Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

10-AMCP-0009

NOV 02 2009

Ms. J. A. Hedges, Program Manager
Nuclear Waste Program
State of Washington
Department of Ecology
3100 Port of Benton
Richland, Washington 99354

Dear Ms. Hedges:

HANFORD SITE SOLID WASTE LANDFILL CLOSURE PLAN, DOE/RL-2008-54, DRAFT A, AND NONRADIOACTIVE DANGEROUS WASTE LANDFILL CLOSURE/POSTCLOSURE PLAN, DOE/RL-90-17, REVISION 1

This letter transmits the Hanford Site Solid Waste Landfill Closure Plan, DOE/RL-2008-54, Draft A, and Nonradioactive Dangerous Waste Landfill Closure/Postclosure Plan, DOE/RL-90-17, Revision 1 for the State of Washington Department of Ecology's (Ecology) review and comment.

The Closure Plan is submitted in pursuit of an approval to close under WAC 173-350, and Postclosure Plan for approval to close under WAC 173-303. The plans are submitted together to facilitate the review and approval process as the landfills are physically co-located.

The Tri-Party Agreement Action Plan, Section 9.2.2, Part B Permit Applications and Closure/Postclosure Plans, identifies a 90 day Ecology review of the closure plans that begins the review and approval process. The U.S. Department of Energy Richland Operations Office (RL) appreciates Ecology's willingness to support early discussions and information exchanges during this past summer. These efforts, and an ongoing dialog during the process, are expected to enable the parties to accelerate the review and approval process in order to make use of available American Recovery and Reinvestment Act funding for the closure of these landfills prior to October 2011. RL proposes a meeting within 30 days of receipt of this letter to chart a realistic path forward to meet this goal by accelerating the Tri-Party Agreement process as outlined in Section 9.2.2, Part B Permit.

If there are any questions, please contact me, or your staff may contact Briant Charboneau, of my staff on (509) 373-6137.

Sincerely,

Matthew S. McCormick, Assistant Manager
for the Central Plateau

AMCP:KDL

Attachments

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NRDWL, SWL, D-6-1)
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DOE/RL-2008-54
Draft A

Hanford Site Solid Waste Landfill Closure Plan

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY Richland Operations Office

P.O. Box 550
Richland, Washington 99352

DOE/RL-2008-54
Draft A

Hanford Site Solid Waste Landfill Closure Plan

Date Published
September 2009

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY Richland Operations Office

P.O. Box 550
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J. D. Aardal 09/01/2009
Release Approval Date

Executive Summary

The Solid Waste Landfill (SWL), centrally located within the 600 Area of the Hanford Site, is a non-operating landfill that is being closed according to the requirements of WAC 173-350-400, "Limited Purpose Landfills."[1] The SWL received nondangerous and nonradioactive solid waste (e.g., sanitary waste and both friable and non-friable asbestos) from 1973 through March 1996. In 1996, all SWL operations ceased and the waste trenches were covered with 0.6 to 1.2 m (2.0 to 4.0 ft) of native soil.

Since it ceased operations, the landfill has been monitored for both groundwater contamination and gas releases. Quarterly groundwater monitoring at the SWL has been performed in accordance with a site-specific monitoring plan and is coordinated with the overall Hanford Site groundwater-monitoring project. Results for groundwater monitoring parameters have been at or near background for most constituents. Also, results of past and recent soil gas monitoring indicate that soil gas release from the SWL has significantly decreased and subsequently stabilized. Concentrations of methane and other key volatile organic compounds of concern are at or below detection limits, and well below the lower explosive limit.

Closure activities will focus on final cover installation, including oversight of the unit during the installation activities. An evapotranspiration cover is planned for the SWL. The evapotranspiration final cover will consist of 0.6 m (2 ft) of a fine-grained, low permeability soil and 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion resistant top soil that will sustain native vegetation. This design meets the design and performance criteria specified by WAC 173-350, "Solid Waste Handling Standards."[2] A basin lysimeter, currently in place under a double trench within the landfill, will remain operational throughout the closure and postclosure period; however, the lysimeter monitoring station, which contains the apparatus required to remove, measure, and sample the leachate collected on the basin lysimeter, will be relocated to a point removed from the proposed landfill cover footprint.

[1]WAC 173-350-400, "Solid Waste Handling Standards," "Limited Purpose Landfills," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350.

[2] WAC 173-350, "Solid Waste Handling Standards," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350.

Postclosure activities will begin after completion of closure activities (e.g., installation of the cover) and after Washington State Department of Ecology has verified that the landfill has been closed in accordance with the specifications of the approved closure plan per WAC 173-350-400(6)(h). Postclosure activities will include long-term monitoring activities, periodic inspections, and maintenance activities to ensure the long-term integrity of the closed landfill. Groundwater monitoring and leachate collection will continue during the postclosure period. Per WAC 173-350-400(7), the postclosure period will lasts 20 years, or as long as necessary for the site to stabilize. If any additional groundwater wells are required, these new wells will be placed as close to the perimeter of the landfill as possible, given the constraints of the proposed cover. Groundwater monitoring will be managed through the equally protective groundwater-monitoring program conducted pursuant to the 200-PO-1 Groundwater Operable Unit requirements. Soil gas monitoring will be discontinued as a closure activity. Data indicates that the site has stabilized with respect to gas generation with concentrations well below lower explosive limits (WAC 173-350).

The activities described do not include the closure or postclosure plans of the adjacent Nonradioactive Dangerous Waste Landfill. However, the closure of the SWL will be performed in a manner to allow the cover and other closure features of the two facilities to be coordinated, as appropriate. The Nonradioactive Dangerous Waste Landfill will eventually be closed in accordance with the requirements of WAC 173-303, "Dangerous Waste Regulations."[3]

[3] WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington.

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Terms

CFR	*Code of Federal Regulations*
Ecology	Washington State Department of Ecology
ET	evapotranspiration
FY	fiscal year
NRDWL	Nonradioactive Dangerous Waste Landfill
SWL	Solid Waste Landfill
VOC	volatile organic compound
WAC	*Washington Administrative Code*

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1 Introduction

The Solid Waste Landfill (SWL), centrally located within the 600 Area of the Hanford Site, is a non-operating landfill that is being closed according WAC 173-350-400, "Limited Purpose Landfills,"and the specific requirements of WAC 173-350-400(6) and WAC 173-350-400(7). The SWL is located adjacent to the Nonradioactive Dangerous Waste Landfill (NRDWL), a treatment, storage, and disposal unit. Both units were originally developed and operated as a single landfill, which was called the Central Landfill and began operating in 1973. The Central Landfill was designated to receive sanitary solid, friable and non-friable asbestos, and containerized chemical waste (dangerous waste) from Hanford Site operations. In 1975, the Central Landfill was subdivided into two units. The northernmost unit of the Central Landfill was isolated for the disposal of asbestos waste materials and nonradioactive chemical waste and became known as the NRDWL. The southernmost unit of the Central Landfill, which did not include any containerized waste, was designated the SWL (Figures 1-1 and 1-2). When the NRDWL ceased operations in May 1988, asbestos waste disposal was transferred to the SWL.

The SWL received nondangerous and nonradioactive solid waste from 1973 through March 1996. In 1992, a basin lysimeter was installed under one of the double landfill trenches to monitor interim cover (Section 2.7) performance. Soil gas has been monitored at the perimeter of the SWL since 1993. In 1996, all SWL waste disposal operations ceased. The soil above the waste was graded and contoured to prevent run-on/runoff from precipitation and snowmelt events from eroding the cover and to minimize infiltration of moisture into the disposal area. A soil gas monitoring system also was installed. Monitoring activities (e.g. leachate collection, soil gas sampling, and groundwater monitoring) have continued through the present time. This closure plan summarizes information about the site's operational history and environmental conditions, describes current monitoring systems, and provides a plan and schedule for actions through postclosure.

This document supersedes all previously submitted SWL landfill closure documents and serves as the sole document describing closure and postclosure action plans.

This closure plan does not address closure or postclosure of the adjacent NRDWL. However, the closure of the SWL will be performed in a manner to allow the cover and other closure features of the two facilities to be coordinated, as appropriate. The NRDWL will eventually be closed in accordance with the requirements of WAC 173-303, "Dangerous Waste Regulations."

This plan meets the requirements for closure found in WAC 173-350-400 for the sanitary waste and 40 CFR 61.151 "Standard for Inactive Waste Disposal Sites for Asbestos Mills and Manufacturing and Fabricating Operations," for the asbestos waste disposed in the SWL. This plan is subject to change, as described in Chapter 6, if monitoring or other conditions indicate the need for additional actions or an expedited schedule to protect human health and the environment.

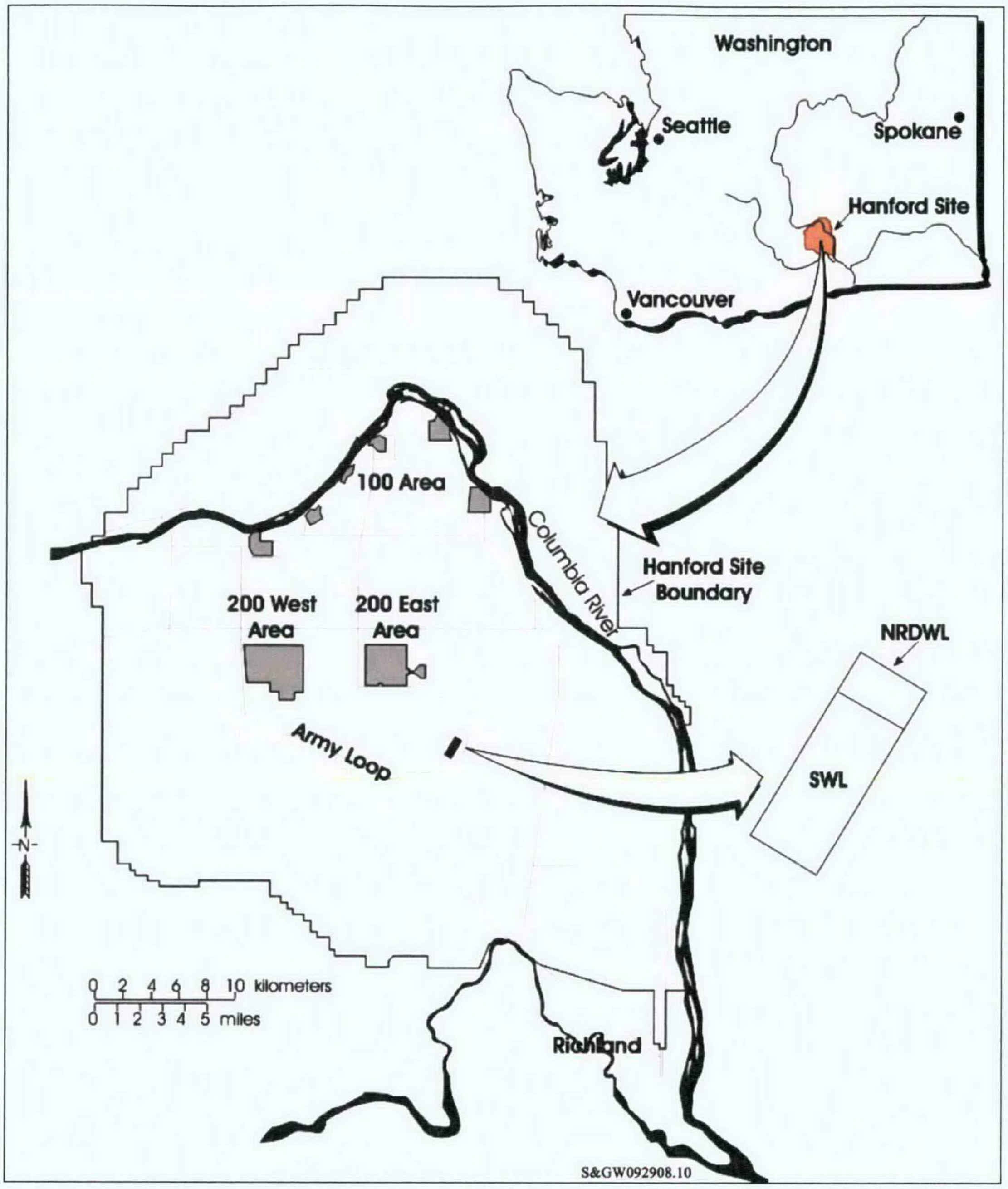
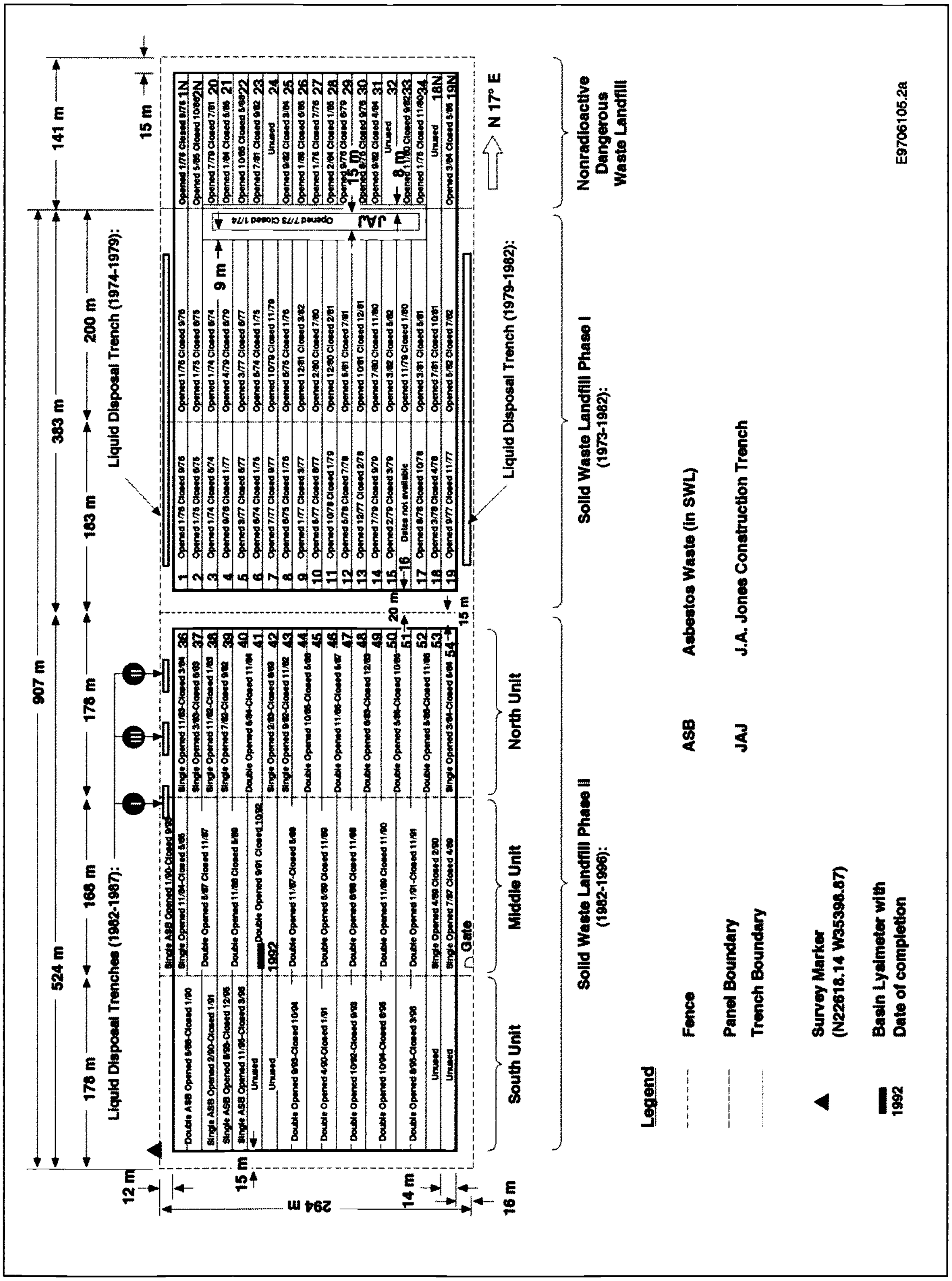


Figure 1-1. Regional Map with Locations of the Hanford Site, the SWL, and the NRDWL



Note: In 2009, fencing around the Solid Waste Landfill is not continuous.

Figure 1-2. SWL and NRDWL Arrangement

1.1 Site and Facility Description

This section provides a general description of the Hanford Site and the SWL.

1.1.1 Hanford Site Description

The SWL exists within the Hanford Site. The Hanford Site, approximately 1,520 km^2 (586 mi^2) of semiarid land, is located in Benton County northwest of the city of Richland, Washington (Figure 1-1). The city of Richland adjoins the southernmost portion of the Hanford Site boundary and is the nearest population center. In early 1943, the U.S. Army Corps of Engineers selected this site as the location for reactors, chemical separations, and related activities for the production and purification of plutonium for atomic weapons used in 1945 at the end of the Second World War. After the end of the Second World War, the Hanford Site engaged in the production of radioactive isotopes and plutonium for the nation's defense, as well as nuclear energy research and development. The current mission at the Hanford Site includes research and development, waste management, and environmental restoration and remediation.

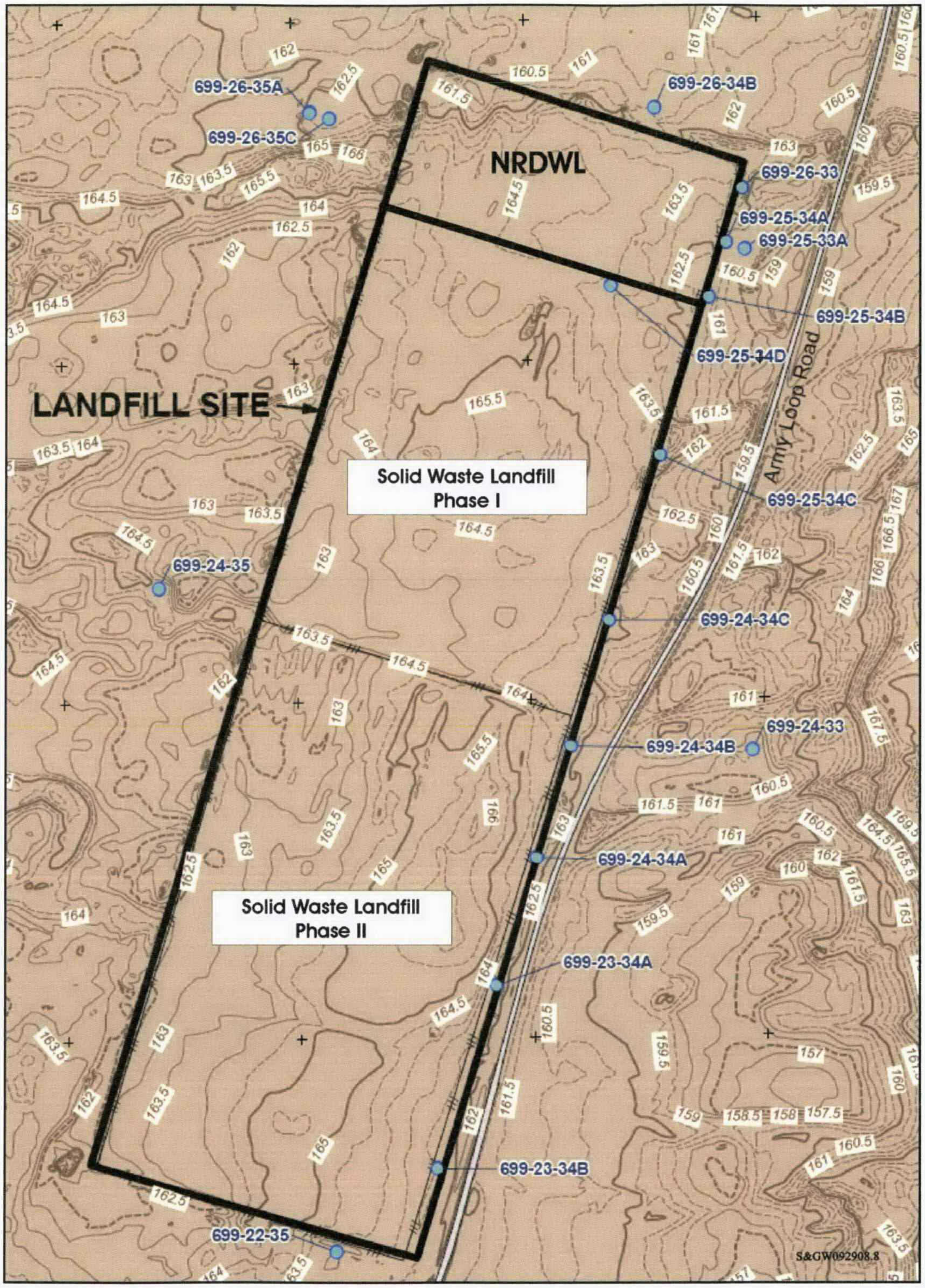
1.1.2 Solid Waste Landfill Facility Description

The SWL is a non-operating land disposal facility located near the geographic center of the Hanford Site (Figure 1-1). The SWL covers approximately 27 ha (66 a). The SWL received various nonradioactive, nondangerous solid and liquid wastes from 1973 through 1996. Hauling routes to the SWL were along Army Loop Road, which is a paved roadway.

Figure 1-2 illustrates the site plan for the SWL identifying the size, trench locations, boundary, and location of the existing basin lysimeter. The SWL is approximately 907 m (2,980 ft) in length and 294 m (965 ft) in width. It is divided into five units, each consisting of a series of parallel trenches. The two oldest units of the SWL are identified as the Phase I area, covering approximately 11 ha (28 a), and have been active since 1973. The Phase II area is divided into three units: north, middle, and south. Phase II was constructed in 1982 and covers approximately 15 ha (38 a). In 1996, all excavated solid waste trenches were covered with 0.6 to 1.2 m (2 to 4 ft) of soil from SWL trench excavations. All waste disposal trenches have operational covers in place. The site has been graded and contoured to minimize infiltration of moisture from precipitation into the disposal areas. A topographical map is provided in Figure 1-3 and an aerial photograph that includes the SWL is provided in Figure 1-4.

1.2 Waste Types and Volumes

The SWL received a variety of nondangerous, nonradioactive sanitary wastes and friable and non-friable asbestos wastes generated from Hanford Site operations. The SWL did not accept waste from the general public. Disposal of radioactive and process chemical waste was prohibited. Disposal of free liquids (e.g., sewage and catch tank liquids from shop facilities) was initiated in 1975 and prohibited in April 1987. Prior to 1982, no detailed log of waste types and volumes was maintained for the SWL. However, in 1982, following the extension of the SWL Phase II, weekly inventory logs were initiated. Later, inventory and inspection procedures were expanded to require daily, weekly, and monthly logs. The general waste types and inventory of waste buried at the SWL are described in Table 1-1.



Groundwater-monitoring wells are included and are identified by the prefix 699.

Topography shown in 0.5 m intervals.

Figure 1-3. Topographical Map of the SWL and NRDWL

Photograph taken in 2006

Figure 1-4. Aerial Photograph of the SWL and the NRDWL

Table 1-1. SWL Inventory

Solid Waste Landfill Inventory 1973 through Cessation of Operations in 1996			
Date	Solid Waste[a] (m^3)	Asbestos Waste[b] (m^3)	Liquid Waste[c] (L)
1973-1981	4,200	--	1,325,000[d]
1982	650	--	189,300
1983	1,070	--	707,900
1984	31,300	--	636,000
1985	32,900	--	836,600
1986	42,800	--	575,400
1987	44,300	--	371,000
1988	42,800	323	--
1989	44,300	2,982	--
1990	36,307	614	--
1991	21,073	1,161	--
1992	22,220	1,017	--
1993	25,800	1,508	--
1994	28,791	2,062	--
1995	21,755	1,252	--
1996	190	80	--
Total	400,456	10,999	4,641,200

a. Volumetric data are taken from annual letter reports for the SWL operation. Solid waste volume estimates through 1990 are based on the capacity of a typical trench and should be considered maximum values. In 1991, management modified the technique used for reporting volumes based on the daily log volumes of waste. The volumes from the daily logs do not include the amount of backfill (cover) material in the total volume, and thus provide a more accurate estimate of waste disposed.

b. Asbestos waste volumes are summarized from asbestos disposal request forms. Asbestos waste was disposed in the NRDWL trenches until May 1988 and in the SWL trenches starting in May 1988. Asbestos volume for 1988 estimated for SWL, based on a total of total of 776 m^3 of asbestos disposed into both the NRDWL and SWL during calendar year 1988.

c. Liquid waste volumes, including sewage and 1100 Area catch tank liquid, are based on estimated numbers and capacities of transport vehicles (tanker trucks). Free liquid was prohibited from disposal at the SWL as of May 1987.

d. No disposal of free liquids occurred in 1973 or 1974.

Based on trench geometry and the thickness of the waste layer, the capacity of a trench per linear foot is approximately 30 m^3 (40 yd^3) for a double trench and approximately 8.4 m^3 (11 yd^3) for a single trench (Figure 1-5). This volume includes the space occupied by the waste and the daily cover. Based on these calculations, the capacity of the Phase I area (consisting of only single trenches) is estimated at 179,000 m^3 (234,000 yd^3), and the Phase II area (consisting of both single and double trenches) is estimated at 417,000 m^3 (546,000 yd^3). The design capacity of the entire SWL is estimated to be 596,000 m^3 (780,000 yd^3).

Waste Types

The types of waste disposed to the SWL can be categorized (based on waste receipt records) as follows:

- Office waste
- Construction and demolition debris
- Bulky items
- Other non-liquid waste
- Asbestos material (including friable and non-friable asbestos)
- Sewage and catch tank liquids.

Office waste, approximately 40 percent of the total volume of non-liquid waste disposed of in the SWL, consists largely of waste paper products.

Construction and demolition debris, approximately 30 percent of the non-liquid waste volume, resulted from construction activities and the demolition or renovation of buildings. Such debris consists mainly of wood and wood products. Wood from Hanford Site operations (e.g., wooden pallets) also was included in this category.

Bulky items, approximately 10 percent of the non-liquid waste volume, included large items of refuse (e.g., appliances and office furniture that typically do not fit into solid waste collection containers).

Other non-liquid waste, approximately 10 percent of the total non-liquid waste volume, consists of miscellaneous waste types that contribute minor amounts to the total waste volume. This category includes garbage from Hanford Site lunchrooms, industrial waste (e.g., packaging and empty containers), medical waste from first-aid stations, and various inert materials.

Asbestos material, accounts for less than 10 percent of the non-liquid waste volume. The bulk of the asbestos material comes from the demolition and/or renovation activities to buildings on the Hanford Site. Asbestos waste was disposed in specially-designated waste trenches and was not mingled with nonasbestos waste.

Sewage and catch tank liquids, include liquid waste from septic tanks, chemical toilets, and wash water from bus and heavy equipment maintenance operations and were received at the SWL from 1975 through April 1987. The trenches that received liquid wastes are located along the east and west sides of the SWL (Figure 1-2). Until 1982, the sewage was disposed in two long trenches on the west and east perimeter in the Phase I area. From 1982 until April 1987, the sewage was released into one of three short trenches located on the northwest perimeter of the Phase II area. The sewage originated from portable toilets and septic tanks. Catch tank liquid from the 1100 Area heavy equipment garage and bus shop also was discharged into the short trenches from January 1985 through January 1987.

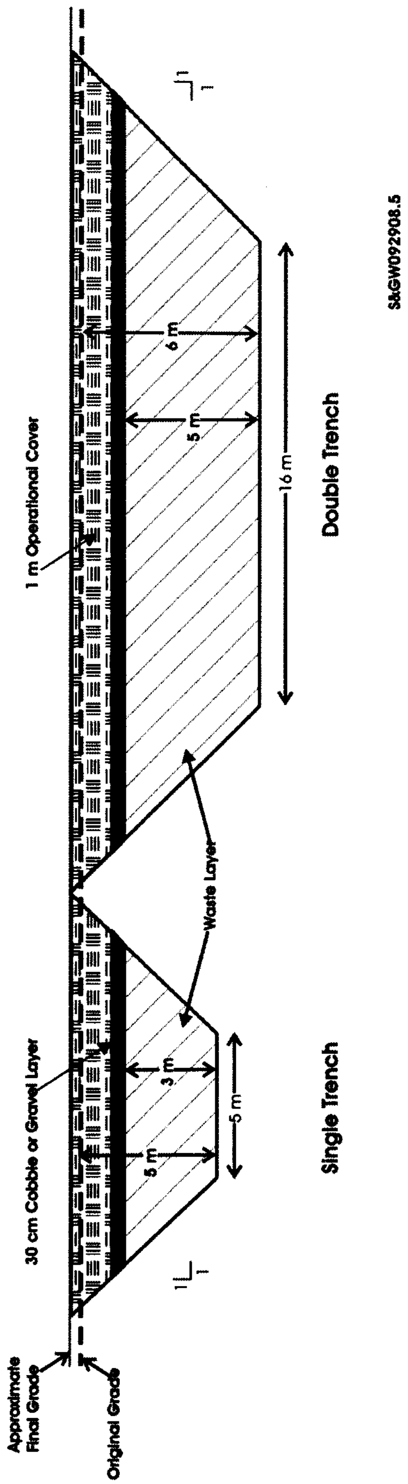


Figure 1-5. Typical Trench Cross Section (Single and Double)

1.3 History and Current Status

The SWL began operations in 1973 with receipt of waste into the J.A. Jones construction trench (Figure 1-2). Trenches were excavated as needed. A soil gas survey was performed between 1988 and 1989. In 1992, a basin lysimeter was installed under one of the double trenches prior to it being filled with sanitary waste. Continuous perimeter soil gas monitoring began in 1993. In 1996, the SWL ceased operations; the site was graded and contoured to control run-on/runoff and has been maintained in a period of interim closure care since that time.

1.3.1 Operational History

The SWL was part of the 600 Area Central Landfill, which was originally developed and operated as a single landfill. The Central Landfill began operating in 1973 and was designated to receive sanitary solid, asbestos, and containerized chemical waste (e.g., labpacks) from Hanford Site operations. The original boundary of the Central Landfill covered an area of approximately 15 ha (38 a). In 1975, the Central Landfill was subdivided into two units for operational purposes. The northernmost unit (4.1 ha [10 a]) of the Central Landfill was isolated for the disposal of asbestos waste materials and nonradioactive chemical waste and became known as the NRDWL. This NRDWL, which contained the chemical waste previously received, is not addressed by this plan. The southern unit (11 ha [28 a]), used for disposal of nonradioactive, nonhazardous sanitary waste, was later designated as the SWL (Phase I area). In 1982, the SWL was extended (Phase II area) approximately 15 ha (38 a) to the south (Figure 1-2). Because of the nature of the waste disposed at the SWL and NRDWL, they are considered separate facilities. The boundary line separating the NRDWL from the SWL is located halfway between the trench designated as "JAJ" and the southern border of NRDWL trenches.

The general method of landfilling used at the SWL was the trench method, wherein waste was placed in an excavated trench and covered with soil. As landfill space was needed, trenches were excavated along 14 m (46 ft) center lines. The landfill was managed in panels that consisted of a series of parallel trenches approximately 160 to 190 m (530 to 620 ft) long. Although the landfill was developed in panels, the trenches were actually constructed to be continuous within a phase area. Excavated soil was deposited on both sides of the trenches as spoil piles and was reserved to be operational cover material (BHI-01063, *Conceptual Model for the Solid Waste Landfill*).

Two geometries of trenches were used: single and double. The single trench was approximately 14 m (46 ft) wide at the top, 5 m (16 ft) wide at the base, and 5 m (16 ft) deep. The double trench (two single trench widths) was 28 m (92 ft) wide at the top, 16 m (52 ft) wide at the base, and 6 m (19 ft) deep. The trenches were separated by a triangular column of undisturbed soil with a ratio of approximately 1 to 1 for the side slopes.

Sanitary waste from the Hanford Site was trucked to the landfill. The trucks backed up to the working face of the trench and dumped waste under the supervision of the operating personnel who visually examined for prohibited waste. At the end of a day of operation, a portion of the spoil pile was pushed over the refuse to form the daily cover, which was typically 15 to 30 cm (6 to 12 in.) thick. The native cover soils were often inadequate to support heavy vehicular traffic. As the trench infilling progressed, a 20 to 30 cm (8 to 12 in.) gravel or cobble layer was occasionally placed on top of the filled areas to form a temporary road base to allow vehicles to reach the working face. After a trench was filled, the remaining spoil pile was bulldozed over the trench to form an operational cover. The operational cover was typically 1 m (3.3 ft) thick, but could vary from about 0.6 to 1.2 m (2.0 to 4 ft), depending on the thickness and type of the waste layer. While disposal of dangerous waste was ceased at the NRDWL in May 1985, it received asbestos waste until 1988. In 1988, the NRDWL ceased operations. At that time, a dedicated trench in the Phase II area of the SWL was opened for the disposal of asbestos waste. Asbestos debris was segregated from general sanitary waste. The asbestos waste in the SWL was disposed in accordance with 40 CFR 61, Subpart M, "National Emission Standards for Asbestos."

A soil gas monitoring study was performed within the SWL boundary in 1988 to 1989. Perimeter soil gas has been monitored continuously since 1993. Details of the soil gas monitoring surveys are presented in Section 3.4. In 1992, a lysimeter was buried beneath the soil in the southern portion of the SWL under the double trench 41 and 42 prior to being filled (Figure 1-2). The trench was used for disposal of sanitary waste. Leachate was first collected in July 1996. The SWL ceased receiving waste in March 1996.

1.3.2 Regulatory History

In January 1991, the Department of Energy, Richland Operations Office applied to the Benton-Franklin Public Health Department for a permit to operate the SWL. The permit application (DOE/RL-90-38, *Hanford Site Solid Waste Landfill Permit Application*, Rev. 0) was made according to the requirements of WAC 173-304. In 1992, regulatory responsibility for the landfill was transferred from Benton-Franklin Public Health Department to the State of Washington Department of Ecology (Ecology) via letter (Ecology, 1992, "Re: Ecology Preemption at Hanford Reservation"). A revised permit application was submitted to Ecology in 1993. Upon review of the application, Ecology requested that a corrective action plan be developed to address groundwater contamination downgradient of the site. The corrective action plan was submitted as an addendum to the permit application in 1994. Because of the existing groundwater contamination, Ecology did not issue the permit and requested that the landfill be closed.

The SWL ceased operation in March 1996. The site was graded (3 percent maximum slopes) and contoured to control run-on/runoff, thus beginning a period of interim closure care. An interim closure plan (DOE/RL-90-38, *Hanford Site Solid Waste Landfill Interim Closure Plan*, Rev. 1) was submitted to Ecology on July 5, 1996.

Subsequent meetings with Ecology were held to discuss the path forward for closure of the SWL. The current and future threats to human health and the environment from SWL contaminants were evaluated in BHI-01063. Based on that report, it was agreed that an engineered final cover should be placed over the landfill and that a new closure plan should be developed to document and formalize the closure and postclosure actions and schedule.

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2 Site Conditions

2.1 Geology

The terrain surrounding the SWL is relatively flat with small ridges of dune sand that trend generally east-west. The average elevation at the SWL is approximately 160 m (530 ft) above mean sea level; the relief on the small ridges is approximately 1.5 to 7.5 m (5 to 25 ft). As noted in BHI-01063, the major geologic units underlying the SWL are as follow (in descending order).

- The Pleistocene Hanford formation consists of glacio-fluvial sediments deposited when ice dams in western Montana and northern Idaho were breached, resulting in cataclysmic flooding through eastern Washington. The last major flood sequence is dated about 13,000 years before present. The Hanford formation is overlain by eolian deposits of fine-grained sediments.
- The late Miocene to Pliocene Ringold Formation consisting of fluvial and lacustrine sediments deposited 3.7 to 8.5 million years before present by the ancestral Columbia River and its tributaries.
- The Miocene Columbia River Basalt Group formed 6 to 17 million years before present when large volumes of lava erupted from vents in southeastern Washington, northern Oregon, and western Idaho. The basalts are interbedded with sediments of the Ellensburg Formation.

The trenches in the SWL were excavated in eolian and glacio-fluvial sediments of the Hanford formation. Bedrock, consisting of basalt, is found at a depth of approximately 183 m (600 ft) below the SWL surface. The SWL is not located over or adjacent to any known geologic features or structures that could compromise the structural integrity of the landfill. No active faults or evidence of a fault with subsidence occurring during the Holocene time have been found at the Hanford Site (WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Report*). Additional information on the geology of the SWL area is provided in BHI-01063.

2.2 Groundwater

The water table is located at a depth of approximately 38 m (125 ft) beneath the SWL. The SWL is not located over a "sole source aquifer," as defined in Section 1424(e) of the *Safe Drinking Water Act of 1974*. The closest downgradient well for drinking water is located about 7.2 km (4.5 mi) from the SWL at the Laser Interferometer Gravitational Wave Observatory. This drinking water well was drilled to a depth of 180 m (592 ft); therefore, groundwater is extracted from a deep and relatively isolated aquifer.

2.3 Surface Water

The SWL is not near any surface water. The Columbia River is more than 9.7 km (6 mi) to the northeast from the SWL. The Cold Creek drainage, an ephemeral and discontinuous stream, is approximately 6.4 km (4 mi) away to the southwest. The SWL is not located near any wetland or any public land being used by a public water system.

2.4 Slope

The terrain surrounding the landfill is relatively flat to gently rolling. The surface geology consists of stabilized dune sand. There are no known naturally unstable hillsides or soils within or adjacent to the SWL.

2.5 Land Use

The SWL is located in a remote area of the Hanford Site. The closest Hanford Site building is part of Laser Interferometer Gravitational Wave Observatory and is approximately 7.2 km (4.5 mi) to the southeast. The nearest building in the 200 East Area is more than 4.2 km (2.6 mi) to the northwest. The city of Richland is the nearest population center and the closest airport is more than 22.5 km (14 mi) to the southeast. The area surrounding the SWL has not been designated as critical habitat for endangered or threatened species of plants, fish, or wildlife. No state or national parks are located adjacent to the Hanford Site; however, in June 2000 a major portion of the Hanford Site was used to create the Hanford Reach National Monument. The SWL is in the outer area and land use will be consistent with Hanford Future Site Uses Working Group, 1992, *The Future for Hanford: Uses and Cleanup* and DOE/EIS-0222-F, *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement.*

2.6 Structures and Utilities

The only structures currently remaining at the SWL are the lysimeter and its monitoring station located near the center of the southwestern quadrant of the landfill. The lysimeter was buried beneath the soil in the southern portion of the SWL under the double trench 41 and 42 in 1992 (Figure 1-2). The lysimeter is a lined basin designed to collect leachate generated by water infiltrating through the overlying waste trench and to drain the leachate to a collection system. The leachate quality and quantity is routinely analyzed to evaluate the impact that leachate would have on groundwater quality. The lysimeter is 21 m (69 ft) long, 4.6 m (15 ft) wide on one end, 3.7 m (12 ft) wide on the other end, with a collection area of approximately 88 m^2 (950 ft^2). The monitoring station, currently located within the landfill boundary, contains the apparatus required to collect leachate from the SWL basin lysimeter located under one of the Phase II trenches. The lysimeter monitoring station will be relocated just off the west side of the landfill during initial closure activities to allow for remote control and collection of leachate from a point removed from the proposed landfill cover. No public utilities exist at the SWL.

The principal access road is Army Loop Road (Figure 1-3). During operations, on-site routing of trucks within the landfill was via temporary roads. Temporary roads were built as needed by compacting the native soil and, if necessary, topping the soil with 20 to 30 cm (8 to 12 in.) of pit-run gravel or cobble.

2.7 Interim Cover

After the SWL ceased operations in March 1996, an interim cover was placed over the SWL trenches. All excavated solid waste trenches were covered with 0.6 to 1.2 m (2 to 4 ft) of native soil from SWL trench excavations. The cover consists of native, well-graded sand with a very low percentage of fines (DOE/RL-90-38, Rev. 1). The cover materials were taken from stockpiled soils from SWL excavations; no new material was added to the SWL. From March through June 1996, the remaining soils were evenly distributed in the southern portion of the SWL (primarily the southern and middle units) to minimize topographic lows, which could collect precipitation and runoff (Figure 1-3).

2.8 Potential for Subsidence

Very little settling or subsidence is expected at the site because of the nature of the native soil and the method of landfilling used. To minimize any subsidence that would require corrective measures, site preparation activities have been proposed (e.g., geophysical tests, grading, and compaction of the operational cover) to ensure that a proper foundation is prepared for the final cover. In addition, the monofill evapotranspiration (ET) cover can accommodate moderate differential subsidence or subsidence with no detrimental effects. Should any subsidence develop requiring corrective measures, fine-grained soils would be added to fill in any potential depression that would impede runoff. Repaired areas will be revegetated, as necessary. Additional information on subsidence monitoring and response during closure and postclosure activities is presented in Sections 4.1.4, 4.3, and 5.2.2.

3 Current Monitoring Systems and Results

3.1 Interim Cover Monitoring

The interim cover is visually inspected quarterly for compliance with appropriate interim cover standards specified in WAC 173-350.

3.2 Groundwater-Monitoring Program

The depth to the water table at the SWL is approximately 40 m (130 ft). Groundwater monitoring at the SWL is performed in accordance with a site-specific monitoring plan and is coordinated with the overall Hanford Site groundwater-monitoring project. To date, the wells, constituents, and sampling frequencies have followed the requirements of WAC 173-304-490, "Ground Water Monitoring Requirements."

The constituent list for groundwater monitoring includes requirements in WAC 173-304-490(2)(d) and site-specific parameters from the waste disposal and groundwater monitoring history and results of leachate sample analyses. The groundwater-monitoring wells are placed as close to the perimeter of the landfill as practical. If any additional wells are required, these new wells will be placed as close to the perimeter of the landfill as practical, given the constraints of the proposed cover. The data from sampling of the wells are regulatorily compliant to determine concentrations of constituents at the point of compliance. Groundwater samples are collected quarterly and analyzed for WAC 173-304-490 required parameters and several site-specific contaminants of concern.

The current monitoring program is designed with the following goals.

- Represent the quality of background groundwater that has not been affected by the SWL (sample and analyze groundwater from upgradient wells), but may be impacted by regional plumes originating in 200 East Area.
- Represent the quality of the groundwater passing the point of compliance (sample and analyze groundwater from upgradient wells).
- Determine whether downgradient concentrations of groundwater constituents specifically required by government regulations are statistically increased over background concentrations.
- Determine whether concentrations of other groundwater constituents of concern (volatile organic compounds [VOC]) have exceeded groundwater quality criteria (performance standards). Table 3-1 provides the criteria.

Two hydrogeological conditions at the SWL are of special concern to the development of this groundwater-monitoring plan. The first is the low-permeability unit within the upper Ringold unit of the Ringold Formation. The thickness of the uppermost aquifer is limited to 22 m (72 ft) by an underlying low-permeability layer.This underlying layer is believed to limit the depth of any contamination from the SWL.

The second special condition involves the extremely low hydraulic gradient and the difficulty to determine an accurate direction of groundwater flow in the uppermost aquifer. Water-table maps indicate the flow should be generally from west to east in the immediate vicinity of the SWL. Contaminant plumes from the 200 East Area (e.g., tritium) are moving from the northwest to the southeast.

Additional information about groundwater monitoring is contained in the annual Hanford Site groundwater monitoring reports (e.g., DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*).

Table 3-1. Groundwater Quality Criteria for SWL Groundwater Waste Parameters and Associated Method Detection Limits

Groundwater Constituent	GWQC[a] (or MCL)[b]	MDL (IDL for metals)[c]
Temperature	--	--
Specific Conductance	700 µS/cm (WAC 246-290-310)	0.278 mS/cm
Field pH	6.5 - 8.5	+/- 0.1
Total Organic Carbon	--	300 µg/L
Chloride	250,000 µg/L	60 µg/L
Nitrate	(45,000 µg/L)	44.3 µg/L
Nitrite	(3,300 mg/L)	65.7 µg/L
Ammonium	--	12 µg/L
Sulfate	250,000 µg/L	140 µg/L
Dissolved Iron	300 µg/L	(9 µg/L)
Dissolved Zinc	5,000 µg/L	(4 µg/L)
Dissolved Manganese	50 µg/L	(4 µg/L)
Coliform (most prob. number)	1 colony /100 mL	1 colony /100 mL
Chemical Oxygen Demand	--	10,000µg/L
Arsenic (filtered)	0.05 µg/L	(0.4 µg/L)
Carbon Tetrachloride	0.3 µg/L	1.0 µg/L
1,1-Dichloroethane	1.0 µg/L	1.0 µg/L
1,2-Dichloroethane	0.5 µg/L	1.0 µg/L
Tetrachloroethene	0.8 µg/L	1.0 µg/L
Trichloroethene	3.0 µg/L	1.0 µg/L
1,1,1-Trichloroethane	(200 µg/L)	1.0 µg/L
1,4-Dioxane	7.0 µg/L	12 µg/L
1,4-Dichlorobenzene	(4.0 µg/L)	1.0 µg/L

a. Groundwater quality criteria in WAC 173-200, "Water Quality Standards for Ground Waters of the State of Washington."

b. Maximum contaminant levels in 40 CFR 141, "National Primary Drinking Water Regulations,"40 CFR 143, "National Secondary Drinking Water Regulations," and EPA/822/R-96/001, *Drinking Water Regulations and Health Advisories*.

c. MDL and IDL may vary based on laboratory contracts and capabilities.

WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)"

-- = not available

GWQC = groundwater quality criteria

IDL = instrument detection level

MCL = maximum contaminant levels

MDL = method detection level

3.2.1 Well Monitoring Network

Wells in the current monitoring network screen the uppermost portion of the uppermost aquifer. The monitoring network consists of two upgradient wells on the west side of the SWL (well 699-26-35A is shared with the NRDWL) and seven downgradient wells along the east and south of the SWL.

Upgradient Wells

- 699-26-35A
- 699-24-35

Downgradient Wells

- 699-24-34A
- 699-24-34B
- 699-24-34C
- 699-23-34A
- 699-23-34B
- 699-22-35
- 699-24-33 (used for supporting data only, not constructed to WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," standards)

Well 699-25-34C (Figure 3-1) was formally in the groundwater-monitoring network, but went dry in 2003. A new downgradient well may be installed near the location of well 699-25-34C (adjacent to the landfill cover) if deemed necessary.

A construction diagram for a typical SWL groundwater monitoring well is shown in Figure 3-2. Only one of the existing groundwater-monitoring wells (well 699-24-33) was not constructed in compliance with the requirements of WAC 173-160. Well 699-24-33 was constructed in 1948 prior to the existence of the SWL and is used for supporting data only (i.e., data not used for statistical comparisons, determination of performance standards, or regulatory determinations). The last two groundwater-monitoring wells (699-23-34B and 699-22-35) were installed in 1993 to complete the downgradient-monitoring network on the eastern and southern boundaries of the landfill. Figure 3-1 shows all well locations for the SWL.

3.2.2 Groundwater Flow and Direction

The direction and flow of groundwater beneath the SWL is difficult to determine from water table maps because of the extremely low hydraulic gradients. However, groundwater is known to flow southeast between the 200 East Area and the SWL because the average water-level elevation at the landfill is about 13 cm (5 in.) less than the average elevation in the 200 East Area. The groundwater flow rate was estimated in PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, range from 2 to 13 cm (0.8 to 5 in.) per day, based on measurements of the hydraulic gradient from water table maps and current understanding of the local hydraulic conductivity and effective porosity.

3.2.3 Depth to Water Table

The depth to the water table beneath the SWL varies from about 38 m (125 ft) near well 699-24-33 to about 43 m (140 ft) near well 699-24-35. This variation is caused by the slightly rolling topography over the SWL. The actual water table is fairly flat, and consistently remains between 121.5 to 121.6 m (398.6 and 398.9 ft) in elevation. Over the past 10 years, the water table underneath the SWL has been declining as part of a regional effect. Throughout production years, millions of gallons of wastewater were discharged to the ground in the 200 Area producing large mounds and changing groundwater flow rates and directions. Subsequently, when production ceased, the wastewater discharge ceased and the water table began to recover. The mounds decreased and the water table at the 200 East Area declined, including the water levels at the SWL. The average rate of decline in water level for the past 10 years is approximately 0.08 m/yr (0.3 ft/yr), with a lower rate of decline in recent years. Previous monitoring well 699-25-34C has gone dry.

