markers, in contrasting color.

1.4.2 Contract Documents: Keep 1 set in field office, apart from documents used in construction, and maintain in clean, dry, and legible condition. Legibly mark items to record actual construction, including changes to dimensions and details, manufacturer's name, catalog number, and substitute products.

1.4.3 Certified Payrolls: Each week deliver certified payrolls, required by Section 108 of the Contract General Conditions, with KEH. Progress payments will not be processed unless certified payrolls for work period have been received by KEH.

1.4.4 Weekly Manpower Report: Complete weekly manpower reports daily and submit weekly, before 10:00 a.m. on Monday for previous week, during performance period of the Contract. Forms will be furnished by KEH.

1.4.5 Survey Notes: Deliver notes, specified in Section 01050, to KEH.

1.4.6 Backfill Permit: Retain backfill permits approved for work required in Section 02200.

1.4.7 Soil Compaction Procedure: Retain Form KEH-382 completed for work required in Sections 02200.

1.4.8 Soil Tests: If Contractor elects to test any soil or to have independent test performed, copies of tests shall be given to KEH.

1.4.9 Field Seam Tests: Provide documentation required in Section 02754, Paragraph 3.3.3.

1.4.10 Product Samples and Manufacturer's Instructions: In addition to submittal required in Section 01300 and requirements of this Section, information received by Contractor from suppliers that can document products used and how they were installed shall be forwarded to KEH for Project Records.

PART 2 - PRODUCTS

Not Used

PART 3 - EXECUTION

Not Used

END OF SECTION

SECTION 02200

EARTHWORK

PART 1 - GENERAL

1.1 REFERENCES

1.1.1 Reference Standards and Specifications: The following standards and specifications, including documents referenced therein, form part of this Section to extent designated herein.

1.1.1.1 American Society for Testing and Materials (ASTM)

C 33-86	Standard Specification for Concrete Aggregates
C 294-86	Standard Descriptive Nomenclature for Constituents of Natural Mineral Aggregates
C 295-85	Standard Practice for Petrographic Examination of Aggregates for Concrete
D 421-85	Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D 422-63 (1972)	Standard Method for Particle-Size Analysis of Soils
D 1117-80	Standard Methods of Testing Nonwoven Fabrics
D 1682-64 (1975)	Standard Test Methods for Breaking Load and Elongation of Textile Fabrics
D 1777-64 (1975)	Standard Method for Measuring Thickness of Textile Materials
D 3776-85	Standard Test Methods for Mass Per Unit Area (Weight) of Woven Fabric
D 3787-80a	Standard Test Method for Bursting Strength of Knitted Goods--Constant-Rate-of-Traverse (CRT) Ball Burst Test

D 4318-84	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D 4491-85	Standard Test Methods for Water Permeability of Geotextiles by Permittivity
E 11-87	Standard Specification for Wire-Cloth Sieves for Testing Purposes

1.1.1.2 Washington State Department of Transportation (WSDOT)

M41-10-88	Standard Specifications for Road, Bridge, and Municipal Construction

1.2 SUBMITTALS: Refer to Section 01300 for submittal procedures.

1.2.1 Method to Prevent Damage During Excavation: Submit procedure proposed to prevent overstressing existing structures or interrupting service to existing facilities.

1.2.2 Gravel Laboratory Reports: Submit reports from independent laboratory showing following.

1.2.2.1 Proposed aggregate source will produce gravel classified as igneous or metamorphic rock in accordance with ASTM C 294. Examine aggregate in accordance with ASTM C 295.

1.2.2.2 Gravel meets the requirements of ASTM C 33 and this Section.

1.2.3 Method of Mixing Soil/Bentonite: Submit proposed method to achieve uniform mix at specified water content for constructing test fill.

1.2.4 Test Fill Reports: Submit reports showing results of test fill soil tests. Include documentation required in subparagraph 1.3.1.2.

1.2.5 Manufacturer's Data: Provide data defining physical properties of geotextile material. As minimum, properties shall meet the requirements of subparagraph 2.1.4.5.

1.2.6 Certificate of Conformance: Submit legible certificate from supplier stating that bentonite furnished meets the requirements of subparagraph 2.1.4.2a.

1.3 QUALITY ASSURANCE

1.3.1 Test Fill: Construct to demonstrate to KEH that equipment, procedures, and mix ratio meet compaction and permeability requirements.

1.3.1.1 Mix materials with pug mill.

a. Use 15 percent bentonite and 85 percent specified soil, mixed and compacted 2 percent dry of optimum moisture content.

b. Lifts not to exceed 6 inches in depth before compaction.

c. Compact lifts to 92 percent of maximum density.

1.3.1.2 Document construction of test fill including, as minimum, test fill number, thickness of each lift, equipment and procedures used for measuring, mixing, hauling, spreading and compacting materials.

1.3.1.3 Perform 3 each of following tests on each lift of compacted soil/bentonite mix.

a. Particle-size analysis: In accordance with ASTM D 421 and D 422.

b. Liquid limit, plastic limit, and plasticity index: In accordance with ASTM D 4318.

1.3.1.4 Perform permeability test, in accordance with method described in "Field Measurement of Infiltration Rates Using a Sealed Double-Ring Infiltrometer" by S. J. Trautwein, on completed test fill. Maximum allowable permeability is 10E-7 cm/sec.

1.3.1.5 Compaction and moisture content tests will be performed by KEH.

1.3.1.6 Substitution of original pug mill spreading or compacting equipment, not of same type used for test fill, requires reconstruction of test fill and retesting to verify substitution yields acceptable results.

1.3.1.7 If permeability or density tests fail, construct and test additional test fill using mix ratio and procedures modified by KEH. Repeat until permeability and density tests pass.

1.4 DELIVERY, STORAGE, AND HANDLING

1.4.1 Geotextiles

1.4.1.1 Delivery

a. During shipment and storage, wrap in heavy-duty protective covering to prevent damage.

b. Inspect materials, delivered to site, for damage. If damaged, set aside and do not use. Do not remove material identification label.

9011179692

1.4.1.2 Storage

a. Unload and store with minimum of handling.

b. Do not store materials on ground.

c. Storage area shall protect materials from mud, soil, dust, debris, ultraviolet light, heavy winds, temperature extremes, and precipitation.

d. If temporarily outdoors, place on pallet and protect from direct rays of sun under light colored heat-reflective opaque cover in manner to provide free air flowing space between materials and cover.

1.4.1.3 Handling: Handle materials to ensure sound, undamaged condition.

PART 2 - PRODUCTS

2.1 MATERIALS

2.1.1 General: Obtain select soils from excavation or other designated locations. Obtain on-site approval for soils.

2.1.2 Structural Fill or Backfill: Well graded soil mixtures which may contain cobbles up to 3 inches in greatest dimension if uniformly distributed and not constituting more than 20 percent of volume of fill.

2.1.3 Stabilization: Gravel, specified in WSDOT M41-10, Section 9-03.9(3), Base Course Classification.

2.1.4 Closure Cover

2.1.4.1 Gravel: Composed of crushed stone or gravel aggregates classified in ASTM C 294 as either igneous or metamorphic rocks, and meeting following requirements.

a. Limits for deleterious substances and physical property: Class 5S in accordance with ASTM C 33, Table 3 except footnote D does not apply.

b. Grading: Amounts finer than each laboratory sieve (square-openings), weight percent.

Nominal Square Opening Sieve Size	Percent
1 in.	100
3/4 in.	85 to 95
3/8 in.	45 to 55
No. 4	20 to 25
No. 8	0 to 10

2.1.4.2 Soil/bentonite mix

a. Bentonite: Sodium montmorillonite clay meeting following minimum standards.

1) Free swell: 2 gms to 16 cc when added to 100 ml of distilled water in graduated cylinder.

2) Colloid content: 85 percent, minimum.

3) Fineness: Less than 20 percent retained on 20 mesh screen and less than 20 percent passing 200 mesh screen.

b. Soil: Sandy silt, obtainable within 17 miles of vault site, having following gradation.

ASTM E 11 Sieve Designation	Percent Passing, By Weight
No. 4	100
No. 60	More than 90
No. 200	More than 50

2.1.4.3 Filter sand and sand bedding: Sand, defined in ASTM D 653 having following gradation.

ASTM E 11 Sieve Designation	Percent Passing, By Weight
No. 4	100
No. 8	80 - 95
No. 16	55 - 80
No. 30	30 - 50
No. 50	15 - 30
No. 100	0 - 15
No. 200	0

2.1.4.4 Top soil: Obtain from borrow areas designated by KEH within 17 miles of vault site.

2.1.4.5 Nonwoven geotextile: Long-chain synthetic polymer composed of at least 85 percent, by weight, polypropylene and containing stabilizers and inhibitors added to base plastic to make filaments resistant to deterioration due to ultraviolet and heat exposure. Geotextile shall be composed of continuous geotextiles held together through needle-punching. Seal or otherwise finish edges of fabric to prevent outer material from pulling away from fabric, or ravelling. Geotextile shall meet following requirements.