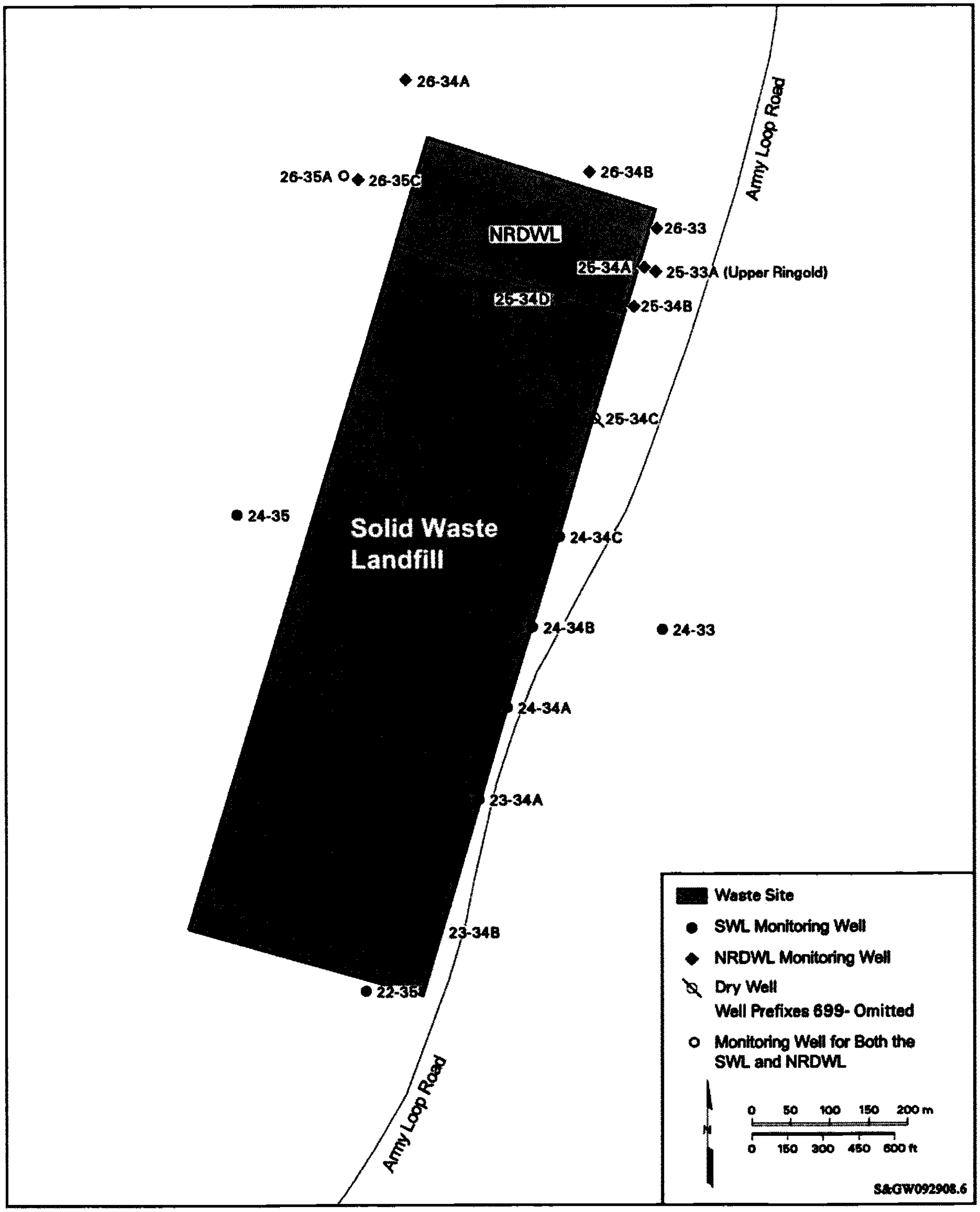


Figure 3-1. SWL and NRDWL Groundwater Monitoring Well Locations

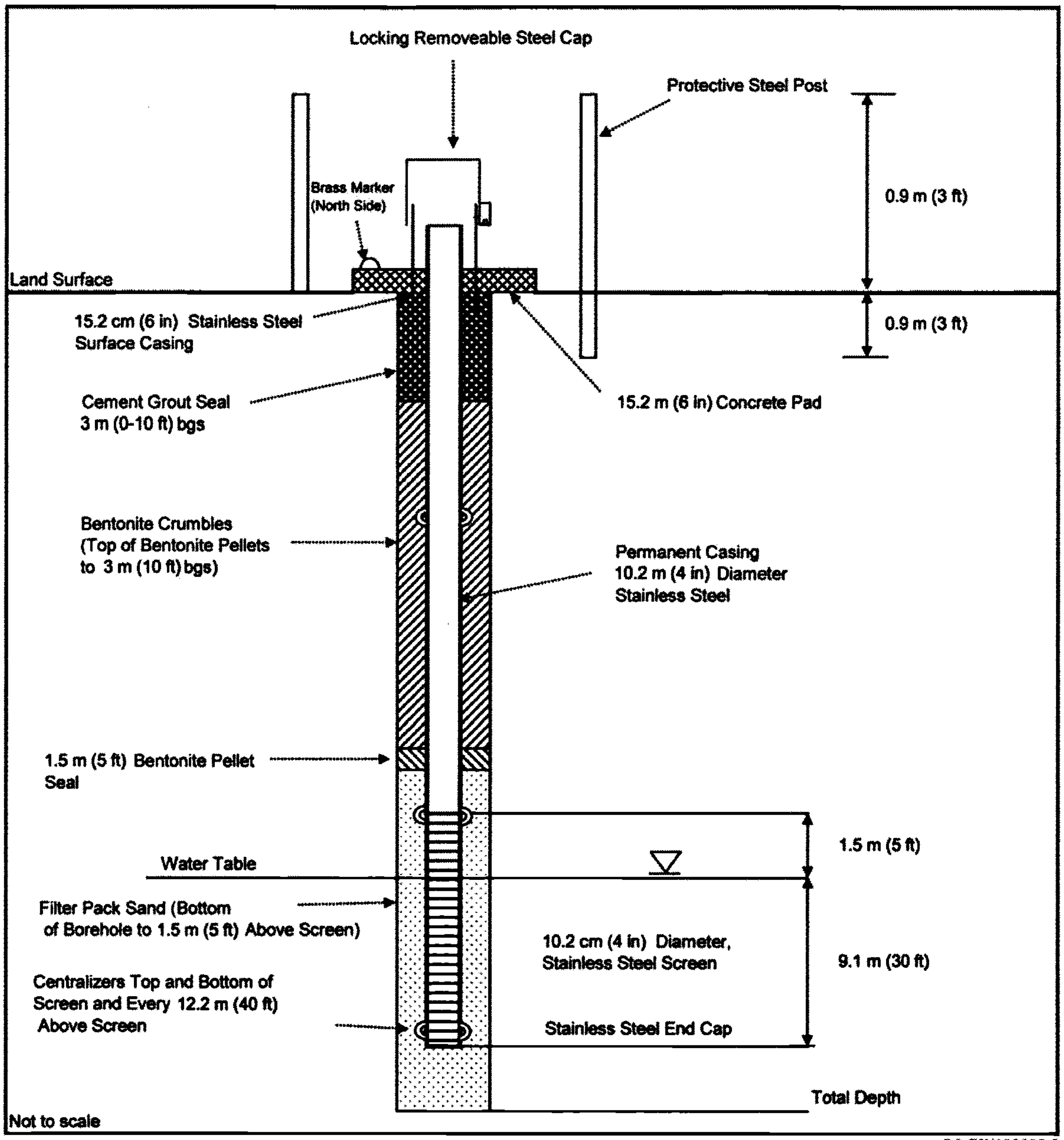


Figure 3-2. Construction Diagram of a Typical Groundwater Monitoring Well

3.2.4 Groundwater Monitoring Constituents

The groundwater is sampled quarterly. The constituent list for groundwater sampling and analysis at the SWL includes the following analytes required by WAC 173-304-490(2)(d):

- Temperature
- Specific Conductance
- pH
- Chloride
- Nitrate, nitrite, and ammonia as nitrogen

- Sulfate
- Dissolved iron
- Dissolved zinc
- Dissolved manganese
- Chemical oxygen demand
- Total organic carbon
- Total coliform.

In addition, the groundwater is sampled for site-specific parameters. Site-specific parameters selection is based on waste disposal and groundwater monitoring history at the SWL and results of leachate sample analyses. The site-specific parameters include the following:

- Volatile chlorinated hydrocarbons (including, but not limited to, carbon tetrachloride, 1,1-dichloroethane, 1,2-dichloroethane, tetrachloroethene, trichloroethene, 1,1,1-trichloroethane, and 1,4-dichlorobenzene)
- 1,4-Dioxane
- Dissolved arsenic.

Table 3-1 lists the groundwater analysis method detection limits currently in use for groundwater parameters and the groundwater quality criteria (also called groundwater performance standards). (Note: If there are no applicable groundwater quality criteria for a particular analyte, then the groundwater performance standard is the maximum contaminant level.) The groundwater analyses methods currently used to analyze the groundwater samples are designed, for the most part, to meet the groundwater quality criteria. However, the groundwater quality criteria for a few constituents are below the method detection level, and the corresponding cost too high, to be cost effective at the present level of technology for routine analyses. These constituents include arsenic, 1,4-dioxane, carbon tetrachloride, 1,2-dichloroethane, and tetrachloroethene.

3.2.5 Groundwater Monitoring Results

The following information is taken from DOE/RL-2008-66. Additional information is in preceding and succeeding years' annual groundwater monitoring reports.

3.2.5.1 WAC 173-304 Parameters

The 2008 results for each WAC 173-304 required parameter are as follows.

Ammonium – Results for ammonium ion (background threshold value 90 µg/L) in SWL wells during fiscal year (FY) 2008 ranged from less than the method detection limit (12 µg/L) to 33.9 µg/L (from February 2008) at well 699-24-35. Ammonium ion was detected at the upgradient and downgradient wells. Detections of this groundwater constituent have been sporadic in previous years at the SWL and continued in FY 2008.

Chemical Oxygen Demand – Chemical oxygen demand (background threshold value 10 mg/L) ranged from less than the method detection limit (10 mg/L) at upgradient wells and some downgradient wells to 23 mg/L at well 699-24-33. Historically, chemical oxygen demand values are sporadic at the SWL. Elevated values of this constituent could be an indication of groundwater contamination by sewage, which was known to have been discharged to SWL trenches.

Chloride – Chloride ranged from 5.9 mg/L (at downgradient well 699-23-34A) to 7.6 mg/L (at downgradient well 699-24-34A). The background threshold value (7.8 mg/L) was not exceeded. Chloride slightly increased in concentration in most SWL wells until about 2005, and stabilized thereafter.

Coliform Bacteria – The background threshold value (1 colony per 100 mL of groundwater) was exceeded at one well during FY 2008. That exceedance was 2 col./100 ml in background well 699-24-35. Like chemical oxygen demand, elevated levels of coliform bacteria have been detected sporadically at the SWL in past years. Elevated levels of this constituent are expected with the known disposal of sewage at the SWL.

Filtered Iron – None of the filtered iron results exceeded the 160 μg/L background threshold value during FY 2008. The reported values ranged from less than 9 to 109 μg/L. Elevated filtered iron results have been reported above the background threshold value occasionally at SWL wells in recent years, but are not typical of the overall historical results.

Filtered Manganese – Filtered manganese was mostly undetected (above the method detection level of 4 μg/L) in SWL wells during FY 2008. The maximum level detected was 8.2 μg/L at downgradient well 699-24-34A. The background threshold value was 18 μg/L.

Nitrate – The SWL is located on the western edge of the major nitrate plume emanating from the 200 East Area. Downgradient wells have similar levels of nitrate as the upgradient wells. During FY 2008, the highest level of nitrate at the SWL was 19.2 mg/L at downgradient well 699-23-24A, which was significantly lower than the 29 mg/L background threshold value.

Nitrite – Although the background threshold value was 148 μg/L, the highest reported detected result of 88.4 μg/L was still below the analytical laboratory's required detection limit.

Field pH – Six wells at the SWL during FY 2008, including upgradient well 699-24-35, had pH levels that were lower than the background threshold range (6.68 to 7.84). The downgradient wells that exceeded the background threshold range were 699-23-34A, 699-23-34B, 699-24-33, 699-24-34A, and 699-24-34B. The lowest pH value was 6.52 at well 699-23-34A. Trends of pH are relatively steady at SWL wells.

Specific Conductance – Specific conductance values at all seven downgradient wells exceeded the 583 μS/cm background threshold value during FY 2008. At the two upgradient wells (699-24-35 and 699-26-35A), the values were lower. Six of the seven downgradient wells also had specific conductance values greater than the 700 μS/cm WAC 246-290-310 limit. The highest reported value during FY 2008 was 829 μS/cm at the downgradient well 699-22-35. Specific conductance values at the SWL have remained relatively stable since 2001. Elevated specific conductance may caused by increased concentrations of sulfate and other anions in groundwater at the SWL.

Sulfate – Reported results in downgradient wells ranged from 40.3 to 55.5 mg/L. Four of the seven downgradient wells had at least one result that exceeded the 47.2 mg/L background threshold value. The overall trend for sulfate at the SWL is stable to slightly increasing in concentration.

Temperature – Two results at well 699-22-35 (24 and 25.9°C) exceeded the 20.7°C background threshold value during FY 2008. None of the other wells exceeded the limit. Both of the exceedances (one in May 2008 and one in August 2008) appear to be anomalous and not consistent with historical trends at this well. The elevated temperature data were reviewed and were assumed to be errors.

Total Organic Carbon – Five of the downgradient wells and one of the upgradient wells had total organic carbon results that exceeded the 1,430 μg/L background threshold in the February 2008 sampling event. Results in the other three quarters were all below the background threshold value. The exceedances ranged from 2,910 μg/L at well 699-24-34B to 38,300 μg/L at well 699-24-33. Spurious elevated total organic carbon results have been reported previously at the SWL.

Filtered Zinc – Reported values for filtered zinc during FY 2008 at the SWL ranged from less than 4 μg/L (the analytical method detection limit) to 25.9 μg/L at the upgradient well 699- 24-35. None of the SWL wells had filtered zinc values exceeding the 43.2 μg/L background threshold value.

3.2.5.2 Site-Specific Parameters

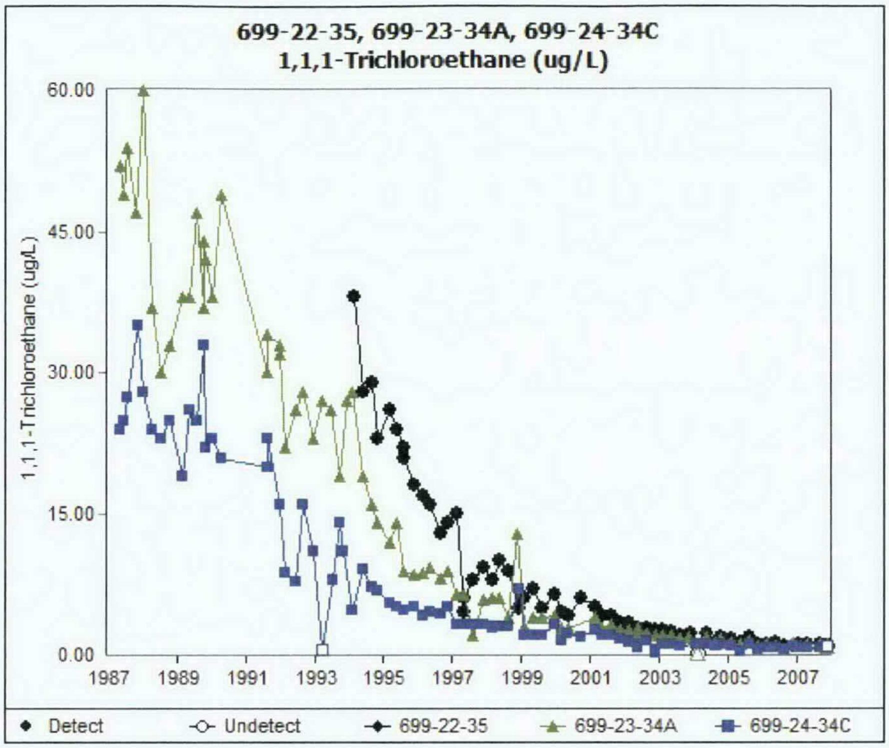
The concentrations of chlorinated hydrocarbons at the SWL have decreased over the years and were barely detectable during FY 2008. The only chlorinated hydrocarbons exceeding WAC 173-200-040, "Criteria.," limits during FY 2008 were tetrachloroethene (limit 0.8 μg/L) and carbon tetrachloride (limit 0.3 μg/L). The highest reported tetrachloroethene result was 2.6 μg/L at the downgradient well 699-24-33; and the only detected carbon tetrachloride result was 1.0 μg/L at downgradient well 699-22-35. These results were below the analytical laboratory's practical quantitation limit (required detection limit). Four chlorinated hydrocarbons (1,1,1-trichloroethane, chloroform, methylene chloride, and trichloroethene) were detected at low concentrations in SWL wells during FY 2008. Like the tetrachloroethene and carbon tetrachloride results, the results for these chlorinated hydrocarbons were below the analytical laboratory's practical quantitation limits (required detection limits). The general trends for these detected chlorinated hydrocarbons are stable to decreasing. Charts showing decreases in concentrations for some chlorinated organic chemical contaminants in the groundwater are provided in Figures 3-3 through 3-8. Two of the VOCs, 1,1-trichloroethane (Figure 3-3) and chloroform (Figure 3-6), have been below the WAC 173-200, "Water Quality Standards for Ground Waters of the State of Washington," limits since monitoring began in 1987, The other VOCs, 1,1-dichloroethane (Figure 3-4), carbon tetrachloride (Figure 3-5), tetrachloroethene (Figure 3-7), and trichloroethene (Figure 3-8), have had concentrations that decreased to levels lower than the WAC 173-200 limits since the well were installed in 1987. The reason for the spikes in carbon tetrachloride and chloroform concentrations in 1996 and1997 is unknown.

A potential cause of the widespread, low-level chlorinated hydrocarbon contamination at the SWL, including the upgradient wells and the adjacent NRDWL, is the dissolution of vadose zone VOC vapors into groundwater. However, the source of the vapors is uncertain. Potential sources are the chlorinated hydrocarbons dissolved in the liquid sewage or the catch tank liquid from the 1100 Area heavy equipment garage and bus shop that were disposed to the SWL (DOE/RL-2008-66).

The other constituents discovered in the leachate collection system at the SWL (barium, copper, fluoride, nickel, and arsenic) were all detected in groundwater but had results lower than primary drinking water standards (or secondary drinking water standards, if appropriate) or WAC 173-200-040 limits, except for arsenic. Although the drinking water standard for arsenic is 10 μg/L, the WAC 173-200-040 limit is 0.05 μg/L. Results for filtered arsenic ranged from 1.1 to 5.8 μg/L, all exceeding the WAC 173-200-040 limit. However, results from downgradient wells were not significantly different than results from upgradient wells.

3.2.5.3 Sampling and Analysis Protocol

Procedures for groundwater sampling, documentation, sample preservation, shipment, and chain-of-custody requirements are described in the Hanford Site contractor or subcontractor procedures manuals. Samples generally are collected after three casing volumes of water have been purged from the well or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized. For routine groundwater samples, preservatives are added to the collection bottles, if required, before their use in the field. Samples for metals analysis are usually filtered in the field so that results represent dissolved metals. Procedures for field measurements are specified in the contractor's, subcontractor's, or manufacturer's manuals. Analytical methods are specified in contracts with laboratories, and most are standard methods from SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B* and EPA/600/4-79/020, *Methods of Chemical Analysis of Water and Wastes.*



NOTE: WAC 173-200, "Water Quality Standards for Ground Waters of the State of Washington," limit is 200 µg/L.

Figure 3-3. 1,1,1-Trichloroethane Trend in Groundwater-Monitoring Wells at the SWL

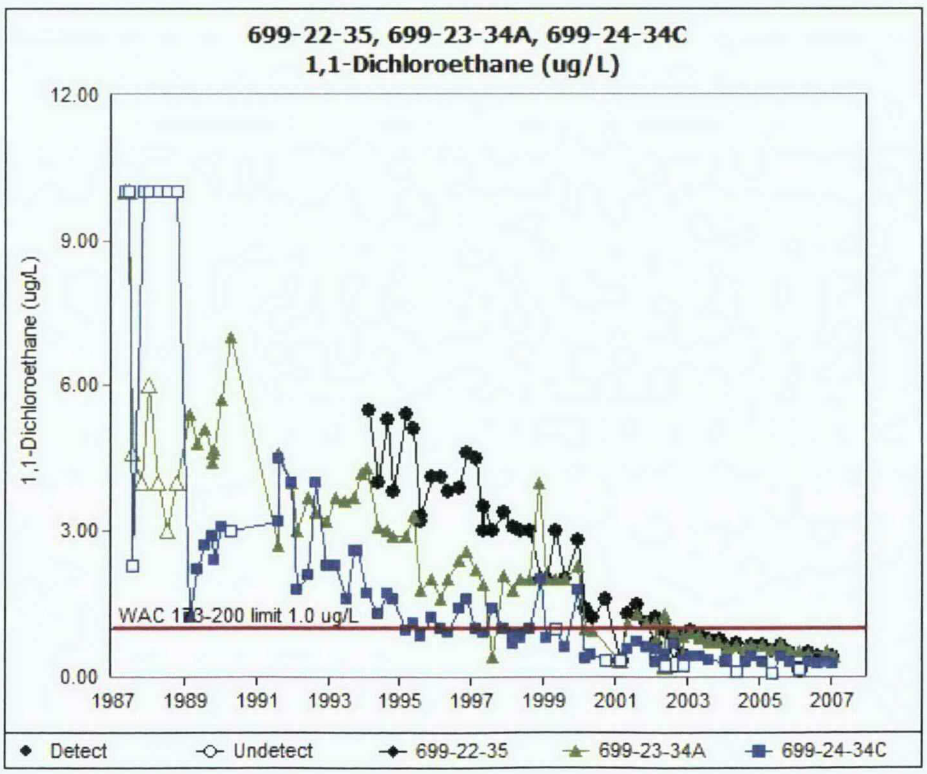


Figure 3-4. 1,1-Dichloroethane Trend in Groundwater-Monitoring Wells at the SWL

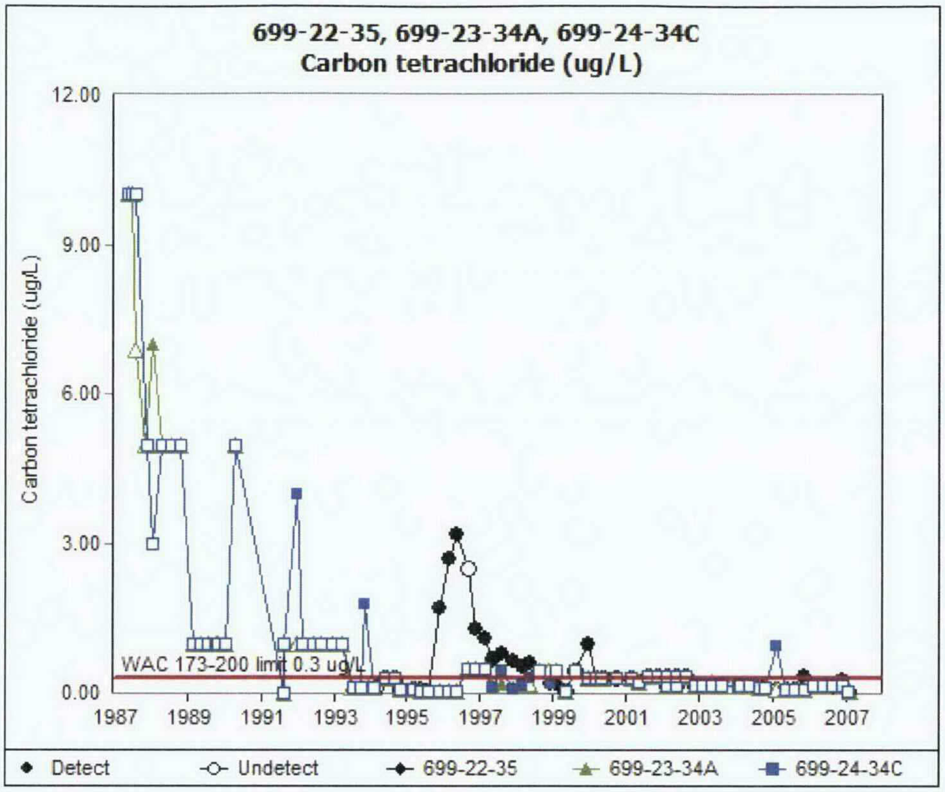


Figure 3-5. Carbon Tetrachloride Trend in Groundwater-Monitoring Wells at the SWL

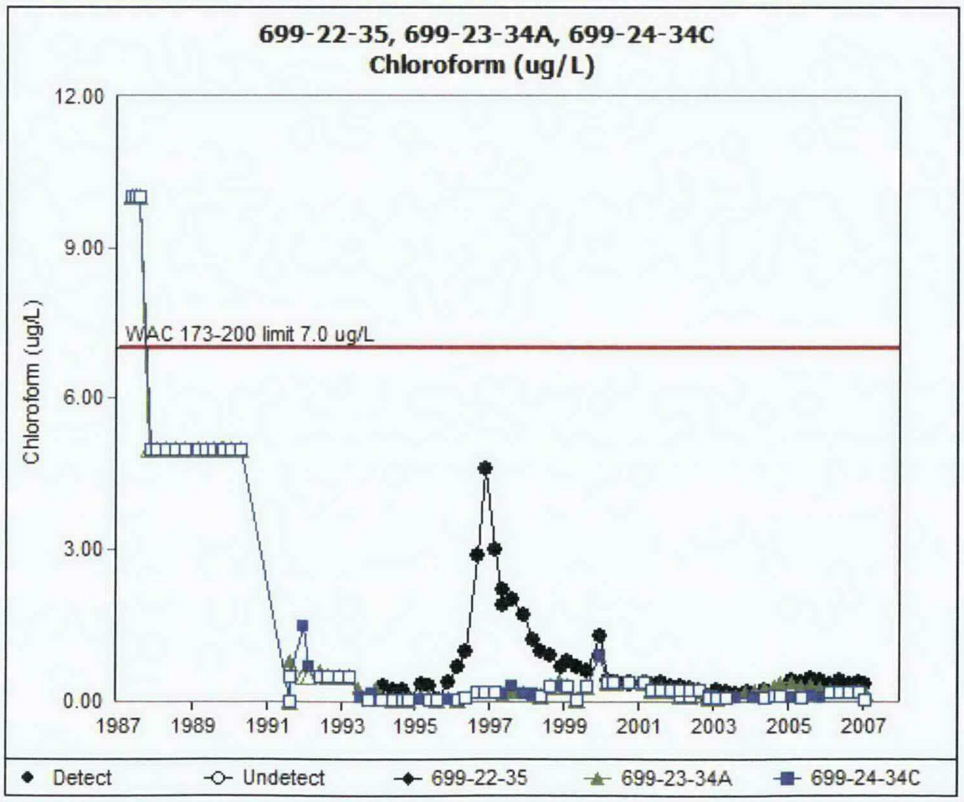


Figure 3-6. Chloroform Trend in Groundwater-Monitoring Wells at the SWL

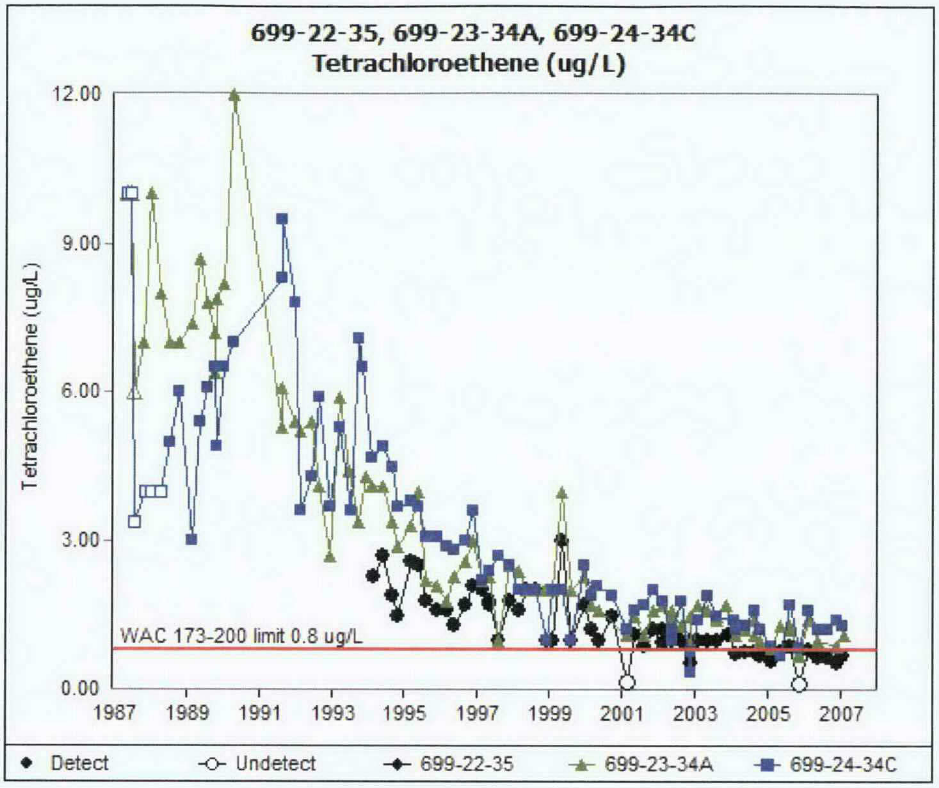


Figure 3-7. Tetrachloroethene Trend in Groundwater-Monitoring Wells at the SWL

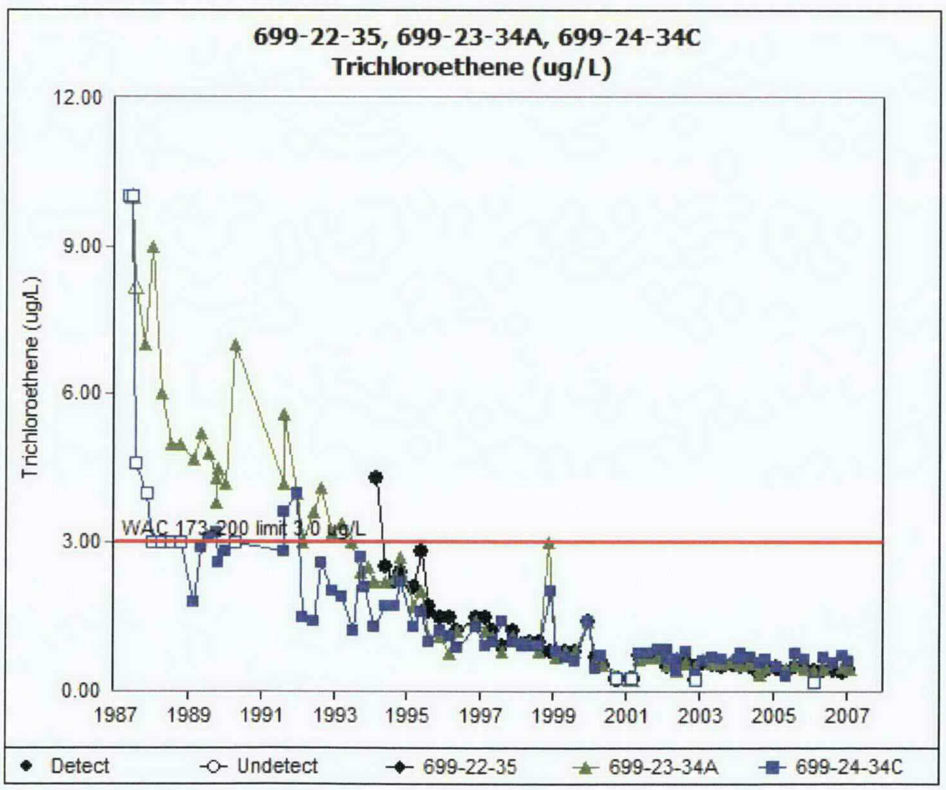


Figure 3-8. Trichloroethene Trend in Groundwater-Monitoring Wells at the SWL

3.2.5.4 Quality Assurance and Quality Control

The groundwater-monitoring project's quality assurance/quality control program is designed to assess and enhance the reliability and validity of groundwater data. The primary quantitative measures or parameters used to assess data quality are accuracy, precision, completeness, and the method detection limit. Qualitative measures include representativeness and compatibility. Goals for data representativeness for groundwater monitoring projects are addressed qualitatively by the specification of well locations, well construction, sampling intervals, and sampling and analysis techniques in the groundwater-monitoring plan for each facility. Comparability is the confidence with which one data set can be compared to another.

The quality control parameters are evaluated through laboratory checks (e.g., matrix spikes, laboratory blanks, audits), replicate sampling and analysis, analysis of blind standards and blanks, and inter-laboratory comparisons. Acceptance criteria have been established for each of these parameters, based on guidance from the U.S. Environmental Protection Agency (SW-846) and EPA/600/4-79/020. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence and affected data are flagged in the database.

3.2.6 Groundwater Monitoring Results Reporting

Chemistry and water-level data are reviewed at least quarterly and are available in the Hanford Environmental Information System database.

WAC 173-304-490 requires that the groundwater flow direction in the uppermost aquifer be determined at least annually. Data from all wells will be routinely analyzed for statistically significant increases and variations from background levels. Significant changes in groundwater quality will be reported to Ecology as information becomes available. The interpreted flow direction is reported annually (usually in March) along with interpretations of groundwater quality data for the previous FY in the annual report on Hanford Site groundwater monitoring (e.g., DOE/RL-2008-66).

3.3 Barrier Performance Monitoring

The existing barrier performance monitoring system consists of a large basin lysimeter. The SWL basin lysimeter was designed and installed in 1992 beneath the southern end of double trench 41 and 42 (Figure 1-2), which was opened in September 1991 and closed in October 1992. The trench was filled from the north to the south. The SWL basin lysimeter is a lined basin beneath a portion of a waste trench and functions as a large-scale collection and sampling device for leachate (Figure 3-9). Leachate quality and quantity are analyzed to evaluate the potential impact that the leachate would have on groundwater quality. Any leachate generated by natural precipitation percolating through the waste layer above the lysimeter is collected by the basin lysimeter. A collection pipe connected to the lysimeter allows any leachate to drain into a collection sump. The lysimeter is 21 m (69 ft) long, 4.6 m (15 ft) wide on one end, 3.7 m (12 ft) on the other end, with a collection area of 88 m^2 (950 ft^2).

It is anticipated that five or ten years after landfill barrier construction little or no leachate will be generated. However, following construction of the barrier, a slight increase in leachate may occur because of the water used for dust mitigation and compaction during barrier construction. Routine activities associated with leachate monitoring will continue, but are expected to gradually decrease or cease in frequency once the final cover is in place. These routine activities include the following:

- Maintaining the basin lysimeter
- Pumping out leachate collected
- Sampling and analysis of leachate collected for chemical constituents
- Disposal of collected leachate.

The only structure at the SWL that needs regularly scheduled maintenance is the lysimeter monitoring station. Leachate drains by gravity from the lysimeter through a plastic (high-density polyethylene) drain pipe to two stainless steel receiver vessels or tanks placed in series near the bottom of the lysimeter sump, which is approximately 6 m (20 ft) below grade. The first tank contains float switches to indicate the presence of leachate and overflows to the much larger holding tank. The tanks are individually vented through stainless steel tubing that extends above grade to a valve manifold in the lysimeter monitoring station. The valves are normally left open, venting the tanks to the atmosphere. During sampling intervals, leachate is extracted by pressurizing the tanks using bottled inert gas (i.e., argon) connected to the tank vents at the manifold. Check valves placed at the inlet to the tanks prevent the leachate and argon gas from flowing back to the lysimeter. Stainless steel drain lines, connected to the bottom of the tanks, transport the leachate to the surface. The leachate is then transferred into sampling bottles and/or 208 L (55-gal) steel drums staged adjacent to the lysimeter monitoring station. All drums are provided with secondary containment and are covered to protect from the weather. Periodically, as needed, collected leachate is shipped to and disposed at a facility approved to receive the leachate. It is anticipated that once the final cover is installed, leachate generation will gradually diminish to the point where very little or no leachate will be collected by the lysimeter. Sampling and maintenance intervals may need to be adjusted accordingly in the future.

3.3.1 Leachate Monitoring Constituents

The constituents analyzed in the leachate are based on the constituent list for groundwater monitoring, contained in WAC 173-304-490, and suspected contaminants of concern known to be contained within the waste inventory. Leachate constituents include conductivity, pH, chloride, nitrite, nitrate, ammonia, sulfate, dissolved iron, dissolved zinc, dissolved manganese, chemical oxygen demand, and total organic carbon. In addition, select metals and organic constituents are routinely monitored, based on historic monitoring of both the leachate and groundwater. Table 3-2 provides results of monitoring for reporting year 2006 to 2007. Monitoring results for additional years can be found in the Hanford Site SWL annual monitoring reports (e.g., 09-AMCP-0010, 2008, "Hanford Site Solid Waste Landfill Annual Monitoring Report: July 2007 through June 2008").

3.3.2 Primary Leachate Contaminants

The analysis of leachate samples collected between 1996 and 2007 indicates that the leachate constituents are typical of sanitary landfills. Some contaminants have been detected and concentrations vary. These variations appear to be sampling and analytical anomalies. Only one chlorinated organic compound (1,4-dichlorobenzene) has been detected on a routine basis with concentrations at the WAC 173-200 ground water quality criteria. In addition, some of the indicator parameters (metals and organics) have been detected above ground water quality criteria. These include conductivity, total dissolved solids, arsenic, manganese, and 1,4-dioxane; however, monitoring of these same constituents in the underlying groundwater has not revealed any elevated trends towards the ground water quality criteria at the facility compliance point.

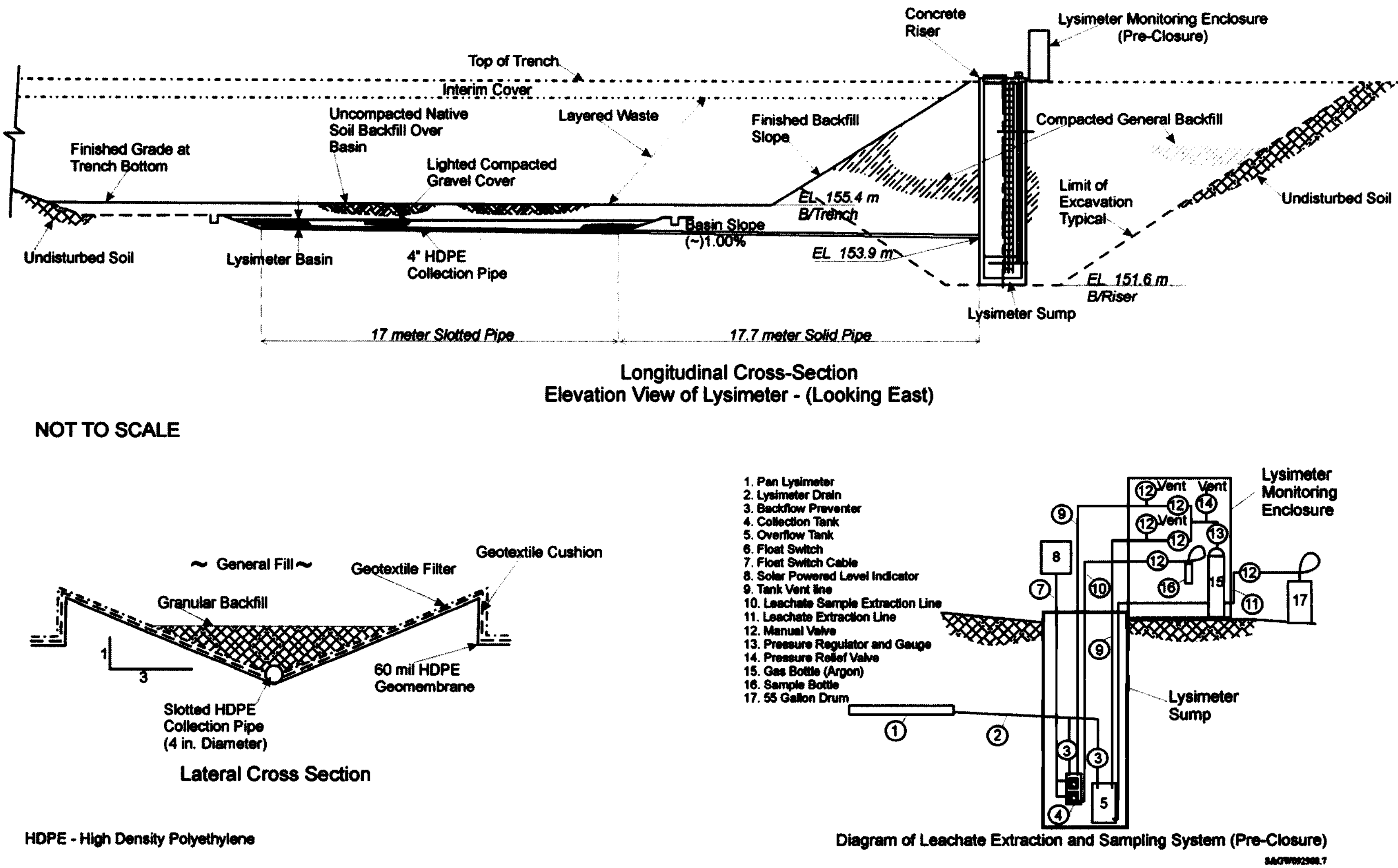


Diagram of Leachate Extraction and Sampling System prepared in consultation with Applied Geotechnical Engineering and Construction, Incorporated, Richland, WA

Figure 3-9. SWL Lysimeter Schematic

Table 3-2. Leachate Monitoring Results

Parameter	Results by Quarter 3rd 2006	4th 2006	1st 2007	2nd 2007	GWQC	MCL
Indicator Parameters						
Specific Conductance (μS/cm)	1,680	1,860	1,920	2,000	N/A	700 μS/cm
Field pH	7.35	6.74	6.89	7.32	6.5-8.5	N/A
Total Organic Carbon (mg/L)	701	100	76.5	275	N/A	N/A
Chloride (mg/L)	210	191	192	199	250	25.0
Ammonia as N (mg/L)	0.330	0.340	0.292	NT	N/A	N/A
Sulfate (mg/L)	5.66	7.67	6.32	7.77	250	25
Dissolved Iron (μg/L)	87.9	9,850	8,870	6,400	300	300
Dissolved Zinc (μg/L)	187	40.5	109	155	5000	5000
Dissolved Manganese (μg/L)	1,580	1,590	1,540	1,295	50	50
Chemical Oxygen Demand (mg/L)	222	220	208	204	N/A	N/A
Site-Specific Parameters						
Arsenic (μ/L)	29.3	NT	NT	20.1	0.05	0.010
Carbon Tetrachloride (μg/L)	<1.0	NT	NT	<1.0	0.3	5
Chloroform (μg/L)	<1.0	NT	NT	<1.0	7.0	N/A
1,4-Dichlorobenzene (μg/L)	6.5	NT	NT	4.15	4	N/A
1,1-Dichloroethane (μg/L)	<1.0	NT	NT	<1.0	1.0	N/A
Methylene Chloride (μg/L)	<1.0	NT	NT	1.25	5	N/A
Tetrachloroethene (μg/L)	<1.0	NT	NT	<1.0	N/A	N/A
Trichloroethene (μg/L)	<1.0	NT	NT	<1.0	N/A	N/A
1,1,1-Trichloroethane (μg/L)	<1.0	NT	NT	<1.0	200	200
1,4-Dioxane (μg/L)	<25.0	NT	NT	<20.0	7	N/A
Total Dissolved Solids (mg/L)	1,460	NT	NT	1,380	500	500
Total Organic Halides (μg/L)	NT	NT	NT	846	N/A	N/A
Barium (μg/L)	519	NT	NT	452	1000	2000
Cadmium (μg/L)	<0.100	NT	NT	<0.100	10	5
Copper (μg/L)	1.60	NT	NT	1.03	1000	N/A
Fluoride (mg/L)	<0.145	<0.0315	<0.321	0.207	4	4
Nickel (μg/L)	110	NT	NT	92.9	N/A	100
Selenium (μg/L)	2.58	NT	NT	2.15	10	50

GWQC = groundwater quality criteria
IDL = instrument detection level
MCL = maximum contaminant levels
MDL = method detection level
N/A = not applicable

3.3.3 Leachate Generation and Drainage Trends

Leachate has been collected from the basin lysimeter since July 1996. Appendix A provides leachate volumes by collection date, cumulative volumes since initial collection, and volumes per day based on elapsed time between collection dates. Figure 3-10 depicts the information provided in Appendix A. As noted in Section 3.3, the average annual precipitation at the Hanford Site is 170 mm (6.8 in.), therefore approximately 27 percent of the precipitation has drained through the existing operational soil cover based on collections since 1996 (Appendix A). The high leachate volume seen from 1997 through 1999 might be a result of the years 1995 and 1996 being the two wettest years recorded at the Hanford Site over a 95 year period. Each of those two years produced almost double the average precipitation (e.g., 313 mm [12.3 in.] and 310 mm [12.2 in.] respectfully) (http://hms.pnl.gov/totprcp.htm). DOE/RL-2008-66 states, "during the July 2003 through June 2004 and July 2004 through June 2005 reporting periods, the generation rates increased significantly to ~19 liters/day. This increase mainly was attributed to above average rainfall recorded at the Hanford Site."

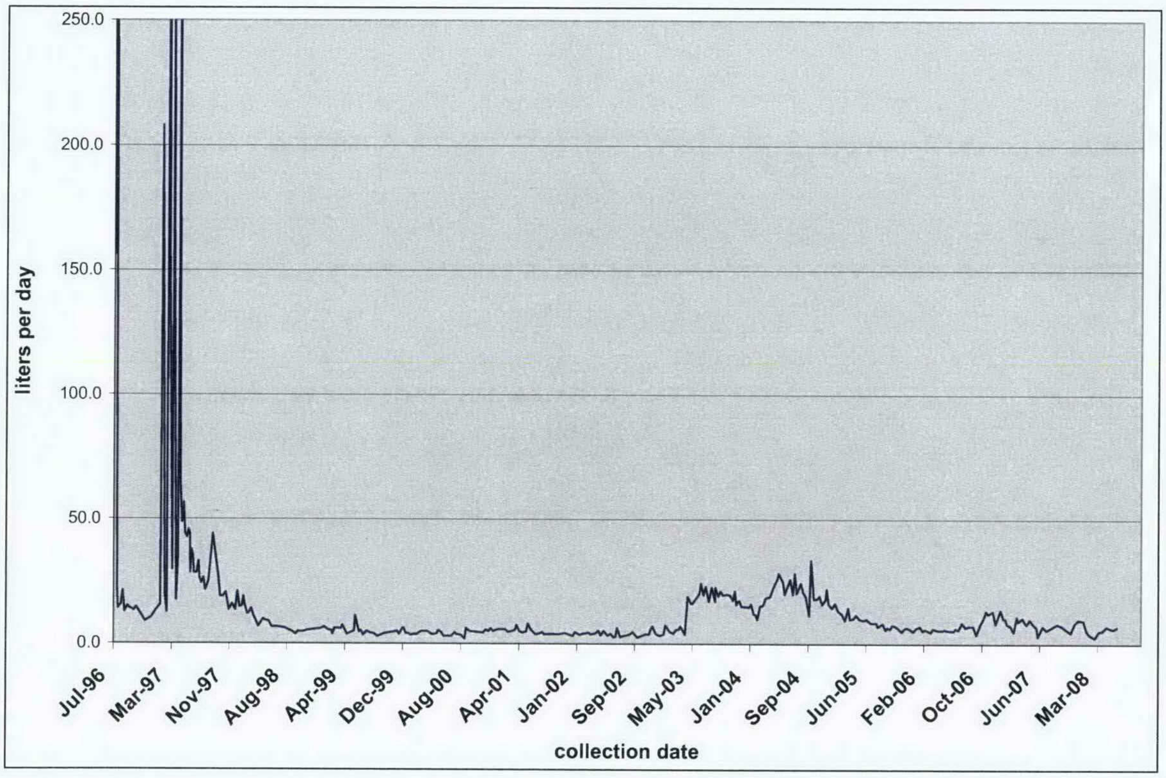


Figure 3-10. Leachate Generation Rates

Leachate generation provides an indication of drainage patterns at the SWL. Drainage can be attributed to a specific combination of soils, vegetation, and climate. Soil type and soil cover thickness affects the soil water holding capacity and subsequent drainage to the subsurface. Coarse soils (e.g., gravelly sands with low water-holding capacities) drain readily leaving little water at the surface to evaporate. Coarse soils can drain up to 50 percent or more of the annual precipitation and up to 70 percent or more of the winter precipitation under the Hanford Site climatic conditions (Gee et al., 1992, "Variations in Recharge at the Hanford Site;" PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment*). The interim cover at the SWL consists of stockpiled soil from SWL excavations; no new material was added to the SWL (BHI-01063). The native soil at the SWL has over 95 percent sand content and is considered a coarse soil.

Leachate collected from the SWL basin lysimeter over the past ten years is typical of drainage expected from a sparsely vegetated area with coarse sand under the Hanford Site climatic conditions. Observed changes in drainage rates are attributed primarily to variations in winter precipitation and vegetative cover. Winter precipitation at the Hanford Site controls the drainage at any given site, because winter rains and snowmelt come when atmospheric conditions (e.g., lower solar radiation and air temperatures, higher humidity) combine to minimize evaporative demand. Late spring and summer rains are readily lost to the atmosphere because of high evaporative demand (high temperatures, high solar radiation, high plant transpiration, and low humidity).

Soil added during 2008 over the asbestos trenches in the southwest corner of the SWL is even coarser and could be classified as gravelly sand to sandy gravel. These type of soils have very limited water storage capacity, which affects the type and amount of vegetation that will grow. The type and amount of vegetative cover also affect drainage rates. Deep-rooted shrubs are more effective in removing stored winter precipitation and reducing drainage than shallow-rooted grasses (Gee et al., 1992). At the SWL, the vegetation is sparse (i.e., less than 10 percent) and dominated by grasses (e.g., Indian ricegrass), particularly in the southern portion of landfill. However, portions of the older sections of the SWL (Phase I) show signs of natural plant succession towards a typical sage/steppe community resulting in much greater soil moisture removal via plant transpiration.

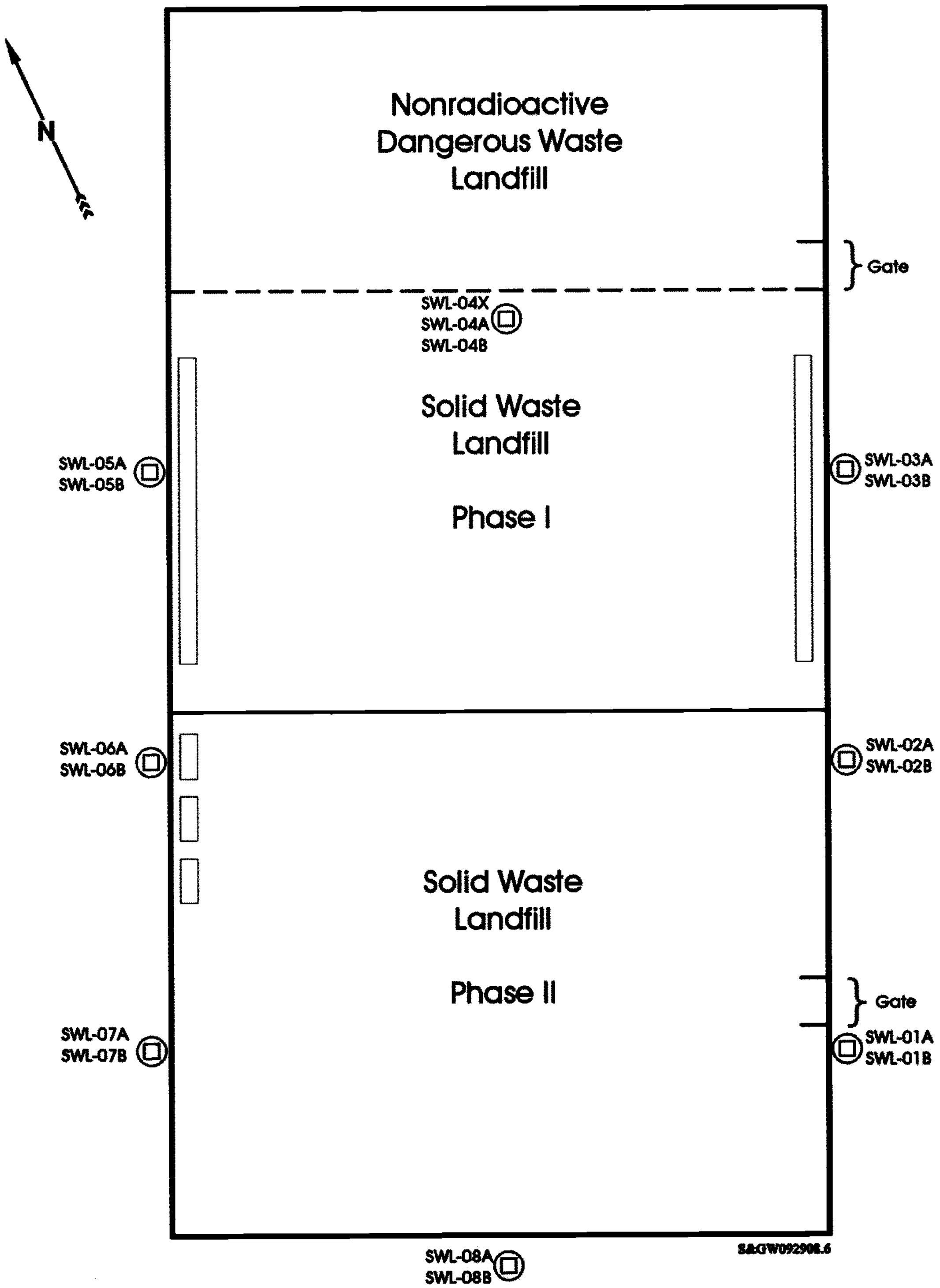
As the vegetative cover increases, it is expected that the amount of precipitation entering the waste disposal areas will decrease with a commensurate decrease in leachate generation. Additional information on leachate generation and testing results is in BHI-01063.

In stark contrast, the surface cover constructed over the 216-B-57 Crib in the 200 East Area as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* treatability study has been in-place since 1994. This surface cover design contains native plants and an extremely high water-holding capacity fine-grained soil layer (commonly referred to as an ET cover). Data collected since 1994 indicate essentially zero drainage as a result of effective control of near-surface water balance because of enhanced evaporation and plant transpiration provided by the revegetated, fine-grained soil layer (PNNL-17176, *200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Years 2005 through 2007*). A similar fine-grained ET cover is proposed for SWL closure.

3.4 Landfill Soil Gas Monitoring

A soil gas sampling/monitoring survey was conducted within the boundaries at the SWL from June 1988 through February 1989. The survey found detectable concentrations of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, 1,1dichloroethane, carbon tetrachloride, carbon dioxide, and methane. Soil gas probes have been located at perimeter locations around the SWL since that time (Figure 3-11). The initial focus of the perimeter probes was on the monitoring of methane (in accordance with WAC 173-304-460(2)(b), "Air Quality and Toxic Air Emissions") and carbon dioxide. Starting in 1996, these probes also were used to monitor for the detected volatile compounds. Results of this monitoring effort indicate that soil gas release from the SWL has stabilized (see the Hanford Site soil gas monitoring reports [e.g., 09-AMCP-0010] and the Hanford Site groundwater monitoring reports [e.g., DOE/RL-2008-66]).

Concentrations of methane and other key VOCs of concern are at or below detection limits and trends have been in the decreasing direction; methane (the primary component of landfill cases) concentrations are well below the lower explosive limit. Consequently, discontinuation of soil gas monitoring is proposed. This also eliminates the need to provide penetrations through the proposed ET cover for existing soil gas monitoring stations that could compromise cover performance if penetrations are not properly sealed and maintained.



Not to scale

Figure 3-11. Location of Soil Gas Monitoring Stations

3.4.1 Initial Soil Gas Survey at Solid Waste Landfill

A soil gas survey was conducted at the SWL from June 1988 through February 1989 to determine the extent of chlorinated hydrocarbons in the soil gas at the SWL (PNL-7147, *Final Report: Soil Gas Survey at the Solid Waste Landfill*). Soil gas samples were collected from 74 locations using probes placed at depths of 1.2 or 1.8 m (3.9 or 5.9 ft) within the southern portion of the SWL. The survey found detectable concentrations of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, 1,1-dichloroethane, carbon tetrachloride, carbon dioxide, and methane. The data are provided in BHI-01063, Appendix B. 1,1,1-Trichloroethane was detected at all sample locations at concentrations ranging from 0.06 to 73.5 µg/L (0.01 to 13.1 ppmv [parts per million by volume]). The highest concentration, 73.5 µg/L (13.1 ppmv), for trichloroethane was found in an unused portion of trench 41, approximately 60 m (200 ft) east of the Liquid Disposal Trench I (Figure 1-2).

In addition, tetrachloroethylene was detected at 62 sample locations at concentrations ranging from 0.01 to 16.5 µg/L (0.001 to 2.4 ppmv). In general, the spatial distribution of tetrachloroethylene was very similar to that observed for trichloroethane. Trichloroethylene was detected at 66 sample locations at concentrations ranging from 0.02 to 12.97 µg/L (0.004 to 2.37 ppmv). 1,1-Dichloroethane was detected at concentrations ranging from 0.5 to 7.4 µg/L (0.12 to 1.80 ppmv) in seven samples with relatively high 1,1,1-trichloroethane concentrations within the boundary of the SWL. 1,1-Dichloroethane may be present as a partial degradation product of 1,1,1-trichloroethane; its distribution may be related to variations in subsurface bacterial processes.

Carbon tetrachloride was found at low levels (0.02 to 0.09 µg/L [0.003 to 0.014 ppmv]) during a preliminary soil gas survey in June 1988 at five locations along the outside of the eastern perimeter fence of the SWL, Phases I and II. Carbon tetrachloride was not detected at any probes during the full-scale soil gas survey (October 1988 to February 1989).

The maximum carbon dioxide level was in excess of 6 volume percent, which is the upper calibration range of the colorimetric indicator tubes. The atmospheric background concentration for carbon dioxide is 0.06 volume percent. Methane levels ranged from nondetect to a maximum of 55.4 µg/L (83 ppmv) in trench 41. The spatial distributions of carbon dioxide and methane are similar to those of 1,1,1-trichloroethane and tetrachloroethylene.

There have been no other soil gas measurements at these probe locations that can be used to establish trends in the VOC concentrations within the boundaries.

3.4.2 Perimeter Soil Gas Monitoring at the Solid Waste Landfill

Quarterly monitoring at eight perimeter soil gas probes has been used to monitor for methane and carbon dioxide since 1993 and, to a limited extent, VOCs (Figure 3-11). Regular quarterly monitoring for the specific VOC noted above was initiated at these perimeter probe locations in 1996.

3.4.2.1 Methane and Carbon Dioxide Soil Gas Results

Under WAC 173–350-400(4)(b)(v), the requirements for conducting soil gas monitoring are to ensure that flammable gases are not generated and collected, and that air quality is not adversely impacted by toxic air emissions. An owner or operator of a landfill is responsible for not allowing flammable gases generated by the facility to exceed 25 percent of the lower explosive limit for the gases in facility structures (excluding gas control or recovery system components). Furthermore, the lower explosive limit for the gases must not be exceeded at the property boundary or beyond. Finally, the volume of hydrocarbons (expressed as methane) must not exceed 100 ppmv in off-site structures.

Carbon dioxide and methane are typically the two primary components of landfill gases that are of interest. Methane is highly flammable and poses an explosion hazard. Carbon dioxide is not flammable. Methane concentrations remain low, or are not detected at the SWL. Carbon dioxide concentrations continue to be consistent with data provided in previous reports. When barometric pressure is rising, the carbon dioxide values are lower. Soil gas monitoring station SWL-04A continues to show high carbon dioxide values. This sample port usually has at least one tube with high carbon dioxide values.

Landfill gas can pose an asphyxiation hazard if it collects in an enclosed space at concentrations high enough to displace existing air and create an oxygen-deficient environment. Carbon dioxide typically comprises 40 to 60 percent of landfill gas. Because it is denser than air, carbon dioxide can collect in confined spaces or low-lying areas creating an oxygen-deficient environment. The existing basin lysimeter manhole is a potential confined space that is equipped with a ventilation system. The existing basin lysimeter will be retained as discussed herein.

3.4.2.2 Volatile Organic Compounds Soil Gas Results

In addition to methane and carbon dioxide, the landfill soil gas monitoring program at the SWL has included routine sampling for VOCs (e.g., 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, 1,1-dichloroethane, carbon tetrachloride, and chloroform) using EPA Method 8260. Over the last several years of quarterly sampling, the VOC concentrations have been below detection limits. Methane is typically not detected. The only analyte noted in the 1996 sampling is 1,1,1-trichloroethane, which quickly decreased from a high of 2.44 μg/L (0.44 ppmv) in November 1996 to nondetectable starting in January 1999. All of the VOCs monitored have been nondetect since 1999.

3.4.2.3 Summary of Soil Gas Monitoring

Existing information indicates that methane production is well below WAC 173-350-400 performance standards. Methane concentrations in soil gas located in the near subsurface within the Phase II area of the landfill are substantially less than the lower explosive limit for methane (5 percent or 50,000 ppm). Soil gas measured outside the landfill boundary contains less than 3 ppm of methane. Carbon dioxide is generally the only detectable constituent.

A summary of the most recent soil gas monitoring results and associated upper/lower flammability limits are provided in Table 3-3. Results are consistent with previous monitoring data. The concentrations for the VOCs were at or below the detection limits and well below the upper/lower flammability limits.

Under WAC 173–350(6)(a), closure/postclosure activities include groundwater monitoring; surface water monitoring; gas monitoring; and maintenance of the facility, facility structures, and monitoring systems for their intended use for a period of 20 years and other activities deemed appropriate by the jurisdictional health department. The closure/postclosure plan must address facility maintenance and monitoring activities for at least a 20-year period or until the site becomes stabilized (i.e., little or no settlement, gas production, or leachate generation), and monitoring of groundwater, surface water, and/or gases can be safely discontinued.

With respect to gas generation, the SWL site appears to have stabilized, based on data initially collected in 1988 and 1989, and collected through the exiting eight station soil gas monitoring network since 1993. Concentrations of methane and key VOCs of concern are at or below detection limits, are declining, and are well below lower flammability limits. Consequently, discontinuation of soil gas monitoring is proposed. This has an added benefit of eliminating the need to provide penetrations through the proposed ET cover for existing soil gas monitoring stations that could compromise cover performance if penetrations are not properly sealed and maintained. Existing provisions for monitoring groundwater contamination, and subsidence will continue until such time as it can be determined that any or all of these activities can be safely discontinued.

Table 3-3. Highest Soil Gas Monitoring Concentrations Reported Compared to Explosive Limits (1996 to 2008)

Year/Limit	Methane (ppm)	Carbon Dioxide (ppm)	Methylene chloride (ppm)	1,1-Dichloro-ethane (ppm)	Chloroform (ppm)	1,1,1-Trichloro-ethane (ppm)	Carbon Tetrachloride (ppm)	Trichloro-ethylene (ppm)	1,1,2-Trichloro-ethane (ppm)	Tetrachloro-ethylene (ppm)
Calendar Year										
1996[a]	<0.10	33,000	---	---	---	4.4	---	---	---	---
1997	1,000	43,000	---	---	---	4.3	---	---	---	---
1998	2,000	35,000	<0.10	<0.10	<0.10	0.21	<0.10	<0.10	<0.10	<0.10
1999	2,000	38,000	<0.10	<0.10	<0.15	<0.15	<0.30	<0.10	<0.10	<0.20
2000	1,000	32,000	<0.10	<0.15	<0.25	<0.15	<0.30	<0.2	<0.1	<0.25
2001	2,000	29,000	<0.10	<0.25	<0.22	<0.1	<0.15	<0.15	<0.1	<0.25
2002	1,000	26,000	<0.10	<0.25	<0.22	<0.2	<0.32	<0.2	<0.1	<0.25
2003	2,000	23,000	<0.10	<0.25	<0.20	<0.15	<0.20	<0.1	<0.1	<0.25
2004	2,000	26,000	3.9[b]	<0.25	<0.25	<0.17	<0.20	<1.2	<0.13	<0.31
2005	0	5,128	<0.44	<0.22	<0.07	<0.15	<0.09	<1.2	<0.07	<0.16
2006	0	11,310	<0.44	<0.22	<0.07	<0.15	<0.09	<1.2	<0.07	<0.16
2007	12.53	13,971	<0.44	<0.22	<0.07	<0.15	<0.09	<1.2	<0.07	<0.16
2008	60	4,696	<0.44	<0.22	<0.07	<0.15	<0.09	<1.2	<0.07	<0.16
Applicable Limits										
LEL	50,000	N/A	130,000	56,000	N/A	75,000	N/A	125,000	N/A	N/A
UEL	150,000	N/A	230,000	114,000	N/A	150,000	N/A	900,000	N/A	N/A
25% of LEL	12,500	N/A	32,500	14,000	N/A	18,750	N/A	31,250	N/A	N/A

a. Data only available for November/December 1996.

b. Value believed to be a false positive caused by high carbon dioxide concentrations.

-- = data not available

N/A = not applicable as material is not flammable

LEL = lower explosive limit

UEL = upper explosive limit

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4 Closure Activities

The SWL will be closed in accordance with WAC 173-350-400(6) and WAC 173-350-400(7). This plan describes the actions necessary for closure and postclosure care and supersedes previous closure documents, as noted in Chapter 1.

As required by WAC 173-350-400(6)(a) the SWL will be closed in a manner that meets the following postclosure requirements:

- "Minimizes the need for further maintenance
- Controls, minimizes, or eliminates threats to human health and the environment from post-closure escape of solid waste constituents, leachate, landfill gases, contaminated runoff or waste decomposition products to the ground, ground water, surface water, and the atmosphere, and
- Prepares the facility for the postclosure period."

Closure activities will focus on final cover installation, including oversight of the unit during cover installation and appropriate certifications. Section 4.5 provides the closure schedule.

Postclosure activities (Chapter 5) will begin after installation of the cover and Ecology acceptance of closure. Postclosure activities will include long-term monitoring activities, periodic inspections, and maintenance activities to ensure the long-term integrity of the closed landfill.

In general, the closures activities include the following:

- Monitoring of groundwater
- Periodic inspections and maintenance of the facility
- Modification of the above grade portions of the lysimeter and associated facilities (as necessary to allow final cover installation and remote control and collection of leachate)
- Installation of the final cover including revegetation
- Certification of closure, as required by WAC 173-350-400(6)(f).

4.1 Monitoring

Groundwater monitoring will continue during the closure period. The lysimeter monitoring station will be relocated so that leachate monitoring can continue. Of specific concern is the volume of leachate generated during postclosure which will be used as one indicator of barrier performance. After initial barrier construction, a slight increase in leachate production may occur as a result of the water applied during barrier construction; however, the leachate should rapidly dissipate to near zero approximately 5 to 10 years after construction. No further soil gas monitoring is planned (Section 3.4).

4.1.1 Groundwater Monitoring

Groundwater monitoring at the SWL will continue into the closure period as described in Section 3.2. Because groundwater monitoring for the SWL is closely associated with the 200-PO-1 Groundwater OU; SWL groundwater monitoring will be coordinated with, and managed under, the 200-PO-1 Groundwater OU. Groundwater monitoring results will be evaluated during the closure period with specific regard to the frequency of sampling and number of analytes. Changes may be recommended based on the results of the evaluations.

If it is necessary to relocate groundwater monitoring wells to accommodate placement of the final cover, new groundwater wells will be installed prior to decommissioning of current wells and installation of the cover. If warranted, preliminary plans are to extend the casing of the monitoring wells above the final barrier surface to avoid decommissioning of any current operation wells and the unnecessary cost of drilling and constructing any new monitoring wells. Groundwater wells will be installed and/or decommissioned according to the requirements of WAC 173-160.

4.1.2 Barrier Performance Monitoring

The lysimeter system will be modified to allow for remote control and collection of leachate from a point removed from the proposed landfill cover. The above grade portions of the lysimeter within the SWL boundary will be relocated in preparation for installation of the final cover. A covered (roofed) corrugated metal caisson or extension will be placed over the lysimeter sump riser to maintain sump ventilation and provide access for maintenance of sump tanks and controls once the final cover is in place. As the lysimeter sump riser is situated beyond the end of the double trench and adjacent to the end of two unused trenches, any additional infiltration caused by preferential flow that might develop along the sump walls because of the sump penetrating through the final cover would have a negligible effect. Piping will be extended under the final cover from the collection sump riser to the monitoring station, which will be relocated just off the side of the landfill. Removal of leachate will be by remote operation to minimize the need for traffic onto the cover. Locating the lysimeter monitoring station on the west side of the SWL, as shown on the sketches provided at the end of Appendix B, would require that a 0.5 km (0.3 mi) gravel road be constructed and maintained for access. A location on the east side of the SWL would eliminate the need for a road, but may require additional features in the system because of the piping run being twice as long and having to cross over a crest.

Though not required by the governing regulations, additional performance monitoring including a meteorological station and various devices to measure soil moisture, might be installed and maintained at the discretion of DOE. A meteoritic weather station would measure precipitation, wind, temperature, humidity, and pressure profiles. Soil moisture devices could include a combination of heat dissipation units, time domain reflectometry, and neutron probe tubes to measure and record the changes in water content at various soil depths.

4.1.3 Soil Gas Monitoring

Soil gas monitoring will not occur during the closure period. The soil gas has been routinely monitored quarterly since 1993. Initially, some volatile organics were being detected at low concentrations (i.e., 1,1,1-trichloroethane), but this has significantly decreased and has not been detected for several years. The methane levels also have been very low. Because no soil gas has been detected in recent years, no additional soil gas monitoring is planned (Section 3.4).

4.1.4 Subsidence, Erosion, and Vegetation

Subsidence will be measured with either some form of geophysics (e.g., time-domain reflectometry cable) or remotely using Light Detection and Ranging. Erosion Vegetation will initially be measured using on-ground surveys, but will eventually be monitored long-term using remote sensing.

4.1.5 Reporting

An annual monitoring report (Section 3.2.6) will be provided to Ecology during the closure period. The report will summarize the results from the groundwater monitoring as described above.

4.2 Inspection and Maintenance

During the closure period, periodic inspections of the SWL will be conducted. Additional inspections may be necessary after a major weather event (wind and/or rain). The purpose of the inspection will be to identify deterioration of the cover (as applicable) to ensure that site access controls are in place, the lysimeter system is functional, and to ensure there are no other problems that should be addressed during final cover installation. Corrective actions will be performed as needed to address problems identified from the inspections.

Vectors typically include rodents, insects and other arthropods, and birds. These animals are attracted to landfills as a source of food and shelter, especially when the waste is not covered. Potential food sources are only a small percentage of the waste in the SWL. Since all trenches are covered under 0.6 to 1.2 m (24 to 48 in.) of soil prior to installation of the final cover, vectors are not a concern and none have been noted in previous inspections.

The soils at the SWL are relatively coarse and dust is not a usual problem, unless high winds develop. Because of the remote location, dust generated from the bare cover would not affect structures or personnel off the SWL site.

4.3 Final Landfill Cover

The final landfill cover will be designed to control, minimize, or eliminate threats to human health and the environment. The final cover will accomplish this by minimizing or eliminating the escape of solid waste constituents and their by-products into the environment through recharge into the groundwater or erosion of the surface cover soil. In addition, a vegetative cover is an integral part of the final cover and should minimize dust generation at the site to the same levels as the surrounding terrain. A full description of the conceptual design for the final cover is presented in Appendix B.

Prior to installation of the cover, the trench boundaries and the location and extent of voids will be assessed using a ground penetrating radar and/or other surface geophysical investigation methods. Ground penetrating radar uses essentially the same principle as ultrasound sensing. Electromagnetic waves are backscattered from objects or interfaces in the ground. Real-time data will be collected in the field so that adjustments can be made to optimize data collection capabilities. Digital data can be processed and interpreted before output as a final product. If any large voids are detected (i.e., detectable by a standard surface geophysical survey method), they will either be filled with grout or consolidated by mechanical means. The action taken will depend on the potential for release of the waste into the air when the void is reduced, the projected extent of future subsidence, and the estimated adverse impacts on the surface barrier.

The final cover will be designed to meet the requirements of WAC 173-350-400(6), These requirements will be met by constructing an ET final cover of approximately 0.75 m (2.5 ft) in thickness over the current interim cover. In some areas of the landfill, the interim cover may require some reshaping and/or placement of additional soil in preparation for the installation of the final cover so that the cover surface will drain to the perimeter of the landfill. The ET final cover will consist of approximately 0.6 m (2 ft) of a fine-grained, low permeability soil and approximately 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion resistant top soil that will sustain native vegetation. The slope of the final cover will be maintained at approximately 2 percent since fine-grained soils (e.g., silt-loam) are more susceptible to erosional forces when the slope is greater than 2 percent (PNL-8478, *Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel*).

ET covers rely on the natural systems of the water-holding or storage capacity of a fine-grained soil, evaporation from the near-surface, and plant transpiration to minimize or eliminate water movement through the cover. Deploying an ET cover in an arid climate, like at the Hanford Site, takes advantage of several natural systems. Specifically, a low annual precipitation of approximately 170 mm/yr (6.8 in./yr) (PNNL-15160), the high water storage capacity of the fine-grained soils associated with the ET cover (e.g., locally available silt and silt-loam soils have a total water storage capacity of up to 30 percent volume/volume [PNNL-14143, *The Hanford Site 1000-Year Cap Design Test*]), the ability of the native, semiarid vegetation to extract water stored within those fine-grained soils, and a potential ET rate of approximately 1,270 mm/yr (50 in./yr) (PNL-6750, *Status of FY 1988 Soil-Water Balance Studies on the Hanford Site*) result in severely limiting water flux through the cover and therefore little or no potential for leachate generation.

The SWL final cover will consist of approximately 0.75 cm (30 in.) of silt-loam; approximately 0.60 m (2 ft.) of silt-loam for the low permeability soil cover plus approximately 15 cm (6 in.) of the same silt-loam modified with 15 percent by weight pea-gravel and vegetated with native grasses, forbs, and shrubs to form an erosion resistant topsoil, which is in accordance with WAC 173-350-400(3)(e)(ii)(A). It is anticipated that the silt-loam will be placed in a single 75 cm lift and a thin layer of pea-gravel spread and tilled into the top 15 cm (6 in.) to create the erosion resistant top-soil and remove any over-compacted areas. The most likely source for the silt-loam soil would be a borrow site in the southeast corner of Area C, which is approximately 9.7 km (6 mi) west-southwest of the Central Landfill. The fine-grained soils available at this borrow site have a mean saturated hydraulic conductivity of 1.5×10^{-5} cm/sec. The permeability of the silt-loam is slightly lower when modified to an admix of 15 percent by weight pea-gravel (PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*).

As the mean annual precipitation at the Hanford Site (17 cm [6.8 in.]) is considerably less than 30 cm (12 in.), the slight variance in saturated hydraulic conductivity above the 1×10^{-5} cm/sec or lower criteria is considered negligible. This rationale is supported by the performance modeling that indicates the long term average water flux through an ET cover constructed with Area C soil will be essentially zero (Appendix B). This also is supported by performance data from the Hanford Prototype Barrier, which was constructed in 1994 as a treatability study over the 216-B-57 Crib in 200 East Area. The upper 2 m (6.6 ft) of the Hanford Prototype Barrier is a silt-loam soil similar to that proposed for the ET cover at the SWL. The year record of near-surface water balance for the Hanford Prototype Barrier shows essentially zero drainage through the silt-loam soil, even though a portion of the cover was irrigated with as much as 3 times the annual precipitation plus a 1,000 year frequency rain storm (PNNL-17176). Incipient moisture is being effectively stored in the silt-loam soil for recycle to the atmosphere by evaporation and plant transpiration. In addition to other data gathered at the Hanford Site, the Lysimeter Test Facility has provided excellent arid zone water balance data.

The surface of the final cover will be graded to a general overall slope of 2 percent, from the crest or high points to the landfill perimeter. Storm-water runoff will be collected at the landfill perimeter and channeled away from the landfill to local depressions capable of holding the anticipated flow from a 24-hour, 25-year frequency storm. To return the land to the appearance and use of surrounding land areas to the best possible degree, in small localized areas the slope may have minor variations from a strictly 2 percent flat plane. This will allow incorporation of some localized hummock and swale features, which are prevalent in the surrounding area. All hollows will be oriented to drain to the perimeter of the landfill during extreme rainfall or snowmelt events. Run-on and runoff damage are expected to be minimal as a result of the combination of porous soils, arid regional climate, high ET rates, localized collection or drainage areas, and minimal local slope in the area. The probability of serious damage to the landfill because of flooding or storm-water runoff/run-on is low. Additional information (e.g., schematics) is provided in Appendix B.

The soil cover will be seeded with an appropriate grass, forb, and shrub mix and stabilized (which could consist of a tackifier and/or straw mulch) to establish a temporary ground cover for protection from erosion. The size of the area and the lack of readily available water preclude post-planting watering. Design specifications will require seeding to occur during a narrow time frame in the fall. This timing will take advantage of fall and winter precipitation to ensure the best success for germination. Should closure occur in the fall or winter, the area will be seeded to initiate growth of a vegetative cover. If closure occurs in the spring or summer, the soil should be stabilized and herbicides applied to prevent undesirable weed growth until seeded in the fall. The selection of the brand or type of soil stabilizer used will require care, as some products inhibit plant growth. Even then, most soil stabilizer applications will require tilling prior to seeding.

4.4 Schedule

Subsurface investigations and a topographical survey accurate to 30 cm (1 ft) contours will precede definitive design efforts and are anticipated to take about 6 months to complete. Definitive design will include performance modeling (computer simulation) to identify the optimum cover profile and the preparation of construction drawings, specifications, construction quality assurance plan, and a final design report. As the final design will require review and approval by the regulating authority (Ecology), it is expected to take 9 months to a year to complete. Integration with the design of the final cover for the NRDWL may require this schedule to be extended up to 6 months because of the more complex regulatory issues. Prior to initiating field activities, it will be necessary to procure the contractor services (e.g., earthwork) for site preparation and cover construction. In addition, it will be necessary for the *National Environmental Policy Act of 1969* for Area C to be completed and the borrow source reclamation plan approved.

Schedule assumes sound work practices, including the avoidance of harsh winter conditions. The silt cannot be placed when the ground is frozen (i.e., during the winter months). Also, during freezing weather, there are no satisfactory means of stabilizing the silt during excavation or after placement in the event of high winds. Initiating placement of the silt during the first week in April would allow the process to be completed by mid- to late September. The blending of the pea-gravel could then be accomplished by mid- to late October, with the surface prepared and ready for planting by November, which is the best time of the year to place native plant seeds. However, to reduce the risk of having to delay construction until after July, efforts should be made in March and April to deter migratory birds from nesting in the construction area.

4.4.1 Scheduled Activities

The closure activities focus on barrier installation. The required activities, durations, and schedule limitations are provided below.

The ET cover will be placed on the SWL in two separate phases (Phase I and Phase II) and the schedule, starting with silt placement, repeated twice over the course of two to three years. (While closure of the SWL and NRDWL are being managed separately, one of these placement phases is expected to be performed in conjunction with construction of a final cover over the NRDWL.) This break in the schedule is required because of the volume of silt required to construct the final cover, approximately 240,000 m^3 (315,000 yds^3) are required to complete both the SWL and NRDWL. Washington State Department of Transportation restrictions for the Beloit Avenue/SR240 intersection, which is the entrance to Area C, will limit the volume of silt that can be moved to approximately 5,300 m^3 (7,000 yd^3) per week. Coupled with the need to avoid placing the silt during the winter months, the construction of the final cover will take approximately 2.5 years.

Phase I will address the northern portion of the SWL and the NRDWL and Phase II the southern portion of the SWL. *Phase II activities are in italics for clarity.* Activities common to both phases are noted as general activities. (The soil gas probes will be pulled just prior to the initiation of grading activities for each phase.)

1) General Mobilization - 4 weeks
   - Water sources (storage tanks), construction trailers, silt borrow source development
   - Provide Ecology with 30 day notification of construction work
2) General Component Preparation - 12 weeks
   - Widening and grading of haul roads [approximately 13 km (8 mi) of road]
   - Preparation of groundwater-monitoring wells
3) Phase I Cover Installation Preparation – 8 to 12 weeks
   - Void fill (grouting/filling/compacting)
   - Subgrade preparation (filling of low areas, re-grading/compacting)
   - Excavation of Runoff Basins
   - Possible Installation of Performance Monitoring instrumentation as appropriate
4) Phase I Silt Placement – 26 weeks
   - Restriction: start placement after April 1st (to avoid freezing weather conditions)
5) *Cover Installation Preparation – Phase II activity (starts concurrent to item 4)*
   - *Relocation of lysimeter monitoring station (building, piping, riser extension, etc), including side road to remote access location*
   - *Void fill (grouting/filling/compacting)*
   - *Subgrade preparation (filling of low areas, re-grading/compacting)*
   - *Finish grading of Runoff Basins*
6) Phase I Side Slope Placement – 6 weeks (occurs during latter part of item 4)
7) Phase I Pea-Gravel Placement – 6 weeks
8) Phase I Seeding/Mulching with Tackifier

--- WINTER ---

9) *Phase II Silt Placement – 26 weeks*
   - *Restriction: start placement after April 1st (to avoid freezing weather conditions)*
10) *Phase II Side Slope Placement – 6 weeks (occurs during last part of item 11)*
11) *Phase II Pea-Gravel Placement – 6 weeks*
12) *Phase II Seeding/Mulching with Tackifier*
13) General Fencing/Signs and Demobilization

4.4.2 Construction Inspection

Inspection by Ecology and other regulators is anticipated during the construction of the closure cover. Inspections are anticipated during the following stages of construction:

- Subgrade preparation and regrading
- Modification of basin lysimeter
- Final cover placement
- Seeding for vegetative cover
- Abandonment/installation of groundwater-monitoring wells.

4.5 Certification of Closure

As required by WAC 173-350-400(6)(f), when closure of the SWL is completed the owner and operator will submit the following:

- Landfill closure plan sheets signed by a professional engineer registered in the state of Washington and modified as necessary to represent as-built changes to final closure construction for the landfill, or a portion thereof, as approved in the closure plan
- Certification by the owner or operator and a professional engineer registered in the state of Washington that the landfill, or a portion thereof, has been closed in accordance with the approved closure plan.

4.6 Notice in Deed

Within three months of closure, RL will submit notice (record maps and a statement of fact) concerning the location of the disposal facility as part of the deed with the county auditor, meeting the requirements of WAC 173-350-400(6)(g). The notice will be sent to the Auditor of Benton County, P.O. Box 470, Prosser, Washington.

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5 Postclosure Activities

Postclosure activities will begin upon acceptance of the closure by Ecology. After receipt of the certification of closure (Section 4.5) and as noted in WAC 173-350-400(h), Ecology will verify the facility has been closed in accordance with the specifications of the approved closure plan at which time the postclosure period shall commence.

In general, the postclosure activities include the following:

- Postclosure groundwater and barrier performance monitoring
- Periodic inspections of the facility
- Maintenance activities to maintain cover and runoff systems
- Stabilization of any dunes that might encroach onto the landfill.

As required by WAC 173-350-400(7)(a), the postclosure activities will continue "a period of twenty years, or as long as necessary for the landfill to stabilize and to protect human health and the environment."

5.1 Postclosure Groundwater and Barrier Performance Monitoring

Groundwater/barrier monitoring and leachate collection will continue during the postclosure period. Groundwater monitoring will be managed through the equally protective groundwater-monitoring program conducted pursuant to 200-PO-1 Groundwater Operable Unit. The information presented in this section summarizes the postclosure monitoring planned for the SWL.

5.1.1 Postclosure Groundwater Monitoring

Groundwater monitoring at the SWL will continue to be monitored throughout the postclosure period or until the site becomes stabilized (i.e., analytes have remained below limits [Table 3.1] for a period of three consecutive years). Because groundwater monitoring for the SWL is closely associated with the 200-PO-1 Groundwater OU, groundwater monitoring will be coordinated with, and managed under, the 200-PO-1 Groundwater OU. Groundwater monitoring results will be evaluated periodically during the postclosure period with specific regard to the frequency of sampling and number of analytes. Individual analytes will be removed from the analysis list if they have remained below limits (Table 3.1) for three consecutive years. Recommendations to change the sampling frequency will be discussed and approved by Ecology.

An annual monitoring report, as described in Section 3.2.6, will be provided to Ecology during the postclosure period. The report will summarize the results from the groundwater monitoring.

5.1.2 Postclosure Barrier Performance Monitoring

The zone directly below the SWL will continue to be monitored during the postclosure period using the lysimeter (Section 3.3) by measuring the volume of leachate collected from the lysimter. It is expected over the course of the first few years after the placement of the final cover that the amount of leachate will decrease dramatically and that no measurable amount of leachate will be collected after approximately 5 to 10 years. As the volume of leachate collected decreases, the schedule for leachate collection may be adjusted to longer time intervals. An initial increase may occur in leachate produced from water used during construction of the barrier. In addition, performance monitoring instrumentation may be installed (at the discretion of the landowner, DOE) that may include time-domain reflectometry for measuring soil moisture, horizontal neutron access tubes (for measuring moisture and observing roots if the tubing is clear), and heat dissipation units for measuring soil matric potential (the primary driving force for moisture movement in the unsaturated zone).

5.2 Postclosure Facility Inspection and Maintenance

Inspections, except for groundwater wells, are scheduled to observe the site and vegetative cover during different seasonal conditions. Groundwater well conditions will be evaluated during sampling events. Extra inspections may be made as needed (e.g., unusual weather occurrences such as heavy thunderstorms, or rapid snowmelt).

Inspections will focus on evaluating:

- Erosion Control
- Cover Integrity, including subsidence
- Vegetative Cover Integrity
- Cover Drainage System Functioning.

As required by WAC 173-350-400(7)(a), this section also provides for maintenance of the closed facility area throughout the postclosure period. Elements of this maintenance plan include repair of erosion damage; correction of subsidence; vegetative cover maintenance; and repair of run-on and runoff control structures. The maintenance plan is based on observations made during inspection and monitoring.

5.2.1 Erosion Control

The overall erosion control for the site will be dictated primarily by the health of the vegetative cover. Erosion damage for areas surrounding the landfill will be addressed in the following three components.

- Precipitation – The Hanford Site climate is mild and dry (arid to semiarid). The Hanford Site typically receives 170 mm (6.8 in.) of annual precipitation. Because of the dry climate, most of the annual precipitation is lost to ET (Section 3.3.3). The landfill area site surface consists of stabilized dune sand. The dune sediments vary from 0.0 to 3.7 m (0.0 to 12 ft) and consist of very fine to medium sand overlying a relatively flat base. The combination of low annual precipitation, high ET rates, relatively flat topography, and a stable vegetative cover reduces the possibility of erosion damage because of precipitation. However, the integrity of the final cover will be inspected periodically to ensure that no appreciable erosion has occurred. Erosion pins will be placed throughout the landfill to assist in monitoring for surface erosion.

- Flood – The flow in the Hanford Reach of the Columbia River is controlled by the Priest Rapids Dam. The present river channel was developed at the end of the last ice age, a time when much higher volumes of water flowed through the river than today. The flood water associated with a regulated (by Priest Rapids Dam) 100-year flood of 12,500 m^3/sec (440,000 ft^3/sec) would not leave the present channel banks (390 ft mean sea level contour), while the 100-year flood waters from the Cold Creek would not approach the site. Therefore, the probability of flood-induced, erosional damage to the final cover is very low.

- Wind – The monthly average wind speeds for the Hanford Site range from about 13.7 km/h (8.5 m/h) in the summer to 10.3 km/h (6.4 m/h) in the winter. The prevailing regional winds are from the northwest. High/intense winds are typically from the southwest. Wind storms do occasionally occur on the Hanford Site and peak gusts can commonly exceed 80 km/h (50 m/h). The highest wind speed recorded at Hanford Meteorological Tower was 120 km/h (80 m/h) at the 50 ft level (January 1972). The average number of days in a year where gusts can exceed 80 km/h is five. In the spring, early summer, and late fall, the local floral community helps control wind erosion. When the floral communities begin to dry out in late summer, the probability of wind erosion remains low because winds usually tend to decrease during this period. One half of the annual precipitation typically falls during the 4 months of late fall and winter, when the lowest average wind speeds occur. This, coupled with a low ET rate, decreases the potential for winter wind erosional damage.

Surface erosion pins will be strategically placed throughout the landfill cover to provide a general indication of surface deflation and/or deposition. If the erosion pins indicate an undue amount of soil movement during the inspections, the affected area will be surveyed using one of several methodologies available to develop a surface contour map with vertical accuracy to 15 cm [6 in.] (e.g., Global Positioning System grid, Light Detection and Ranging, or remote sensing). Appropriate actions will be taken based on the results of the survey. If erosion greater than or equal to 0.3 m (1 ft) in the run-on and run-off control systems areas or that results in the development of gullies in an excess of 0.3 m (1 ft) deep is identified, an evaluation will be performed to determine a corrective action.

Because of the low probability of serious damage caused by wind or storm-water erosion, preventative measures beyond those already described are considered unnecessary. However, any erosion damage will be properly noted and reported to the responsible maintenance organization. Minor damage will be repaired with hand tools. Major erosion damage repairs will be made using grading equipment and fill soils, as appropriate. Repairs will return all site surfaces to pre-damaged conditions.

5.2.2 Cover Integrity

Cover integrity will be assessed by monitoring for differential subsidence (e.g., any surface breach or depressions on the exterior of the final cover). Also, regular cover integrity inspections will look for any major disruption caused by animals burrowing or wallowing on the surface (digging large depressions) that might breach or otherwise impact the performance of the final cover. Significant breaches or depressions will require an evaluation to determine the root cause, evaluate the long-term environmental impacts, and provide a corrective solution, as needed.

The deformation or compression of waste products, fill soils, and voids are the primary cause for subsidence (i.e., settlement and displacement). Because large voids or cavities could exist in the closed landfill, the voids will be located during closure activities using ground penetrating radar. Measures, such as pressure grouting of voids, will be used to mitigate the risk of subsidence from waste deformation. Careful placement and compaction during construction of the cap will greatly reduce the occurrence of post construction subsidence. Even if differential subsidence is not expected, however, a small amount of uniform compression and consolidation will occur with time. Any subsidence effects revealed by inspections will be repaired by backfilling to grade with silt-loam soil and revegetating.

Use of periodic elevation surveys (by conventional survey instruments, Light Detection and Ranging or aerial phototopography/remote sensing) of control points placed throughout the landfill will assess subsidence. Control points (survey markers) will be set around the perimeter and at critical points on the cover. Survey methods may include the direct measurement of control points and local surfaces, as well as the comparison of record topographical maps with updated maps generated through periodic topographical surveys using aerial photography or more modern technology such as Light Detection and Ranging.

The proposed maintenance action will be to fill in the depression with silt/silt-loam soil and reestablishing the vegetative cover, as needed. The ET Barriers generally are self-healing (i.e., there are no critical engineered interfaces between multiple soil layers that, if disrupted, could compromise the functionality of the cover). Filling in any depression that may develop allows the surface to continue to drain to the landfill perimeter.

5.2.3 Vegetative Cover Integrity

The vegetative cover is a very important factor for the long-term stability of the site and performance of the ET cover. After evaluation, maintenance action might include replacement of the fine soil top layer at the affected area, reseeding, and other tasks performed during closure (such as the application of a pea-gravel admix) to ensure an erosion resistant surface. No cover damage is expected from inspectors walking over the site during the inspections. Maintenance actions might be required if the vegetation on the final cover fails to progress towards a plant density similar to that of the surrounding undisturbed native vegetation. Those actions might include reseeding and the possible application of soil amendments. The vegetative cover will be inspected periodically and follow the same procedures as outlined for erosion damage.

5.2.4 Cover Drainage System Functioning

The integrity of the runoff precipitation control systems and the gravel stabilized perimeter of the final cover will be evaluated periodically. The probability of serious damage to the landfill because of flooding or storm-water run-on/runoff is low. Run-on/runoff damage are expected to be minimal as a result of the combination of porous soils, arid regional climate, high ET rates, localized collection or drainage areas, and minimal local slope in the surrounding area. Specific run-on prevention structures are not necessary in the final cover design because of the elevated profile.

If erosion greater than or equal to 0.3 m (1 ft) in the run-off control systems areas or that results in the development of gullies in an excess of 0.3 m (1 ft) deep is identified, an evaluation will be performed to determine a corrective action. Proposed maintenance action will be to fill and armor the eroded area with 10 cm (4 in.) minus gravel or rip-rap. Damage to runoff control structures (ditches surrounding the cover) noted during inspections will be reported to the responsible maintenance organization for action. All suspected blockages will be eliminated. Minor damage to ditches will be repaired with shovels and other hand tools and/or other appropriate equipment, while minimizing disturbance of the landfill cover.

5.2.5 Well Condition Inspection

Postclosure inspection of groundwater-monitoring wells will include a surface inspection of a well every time the well is sampled. Well inspection activities may include, but not be limited to, the condition of casings, surface seals, protective posts, security devices (i.e., hasps, caps, and locks), identification markings, access roadways, and screens.

5.3 Certification and Completion of Postclosure

As required by WAC 173-350-400(7)(e), when postclosure of the SWL is completed the owner and operator will submit a certification signed by the owner or operator, and a professional engineer registered in the state of Washington stating why postclosure activities are no longer necessary.

Postclosure will be considered complete upon Ecology acceptance that postclosure monitoring has established that the facility is stabilized. Postclosure maintenance and monitoring activities will be discontinued when authorized by Ecology.

6 Plan Amendments

If an amendment to the substantive portions of this closure plan is needed, a plan revision will be prepared by the Department of Energy, Richland Operations Office and submitted to Ecology for approval. Updates to the Appendices, editorial corrections, and similar changes will be submitted to Ecology for information. The Hanford Site groundwater monitoring reports provide annual results and interpretations (e.g., DOE/RL-2008-66). Data are placed in the Hanford Environmental Information System database. (Updates to the monitoring data will be provided annually.)

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Appendix A

Leachate Generation Volumes

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A1 Introduction

For the lysimeter at the Solid Waste Landfill, the following table provides leachate volumes by date of collection, cumulative volumes since initial collection, and volumes per day based on elapsed time between collection dates. The lysimeter is positioned beneath the double trench 41 and 42 and has a collection surface of 88 m^2 (950 ft^2).

Based on the leachate volumes collected as noted in this table, (48,834 L collected over 4,324 days) the average calculated drainage for the entire collection period noted is 47 mm/yr. This value correlates well with an average drainage of 51 mm/yr at the Solid Waste Landfill presented by Gee et al, 2005a, "Measurement and Prediction of Deep Drainage from Bare Sediments at a Semiarid Site," This value is also comparable in magnitude with the recharge rate of 44 mm/yr identified as the best estimate value for bare unvegetated soil (PNNL-14725, *Geographic and Operational Site Parameters List (GOSPL) for Hanford Assessments*;" DOE/RL-2007-35, *Hanford Facility Dangerous Waste Permit Application: Encapsulation and Storage Facility*, Appendix A), and is about 25 percent lower than the average recharge rate of 63 mm/yr determined from lysimeter data representing infiltrations for medium-grained sand kept free of vegetation for a period of over 20 years (DOE/RL-2007-35; Gee et al, 2005a; Gee et al., 2005b "Chloride Mass Balance: Cautions in Predicting Increased Recharge Rates,")

Hanford Site meteorological data (http://hms.pnl.gov/totprcp.htm) states that the average annual precipitation is 170 mm/yr. Therefore, the calculated infiltration rate of 47 mm/yr indicates approximately 27 percent of the precipitation has reached the lysimeter since collection started in 1996. This magnitude of value is also consistent with "default annual infiltration" value of 25 percent specified in WAC 173-340-747(5)(f)(ii)(A), "Deriving Soil Concentrations for Ground Water Protection," for sites east of the Cascade Mountains.