Property	Test Method	Values
Fabric Weight (oz/sq yd, min)	ASTM D 3776	10
Thickness (mil, min)	ASTM D 1777	70
Grab Tensile Strength (lbs/min.)	ASTM D 1682	200
Grab Elongation (%, min)	ASTM D 1682	30 in any principal direction
Coefficient of Water Permeability (cm/sec, min)	ASTM D 4491	0.2
Puncture Strength (lbs, min)	ASTM D 3787	100
Tear Strength (lbs, min. trapezoidal)	ASTM D 1117	100 in any principal direction
Equivalent Opening Size (EOS), US Sieve	----	100-140 in accordance with ASTM E 11
Minimum Width (ft)	----	12

PART 3 - EXECUTION

3.1 EXCAVATION

3.1.1 Obtain excavation permit before performing excavation.

3.1.2 Locate and expose underground utilities by hand tools. Use of heavy equipment and machinery is subject to approval of KEH.

3.1.3 Shore excavations more than 4 feet deep and with sides sloped steeper than 1-1/2 horizontal to 1 vertical. Install shoring as excavation progresses and remove as backfilling is accomplished.

3.1.4 Do not store excavated or other material closer than 2 feet from edge of excavation unless barrier is erected to retain excavated materials. Store and maintain materials in manner that they are prevented from falling or sliding into excavation.

3.1.5 Wherever slopes of excavations will intersect existing underground lines or structures such as building foundations, underground piping, electrical ducts or direct buried electrical lines, install shoring or other means of support to prevent overstressing existing structure or underground lines or to prevent interrupting service to existing buildings.

3.2 INSTALLATION

3.2.1 Fill and Backfill

3.2.1.1 General

a. Backfill Permit: Obtain signatures required on backfill permit for each element to be filled or backfilled. Work not started within 5 calendar days from time permit is approved shall not be started until new permit has been approved. A continuing job that has not had backfill installed within past 5 calendar days will require new backfill permit.

b. Remove debris and organic matter from area to be filled or backfilled.

c. Use only select materials for fill or backfill. Keep materials free of frozen particles, lumps, organic matter and trash.

d. Do not place fill or backfill on frozen ground.

e. Filling or backfilling by sluicing or flooding with water will not be permitted.

3.2.1.2 Structural

a. Before placement of fill or backfill, demonstrate, to KEH by physical test at site, that procedure proposed for installation and compaction of soils will provide degree of compaction specified. Prepare "Soil Compaction Procedure" Form KEH-382 (sample appended) in accordance with printed instructions. Forms will be furnished by KEH.

b. Place backfill in accordance with WSDOT M41-10, Section 2-03.3(14)C and approved procedure using Method C.

3.2.2 Closure Cover

3.2.2.1 Gravel

a. Place and spread in accordance with WSDOT M41-10, Section 4-04.3 (4).

b. Shape and compact in accordance with WSDOT M41-10, Section 4-04.3 (5).

3.2.2.2 Soil/bentonite mix

a. KEH will review test fill documentation and soil test results to determine mix ratio, soil parameters, and procedures for mixing, hauling, and spreading.

b. Perform same tests required in subparagraph 1.3.1.3 on material to be used for each lift.

c. Obtain test results and approval from KEH for each lift before placing material. KEH will perform compaction and moisture content tests.

d. Mix, spread, and compact in accordance with approved submittal.

e. Remove and remix lift areas that fail to meet compaction or moisture content test requirements. Replace, recompact, and retest until compaction requirements are met.

f. Areas to be replaced or reworked include location where test failed and extend to edge of lift or to location where test passed, whichever is closest.

3.2.2.3 Filter sand and sand bedding: Place and compact in accordance with subparagraph 3.2.1.2.

3.2.2.4 Top soil: Place and compact in accordance with subparagraph 3.2.1.2 except top lift shall not be compacted.

3.2.2.5 Geotextile

a. During unrolling of material, visually inspect surfaces. Do not use material showing defects, ribs, holes, flaws, deterioration, or other damage.

b. Climatic conditions while handling material: Within following limits.

1) Temperature: 40 to 140 F.

2) Winds: 15 mph maximum.

c. Lay smooth and free of tension, stress, folds, wrinkles, or creases, and provide minimum 12 inch overlap for each joint.

d. Measure overlap joints and seams as single layer of cloth.

e. Use bags of clean washed gravel to secure material during installation. Do not use securing pins.

f. Protect material during construction from contamination by surface run-off.

3.2.3 Finish Grading and Stabilization

3.2.3.1 Remove surface stones larger than 6 inches and dispose of excess material and debris at area designated by KEH.

3.2.3.2 Stabilize unseeded area disturbed by work with 3 inch course of gravel meeting the requirements of Paragraph 2.1.3. Finish stabilization course to elevations shown on the Drawings.

3.3 FIELD QUALITY CONTROL

3.3.1 Soil Compaction Tests: Sampling and testing of compacted fill and backfill will be performed by KEH.

SOIL COMPACTION PROCEDURE

Project No.	Project Title	Date

Contract No.	Procedure No.	Location of Demonstration

A

REQUIREMENTS	EQUIPMENT DEMONSTRATED
Applicable Spec./Dwg.	Type
Compaction Required %	Manufacturer
Maximum Lift Size	Model

B

LABORATORY SOIL TEST RESULTS

☐ Non-granular Materials (WSDOT Test Method No. 609)

☐ Granular Materials (WSDOT Test Method No. 606-A)

C

COMPACTION DEMONSTRATION TEST RESULTS

Formula for Percent Compaction:

$$\frac{\text{dry density}}{\text{max density}} \times 100 = \text{Percent Compaction}$$

No. of Passes	Depth of Lift	Percent Moisture	Lbs/ft^3 Dry	Maximum Density	Percent Compaction	Accept	Reject

Observations or Comments

TEST METHOD USED FOR DEMONSTRATION

☐ Nuclear Gage (ASTM D2922 & D3017)

☐ Sand Cone (ASTM D1556)

☐ Other _____

Apparatus No. _____

D

Contractor Representative		Date
Government Representative		Date

APP 11A-60

9011198669

INSTRUCTIONS

This Soil Compaction Procedure form, when approved by the Government Representative, constitutes an approved compaction procedure.

Section A is the responsibility of the Construction Contractor. It is to be completed at the time of backfill compaction demonstration and presented to the Government Representative.

Section B is completed by the Government Representative. Data entered is obtained from the agency that performs the laboratory testing.

Section C is completed by the Government Representative as the demonstration is performed. Using the applicable formula, the percent compaction achieved is determined and entered. Acceptance is based on the results as compared with the compaction percent required in Section A.

Section D is signed and dated by the Construction Contractor Representative acknowledging responsibility for this procedure and compliance thereto for applicable backfill operations. Section D is signed and dated by the Government Representative to signify approval.

END OF SECTION

SECTION 02754

PLASTIC MEMBRANE LINERS

PART 1 - GENERAL

1.1 REFERENCES

1.1.1 Reference Standards and Specifications: The following standards and specifications, including documents referenced therein, form part of this Section to the extent designated herein.

1.1.1.1 American Society for Testing and Materials (ASTM)

D 413-82 (1988)	Standard Test Methods for Rubber Property--Adhesion to Flexible Substrate
D 570-81	Standard Test Method for Water Absorption of Plastics
D 638-87b	Standard Test Method for Tensile Properties of Plastics
D 696-79	Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics
D 746-79 (1987)	Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D 751-79	Standard Methods of Testing Coated Fabrics
D 792-86	Standard Test Methods for Specific Gravity and Density of Plastics by Displacement
D 1004-66 (1981)	Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting
D 1203-86	Standard Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods
D 1204-84	Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature

D 1238-86	Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1593-81	Standard Specification for Nonrigid Vinyl Chloride Plastic Sheeting
D 1603-76 (1983)	Standard Test Method for Carbon Black in Olefin Plastics
D 1693-70 (1980)	Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
D 3083-76 (1980)	Standard Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining
E 96-80	Standard Test Methods for Water Vapor Transmission of Materials

1.1.1.2 Environmental Protection Agency (EPA)

EPA/530-SW-86-031	Technical Guidance Document Construction Quality Assurance for Hazardous Waste Land Disposal Facility

1.1.1.3 Federal Standards (FED STD)

FED-STD-101C, Including CHGS NOT 1, And 2	Test Procedure for Packaging Materials
Method 2065.1	Puncture Resistance And Elongation Test (1/8 Inch Radius Probe Method)

1.1.1.4 National Sanitation Foundation (NSF)

NSF Standard 54-85	Flexible Membrane Liners

1.2 SUBMITTALS: Refer to Section 01300 for submittal procedures.

1.2.1 Installation Drawings: Submit drawings showing lining sheet layout with proposed size, number, position, placing sequence, and location of field seams. Include details and methods for making field seams.