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Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
7/15/1996	0	0	79	79	–
7/18/1996	3	3	469	549	156
7/19/1996	1	4	360	908	360
7/29/1996	10	14	227	1136	22.7
8/2/1996	4	18	57	1192	14.2
8/14/1996	12	30	189	1382	15.8
8/22/1996	8	38	170	1552	21.3
8/30/1996	8	46	102	1654	12.8
9/12/1996	13	59	197	1851	15.2
9/20/1996	8	67	114	1965	14.3
10/10/1996	20	87	265	2230	13.3
10/19/1996	9	96	132	2362	14.7
11/7/1996	19	115	227	2589	11.9
11/26/1996	19	134	170	2759	8.9
12/23/1996	27	161	284	3043	10.5
1/13/1997	21	182	284	3327	13.5
1/30/1997	17	199	265	3592	15.6
2/3/1997	4	203	511	4103	128
2/5/1997	2	205	416	4519	208
2/19/1997	14	219	284	4803	20.3
2/28/1997	9	228	114	4917	12.7
3/3/1997	3	231	795	5712	265
3/5/1997	2	233	757	6469	379
3/7/1997	2	235	454	6923	227
3/10/1997	3	238	454	7377	151
3/24/1997	14	252	416	7793	29.7
3/26/1997	2	254	568	8361	284
3/28/1997	2	256	322	8683	161
4/10/1997	13	269	227	8910	17.5
4/18/1997	8	277	284	9194	35.5
4/21/1997	3	280	530	9724	177
4/22/1997	1	281	473	10197	473
4/23/1997	1	282	189	10386	189
4/28/1997	5	287	322	10708	64.4
5/5/1997	7	294	341	11049	48.7
5/10/1997	5	299	246	11295	49.2
5/13/1997	3	302	170	11465	56.7
5/19/1997	6	308	265	11730	44.2
5/27/1997	8	316	341	12071	42.6

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
6/3/1997	7	323	322	12393	46.0
6/9/1997	6	329	265	12658	44.2
6/11/1997	2	331	57	12715	28.5
6/16/1997	5	336	189	12904	37.8
6/23/1997	7	343	246	13150	35.1
6/27/1997	4	347	114	13264	28.5
7/9/1997	12	359	341	13605	28.4
7/17/1997	8	367	265	13870	33.1
7/22/1997	5	372	132	14002	26.4
7/29/1997	7	379	170	14172	24.3
8/8/1997	10	389	265	14437	26.5
8/15/1997	7	396	151	14588	21.6
8/20/1997	5	401	114	14702	22.8
8/29/1997	9	410	227	14929	25.2
9/17/1997	19	419	397	15326	44.2
10/3/1997[b]	16	435	264	15591	16.5
10/10/1997	7	442	189	15781	27.0
10/19/1997	9	451	170	15951	18.9
10/31/1997	12	463	227	16178	18.9
11/11/1997	11	474	227	16405	20.6
11/25/1997	14	488	189	16594	13.5
12/8/1997	13	501	208	16803	16.0
12/22/1997	14	515	189	16992	13.5
12/31/1997	9	524	189	17181	21.0
1/9/1998	9	533	132	17314	14.7
1/19/1998	10	543	151	17465	15.1
1/25/1998	6	549	114	17579	18.9
1/31/1998	6	555	95	17673	15.8
2/11/1998	11	566	132	17806	12.0
2/20/1998	9	575	114	17919	12.6
2/28/1998	8	583	114	18033	14.2
3/12/1998	12	595	132	18165	11.0
3/20/1998	8	603	76	18241	9.5
3/31/1998	11	614	76	18317	6.9
4/21/1998	21	635	208	18525	9.9
4/29/1998	8	643	76	18600	9.5
5/16/1998	17	660	151	18752	8.9
5/30/1998	14	674	95	18847	6.8
6/24/1998	25	699	170	19017	6.8

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
7/27/1998	33	732	208	19225	6.3
8/6/1998	10	742	57	19282	5.7
8/27/1998	21	763	102	19384	4.9
9/10/1998	14	777	53	19437	3.8
9/23/1998	13	790	64	19501	4.9
10/8/1998	15	805	72	19573	4.8
10/23/1998	15	820	76	19649	5.0
10/30/1998	7	827	38	19687	5.4
12/30/1998	61	888	371	20058	6.1
1/13/1999	14	902	95	20152	6.8
1/28/1999	15	917	83	20236	5.6
2/11/1999	14	931	76	20311	5.4
2/16/1999	5	936	19	20330	3.8
2/25/1999	9	945	57	20387	6.3
3/25/1999	28	973	170	20557	6.1
3/30/1999	5	978	38	20595	7.6
4/19/1999	20	998	76	20671	3.8
4/28/1999	9	1007	38	20709	4.2
5/20/1999	22	1029	114	20822	5.2
5/25/1999	5	1034	57	20879	11.4
6/10/1999	16	1050	76	20955	4.7
6/17/1999	7	1057	38	20993	5.4
6/28/1999	11	1068	38	21030	3.4
7/13/1999	15	1083	76	21106	5.0
7/26/1999	13	1096	57	21163	4.4
8/14/1999	19	1115	76	21239	4.0
8/27/1999	13	1128	38	21276	2.9
9/17/1999	21	1149	76	21352	3.6
9/28/1999	11	1160	45	21398	4.1
11/23/1999	56	1216	284	21681	5.1
11/30/1999	7	1223	26	21708	3.8
12/15/1999	15	1238	95	21803	6.3
12/21/1999	6	1244	38	21840	6.3
12/30/1999	9	1253	38	21878	4.2
1/10/2000	11	1264	45	21924	4.1
1/21/2000	11	1275	38	21962	3.4
1/31/2000	10	1285	38	21999	3.8
2/8/2000	8	1293	30	22030	3.8
2/16/2000	8	1301	30	22060	3.8

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
3/6/2000	19	1320	95	22155	5
3/15/2000	9	1329	45	22200	5
3/30/2000	15	1344	76	22276	5
4/19/2000	20	1364	76	22351	3.8
4/27/2000	8	1372	30	22382	3.8
5/11/2000	14	1386	57	22438	4.1
5/18/2000	7	1393	38	22476	5.4
5/30/2000	12	1405	57	22533	4.7
6/9/2000	10	1415	30	22563	3
6/27/2000	18	1433	57	22620	3.2
7/12/2000	15	1448	45	22666	3
7/27/2000	15	1463	68	22734	4.5
8/4/2000	8	1471	30	22764	3.8
8/22/2000	18	1489	64	22828	3.6
9/8/2000	17	1506	34	22862	2
9/14/2000	6	1512	38	22900	6.3
9/29/2000	15	1527	76	22976	5
11/27/2000	59	1586	265	23241	4.5
12/7/2000	10	1596	57	23298	5.7
12/19/2000	12	1608	61	23358	5
12/28/2000	9	1617	57	23415	6.3
1/8/2001	11	1628	57	23472	5.2
1/15/2001	7	1635	38	23510	5.4
1/31/2001	16	1651	95	23604	5.9
2/13/2001	13	1664	76	23680	5.8
3/1/2001	16	1680	95	23775	5.9
3/12/2001	11	1691	53	23828	4.8
3/27/2001	15	1706	76	23903	5
4/13/2001	17	1723	95	23998	5.6
4/19/2001	6	1729	45	24043	7.6
4/30/2001	11	1740	57	24100	5.2
5/15/2001	15	1755	68	24168	4.5
5/31/2001	16	1771	79	24248	5
6/7/2001	7	1778	57	24304	8.1
6/20/2001	13	1791	76	24380	5.8
7/10/2001	20	1811	76	24456	3.8
7/28/2001	18	1829	76	24532	4.2
8/9/2001	12	1841	57	24588	4.7
8/17/2001	8	1849	30	24619	3.8

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
9/5/2001	19	1868	76	24694	4
9/24/2001	19	1887	76	24770	4
10/23/2001	29	1916	114	24884	3.9
11/14/2001	22	1938	95	24978	4.3
12/5/2001	21	1959	76	25054	3.6
12/19/2001	14	1973	45	25099	3.2
12/27/2001	8	1981	38	25137	4.7
1/17/2002	21	2002	76	25213	3.6
1/31/2002	14	2016	57	25270	4.1
2/25/2002	25	2041	114	25383	4.5
3/5/2002	8	2049	30	25413	3.8
3/25/2002	20	2069	83	25497	4.2
4/8/2002	14	2083	76	25572	5.4
4/17/2002	9	2092	30	25603	3.4
4/30/2002	13	2105	68	25671	5.2
5/17/2002	17	2122	57	25728	3.3
5/31/2002	14	2136	57	25784	4.1
6/11/2002	11	2147	30	25815	2.8
6/21/2002	10	2157	30	25845	3
6/28/2002	7	2164	45	25890	6.5
7/12/2002	14	2178	38	25928	2.7
7/25/2002	13	2191	42	25970	3.2
8/12/2002	18	2209	64	26034	3.6
8/22/2002	10	2219	38	26072	3.8
9/3/2002	12	2231	57	26129	4.7
9/25/2002	22	2253	57	26186	2.6
10/14/2002	19	2272	64	26250	3.4
10/31/2002	17	2289	68	26318	4
11/14/2002	14	2303	53	26371	3.8
11/20/2002	6	2309	34	26405	5.7
11/29/2002	9	2318	64	26470	7.1
12/13/2002	14	2332	57	26526	4.1
12/30/2002	17	2349	57	26583	3.3
1/16/2003	17	2366	64	26647	3.8
1/24/2003	8	2374	61	26708	7.6
2/12/2003	19	2393	95	26803	5
2/28/2003	16	2409	68	26871	4.3
3/12/2003	12	2421	68	26939	5.7
3/23/2003	11	2432	64	27003	5.8

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
3/31/2003	8	2440	57	27060	7.1
4/18/2003	18	2458	68	27128	3.8
4/30/2003	12	2470	227	27355	18.9
5/14/2003	14	2484	227	27582	16.2
5/21/2003	7	2491	114	27696	16.2
6/3/2003	13	2504	235	27931	18.1
6/19/2003	16	2520	322	28252	20.1
6/26/2003	7	2527	170	28423	24.3
7/7/2003	11	2538	216	28638	19.6
7/16/2003	9	2547	208	28846	23.1
7/30/2003	14	2561	238	29085	17
8/11/2003	12	2573	273	29357	22.7
8/26/2003	15	2588	257	29615	17.2
8/27/2003	1	2589	23	29638	22.7
9/8/2003	12	2601	231	29868	19.2
9/18/2003	10	2611	212	30080	21.2
9/29/2003	11	2622	216	30296	19.6
10/17/2003	18	2640	360	30656	20
10/30/2003	13	2653	254	30909	19.5
11/12/2003	13	2666	227	31136	17.5
11/20/2003	8	2674	170	31307	21.3
11/26/2003	6	2680	95	31401	15.8
12/2/2003	6	2686	102	31504	17
12/9/2003	7	2693	121	31625	17.3
12/18/2003	9	2702	136	31761	15.1
1/20/2004[c]	33	2735	428	32189	13
1/21/2004[c]	1	2736	76	32264	75.7
1/29/2004	8	2744	129	32393	16.1
2/10/2004	12	2756	144	32537	12
2/18/2004	8	2764	95	32631	11.8
2/25/2004	7	2771	68	32700	9.7
3/8/2004	12	2783	182	32881	15.1
3/22/2004	14	2797	220	33101	15.7
4/2/2004	11	2808	204	33305	18.6
4/20/2004	18	2826	341	33646	18.9
5/5/2004	15	2841	344	33990	23
5/21/2004	16	2857	416	34407	26
5/27/2004	6	2863	170	34577	28.4
6/15/2004	19	2882	473	35050	24.9

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
6/22/2004	7	2889	140	35190	20
7/7/2004	15	2904	360	35550	24
7/15/2004	8	2912	208	35758	26
7/27/2004	12	2924	238	35996	19.9
8/4/2004	8	2932	227	36223	28.4
8/12/2004	8	2940	163	36386	20.3
8/30/2004	18	2958	439	36825	24.4
9/9/2004	10	2968	208	37033	20.8
9/20/2004	11	2979	208	37242	18.9
10/5/2004	15	2994	170	37412	11.4
10/13/2004	8	3002	269	37681	33.6
10/25/2004	12	3014	216	37896	18
11/8/2004	14	3028	254	38150	18.1
11/18/2004	10	3038	193	38343	19.3
11/29/2004	11	3049	174	38517	15.8
12/14/2004	15	3064	269	38786	17.9
12/20/2004	6	3070	132	38918	22.1
12/28/2004	8	3078	129	39047	16.1
1/12/2005	15	3093	216	39263	14.4
1/24/2005	12	3105	197	39460	16.4
2/7/2005	14	3119	185	39645	13.2
2/23/2005	16	3135	193	39838	12.1
3/9/2005	14	3149	132	39971	9.5
3/23/2005	14	3163	204	40175	14.6
3/31/2005	8	3171	79	40254	9.9
4/14/2005	14	3185	144	40398	10.3
4/26/2005	12	3197	140	40538	11.7
5/12/2005	16	3213	159	40697	9.9
5/27/2005	15	3228	144	40841	9.6
6/10/2005	14	3242	140	40981	10
6/16/2005	6	3248	57	41038	9.5
6/28/2005	12	3260	102	41140	8.5
7/22/2005	24	3284	204	41345	8.5
7/28/2005	6	3290	42	41386	6.9
8/19/2005	22	3312	182	41568	8.3
8/31/2005	12	3324	68	41636	5.7
9/8/2005	8	3332	53	41689	6.6
9/21/2005	13	3345	79	41768	6.1
9/30/2005	9	3354	68	41837	7.6

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
10/12/2005	12	3366	87	41924	7.3
10/21/2005	9	3375	61	41984	6.7
11/9/2005	19	3394	95	42079	5
11/21/2005	12	3406	76	42155	6.3
11/29/2005	8	3414	53	42208	6.6
12/14/2005	15	3429	91	42298	6.1
12/28/2005	14	3443	72	42370	5.1
1/10/2006	13	3456	83	42454	6.4
1/26/2006	16	3472	114	42567	7.1
2/7/2006	12	3484	64	42631	5.4
2/16/2006	9	3493	53	42684	5.9
2/27/2006	11	3504	61	42745	5.5
3/14/2006	15	3519	72	42817	4.8
3/23/2006	9	3528	57	42874	6.3
4/5/2006	13	3541	76	42949	5.8
4/18/2006	13	3554	72	43021	5.5
5/1/2006	13	3567	72	43093	5.5
5/12/2006	11	3578	64	43158	5.8
5/25/2006	13	3591	72	43229	5.5
6/19/2006	25	3616	132	43362	5.3
6/28/2006	9	3625	57	43419	6.3
7/11/2006	13	3638	76	43494	5.8
7/25/2006	14	3652	121	43616	8.7
8/9/2006	15	3667	102	43718	6.8
8/21/2006	11	3678	79	43797	7.2
9/12/2006	22	3700	159	43956	7.2
9/26/2006	14	3714	53	44009	3.8
10/13/2006	17	3731	136	44145	8
10/26/2006	13	3744	132	44278	10.2
11/7/2006	12	3756	159	44437	13.2
11/17/2006	10	3766	121	44558	12.1
12/7/2006	20	3786	265	44823	13.2
12/19/2006	12	3798	98	44921	8.2
1/9/2007	21	3819	288	45209	13.7
1/23/2007	14	3833	144	45353	10.3
1/30/2007	7	3840	72	45425	10.3
2/6/2007	7	3847	57	45482	8.1
2/22/2007	16	3863	117	45599	7.3
3/8/2007	14	3877	68	45667	4.9

Table. Leachate Volumes

Collection Date	Elapsed Time (days)	Total time (days)	Liters[a]	Cumulative Liters[a]	Liters Per Day
3/22/2007	14	3891	155	45822	11.1
3/27/2007	5	3896	45	45868	9.1
4/16/2007	20	3916	212	46080	10.6
4/24/2007	8	3924	72	46152	9
5/3/2007	9	3933	72	46223	8
5/16/2007	13	3946	129	46352	9.9
5/31/2007	15	3961	121	46473	8.1
6/14/2007	14	3975	95	46568	6.8
6/19/2007	5	3980	15	46583	3
7/11/2007	22	4002	159	46742	7.2
7/27/2007	16	4018	91	46833	5.7
9/13/2007	48	4066	390	47223	8.1
10/3/2007	20	4086	144	47366	7.2
11/9/2000	37	4123	170	47537	4.6
11/26/2007	17	4140	142	47679	8.3
12/12/2007	16	4156	156	47835	9.7
1/4/2008	23	4179	218	48052	9.5
1/17/2008	13	4192	68	48120	5.2
1/30/2008	13	4205	49	48170	3.8
2/21/2008	22	4227	59	48228	2.7
3/12/2008	19	4246	100	48329	5.3
3/24/2008	13	4259	70	48399	5.4
4/14/2008	21	4280	150	48548	7.1
4/28/2008	14	4294	91	48639	6.5
5/12/2008	14	4308	85	48724	6.1
5/28/2008	16	4324	110	48834	6.9

a. Numbers rounded to nearest whole number.

b. Volume includes 132 L collected prior to this date not accounted for elsewhere.

c. A single sampling event occurring over two days, treated as a single collection of 504 L.

Appendix B

Conceptual Design of the Evapotranspiration Final Cover for the Solid Waste Landfill

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Contents

Figures

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B1 Introduction

The conceptual design of the final cover for the Solid Waste Landfill (SWL) is based on conformance to WAC 173-350-400, "Limited Purpose Landfills." These requirements will be met by specifying an evapotranspiration (ET) final cover of approximately 75 cm (30 in.) with a general slope of approximately 2 percent. An interim soil cover is already in place, but in some areas of the landfill it may require some reshaping and/or placement of additional soil fill in preparation for the installation of the ET final cover. These preparations should achieve a general 2 percent slope so that the cover surface drains to the perimeter of the landfill. The ET final cover will consist of 60 cm (24 in.) of a fine-grained, low permeability soil and 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion-resistant top soil (Figure B-1). The slope of the final cover will be maintained at approximately 2 percent as fine-grained soils (e.g., silt-loam) are more susceptible to erosional forces when the slope is greater than 2 percent (PNL-8478, *Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel*).

A single soil cover design was developed for the entire area containing asbestos and solid waste trenches. Because of the close proximity to the Nonradioactive Dangerous Waste Landfill (NRDWL), the cover designs for the SWL and NRDWL will be fully coordinated and/or integrated. This will eliminate the potential for one design to impact the design and construction costs for the placement of a cover over the other. The need for coordination is evident when noting that the SWL and NRDWL share a common boundary, with less than 8 m (25 ft) separating trenches within the two landfills. In examining the topography, the existing grade will require some rework to minimize the amount of fill required to create a general 2 percent slope for both covers, while at the same time assuring the final covers will drain to runoff/run-on control ditches and basins at the outer perimeter of the landfill. Preliminary modeling indicates that up to six percent of annual precipitation will be removed as runoff. With the evidence provided at the Hanford Prototype Barrier and other study sites, actual runoff is expected to be much less. However, the inclusion of perimeter channels or ditches and low area collection basins is advisable because of the large surface area of the landfill. Some native material will be required to form the general shape/slope of the cover. By selectively siting local borrow areas, a sufficient runoff/run-on control system could be formed. Siting of borrow areas should also consider the potential for lateral subsurface flow of any percolating runoff water back into waste trenches from contrasting soil textural boundaries within the underlying soils.

As the interim cover of the SWL is documented to be 0.6 to 1.2 m (2 to 4 ft) thick, and the interim cover for the NRDWL is documented to be 1.2 to 3 m (4 to 10 ft) thick, an assumption was made that with the expected gradual consolidation of the waste in the trenches the maximum amount of cover that could be safely removed from any particular location during regrading activities, while retaining a minimum thickness interim cover, would be approximately 5 cm (19 in.). Using these concepts, a set of conceptual integrated final cover design grading plans were generated (Figure B-2 and B-3). The amount of soil removal that could be safely allowed during any regrading activity will be established during definitive design using topographical maps (historical and current), geophysical survey, and/or probes or potholes.

The design of the cover for the SWL will conform to WAC 173-350-400(3) even though a few of the trenches within the area received waste of a type not specifically regulated under this statute. According to 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," final closure of the asbestos trenches could have been achieved simply by covering with a sufficient thickness of soil and rock to provide a simple physical barrier. However, because of the commingling of the trenches that received asbestos waste with the trenches that received solid waste, the entire landfill will be covered with the same cover. Suitable soil material having adequate water storage capacity and rooting thickness must be placed over the asbestos trenches to develop and retain vigorous native perennial cover vegetation at the site so that the SWL would blend in with the surrounding landscape.

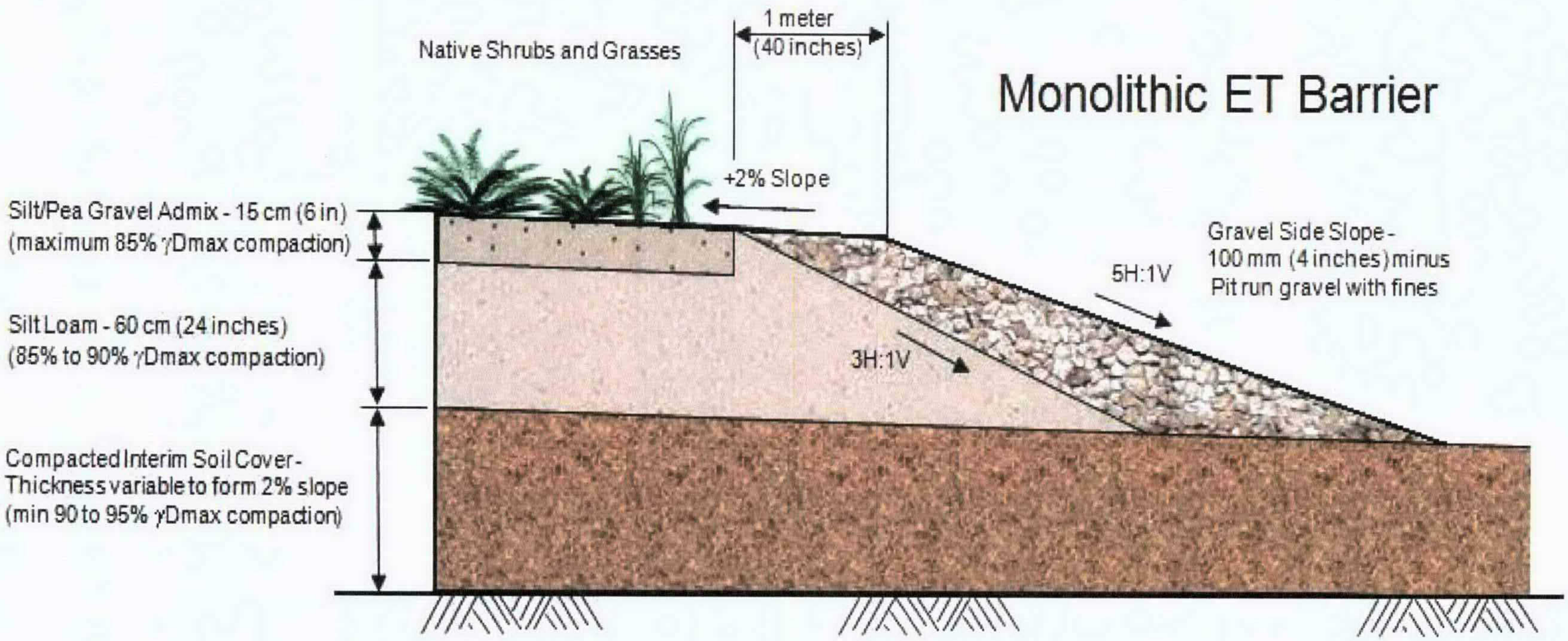

Figure B-1. Proposed Final Cover Design for the SWL

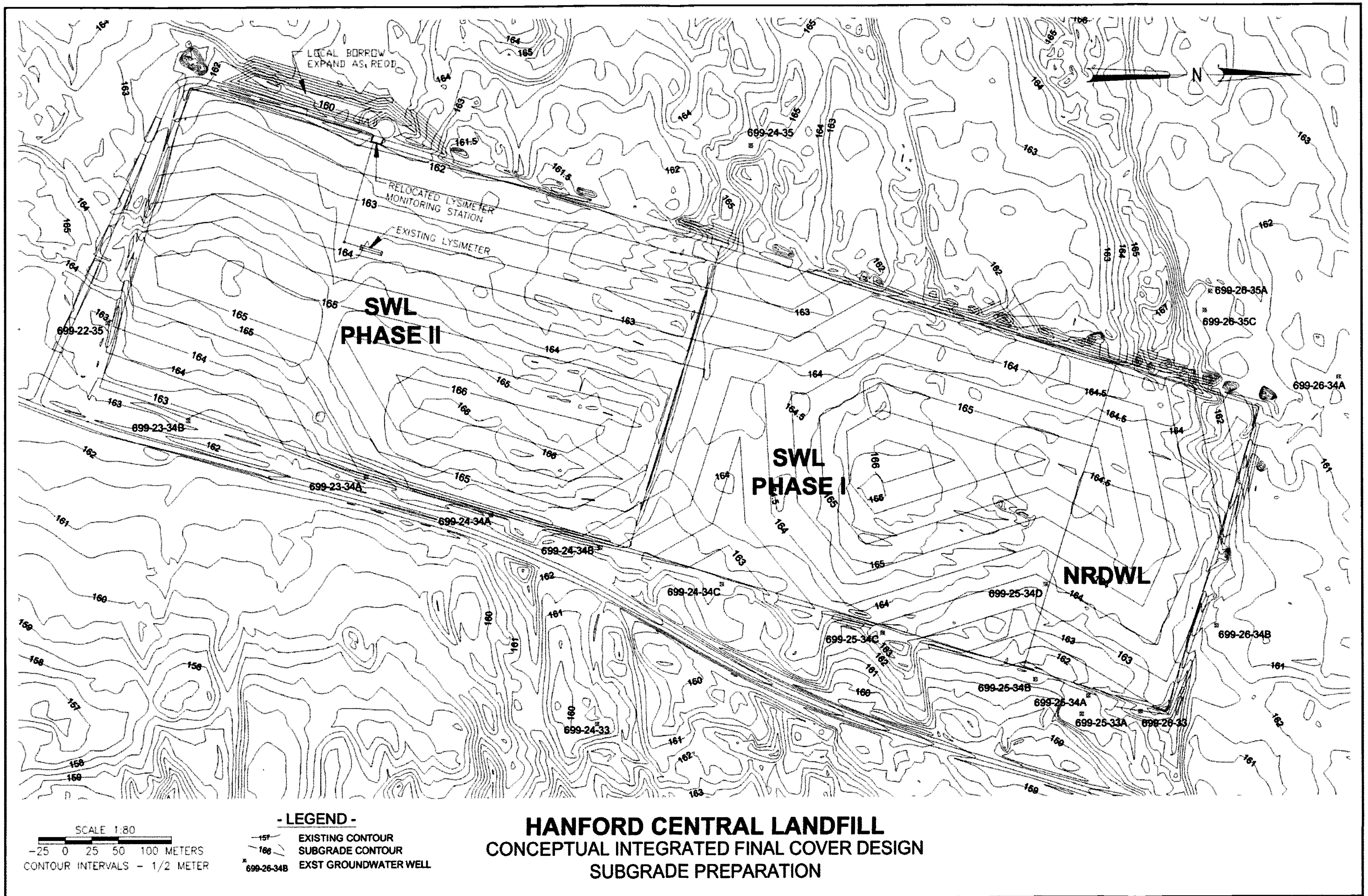

Figure B-2. Conceptual Integrated Final Cover Design Subgrade Preparation

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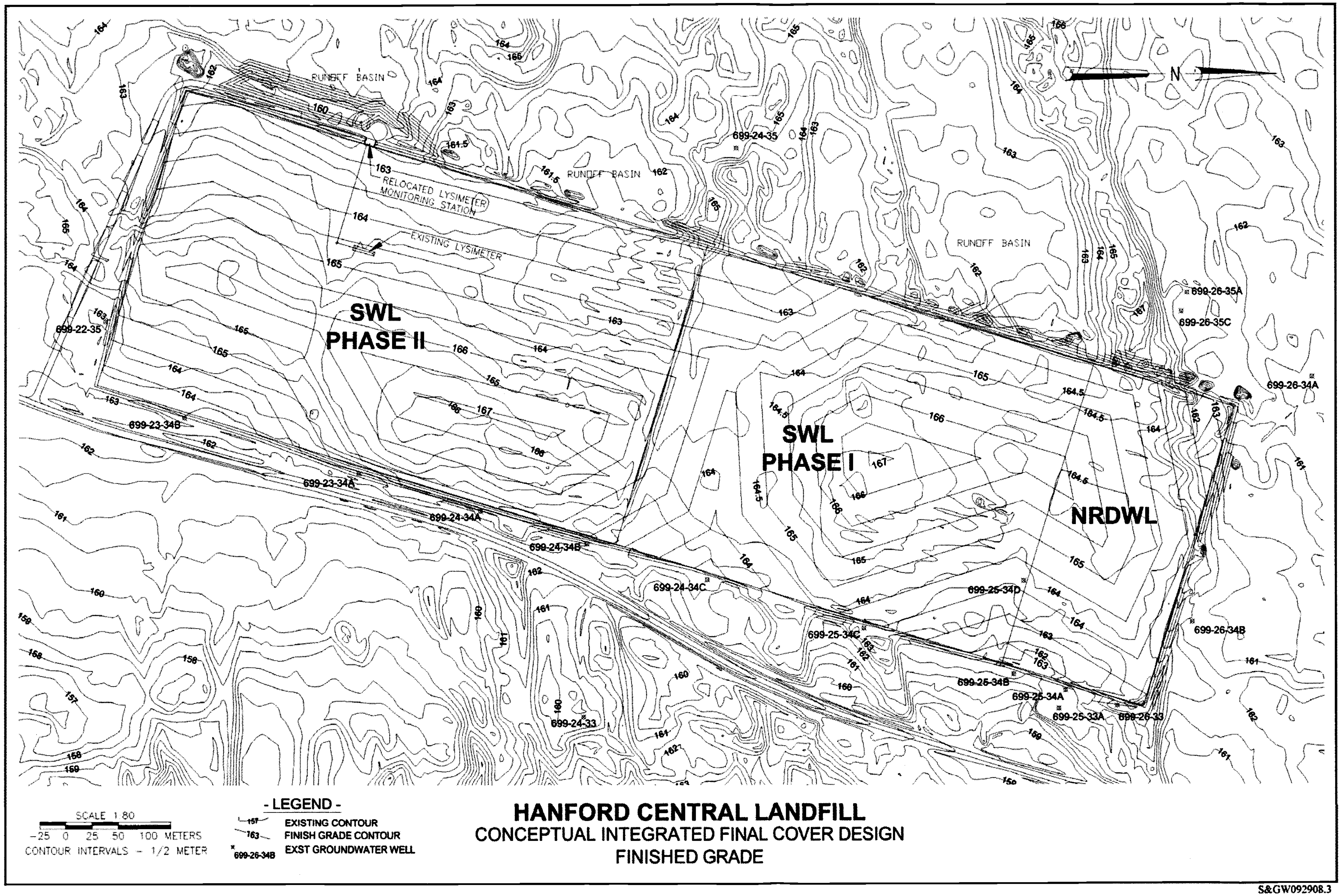

Figure B-3. Conceptual Integrated Final Cover Design Finished Grade

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B1.1 Selection of the Evapotranspiration Cover Design Concept

The ET cover design concept has been selected for the SWL final cover. ET covers, or surface barriers, rely on the natural systems of the water-holding (storage) capacity of a fine-grained soil, evaporation from the near-surface, and plant transpiration to control water movement through the cover. Precipitation is allowed to infiltrate at the surface, where it is retained in the soil until natural ET processes release the water back to the atmosphere. Such designs are particularly suitable for semiarid and arid climates with a low annual amount of precipitation and a relatively high ET potential. When precipitation exceeds ET, water is stored in the final cover, and when ET exceeds precipitation, water is removed from the final cover. This design dramatically reduces or even eliminates the amount of water passing through the cover and into the waste.

Cover design has been studied at the Hanford Site since the 1980's. Since the principal concern at the Hanford Site deals with resolving issues with radioactive waste, the Hanford Barrier Program has focused on extremely long term performance (> 1,000 years). Several natural analogue sites have been evaluated. Numerous laboratory analyses have been performed. Various test plots and lysimeters were constructed and monitored, some for well over a decade. All of these tests and studies have verified that, because of the arid climate, the Hanford Site should employ covers that rely upon the natural processes of ET to control leachate generation (DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*). In 1994, a large test barrier was constructed that incorporated a layer of locally available fine-grained soils as the principal component in restricting water movement towards and through the waste. After 8 years of monitoring, drainage through the vegetated fine-soil layer only occurred during the third year, even though a portion of the test barrier was stressed for the first three years with three times the average annual precipitation, as well as an additional simulated precipitation event that exceeded a 1,000-year probability of occurrence,. That one year's drainage did not exceed the design goal of 0.5 mm (0.02 in.) (PNNL-14143, *The Hanford Site 1000-Year Cap Design Test*), demonstrates the ability of the cover to control leachate generation.

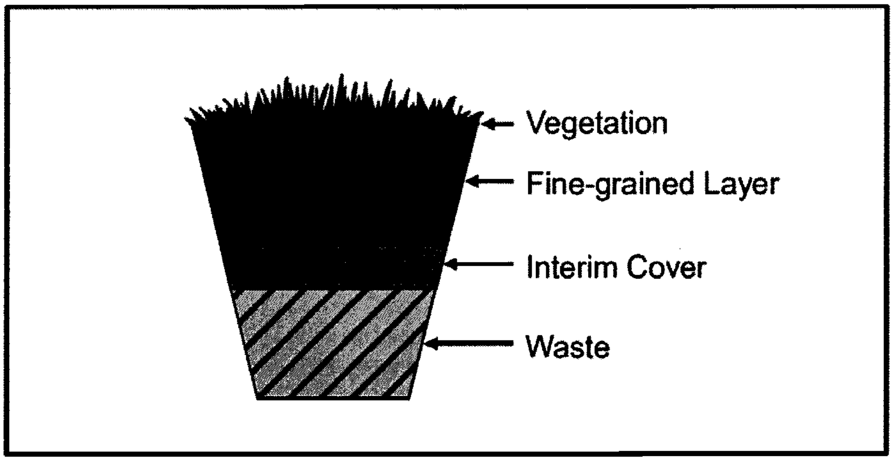
Over the past few decades there have been numerous studies performed across the nation, sponsored by regulatory agencies and landfill owners, on the performance of various cover design concepts. One of the more comprehensive studies is being performed under the Alternative Cover Assessment Program, of which the U.S. Environmental Protection Agency (EPA) is one of the principal sponsors. Under this program, large-scale test plots of a set of several cover concepts were constructed at locations throughout the U.S., and the performance at each location compared. Alternative Cover Assessment Program has concluded that covers that rely on the natural process of ET are well suited for application where the climate is arid or semiarid as long as the type and thickness of the soils used in constructing the cover provide sufficient water storage capacity (DRI, 2002, *Alternative Cover Assessment Project Phase I Report*).

Another comprehensive study on cover concepts is being performed for the U.S. Department of Energy (DOE) at the Los Alamos National Laboratory (LANL), a semiarid site that receives almost three times the average annual precipitation that the Hanford Site receives. Several test plots were constructed at the LANL that have demonstrated that a simple ET cover will adequately protect the environment. In 2007, the LANL published a design guidance and requirements document that identifies a monolithic ET cover as the typical cover design to be used at the LANL for hazardous and radioactive mixed waste sites (LA-UR-06-4715, *Cover System Design Guidance and Requirements Document*).

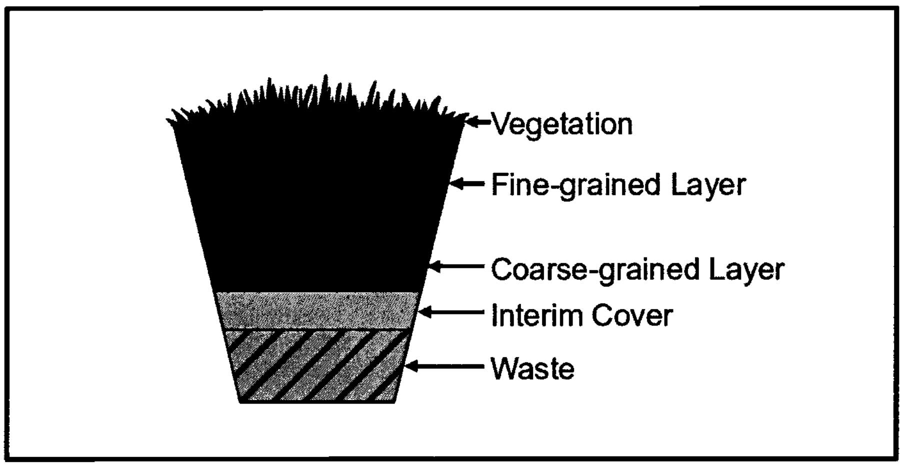
Though the focus of most of the aforementioned studies was on final covers for radioactive waste sites or dangerous or hazardous waste landfills, most of the lessons learned can also be applied to final covers for solid waste landfills located in arid or semiarid locations.

In 1995, the Interstate Technology & Regulatory Council (ITRC) was established as a state-led, national coalition of personnel from the environmental regulation agencies of some 40 states, the District of Columbia, three federal agencies, several tribes, and numerous public and industry stakeholders. The ITRC is devoted to reducing obstacles in developing and deploying better, more cost-effective, and innovative environmental techniques. Within the ITRC, the Alternative Landfill Technologies team was formed, which, published ITRC, 2003, *Technical and Regulatory Guidance for Design, Installation, and Monitoring of Alternative Final Landfill Covers*. The guide focuses on a particular class or type of alternative final landfill cover (i.e., the ET cover) indicating a preference for the ET cover concept.

The two most common types of ET covers include monofill (or monolithic) covers, which rely on a relatively thick single layer of fine-grained soil, and capillary covers, which consist of a fine-grained soil layer overlying a relatively coarse-grained soil layer (Figure B-4).



Monofill (monolithic) ET Cover



Capillary ET Cover

Source: EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet*

Figure B-4. Common ET Cover Designs

In the capillary ET cover, the distinct textural interface between the fine- and coarse-grained soil layers creates a capillary break, which functionally increases the water-holding capacity of the fine-grained soil. Water will not flow into the coarse layer until the water content in the fine-grained soil approaches saturation. Given the same soil type, for an equivalent water-holding capacity the capillary ET cover will typically require less soil thickness relative to that required for a monofill ET cover.

The site-specific decision on whether to use a monofill or capillary type of ET cover design is based on soil characteristics (e.g., water-holding capacity), the rooting depth of native plants, and the potential for subsidence. Assuming equivalent performance is achieved by the two cover design types, cost of construction may also be considered. In addition, in some locations under certain environmental conditions, interflow discharges along the toe of the capillary boundary may necessitate the installation of water routing structures to mitigate or eliminate focused interflow discharge. The installation of water routing structures, such as French drains, are especially needed in areas where multiple capillary barriers are in close proximity to one another. With the monofill and the capillary ET cover designs utilizing the same fine-grained soils and requiring the same minimum rooting depth for native plants, the only variables are the potential for subsidence and the cost of construction.

The monofill type ET cover is better able to accommodate differential settlements or subsidence relative to a capillary ET cover, which relies on maintaining a planar textural interface. If the textural interface is compromised or disrupted because of differential settlement or some other occurrence, water-holding capacity of the capillary cover would diminish to that of a monofill cover of equivalent thickness. In addition, if subsidence were significant enough in the case of deploying a capillary barrier, a large break in the capillary barrier could result in focused recharge. Since solid waste landfills typically have a high potential for differential settlement, the thicker monofill ET cover, which is essentially self-healing under minor subsidence conditions, is better suited for the SWL.

Additionally, a 75 cm (30 in.) thick ET cover would be needed to provide adequate water storage and rooting medium to sustain a robust native plant community. Median root depths for Hanford native perennial forbs and grasses are 6 cm (24 in.) and 7 cm (28 in.), respectively (PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*, Table 5-10). The functional water storage capacity of a 0.75 m thick monofill ET cover alone is 75 percent of an entire average year of precipitation. Functional water storage capacity is determined by the difference in water content between the field capacity and the wilting point of a given soil, times its thickness. Field capacity (or water-holding capacity) is defined as the amount of water held in a soil after excess moisture has drained away by gravity and the soil is no longer draining (pore pressures of negative 1/3 bar). Wilting point is defined as the water content when a common agricultural crop can no longer draw water from the soil (pore pressures of negative 15 bars). The field capacity of the fine-grained soil from a nearby borrow site (Area C) is 0.229 vol/vol (mean soil properties for Area C soil [PNNL-17134]). The wilting point for that same soil is 0.056 vol/vol, which is a typical condition at the end of the dry season. Field capacity (0.229), minus wilting point (0.056), times 0.75 m of soil, equals 130 mm (5.1 in.) of functional water storage capacity. This is a conservative calculation since it has been demonstrated by numerous studies that desert plants, physiologically adapted to hot arid climates, can extract water from the soil far below that of an agricultural crop (some exceeding 200 bars).The average annual precipitation at the Hanford Site of 173 mm (6.81 in.) (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*) is coupled with an average annual potential ET of approximately 1270 mm/yr (50 in./yr) (PNL-6750, *Status of FY 1988 Soil-Water Balance Studies on the Hanford Site*). Forty percent of the average annual precipitation at the Hanford Site falls during winter, when potential ET is slightly less than precipitation. During all other times of the year, potential ET greatly exceeds precipitation. As a 0.75 m thick monofill ET cover would be capable of storing almost twice the average winter precipitation, the water-storage enhancement provided by a capillary break would seldom be needed.

A 75 cm (30 in.) thick monofill ET cover design is being proposed for placement over the SWL. A 75 cm thick monofill ET cover would severely limit water flux through the cover, and effectively reduce leachate generation without the enhancement of a capillary break. However, the interim cover at the SWL consists of soils that are medium sands to gravelly coarse sands. These types of soils have a textural contrast that is distinct enough from the fine-grained soils at Area C that a capillary break would most likely form at the interface, adding to the conservatism in the design (EPA/600/R-94/168a, *The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3*; EPA/600/R-94/168b, *The Hydrologic Evaluation Of Landfill Performance (Help) Model: Engineering Documentation For Version 3*).

B1.2 Modeling

Performance modeling using Schroeder et al., 1994, *Hydrologic Evaluation of Landfill Performance* Model (HELP) suggests that 75 cm (30 in.) of Hanford silt-loam will reduce leachate generation within the SWL to near zero. The HELP computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. HELP is widely used and accepted in the industry, particularly for preliminary design, parametric evaluations, and indication of regulatory compliance (EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet*, Table 4-1).

Several HELP model simulations of the SWL, with slight variations for a final cover, were run for comparison and to identify sensitivities to certain parameters (e.g., soil type, thickness, and plant community).

Because of the uncertainties and spatial variability in water balance model input parameters, models such as HELP generally should be viewed as a means to compare alternatives rather than to predict performance. Recent studies have compared available numerical models and found that cover design depends on site-specific factors (e.g., climate, cover type, available soils), and that no single model is adequate to accurately predict the performance of an ET cover (EPA/542/F-03/015). Even when calibrated to a specific site, some models tend to under predict, while others over predict cover performance. The HELP model is the most widely used water balance model for landfill cover design, however, it tends to over-predict drainage at arid sites, which could lead to a conservative design (DRI, 2002). Also, to minimize processor demands and computational time, the HELP model uses daily average weather, quarterly averaged humidity, and other broadly averaged inputs. With these averaged inputs, the HELP model will sometimes predict cover performance in the small fractions of a percent of the precipitation that historically fell at or near the site. Cover performance predicted by the HELP model should be considered a general approximation.

The HELP model was used as a preliminary screening tool to evaluate whether an ET cover would be appropriate for the SWL. During definitive or final design, a more rigorous analysis, using a model based on the Richards' equation, will be performed. Models that are based on the Richards' equation are considered more physically correct for characterizing water movement through a surface barrier or cover than models like HELP, which are based on enhanced water balance methods (ITRC, 2003). A more comprehensive model will be run during the design phase of the cover and will provide enhanced precision and accuracy in predicting future barrier performance.

B1.2.1 Design Standards

WAC 173-350-400 identifies the closure system design requirements for the SWL final cover. The design must prevent exposure to waste, minimize infiltration, prevent wind and water erosion, address settlement, provide stability, manage run-on and runoff, and minimize post-closure maintenance.

Arid regions of Washington State are defined as regions receiving less than 30 cm (12 in.) of average annual precipitation, such as the Hanford Site. The closure design for the SWL consists of a vegetated 15 cm (6-in.) thick topsoil layer overlying a 60 cm (24-in.) thick barrier soil layer with a maximum saturated hydraulic conductivity of 1x10-5 cm/sec, or equivalent. Other designs are acceptable if they meet the requirements of WAC 173-350-400(3)(e)(i)(A) through (D)..

A site-specific version of the closure design was developed so that the water balance performance of the design could be evaluated with the HELP model. The purpose of the evaluation was to provide a reference case for use in consideration of suitable alternative site-specific designs. The thicknesses of the two layers in the design are not stipulated in WAC 173-350-400; however, performance predictions for the design as applied to a given locality will be influenced by site-specific climatic factors and specific material properties of available soils. Climatic factors to be considered include average annual precipitation, temperature, and solar radiation for the site; the length of the growing season; and the evaporative zone depth. Specific material properties include size-gradation and moisture properties of suitable, locally available borrow materials, the rooting depth, aboveground biomass development, and transpiration efficiency of the selected cover vegetation.

Topsoil and barrier soil layers for the cover were modeled as follows:

- Layer 1 (topsoil layer) – Composed of uncompacted Area C silt/silt-loam and pea gravel admix; a 6-in. thick vertical percolation layer with 0.375 porosity, 0.230 field capacity, 0.051 wilting point, and effective hydraulic conductivity of 1.31 x 10-5 cm/sec (mean soil properties of a series of samples taken at Area C and adjusted to represent the addition of pea gravel at 15 percent by weight, PNNL-17134); supporting a poor stand of perennial grass vegetation (conservative)
- Layer 2 (barrier soil layer) – Composed of uncompacted Area C silt/silt-loam (placed at 86 percent of relative density); a 24-in. thick layer with 0.409 porosity, 0.229 field capacity, 0.056 wilting point, and an effective hydraulic conductivity value of 1.00 x 10-5 cm/sec, with projected rooting zone and evaporative zone depths equal to the thickness of the cover.

Area C silt/silt-loam is the best available topsoil borrow material identified to date around the Hanford Site. It is also the best available material for constructing the barrier soil layer.

B1.2.2 Model Inputs - Weather

The HELP model requires climate data for daily total precipitation, daily average temperature, daily solar radiation, quarterly average humidity, and annual average wind speed. The model contains a limited database of values that allow the model to synthetically generate weather information for 139 cities within the United States should adequate weather data for the specific site not be available. The Hanford Site has kept weather records since 1912, with hourly temperature, dew point, atmospheric pressure, precipitation, relative humidity, solar radiation, and wind speed and direction recorded since July 1946. Daily maximum and minimum temperatures and total precipitation have been recorded since 1912.

The Alternative Landfill Technologies Team of the ITRC and others have suggested that, when comprehensive weather data is available, a conservative but reasonable approach to modeling cover performance is to use the wettest ten year cycle on record (DRI, 2002). A ten-year span will usually include a combination of wet and dry years so that the cycle is not overly conservative. The Alternative Landfill Technologies Team also suggests the following: "The cover should be evaluated during its critical conditions (for example, during the period of minimum ET or a spring snowmelt event). The design may be based on events predicted from models or extrapolated from available records" (ITRC, 2003, Section 4.3.1). During the years 1989 through 1998, the Hanford Site received 115 percent of normal precipitation. This period included the two wettest years on record (1995 and 1996), the wettest month on record (December 1996), the wettest winter on record (November 1996 through March 1997), the second highest snow accumulation on record (15-in. from January 15 to 20, 1993, which equates to a 50 year frequency accumulation), and a 150-year frequency, 24-hour storm (November 18 to 19, 1996)

(PNNL-15160). The monthly total precipitation for the years 1946 through 2007 is provided in Table B-1. The far right column shows the running ten-year average for the years 1958 through 2007, with the highest ten-year average occurring at the end of 1998.

Hourly total precipitation and solar radiation records for the years 1989 through 1998 at the Hanford Site were summed into daily total values, and an input file created for each. Hourly temperatures for the years 1989 through 1998 were averaged for each given day to create the daily average temperature input file. Quarterly relative humidity values were derived from the monthly averages provided in Table 6.3 of PNNL-15160, and the annual average wind speed was taken from Table 5.1 of PNNL-15160.

All model runs use the same climate data.