1.2.2 Installation Procedure: Submit procedures for installation and testing of liner and components. Include list of equipment and amount of utilities required, proposed methods for laying liner and components, and following.

1.2.2.1 Procedures for welding seams in accordance with manufacturer's recommendations and this Section.

1.2.2.2 Method for holding liner sections in place during installation.

1.2.2.3 Method for examining liner and components, and testing joints, seams, welds, and bolt tightening.

1.2.3 Manufacturer's Data

1.2.3.1 Resin: Provide data defining physical properties of high density polyethylene (HDPE) resin to be supplied. For each resin batch, test as shown in Table 02754-I. Complete testing and submit for review before using.

TABLE 02754-I

PHYSICAL PROPERTIES QUALITY CONTROL

Property	Test Method	Values
Specific Gravity (min)	ASTM D 792	0.94
Melt Flow Index (gr/10 mins, max)	ASTM D 1238, condition E	0.3
Volatile Loss (max%)	ASTM D 1203, Method A	0.1

1.2.3.2 Liner: Provide data defining physical properties for high density polyethylene (HDPE) liner to be supplied. As minimum, properties shall meet the requirements of NSF Standard 54. Provide documentation of verification of physical properties of liner sheets. For each resin batch used, test using parameters defined in subparagraph 2.1.1.2 to document material properties. Complete testing and submit for review before fabrication. Submit additional copy of documentation with each panel.

1.2.4 Samples: Submit samples of lining material and field seams.

1.2.4.1 Lining material: Submit 8 inch by 10 inch samples from same batch of liner used for construction, and totaling approximately 20 square feet.

1.2.4.2 Field seams: Submit numbered dated samples, measuring 12 inches plus seam width in width and 18 inches in length, fabricated with materials specified for lining in accordance with approved procedures and this Section, and tested in accordance with Paragraph 1.3.5.

1.2.5 Certified Material Test Reports (CMTR): Submit materials test reports, for each item furnished by each supplier certified by manufacturers

of resins and liners, and stating that liner and extrudate are of 100 percent virgin materials. Reports shall identify items, show results of chemical analysis and physical tests and meet following requirements.

1.2.5.1 Raw materials: Table 02754-I.

1.2.5.2 Lining material: Subparagraph 2.1.1.2.

1.2.6 Care and Repair Instructions: Submit information concerning recommended care and repair procedures for liner and components. Include recommended shoe types for construction personnel, tools for cleaning and removing wind-blown sand and debris, and minimum and maximum temperatures at which cleaning, inspecting, and repair operations may be performed.

1.2.7 Certificates of Experience: Submit "Certificates of Experience" from manufacturer and installer showing qualification in accordance with Paragraphs 1.3.1 and 1.3.2. Installer shall provide list showing names addresses, and telephone numbers for completed projects.

1.2.8 Manufacturer's Quality Control Plan: Submit specific plan for Project. Plan shall address requirements of Paragraph 1.3.3.

1.2.9 Certification: Submit certificates of compliance in accordance with paragraph 1.3.6.

1.3 QUALITY ASSURANCE

1.3.1 Qualification of Manufacturer: Manufacturer shall have successfully manufactured minimum of 5,000,000 square feet of similar liner material for hydraulic lining installations, and be listed by NSF as meeting the requirements for manufacturing HDPE. Material supply shall also include projects for Resource Conservation and Recovery Act (RCRA) Landfills and Surface Impoundments.

1.3.1.1 Make arrangements with manufacturer for KEH visit to plant before manufacture of lining material to verify quality control program, and during manufacture to observe manufacturing methods.

1.3.2 Qualification of Installer: Provide evidence of successfully installing at least 10 projects, and at least 5,000,000 square feet of liner. Projects shall include RCRA Landfills and Surface Impoundments.

1.3.3 Manufacturer's Quality Control Plan: Quality control plan to be implemented for Project shall be in accordance with EPA/530-SW-86-031. Include name of polymer resin supplier, product identification, acceptance testing, fabrication and production testing, documentation of changes, retests, and acceptance.

1.3.4 Construction Quality Assurance

1.3.4.1 Preinstallation meeting: Manufacturer and Contractor shall attend meeting, initiated by KEH, before installation of lining to review and discuss

training and qualification procedures for Contractor personnel, and demonstration of making field welded seams including peel and shear tests.

1.3.4.2 Manufacturer shall provide onsite technical supervision and assistance during installation of lining.

1.3.5 Qualification of Welds: Before welding liner, provide field weld samples using same equipment and procedure to be used for welding liner. Perform nondestructive testing in accordance with Paragraph 3.3.1. Perform destructive testing in accordance with Paragraph 3.3.2. Entire seam shall pass nondestructive tests, and 2 of 3 samples shall pass destructive tests, third sample shall attain at least 95 percent of required values.

1.3.6 Upon completion of work, and as condition of acceptance, deliver to KEH 2 copies of certificate signed by authorized agent of manufacturer of liner, and cosigned by installer, stating materials and methods used meet specified requirements.

1.4 DELIVERY, STORAGE, AND HANDLING

1.4.1 Pack fabricated pieces and rolls wrapped with sheet of same material in containers supported and padded to prevent damage during shipment. Pack containers for minimum handling at site and clearly mark with location of installation. Provide label for each roll and prefabricated piece showing results of tests in subparagraph 2.1.1.2 and stating name of manufacturer, product type, thickness, manufacturers batch code, date of manufacture, physical dimensions, panel number or placement of prefabricated pieces according to Paragraph 1.2.1, and directions for unrolling membrane. Do not remove labels.

1.4.2 Examine lining materials delivered to Site for:

1.4.2.1 Puncture from nails or splinters.

1.4.2.2 Tears from operation of equipment or inadequate packaging.

1.4.2.3 Exposure to temperature extremes resulting in unusable material.

1.4.2.4 Bonding together of adjacent membrane layers which may be caused by excessive heat.

1.4.2.5 Crumpling or tearing from inadequate packaging support.

1.4.3 Unload and store with minimum of handling.

1.4.4 Store materials off ground on padded dunnage in secure area sheltered from mud, soil, dirt, debris, adverse weather, precipitation, ultraviolet light, heavy winds, and temperature extremes.

PART 2 - PRODUCTS

2.1 MATERIALS

2.1.1 High Density Polyethylene (HDPE) Liner: Add carbon black, antioxidants and heat stabilizers to resin for ultraviolet resistance and manufacturing purposes. Supply HDPE as single ply continuous sheet with no factory seams and in rolls with minimum 22 foot width. Maximize roll length to provide largest manageable sheet for fewest field seams.

2.1.1.1 Materials similar to those manufactured by Gundle Lining Systems Inc, Houston, Texas; or Poly-America Inc, Grand Prairie, Texas.

2.1.1.2 Lining material shall meet following minimum physical property values.

Property	Test Method	Values
Thickness (mils ±10%)	ASTM D 1593	60
Specific Gravity (min)	ASTM D 792	0.94
Carbon Black Content (%)	ASTM D 1603	2 to 2-1/2
Melt Flow Index (g/10 min, maximum)	ASTM D 1238, Condition E	0.3
Tensile Properties (each direction)	ASTM D 638, Type IV Specimen, 2 ipm	
Tensile Strength at Yield (lb/in. width, min)		120
Tensile Strength at Break (lb/in. width, min)		180
Elongation at Yield (%, min)		10
Elongation at Break (%, min)		500
Modulus of Elasticity (lbs/sq in., min)		80,000
Tear Resistance (lb, min)	ASTM D 1004, Die C	30
Puncture Resistance (lbs, min)	FED-STD-101, Method 2065.1	69
Low Temperature/Brittleness (F max)	ASTM D 746, Procedure B	-40
*Dimensional Stability (max % change each direction)	ASTM D 1204, 212 F 1 hr	±2

Property	Test Method	Values
*Volatile Loss (max %)	ASTM D 1203, Method A	0.1
*Environmental Stress Crack (min hours)	ASTM D 1693, Condition C (100 C)	750
Water Absorption (max % weight change)	ASTM D 570	0.1
Coefficient of Linear Thermal Expansion (cm/cm C, max)	ASTM D 696	1.2 X 10-4
Hydrostatic Resistance (psi, min)	ASTM D 751, Method A-1	490
Moisture Vapor Transmission (g/m^2 day, max)	ASTM E 96	0.03
Resistance to Soil Burial	ASTM D 3083, using ASTM D 638, Type IV, specimen at 2 ipm	
Change in Tensile Strength at Break and Yield (%)		±5
Change in Elongation at Break and Yield (%)		±10
Bonded Seam Strength, Field Tensile min Peal Adhesion, min	ASTM D 638 ASTM D 413	90% of parent material film tear band

*Format uses NSF Standard 54, Table 9 for HDPE as guide. However, RCRA values for volatile loss, dimensional stability, and environmental stress crack have been added.

2.1.1.3 Resin used for extrudate fusion welding shall be HDPE produced from and same as HDPE sheet resin. Physical properties shall be same as HDPE lining sheets.

2.1.1.4 Liner thickness shall be at least 54 mils at any point on liners.

2.1.1.5 Fabricate liner from large pieces of sheeting to proper size and shape to fit contours of leachate extension pit. Prefabricate corner pieces in factory. Keep field joints to minimum and in accordance with approved installation drawings.

2.1.1.6 Liner material will be required for EPA's method 9090 testing. There shall be no changes in formulation of liner material once testing has begun.

2.2 SOURCE QUALITY CONTROL

2.2.1 Tests

2.2.1.1 Preparation: Obtain 1 sample from preformed products from each form in use each day. Cut sample in half. Keep 1/2 for testing and deliver remaining half to independent EPA approved laboratory for testing.

2.2.1.2 Testing: Test samples for thickness, tensile strength at yield, and tensile strength at break as specified in subparagraph 2.1.1.2 except values may be reduced by 10 percent.

PART 3 - EXECUTION

3.1 EXAMINATION

3.1.1 Before work is started examine sheet rolls for damage from transit. If damaged set aside. Those that cannot be repaired, shall be rejected.

3.1.2 Before installation of liner, ensure surface is free of soil rocks, standing water or other debris, and provide written documentation to KEH that surfaces to receive liner have been inspected and found to be acceptable for installation.

3.1.3 During unrolling of material, visually inspect sheet surface. Mark and repair faulty areas in accordance with approved procedure. Document repaired areas on installation drawings by showing location and identity of repair crew.

3.2 INSTALLATION

3.2.1 Climatic Conditions: Within limits given in NSF Standard 54, appendix C while handling, repairing, or seaming plastic sheeting material. Maximum wind 15 mph and no precipitation or fog.

3.2.2 Placing: Place fabricated pieces in position shown on approved installation drawings. Verify preformed pieces fit snugly in position to prevent undue stress. Unroll, position, and smooth out folds and wrinkles. Allow sheets to relax before splicing. Anchor liner temporarily, in accordance with installer's approved procedure, to prevent wind damage until material is secured.

3.2.3 Field Seams: Do not make horizontal welds on vertical surfaces. Overlap panels 4 to 6 inches. Ensure liner surface is free of dirt, dust, moisture, and deleterious materials before seaming, and climatic conditions meet the requirements of Paragraph 3.2.1.

3.2.3.1 Extrusion welding: Weld sheeting together using extrudate with composition identical to sheeting material.

3.2.3.2 Fusion welding: Weld sheeting together by producing a double seam with an enclosed space.

3.2.3.3 Welding equipment shall be capable of continuously monitoring and controlling temperature in zone of contact so changes in environmental conditions will not effect integrity of weld.

3.2.3.4 Where "fish mouths" occur, repair area in accordance with Paragraph 3.2.4.

3.2.3.5 "Fish mouths" are not acceptable within seam area.

3.2.3.6 Traverse entire surface and examine for tears, punctures, and thin spots. Replace or repair, in accordance with Paragraph 3.2.4, liner area showing out of tolerance injury.

3.2.3.7 Welds, on completion of work, shall be tightly bonded.

3.2.4 Damage Repairs: Make repairs to liner by applying piece of sheeting, sufficient in size to extend approximately 3 to 6 inches beyond damaged area. Make patch round or oval and install using same materials and procedures used in making field joints. Do not use cutting tools while working on top of installed liner except when cutting destructive test samples.

3.2.4.1 Seam repairs: Repair seam areas represented by failed samples. To determine extent of failure area, additional samples may be taken 10 feet minimum from either side of failure area. Area to be repaired includes failure area and extends in both directions to location where sample passed. Document failed seams on installation drawings by showing location and seaming crew identity.

3.3 FIELD QUALITY CONTROL

3.3.1 Nondestructive Testing

3.3.1.1 Test fusion welds in their entirety using air pressure test or vacuum box. Pressurize channels between seams to minimum 60 psi, indicated by calibrated gage or manometer inserted in channel. Maintain pressure for minimum 15 minutes.

3.3.1.2 Vacuum test of extrusion welded seams and repairs.

a. Equipment: Aluminum frame box with calibrated vacuum gage on frame, fitted with sponge gasket on bottom, sealed with transparent Plexiglas top, and connected to vacuum pump.

b. Test: Spread soap solution over seam, press box down over seam, and apply 10 inches Hg vacuum, plus or minus 2 inches, for minimum 30 seconds to each portion of seam. If defect is present, bubble will form and indicate area for repair. Test seams and repairs in their entirety.

3.3.1.3 KEH will observe testing and review results.

3.3.2 Destructive Testing

3.3.2.1 Preparation: Obtain samples of field seams at beginning and end of each work day, and at 1 or more intervals during day if seaming conditions have been altered.

a. Use 10 foot long test weld from each welding machine, and mark with date, ambient temperature, and machine number.

b. Take 2 foot long random weld samples from installed welded sheeting at rate of 1 sample for each seaming crew for each day.

c. Cut samples in 2 parts, keep 1/2 for testing and deliver remaining half to KEH.

3.3.2.2 Tests: Test samples for bonded seam strength in accordance with ASTM D 3083, and for peel adhesion in accordance with ASTM D 413.

3.3.3 Documentation

3.3.3.1 Document field seam test results by marking installation drawings with location of sample identification number and label sample with location, date, time, crew identity, and machine number.

3.3.3.2 Certify test results.

3.3.3.3 Deliver documentation to KEH within 7 working days.

3.3.4 Final Examination and Acceptance

3.3.4.1 Measure overlap of seams and verify no damage has occurred to liner.

3.3.4.2 Prepare record drawings showing field changes.

3.3.4.2 Prepare record drawings to KEH within 10 working days after completion of liner installation.

END OF SECTION

SECTION 02900

LANDSCAPING

PART 1 - GENERAL

1.1 REFERENCES: Not applicable.

1.2 SUBMITTALS: Refer to Section 01300 for submittal procedures.

1.3 DELIVERY AND STORAGE

1.3.1 Deliver materials to site in undamaged condition. Defective and damaged materials shall be replaced.

1.3.2 Storage

1.3.2.1 Store fertilizer in dry location protected from weather.

1.3.2.2 Store seeds not to be planted upon delivery, off ground in covered area away from sources of moisture.

PART 2 - PRODUCTS

2.1 MATERIALS

2.1.1 Seed: Siberian and Thickspike wheatgrass, or cereal rye.

2.1.2 Mulch: Long straw free of seeds and weeds.

2.1.3 Fertilizer: Nonburning, slow release, formula 16-8-8.

PART 3 - EXECUTION

3.1 PREPARATION

3.1.1 Clear and grub areas to receive seed to 6 inches below finish grade.

3.1.2 Remove visible rocks, clods and debris 3 inches or larger in any dimension.

3.2 INSTALLATION

3.2.1 Seed

3.2.1.1 Before seeding, apply fertilizer to topsoil at rate of 5 to 6 pounds per 1000 square feet.

3.2.1.2 Before seeding, moisten soil surface with fine spray so not to disturb topsoil.

3.2.1.3 Time and mix

a. September through November: Mix seed at ratio of 2 parts Siberian to 1 part Thickspike wheatgrass.

b. January through March: Use 100 percent cereal rye, then reseed in fall, as specified in subparagraph a. above.

c. Seed may be applied at other times if permitted, in writing, by KEH.

3.2.1.4 Drill-in seed to depth of 1/2 to 1 inch and rate of 15 lbs/acre in area backfilled with topsoil.

3.2.1.5 Water seeded areas with fine spray, to 4 inch depth.

3.2.2 Mulch: Apply by hand or blower at rate of 4000 lbs/acre. Anchor in place by crimping or rolling with straw roller.

3.2.3 Fertilizer: Apply at same rate as initial application to seeded area 3 to 4 weeks after seeding.

END OF SECTION

This page intentionally left blank.