Table B-1. Summary of Monthly and Annual Precipitation Totals (in inches) from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten year running Average
1946	--	--	--	--	--	--	0.15	0.35	0.52	0.65	0.66	0.11	--	--
1947	0.32	0.27	0.42	0.7	0.02	1.07	0.71	0.68	1.34	2.2	0.81	0.75	9.29	--
1948	1.36	0.69	0.07	0.95	1.71	1.47	0.4	0.39	0.16	0.45	0.95	1.11	9.71	--
1949	0.13	0.68	1.12	0.02	0.16	0.01	0.01	0.03	0.23	0.1	1.47	0.16	4.12	--
1950	1.8	1.06	0.87	0.47	0.27	2.92	0.07	T	0.01	2.46	0.55	0.97	11.45	--
1951	0.84	0.51	0.46	0.53	0.43	1.38	0.37	0.15	0.1	0.71	0.82	0.7	7	--
1952	0.65	0.5	0.06	0.13	0.58	1.07	T	0.08	0.08	0.04	0.2	0.77	4.16	--
1953	2.16	0.25	0.17	0.77	0.28	0.55	T	0.96	0.13	0.2	0.96	0.49	6.92	--
1954	1.48	0.28	0.59	0.07	0.41	0.1	0.22	0.42	0.51	0.42	0.86	0.35	5.71	--
1955	0.56	0.22	0.17	0.4	0.59	0.28	0.57	0	0.77	0.4	1.54	2.03	7.53	--
1956	1.71	0.56	0.1	T	0.22	0.86	T	0.38	0.01	1.03	0.15	0.58	5.6	7.149
1957	0.48	0.23	1.86	0.38	0.82	0.47	0.05	0.02	0.34	2.72	0.39	0.53	8.29	7.049
1958	1.74	1.48	0.46	0.64	0.74	0.81	0.02	T	0.05	0.19	0.77	1.84	8.74	6.952
1959	2.05	1.17	0.4	0.2	0.5	0.23	T	0.03	1.26	0.56	0.41	0.26	7.07	7.247
1960	0.51	0.58	0.67	0.53	0.71	0.14	T	0.26	0.23	0.23	0.92	0.64	5.42	6.644
1961	0.33	2.1	1.02	0.48	0.8	0.42	0.15	0.09	T	0.07	0.49	0.89	6.84	6.628
1962	0.13	0.9	0.14	0.34	1.35	0.12	T	0.5	0.38	0.95	0.65	0.6	6.06	6.818
1963	0.95	0.69	0.53	1.17	0.43	0.28	0.31	0.01	0.02	0.04	0.74	1.14	6.31	6.757
1964	0.37	0.01	0.03	0.11	0.04	0.9	0.04	0.24	0.09	0.28	0.94	2.34	5.39	6.725
1965	0.93	0.14	0.03	0.09	0.15	0.49	0.11	0.03	0.11	0.01	1.17	0.39	3.65	6.337
1966	0.68	0.03	0.39	0.03	0.05	0.43	0.81	T	0.27	0.39	2.25	0.6	5.93	6.37
1967	0.32	T	0.14	0.9	0.56	0.57	T	T	0.05	0.13	0.16	0.43	3.26	5.867
1968	0.88	0.58	0.02	0.01	0.06	0.19	0.04	0.51	0.25	0.93	1.23	1.25	5.95	5.588

Table B-1. Summary of Monthly and Annual Precipitation Totals (in inches) from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten year running Average
1969	1.24	0.54	0.1	1.22	0.51	0.75	T	T	0.48	0.1	0.13	1.29	6.36	5.517
1970	2.47	0.75	0.27	0.45	0.54	0.25	0.01	T	0.03	0.24	0.71	0.61	6.33	5.608
1971	0.78	0.1	1.02	0.07	0.56	0.71	0.13	0.09	1.13	0.18	0.46	1.07	6.3	5.554
1972	0.19	0.27	0.58	0.1	2.03	0.66	0.16	0.56	0.02	T	0.55	1.27	6.39	5.587
1973	0.9	0.21	0.08	T	0.24	0.01	T	0.02	0.43	1.72	2.64	2.02	8.27	5.783
1974	0.9	0.41	0.52	0.46	0.28	0.12	0.71	T	0.01	0.21	0.71	0.97	5.3	5.774
1975	1.43	0.98	0.33	0.42	0.38	0.24	0.32	1.16	0.03	0.87	0.6	0.7	7.46	6.155
1976	0.56	0.36	0.23	0.41	0.08	0.11	0.13	0.96	T	0.04	T	0.11	2.99	5.861
1977	0.08	0.57	0.41	T	0.65	0.37	0.06	1.36	0.66	0.15	0.63	1.47	6.41	6.176
1978	1.72	0.92	0.3	0.46	0.41	0.09	0.52	0.57	0.11	T	1.21	0.26	6.57	6.238
1979	0.54	0.17	0.54	0.52	0.1	T	0.09	0.38	0.2	0.67	1.36	0.99	5.56	6.158
1980	1.32	1.3	0.3	0.86	1.41	0.96	T	0.02	0.85	0.33	0.44	1.89	9.68	6.493
1981	0.56	0.6	0.7	0.02	0.99	0.43	0.19	0.03	0.6	0.39	1.08	1.45	7.04	6.567
1982	0.33	0.57	0.3	0.75	0.28	0.75	0.22	0.2	0.55	1.33	0.91	1.79	7.98	6.726
1983	1.44	1.36	1	0.42	0.52	0.68	0.31	0.12	0.46	0.52	2.12	2.12	11.07	7.006
1984	0.23	0.94	1.01	0.6	0.55	0.99	0.06	T	0.42	0.07	1.83	0.57	7.27	7.203
1985	0.34	0.82	0.36	0.01	0.12	0.15	0.12	0.01	0.63	0.46	1.24	0.84	5.1	6.967
1986	1.76	1.37	0.76	T	0.3	T	0.21	0.02	0.96	0.29	0.65	0.77	7.09	7.377
1987	0.8	0.19	1.05	0.14	0.17	0.11	0.5	0.07	0.01	T	0.4	1.63	5.07	7.243
1988	0.48	T	0.39	1.12	0.33	0.11	0.13	0	0.39	0.01	0.82	0.4	4.18	7.004
1989	0.21	1.67	1.56	0.84	0.59	0.01	0.01	0.26	0.02	0.42	1.04	0.29	6.92	7.14
1990	0.77	0.09	0.1	0.4	0.86	0.36	0.14	0.83	T	0.78	0.02	0.72	5.07	6.679
1991	0.33	0.19	1.12	0.45	0.49	1.44	0.29	0.07	0	0.53	1.44	0.4	6.75	6.65
1992	0.44	0.94	0.09	0.94	T	1.14	0.38	0.2	0.27	0.61	1.07	1.82	7.9	6.642
1993	1.3	1.17	0.67	0.71	0.6	0.12	1.76	0.24	0.04	0.09	0.19	0.94	7.83	6.318
1994	0.44	0.11	0.03	0.61	1.27	0.38	0.15	0.08	0.08	0.93	0.68	1.36	6.12	6.203
1995	2.14	0.69	0.95	1.54	0.79	0.77	0.34	0.07	0.79	0.87	1.04	2.32	12.31	6.924
1996	1.42	1.22	0.83	0.43	0.62	0.05	0.14	0.02	0.22	0.88	2.67	3.69	12.19	7.434
1997	1.51	0.25	0.7	0.33	0.33	0.46	0.19	0.06	0.32	0.92	1.01	0.31	6.39	7.566
1998	1.24	1.15	0.5	0.07	0.52	0.48	0.34	0.04	0.1	0.28	1.29	0.44	6.45	7.793

Table B-1. Summary of Monthly and Annual Precipitation Totals (in inches) from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten year running Average
1999	0.89	0.7	0.06	T	0.34	0.31	0.07	0.57	0	0.48	0.26	0.07	3.75	7.476
2000	1.09	1.12	0.94	0.57	0.77	0.25	0.46	T	0.56	0.57	1.08	0.67	8.08	7.777
2001	0.29	0.42	0.67	0.83	0.08	1.27	0.05	0.08	0.13	0.37	1.67	0.8	6.66	7.768
2002	0.42	0.67	0.19	0.29	0.16	0.65	0.16	0.01	T	0.12	0.38	2.36	5.41	7.519
2003	1.87	0.82	0.26	2.23	0.08	T	0	0.46	0.24	0.07	0.15	1.96	8.14	7.55
2004	2.12	0.92	0.36	0.21	0.89	0.82	0.03	0.95	0.14	0.86	0.29	0.37	7.96	7.734
2005	0.93	0.04	0.31	0.26	0.79	0.06	0.09	0.06	0.66	0.29	0.89	2.01	6.39	7.142
2006	1.18	0.41	0.24	1.3	0.57	1.33	T	T	0.21	0.76	0.71	1.75	8.46	6.769
2007	0.14	0.76	0.74	0.26	0.3	0.45	0.07	0.32	0.57	0.21	1.13	0.53	5.48	6.678
AVERAGE[a]	0.95	0.64	0.5	0.47	0.52	0.52	0.21	0.24	0.3	0.53	0.88	1.04	6.8	NA
NORMAL[b]	0.87	0.68	0.58	0.44	0.55	0.41	0.27	0.27	0.33	0.49	0.98	1.11	6.98	NA

a The average is the mean value of the historic record, 1945-2005.

b By convention, a climatological normal is the average over a 30-year period, in this case the period 1971-2000.

Source: PNNL-15160, Table 4.1, with 2005, 2006, and 2007 updates

The shaded portion is the wettest ten years on record. Values in bold type are greatest and least records for the period.

-- = not available

NA = not applicable

T = trace

B1.2.3 Model Inputs – Soil Properties

The HELP model requires input values for cover layer thickness, porosity, field capacity, wilting point, initial soil water content, and effective saturated hydraulic conductivity. The model contains a small database containing the physical properties of a number of default soil types, however, it is preferred to use properties of the soils that are or will be part of the cover.

The most likely source for the fine-grained soil that would be used in constructing the final cover for the SWL will be Area C, which is approximately 9.7 km (6 mi.) west-southwest of the Central Landfill. An extensive study of the soils contained within the southeast portion of Area C was performed recently to support the design of surface barriers or covers for several waste sites within the 200-UW-1 Operable Unit as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* remedial action. A set of best-estimate parameter values for modeling the performance of the Area C soils was developed and documented in PNNL-17134.

During the 1990's, a set of studies were performed on the erosion resistance of a typical silt-loam soil under the Hanford Barrier Program. The mission was to identify components of a long-term (1,000 years) surface barrier design. Several of the studies concluded that to enhance resistance of a bare fine-grained soil to erosion, 3/8 in. pea-gravel should be blended or tilled into the upper 12 in. of the surface (PNL-8478). As a bare soil surface deflates over time, more of the pea-gravel becomes exposed, eventually creating what is termed as a desert pavement, which would be highly resistant to wind and water erosion. These studies also determined that a mixture of 15 percent by weight 3/8 in. pea-gravel and silt would not inhibit native plant germination or growth. Recent analysis, using agricultural industry standard methods, predict that at a 2 percent slope, the gravel admix would be sufficient to limit erosion to an average of less than 6 mm (1/4 in.) every 100 years (CH2M Hill Hanford Group Inc., 2006a, *Engineered Surface Barrier Design-Soil Losses Due to Water Erosion*; CH2M Hill Hanford Group Inc., 2006b, *Engineered Surface Barrier Design-Soil Losses Due to Wind Erosion*).

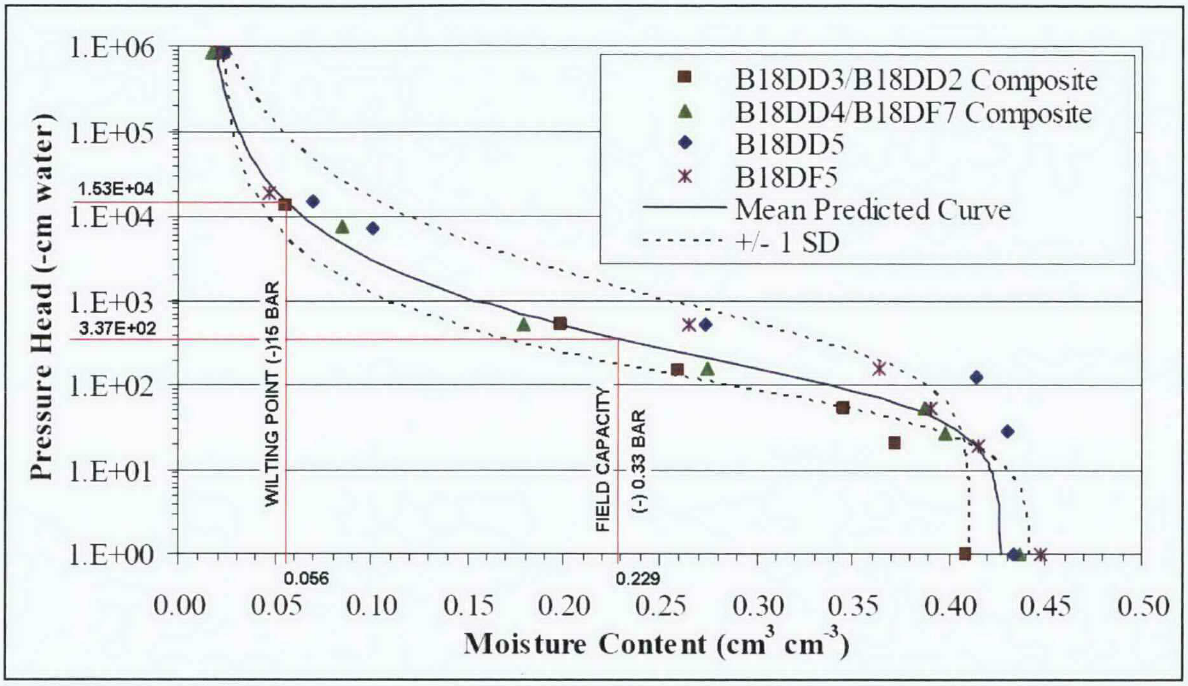
To provide a life expectancy of at least 100 years, the top 152 mm (6 in.) of the final cover (Layer 1) for the SWL will consist of Area C silt-loam with 3/8 in. pea-gravel blended/tilled into it at 15 percent by weight. Layer 2 will consist of 24 in. of Area C silt-loam soil. Most of the best-estimate parameters for the silt-loam soil and silt-loam soil gravel admix are found in PNNL-17134, Tables 3.4 and 3.5. Saturated hydraulic conductivity for the mean silt-loam soil and silt-loam admix is taken directly from the tables. The density values (particle density [ρs] and dry bulk density [ρb]) for the mean soil parameters were used to derive the porosity (ϕs) of the soil using the equation:

$$\phi_s := 1 - \frac{\rho_b}{\rho_s}$$

Field capacity and wilting point for the silt-loam admix and the silt-loam soil were derived by interpolating the pore pressure and moisture content values provided in PNNL-17134, Table B5 for the sample B18DD3/B18DD2 Composite. Pore pressures between field capacity (-3.37 x 102 cm of water [-0.33 BAR]) and wilting point (-1.53 x 104 cm of water [-15 BAR]) for composite blend B18DD3/B18DD2 plot on, or very close to, the "Mean Predicted Curve" shown in PNNL-17134, Figure 3.3. Interpolating from PNNL-17134, Table B5 provided values to three significant figures. Intersects were plotted on the "Mean Predicted Curve" shown on PNNL-17134, Figure 3.3 for pore pressures of -3.37 x 102 cm for field capacity and -1.53 x 104 cm for wilting point to confirm the interpolated results (Figure B-5). This process provided the resultant moisture content parameters of 0.229 vol/vol for field capacity and 0.056 vol/vol for the wilting point for the mean Area C silt-loam.

The initial moisture content was developed through an iterative process of repeatedly running the model to identify the water storage at the end of the ten-year period, then entering that value as the initial soil water content until the two sets of values were essentially the same. This equilibrates the model to infinite repeated wettest ten-year weather cycles.

Other than thickness, the properties for the interim soil cover (Layer 3) and the waste layer (Layer 4) were entered by selecting generic materials from the HELP database that best approximate the SWL. The interim cover is documented to be 0.6 to 1.2 m (2 to 4 ft) in thickness and consists mostly of a coarse to fine sand, with gravel. For simplicity, Layer 3 will be modeled in all simulations as a 0.6 m layer of soil having properties best described by HELP as Material Texture Number 3 (a well graded, gravelly sand with few fines, defined by the Unified Soil Classification System as SW). The 3.65 m (12 ft) thick waste layer will be defined as Layer 4, and will be modeled in all simulations as a waste layer having properties best described by HELP as Material Texture Number 18, Municipal Waste.



Source: PNNL-17134, Figure 3.3, modified to show field capacity and wilting point

Figure B-5. Measured and Predicted Water Characteristics and Moisture Content Curve for the Silt-loam Soil at Area C

As a sensitivity analysis on Area C soil properties, several comparative HELP model runs were made using the properties for a blend of some of the more coarse soil samples taken at Area C. Using the same process identified above for determining the properties for the mean Area C soil, properties for the sample blend B18DD3/B18DD2 were input into the model. A soil represented by sample blend B18DD3/B18DD2 will have a slightly lower porosity (0.402 verses 0.409) and a slightly higher saturated hydraulic conductivity (3.96 x 10-5 cm/sec verses 1.53 x 10-5 cm/sec) than the mean for Area C silt-loam soil, but will have very close to the same water storage capacity.

B1.2.4 Model Inputs – General Design and Evaporative Data

The HELP model requires the inputs for Soil Conservation Service (SCS) Runoff Curve Number (RCN), the fraction of the cover that will allow runoff (the portion of the area that is sloped in a manner that would permit drainage off the surface [EPA/600/R-94/168a]), the area of the cover, the Latitude of the site, the maximum leaf area index (LAI), the Julian date for the start of the growing season, the Julian date of the end of the growing season, and the depth of the evaporative zone.

The HELP model has a routine that assists in calculating the SCS RCN. The RCN is a widely used method in determining the approximate amount of runoff from a rainfall or snowmelt event over a particular area, and is based on that area's hydrologic soil group, land use, treatment (e.g., plant community), and hydrologic condition. The HELP model will only calculate the RCN when one of the default soils contained in the HELP database is used as the surface soil. To use the properties for an Area C soil for Layer 1 in the model, an iterative process was employed using the HELP default soils to identify an RCN that would be appropriate for a 147 m (480 ft) long, 2 percent slope consisting of a general Hanford silt-loam type of soil. A conservative value of 75 was selected for the majority of comparative runs with a value of 85 used in a sensitivity analysis. The lower RCN would produce less runoff; therefore, more water would be available to infiltrate the final cover. This correlates well with what has been observed at the Hanford Prototype Barrier (i.e., little runoff).

However, the HELP model also calculates when the temperature is near or below freezing and holds precipitation at the surface, simulating snow. When the model calculates the temperature has risen above freezing, it releases the stored water, inducing snow melt events to the simulation. A separate routine calculates when the ground could be frozen and, when it is, automatically changes the RCN to 95 for surfaces where the RCN is set to 80 or lower, and 98 when set above 80 (EPA/600/R-94/168b). These RCN values are typical for a tight clay soil surface and the model will derive significantly more runoff. This feature cannot be turned off or adjusted by the user, and may result in the over-prediction of runoff. With the exception of one day in one of the sensitivity runs, the only times the model predicted there would be runoff at the SWL was during snowmelt events on frozen soil. In actuality, when the surface has not been compacted, and native vegetation is present, runoff very rarely occurs on the Hanford Site.

As the entire surface of the final cover will be sloped a nominal 2 percent towards the landfill perimeter the fraction of landfill cover allowing runoff will be set to 100 percent for all model runs, with the exception of a runoff area sensitivity run, in which the variable will be set to a conservative 10 percent. The area of the cover will be approximately 27 ha (66 a) and the Latitude of the site is 46.505°.

The start and end of the growing season was derived by subjectively (and conservatively) averaging the growth start dates contained in PNNL-17134, Tables 5.15 (Leafy Spurge as a typical perennial forb), 5.16 (Indian Rice Grass), 5.17 (Thickspike Wheatgrass), 5.18 (Needle-and-Thread Grass), 5.19 (Sandberg Bluegrass), 5.21 (Big Sagebrush), and 5.22 (Rabbitbrush). These native species are predominant in the area that surrounds the SWL. Leaf growth for the grasses typically starts around day 91 to day 98, earlier for the shrubs and perennial forbs. For conservatism, the start of the growing season was set to day 98. The end of the growing season is based on seed dissemination for the deeper-rooted shrubs, which occurs between day 278 (Rabbitbrush) and day 327 (sagebrush), and plant senescence for the typical deep-rooted forb, which occurs near day 328. Dormancy occurs much earlier for the grasses because of the shallower rooting system as opposed to forbs and shrubs. Day 304 was selected as the end of the growing season as a conservative average of for the deeper-rooted plants.

For the maximum leaf area index, a poor stand of grass (LAI=1.0) was conservatively selected as the base case per the guidance given in the HELP users guide (EPA/600/R-94/168a). The HELP model uses a single input parameter labeled "Evaporative Zone Depth" for both rooting (transpiration) depth and active evaporation depth. The depth of the evaporative zone was conservatively set at the bottom of the final cover, even though PNNL-17134, Table 5.11 notes that root depths for a majority of plant species native to the area could extend deeper, with certain species extending as far as 3 m (10 ft) deep.

Additional model runs using a LAI equal to 0 (bare soil) and an LAI of 2.14 were made as part of a sensitivity analysis. The LAI of 2.14 was derived from PNNL-17134, Tables 5.6 and 5.9, for a mature vegetation area at the Hanford Site (the BC Crib area, which is roughly 4.8 km [3 mi.] northwest of the SWL). PNNL-17134, Table 5.9, provides the Plant-Area Index for various plant groupings at selected areas at the Hanford Site; Table 5.6 provides empirical relationship equations for estimating leaf-area index from the plant-area index. Inputting the values for plant area index from PNNL-17134, Table 5.9 into the respective equation in Table 5.6 for forbs, grasses, and shrubs, and summing the results provides a LAI=2.14.

B1.2.5 HELP Model Results

Simulations were run for the design, the proposed design (or base case), and seven sensitivity cases. The sensitivity cases identify the variations that would occur in the results because of a change of a single input variable from that of the proposed design (i.e., the quality of vegetation) (two cases), cover thickness, cover soil properties (i.e., gradation), runoff factors (two cases), and a sensitivity case that looks at the effects of a combination of a coarser soil and increased cover soil thickness.

B1.2.5.1 Input Design Parameters

All inputs to the design model are essentially the same as for the proposed design (or base case). The HELP model assumes that uniformly saturated flow conditions will exist within any layer identified as a barrier soil layer. This assumption mathematically precludes modeling of seasonal fluctuations in moisture content within the barrier soil layer. In actuality, such changes would occur where the barrier layer (or a portion of it) is situated within the evaporative zone and is subject to pedogenesis because of freeze-thaw cycles; organic matter accumulation; root, insect, and animal penetration; and other soil pedogenic processes (e.g., soil elluviation and illuviation, changes in bulk density, porosity, and soil structure). At the SWL, the evaporative zone would be expected to extend completely through Layer 2 of the cover. Therefore, the saturated flow constraint is inappropriate, and Layer 2 was therefore modeled as a vertical percolation layer. The simulation was repeated numerous times, reinitializing moisture conditions in the various cover layers at the beginning of each simulation, until initial and final moisture values for all layers became invariant. The purpose of this procedure was to evaluate the long-term steady-state performance.

When Layer 2 is modeled as a vertical percolation layer, the HELP model indicates that 94 percent of the annual precipitation will be removed by ET and 6 percent removed as runoff with almost no leachate (i.e., 0.094 mm/yr [0.0037 in./yr] or less than 0.09 percent of annual precipitation) at steady state. The summary output report for the HELP model simulation of the cover is provided in output file MFS-VP-P OUT (Section B2.1.)

B1.2.5.2 Proposed Design (Base Case)

The base case final cover consists of 60 cm (24 in.) of a typical (mean) Area C fine-grained soil plus 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 75 cm (30 in.). The cover will have a poor stand of grass (LAI=1.0). The evaporative zone depth is the thickness of the final cover (75 cm [30 in.]).

Model results for the proposed design are provided in output file AS-PV-30.OUT (Section B2.2). Average annual percolation through the landfill is predicted to be 0.18 mm (0.0070 in.) of leachate, or approximately 0.09 percent of annual precipitation. This indicates that the proposed design will provide essentially the same performance as the cover (Section B2.1). Over 94 percent of the annual precipitation will be removed by ET and slightly less than 6 percent removed as runoff. The model predicted runoff would only occur during periods when there was snowmelt on frozen ground and that there would be no runoff in six of the ten years of the wettest ten years on record. The model also predicted that there would be no runoff during a 150-year frequency precipitation event (November 18 to 19, 1996). With of the annual average percolation through the landfill predicted to be 0.18 mm/yr (0.0071 in./yr), the proposed design would be expected to achieve performance equal to or better than EPA's prescriptive design for a *Resource Conservation and Recovery Act of 1976* Subtitle C (hazardous/dangerous waste) final cover (EPA/542/F-03/015). In an arid to semiarid climate, such as at the Hanford Site, a conventional *Resource Conservation and Recovery Act of 1976*, Subtitle C cover would be expected to produce a flux of 1.5 mm/yr (Albright et. al., 2004, "Field Water Balance of Landfill Final Covers")

B1.2.5.3 Sensitivity Case 1 - Bare Soil (No Plants)

Model results for the bare soil sensitivity case are provided in output file AS-BS-30.OUT (Section B2.3).Sensitivity case 1 is the same as the base case except with bare soil (LAI=0.0) and slight differences in initial moisture content of each layer because of the iterative process for developing these values. Though such a case is highly unlikely (repeated ten year cycles of bare cover), the average annual percolation through the landfill is predicted to be 16.0 mm (0.62 in.) of leachate, which is 8 percent of the annual average precipitation that fell during the wettest ten years on record (1989 through 1998), and less than a third of the average annual leachate collected in the SWL lysimeter from 1996 to 2007 under the current interim cover conditions (i.e., coarse sand with sparse vegetation). Runoff was predicted to be slightly more than 6 percent of the annual precipitation, indicating that vegetation with a LAI=1.0 has only a slight impact to the amount of runoff generated. With an increase in percolation of two orders of magnitude over that of the base case, this sensitivity case does indicate the importance of maintaining the cover vegetation.

B1.2.5.4 Sensitivity Case 2 – Increase in Plant Density

Sensitivity case 2 is the same as the base case except with a good stand of shrubs and grass (LAI=2.14) and slight differences in initial moisture content of each layer because of the iterative process for developing these values. Model results are provided in output file AS-GV-30.OUT (Section B2.4). The average annual percolation through the landfill is predicted to be 0.17 mm (0.0067 in.). This is an extremely slight reduction in water flux over that allowed by a poor stand of grass. Coupled with the results of sensitivity case 1 (bare ground) the results indicate that a nominal stand of vegetation would be sufficient for the proposed cover to function optimally. Runoff was predicted to be essentially the same as with the proposed design (5.7 percent of the annual precipitation) indicating that that a LAI=2.14 is still too sparse to have a noticeable impact on the amount of runoff generated.

B1.2.5.5 Sensitivity Case 3 – Increase in Cover Thickness

Sensitivity case 3 is the same as the base case except for an additional 25 cm (10 in.) in thickness of cover and slight differences in initial moisture content of each layer because of the iterative process for developing these values. Model results are provided in output file AS-PV-40.OUT (Section B2.5). This case consists of 70 cm (28 in.) of a typical (mean) Area C fine-grained soil plus 3 cm (12 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 100 cm (40 in.). Evaporative zone is increased to the thickness of the fine-grained soil. The LAI is set to the same as the base case, or an LAI=1.0. Model results are provided in Section B2.5. The average annual percolation through the landfill is predicted to be 0.0039 mm (0.0002 in.), or less than 0.01 percent of annual precipitation. Runoff and ET values between the base case and this sensitivity case have a variance of less than 0.5 percent, with ET increasing to almost 95 percent of the annual precipitation. This demonstrates that additional water storage capacity would, as expected, reduce the amount of leachate generated. However, though the numbers indicate that this sensitivity case would result in a flux that is almost two orders of magnitude lower than the proposed design; both values are so small that they are essentially zero.

B1.2.5.6 Sensitivity Case 4 - Coarser Soil

Sensitivity case 4 is the same as the base case except for using a coarse blend of Area C soil (sample blend B18DD3/ B18DD2) and slight differences in initial moisture content of each layer. Model results are provided in output file COMP-30.OUT (Section B2.6).This soil has a slightly lower porosity (0.402 verses 0.409) and a slightly higher saturated hydraulic conductivity (3.96 x 10-5 cm/sec verses 1.53 x 10-5 cm/sec) than the mean for Area C silt-loam soil, yet has approximately the same water storage capacity (Figure B-5). Accordingly, the top soil layer also has a slightly lower porosity (0.363 versus 0.375) than the mean for Area C silt-loam soil modified with 15 percent by weight pea-gravel. All other inputs are the same as the proposed design. Model results are provided in Section B2.6. The average annual percolation through the landfill is predicted to be 2.0 mm (.0.079 in.), or approximately 1 percent of annual precipitation. The performance of this sensitivity case is more than an order of magnitude higher than that of the base case. This sensitivity case demonstrates the importance in selecting the appropriate barrier soil and establishing adequate construction quality controls. Variations in soil gradation beyond design limits could reduce performance. Even then, this sensitivity case predicts performance of a cover using the coarsest soil blends discovered at Area C would still be basically equivalent to the theoretical performance of EPA's prescriptive design for a *Resource Conservation and Recovery Act of 1976*, Subtitle C (hazardous/dangerous waste) final cover (EPA/542/F-03/015).

B1.2.5.7 Sensitivity Case 5 - Coarser Soil and Increase in Cover Thickness

Sensitivity Case 5 is the same as the base case except for using a coarse blend of Area C soil (sample blend B18DD3/ B18DD2), an additional 25 cm (10 in.) in thickness of cover, and slight differences in initial moisture content of each layer. Model results are provided in output file COMP-40.OUT (Section B2.7).This case consists of 7 cm (28 in.) of the coarse blend of Area C soil plus 3 cm (12 in.) of the same soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 100 cm (40 in.). The evaporative zone is increased to the thickness of the fine-grained soil. Hydraulic conductivity and porosity were adjusted accordingly for both layers. All other inputs are the same as the proposed design. Model results are provided in Section B2.7. The average annual percolation through the landfill is predicted to be 0.043 mm (0.0017 in.), or 0.02 percent of annual precipitation illustrating that added thickness could be used to overcome having to use a coarser soil.

B1.2.5.8 Sensitivity Case 6 - Higher Runoff Curve Number

Sensitivity Case 6 is the same as the base case except for using an RCN of 85 instead of 75 and slight differences in initial moisture content of each layer. Model results are provided in output file 30PVRC85.OUT (Section B2.8).All other input values remained the same, including the amount of surface area that will allow runoff (set to 100 percent). Model results are provided in Section B2.8. As expected, the model calculated the amount of runoff would be greater than when a lower runoff curve number is used. Runoff increased from 5.7 percent to 8.0 percent of the annual precipitation with a corresponding decrease in ET from 94.2 percent for the base case to 92.0 percent. It also predicted almost half the leachate that the base case model predicted when a RCN of 75 is used (0.074 mm/yr [0.0029 in./yr] verses 0.18 mm/yr [0.0071 in./yr]). With the exception of a single day in the entire ten-year cycle, the model predicted that runoff would only occur during periods where the model also predicted that the soil would be frozen. In all the other cases (i.e., proposed design, and sensitivity), the model predicted that runoff would only occur when there was snow melt on frozen ground.

B1.2.5.9 Sensitivity Case 7 - Less Area Allowing Runoff

Sensitivity Case 7 is the same as the base case except for reducing the amount of surface area that will allow runoff from 100 percent to 10 percent and slight differences in initial moisture content of each layer. Model results are provided in output file 30ASPV10.OUT (Section B2.9).All other input values remained the same as used in the proposed design model, including using a RCN of 75. Model results are provided in Section B2.9. Even though the potential area contributing to runoff was decreased by 90 percent, the model predicted that runoff would still be over 70 percent of the base case, or 4.2 percent of annual precipitation. ET increased to 95.7 percent of annual precipitation from the 94.2 percent predicted in the proposed design model. Flux (leachate generation) increased to .0.25 mm/yr (0.019 in./yr) from the 0.18 mm/yr (0.0071 in./yr) predicted for the base case. Even so, flux is still only 0.15 percent of annual precipitation.

B1.3 Conclusion

During the past couple of decades, there have been numerous studies and evaluations performed on cover system design that have demonstrated the benefits of employing a simple cover system that utilizes fine-grained soils coupled with the natural forces of ET (DOE/RL-93-33; DRI, 2002; EPA/542/F-03/015; ITRC, 2003; LA-UR-06-4715). At arid or semiarid sites, the use of ET covers for final covers at both dangerous and municipal waste sites is becoming the standard.

Performance modeling, using EPA's HELP model with site-specific weather data and soil information, indicates that a 75 cm (30 in.) thick monofill ET cover, employed as a final cover at the SWL, will severely limit the generation of leachate. The modeling also shows that a 75 cm (30 in.) thick monofill ET cover (consisting of 6 cm [24 in.] of uncompacted, fine-grained, low permeability soil, 15 cm [6 in.] of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion resistant top soil, constructed at a general slope of 2 percent, and planted with native vegetation).

B2 Data Results

This section provides the output file for each of the simulations summarized in Section B1.2.5.

B2.1 Output File: Basic Design

Section B1.2.5.1 summarizes the following output file for the minimum functional standard design.

```
                              MFS-VP-P.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                     USAE WATERWAYS EXPERIMENT STATION                    **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\SWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\SWL\MFS-VP-P.D10
OUTPUT DATA FILE:             C:\HELP3\SWL\MFS-VP-P.OUT


TIME:  11:44     DATE:   6/30/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (Min Functional Std - VPERC w/ POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   0
           THICKNESS                 =       6.00   INCHES
           POROSITY                  =       0.3750 VOL/VOL
           FIELD CAPACITY            =       0.2100 VOL/VOL
           WILTING POINT             =       0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.2096 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.130999997000E-04 CM/SEC


                                   LAYER  2
                                   --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                                    Page 1
```

```
                          MFS-VP-P.OUT
               MATERIAL TEXTURE NUMBER   0
THICKNESS                        =    24.00   INCHES
POROSITY                         =     0.4090 VOL/VOL
FIELD CAPACITY                   =     0.2290 VOL/VOL
WILTING POINT                    =     0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT       =     0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.        =  0.999999975000E-05 CM/SEC


                          LAYER  3
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   3
THICKNESS                        =    48.00   INCHES
POROSITY                         =     0.4570 VOL/VOL
FIELD CAPACITY                   =     0.0830 VOL/VOL
WILTING POINT                    =     0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT       =     0.0816 VOL/VOL
EFFECTIVE SAT. HYD. COND.        =  0.310000009000E-02 CM/SEC


                          LAYER  4
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
THICKNESS                        =   144.00   INCHES
POROSITY                         =     0.6710 VOL/VOL
FIELD CAPACITY                   =     0.2920 VOL/VOL
WILTING POINT                    =     0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT       =     0.2832 VOL/VOL
EFFECTIVE SAT. HYD. COND.        =  0.100000005000E-02 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER            =     75.00
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     66.000  ACRES
EVAPORATIVE ZONE DEPTH             =     30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      3.010  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     12.066  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      1.650  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     47.707  INCHES
TOTAL INITIAL WATER                =     47.707  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


              EVAPOTRANSPIRATION AND WEATHER DATA
                             Page 2
```

MFS-VP-P.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.821	2.699	1.194	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.619
STD. DEVIATIONS	3.989	5.507	2.758	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.769
EVAPOTRANSPIRATION						
TOTALS	9.408	9.985	23.574	27.173	20.609	26.416
	36.558	5.383	4.430	5.893	8.788	8.319
STD. DEVIATIONS	4.472	5.524	8.473	16.619	11.222	6.401

1

	19.453	5.638	4.273	2.529	3.126	1.534

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0468	0.0000	0.0000	0.0000	0.0468	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1479	0.0000	0.0000	0.0000	0.1480	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	11.332	(21.0178)	3026.85	5.725
EVAPOTRANSPIRATION	186.535	(47.8092)	49823.29	94.237
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.09358	(0.19727)	24.994	0.04727
CHANGE IN WATER STORAGE	-0.019	(1.3165)	-5.10	-0.010

****

□
****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	56.191	15008.6113
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.468043	125.01352
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2238	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

□
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1 Page 4

MFS-VP-P.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.1946	0.2096
2	4.4477	0.0730
3	9.9486	0.0816
4	103.5663	0.2832
SNOW WATER	0.000	

****
****

B2.2 Output File: Proposed Design (Base Case)

Section B1.2.5.2 summarizes the following output file for the proposed design.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:   C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:     C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE: C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:   C:\HELP3\SWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE: C:\HELP3\SWL\AS-PV-30.D10
OUTPUT DATA FILE:          C:\HELP3\SWL\AS-PV-30.OUT


TIME:  8: 5    DATE:  6/30/2009


******************************************************************************

  TITLE:  30-INCH SOIL COVER (AVE.[Mean] AREA C SILT PROP w/ POOR VEG)

******************************************************************************


  NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
         WERE SPECIFIED BY THE USER.


                        LAYER  1
                        --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  0
        THICKNESS             =     6.00  INCHES
        POROSITY              =   0.3750 VOL/VOL
        FIELD CAPACITY        =   0.2100 VOL/VOL
        WILTING POINT         =   0.0510 VOL/VOL
```

INITIAL SOIL WATER CONTENT = 0.2107 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.130999997000E-04 CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0
THICKNESS = 24.00 INCHES
POROSITY = 0.4090 VOL/VOL
FIELD CAPACITY = 0.2290 VOL/VOL
WILTING POINT = 0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0737 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.153000001000E-04 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 3
THICKNESS = 48.00 INCHES
POROSITY = 0.4570 VOL/VOL
FIELD CAPACITY = 0.0830 VOL/VOL
WILTING POINT = 0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0841 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.310000009000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 144.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2917 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER = 75.00
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 66.000 ACRES
EVAPORATIVE ZONE DEPTH = 30.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 3.033 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 12.066 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.650 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 49.075 INCHES
TOTAL INITIAL WATER = 49.075 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE = 46.51 DEGREES
MAXIMUM LEAF AREA INDEX = 1.00
START OF GROWING SEASON (JULIAN DATE) = 98
END OF GROWING SEASON (JULIAN DATE) = 304
EVAPORATIVE ZONE DEPTH = 76.2 CM
AVERAGE ANNUAL WIND SPEED = 12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

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ANNUAL TOTALS FOR YEAR 1989

	MM	CU. METERS	PERCENT
PRECIPITATION	175.77	46947.355	100.00
RUNOFF	17.219	4599.073	9.80
EVAPOTRANSPIRATION	164.406	43912.527	93.54
PERC./LEAKAGE THROUGH LAYER 4	0.595025	158.930	0.34
CHANGE IN WATER STORAGE	-6.452	-1723.197	-3.67
SOIL WATER AT START OF YEAR	1246.495	332936.625	
SOIL WATER AT END OF YEAR	1240.043	331213.437	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.024	0.00

****

****

ANNUAL TOTALS FOR YEAR 1990

	MM	CU. METERS	PERCENT
PRECIPITATION	128.78	34396.391	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	142.934	38177.453	110.99
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-14.156	-3781.052	-10.99
SOIL WATER AT START OF YEAR	1240.043	331213.437	
SOIL WATER AT END OF YEAR	1221.906	326369.031	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	3.981	1063.355	3.09
ANNUAL WATER BUDGET BALANCE	0.0000	-0.006	0.00

****

****

ANNUAL TOTALS FOR YEAR 1991

	MM	CU. METERS	PERCENT
PRECIPITATION	171.45	45794.016	100.00
RUNOFF	0.056	14.938	0.03
EVAPOTRANSPIRATION	150.170	40110.156	87.59
PERC./LEAKAGE THROUGH LAYER 4	0.595463	159.047	0.35
CHANGE IN WATER STORAGE	20.629	5509.839	12.03
SOIL WATER AT START OF YEAR	1221.906	326369.062	
SOIL WATER AT END OF YEAR	1246.516	332942.250	
SNOW WATER AT START OF YEAR	3.981	1063.355	2.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.035	0.00

****

****

ANNUAL TOTALS FOR YEAR 1992

	MM	CU. METERS	PERCENT
PRECIPITATION	200.66	53595.961	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	174.520	46613.926	86.97
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	26.140	6982.020	13.03
SOIL WATER AT START OF YEAR	1246.516	332942.219	
SOIL WATER AT END OF YEAR	1257.072	335761.781	

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	15.584	4162.466	7.77
ANNUAL WATER BUDGET BALANCE	0.0001	0.019	0.00

****

****

ANNUAL TOTALS FOR YEAR 1993

	MM	CU. METERS	PERCENT
PRECIPITATION	198.88	53121.059	100.00
RUNOFF	15.458	4128.797	7.77
EVAPOTRANSPIRATION	228.161	60941.512	114.72
PERC./LEAKAGE THROUGH LAYER 4	0.596142	159.229	0.30
CHANGE IN WATER STORAGE	-45.333	-12108.451	-22.79
SOIL WATER AT START OF YEAR	1257.072	335761.781	
SOIL WATER AT END OF YEAR	1226.505	327597.594	
SNOW WATER AT START OF YEAR	15.584	4162.466	7.84
SNOW WATER AT END OF YEAR	0.817	218.211	0.41
ANNUAL WATER BUDGET BALANCE	-0.0001	-0.026	0.00

****

****

ANNUAL TOTALS FOR YEAR 1994

	MM	CU. METERS	PERCENT
PRECIPITATION	155.45	41519.918	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	123.065	32870.437	79.17

PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	32.383	8649.456	20.83
SOIL WATER AT START OF YEAR	1226.505	327597.594	
SOIL WATER AT END OF YEAR	1259.705	336465.250	
SNOW WATER AT START OF YEAR	0.817	218.211	0.53
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.027	0.00

****

****

ANNUAL TOTALS FOR YEAR 1995

	MM	CU. METERS	PERCENT
PRECIPITATION	312.67	83514.727	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	278.375	74353.469	89.03
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	34.299	9161.267	10.97
SOIL WATER AT START OF YEAR	1259.705	336465.250	
SOIL WATER AT END OF YEAR	1292.849	345317.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.156	308.764	0.37
ANNUAL WATER BUDGET BALANCE	0.0000	-0.009	0.00

****

****

ANNUAL TOTALS FOR YEAR 1996

	MM	CU. METERS	PERCENT
PRECIPITATION	309.63	82700.617	100.00
RUNOFF	66.864	17859.207	21.60
EVAPOTRANSPIRATION	224.084	59852.523	72.37
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	18.678	4988.872	6.03
SOIL WATER AT START OF YEAR	1292.849	345317.719	
SOIL WATER AT END OF YEAR	1305.526	348703.812	
SNOW WATER AT START OF YEAR	1.156	308.764	0.37
SNOW WATER AT END OF YEAR	7.157	1911.543	2.31
ANNUAL WATER BUDGET BALANCE	0.0001	0.015	0.00

****

****

ANNUAL TOTALS FOR YEAR 1997

	MM	CU. METERS	PERCENT
PRECIPITATION	162.31	43351.672	100.00
RUNOFF	12.768	3410.443	7.87
EVAPOTRANSPIRATION	214.208	57214.477	131.98
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-64.670	-17273.264	-39.84
SOIL WATER AT START OF YEAR	1305.526	348703.812	
SOIL WATER AT END OF YEAR	1248.013	333342.094	
SNOW WATER AT START OF YEAR	7.157	1911.543	4.41
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.021	0.00

****

****

ANNUAL TOTALS FOR YEAR 1998

	MM	CU. METERS	PERCENT
PRECIPITATION	163.83	43758.730	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	165.215	44128.594	100.85
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-1.385	-369.852	-0.85
SOIL WATER AT START OF YEAR	1248.013	333342.094	
SOIL WATER AT END OF YEAR	1246.628	332972.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.010	0.00

****

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07

RUNOFF

```
------
 TOTALS            1.791   2.651   1.183   0.000   0.000   0.000
                   0.000   0.000   0.000   0.000   0.000   5.612

 STD. DEVIATIONS   3.911   5.453   2.754   0.000   0.000   0.000
                   0.000   0.000   0.000   0.000   0.000  17.748

EVAPOTRANSPIRATION
------------------
 TOTALS            9.690  10.237  24.053  27.311  20.174  26.405
                  35.770   5.236   4.368   5.788   8.864   8.619

 STD. DEVIATIONS   4.793   5.817   9.337  17.177  10.732   6.213
                  18.349   5.750   4.159   2.481   3.319   1.505

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
 TOTALS            0.0595  0.0596  0.0000  0.0000  0.0000  0.0000
                   0.0000  0.0000  0.0000  0.0000  0.0000  0.0595

 STD. DEVIATIONS   0.1882  0.1885  0.0000  0.0000  0.0000  0.0000
                   0.0000  0.0000  0.0000  0.0000  0.0000  0.1883

*******************************************************************************


*******************************************************************************

  AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998
------------------------------------------------------------------------------
                           MM           CU. METERS    PERCENT
                    -------------------  ----------  ---------
PRECIPITATION           197.94  ( 63.124)    52870.0   100.00

RUNOFF                   11.236  ( 20.8344)    3001.25    5.677

EVAPOTRANSPIRATION       186.514  ( 47.9393)    49817.50   94.226

PERCOLATION/LEAKAGE THROUGH    0.17866 (  0.28767)     47.721    0.09026
 LAYER  4

CHANGE IN WATER STORAGE     0.013  (  1.3231)      3.56    0.007
*******************************************************************************


*******************************************************************************

         PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998
---------------------------------------------------------------------
                                     (MM)      (CU. METERS)
```

---------- ------------

PRECIPITATION 35.31 9430.174

RUNOFF 56.123 14990.3936

PERCOLATION/LEAKAGE THROUGH LAYER 4 0.596142 159.22865

SNOW WATER 49.93 13336.5186

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2250

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0550

****

****

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.2115	0.2107
2	4.4943	0.0737
3	10.2488	0.0841
4	106.7082	0.2917

SNOW WATER 0.000

****
****

B2.3 Output File: Sensitivity Case 1

Section B1.2.5.3 summarizes the following output file for the sensitivity case 1.

```
                              AS-BS-30.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\SWL\HBS-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\SWL\AS-BS-30.D10
OUTPUT DATA FILE:             C:\HELP3\SWL\AS-BS-30.OUT


TIME:  12:13     DATE:   6/30/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (AVE.[mean] AREA C SILT PROP - BARE VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =       6.00    INCHES
          POROSITY                   =       0.3750 VOL/VOL
          FIELD CAPACITY             =       0.2100 VOL/VOL
          WILTING POINT              =       0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.2287 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                                   Page 1
```

```
                         AS-BS-30.OUT
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                        =     24.00   INCHES
  POROSITY                         =      0.4090 VOL/VOL
  FIELD CAPACITY                   =      0.2290 VOL/VOL
  WILTING POINT                    =      0.0560 VOL/VOL
  INITIAL SOIL WATER CONTENT       =      0.1793 VOL/VOL
  EFFECTIVE SAT. HYD. COND.        =  0.153000001000E-04 CM/SEC


                         LAYER  3
                         --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   3
  THICKNESS                        =     48.00   INCHES
  POROSITY                         =      0.4570 VOL/VOL
  FIELD CAPACITY                   =      0.0830 VOL/VOL
  WILTING POINT                    =      0.0330 VOL/VOL
  INITIAL SOIL WATER CONTENT       =      0.1116 VOL/VOL
  EFFECTIVE SAT. HYD. COND.        =  0.310000009000E-02 CM/SEC


                         LAYER  4
                         --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  18
  THICKNESS                        =    144.00   INCHES
  POROSITY                         =      0.6710 VOL/VOL
  FIELD CAPACITY                   =      0.2920 VOL/VOL
  WILTING POINT                    =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT       =      0.2909 VOL/VOL
  EFFECTIVE SAT. HYD. COND.        =  0.100000005000E-02 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER             =    75.00
FRACTION OF AREA ALLOWING RUNOFF    =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =    66.000  ACRES
EVAPORATIVE ZONE DEPTH              =    30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =     5.675  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =    12.066  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =     1.650  INCHES
INITIAL SNOW WATER                  =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    52.922  INCHES
TOTAL INITIAL WATER                 =    52.922  INCHES
TOTAL SUBSURFACE INFLOW             =     0.00   INCHES/YEAR


             EVAPOTRANSPIRATION AND WEATHER DATA
                             Page 2
1
```

AS-BS-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	2.383	2.772	1.756	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.676
STD. DEVIATIONS	5.043	5.521	4.206	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.904
EVAPOTRANSPIRATION						
TOTALS	14.436	13.648	28.325	21.021	15.130	12.581
	11.865	8.779	7.242	9.426	13.406	13.623
STD. DEVIATIONS	8.618	12.505	17.730	13.654	8.851	9.359

Page 3

1

AS-BS-30.OUT

	10.329	3.077	2.182	8.088	7.557	5.623

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	1.0027	0.8244	0.8275	2.3966	1.9688	1.4101
	1.5465	1.3904	1.4953	1.1839	0.8246	0.9991
STD. DEVIATIONS	1.1098	0.7426	0.9284	4.7125	4.7929	2.2258
	2.3876	2.0926	2.1860	1.2212	1.0429	0.7297

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	12.587	(21.5378)	3361.95	6.359
EVAPOTRANSPIRATION	169.481	(42.5209)	45268.22	85.622
PERCOLATION/LEAKAGE THROUGH LAYER 4	15.86984	(21.97929)	4238.808	8.01741
CHANGE IN WATER STORAGE	0.004	(1.6415)	1.06	0.002

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	56.632	15126.3691
PERCOLATION/LEAKAGE THROUGH LAYER 4	1.260208	336.59946
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3223	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1353	

****

****

Page 4

1

AS-BS-30.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.4859	0.2287
2	10.9289	0.1793
3	13.6119	0.1116
4	106.3985	0.2909
SNOW WATER	0.000	

****
****

1

B2.4 Output File: Sensitivity Case 2

Section B1.2.5.4 summarizes the following output file for the sensitivity case 2.

AS-GV-30.OUT

```

******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\SWL\HGV-ET30.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\SWL\AS-GV-30.D10
OUTPUT DATA FILE:            C:\HELP3\SWL\AS-GV-30.OUT


TIME:  13:22     DATE:   7/ 2/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (AVE.[mean] AREA C SILT PROP w/ GOOD VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                     =       6.00  INCHES
           POROSITY                      =     0.3750 VOL/VOL
           FIELD CAPACITY                =     0.2100 VOL/VOL
           WILTING POINT                 =     0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT    =     0.2079 VOL/VOL
           EFFECTIVE SAT. HYD. COND.     =  0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                                  Page 1
```

AS-GV-30.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4090 VOL/VOL
FIELD CAPACITY	=	0.2290 VOL/VOL
WILTING POINT	=	0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0717 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.0830 VOL/VOL
WILTING POINT	=	0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0837 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2902 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	66.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.064	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	48.775	INCHES
TOTAL INITIAL WATER	=	48.775	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

1

AS-GV-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.14
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.811	2.642	1.179	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.612
STD. DEVIATIONS	3.920	5.444	2.765	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.745
EVAPOTRANSPIRATION						
TOTALS	8.412	8.297	21.375	29.230	32.340	45.755
	10.289	4.724	4.518	5.773	8.050	7.747
STD. DEVIATIONS	3.766	4.737	10.446	15.992	12.374	18.019

1 Page 3

	12.844	4.853	5.441	2.346	3.159	1.332

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0571	0.0000	0.0000	0.0000	0.0572	0.0000
	0.0000	0.0571	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1805	0.0000	0.0000	0.0000	0.1808	0.0000
	0.0000	0.1806	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	11.243	(20.8017)	3002.95	5.680
EVAPOTRANSPIRATION	186.511	(49.0033)	49816.68	94.225
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.17135	(0.27590)	45.767	0.08656
CHANGE IN WATER STORAGE	0.017	(1.2779)	4.64	0.009

****

□
****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	56.115	14988.2559
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.571609	152.67578
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2231	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

□
****

1

AS-GV-30.OUT

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.1681	0.2079
2	4.3751	0.0718
3	10.2006	0.0837
4	106.1610	0.2902
SNOW WATER	0.000	

****
****

1

B2.5 Output File: Sensitivity Case 3

Section B1.2.5.5 summarizes the following output file for the sensitivity case 3.