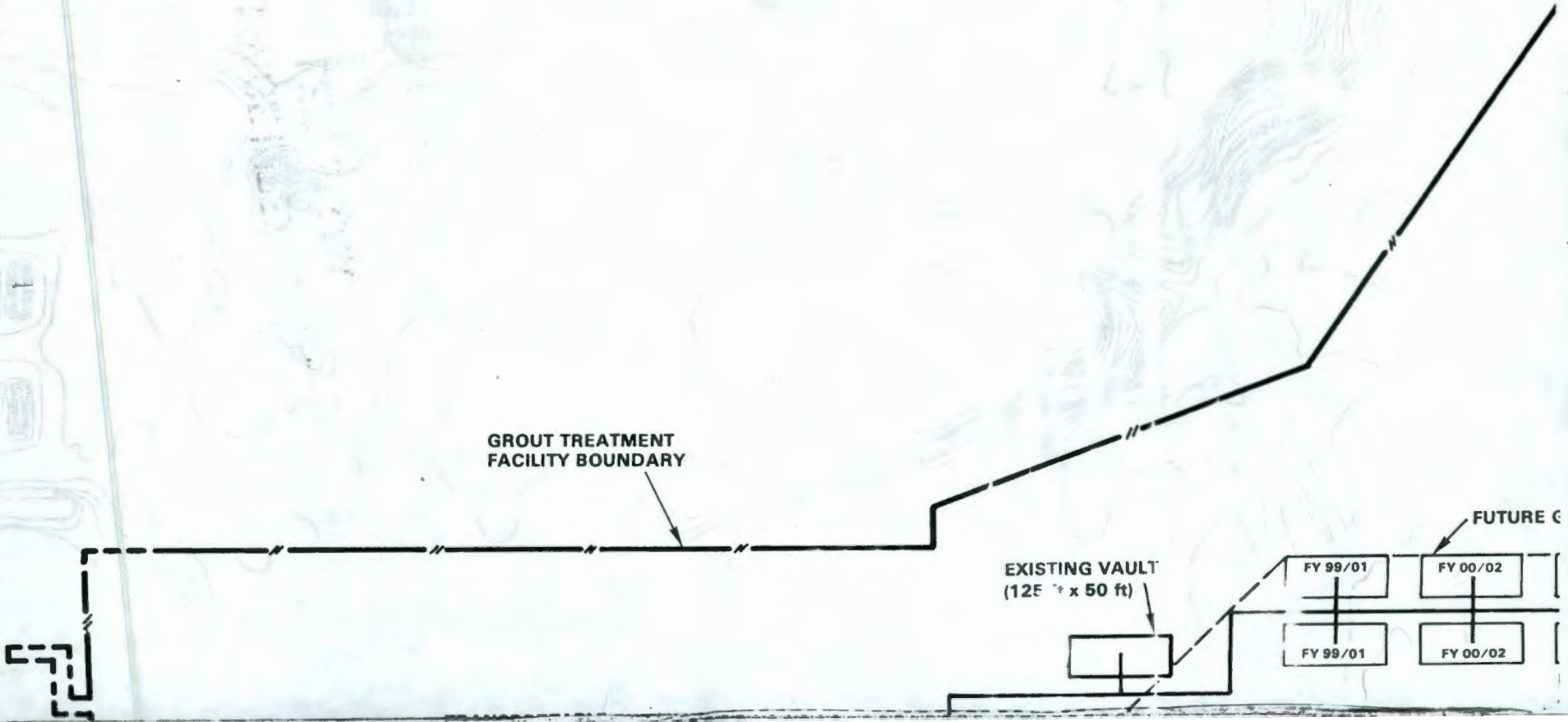
APPENDIX 11B

CLOSURE PLAN DRAWING

This page intentionally left blank.

PLATE 11-1

VAULT LAYOUT, FILLING AND CLOSURE SCHEDULE



THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX 11C

CLAY LINERS (ADMIXTURES) IN SEMIARID ENVIRONMENTS

9 0 1 1 7 8 6 2 0 1 7

This page intentionally left blank.

9 0 1 1 1 7 8 6 2 0 1 8

APPENDIX 11C

CLAY LINERS (ADMIXTURES) IN SEMIARID ENVIRONMENTS

The following paragraphs discuss the use of admixing clays to local soils to create low-permeability components for covers in semiarid environments such as that at the Hanford Site. Pure clay liners are not considered feasible for use in semiarid environments. However, with proper design, materials handling, construction, and quality control, a functional low-permeability liner consisting of local soils admixed with clay can be used in covers at the Hanford Site. A quick overview of clay liner failure mechanisms and documentation supporting clay liner use at the Hanford Site are discussed.

The following list of clay liner failure mechanisms has been thoroughly discussed (EPA 1986):

- Desiccation cracking
- Penetration
- Slope instability
- Settlement
- Erosion
- Freeze/thaw cycling
- Piping
- Design construction errors.

Of particular concern at the Hanford Site is desiccation cracking, a characteristic of clay-rich soils caused by volume changes in the clay structure. Volume changes occur because of stresses imparted to the soil as a result of wet/dry cycling. This occurs when soils are exposed to the atmosphere. In the case of the grout vaults, an additional component affecting the wet/dry cycling potential of the clay liner is the thermal energy conducted through the soil because of grout heat of hydration and radioisotope decay heat. As soil pore water evaporates, a negative pore water pressure develops in the soil, causing a reduction in soil volume. The pore pressure acts in all directions, causing soil shrinkage and cracks. When the soil is rewetted, the clay swells and the cracks are sealed. Failure occurs if foreign material such as sand is washed or blown into the cracks. The cracks can propagate deeper upon continuation of wet/dry cycling, providing preferential drainage paths for water.

Slope instability can occur when a liner is constructed on a sloped surface. Of particular concern in cover applications are clays placed over a synthetic membrane. The clay may slide over the smooth membrane surface. Failure also can occur in soils because of insufficient shear strength.

A small settlement, in general, is not a problem when it is uniform throughout the site. However, differential settlement can lead to cracks and cause pathways for water flow.

Piping failure is another important concern for clay liners. Piping is a form of soil erosion that occurs underground. Piping occurs when fine-grained soils (clays) contain particles that are bound together. When water percolates through the clay liner, it can detach some of these bound particles, thereby transporting them to coarser underlying soils. With time, progressively larger particles are removed, causing an underground flow channel or pipe. The pipe would start at the underside of the clay liner and move progressively upward opposite the direction of flow. Clay liners underlain by soils containing less than 15% clay may be susceptible to piping. For piping to occur, the hydraulic gradient at the base of the clay liner must be greater than the interparticle bonding forces.

Penetration failure occurs when plant roots, animals, or humans are able to reach and disrupt the clay liner. Other potential penetrations are seal failures around manholes and LDCRS pipes.

Erosion failure occurs when raindrops detach soil particles, which are then transported uniformly downslope (sheet erosion). Another type (rill erosion) occurs when channels are developed by concentrated flow, often caused by the slumping of undercut slopes.

Freeze/thaw cycling can cause the formation of ice lenses at the frost line. Cold atmospheric temperatures cause soil moisture to migrate upward where freezing occurs at the frost line. For soils with only pore (interlayer) water present during the freezing cycle, this is not a major problem. Very little, if any, soil heaving is expected from this scenario. However, if water is added to the soil system before freezing occurs, considerable ice lenses could form at the frost line, thus heaving the overlying soil and causing vertical cracks within the soil matrix.

The following construction errors have led to clay liner failures in past surface impoundment facilities (EPA 1986).

- Desiccation of the clay liner between completion of construction and commencement of operations allows the clay to crack.

- A nonuniform moisture distribution in the soil results in clods with wet surfaces and dry, cracked interiors. This is caused by inadequate breakup of large clods before compaction, uneven water distribution by water trucks, and inadequate time for water to penetrate the soil.

- High permeabilities result from inadequate control of moisture, density, and compactive effort.

- Improper screening of incoming liner material can result in small roots, rocks, lenses, and other heterogeneities in the clay liner that can increase permeability.

Of the abovestated failure mechanisms, desiccation cracking seems to be of the most concern. The following discussion indicates how all the clay liner

failure mechanisms are addressed by proper design, materials handling, construction, and quality control with special emphasis placed on desiccation cracking. Failure caused by cracking of clay liners in covers is controlled by implementation of the following factors:

- Optimizing the clay-to-native-soil ratio
- Constructing the clay liner to such a depth that the relative humidity of the soil remains greater than 54%
- Burying the clay liner below the frost line
- Preventing overlying materials from entering cracks.

Reduction of potential desiccation cracks in the grout liner is provided by optimizing the clay-to-sandy-silt ratio, thereby reducing shrinkage strains caused by thermal heat that is radiated from the grout vaults. Sodium bentonite, a montmorillonite clay, will be admixed with McGee Ranch site soils (sandy silt) at approximately 10 wt%. Several clay-to-sandy-silt soil mixtures were tested for permeability and shrinkage data using McGee Ranch soils and bentonite clay (see Appendix 4I, pp. APP 4I-73). These tests were performed based on the results of previous work described by Kleppe and Olson (1985) as described in the following paragraphs.

Optimizing the clay-to-sandy-silt ratio was based on data that indicated that desiccation cracks resulted from clay shrinkage strains (Kleppe and Olson 1985). Therefore, a shrinkage-resistant clay liner system can be designed by providing a large percentage of sand in the liner matrix, forming a framework of rigid particles. Only enough clay is admixed such that, upon wetting, the clay effectively plugs up the void spaces between sand particles, providing a low-permeability mix.

A number of shrinkage, cracking, and permeability tests were performed on a range of clay and sand mixes including Wyoming bentonite and Los Alamos silty sand. The data indicate that compactive effort, compaction water content, and percent of silty sand influence soil matrix shrinkage potential (Kleppe and Olson 1985).

Less than 1% shrinkage strain was found for the 12% bentonite/88% silty-sand mix, which was compacted at less than 20% water content with complementary permeabilities less than 1×10^{-7} cm/s. In fact, Los Alamos silty sand mixed with 25% Wyoming bentonite produced a low-shrinkage strain of less than 3%. The laboratory tests conducted on the McGee Ranch soils and bentonite clay showed that the diametral shrinkage cracks for 10% clay samples were less than 1%. Permeability tests were performed on 10% Bentonite/90% McGee Ranch soil samples desiccated before testing that showed rehydration of the sample and achievement of required permeability values (see Appendix 4I, pp. APP 4I-73). These tests were run because the bentonite is expected to dehydrate in the grout vault cover because of the grout heat of hydration and radioisotope decay heat. In most cover designs only the effects of atmospheric-caused wet/dry cycling are encountered. This phenomenon is also accounted for

in the grout design by placing the clay liner layer at least 3 1/2-ft below grade.

When small cracks form, because of the approximately 1% anticipated shrinkage of the clay, failure would be dependant on the cracks filling with foreign materials before reswelling. The cover design calls for the use of geotextiles and properly graded filter materials to prevent the migration of overlain materials. This alone will help reduce the availability of soils to fill cracks.

Slope stability analysis has been performed that provides for appropriate slope validation as described in Appendix 11A. The controlling factor for most liners using geomembranes is the relatively shallow friction angles between the geomembrane and the overlain clay soil.

Differential settlement is not anticipated to be a problem for the grout vault cover because the waste form is stable. A detailed analysis of settlement is provided in Appendix 11A.

Surface erosion of the clay liner may be a problem if much precipitation occurs during construction. However, subsurface erosion of a buried clay liner (piping) must be considered. The topsoil of the cover is designed to recycle water to the atmosphere, thus preventing most of the water from reaching the clay liner. A sand drainage layer is provided directly above the clay liner to remove any water that does permeate the topsoil. The HELP model has indicated that evapotranspiration accounts for approximately 94% of annual precipitation. Only a very small percentage of precipitation is ever expected to contact the clay liner, which effectively controls erosion potential.

Penetration of the clay liner by plants, animals, and humans will for the most part, be prevented by the depth of the liner. Plants, specifically, will not want to penetrate past the topsoil layer, because the sand drainage layer will be at a much lower water potential most of the time. The 60-mil HDPE geomembrane that is located directly on top of the clay liner will also act as a deterrent to further growth of plant roots and animal intrusion of the clay liner layer. Data indicate that buried 40-mil polyethylene liners were not penetrated by rats, even when they were faced with starvation (Mitchell 1984). Most of the burrowing animals that live on the Hanford Site live in the top 4 ft of soil. Cobble on the embankment slopes will reduce the potential for animals to burrow dens laterally into the cover embankment.

Of perhaps the most importance regarding successful clay liner performance are the materials handling, construction methods, and construction quality control measures applied to the project. Continuous daily inspections of the liner installation project are mandatory to identify and document problems and successes and to provide a mechanism to obtain corrective action to problem areas. Bad weather conditions should be avoided during construction. Precipitation events can flood or erode the construction site. Hot dry weather could desiccate the liner, if it is left unprotected. Frozen soils prevent adequate compaction. Depending on climatic conditions, the clays may need to be protected from moisture loss and erosion while stockpiled before

construction. A plastic cover may need to be placed over the clay liner during inactive periods to prevent drying of the liner during construction.

Proper screening of materials used in liner construction to remove roots, rocks, and miscellaneous debris is imperative. Also, proper control of moisture content, density, and compactive effort during construction will help ensure successful liner installation. These are standard construction practices. Reduction of clods in the clay/native-soil mixture is important to provide a homogeneous mixture of water in the liner materials.

The two design features discussed above are the proper clay/native-soil composition and the depth of burial. These coupled design features provide for a low-shrinkage, low-permeability, stable clay liner installation. When coupled with proper construction/installation techniques, the clay liner will function over the proposed lifetime of the cover.

REFERENCES

EPA, 1986, *Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities*, EPA/530-SW-86-007, U.S. Environmental Protection Agency, Washington, D.C.

Kleppe, J. H. and R. E. Olson, 1985, *Desiccation Cracking of Soil Barriers*, STP-874, American Society for Testing and Materials, Philadelphia, Pennsylvania, pp.263-265, 1985.

Mitchell, D. H., 1984, *Technology for Uranium Mill Ponds Using Geomembranes*, PNL-5164, NUREG/CR-3890, Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

1 This page intentionally left blank.

APPENDIX 13

OTHER RELEVANT LAWS

APPENDIX 13

OTHER RELEVANT LAWS

13A Grout Treatment Facility Hazardous Air Pollutant Permit Application

13B Grout Treatment Facility Approval of Construction

13C Grout Treatment Facility Cultural Resources Review

APPENDIX 13A

GROUT TREATMENT FACILITY
HAZARDOUS AIR POLLUTANT PERMIT APPLICATION

9 0 1 1 7 8 6 2 0 2 7

1 This page intentionally left blank.

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 14 1986

Mr. Gary O'Neil, Director
Air and Toxics Division
Environmental Protection Agency
Region 10
1200 6th Avenue
Seattle, Washington 98101

Dear Mr. O'Neil:

REQUEST FOR APPROVAL--GROUT FACILITY

As discussed in the telephone conversation with you on November 14, 1986, we are enclosing a copy of the complete package relating to request for approval to construct the Grout Facility on the Hanford Site. This package was originally forwarded to Environmental Protection Agency (EPA) Headquarters by U.S. Department of Energy Headquarters (DOE-HQ) on August 22, 1986. This was followed by a second identical package on October 31, 1986.

Also enclosed is a copy of the offsite dose calculation using the AIRDOS-EPA model for comparison with the doses calculated with the Hanford models. This was not included in the original package.

As we discussed, if you are not the appropriate person to receive the information, to grant approval in accordance with 40 CFR 61 to construct the Grout Facility, we would appreciate information as to the proper approval authority. The delay has already impacted the start of construction.

If we can be of further assistance in this matter, in the event you need additional information, please contact Mr. Erik Erichsen, of my staff, on FTS 444-8007 or (509) 376-8007.

Sincerely,

ORIGINAL SIGNED BY

Ronald E. Gerton, Director
Environment, Safety, and Health
Division

ES&H:EAE

Enclosure cc w/o encl.: EH-20

EPA CONSTRUCTION APPROVAL INFORMATION (40 CFR 61)

Proposed Nature

The proposed action is construction and operation of the Transportable Grout Facility (TGF) to be used for the immobilization of liquid low-level radioactive wastes in cement-based grout for near-surface disposal. This action is in compliance with the U.S. Department of Energy (DOE) Order 5820.2, Radioactive Waste Management requirement that liquid low-level wastes be solidified prior to shallow-land burial or greater confinement disposal. Facilities will also be designed to comply with the requirements of the Resource Conservation and Recovery Act (RCRA) for disposal of wastes containing hazardous chemical constituents. The proposed action would dispose of the waste in a manner that would ensure isolation of the waste from man and the biosphere without the need for long-term maintenance.