```
                                 AS-PV-40.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\SWL\HPV-ET40.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\SWL\AS-PV-40.D10
OUTPUT DATA FILE:            C:\HELP3\SWL\AS-PV-40.OUT


TIME:   9:45     DATE:   7/ 2/2009


******************************************************************************

     TITLE:  40-INCH SOIL COVER (AVE.[mean] AREA C SILT PROP W/ POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =       6.00   INCHES
           POROSITY                    =       0.3750 VOL/VOL
           FIELD CAPACITY              =       0.2100 VOL/VOL
           WILTING POINT               =       0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT  =       0.2232 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =   0.130999997000E-04 CM/SEC


                                   LAYER  2
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                                    Page 1
```

```
                          AS-PV-40.OUT
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                     =      34.00    INCHES
   POROSITY                      =       0.4090 VOL/VOL
   FIELD CAPACITY                =       0.2290 VOL/VOL
   WILTING POINT                 =       0.0560 VOL/VOL
   INITIAL SOIL WATER CONTENT    =       0.0673 VOL/VOL
   EFFECTIVE SAT. HYD. COND.     =  0.153000001000E-04 CM/SEC


                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   3
   THICKNESS                     =      48.00    INCHES
   POROSITY                      =       0.4570 VOL/VOL
   FIELD CAPACITY                =       0.0830 VOL/VOL
   WILTING POINT                 =       0.0330 VOL/VOL
   INITIAL SOIL WATER CONTENT    =       0.0643 VOL/VOL
   EFFECTIVE SAT. HYD. COND.     =  0.310000009000E-02 CM/SEC


                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  18
   THICKNESS                     =     144.00    INCHES
   POROSITY                      =       0.6710 VOL/VOL
   FIELD CAPACITY                =       0.2920 VOL/VOL
   WILTING POINT                 =       0.0770 VOL/VOL
   INITIAL SOIL WATER CONTENT    =       0.1638 VOL/VOL
   EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

 SCS RUNOFF CURVE NUMBER            =      75.00
 FRACTION OF AREA ALLOWING RUNOFF   =     100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      66.000  ACRES
 EVAPORATIVE ZONE DEPTH             =      40.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =       3.627  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      16.156  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =       2.210  INCHES
 INITIAL SNOW WATER                 =       0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =      30.301  INCHES
 TOTAL INITIAL WATER                =      30.301  INCHES
 TOTAL SUBSURFACE INFLOW            =       0.00   INCHES/YEAR


             EVAPOTRANSPIRATION AND WEATHER DATA
                            Page 2
```

AS-PV-40.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	101.6 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.431	3.637	0.822	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.592
STD. DEVIATIONS	3.161	7.466	2.046	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.683
EVAPOTRANSPIRATION						
TOTALS	7.771	7.064	17.498	28.629	23.448	25.897
	44.446	7.012	4.620	5.989	7.235	6.831
STD. DEVIATIONS	2.547	3.135	9.152	14.833	11.762	5.328

Page 3

1

AS-PV-40.OUT

	17.300	5.564	4.416	2.348	2.858	2.412

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0033	0.0004	0.0013	0.0029	0.0017	0.0004
	0.0029	0.0021	0.0004	0.0033	0.0008	0.0008
STD. DEVIATIONS	0.0018	0.0013	0.0020	0.0020	0.0022	0.0013
	0.0020	0.0022	0.0013	0.0018	0.0018	0.0018

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	11.482	(23.6136)	3066.84	5.801
EVAPOTRANSPIRATION	186.441	(48.0410)	49798.02	94.189
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.02048	(0.00725)	5.471	0.01035
CHANGE IN WATER STORAGE	-0.001	(1.2796)	-0.30	-0.001

****

□
****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	55.918	14935.5908
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.004195	1.12056
SNOW WATER	49.93	13336.5186

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.1898
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0552

****

□
****

1 Page 4

AS-PV-40.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.4021	0.2232
2	5.8112	0.0673
3	7.8393	0.0643
4	59.9108	0.1638
SNOW WATER	0.000	

****
****

B2.6 Output File: Sensitivity Case 4

Section B1.2.5.6 summarizes the following output file for the sensitivity case 4.

```
                              COMP-30.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\SWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\SWL\COMP-30.D10
OUTPUT DATA FILE:            C:\HELP3\SWL\COMP-30.OUT


TIME:   9:55     DATE:   7/ 2/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (Area C Composite Blend D3/D2 - POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =     6.00   INCHES
          POROSITY                   =     0.3630 VOL/VOL
          FIELD CAPACITY             =     0.2100 VOL/VOL
          WILTING POINT              =     0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.1937 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.341000014000E-04 CM/SEC


                              LAYER  2
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                                Page 1
```

```
                          COMP-30.OUT
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      24.00   INCHES
POROSITY                     =       0.4020 VOL/VOL
FIELD CAPACITY               =       0.2290 VOL/VOL
WILTING POINT                =       0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT   =       0.0799 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.395999996000E-04 CM/SEC


                          LAYER  3
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   3
THICKNESS                    =      48.00   INCHES
POROSITY                     =       0.4570 VOL/VOL
FIELD CAPACITY               =       0.0830 VOL/VOL
WILTING POINT                =       0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT   =       0.1046 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.310000009000E-02 CM/SEC


                          LAYER  4
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                    =     144.00   INCHES
POROSITY                     =       0.6710 VOL/VOL
FIELD CAPACITY               =       0.2920 VOL/VOL
WILTING POINT                =       0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =       0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER            =      75.00
FRACTION OF AREA ALLOWING RUNOFF   =     100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      66.000  ACRES
EVAPORATIVE ZONE DEPTH             =      30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =       3.080  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      11.826  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =       1.650  INCHES
INITIAL SNOW WATER                 =       0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =      50.149  INCHES
TOTAL INITIAL WATER                =      50.149  INCHES
TOTAL SUBSURFACE INFLOW            =       0.00   INCHES/YEAR


          EVAPOTRANSPIRATION AND WEATHER DATA
                        Page 2
1
```

COMP-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	2.047	1.317	1.241	0.000	0.012	0.016
	0.000	0.000	0.000	0.011	0.006	3.992
STD. DEVIATIONS	4.682	2.489	2.772	0.000	0.038	0.051
	0.000	0.000	0.000	0.036	0.019	12.604
EVAPOTRANSPIRATION						
TOTALS	10.550	11.289	25.111	24.855	17.748	26.627
	36.878	4.021	4.278	6.423	9.691	9.840
STD. DEVIATIONS	5.694	7.199	13.144	16.696	9.096	6.719

Page 3

1

COMP-30.OUT

	16.345	2.772	4.027	4.487	3.993	2.324

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1215	0.3035	0.1214	0.0607	0.2427	0.1215
	0.3643	0.0000	0.0606	0.3036	0.1215	0.1821
STD. DEVIATIONS	0.2562	0.3199	0.2560	0.1919	0.3133	0.2562
	0.3135	0.0000	0.1918	0.3200	0.2561	0.2932

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	8.642	(15.4752)	2308.30	4.366
EVAPOTRANSPIRATION	187.312	(49.4770)	50030.59	94.629
PERCOLATION/LEAKAGE THROUGH LAYER 4	2.00342	(0.90679)	535.110	1.01212
CHANGE IN WATER STORAGE	-0.015	(1.4453)	-3.96	-0.007

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	39.864	10647.5039
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.608010	162.39839
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2423
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0550

****

****

Page 4

1

COMP-30.OUT

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	2.9513	0.1937
2	4.8717	0.0799
3	12.7500	0.1046
4	106.7896	0.2920
SNOW WATER	0.000	

****
****

1 Page 5

B2.7 Output File: Sensitivity Case 5

Section B1.2.5.7 summarizes the following output file for the sensitivity case 5.

COMP-40.OUT

```
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\SWL\HPV-ET40.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\SWL\COMP-40.D10
OUTPUT DATA FILE:            C:\HELP3\SWL\COMP-40.OUT


TIME:  10:17     DATE:   7/ 2/2009


******************************************************************************

     TITLE:  40-INCH SOIL COVER (Area C Composite Blend D3/D2 - POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                 LAYER  1
                                 --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =     6.00   INCHES
           POROSITY                    =     0.3630 VOL/VOL
           FIELD CAPACITY              =     0.2100 VOL/VOL
           WILTING POINT               =     0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.1896 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.341000014000E-04 CM/SEC


                                 LAYER  2
                                 --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                                  Page 1
```

```
                      COMP-40.OUT
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =       34.00   INCHES
POROSITY                   =       0.4020 VOL/VOL
FIELD CAPACITY             =       0.2290 VOL/VOL
WILTING POINT              =       0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.0657 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.395999996000E-04 CM/SEC


                         LAYER  3
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   3
THICKNESS                  =       48.00   INCHES
POROSITY                   =       0.4570 VOL/VOL
FIELD CAPACITY             =       0.0830 VOL/VOL
WILTING POINT              =       0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.0804 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.310000009000E-02 CM/SEC


                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
THICKNESS                  =      144.00   INCHES
POROSITY                   =       0.6710 VOL/VOL
FIELD CAPACITY             =       0.2920 VOL/VOL
WILTING POINT              =       0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT =       0.2801 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


              GENERAL DESIGN AND EVAPORATIVE ZONE DATA
              ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER            =      75.00
FRACTION OF AREA ALLOWING RUNOFF   =     100.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      66.000   ACRES
EVAPORATIVE ZONE DEPTH             =      40.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =       3.371   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      15.846   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =       2.210   INCHES
INITIAL SNOW WATER                 =       0.000   INCHES
INITIAL WATER IN LAYER MATERIALS   =      47.565   INCHES
TOTAL INITIAL WATER                =      47.565   INCHES
TOTAL SUBSURFACE INFLOW            =       0.00    INCHES/YEAR


              EVAPOTRANSPIRATION AND WEATHER DATA
                            Page 2
```

COMP-40.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	101.6 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.564	1.090	0.805	0.000	0.000	0.008
	0.000	0.000	0.000	0.000	0.000	3.925
STD. DEVIATIONS	3.628	2.241	1.930	0.000	0.000	0.024
	0.000	0.000	0.000	0.000	0.000	12.413
EVAPOTRANSPIRATION						
TOTALS	13.357	12.652	25.393	28.219	21.698	23.514
	25.847	7.732	3.601	6.218	11.862	10.430
STD. DEVIATIONS	6.185	7.233	12.074	16.132	13.750	7.405

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COMP-40.OUT

```
                              24.774    7.754    3.943    3.870    4.010    3.145

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                      0.0428   0.0000   0.0000   0.0000   0.0000   0.0000
                              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS             0.1352   0.0000   0.0000   0.0000   0.0000   0.0000
                              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

*******************************************************************************


*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998
-------------------------------------------------------------------------------
                                     MM               CU. METERS     PERCENT
                              --------------------    ----------    ---------
 PRECIPITATION                197.94    ( 63.124)      52870.0      100.00

 RUNOFF                         7.392   ( 14.7916)      1974.44       3.735

 EVAPOTRANSPIRATION           190.523   ( 49.1611)     50888.48      96.252

 PERCOLATION/LEAKAGE THROUGH    0.04277 (  0.13525)       11.423      0.02161
   LAYER  4

 CHANGE IN WATER STORAGE       -0.016   (  1.5582)        -4.31      -0.008
*******************************************************************************


*******************************************************************************

             PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998
   ------------------------------------------------------------------------
                                                 (MM)       (CU. METERS)
                                              ----------    ------------
     PRECIPITATION                              35.31         9430.174

     RUNOFF                                     39.255       10484.9033

     PERCOLATION/LEAKAGE THROUGH LAYER  4        0.427682      114.23323

     SNOW WATER                                 49.93        13336.5186

     MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.1989

     MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.0552
*******************************************************************************


*******************************************************************************
```

COMP-40.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	2.8893	0.1896
2	5.6725	0.0657
3	9.8053	0.0804
4	102.4318	0.2801
SNOW WATER	0.000	

****
****

1

B2.8 Output File: Sensitivity Case 6

Section B1.2.5.8 summarizes the following output file for the sensitivity case 6.

```
                              30PVRC85.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                  **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\SWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\SWL\30PVRC85.D10
OUTPUT DATA FILE:            C:\HELP3\SWL\30PVRC85.OUT


TIME:  10:32      DATE:   7/ 2/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER, M.AREA C SILT, P.VEG, 100% RUNOFF SCS 85

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =       6.00   INCHES
          POROSITY                   =       0.3750 VOL/VOL
          FIELD CAPACITY             =       0.2100 VOL/VOL
          WILTING POINT              =       0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =       0.2092 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.130999997000E-04 CM/SEC


                              LAYER  2
                              --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                                Page 1
```

30PVRC85.OUT

```
                MATERIAL TEXTURE NUMBER    0
THICKNESS                    =     24.00    INCHES
POROSITY                     =      0.4090 VOL/VOL
FIELD CAPACITY               =      0.2290 VOL/VOL
WILTING POINT                =      0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0727 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.153000001000E-04 CM/SEC


                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER    3
THICKNESS                    =     48.00    INCHES
POROSITY                     =      0.4570 VOL/VOL
FIELD CAPACITY               =      0.0830 VOL/VOL
WILTING POINT                =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0796 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.310000009000E-02 CM/SEC


                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   18
THICKNESS                    =    144.00    INCHES
POROSITY                     =      0.6710 VOL/VOL
FIELD CAPACITY               =      0.2920 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2754 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


               GENERAL DESIGN AND EVAPORATIVE ZONE DATA
               ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER            =     85.00
FRACTION OF AREA ALLOWING RUNOFF   =    100.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     66.000   ACRES
EVAPORATIVE ZONE DEPTH             =     30.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      3.000   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     12.066   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      1.650   INCHES
INITIAL SNOW WATER                 =      0.000   INCHES
INITIAL WATER IN LAYER MATERIALS   =     46.478   INCHES
TOTAL INITIAL WATER                =     46.478   INCHES
TOTAL SUBSURFACE INFLOW            =      0.00    INCHES/YEAR


                EVAPOTRANSPIRATION AND WEATHER DATA
```


1

30PVRC85.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	4.126	3.430	2.707	0.000	0.000	0.000
	0.001	0.000	0.000	0.000	0.000	5.508
STD. DEVIATIONS	8.359	6.570	5.194	0.000	0.000	0.000
	0.002	0.000	0.000	0.000	0.000	16.479
EVAPOTRANSPIRATION						
TOTALS	9.575	10.348	23.190	27.266	20.283	26.285
	31.955	5.488	4.390	5.881	8.986	8.464
STD. DEVIATIONS	4.510	6.052	8.623	16.762	10.794	6.304

Page 3

1

15.402	6.539	4.165	2.488	3.279	1.290

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0372	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0372
STD. DEVIATIONS	0.1177	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1178

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	15.771	(24.1662)	4212.32	7.967
EVAPOTRANSPIRATION	182.111	(45.2530)	48641.61	92.002
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.07445	(0.15696)	19.886	0.03761
CHANGE IN WATER STORAGE	-0.014	(1.3608)	-3.78	-0.007

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	52.346	13981.6191
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.372373	99.46016
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2123	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

****

1

30PVRC85.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.1885	0.2092
2	4.4320	0.0727
3	9.7059	0.0796
4	100.7145	0.2754
SNOW WATER	0.000	

****
****

B2.9 Output File: Sensitivity Case 7

Section B1.2.5.9 summarizes the following output file for the sensitivity case 7.

```
                                   30ASPV10.OUT
0
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\SWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\SWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\SWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\SWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\SWL\30ASPV10.D10
OUTPUT DATA FILE:             C:\HELP3\SWL\30ASPV10.OUT


TIME:  10:43      DATE:   7/ 2/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (Mean AREA C SILT, POOR VEG, 10% RUNOFF)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =       6.00   INCHES
           POROSITY                    =       0.3750 VOL/VOL
           FIELD CAPACITY              =       0.2100 VOL/VOL
           WILTING POINT               =       0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT  =       0.2105 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =   0.130999997000E-04 CM/SEC


                                   LAYER  2
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                                      Page 1
```

```
                    30ASPV10.OUT
             MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4090 VOL/VOL
FIELD CAPACITY             =      0.2290 VOL/VOL
WILTING POINT              =      0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0736 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.153000001000E-04 CM/SEC


                        LAYER  3
                        --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER   3
THICKNESS                  =     48.00   INCHES
POROSITY                   =      0.4570 VOL/VOL
FIELD CAPACITY             =      0.0830 VOL/VOL
WILTING POINT              =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0841 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.310000009000E-02 CM/SEC


                        LAYER  4
                        --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER  18
THICKNESS                  =    144.00   INCHES
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2852 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER            =     75.00
FRACTION OF AREA ALLOWING RUNOFF   =     10.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     66.000  ACRES
EVAPORATIVE ZONE DEPTH             =     30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      3.029  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     12.066  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      1.650  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     48.135  INCHES
TOTAL INITIAL WATER                =     48.135  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