The waste streams proposed for grouting in the TGF include phosphate/sulfate Hanford facilities waste (HFW) and other tank wastes. The environmental impacts associated with the grout disposal of HFW are being evaluated in an Environmental Assessment currently being prepared. The environmental impacts associated with grout disposal of other tank wastes (as well as the impacts associated with disposal of other wastes) are evaluated in the Draft Environmental Impact Statement--Disposal of Hanford High-Level, Transuranic, and Tank Waste (draft HDW-EIS, DOE, 1986).

Size

The processing facilities within the TGF will cover an area less than 1 ha inside the Hanford Site 200 East Area. The near-surface disposal site will have a total area of approximately 73 ha and contain approximately 75 disposal vaults. Each vault is expected to have a rectangular cross-section and have inside dimensions that are approximately 125 ft long, 50 ft wide, and 34 ft deep (38 m X 15 m X 9 m). The top of the disposal vault is expected to be approximately 5 m below grade.

Design

The TGF consists of two component facilities: the Transportable Grout Equipment (TGE) and the Near-Surface Disposal Site (NSDS).

The TGE contains six modules: the Dry Blend Transfer and Lag Storage Module, the Grout Mixer/Pump and Liquid Collection Module, the Additives Module, the Decontamination Solution Module, the Exhauster Module, and the Control Room Module. The Dry Blend Transfer and Lag Storage Module will receive the dry blended materials from an existing dry blend handling facility. The dry materials will be weighed via a weighbelt feeder and fed into the Grout Mixer/Pump and Liquid Collection Module. There, a continuous in-line mixer will be used to mix the dry blended materials with the low-level liquid waste feed. The resultant grout will be discharged from the mixer into a surge tank which will feed a progressive cavity pump. The grout pump will transfer the grout via an encased pipeline to the Near-Surface Disposal Site.

9 0 1 1 7 8 5 2 0 3 0

The Near-Surface Disposal Site will be comprised of the grout disposal vaults and associated support equipment and instrumentation. The grout vaults will be engineered structures with reinforced concrete walls, roof, and floor. Each vault will be equipped with grout level indicators, temperature indicators, and liquid removal equipment. Each vault will also include a liner and leachate collection system. The top of the vault will be approximately 16 ft (5 m) below grade. The concrete roof of the vault will be covered with a soil backfill to provide shielding protection during the vault fill operations. Grout will be placed in the vault through an encased pipeline which enters through the roof.

Operating Design Capacity

Dry materials used in grout formulation will be produced at a rate of 6.8 to 14.0 t/h. The TGE will mix grout at a rate of approximately 30-70 gallons per minute (7-16 m^3/hour). A nominal campaign is expected to process one million gallons (3800 m^3) of liquid waste feed, produce 1.3 million gallons (5,000 m^3) of grout, and fill one disposal vault. A nominal campaign duration is expected to be 36 days at 50% efficiency, excluding feed preparation and staging requirements. The expected operational mode will be 24 hours per day, 7 days per week. The TGE design life is 10 years. It is anticipated that approximately 75 million gallons (280,000 m^3) of low-level waste could be processed through the TGF, producing approximately 105 million gallons (400,000 m^3) of grout slurry, and filling approximately 75 disposal vaults.

Method of Operation of the Source

The disposal process will involve mixing low-level radioactive wastes with a blend of nonradioactive dry materials (Portland cement, flyash, clays, and lime) and pumping the resulting grout slurry to preconstructed concrete vaults. Any liquids, such as flush water, will be used for water of hydration of the grout monolith or recycled.

The grout slurry will cure and solidify to form a grout monolith and immobilize the wastes within the grout matrix. After the grout monolith has hardened, the vault will be filled with nonradioactive grout to seal the radioactive monolith and to provide subsidence control. The vault excavation area will then be covered with soil backfill to grade level. Some of the disposal vaults may be covered with an additional protective barrier to inhibit water infiltration or plant, animal, and human intrusion into the waste zone.

Description of Equipment to be Used for Control of Emissions

The TGE will be equipped with a filter system to clean incoming air and an exhauster system which will filter and monitor air being discharged for radionuclides. The exhauster will consist of two parallel redundant filter systems. Each filter system will have two high efficiency particulate air (HEPA) filter banks in series with a fan, prefilter, demister, and heater. The HEPA filters remove any particles greater than 0.3 microns diameter with a 99.97% efficiency. Instrumentation to monitor differential pressure across the filters, air flow, air temperature, etc., will be provided to monitor system operation. In the event one leg of the exhaust system fails, the

9011173520 31

redundant leg automatically activates. The exhauster legs will be discharged through a common stack. The stack will be provided with a stack sampler which will monitor and record the level of radioactive emissions. The underground grout disposal vaults will also be equipped with an air sampler and HEPA filter to handle the displaced air which will be filtered and monitored for radioactive emissions. Process operations, including radiological instrumentation, will be monitored from the control room and also monitored and recorded at a central site computer surveillance system.

Expected Radionuclide Emissions

The grout facilities will emit minor amounts of airborne radionuclides, including ^{90}Sr and ^{137}Cs.

Dose Commitment

Dose commitments to the general population and to the maximally exposed individual for evaporation and grouting of existing and future tank wastes were calculated for the draft HDW-EIS (Appendix D, Page D.11). Dose commitments are calculated according to the methodology presented in Appendix F of the draft HDW-EIS. This methodology uses site-specific meteorological data gathered at Hanford over past decades. The dose commitments presented in the draft HDW-EIS are expected to be the maximum potential dose commitments as a result of any grouting operations and are, therefore, bounding for all lower activity waste streams. The doses are presented for exposure periods of one year and seventy years.

The bounding potential one-year whole-body dose commitment to the maximally exposed individual from air submersion, inhalation, and terrestrial pathways is 3×10^{-8} rem. This can be compared to the currently applicable limit of 2.5×10^{-2} rem for one-year whole-body dose equivalent to the maximally exposed individual from airborne sources.

The bounding potential one-year population whole-body dose commitment from air submersion, inhalation and terrestrial pathways is 2×10^{-3} man-rem. This is approximately three orders of magnitude below the already low exposure from 1985 operations at the Hanford Site (Price, 1986). The bounding potential 70-year population whole-body dose commitment from the same pathways is 1×10^{-2} man-rem.

Methodology for Evaluating Dose Commitment

The models and computer codes used to estimate the radiological impacts are identical to those used for the draft HDW-EIS. Table 1 lists the codes used to estimate contaminant transport in air and water and the associated radiation dose codes used to estimate the radiological impacts. The dose models used are derived from the model originally given by the International Council on Radiation Protection (ICRP, 1959) for body burden and maximum permissible concentration. Effective decay energies for radionuclides are calculated using the ICRP model. Metabolic parameters for the Standard Man are used (ICRP, 1975). Some of the parameters are updated from later ICRP publications.

9 0 1 1 7 8 6 2 0 3 2

The internal distribution of radionuclides following inhalation adds some complexity due to retention in the lungs. The model of the respiratory tract adopted by the Task Group on Lung Dynamics (ICRP, 1966) forms the general basis for the mathematical models developed to calculate the dose from inhalation of radionuclides.

Radiological doses from routine operations were calculated using the computer codes SUBDOSA, DACRIN, and PABLM, which cover the various pathways of radionuclides to humans. The results are then summarized and reported in terms of dose to the maximally exposed individual.

Table 1. Computer Codes Used to Estimate Contaminant Transport Rates and Potential Radiation Doses From Release During Disposal of Wastes in Grout.

Program	Calculational Objective	Reference
SUBDOSA	One-year air submersion dose from acute (finite cloud) or chronic (semi-infinitive cloud) releases, individual and collective doses.	Strenge, et.al. 1975
DACRIN	Individual and collective inhalation doses from chronic or acute releases, one-year doses, dose commitments and accumulated doses.	Houston, et.al. (1974); Strenge (1975)
PABLM	Individual and collective doses from contaminated farm products, from either air deposition or irradiation, one-year dose, dose commitment, and accumulated dose. Individual and collective doses from contaminated water and aquatic foods and aquatic recreation, one-year dose, dose commitment, and accumulated dose.	Napier, et.al. (1980)

Schedule

Construction of the Transportable Grout Equipment and the Near-Surface Disposal Site are planned to begin in the Fall of 1986. Initiation of grout disposal of phosphate/sulfate HFW is scheduled for fiscal year (FY) 1988. Grout disposal of other tank wastes is planned to begin in FY 1990 or as the HDW-EIS record-of-decision allows.

References

DOE, 1986, Draft Environmental Impact Statement--Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, DOE-EIS-0113, U.S. Department of Energy, Washington D. C.

DOE, 1982, Radioactive Waste Management, DOE Order 5820.2, Chapter III, Washington, D. C.

Houston, J. R., D. L. Strenge, and E. C. Watson, 1974, DACRIN: A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation, BNWL-B-389, Pacific Northwest Laboratory, Richland, Washington.

ICRP, 1959, "Report of ICRP Committee II on Radiological Protection," ICRP Publication 2, International Commission on Radiological Protection, Pergamon Press, New York, New York.

ICRP, 1966, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tracts," International Council on Radiation Protection, Health Physics, 12:173.

ICRP, 1975, "Report of the Task Group on Reference Man," ICRP Publication 23, International Commission on Radiological Protection, Pergamon Press, Oxford England.

Napier, B. A., W. E. Kennedy, Jr., and J. K. Soldat, 1980, PABLM--A Computer Program to Calculate Accumulated Radiation Dose From Radionuclides in the Environment, PNL-3209, Pacific Northwest Laboratory, Richland, Washington.

Price, K .R., 1986, Environmental Monitoring at Hanford for 1985, PNL-5817, Pacific Northwest Laboratory, Richland, Washington.

Strenge, D. L., E. C. Watson, J. R. Houston, 1975, SUBDOSA--A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation, BNWL-B-389, Pacific Northwest Laboratory, Richland, Washington.

Strenge, D. L., 1975, DACRIN--Modification of Gastrointestinal Tract Dose, BNWL-B-399, Pacific Northwest Laboratory, Richland, Washington.

9011178520 34

COMPARISON OF ENVIRONMENTAL DOSE CALCULATIONS FOR HANFORD TRANSPORTABLE GROUT FACILITY USING AIRDOS-EPA AND HANFORD SITE-SPECIFIC COMPUTER CODES

A comparison of the calculated doses projected for the Hanford Transportable Grout Facility has been made with AIRDOS-EPA and the Hanford suite of codes. The results are presented in Table 1 for the atmospheric dispersion calculations and in Table 2 for the projected radiation doses to total body.

The dispersion calculations were made with identical data sets of joint frequency of wind speed, wind direction, and stability class. The AIRDOS-EPA code does not consider data on actual location of people in calculating the "maximum individual" (MI) air concentration, and so assumes the MI to be on site. When this is corrected, the predicted values for $\bar{\chi}/Q'$ for AIRDOS-EPA is very close to that calculated using the Hanford codes. The population result is only slightly higher.

The source term for the dose calculations is attached. This is the same source term used for the EPA Construction Approval Information submittal. The doses for The Transportable Grout Facility releases are dominated by tritium. The specific-activity models used in AIRDOS-EPA and the Hanford codes are significantly different. However, minor adjustments may be made. The AIRDOS-EPA equilibrium factor for tritium has been adjusted to ICRP Publication 30 dosimetry, and the Hanford diet adjusted for in the population calculation. Thus, the projected individual dose varies by less than a factor of two, and the population dose by about a factor of two. For modeling purposes, these are excellent comparisons.

9011178620 35

TABLE 1. Comparison of Calculated Hanford 200 Area Dispersion Parameters, Using AIRDOS-EPA and Hanford Codes

	$\bar{\chi}/Q'$ for the Maximum Individual at Ringold (sec/m^3)	50-mile Population Weighted $\bar{\chi}/Q'$ ($person \cdot sec/m^3$)
AIRDOS-EPA	2.0×10^{-8}*	3.5×10^{-3}
Hanford Codes	1.8×10^{-8}	2.3×10^{-3}

*AIRDOS-EPA incorrectly predicts the Maximum Individual to reside in the Hanford 200E Area. All results have been corrected to the actual Ringold location.

TABLE 2. Comparison of Calculated Total-Body Radiation Doses for Releases from Transportable Grout Facility Using AIRDOS-EPA and Hanford Codes

	Maximum Individual at Ringold (rem)	50-Mile Population (man-rem)
AIRDOS-EPA	3.3×10^{-8}	4.2×10^{-3}
Hanford Codes	3.1×10^{-8}	2.0×10^{-3}

9 0 1 1 7 8 6 2 0 3 6

TRANSPORTABLE GROUT FACILITY
RADIONUCLIDE EMISSION SOURCE TERM

Radionuclide	Inventory in Curies/Day*
^{3}H	3.8×10^{-2}
^{14}C	1.0×10^{-14}
^{90}Sr	2.0×10^{-10}
^{93}Zr	1.0×10^{-14}
^{95}Zr	4.0×10^{-16}
^{99}Tc	9.0×10^{-14}
^{106}Ru	2.0×10^{-10}
^{129}I	2.0×10^{-16}
^{137}Cs	5.0×10^{-11}
^{151}Sm	2.0×10^{-12}
^{239}Pu	2.0×10^{-15}
^{241}Am	2.0×10^{-13}

From: "Hanford Defense Waste Disposal Alternatives: Engineering Support Data for the Hanford Defense Waste - Environmental Impact Statement," RHO-RE-ST-30 P, Rockwell Hanford Operations (December 1985)

*230 operating days per year

9011786203 7

This page intentionally left blank.

APPENDIX 13B

GROUT TREATMENT FACILITY APPROVAL OF CONSTRUCTION

1 This page intentionally left blank.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WASHINGTON 98101

November 28, 1986

REPLY TO ATTN OF: M/S 532

Michael J. Lawrence
Manager, Hanford Operations Office
U.S. Department of Energy
P.O. Box 550
Richland, WA 99352

Dear Mr. Lawrence:

This is in response to a submission pursuant to The National Emission Standards for Hazardous Air Pollutants dated August 22, 1986 by Assistant Administrator Craig Potter. It concerns the Transportable Grout Facility at the Hanford Site, Richland, Washington.

With the additional data submitted by Ronald Gerton to Gary O'Neal on November 14, 1986, we are able to approve the construction of the Transportable Grout Facility in accordance with Title 40 Code of Federal Regulations Part 61.07.

Sincerely,

Gary L. O'Neal
for Robie G. Russell
Regional Administrator

cc: Al Colli, ANR 460

9011178620 41

This page intentionally left blank.

APPENDIX 13C

GROUT TREATMENT FACILITY CULTURAL RESOURCES REVIEW

This page intentionally left blank.

Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509)
Telex 15-2874

September 1, 1988

Mr. Lee Bostic
Waste Management
Westinghouse Hanford Company
P.O. Box 1970 (R1-48)
Richland, Washington 99352

Dear Mr. Bostic:

CULTURAL RESOURCES SURVEY OF THE NEAR SURFACE DISPOSAL SITE [GROUTED WASTE DISPOSAL FACILITY] HCRC #87-200-002

At the request of Karen McGinnis of the DOE Waste Management Division, PNL's Hanford Cultural Resources Laboratory (HCRL) conducted a cultural resources review of the Near Surface Disposal Site (NSDS) on March 26, 1987. Results of that review were reported in letters to you and T. B. Bergman dated May 12 and December 2, 1987, respectively, and in a letter report to K. V. Clarke of DOE-RL dated August 11, 1987. This letter is intended to clarify our findings and recommendations.

The cultural resources review consisted of two phases. The first was a literature and records search to determine if any previous archaeological surveys had been conducted and if any significant cultural properties were already known to exist in the area. The second phase was an on-foot inspection of the entire 73-ha NSDS. No cultural properties were discovered. This is consistent with other surveys in the 200 areas. There is, however, the potential that large mammal fossils might be found in the glacial flood gravels that underlie the site, and the possibility that information useful to paleoclimatic studies, being conducted for the HDW program, might be obtained there.

I therefore recommend that:

1. Construction personnel must be cautioned to watch for bones while excavating in the area. If any bones are observed, excavation activities in the vicinity of the find must cease until a cultural resource specialist has had the opportunity to inspect the find, determine its significance, and recommend action to be taken if it is significant.

2. A cultural resource specialist should make periodic inspections of the site during excavation to watch for potential sources of paleontological data that are not likely to be recognized by construction personnel.

3. Serious consideration should be given to collecting samples from the fine sediment exposed in the construction pit. These samples should be analyzed for their potential to contribute information about past environmental conditions in the 200 area. This action would have no effect on construction activities.

If these recommendations are followed, there will be no effect on cultural resource values of the NSDS, and a considerable amount of information of value to ongoing waste management programs might be obtained.

Very truly yours,

James C. Chatters, Ph.D.
Senior Research Scientist.

JCC:Jfs

cc. K.V. Clarke, DOE-RL

9 0 1 1 1 7 8 5 2 0 4 6