          EVAPOTRANSPIRATION AND WEATHER DATA
                        Page 2

1
```

30ASPV10.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	4.438	2.215	0.683	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.955
STD. DEVIATIONS	12.353	4.338	2.069	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	3.019
EVAPOTRANSPIRATION						
TOTALS	11.102	11.707	24.466	27.267	20.231	26.421
	34.961	5.585	4.373	5.812	8.878	8.590
STD. DEVIATIONS	4.747	5.744	9.154	17.013	10.719	6.221

1

30ASPV10.OUT

	17.943	5.616	4.170	2.478	3.299	1.444

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0495	0.0000	0.0496	0.0000	0.0000	0.0497
	0.0000	0.0496	0.0496	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1566	0.0000	0.1570	0.0000	0.0000	0.1571
	0.0000	0.1568	0.1568	0.0000	0.0000	0.0000

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	52870.0	100.00
RUNOFF	8.290	(13.5152)	2214.32	4.188
EVAPOTRANSPIRATION	189.395	(49.4326)	50587.19	95.682
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.24798	(0.26139)	66.235	0.12528
CHANGE IN WATER STORAGE	0.009	(1.9458)	2.28	0.004

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****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	9430.174
RUNOFF	9.545	2549.5747
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.496654	132.65538
SNOW WATER	49.93	13336.5186
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2289	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

****

1 Page 4

30ASPV10.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.2082	0.2105
2	4.4856	0.0736
3	10.2530	0.0841
4	104.3246	0.2852
SNOW WATER	0.000	

****
****

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DOE/RL-90-17
Revision 1

Nonradioactive Dangerous Waste Landfill Closure/Postclosure Plan

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY Richland Operations Office

P.O. Box 550
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DOE/RL-90-17
Revision 1

Nonradioactive Dangerous Waste Landfill Closure/Postclosure Plan

Date Published
October 2009

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY Richland Operations Office
P.O. Box 550
Richland, Washington 99352

J. D. Aardal 09/28/2009
Release Approval Date

Executive Summary

This document contains the closure plan and postclosure actions for the Nonradioactive Dangerous Waste Landfill (NRDWL). The NRDWL is a non-operating landfill that is being closed according to the requirements of WAC 173-303, "Dangerous Waste Regulations."[1] It is centrally located within the 600 Area of the Hanford Site and is contiguous with the Solid Waste Landfill (SWL). The NRDWL received nonradioactive, containerized, dangerous waste constituents from 1975 through 1985. It also received a substantial amount of both friable and non-friable asbestos-containing waste material through 1988 (over 50 percent by volume), when the site ceased operations. Sanitary solid waste was placed in one trench that operated in 1976. The closure plan summarizes information about the site's operational history and environmental conditions, describes current monitoring systems, closure strategy and performance standards, and provides a plan and schedule for actions through postclosure.

Groundwater has been monitored at NRDWL since it ceased operations in accordance with a unit-specific monitoring plan coordinated with the overall Hanford Site groundwater-monitoring project. The wells are sampled semiannually for contaminant indicator parameters and site-specific parameters and annually for groundwater quality parameters (PNNL-12227, *Groundwater Monitoring Plan for Nonradioactive Dangerous Waste Landfill*).[2] In 2008, the only groundwater quality parameter exceeding drinking water standards was unfiltered iron.

Because groundwater monitoring for the NRDWL is closely associated with the underlying groundwater operable Unit (OU), the Permittees request the Washington State Department of Ecology (Ecology) exercise their authority and allow management of NRDWL groundwater through the underlying groundwater OU. The monitoring will be performed in compliance with the applicable regulatory requirements and would continue through the compliance period and, as necessary, during the postclosure period.

[1] WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303

[2] PNNL-12227, 1999, *Groundwater Monitoring Plan for Nonradioactive Dangerous Waste Landfill*, Pacific Northwest National Laboratory, Richland, Washington. http://www5.hanford.gov/arpir/?content=findpage&AKey=D1660026

All waste will be left in place as the landfill is closed. Closure activities will focus on the -installation of the final cover, including oversight during cover installation and appropriate certifications. Based on extensive research, an evapotranspiration cover is proposed for the NRDWL to minimize long-term migration of liquids through the closed landfill. This cover will consist of 60 cm (24 in.) of a fine-grained, low permeability soil covered by 15 cm (6 in.) of the same fine-grained soil mixed with 15 percent pea-gravel (by weight) to form an erosion-resistant topsoil that will sustain native vegetation. Construction of the final cover is estimated to take 56 to 60 weeks.

Geophysical surveys will be conducted before the cover is constructed to determine if voids of significant size are present in the subsurface. Trench boundaries and the approximate locations of waste containers will also be determined using geophysical techniques. Large voids will either be grouted or compacted, and the site surface graded.

The Area C borrow site tentatively has been identified as a source of suitable fine-grained soil material for the final cover. Compliance with *National Environmental Policy Act of 1969*[3] (NEPA) for Area C is necessary and therefore all NEPA documentation must be completed and the borrow source reclamation plan approved prior to initiating field activities. A Memorandum of Agreement and Implementation Plan for use of the Borrow Source at Area C were finalized and become effective in April 2009. Subject to meeting final volume requirements and final NEPA documentation requirements, the Area C borrow source, or its approved equivalent, has been identified as the most likely source of suitable fine-grained soil material for the final cover. Other necessary fill material such as non-structural fill, cobbles or riprap will likely be procured from locally available commercial (off-site) sources.

The proposed strategy is to close the site as a landfill in accordance with WAC 173-303-610, "Closure and Post-Closure,"[4] and WAC 173-303-665(6), "Closure and Post-Closure Care."[5] To facilitate closure of the entire Central Landfill, closure of the NRDWL will be coordinated and integrated with closure of the adjoining SWL, which will be closed in accordance with WAC 173-350, "Solid Waste Handling

[3] *National Environmental Policy Act of 1969*, 42 USC 4321, et seq. http://ceq.hss.doe.gov/Nepa/regs/nepa/nepaeqia.htm

[4] WAC 173-303-610, "Closure and Post-Closure," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303

[5] WAC 173-303-665(6), "Closure and Post-Closure Care," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303

Standards"[6] requirements. Postclosure activities will begin after Ecology's approval of closure. Activities include long-term monitoring activities, periodic inspections, and maintenance activities to ensure the long-term integrity of the closed landfill.

[6] WAC 173-350, "Solid Waste Handling Standards," *Washington Administrative Code*, Washington State Department of Ecology, Olympia, Washington. http://apps.leg.wa.gov/WAC/default.as px?cite=173-350

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Contents

Appendices

Figures

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Terms

bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
HELP	EPA/600/R-94/168, *The Hydrologic Evaluation of Landfill Performance Model*
LANL	Los Alamos National Laboratory
NEPA	*National Environmental Policy Act of 1969*
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	operable unit
RCRA	*Resource Conservation and Recovery Act of 1976*
RL	U.S. Department of Energy, Richland Operations Office
SWL	Solid Waste Landfill
Tri-Party Agreement	Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and/or disposal
WAC	*Washington Administrative Code*

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1 Introduction

The Nonradioactive Dangerous Waste Landfill (NRDWL), centrally located within the 600 Area of the Hanford Site, is a non-operating landfill that is being closed according to the requirements of WAC 173-303, "Dangerous Waste Regulations." The disposal location originally was developed and operated as a single landfill and known as the Central Landfill. When it began operating in 1973, the Central Landfill and was designated to receive sanitary solid waste, asbestos, and containerized chemical waste (e.g., labpacks) from Hanford Site operations. However, in 1975, the Central Landfill was subdivided into two units for operational (waste segregation) purposes. The northernmost unit of the Central Landfill was isolated for the disposal of asbestos waste materials and nonradioactive, containerized chemical waste. This northernmost unit was designated treatment, storage, and/or disposal (TSD) status and became known as the NRDWL. The southern unit was designated the Solid Waste Landfill (SWL).

The NRDWL received chemical waste from 1975 through 1985 and asbestos waste through May 1988. In 1988, all NRDWL operations ceased. This closure plan summarizes information about the site's operational history and environmental conditions, describes current monitoring systems, and provides a plan and schedule for actions through postclosure.

The Hanford Site has been divided into operable units (OU) to facilitate cleanup under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), RCW 70.105, "Hazardous Waste Management," and the *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action provisions. An OU is a grouping of individual waste management units based primarily on geographic area, common waste sources, or similar geohydrologic properties.

The NRDWL is a TSD unit assigned to the 200-SW-1 OU. The 200-SW-1 OU was a process-based OU composed of nonradioactive landfills, dumps, and pits. In June 2002, the U.S. Department of Energy (DOE), Richland Operations Office (RL) and the Washington State Department of Ecology (Ecology) signed the Tri-Party Agreement (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*) change requests concerning modification to the 200 Area's OU cleanup milestones. The change requests established a CERCLA remedial investigation/feasibility study process for the 200-SW-1 OU that included coordination of the closure of the NRDWL (a RCRA TSD unit). The waste sites in the 200-SW-1 OU, along with the 200-SW-2 OU (containing radioactive waste sites in the 200 East and 200 West Areas) were submitted for remedial investigation under DOE/RL-2004-60, *200-SW-1 Nonradioactive Landfills and Dumps Group Operable Unit and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan*, in 2004.

In 2006, a supplemental characterization data quality objective (DQO) process was conducted to provide for additional remedial investigation needs for waste sites on the Central Plateau. As a result of this DQO process, the DOE, U.S. Environmental Protection Agency (EPA), and Ecology agreed to establish new OUs grouped by similarity of remedial decision. The NRDWL is one of two waste sites in the 200-SW-1 OU that were not reassigned; the adjacent SWL is the other site remaining in this OU.

This document replaces the previously submitted NRDWL landfill closure and postclosure documents and serves as the sole document describing closure and postclosure action plans. The NRDWL closure plan originally was submitted to Ecology in August 1990. Since that time, changes to the strategy for closure have occurred and are reflected in this closure plan. This plan does not include the closure or postclosure plans of the adjacent SWL. DOE/RL-2008-54, *Hanford Solid Waste Landfill Closure Plan* describes closure of the SWL. However, the closure of the NRDWL will be performed in a manner to allow the cover and other closure features of the two facilities to be coordinated, as appropriate, to maintain design integrity and cover performance.

As documented in the Tri-Party Agreement, the effective date of RCRA for nonradioactive hazardous waste is November 19, 1980. The TSD activity refers to units that received nonradioactive hazardous waste after this effective date. Waste disposed before the effective date is subject to past practice authority under the Tri-Party Agreement. Past practice waste in this TSD unit can still be addressed by closing the landfill; the closure actions described herein will address the corrective action requirements. Dangerous waste listings described in WAC 173-303-080, "Dangerous Waste Lists," apply to waste disposed before the effective date. As used in this document, the term "dangerous waste" also will apply to waste disposed before the effective date of RCRA; however, a list of dangerous waste disposed prior to the effective date has not yet been generated.

1.1 Closure Approach

The approach proposed in this NRDWL closure plan includes closure of the unit as a landfill in accordance with WAC 173-303-610, "Closure and Post-Closure," and WAC 173-303-665(6), "Closure and Post-Closure Care." A final cover, designed to prevent the postclosure escape of buried waste, will be placed over the unit to return the site to near natural conditions and to function with minimum maintenance through postclosure care.

1.2 Part A Permit Application

A Part B permit application for the NRDWL, dated November 1985, refers to the initial Part A permit application for the NRDWL as being submitted to the EPA in November 1980 and included other TSDs. Revisions to the Part A permit application are as follows.

- In September 1987, the permit application was issued as Revision 1 and the NRDWL was addressed as a stand-alone unit.
- In November 1987, Revision 2 added Westinghouse Hanford as a co-operator.
- In 1990, Revision 3 added 39 waste codes, expanded the process description, and updated other descriptive information.
- In 1992, Revision 4 transferred authority and responsibility for the unit from Westinghouse Hanford as co-operator to Bechtel Hanford as co-operator.
- In 2002, Revision 5 transferred co-operator responsibility from Bechtel Hanford to Fluor Hanford.
- In August 2008, Revision 6 converted the Part A into a new Part A format.
- In October 2008, Revision 7 changed the contractor name and transferred operational control to the CH2M HILL Plateau Remediation Company.

2 Facility Description and Location Information

This chapter describes the Hanford Site, the history and function of the NRDWL, and the current security program.

2.1 Hanford Site Description

The Hanford Site, approximately 1,520 km^2 (586 mi^2) of semiarid land, is located in Benton County northwest of the city of Richland, Washington (Figure 2-1). The city of Richland adjoins the southernmost portion of the Hanford Site boundary and is the nearest population center. In early 1943, the U.S. Army Corps of Engineers selected this site as the location for reactors, chemical separations, and related activities for the production and purification of plutonium for atomic weapons used in 1945 at the end of the Second World War. After the end of the Second World War, the Hanford Site engaged in the production of radioactive isotopes and plutonium for the nation's defense, as well as nuclear energy research and development. The current mission at the Hanford Site includes research and development, waste management, and environmental restoration and remediation.

2.2 Nonradioactive Dangerous Waste Landfill

The NRDWL is a land disposal unit located near the geographic center of the Hanford Site (Figure 2-1). The NRDWL is approximately 4 ha (10 a) consisting of a series of 19 parallel trenches. The SWL, a non-operating sanitary solid waste landfill, is located adjacent to the NRDWL to the south-southwest. Figure 2-2 is a topographical map of the SWL and NRDWL. From 1975 through June 1985, the NRDWL received nonradioactive, dangerous waste constituents from Hanford Site operations. In addition to dangerous waste constituents, the NRDWL received over 50 percent of its waste volume in the form of friable and non-friable asbestos containing material through 1988 and sanitary solid waste in one trench that operated during 1976. Figure 2-3 provides an aerial photograph that includes the NRDWL.

2.2.1 Operational History of the Nonradioactive Dangerous Waste Landfill

The area presently designated as the NRDWL and the SWL originally was developed and operated as a single landfill, referred to as the 600 Area Central Landfill. The landfill began operating in 1973 and was designated to receive sanitary solid waste, asbestos, and containerized chemical waste from Hanford Site operations. The original boundary of the Central Landfill covered an area of approximately 15 ha (38 a) and was divided into two units: the northernmost unit (approximately 4 ha [10 a]) was allocated for the disposal of nonradioactive chemical waste and asbestos waste materials and the southernmost unit (approximately 11 ha [28 a]) was used for the disposal of nonradioactive, sanitary solid waste. Figure 2-4 shows the present configuration of the 600 Area Central Landfill. The original Central Landfill is designated Phase I. Phase II in the figure refers to additional area later added to the SWL portion of the landfill.

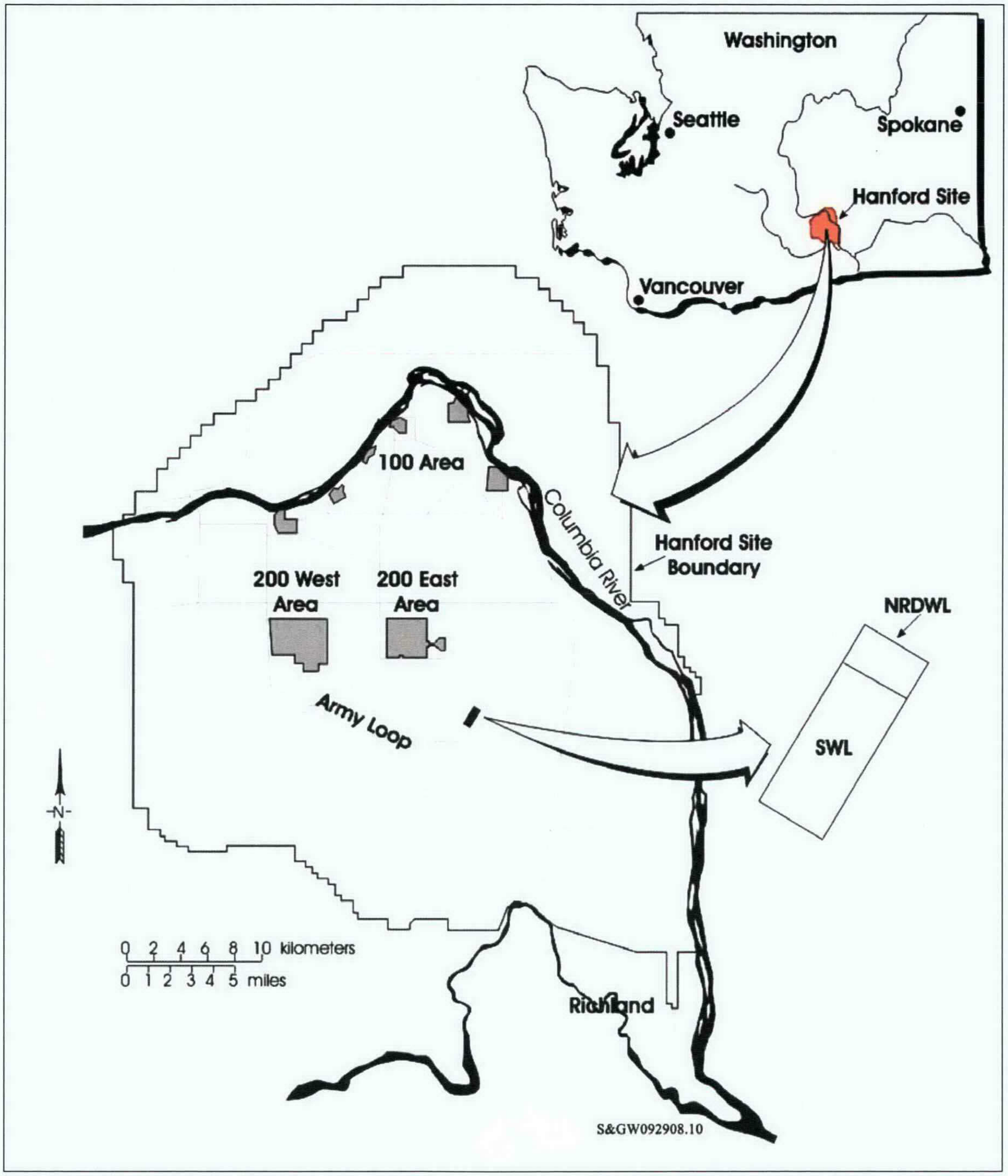
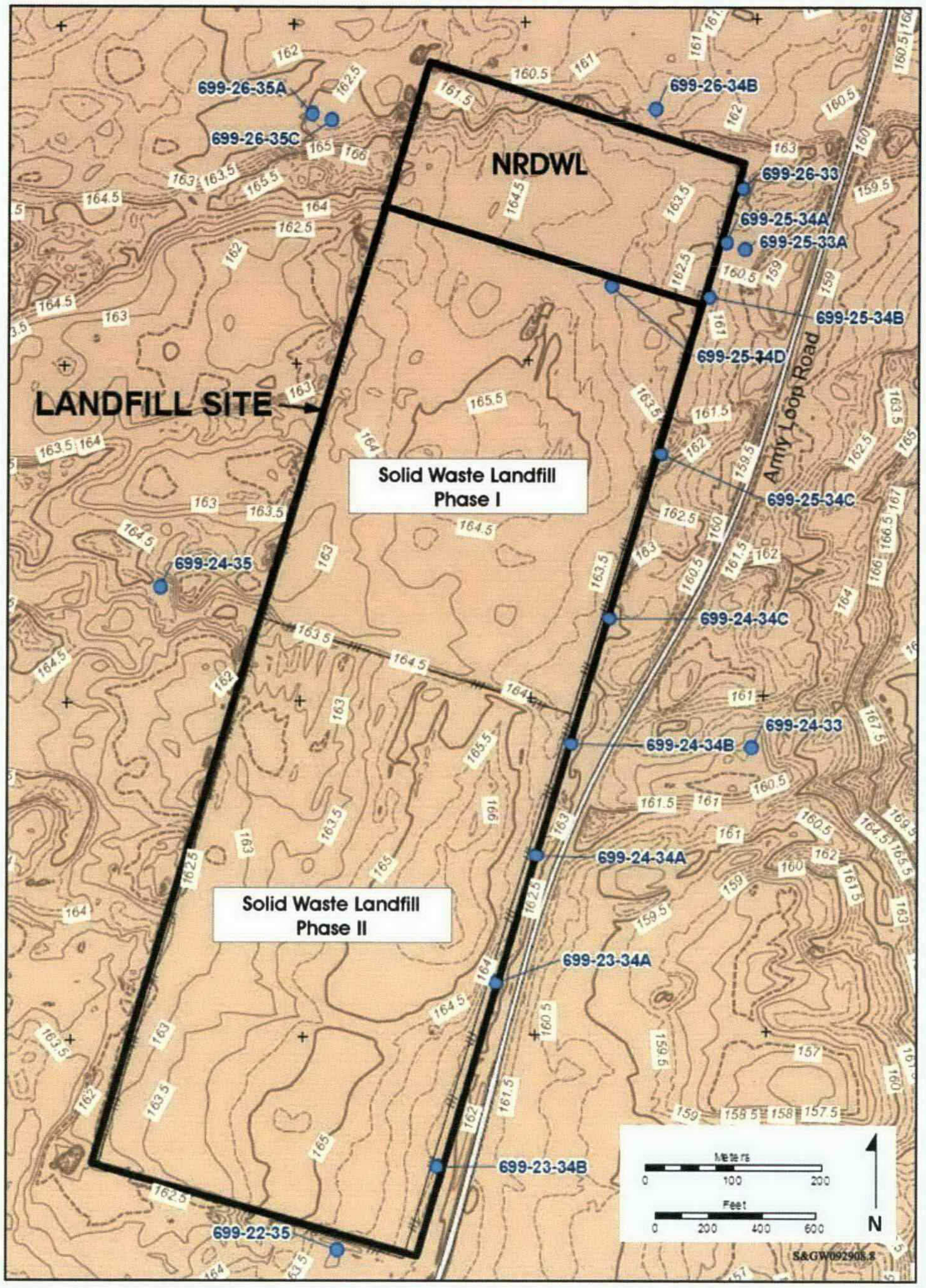


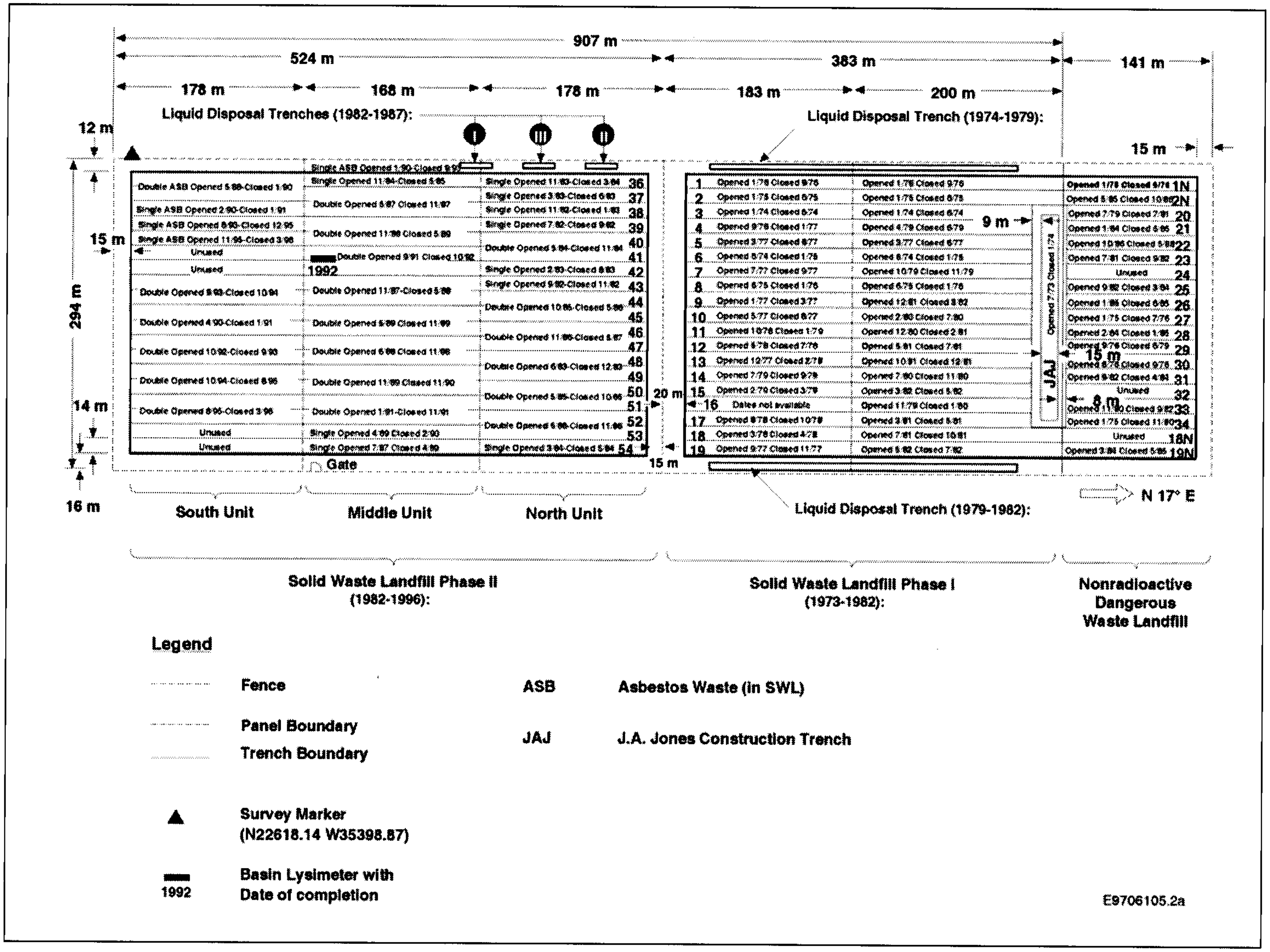
Figure 2-1. Regional Map with Locations of the Hanford Site, the SWL, and the NRDWL



Groundwater-monitoring wells are included and are identified by the prefix 699. Additional information on groundwater monitoring is provided in Section 5. Topography shown in 0.5 m intervals.

Figure 2-2. Topographical Map of the SWL and NRDWL

Figure 2-3. Aerial Photograph of the SWL and the NRDWL (2006)



Note: In 2009, fencing around the SWL was not continuous.

Figure 2-4. SWL and NRDWL Arrangement

Before management of the NRDWL and the SWL was separated, dangerous waste received at the Central Landfill was placed into designated trenches, referred to as chemical trenches, located in the northernmost unit of the Phase I area. This northernmost unit also received asbestos waste materials that were placed into designated asbestos trenches. Although no regulatory requirement existed to segregate waste when the landfill first began operating, chemical and asbestos waste was segregated from the main body of the sanitary waste as a good management practice.

Because of the presence of regulated dangerous waste in the chemical trenches, the northernmost unit of the Phase I area was formally designated the NRDWL and a TSD unit. The southernmost unit of the Phase I area, designated the SWL, is managed and regulated as a separate facility from the NRDWL. Nineteen trenches are defined within the NRDWL boundary. Dangerous wastes were disposed in six chemical trenches (19N, 26, 28, 31, 33, and 34). Trench 34 was the first trench in the NRDWL excavated for disposal and began receiving waste in January 1975. Starting in 1984, chemical wastes were segregated further into either oxidizer or corrosive chemical trenches. While disposal of dangerous wastes ceased at the NRDWL in May 1985, it continued to receive asbestos waste through mid-1988, at which time a dedicated trench in the SWL was opened for the disposal of asbestos waste. Nine trenches at the NRDWL (2N, 20, 21, 22, 23, 25, 27, 29, and 30) were used for the disposal of asbestos waste. In addition, one trench (1N) in the NRDWL was used exclusively for sanitary solid waste. Three trenches (18N, 24, and 32) remain unused.

2.2.2 Landfill Methodology

The NRDWL used the trench method where waste was placed in an excavated trench and covered. As landfill space was needed, trenches were excavated with a dragline excavator following surveyed center lines at 14 m (46 ft) spacings. Excavated soil was deposited on both sides of the trench in the form of spoil piles and reserved for use as cover material. As noted below, at the end of each day a portion of the spoil piles was pushed over the filled portion of trenches to make an operational cover. When the NRDWL ceased accepting waste, the area was final graded and the operational cover became the interim cover. All materials used to construct the operational/interim cover came from NRDWL excavations. No new material was added or imported to create the NRDWL interim cover.

All trenches were excavated to approximately 120 m (400 ft) in length, 5 m (16 ft) in width at the base, and 5 m (15 ft) in depth. Trenches were separated by a triangular column of undisturbed soil with approximately 1:1 side slopes. The final profile of the trench varied depending on the type of waste received. A representative cross-sectional diagram of different trench types is provided in Figure 2-5.

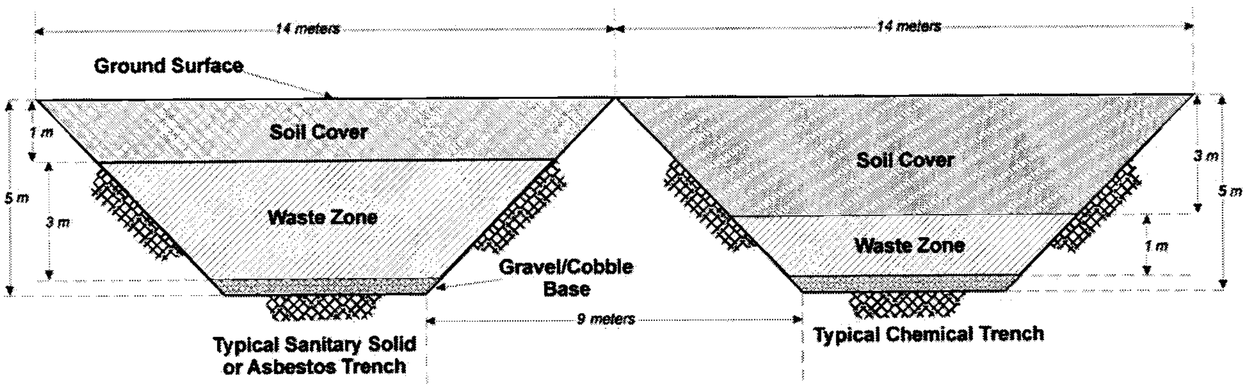


Figure 2-5. Typical NRDWL Trench Cross Section (lengths approximate)

2.2.2.1 Chemical Trenches

The chemical trenches were constructed with a ramp to the bottom of the trench to allow transfer vehicles access to the working face. A 20 to 30 cm (8- to 12-in.) layer of gravel and cobble was placed over the bottom of the trench to form a temporary roadbed.

The transport trucks backed down the access ramp and up to the working face of the trench to offload the containers. A landfill operator supervised waste placement. Containers (primarily 208 L [55-gal] lab packs) were normally arranged in single-layer rows, standing on end in the bottom of the trenches; however, when a large shipment of drums was received, drums were stacked two high. Typically, at the end of each day, a portion of the spoil pile was pushed over the waste containers with a crawler type tractor to form the operational cover. The operational cover thickness for the chemical trenches was approximately 3 m (10 ft). Where drums were stacked two high, the cover was reduced to approximately 2 m (6 ft).

2.2.2.2 Asbestos and Sanitary Trenches

For the asbestos and sanitary waste trenches within the NRDWL, waste was either unloaded at the base of the working face (similar to the chemical trenches) or at the top of the working face. When waste was unloaded at the edge of the top of the trench, a tractor was used to push the waste into the trench to the desired height. In both cases, a portion of the spoil pile was daily pushed over the refuse to form an operational cover with a typical thickness from 1.2 to 1.8 m (4 to 6 ft), depending on the waste layer thickness.

2.2.3 Soil Gas Monitoring at the Nonradioactive Dangerous Waste Landfill

Soil gas sampling, a method of subsurface characterization used at the NRDWL, has been used to assess the status of the contamination in the vadose zone. Three soil gas campaigns (1992, 1993, and 1997) are described below. In addition, soil gas has been monitored on a quarterly basis at 19 soil gas monitoring points at the SWL since 1993. Initially, some volatile organic compounds were occasionally detected at low concentrations (e.g., 1,1,1-trichloroethane was detected at 0.45 ppmv), but the frequency of detections and the concentrations have declined (e.g., 1,1,1-trichloroethane has been below the 0.015 ppmv detection limit) since 1999. The methane levels recorded from the soil gas monitoring points have generally been nondetect or between 0.1 and 0.2 percent over the period of record from 1996 to 2007. No additional soil gas monitoring will be performed as part of the proposed NRDWL closure activities.

In 1992, vadose zone gasses were sampled during installation of the two wells 699-26-33 and 699-25-34A (WHC-SD-EN-AP-026, *Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill, Hanford, Washington*). A chlorinated hydrocarbon, probably carbon tetrachloride, was detected as deep as 37 m (121 ft), which is near the water table. A malfunctioning gas chromatograph prevented identification of the compound beyond a chlorinated hydrocarbon.

In 1993, a comprehensive shallow soil gas study was conducted consisting of approximately 40 soil gas wells at depths from 1.2 to 4.6 m (4 to 16 ft) below ground surface (bgs) and at approximately 30 m (100 ft) spacing over the entire NRDWL footprint (WHC-SD-EN-TI-199, *Nonradioactive Dangerous Waste Landfill Soil Gas Survey: Final Data Report*). Several volatile organic compounds disposed in the NRDWL were detected in the soil vapor. Generally, higher concentrations and diversity of contaminants were detected in the older chemical disposal trench region in the eastern one-third (trenches 31 to 34) of the NRDWL. Compounds detected in this area included trichloroethylene, tetrachloroethylene, carbon tetrachloride, 1,1,1-trichlorethane, and chloroform. The contaminants detected show a high correlation to trench location and waste in the older trenches. Within a single waste trench, the distribution of detected vapors was not uniform. This may indicate the vapors are emanating from discontinuous point sources, such as a drum or single type of disposed waste.

Three volatile organic compounds were reported to have relatively wide distribution throughout the NRDWL in the 1993 study. Acetone appears to be related to disposal of sewage wastes along the western fence of the NRDWL and portions of the SWL. Relatively low concentrations of trichloroethene also were detected in several locations throughout the NRDWL. These vapors appear to be related to wastes disposed in both the NRDWL and SWL. Tetrachloroethene had the widest distribution and highest concentration. The distribution of tetrachloroethene appears to be related to wastes disposed in the NRDWL chemical trenches and in sanitary trench 1N along the west side of the NRDWL. Some tetrachloroethene vapors may also originate from portions of the SWL outside of the shallow soil gas study network. The nature of the shallow soil gas study made extrapolation of vadose zone vapor to volatile organic compounds reported in groundwater inappropriate.

Most of the probes for the shallow soil gas study were installed in shallow holes approximately 1.2 to 1.8 m (4 to 6 ft) bgs. However, four sets of deeper probes (2.7 to 4.6 m [9 to 15 ft] bgs) were installed around the borders of the NRDWL. Three of these sets were located along the shared boundary between NRDWL and SWL. Higher concentrations of carbon dioxide and lower oxygen levels were detected in these deeper probes, which is characteristic of landfills. Tetrachloroethene also was detected in these deeper probes, and the concentration appeared to increase with depth. This trend may be related to downward dispersion of this dense, persistent vapor. However, it was concluded in the report (WHC-SD-EN-TI-199) that extrapolation of these data to sources of groundwater contamination is inappropriate because of the shallow nature of the soil gas study.

The most recent soil gas study was conducted in 1997 (BHI-01115, *Evaluation of the Soil Gas Survey at the Nonradioactive Dangerous Waste Landfill*). This study was conducted in six shallow probes (0.8 m [6 ft] bgs) and 33 deep probes (8.8 to 30 m [29 to 97 ft] bgs), which were mainly located in the eastern portion of the NRDWL where the highest concentrations of soil gas were discovered in the 1993 study (WHC-SD-EN-TI-199). Six volatile organic compounds were detected: 1,1,1-trichloroethane, 1,1-dichloroethane, tetrachloroethene, trichloroethene, carbon tetrachloride, and chloroform. All of these, except for 1,1-dichloroethane also were detected in the 1993 study. 1,1,1-Trichloroethane was the most widespread and detected in all but one of the samples from the deep probes. However, 1,1,1-trichloroethane was not detected in samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 part per million by volume (ppmv). In general, the shallow probes had decreasing maximum detected concentrations of 1,1,1-trichloroethane, tetrachloroethene, and trichloroethene between 1993 and 1997, however the maximum detected concentrations of carbon tetrachloride and chloroform increased during this period.

2.2.4 Local Biology

The Hanford Site lies within the boundaries of the sagebrush vegetation zone. The NRDWL and SWL are within an area covered by sagebrush-bitterbrush/cheatgrass type vegetation that extends south from the old Hanford townsite to the Horn Rapids (Cline et al., 1977, "Plants and Soil of a Sagebrush Community on the Hanford Reservation"). The sagebrush/cheatgrass is likely similar to the vegetation that existed prior to 1941 when the Hanford Site was established. The incorporation of weeds of European origin accounts for the major of vegetative changes. The low species diversity in the area is attributed to the generally level terrain, (i.e., habitat homogeneity) and the low annual precipitation.

This area has been protected from grazing livestock since 1943. The most important mammalian herbivore in the area is the black-tailed hare (*Lepus californicus*). A study of the dietary habits of black-tailed hares on the Hanford Site indicates that the hares prefer perennial forbs, such as yarrow (*Achillea millefolium*) and turpentine cymopterus (*Cymopterus terebinthinus*). Both plants are sparsely represented in the community. In addition, black-tailed hare prefer rabbitbrush to sagebrush. They seldom eat shrubs, and do not eat cheatgrass.

Two kinds of environmental stresses are expected in this area: fire and mechanical soil disturbances. Fire can be caused by lightning or ignited by humans. Burning destroys sagebrush plants, but perennial grasses and forbs generally survive. Some annual seeds survive the fire and begin growing within a year. Surrounding vegetation also provide seeds for revegetation of the burned area. Mechanical disturbances, such as construction activities, effectively destroy all existing vegetation. Invading plants include the very aggressive Russian thistle, which may dominate in the first year, but thereafter cheatgrass dominates and resists invasion by native plants and Salsola. Rabbitbrush is more aggressive than sagebrush in terms of invading disturbed soils.

Unless major changes in land use occur, vegetation is expected to maintain essentially the same composition and productivity for 20 to 30 years. Wildfire is the most likely disturbance. From a longer-term point of view, change in climate, whether wetter or drier, would have a profound impact upon plant species composition and primary productivity.

2.3 Security

Security information for the Hanford Facility is discussed in Permit Condition II.M and Attachment 33 to the Hanford Facility RCRA Permit (WA7890008967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*). The security information pertaining to the 200 Areas applies to this TSD unit.

Changes to security are expected to occur during the course of Central Plateau deactivation and decommissioning activities. Security measures will remain in place that limit entry to authorized personnel and that preclude unknowing access by unauthorized individuals.

Signs will be posted at the NRDWL to meet the requirements of WAC 173-303-310(2)(a), "Security;" "Signs must bear the legend 'Danger-Unauthorized Personnel Keep Out,' or an equivalent legend, written in English and must be legible from a distance of 25 ft or more."

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3 Process Information

The NRDWL received nonradioactive, dangerous waste for disposal from process operations, research and development laboratories, and maintenance and transportation functions throughout the Hanford Site. No actual processing of dangerous waste occurred at the NRDWL. Based on available information, including disposal records and operator knowledge, all dangerous waste disposed at the NRDWL was containerized. The asbestos waste and the sanitary solid waste generally were not containerized before disposal. Shipments of dangerous waste were made from generating units on the Hanford Site to the NRDWL. The waste was placed in an ordered array in the bottom of a designated landfill trench. An approximate 2 to 3 m (6- to 10-ft) thick operational cover of native soil was then placed over the waste containers.

Sanitary waste and asbestos were disposed in accordance with regulatory requirements in place at the time of disposal (e.g., asbestos materials were disposed of in accordance with 40 CFR 61, Subpart M, "National Emission Standard for Asbestos").

Generators of dangerous waste on the Hanford Site were responsible for identifying the dangerous waste constituents of their waste and for packaging the waste in U.S. Department of Transportation-approved containers for transport to the NRDWL. Once identified by the generators, no analytical verification of generator waste information contained on the disposal records was made at the NRDWL. Depending on the waste type, waste was placed in one of three types of trenches designated to receive chemical, asbestos, or sanitary solid waste. Table 3-1 shows the disposal locations of the various waste types. All dangerous waste was disposed in the chemical waste trenches.

Starting in 1984, dangerous waste was further segregated into either an oxidizer or a corrosive chemical trench, according to compatibility. The oxidizer trench (19N) received waste designated as oxidizers and all other dangerous waste went into the corrosive trenches. An excavation occurred at trench 19N in November 1985 to retrieve containers of sodium nitrite mistakenly disposed in the trench (Letter 91-EAB-078, "Report on the Excavation and Inventory of Trench 19N at the Nonradioactive Dangerous Waste Landfill, Hanford Site") (Appendix A). During operations, trench 19N had received seven shipments of empty containers (between April 1984 and May 1985) and four shipments of chemical waste (starting in June 1984). The shipments of empty containers were not regulated under WAC 173-303. In November 1985, trench 19N was excavated. Initially, all containers were removed from the trench. The empty containers were then sent to the adjacent SWL for disposal. Containers with regulated waste were either transferred to the 2727S Building or returned to trench 19N and covered. It was noted during the excavation that there was no evidence of leaking containers or soil contamination.

The normal handling procedure that waste generators followed for containers holding liquid dangerous waste was to absorb all free liquid with absorbent materials or use labpacks or combination packages (described below) before shipment to the NRDWL. No containers holding free liquids are known to have been placed in the NRDWL (liquid in labpacks or combination packages is not considered free liquid). Labpacks refer to a containment system where two or more small containers of compatible chemicals are placed in a single larger container (e.g., 208 L [55-gal] drum). Combination packages consist of small containers of one type of chemical placed in a single larger container. The maximum volumes of these inside or smaller containers were 4 L (1 gal) for glass containers and 19 L (5 gal) for plastic or metal containers. The smaller inside containers were surrounded with enough absorbent material to completely absorb all the contained liquid and to minimize outer container void space. Absorbent materials consisted of vermiculite or an equivalent (e.g., diatomaceous earth) material.

Table 3-1. NRDWL Waste Type by Trench

Trench*	Waste Type Disposed
1N	Sanitary Trash
2N	Asbestos
20	Asbestos
21	Asbestos
22	Asbestos
23	Asbestos
24	Unused
25	Asbestos
26	Corrosive
27	Asbestos
28	Corrosive
29	Asbestos
30	Asbestos
31	Chemical
32	Unused
33	Chemical
34	Chemical
18N	Unused
19N	Oxidizers

*See Figure 2-4 for trench location and orientation.

4 Waste Characteristics

The NRDWL consists of a series of chemical, asbestos, and sanitary solid waste trenches (Table 3-1). Dangerous waste disposal was limited to the chemical trenches. Disposal records indicate that over 2,700 items from the chemical waste inventory were buried at the site over a period of approximately 11 years. The chemical trenches collectively hold a large variety of small quantity laboratory chemical waste and larger quantities of general paint, oil, and solvent waste. This chapter describes the general characteristics of the waste disposed at the NRDWL and provides inventory information.

4.1 Waste Type

Waste disposed in the NRDWL is categorized as follows:

- Chemical waste
  - Small quantity laboratory chemicals
  - Bulk organic waste, solvent waste, paints, paint thinners, and waste oil
  - Empty containers
- Asbestos material
- Sanitary solid waste.

Chemical waste includes both regulated and non-regulated, nonradioactive chemicals. Chemical waste was disposed into six of the NRDWL trenches (Table 3-1).

- The small quantities of laboratory chemicals consisted of out-of-date unused reagent inorganic and organic chemicals, out-of-date used reagent chemicals, spent laboratory chemicals, and laboratory formulations. These chemicals consisted primarily of metallic salts, acids, bases, oxidizers, organic chemicals, and flammable materials.

- Bulk organic waste is nonradioactive solvent waste, paints, paint thinners, and waste oils. The largest quantities of this waste consisted of approximately 8,800 kg (19,400 lb) of solvent waste, paints, paint thinners, and waste oils absorbed on an absorbent and disposed in trench 33. In addition, trench 26 contains approximately 26,000 kg (57,300 lb) of non-regulated, oil-soaked sand.

- Empty containers buried in the NRDWL include both regulated and non-regulated containers (per WAC 173-303-160, "Containers") that at one time held regulated, nonradioactive dangerous waste. These empty containers consist primarily of 208 L (55 gal) metal and fiber drums, but others include fiber, plastic, and metal containers of various sizes.

Compatibility issues are not considered to be of concern with the buried waste. Reactive cyanide- and sulfide-containing chemicals and strong corrosive mineral acids (hydrochloric, sulfuric, nitric, and hydrofluoric acids) disposed in the NRDWL are not considered a concern for the several reasons. Individual occurrences of these incompatible materials are, for the most part, limited to:

- Less than 1 kg (2.2 lb) in quantity
- Physically separate from one another
- Packaged in lab packs surrounded by sorbing materials
- Covered by 3 m (10 ft) of soil.

Asbestos material is defined as asbestos or material containing asbestos. All asbestos material disposed in the NRDWL was nonradioactive and nonhazardous. Asbestos material was disposed into nine of the

NRDWL trenches. The asbestos material accounts for over 50 percent (by volume) of all waste disposed in the landfill. The bulk of the asbestos material at the NRDWL came from building demolition or renovation activities on the Hanford Site. Chrysotile, the main mineral in asbestos insulation is virtually insoluble in water and asbestos does not move with groundwater flow (NHDES-WMD-00-1, *Guidance for Managing Asbestos Disposal Sites*). The asbestos material was disposed in accordance with 40 CFR 61, Subpart M.

Sanitary solid waste is nonradioactive and nonhazardous and consisted of the same type of waste as was disposed in the adjacent SWL. The waste consisted largely of office and lunchroom waste and construction and demolition debris. Trench 1N was dedicated strictly for sanitary solid waste. In addition, one instance on January 5, 1976 of the disposal of approximately 5,300 L (1,400 gal) of septic tank sludge occurred in trench 34.

4.2 Waste Inventory

Appendix B provides the current inventory of chemical waste placed in the NRDWL. The waste inventory was prepared from the original manifests that document the disposal of materials to the NRDWL chemical trenches. The inventory contains approximately 2,700 individual chemical inventory entries. In addition, work performed in 1985 resulted in some changes to the inventory for trenches 19N and 28. This work is summarized in Letter 91-EAB-078 (Appendix A).

4.2.1 Dangerous Waste Inventory (Maximum)

The total maximum quantity of dangerous waste currently in the NRDWL is approximately 141,000 kg (311,000 lb). However, the current waste inventory (provided in Part A of the permit application form) is approximately 135,000 kg (298,000 lb). The maximum estimate is based on the current inventory and takes into account the additional waste (approximately 6,000 kg [13,000 lb]) removed from trench 19N during an excavation in 1985 (Chapter 3). For the maximum inventory, Table 4-1 presents the quantities of waste attributed to each respective trench.

Table 4-1. Maximum Dangerous Waste Inventory

Trench	Approximate Maximum Waste Quantity (kg)
19N	13,000*
26	3,000
28	17,000
31	10,000
33	19,000
34	85,000
Total	135,000

* Approximately 6,000 kg later removed during an excavation in 1985.

4.2.2 Asbestos and Solid Waste Inventory

The estimated maximum inventory of asbestos-containing material and sanitary solid waste, based on the available volume for a typical trench (Figure 2-5) is 28,000 m^3 (36,000 yd^3) and 3,000 m^3 (4,000 yd^3), respectively. Specific inventory records were not kept for asbestos material or sanitary solid waste.

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5 Groundwater Monitoring

This chapter describes groundwater monitoring at the NRDWL, including geology, hydrology, and the current groundwater monitoring programs. In addition, it is proposed that when the closure plan is incorporated into the permit the groundwater section will be updated with a final status groundwater monitoring plan or will be updated to facilitate implementation of the alternative groundwater monitoring requirements in WAC 173-303-645(1)(e), "Applicability." through coordination with the 200-PO-1 Groundwater OU.

A compendium of relevant groundwater and site background information specific to the NRDWL and the SWL is available in the Administrative Record (CH2M HILL, 2009, *Supplemental Groundwater Information Compendium*). Although not required by WAC 173-303, the compendium compiles information on groundwater and underlying geologic conditions from various sources, including routine monitoring reports, electronic databases, and special studies conducted as part of historical or on-going site assessment activities.

5.1 Geology and Groundwater Hydrology

PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, Section 3.1 provides background information, including a discussion on the local stratigraphy and hydrogeology. PNNL-12227 is currently being revised as DOE/RL-2008-65, *Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*, which is scheduled for publication in fiscal year 2010.

5.2 Current Groundwater Monitoring Program

The current interim status groundwater monitoring program, including a sampling and analysis plan, is provided in PNNL-12227, Chapter 5. The document provides information on the monitoring well network, constituent list and sampling frequency, determination of groundwater flow, sampling and analyses protocol, and quality assurance and quality control. The objective of interim status monitoring under WAC 173-303 has been to determine if dangerous constituents from the landfill have contaminated groundwater in the uppermost aquifer (40 CFR 265.93(b), "Preparation, Evaluation, and Response," as referenced by WAC 173-303-400, "Interim Status Facility Standards"). The Hanford Site annual groundwater monitoring reports (e.g., DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*) provides results of the groundwater monitoring at NRDWL in the section dedicated to the 200-PO-1 Groundwater OU.

5.3 Final Status Groundwater Monitoring Program

When the CERCLA Groundwater OU documentation containing the information to meet the alternative groundwater monitoring requirements in WAC 173-303-645(1)(e) is approved, a Class 1 Permit Modification will be processed to remove the text relating to groundwater monitoring from the closure plan. If the closure plan is incorporated into the Hanford RCRA Permit (WA7890008967) prior to the 200-PO-1 Groundwater OU documentation being approved, Section 5.2 will then be revised to include a final status groundwater monitoring plan meeting the applicable requirements of WAC 173-303-645 "Releases from Regulated Units."

Because of the close association between NRDWL monitoring and the 200-PO-1 Groundwater OU, the Permittees are proposing that Ecology exercise their authority and allow the monitoring of NRDWL groundwater through the underlying groundwater OU. Applicable groundwater monitoring requirements of WAC 173-303-645 will be met by complying with WAC 173-303-645(1)(e). Monitoring at the NRDWL will continue through the compliance period identified in WAC 173-303-645(7), "Compliance Period." Monitoring will continue beyond the compliance period, as necessary, during postclosure according to WAC 173-303-610(7), "Post-Closure Care and Use of Property."

6 Closure Strategy and Performance Standards

This chapter describes the proposed final closure strategy for the NRDWL and discusses how the strategy will meet the closure performance standards and specific landfill requirements of WAC 173-303. The NRDWL is in the outer area and future land use will be consistent with Hanford Future Site Uses Working Group, 1992, *The Future for Hanford: Uses and Cleanup* and DOE/EIS-0222-F, *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement.*

6.1 Closure Strategy

The proposed strategy for closure of the NRDWL is to close the site as a landfill in accordance with WAC 173-303-610 and WAC 173-303-665(6). To facilitate closure of the entire Central Landfill facility, which consists of both NRDWL and SWL, the, closure of the NRDWL will be coordinated/integrated with closure of the adjoining SWL, which will be closed in accordance with the requirements of WAC 173-350, "Solid Waste Handling Standards."

All existing waste within NRDWL, including containerized dangerous waste, asbestos materials, and sanitary waste, will be left in place and an integrated final cover will be constructed over the entire Central Landfill (both the NRDWL and the SWL). Proposed postclosure care activities include an inspection and maintenance program, groundwater quality monitoring, and final cover performance monitoring.

Even though the proposed coordinated final cover for the two landfills (the NRDWL and SWL) will be permitted and designed separately(one addressing WAC 173-303 requirements and the other WAC 173-350 requirements) the actual profile and basic design elements of the two final covers will be the same to ensure design integrity and constructability. Before the construction of the final integrated cover, geophysical surveys will be performed to assess the subsurface distribution of waste containers and voids within the NRDWL. The purpose of the characterization effort is to support the final detailed cover design and determine if any void reduction or compaction efforts will be required during construction.

6.2 Final Cover Selection

The final cover for the NRDWL will be of a monofill (or monolithic) evapotranspiration (ET) cover design.

The fundamental design strategy for the chemical trench cover section is to limit infiltration through the waste layer so that long-term leachate generation rates will be maintained below a target value of 3 mm/yr (0.13 in./yr). This specific value was selected as the principal design criterion because it is consistent with the approach that the EPA is currently using in identifying the equivalent performance to conventional RCRA Subtitle C covers (EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet.*). Earlier reviews/seminars sponsored by EPA indicated that conventional RCRA Subtitle C covers would be expected to generate leachate in the range of 1.7 and 6.8 mm/yr (0.07 to 0.27 in./yr or 5 to 20 gal/a/day) (EPA/625/4-89/022, *Seminars Publication – Requirements for Hazardous Waste Landfill Design*). The principal barrier layer within the conventional RCRA Subtitle C cover is a 60 cm (24-in.) thick compacted clay layer underlying a flexible membrane liner (EPA/530/SW-89/047, *Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments*). EPA design guidance stipulates that the compacted clay layer is required to have a saturated hydraulic conductivity of 1×10^{-7} cm/s or lower, which equates to a water flux, or leachate generation rate, of less than 32 mm/yr (1.2 in./yr or 93 gal/a/day). The Alternative Landfill Technologies Team of the Interstate Technology Regulatory Council has suggested that the flexible membrane liner/clay soil composite effectively reduces the saturated hydraulic conductivity by an order of magnitude lower than would exist with the compacted clay alone. Therefore, the equivalent performance to the conventional RCRA Subtitle C design would be a flux of approximately 3 mm/yr (0.12 in./yr or 9 gal/a/day).

The Interstate Technology Regulatory Council was established in 1995 as a state-led, national coalition of personnel from the environmental regulation agencies of some 40 states, the District of Columbia, three federal agencies, several tribes, and numerous public and industry stakeholders. The Interstate Technology Regulatory Council is devoted to reducing obstacles in developing and deploying better, more cost-effective, and innovative environmental techniques. Within the Interstate Technology Regulatory Council, the Alternative Landfill Technologies Team was formed, which, in 2003 published ITRC, 2003, *Technical and Regulatory Guidance for Design, Installation, and Monitoring of Alternative Final Landfill Covers, ALT-2*. The guide focuses on a particular class or type of alternative final landfill cover (i.e., the ET cover) indicating a preference for the ET cover concept.

The guide is based on extensive studies performed by the Alternative Landfill Technologies Team, some of which have indicated that compacted clay liners dry and desiccate when placed near the surface, especially in arid and semi-arid climates such as at the Hanford Site. Desiccation creates preferential leak paths through the clay layer, which in return creates an increase in hydraulic conductivity of the flexible membrane liner/clay soil composite of up to two or three orders of magnitude. For this principal reason, the Alternative Landfill Technologies Team recommends that ET covers should be used in arid and semi-arid climates, rather than the conventional RCRA Subtitle C cover.

The ET covers rely on the natural systems of the water-holding or storage capacity of a soil, evaporation from the near-surface, and plant transpiration to minimize or eliminate water movement through the cover. Precipitation is allowed to infiltrate at the surface, where it is retained in the soil until natural ET processes release the water back to the atmosphere. Such designs are particularly suitable for semiarid and arid climates with a low annual amount of precipitation and a relatively high ET potential. When precipitation exceeds ET, water is stored, and when ET exceeds precipitation, water is removed. Key design criteria require that the soil layer be of a sufficient thickness and quality in terms of water-holding capacity.

Deploying an ET cover in an arid climate, such as at the Hanford Site, takes advantage of several natural systems. Specifically, a low annual precipitation of approximately 173 mm/yr (6.8 in./yr); the high water storage capacity of the fine-grained soils associated with the cover (e.g., locally available silt and silt loam soils have a total water storage capacity of up to 30 percent vol/vol [PNNL-14143, *The Hanford Site 1000-Year Cap Design Test*]); the ability of the native, semi-arid vegetation to extract water stored within those fine-grained soils; and a potential ET rate of approximately 1,270 mm/yr (50 in./yr) (PNNL-6750, *Status of FY 1988 Soil-Water Balance Studies on the Hanford Site*) result in severely limiting water flux, or the potential for leachate generation.

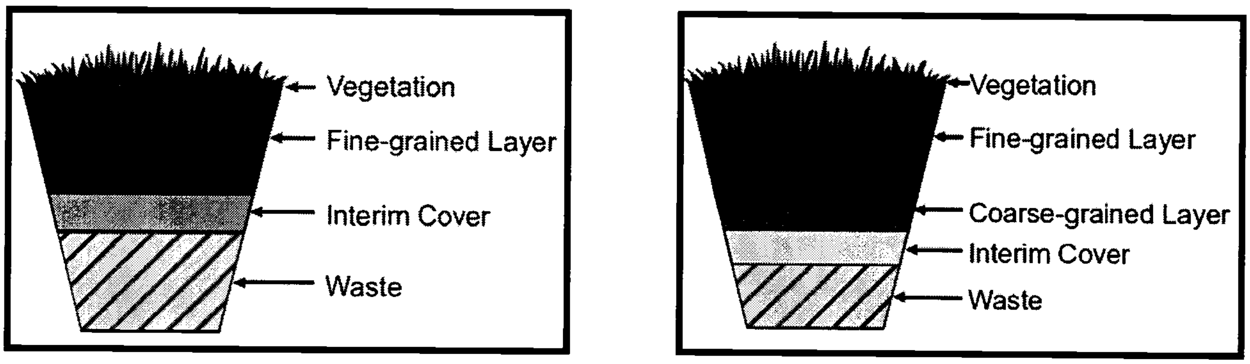
Cover design has been studied at the Hanford Site since the 1980's. Several natural analogue test sites, test plots and lysimeter studies have been completed; some sites have been studied for well over a decade. All of these tests and studies have verified that, because of the arid climate, the Hanford Site for employing covers that rely upon the natural processes of ET to minimize or eliminate leachate generation (Appendix C).

Of particular relevance to the NRDWL is the Hanford Prototype Barrier (a large test cover) that was constructed in 1994 at the Hanford Site. This barrier design incorporated a layer of locally available fine-grained soils as the principal component in restricting water movement towards and through the waste. Despite being stressed for the first three years with three times the annual average precipitation and an additional precipitation event that exceeded a 1,000-year probability of occurrence, the cover performance was undiminished. Refer to Appendix C for additional details.

Another comprehensive study on ET cover design is being performed for the DOE at the Los Alamos National Laboratory (LANL), a semi-arid site than receives almost three times the average annual precipitation that the Hanford Site receives. Several test plots were constructed at the LANL that have demonstrated that a properly designed ET cover will minimize or eliminate leachate flux and have adopted this approach as the standard for barrier design at Idaho National Laboratory for hazardous and radioactive mixed waste sites.

Over the past few decades there have been a number of other studies on ET barriers performed across the nation. Under the Alternative Cover Assessment Program, of which EPA is one of the principal sponsors, large-scale test plots were constructed at locations throughout the U.S. The Alternative Cover Assessment Program studies have repeatedly demonstrated that covers relying on the natural process of ET are well suited for application where the climate is arid or semi-arid (DRI, 2002, *Alternative Cover Assessment Project Phase I Report*).

Two common types of ET covers include monofill (or monolithic) covers, which rely on a relatively thick single layer of fine-grained soil, and capillary covers, which consist of a fine-grained soil layer overlying a relatively coarse-grained soil layer (Figure 6-1).



Monofill (monolithic) ET Cover

Capillary ET Cover

Source: EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet*

Figure 6-1. Common ET Cover Designs

In the capillary ET cover, the distinct textural interface between the fine- and coarse-grained soil layers creates a capillary break, which functionally increases the water-holding capacity of the fine-grained soil. Water will not flow into the coarse layer until the water content in the fine-grained soil approaches saturation. Given the same soil type, to achieve an equivalent water-holding capacity, the monofill ET cover typically requires additional soil thickness relative to a capillary ET cover.

The site-specific decision on whether to use a monofill or capillary type of ET cover design is based on soil characteristics (e.g., water-holding capacity), the rooting depth of native plants, the potential for subsidence, and cost of construction. With the monofill and the capillary ET cover designs utilizing the same fine-grained soils and requiring the same minimum rooting depth for native plants, the only variables are the potential for subsidence and the cost of construction.

The monofill type ET cover is better able to accommodate differential subsidence (e.g. settlement) relative to a capillary ET cover, which relies on maintaining a planar textural interface. If the textural interface is compromised or disrupted because of differential subsidence or some other occurrence, water-holding capacity of the capillary cover would diminish to that of a monofill cover of equivalent thickness. In addition, if subsidence were significant enough in the case of deploying a capillary barrier, a large break in the capillary barrier could result in preferential flow and focused recharge. Since landfills typically have a high potential for differential subsidence, the thicker monofill ET cover is better suited for the NRDWL site.

Additionally, a 75 cm (30-in.) thick ET cover would be needed to provide adequate water storage and rooting medium to sustain a robust native plant community (median root depths for Hanford Site native perennial forbs, grasses, and shrubs are 60 cm [24 in.], 70 cm [28 in.], and 200 cm [80 in], respectively [PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*, Table 5-10]). For some soils, the functional water storage capacity of a 75 cm (30-in.) thick layer can be an equivalent of more than an entire average year of precipitation. However, the coarse sands of the interim cover (i.e. the operational cover, see Section 2.2.2) provide very little functional water storage, which is manifest by the very sparse, limited species vegetation that has developed over the past 15 years. Functional water storage capacity is determined by the difference in water content between the field capacity and the wilting point of a given soil, times its thickness. Field capacity (or water-holding capacity) is defined as the amount of water held in a soil after excess moisture has drained away by gravity and the soil is no longer draining (soil pore pressure of negative 1/3 bar). Wilting point is defined as the water content when a common agricultural crop can no longer draw water from the soil (pore pressure of negative 15 bar).

The field capacity of the fine-grained soil from a nearby borrow site (Area C) is 0.229 vol/vol (mean soil properties for Area C soil [PNNL-17134]). The wilting point for that same soil is 0.056 vol/vol. At the Hanford Site, the water content near the soil surface at the end of the dry season (summer) is typically much lower than the wilting point. Field capacity (0.229), minus wilting point (0.056), times 75 cm (30 in.) of soil, equals 130 mm (5.1 in.) of functional water storage capacity. This is a conservative calculation since it has been demonstrated by numerous studies that desert plants, physiologically adapted to hot arid climates, can extract water from the soil far below that of an agricultural crop (some exceeding 200 bars). The average annual precipitation at the Hanford Site is 173 mm (6.81 in.) (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*) and is coupled with an average annual potential ET of approximately 1,270 mm/yr (50 in./yr) (PNNL-6750), resulting in a very arid climate. Forty percent of the average annual precipitation at the Hanford Site falls during winter, when potential ET is slightly less than precipitation. During all other times of the year, potential ET greatly exceeds precipitation. As a 75 cm (30-in.) thick monofill ET cover would be capable of storing almost twice the average winter precipitation, the water-storage enhancement provided by a capillary break would seldom be needed. Since a minimum rooting depth of 75 cm (30 in.) is considered necessary, there would be little to no advantage in specifically constructing a capillary break layer.

A 75 cm (30-in.) thick monofill ET cover design is proposed for placement over the NRDWL (Section 7.3). A 75 cm (30-in.) thick monofill ET cover would severely limit water flux through the landfill, and effectively reduce leachate generation without utilizing the enhancement of a capillary break. However, the interim cover at the NRDWL consists of soils that are medium sands to gravelly coarse sands. These types of soils have a textural contrast that is distinct enough from the fine-grained soils at Area C that a capillary break would most likely form at the interface, adding conservatism to the monofill ET cover design. This may require routing of interflow (i.e., water flowing laterally between the fines and underlying coarse-textured soil) away from the landfill. The engineering design to mitigate percolation of interflow water into the underlying waste could include such things as extending the barrier a significant distance away from the edge of the landfill or installing a subsurface French-drain at the toe-slope boundary of the barrier.

6.3 Closure Performance Standards

The closure performance standards of WAC 173-303-610(2) , "Closure Performance Standard," require the following.

> The owner or operator must close the facility in a manner that:
> (a)(i) Minimizes the need for further maintenance;
> (ii) Controls, minimizes or eliminates to the extent necessary to protect human health and the environment, postclosure escape of dangerous waste, dangerous constituents, leachate, contaminated run-off, or dangerous waste decomposition products to the ground, surface water, groundwater, or the atmosphere; and
> (iii) Returns the land to the appearance and use of surrounding land areas to the degree possible given the nature of the previous dangerous waste activity.

The NRDWL is to be closed as a landfill by constructing a final cover, as discussed in Section 6.1. The cover design will minimize the need for further maintenance, minimize or eliminate postclosure exposure of dangerous waste, and allow the unit to blend into the surrounding terrain.

6.4 Landfill Requirements

This section lists specific closure and postclosure requirements for landfills per WAC 173-303-665(6) and provides a brief description of how the requirements will be met. Several of these requirements are consistent with the closure performance standards and have been addressed to some extent in Section 6.2. Detailed consideration of these requirements is provided in Chapters 7 and 8.

6.4.1 Closure Requirements

The WAC 173-303-665(6)(a) requires the following.

> At the final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:
>
> (i) Provide long-term minimization of migration of liquids through the closed landfill;
>
> (ii) Function with minimum maintenance;
>
> (iii) Promote drainage, and minimize erosion or abrasion of cover;
>
> (iv) Accommodate settling and subsidence so that the integrity of the cover is maintained; and
>
> (v) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

The landfill closure requirement of WAC 173-303-665(6)(a)(i) is consistent with the closure performance standard of WAC 173-303-610(2)(a)(ii). The proposed final cover is designed to minimize the infiltration of precipitation into the waste layer throughout the postclosure period.

Materials and installation methods specified for the final cover were selected to optimize performance, as well as minimize maintenance requirements throughout the postclosure care period, in accordance with WAC 173-303-665(6)(a)(ii). This requirement is consistent with the closure performance standard of WAC 173-303-610(2)(a)(i) and is addressed in Section 6.2.

In compliance with WAC 173-303-665(6)(a)(iii), the cover surface will be sloped to the outer perimeter so that surface water from extreme rainfall or snow melt events will drain away from the waste trenches. In addition, the top soil layer will be vegetated and have pea-gravel blended into the top 15 cm (6 in.) at approximately 15 percent by weight to establish a stable cover resistant to expected erosion processes. Wind tunnel studies performed on bare silt/silt-loam soils have indicated that the blending of pea-gravel into the soil at 15 percent by weight would reduce wind erosion by over 96 percent, with a nominal reduction in water storage (PNL-8478, *Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel;* PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*; WHC-EP-0650, *Permanent Isolation Surface Barrier: Functional Performance*). As deflation occurs on a bare admix surface, more and more of the pea-gravel becomes exposed, which reduces the potential for further surface erosion. Eventually a desert pavement forms, armoring the bare surface from further erosion. With the addition of the pea-gravel, once the cover has stabilized, the resultant wind erosion potential for a vegetated cover is 0.6 cm (0.25 in.) every 100 years (200-UW1-C-001, *Engineered Surface Barrier Design-Soil Losses Due to Water Erosion*; 200-UW1-C-002, *Engineered Surface Barrier Design-Soil Losses Due to Wind Erosion*).

Very little settling or subsidence is expected at the site because of the nature of the native soil and the method of landfilling that was used. To fulfill WAC 173-303-665(6)(a)(iv), site preparation activities have been proposed consisting of geophysical tests, grading, and compaction of the operational cover to ensure that a proper foundation is prepared for the final cover to minimize any subsidence that would require corrective measures. In addition, the monofill ET cover can accommodate moderate differential subsidence or subsidence with no detrimental effects. Should any subsidence develop that should require future corrective measures, all that would be required would be to add additional fine-grained soils to fill in any potential depression that would impede runoff. Repaired areas also will be revegetated, as necessary.

The proposed final cover will be constructed of a low-permeability silt/silt-loam soil. The proposed source for the silt/silt-loam soil would be a borrow site at Area C, which is approximately 10 km (6 mi) west-southwest of the NRDWL, or an approved equivalent. Compliance with *National Environmental Policy Act of 1969* (NEPA) for Area C is necessary and therefore, all NEPA documentation must be completed and the borrow source reclamation plan approved prior to initiating field activities. At low to moderate compaction, the Area C silt/silt-loam soils have a saturated hydraulic conductivity that ranges between 1.80×10^{-6} cm/sec and 4.81×10^{-5} cm/sec (PNNL-17134). In conformance with WAC 173-303-665(6)(a)(v), the permeability of the silt/silt-loam soil is considerably lower than the sandy subsoils at the NRDWL, which will typically have a saturated hydraulic conductivity of approximately 1×10^{-2} cm/sec.

The surface of the final cover will be graded to a general overall slope of 2 percent (nominal), from the crest or high points to the landfill perimeter. Wind tunnel studies performed as part of the Hanford Barrier Program suggest that silt/silt-loam surfaces should not be sloped greater than 2 percent (PNL-8478). To accommodate WAC 173-303-610(2)(a)(iii) and return the land to the appearance and use of surrounding land areas to the degree possible, in small localized areas, the slope may vary somewhat from a strictly 2 percent flat plane. This will allow incorporation of some localized hummock and swale features, which are prevalent in the surrounding area. All hollows will be oriented to drain to the perimeter of the landfill during extreme rainfall or snowmelt events.

6.4.2 Postclosure Requirements

The WAC 173-303-665(6)(b) requires the following.

> The owner or operator must:
>
> (i) Maintain the integrity and effectiveness of the final cover including making repairs to the cap to correct effects from settling, subsidence, erosion, or other events

(iv) Maintain and monitor the groundwater monitoring system and comply with applicable groundwater protection requirements of WAC 173-303-645

(v) Prevent run-on and run-off from eroding or otherwise damaging the final cover

(vi) Protect and maintain surveyed benchmarks.

The NRDWL does not have a liner/leachate system. As a result, the requirements of WAC 173-303-665(6)(b)(ii and iii), which pertain to the monitoring and operation of a liner/leachate collection system, are not considered in this plan.

Comprehensive postclosure inspection and maintenance plans proposed in Section 8.1 are designed to ensure that the integrity and effectiveness of the cover are maintained. Postclosure inspection, maintenance, and monitoring plans are intended to satisfy requirements of WAC 173-303-665(6)(b)(i).

Run-on and runoff damage is expected to be minimal at the site because of the dry climatic conditions, the geometry of the cover, and the hydraulic properties of the topsoil layer of the final cover and surrounding native soil. The grasses and upper soil materials specified in the final cover have been selected so that nearly 100 percent of the expected precipitation received at the site will be retained and subsequently will be removed by ET. The cover will have a 2 percent general slope that will promote drainage and prevent external run-on.

Benchmarks used to define the NRDWL boundary will most likely be disturbed or buried during construction of the final cover. Those benchmarks that are disturbed or buried will be replaced and all benchmarks will be surrounded by steel posts, or similar markers, to signal their presence and provide protection. Benchmarks will be inspected yearly and resurveyed or repaired, if necessary, as required in accordance with WAC 173-303-665(6)(b)(vi).

Chapter 5 describes the groundwater monitoring system relevant to postclosure conditions.

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7 Closure Activities

This chapter describes how the proposed closure strategy for the NRDWL will be implemented, identifies closure activities, and presents a proposed schedule for implementation. Closure activities include site characterization geophysical surveys, preparation of the area for a final cover, and the construction of the final cover. Groundwater monitoring during closure is described in Chapter 5. This chapter also discusses legal notices.

7.1 Subsurface Sampling Analysis Plan

Individual trench boundaries will be evaluated to properly locate the cover. Void locations will be defined to assess subsidence potential for the cover. Void locations and trench boundaries will be defined using a surface geophysical survey method, such as ground penetrating radar.

7.1.1 Trench Location and Void Extent

Trench boundaries, the approximate locations of waste containers, and the location and extent of voids will be assessed using a surface geophysical survey method, such as ground penetrating radar. Ground penetrating radar uses essentially the same principle as ultrasound sensing. Electromagnetic waves are backscattered from objects or interfaces in the ground.

The geophysical survey will be completed using two sampling grids: a concentrated grid based on the center lines of the trenches in the area of the chemical trenches (trenches 19N to 25) and an intersecting 30 m (100 ft) grid spacing. Grid spacings of 30 m (100 ft) will be used for the remaining area. This area consists of trenches that received municipal or asbestos waste. The grid area will include the landfill, extend outside the facility boundary to the groundwater monitoring wells, and continue approximately 60 m (200 ft) into the SWL.

To avoid running over survey stakes, geophysical survey data will be collected along lines that are offset by measured distances from the grid lines. A geophysical survey procedure will specify the type of equipment, calibration steps, data collection steps, and finished product. Real-time digital data will be collected in the field so that adjustments can be made to optimize data collection capabilities. Digital data can be processed and interpreted in the field before output as a final product for reporting purposes.

7.1.2 Field Documentation

Field documentation requirements for the NRDWL sampling will be fulfilled by the completion of a field logbook. The field team leader/cognizant engineer will maintain an official logbook during the characterization effort. The logbook will be bound and pages will be numbered consecutively. All pertinent sampling information will be recorded in the logbook in a legible fashion with indelible ink.

7.1.3 Evaluation of Data

Geophysical data will be used to delineate trench boundaries and identify locations of subsurface voids. Data will be assessed for reliability and interpreted to determine if the objectives for the characterization were met. An assessment of data reliability will be based on specified quality control limits, along with a review of field documentation.

7.2 Closure Preparation Activities

Before the final cover is constructed, the results of the geophysical tests will be evaluated to determine if any voids of significant size are present in the subsurface. If any large voids are detected (i.e., detectable by geophysical survey as discussed in Section 7.1.1), the voids will either be filled with grout or consolidated through various means of compaction, depending on the size and location of the void, the projected extent of future subsidence, and the estimated adverse impacts on the surface barrier. For example, large voids identified within the chemical trenches would be filled with grout. Compaction of void areas within the chemical trenches would not be proposed because of the possibility of rupturing drums or other containers. Large voids within the sanitary or asbestos trenches would likely either be filled with grout or consolidated by mechanical means, depending on the potential for the release of asbestos particles into the air if the void were to collapse during compaction.

In addition, it will be necessary to decommission well 699-25-34D as it is located in the proposed final cover area (Figure 2-2). This well may be decommissioned and replaced in accordance with the approved groundwater monitoring plan criteria. If necessary to relocate groundwater monitoring wells to accommodate placement of the final cover, new groundwater wells will be installed prior to decommissioning of current wells and installation of the cover. If warranted and approved, preliminary plans are to extend the casing of the monitoring wells above the final barrier surface to avoid decommissioning of any current operation wells and the unnecessary cost of drilling and constructing any new wells. Groundwater wells will be installed and/or decommissioned according to the requirement of WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

Though not required by the governing regulations, additional barrier performance monitoring that may include time-domain reflectometry for measuring soil moisture, horizontal neutron access tubes (for measuring moisture and observing roots if the tubing is clear), and heat dissipation units for measuring soil matrix potential (primary driving force for moisture movement in the unsaturated zone) may be installed and maintained at the discretion of DOE.

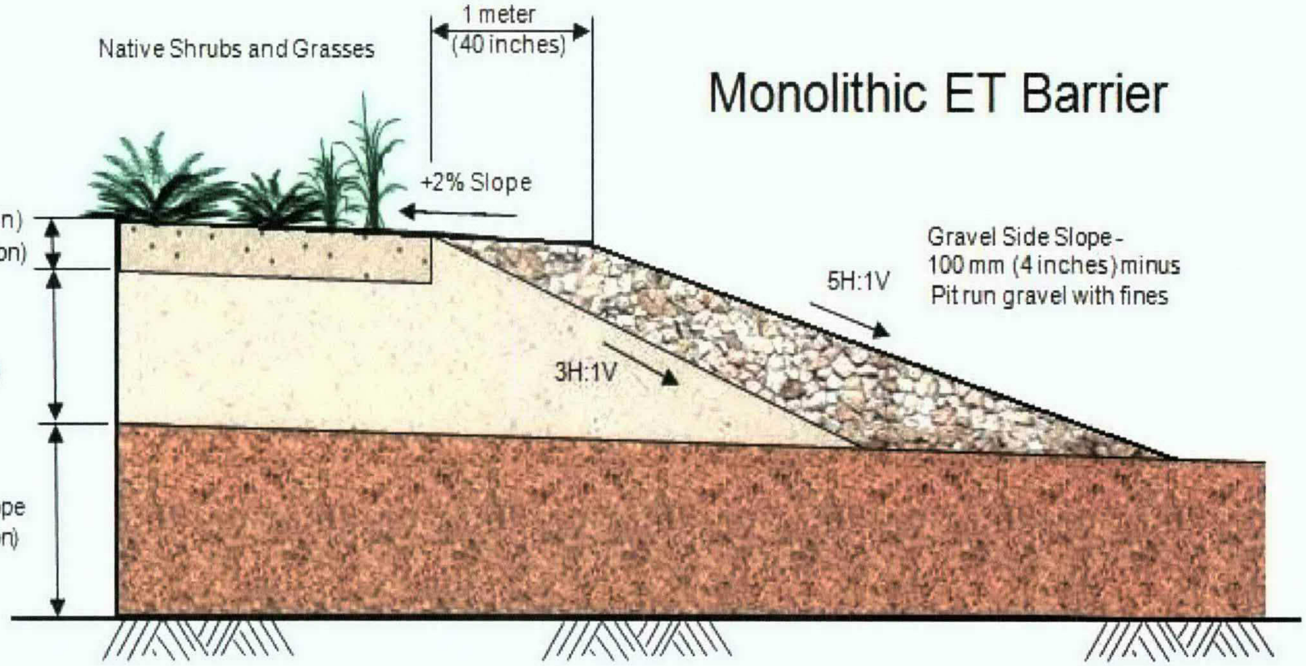
7.3 Final Cover Conceptual Design

The closure cover for the NRDWL has been developed to a conceptual level of detail and is designed to satisfy the WAC 173-303 requirements for a final cover for a dangerous waste disposal landfill. The final design will be developed based on definitive material properties, information from characterization studies, and final site survey. When the final design is complete, the closure plan will be reviewed and revised as necessary. The NRDWL closure cover will be coordinated/integrated with the closure cover for the SWL that lies immediately to the south. The conceptual cover designs are basically uniform in design and construction.

This section provides a general description of the layout of the final cover and associated structures and identifies data needs for definitive design of the closure cover. The section also provides information on the minimization of liquid migration, maintenance needs, subsidence, and cover permeability.

7.3.1 General Description

The design concept selected for the NRDWL final cover is a monolithic ET cover. The final cover will consist of a single layer of fine-grained soil, modified at the surface by the blending in of pea-gravel to increase resistance to erosion. A diverse selection of native plants will be planted on the cover to take advantage of natural ET processes to minimize infiltration of meteoric water into the waste zone and to provide the principal resistance to erosional forces. A generalized cross section of the proposed cover is provided in Figure 7-1. Figure 7-2 shows a plan view of the cover. The covers will be constructed with a 2 percent slope from the high points near the center of the landfill so as to drain any surface water (runoff) to the perimeter of the landfill.



γDmax	=	total unit weight density maximum
H:V	=	horizontal to vertical

Figure 7-1. Elevation View Through Part of the Final Cover Section, Showing Proposed Mode of Termination Along Margins

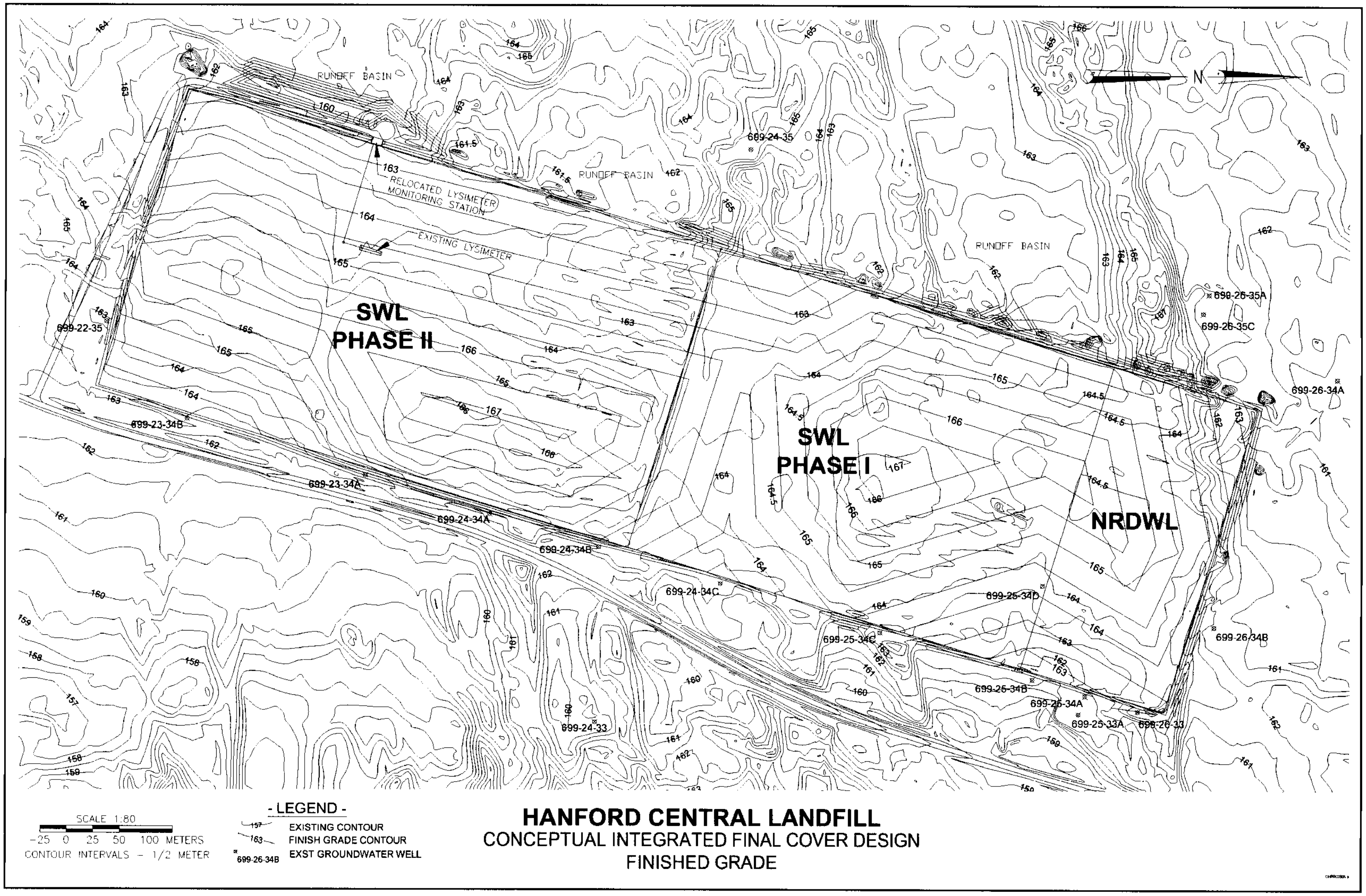


Figure 7-2. Plan View of the Hanford Central Landfill Final Covers for the NRDWL and the SWL

No significant gas generation is expected within the chemical trenches because of the small quantity of biodegradable material disposed of within this area. Only one trench within the NRDWL received municipal solid waste (trench 1N); this trench is located adjacent to the perimeter of the facility on the west side. If significant landfill gas generation is occurring within this trench, the relatively high permeability of the native soils will permit the gas to readily dissipate. Vehicle access to the cover surface will be required for monitoring and maintenance. Details of vehicle access designed to prevent damage to the cover will be developed during the definitive design stage.

The processes of final design, material selection, preparation of construction specifications, and performance assessments are iterative in nature. General approaches have been identified in the conceptual design based on current design and construction practices and best-available information regarding material properties. Scoping calculations have been performed to evaluate key aspects of the design (specifically water balance analyses and estimates of cover erosion rates). Detailed supporting calculations will be prepared as aspects of definitive design. Specific areas where additional information is needed are noted in the following discussions of individual cover components and in Section 7.3.2.3.

7.3.2 Cover Description

This section describes the cover, ventilation, information on data needs to support the definitive design, and construction quality assurance plan.

7.3.2.1 Proposed Design - Cover Components

The final cover will be a monofill (or monolithic) ET cover. The ET final cover will consist of 60 cm (24 in.) of a fine-grained, low permeability soil and 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion resistant topsoil to sustain native vegetation (Figure 7-1). The slope of the final cover will be maintained at approximately 2 percent since fine-grained soils (e.g., silt-loam) are more susceptible to erosional forces when the slope is greater than 2 percent (PNL-8478). An ET cover also provides a suitable medium for establishing and maintaining the cover vegetation that will assist in soil moisture removal and resistance to erosion by wind and water at the soil surface.

The ET covers rely on the natural systems of the water-holding (or storage) capacity of a fine-grained soil, evaporation from the near-surface, and plant transpiration to minimize or eliminate water movement through the cover. Deploying an ET cover in an arid climate takes advantage of several natural systems, specifically: a low annual precipitation of approximately 173 mm/yr (6.81 in./yr) (PNNL-15160); high water storage capacity of fine-grained soils associated with the ET cover (e.g., locally available silt and silt-loam soils have a total water storage capacity of up to 30 percent volume/volume [PNNL-14143]); ability of the native, semiarid vegetation to extract water stored within those fine-grained soils; and, a potential ET rate of approximately 1,270 mm/yr (50 in./yr) (PNNL-6750) result in severely limiting water flux or the potential for leachate generation. The primary objective in selecting a monofill ET cover system is to exploit the relatively low annual precipitation, coupled with the high ET potential present at the Hanford Site, and extract the maximum amount of moisture from the cover by natural ET processes.

The fine-grained soil layer should have sufficient thickness to retain an adequate amount of soil moisture throughout the year to support a healthy vegetative cover. The effectiveness of an ET cover system is contingent on the capacity of the fine-grained soil to store and return water (by ET) such that it will remain essentially unsaturated at all times. The soil material must be sufficiently fine textured to exhibit relatively high water retention characteristics (i.e., high field capacity and porosity values), yet sufficiently coarse textured so that plants can readily access and extract the moisture from storage. The proposed soil material is a sandy silt-to-silt loam soil obtained from the Area C borrow site, located on the

Hanford Site about 10 km (6 mi) west-southwest of the landfill. This fine-textured soil has been characterized by systematic test borings and sampling (D&D-25575, *Silt Borrow Source Field Investigation Report*). The mean values for porosity, field capacity, and wilting point for Area C silt/silt-loam are estimated to be about 0.409, 0.229, and 0.056 vol/vol (PNNL-17134), respectively. Plant available moisture for this soil will be at least 0.17 vol/vol. For a 75 cm (30 -in.) layer of Area C silt/silt-loam, the available water storage will be approximately 75 percent of the average annual precipitation receipts at the Hanford Site, and 188 percent of the normal winter precipitation when ET is typically low. Numerical modeling of the ET cover, using EPA/600/R-94/168, *The Hydrologic Evaluation of Landfill Performance (HELP) Model* (HELP), indicates that even during repeated cycles of the wettest ten years on record for the Hanford Site, ET will be sufficient to remove 94 percent of the annual moisture receipts from the cover area with almost all of the remaining 6 percent removed as runoff. As discussed in Appendix C, the modeling indicates that approximately 0.09 percent (0.18 mm/yr [0.007 in./yr]) of the average annual precipitation will penetrate the landfill, which is equivalent to the theoretical performance of EPA's conventional RCRA Subtitle C design (EPA/542/F-03/015). In an arid to semi-arid climate, such as at Hanford, a conventional RCRA Subtitle C cover would be expected to produce a flux of 1.5 mm/yr (Albright et al., 2004, "Field Water Balance of Landfill Final Covers").

In conformance with regulatory guidance (EPA/530/SW-89/047) stipulating that provisions be made for run-on and runoff control, the surface of the final cover will be graded to a general overall slope of 2 percent, from the crest or high points to the landfill perimeter. If required, storm-water runoff and interflow generated at the silt-loam operational cover interface will be collected at the landfill perimeter and channeled away from the landfill to local depressions capable of holding the anticipated flow from a 24-hour, 25-year frequency storm. To return the land to the appearance and use of surrounding land areas to the best possible degree, in small localized areas the slope may have minor variations from a strictly 2 percent flat plane. This will allow incorporation of some localized hummock and swale features, which are prevalent in the surrounding area. All hollows will be oriented to drain to the perimeter of the landfill during extreme rainfall or snowmelt events. Run-on and runoff damage are expected to be minimal as a result of the combination of porous soils, arid regional climate, high ET rates, localized collection or drainage areas, and minimal local slope in the area. The probability of serious damage to the landfill because of flooding or storm-water runoff/run-on is low. Construction will require approximately 47,000 metric tons (t) (52,000 tons) of Area C soil. The final cover was modeled in simulations as an uncompacted soil layer. The specification of placement density for the soil will be similar to the near-surface (less than 75 cm [30 in.]) in-place density at the borrow site (about 86 percent of maximum density) with the top 15 cm (6 in.) being tilled or disked to blend in the pea-gravel and to remove any overly compacted areas created during construction. There will be no specific requirement to construct the cover in separate lifts of uniform thickness. In a relatively loose condition, the soil will have better water retention characteristics, will provide a better medium for root penetration and optimal (deep) root zone development, and will enable ET processes to extend to greater depths than if it were placed in a highly compacted state. The ET processes are expected to extend to a depth of 100 cm (39 in.) or more. However, sensitivity studies (using the HELP model) indicate that the proposed design will perform adequately, even if the actual ET zone does not exceed the thickness of the fine soil layer, or 75 cm (30 in.). Appendix C summarizes the HELP model results for the cover.

The soil cover will be seeded with an appropriate grass, forb, and shrub native blend seed mix and stabilized (which could consist of a tackifier and/or straw mulch) to establish a temporary ground cover for protection from erosion. Seeding will be performed in a sequence of operations, beginning with disking the soil should it need to be loosened, to promote root development. Design specifications will require seeding to occur during a narrow time frame in the fall. This timing will take advantage of fall and winter precipitation to ensure the best success for germination. The size of the area and the lack of readily available water preclude post-planting watering. The proposed soil material for the final cover is expected to exhibit an acceptably low level of susceptibility to wind erosion. During the 1990's, under the Hanford Barrier Program, a set of studies were performed on the erosion resistance of a typical silt-loam soil found at the Hanford Site. The mission of the Hanford Barrier Program was to identify components of a long-term (1,000 years) surface cover design. Several of the studies concluded that to enhance resistance of a bare fine-grained soil to erosion, it was advisable to keep the slope to no more than 2 percent and to blend or till 10 mm (3/8 in.) pea-gravel into the upper 30 cm (12 in.) of the surface (PNL-8478). As a bare soil surface deflates over time, more and more of the pea-gravel becomes exposed, eventually creating what is termed as a "desert pavement," which would be highly resistant to wind and water erosion. These studies also determined that a mixture of 15 percent by weight 10 mm (3/8 in.) pea-gravel and silt would not inhibit native plant germination or growth. Using agricultural industry standard methods, recent analysis predict that at a 2 percent slope the gravel admix would be sufficient to limit erosion to an average of less than 0.6 cm (0.25 in.) every 100 years (200-UW1-C-001; 200-UW1-C-002).

To provide a life expectancy of at least 30 years, the top 15 cm (6 in.) of the final cover for the NRDWL will consist of Area C silt/silt-loam with 10 mm (3/8 in.) pea-gravel blended/tilled into it at 15 percent by weight (equivalent to approximately 1.3 cm [0.5-in.] thick layer of pea-gravel spread evenly over the surface). The balance of the fine-grained soil layer will consist of 60 cm (24 in.) of Area C silt/silt-loam soil. The methods employed in blending/tilling the pea-gravel with the silt-loam will be determined during final design.

Cover Section Over Asbestos and Solid Waste Trenches

Trenches 2N, 20, 21, 22, 23, 25, 27, 29 and 30 received demolition waste containing asbestos. Disposal of asbestos-containing waste is not specifically regulated under WAC 173-303; such waste is regulated under 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants." Trench 1N received municipal-type solid waste. Solid waste is regulated under WAC 173-350.

A single soil cover design has been developed for the entire NRDWL. In addition to conforming to the requirements of WAC 173-303-610 and 173-303-665(6), the design will conform to the regulatory guidance in WAC 173-350 even though only one trench within the area received waste of a type that is specifically regulated under this statute. According to 40 CFR 61, final closure of the asbestos trenches could have been achieved simply by planting and maintaining cover vegetation, insofar as these trenches already have been covered with a sufficient thickness of soil. However, as a practical matter, some suitable soil material having adequate water storage capacity and rooting thickness would still have to be placed over the asbestos trenches to develop and retain vigorous native perennial cover vegetation at the site.

Proposed Design - Cover Components

The proposed design for the cover is a monofill (monolithic) ET cover modified at the surface so as to form a two-layer system with an armored side slope at the perimeter.

The two-layer system is designed to intercept, temporarily store, and return to the atmosphere by ET processes, or divert by runoff, essentially 100 percent of the annual precipitation received at the site. The materials in both layers will provide a suitable medium for establishing and maintaining the cover vegetation that will facilitate soil moisture removal. The topsoil layer and cover vegetation will be resistant to erosion by wind and water. The proposed cover design has a 2 percent surface slope, but may have minor variations from a strictly 2 percent flat plane in small localized areas to allow incorporation of some localized hummock and swale features. The design does not include provisions for an internal drainage layer. Before construction of the cover section, the site surface will be graded and compacted to provide a suitable foundation layer.

Layer 1: Topsoil Layer and Cover Vegetation. The topsoil in the proposed design must perform the following specific functions.

- Serve as a temporary storage medium capable of retaining a significant portion of the total annual precipitation received at the site and facilitating moisture removal by ET processes.
- Provide a suitable medium for establishing and maintaining the cover vegetation that will assist in soil moisture removal.
- Resist erosion by wind and water in conjunction with cover vegetation.

The primary objective of this design is to exploit the relatively high ET potential at the Hanford Site and extract all moisture from precipitation at the site by ET processes.

The proposed topsoil material (Layer 1) is Area C silt/silt-loam admix, blended with pea-gravel to form an erosion resistant soil. The topsoil is created by blending or tilling 10 mm (3/8 in.) pea-gravel at 15 percent by weight (approximately 1.3 cm [0.5-in.] thick layer of pea-gravel) into the top 15 cm (6 in.) of a 75 cm (30-in.) thick layer of Area C silt/silt-loam. The physical properties of the soil admix relative to water storage are 0.375 porosity, 0.210 field capacity, 0.051 wilting point, and an effective hydraulic conductivity of 1.31×10^{-5} cm/sec (mean soil properties of a series of samples taken at Area C and adjusted to represent the addition of pea-gravel at 15 percent by weight [PNNL-17134]).

The placement density for the soil will be low, as it will be tilled or disked to blend in the pea-gravel and to remove any overly compacted areas created during construction. In a relatively loose condition, the soil will have better water retention characteristics, a much higher success rate/survival rate for seeding/planting of native vegetation, provide a better medium for root penetration and optimal (deep) root zone development, and enable ET processes to extend to greater depths than it would if it were placed in a highly densified state. The ET processes may extend to a depth of 100 cm (39 in.) or more. However, sensitivity studies (using the HELP model) indicate that the proposed design will perform adequately even if the actual ET zone does not exceed 75 cm (30 in.). The HELP model results for the cover are summarized in Appendix C.

The proposed topsoil material for Layer 1 is expected to exhibit an acceptably low level of susceptibility to wind erosion (i.e., less than 0.18 t/a/yr [0.2 ton/a/yr]). Calculations regarding potential susceptibility of the cover surface to erosion by surface water and wind are presented in 200-UW1-C-001 and 200-UW1-C-002, respectively.

Layer 1 will be seeded with a blend of native perennial grasses, forbs, and shrubs. Layer 1 will require approximately 9,400 metric tons (10,400 tons) of loose topsoil and 1,000 metric tons (1,200 tons) of pea-gravel to construct.

Layer 2: Barrier Soil Layer. Low-conductivity soil facilitates retention of soil moisture within the cover system for later removal by natural ET processes, and minimizes percolation of moisture through the cover system into the waste zone. Rates of soil moisture removal characteristically are greatest at and near the soil surface. Removal by direct evaporation occurs at the highest rate at the soil surface and attenuates toward the lower limit of the evaporative zone. Plant transpiration also tends to attenuate with depth, as a function of root density. Extending the residence time for moisture will increase the productivity of moisture removal mechanisms in the lower part of the cover system. Numerical modeling of the cover system with the HELP model indicates that, during the wettest ten years on record, removal of soil moisture by ET processes will average 94 percent of the annual moisture receipts. The model predicted that almost all of the balance of the moisture receipts (6 percent) will be removed as runoff during infrequent periods where there is snow melting on frozen ground. Only 0.09 percent (0.18 mm/yr [0.007 in./yr]) of the average annual precipitation would penetrate the landfill (Appendix C).

Layer 2 will be 60 cm (24 in.) thick. It is envisioned that the low-conductivity soil will consist of Area C silt/silt-loam (the same material specified as topsoil material for construction of Layer 1). Layer 2 will be constructed by placing the soil in a single lift with minimal compaction effort anticipated. The placement density for the soil will be similar to the near-surface (less than 75 cm [30 in.]) in-place density at the borrow site. The physical properties of the soil relative to water storage are 0.409 porosity, 0.229 field capacity, 0.056 wilting point, and an effective hydraulic conductivity value of 1.53 x 10^{-5} centimeters per second (mean soil properties of a series of samples taken at Area C [PNNL-17134]). A specification for placement density and moisture content will be developed during definitive design.

An estimated 37,600 metric tons (41,600 tons) of Area C silt/silt-loam will be required for construction of Layer 2.

Cobble or Riprap Armored Side-slope. On three sides of the cover section, the two-layer system will terminate against a berm of cobble or riprap in-filled with Area C silt/silt-loam (Figure 7-1) with the fourth side being the continuation of and integration with the final cover over the SWL (Figure 7-2). The berm will be sloped down at 5H:1V to intersect the surrounding site surface. The cobble or riprap will protect the perimeter of the topsoil layer from rill erosion and from burrowing animals, allow for the development of armored perimeter channels for controlling runoff, and serve to physically isolate the cover section from run-on of surface water from adjacent areas. However, the principal purpose is to facilitate a steeper side slope design at the margin of the cover where adjoining terrain is too low for an immediate transition. For erosion control, cobble on the order of 5 cm (2 in.) maximum particle size would be required. However, to reduce the potential for small animal intrusion through the side slopes, a 10 cm (4 in.) maximum size aggregate is necessary (Cline et al., 1980, "Loose Rock as Biobarriers in Shallow Land Burial"). A material specification will be developed and a suitable borrow location will be identified during definitive design.

Approximately 2,400 metric tons (2,600 tons) of cobble or riprap will be required for construction of the side-slope armor at the three exposed sides of the NRDWL.

7.3.2.2 Cover Ventilation

Based on the types of waste placed in the chemical trenches, there appears to be little potential for production of landfill gas in those trenches as the result of microbial action on the waste. Some disposed dangerous waste is volatile organic chemicals, and these chemicals may be present at detectable levels in the gas phase in and adjacent to the chemical trenches. A soil gas survey to investigate dangerous waste constituents in the vadose zone has been performed at the site with nothing found above action levels (Section 2.2.3). Volatile organic compounds are not likely to develop significant positive pressure on the cover as the relatively high permeability of the native soils will permit the gas to readily dissipate. Any volatile gas will likely dissipate at the outer margins of the barrier footprint and likely at the interface between the fine silt-loam material and the coarse-textured operational cover.

The one sanitary solid waste trench (1N) included within the NRDWL boundary is a potential site for landfill gas production. However, considering the type of waste (high percentage of dry wood and office paper waste) and the amount of time that has passed since this trench was active (trench 1N was opened in January 1976 and closed in September 1976), it is unlikely that significant landfill gas production presently would be taking place within trench 1N. With the native soils surrounding the trench, the interim cover having a relatively high permeability, and silt/silt loam soils of the monofill ET cover having a moderate gas permeability, any gas generated from trench 1N would likely spread over a large enough area to be able to dissipate through the final cover to the atmosphere without requiring any special features for cover ventilation. As such, no special ventilation features will be incorporated into the design.

7.3.2.3 Data Needs to Support Definitive Design

Borrow areas for topsoil and cobble or riprap must be characterized. As previously indicated, the Area C borrow site tentatively has been identified as a source of suitable fine-grained soil material. Some work already has been performed to characterize this soil material in the field (D&D-25575). However, additional site characterization will be necessary to ensure that material properties of the soil do not vary beyond acceptable limits for the proposed application and that sufficient quantities of suitable material are available. Characterization will include test borings, sampling, and laboratory testing to better define the depth and extent of the soil deposit and to determine if any special blending will be required to provide a consistent material. A borrow area for cobble or riprap has not been identified, but it is anticipated that the material will be procured from off-site (commercial) sources. Compliance with NEPA for Area C is necessary and therefore, all NEPA documentation must be completed and the borrow source reclamation plan approved prior to initiating field activities. Site characterization efforts will include any additional tasks necessary to support permitting activities.

Material properties of the proposed fine-grained soil, the native surface soil at the NRDWL site, and the cobble or riprap must be fully characterized in the laboratory to support definitive design. For the proposed fine-grained soil material and the local sandy soil at the NRDWL site, the following types of tests are required: Atterberg limits, compaction, consolidation, shear strength, water retention, hydraulic conductivity, and gradation curves. Data are required for hydraulic properties of topsoil and local sand under a range of densities (compactive efforts). For the cobble or riprap material, density, durability, and size gradation information is required.

7.3.2.4 Construction Quality Assurance Plan Outline

A construction quality assurance plan will address activities that pertain to the areas outlined in this section. This plan will provide verification that the cover, as built, meets or exceeds design specifications. A technical guidance document for preparation of construction quality assurance plans for hazardous waste land disposal facilities (EPA/530/SW-86/031, *Technical Guidance Document Construction Quality Assurance for Hazardous Waste Land Disposal Facilities*) will be used for the development of the NRDWL construction quality assurance plan. The construction quality assurance plan will address the following areas as a minimum:

- Responsibility and authority of organizations and key personnel involved with preparation and implementation of the construction quality assurance plan
- Personnel qualifications, including a description of qualifications of all personnel and demonstration of proper training and experience, to fulfill identified responsibilities
- Monitoring activities listed in detail, including observations and tests to ensure quality of each installed component.
- Sampling requirements, including a description of sampling and testing activities, to project the quality of materials installed during construction and include the following:
  - Types of sampling activities
  - Types of samples
  - Number and location of samples
  - Frequency of testing

- Data evaluation procedures
- Acceptance and rejection criteria
- Corrective action plans
- Handling of testing errors.

* A description of procedures to document construction quality assurance activities. Documentation must include the following items as a minimum:

  - Daily summary reports
  - Monitoring data sheets
  - Change orders
  - Meeting memoranda
  - Photographs
  - Problem identification and reports on corrective measures
  - Design acceptance reports
  - Final documentation including record drawings.

The construction quality assurance plan must address all cover components including the following:

- Foundation (pre-existing surface)
- Low permeability soil
- Topsoil
- Embankment materials (cobble or riprap)
- Vegetative cover.

Some elements of consideration for the components mentioned previously include the following:

- Degree of compaction/optimum water content
- Special considerations for slope construction
- Storing and handling of materials
- Provisions for construction under adverse weather conditions
- Identification of improper materials and techniques.

7.3.3 Minimization of Liquid Migration

As required in WAC 173-303-665(6)(a)(i), the final cover over the NRDWL facility must be designed and constructed to minimize long-term migration of liquids through the closed landfill. Compliance with this requirement is a primary objective of the cover design. The following features are incorporated into the design of the cover to minimize liquid migration through the landfill.

* Cover will have high water retention characteristics because of the fine texture of the proposed soil material.

* Thickness of the soil layer has been determined to facilitate efficient and essentially complete removal of infiltrating moisture by evaporation and transpiration processes.

The fundamental design strategy is to limit infiltration through the waste layer so that long-term leachate generation rates will be maintained below a target value of 3 mm/yr (0.13 in./yr); a performance that is equivalent to EPA's conventional RCRA Subtitle C design. Monofill ET covers rely on the natural systems of the water-holding or storage capacity of a soil, evaporation from the near-surface, and plant transpiration to minimize or eliminate water movement through the landfill. Precipitation is allowed to infiltrate at the surface, where it is retained in the soil until natural ET processes release the water back to the atmosphere. Such designs are particularly suitable for semiarid and arid climates with a low annual amount of precipitation and a relatively high ET potential. At the Hanford Site, the average annual precipitation is 173 mm/yr (6.81 in./yr) (PNNL-15160), whereas the average potential ET is 1,270 mm/yr (50 in./yr) (PNNL-6750). The key to barrier design is to provide a soil layer of a sufficient thickness and quality in terms of water-holding capacity.

The proposed NRDWL final cover design has been evaluated for minimizing liquid migration through the landfill using the HELP model. Appendix C provides an output listing of the performance simulation for the proposed final cover design. The predicted long-term average annual leachate production from the waste layer (Layer 4 in the output listing) was 0.18 mm/yr (0.007 in./yr), or six-hundredths of the target value (0.3 cm/yr [0.12 in./yr]). On average, ET from Layers 1 and 2 removed about 94 percent of the total precipitation received at the site. Lateral drainage from surface runoff during the infrequent condition of rapid snow-melt on frozen ground accounted for almost all of the remaining 6 percent of the average annual water budget. According to the output listing, lateral drainage (surface runoff) would have been at or near zero in six of the ten years modeled. Predicted percolation from the final cover into and through the waste zone amounted to an average of 7 m^3/yr (250 ft^3/yr) over the entire 4 ha (10 a.) landfill.

7.3.4 Maintenance Needs

In accordance with WAC 173-303-665(6)(a)(ii), the cover has been designed to function effectively with minimal ongoing maintenance. This section identifies design and construction provisions for minimizing maintenance during the postclosure care period. Additional information regarding postclosure inspection, monitoring, and maintenance of the final cover is presented in Chapter 8.

7.3.4.1 Wind Erosion

The following are the hazards of principal concern associated with wind erosion:

- Excessive soil loss from the topsoil layer of the cover, potentially leading to reduced soil moisture storage and removal (through ET) relative to expected performance
- Breaching of the upper part of the cover system, potentially leading to exposure of the waste and/or direct infiltration of soil moisture into the waste zone.

The conceptual design for the NRDWL cover has been evaluated for potential susceptibility to wind erosion. To facilitate surface drainage, the cover will be sloped at 2 percent. With fine-grained soils, the greater the slope, the more the surface is susceptible to erosion. Several studies performed as part of the Hanford Barrier Program concluded that to enhance resistance of a bare fine-grained soil to erosion it was advisable to maintain the slope to no more than 2 percent and to blend or till into the surface 10 mm (3/8 in.) pea-gravel at ratio of 15 percent by weight (PNL-8478). With the application of a pea-gravel admix, soil losses are projected to average approximately 0.18 t/a/yr (0.2 ton/a/yr) (200-UW1-C-001; 200-UW1-C-002).

During the first year after construction, the soil surface will be treated with straw mulch to mitigate wind erosion. Soil loss projections indicate that this treatment should be highly effective in stabilizing the cover surface; projected wind losses for the first year are negligible. The straw mulch should contribute to stabilizing the site surface for one to two more years.

Effective long-term protection against wind erosion will require production of a vigorous stand of cover vegetation. A blend of native grasses, forbs, and shrubs will be planted and cultivated on the NRDWL cover for this purpose.

Projected soil losses represent average annual estimates that are highly dependent on the vegetative factor. Until the vegetative cover becomes established, erosion rates may tend to exceed the estimated average range. After vegetation is established, erosion rates should coincide more closely with the predicted range. In years when the vegetation yield is above average, erosion rates will be significantly below projections. Optimal production of vegetative growth would reduce predicted soil losses to near zero.

The topsoil surface of the cover will require periodic inspection to verify that soil losses are generally within acceptable limits and that pronounced localized erosion does not occur. Wind erosion of local soil surfaces in the vicinity of the NRDWL could cause the perimeter drainage ditches (which protect the cover from run-on) to become plugged with sand and other windblown debris. These ditches will require periodic inspection and may require occasional maintenance. Provisions for postclosure maintenance are addressed in Section 8.1.

7.3.4.2 Water Erosion

The potential hazards associated with water erosion are the same as those identified previously for wind. Damage from water erosion may be relatively uniform over a wide area (sheet erosion), concentrated in a local area (gullying) or rill erosion. Several approaches have been applied in the design to minimize the potential for water erosion as follows:

- Specifying a hardy native plant vegetative cover to slow surface runoff.
- Planting native species that produce high volumes of plant litter that physically mitigates wind and water erosion, as well as increases the overall water-holding capacity of the soil
- Identifying an adequate thickness for the topsoil layer
- Specifying a relatively low placement density (i.e., low compactive effort) for the topsoil layer to promote infiltration and temporary storage rather than runoff
- Limiting surface slopes on the cover to 2 percent
- Providing run-on controls and application of cobble or riprap around the margins of the cover to prevent gullying.

Using the HELP program (Appendix C), numerical modeling of the cover system indicated that during the wettest ten years on record, 6 percent of the precipitation would have been removed as runoff. It should be noted that the HELP model automatically adjusts the Soil Conservation Service runoff curve number to the higher value of a clay soil whenever the temperature pattern indicates the soil could be frozen. The runoff that was calculated by the model occurred in only four of the ten wettest years on record, and only during periods when it calculated snowmelt on frozen ground. At no other time did the model predict runoff to occur, even during the 150 year frequency 24-hour storm that occurred on November 18 to 19, 1996 (4.3 cm [1.7 in.] of rain). In actuality, runoff is very seldom seen or evident in areas at the Hanford Site where fine-grained soils are prevalent, unless the surface has been heavily compacted.

Water erosion potential also was evaluated by the Universal Soil Loss Equation method (Ecology Publication 87-13, *Solid Waste Landfill Design Manual*). The predicted magnitude of soil losses from water erosion is quite low; 0.17 t/ha (0.08 ton/a) per year (200-UW1-C-001). To minimize erosion on the cover, a 2 percent cover slope was selected to promote runoff without inducing excessive erosional forces. The vegetative cover of native grasses, forbs, and shrubs is expected to contribute significantly to limiting soil loss from runoff of surface water. Plant litter organic matter will form a protective layer mitigating wind and water erosion, as well as increasing the soil's overall water-holding capacity. Increasing the water-holding capacity decreases percolation and subsequent leachate formation.

7.3.4.3 Burrowing Animals

Small animals indigenous to the Hanford Site have been reported to burrow to depths of more than 1.8 m (6 ft) (PNL-4241, *Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Disposal*). This depth is sufficient to breach both the final and interim covers in some areas of the landfill and potentially compromise the cover system by creating direct pathways for moisture infiltration. Animal studies performed as part of the Hanford Barrier Program found that in actuality the animal burrows tended to create a drier soil zone by opening the soil profile to direct evaporation. The burrow entrance is typically mounded to prevent storm water runoff from surrounding areas from flowing into the burrow. Any water that did happen to enter the burrow was quickly absorbed by the loosened soil (PNL-10788, *The Role of Plants and Animals in Isolation Barriers at Hanford, Washington*). Over time, the burrows collapse and the surface fills in naturally.

7.3.4.4 Subsidence

Subsidence refers to vertical downward displacement of the ground surface by means of one of several mechanisms (Section 7.3.6). The covered area where subsidence is most likely to develop is near trench 1N (the one trench within the NRDWL that received municipal solid waste). Waste placed within this trench will undergo biodegradation, with attendant reductions in density and volume over time. At sites with arid and semiarid climates (such as the Hanford Site), biodegradation of solid waste often proceeds slowly because water is not present in sufficient quantities to facilitate the process. Also, subsidence has been observed at the asbestos trenches in the adjacent SWL. Consequently, the rate of volume change within the waste zone may be quite low. During the postclosure care, surface elevations will be monitored for long-term topsoil loss and to detect subsidence. If subsidence over trench 1N is detected during the postclosure period, additional fine-grained soil and pea-gravel admix can be placed over the area to prevent localized ponding and to return the surface to design final grade. A plant vegetative cover similar to the original final cover would be planted over the area disturbed in filling the depression. The additional fine-grained soil and pea-gravel admix effectively increases the thickness of the fine soil layer. As a 75 cm (30 in.) fine soil layer will store most of the moisture that would fall on the cover and all of that moisture is eventually recycled back into the atmosphere through the natural process of ET, the filling and replanting of the affected area would be the only remedial action necessary.

At the NRDWL, most trenches received chemical and asbestos waste (materials that are not biodegradable). Dangerous solid and liquid waste generally was packaged in a manner designed to ensure long-term dimensional stability. While subsidence has been observed at the asbestos trenches in the adjacent SWL, subsidence within the area containing chemical trenches are not expected to occur to an extent that would result in loss of integrity of the final cover. Because the primary protection from moisture infiltration in the proposed design is developed within the fine-grained soil layer, the proposed cover section is capable of remaining fully functional and protective, even if the cover sustains localized subsidence.

7.3.4.5 Seismic Events

The principal hazard from seismic events (earthquakes) relates to particle accelerations at the ground surface. Breaching by faulting is not considered a significant risk in that no major faults have been identified at the NRDWL and only one fault on the Hanford Site (located at Gable Mountain) shows evidence of movement within the past 13,000 years (DOE/RW-0164, *Consultation Draft: Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*).

The conceptual design for the cover section over dangerous waste trenches includes a relatively low surface slope (2 percent), which would require higher particle accelerations to induce permanent slip than would be true for a design with a higher slope. Additionally, the thickness and lateral extent of the cover section represent a relatively large mass of material that is expected to successfully resist acceleration under the high-frequency, low-magnitude events that are characteristic for the Hanford Site. Historically, seismic activity at the Hanford Site has been low, and the probability of exceeding even the relatively low acceleration value of 0.05 g (32 ft^2/s) is reported to be only 0.002 per year at the Washington Public Power Supply System No. 2 generating plant (Youngs et al., 1985, "Seismic Hazard Assessment of the Hanford Region, Eastern Washington State"). Consequently, the risk of seismically induced damage to either of the two proposed cover sections for the NRDWL is considered to be small. However, a more rigorous seismic evaluation to determine yield (failure) accelerations of the cover and corresponding probabilities of exceedance will be performed once final design has been completed and soil properties have been characterized in sufficient detail.

7.3.5 Drainage and Erosion

In accordance with WAC 173-303-665(6)(a)(iii), both cover designs have been evaluated for surface runoff production. Using the HELP program (Appendix C), numerical modeling of the cover system indicated that during the wettest ten years on record, 6 percent of the precipitation would have been removed as runoff. Runoff only occurred during periods when the model calculated rapid snow melt on frozen ground. The HELP model automatically adjusts the Soil Conservation Service runoff curve number to the much higher clay soil value whenever the temperature pattern indicates the soil could be frozen. At no other time did the model calculate that runoff would occur, even during the 150 year frequency 24-hour storm that occurred on November 18 to 19, 1996 (4.3 cm [1.7 in.]). In actuality, runoff is very seldom seen or evident in areas at the Hanford Site where fine-grained soils are prevalent (e.g., natural analog sites), unless the surface has been heavily compacted.

Runoff totals calculated by the HELP model indicate a maximum daily volume of 2,270 m^3 (80,000 ft^3). This was a single event that occurred December 31, 1996 because of rainfall on melting snow on frozen ground at the end of the highest precipitation month on record. The next highest daily runoff volume was 620 m^3 (22,000 ft^3), when the model calculated melting snow on a frozen soil surface. As the runoff is surface sheet drainage, it will come off the cover somewhat uniformly along the cover perimeter. A perimeter ditch will be constructed as part of the final cover to channel collected runoff away from the landfill and to a low depression for disposal. Specifics about the perimeter ditch (e.g., location, dimensions, sizing of channel armor) will be determined during definitive (final) design.

7.3.6 Subsidence as a Result of Compression or Consolidation of Subsoils

In accordance with WAC 173-303-665(6)(a)(iv), the cover must accommodate settling and subsidence so that the integrity of the cover is maintained. Surface and near-surface soils at the site consist of sands of fluvial and eolian origin. The vadose zone at the site is relatively thick and consists almost entirely of interbedded sands and gravels, with occasional thin interbedded silts. None of these subsoil materials characteristically exhibit significant compression or consolidation behavior. Compression refers to the change in thickness of subsoils caused by the placement of the weight of the closure cover over the site, exclusive of consolidation effects. Compression of subsoils will be minimized by applying a compactive effort over the site surface before cover construction. As a result of this action, localized areas of soil in an initially loose condition will be eliminated. Compaction will expose the site surface to a static load similar to the combined weight of the cover materials. This practice will significantly reduce compression of subsoils and uneven subsidence of the closure cover after construction. During the re-shaping of the interim cover, the soil will be compacted to a value close to its maximum density. Some lesser degree of compaction also will occur during and after placement of the final cover because of wheel loads applied by construction equipment.

Liquefaction is a term used to describe shear failures of cohesionless soils, generally caused by incremental increases in neutral stress generated by repeated small (cyclical or vibratory) loads. However, quick conditions also can occur under no increased load if loose sands are impacted by shock waves. Liquefaction can be avoided by properly compacting the foundation layer (interim cover) at relative densities above 70 percent (Sowers et al., 1970, *Introductory Soil Mechanics and Foundations*).

Cavities are large voids within a soil or rock mass that have been recognized to cause subsidence at the ground surface (EPA/600/2-85/035, *Settlement and Cover Subsidence of Hazardous Waste Landfills*). Cavity-related subsidence has been documented related to mining, natural karstic (solution cavity) areas, and landfills. No mining activities have been carried out at the NRDWL. No water-soluble rock (such as limestone that frequently contains solution cavities) exists beneath the site to a depth of several thousand feet. Cavity-related subsidence in landfills is caused by waste consolidation (dewatering) over time, decomposition of organic waste, and coalescence of smaller voids created by random dumping of waste. These activities can produce cracks and shearing displacements of the cover, collapse of portions of the cover, and ponding of water in depressions formed by uneven subsidence within the waste layer beneath the cover.

Before construction of the closure cover, the NRDWL site subsurface will be explored by geophysical methods (ground penetrating radar) to detect voids that may be of sufficient size to compromise cover stability. Any large voids identified during the survey will be filled with grout.

The cover over the NRDWL is designed with a 2 percent slope from a central ridge or high point near the center of the southern edge of the covered area or boundary with the SWL, with the slope proceeding in three directions to the outer perimeter of the landfill. The elevation of the cover at the central ridge will be approximately 2.7 m (9 ft) higher than at the edges. Because of the low sloping profile of the cover design, failures of soil materials within the cover (i.e., rotational failures) are considered to be extremely unlikely.

7.3.7 Cover Permeability

In accordance with WAC 173-303-665(6)(a)(v), the cover system must provide a hydraulic conductivity value less than or equal to the natural site subsoils. The intent of this regulation is to control the rate of infiltration through the cover so that it does not exceed the water removal capacity of the liner/leachate collection system (when present) or natural subsoils. No liner/leachate collection system is present at the NRDWL.

The NRDWL is underlain by unconsolidated sands, silts, and gravels deposited by glaciofluvial and fluvial-lacustrine processes, and blanketed by a thin veneer of stabilized Holocene dune sand. Unsaturated hydraulic properties of the subsoils in the vadose zone at the NRDWL have not been tested to date (WHC-EP-0021, *Interim Hydrogeologic Characterization Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington*, p. 39). Measured hydraulic conductivity values from the upper 18 m (60-ft) interval of the Hanford formation (i.e., the upper 18 m [60 ft] of the unconfined aquifer) at the NRDWL range from about 0.6 (1,700 ft/d) to 1.8 cm/s (5,000 ft/d) (WHC-EP-0021, p. 41). These values are four to five orders of magnitude higher than the hydraulic conductivity of the low-permeability soil (barrier soil) layer in the proposed chemical trench cover design.

7.3.8 Freeze/Thaw Effects

Subsurface soil temperatures have been recorded at the Hanford Meteorological Station since 1952. The lowest temperature to be recorded at a depth of 91 cm (36 in.) below the soil surface was 0 °C (32 °F). Freezing conditions at this depth occurred only once between 1952 and 1980 (PNL-4622, *Climatological Summary for the Hanford Area*). It has been concluded from these data that the zone of frost penetration rarely extends as far as 1 m (3 ft) below grade in the Hanford Site vicinity.

The depth to the water table at the NRDWL is approximately 38 m (125 ft) below the surface; too far below the surface to be a contributory factor in the formation of ice lenses within any of the cover layers. Freeze/thaw cycles are not expected to significantly impact the performance of the final cover.

7.4 Closure Plan Schedule

Subsurface investigations and a topographical survey accurate to 0.3 m (1 ft) contours will precede definitive design efforts and are anticipated to take about six months to complete. Definitive design will include performance modeling (computer simulation using a model based on the Richards Equation, such as STOMP, rather than an enhanced water balance model, such as the HELP model) to identify the optimum cover profile and the preparation of construction drawings, specifications, construction quality assurance plan, and a final design report. Integration with the design of the final cover for the SWL may require this schedule to be extended up to six months because of the differing regulatory issues. Prior to initiating field activities, the contractor services (e.g., earthwork) for site preparation and cover construction must be procured. In addition, this closure plan assumes the NEPA documentation for Area C will have been completed and the borrow source reclamation plan approved.

Schedule assumes sound work practices including the avoidance of harsh winter conditions. The silt cannot be placed when the ground is frozen (i.e., during the winter months). Also, during freezing weather there are no satisfactory means of stabilizing the silt during excavation or after placement in the event of high winds. Initiating placement of the silt during the first week in April would allow the process to be completed by mid- to late September. The blending of the pea-gravel could then be accomplished by mid- to late October, with the surface prepared and ready for planting by November, which is the best time of the year to place native plant seeds. However, to reduce the risk of having to delay construction until after July, efforts should be made in March and April to deter migratory birds from nesting in the construction area.

The schedule follows. These activities, listed as Phase I, address the NRDWL and the northern portion of the SWL. A separate activity, Phase 2 not included here, will focus on the southern portion of the SWL.

1. General Mobilization - approximately 4 weeks
   - Water sources (storage tanks), construction trailers, silt borrow source development
   - Provide Ecology with 30 day notification of construction work
2. General Component Preparation - approximately 12 weeks
   - Widening and grading of haul roads [approximately 13 km (8 mi) of road]
   - Preparation of groundwater monitoring wells

1. Phase I Cover Installation Preparation – approximately 8 to 12 weeks
   - Void identification and fill (grouting/filling/compacting)
   - Subgrade preparation (filling of low areas, re-grading/compacting)
   - Excavation of runoff basins

2. Phase I Silt Placement – approximately 26 weeks
   - Restriction: start placement after April 1 (to avoid freezing weather conditions)
3. Phase I Side Slope Placement – approximately 6 weeks (occurs during latter part of item 4)
4. Phase I Pea-Gravel Placement – approximately 6 weeks
5. Phase I Seeding/Mulching with Tackifier
6. General Fencing/Signs and Demobilization.

7.5 Amendment of Plan

As required by WAC 173-303-610(3)(b), "Closure Plan; Amendment of Plan," the closure plan will be amended if unexpected events required a modification of the approved closure plan during final closure activities. If an amendment to the approved closure plan is required, the RL will submit a written request to Ecology to authorize a change to the approved plan. The written request will include a copy of the closure plan amendment for approval.

7.6 Certification of Closure

Within 60 days of final closure, the RL will submit to Ecology a certification of closure. This certification will be signed by both the RL and an independent professional engineer registered in the State of Washington, stating that the facility has been closed in accordance with the approved closure plan. The certification will be submitted by registered mail. Documentation supporting the closure certification will be retained and furnished to Ecology upon request.

7.7 Notice to Local Land Authority

In accordance with WAC 173-303-610(9), "Notice to Local Land Authority," no later than the submission of the certification of closure, the RL will submit to the Benton County Land Planning Department and to Ecology a survey plat indicating the location and dimensions of the NRDWL with respect to permanently surveyed benchmarks. The survey plat submitted will meet the following standards:

- Be prepared and certified by a professional land surveyor
- Contain a note, prominently displayed, that states the RL's obligation to restrict disturbance of the dangerous waste disposal unit, in accordance with the requirements of WAC 173-303-610.

In addition, no later than 60 days after certification of closure, the RL will submit to the Benton County Land Planning Department a record of the type, location, and quantity of dangerous waste disposed within the facility.

7.8 Notice in Deed

Within 60 days of the certification of closure, the RL will sign, notarize, and file a notice in deed meeting the requirements of WAC 173-303-610(10), "Notice in Deed to Property." The notice will be sent to the Auditor of Benton County, P.O. Box 470, Prosser, Washington, with instructions to record this notice in the General Index. This document normally is reviewed in property title searches.

Institutional controls will consist of continued restrictions to access and use of groundwater and may consist of access controls to surface or deeper soils. Institutional controls are required to be maintained to ensure that groundwater is not used as a drinking water or irrigation source. Because RL will maintain control over this site for the foreseeable future and potentially until the groundwater is remediated, it is not anticipated that additional actions will be required to limit controls over groundwater use. Should groundwater use restrictions be required after RL relinquishment of the area, appropriate deed restrictions will be made.

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8 Postclosure Plan

In accordance with WAC 173-303-610(7)(a), the postclosure period begins after certification of closure and will last for 30 years unless it is shortened or extended in accordance with WAC 173-303-610(7)(b). This chapter provides details of the postclosure plan inspection, maintenance, groundwater monitoring, amendments to the closure plan, and certification. Postclosure groundwater monitoring is discussed in Chapter 5.

8.1 Inspection and Maintenance Plans

Inspections include evaluation of security equipment, erosion, and other factors that might affect the integrity of the final cover, the run-on and runoff control measures, and groundwater well conditions. Inspections, except for groundwater wells, are scheduled periodically to observe the site and vegetative cover during different seasonal conditions. Groundwater well conditions will be evaluated during sampling events. Extra inspections may be made if a need is indicated, (e.g., unusual weather occurrences, such as heavy thunderstorms and rapid snowmelt).

Inspections will focus on evaluating:

- Erosion control
- Cover integrity, including subsidence,
- Vegetative cover integrity
- Cover drainage system functioning.

Maintenance of the unit throughout the postclosure period will include repair of security devices and erosion damage; correction of subsidence and animal intrusion; vegetative cover maintenance; and repair of run-on and runoff control structures. Maintenance needs are based on observations made during inspections and monitoring.

8.1.1 Security Control Devices

The NRDWL is located within the Hanford Site controlled access area, where roadways are restricted to unauthorized personnel and, for national security reasons, the general public is excluded. Security information is provided in Section 2.3. Signs required by WAC 173-303-310(2)(a) will be maintained during the postclosure period.

8.1.2 Erosion Control

The overall erosion control for the site will be dictated primarily by the health of the vegetative cover. Erosion damage for areas surrounding the landfill will be addressed in the following three components.

- Precipitation – The Hanford Site climate is mild and dry (arid to semiarid). The Hanford Site typically receives 17 cm (6.8 in.) of annual precipitation. Because of the dry climate, most of the annual precipitation is lost to ET (Section 6.2). The landfill area site surface consists of stabilized dune sand. The dune sediments vary from 0.0 to 3.7 m (0.0 to 12 ft) and consist of very fine to medium sand overlying a relatively flat base. The combination of low annual precipitation, high ET rates, relatively flat topography, and a stable vegetative cover reduces the possibility of erosion damage because of precipitation. However, the integrity of the final cover will be inspected periodically to ensure that no appreciable erosion has occurred. Erosion pins will be placed throughout the landfill area to assist in monitoring for surface erosion. If deemed necessary, repairs will be made by placing additional silt-loam and gravel admix over the deflated area and reseeding.

- Flood – The flow in the Hanford Reach of the Columbia River is controlled by the Priest Rapids Dam. The present river channel was developed at the end of the last ice age, a time when much higher volumes of water flowed through the river than today. The flood water associated with a regulated (by Priest Rapids Dam) 100-year flood of 12,500 m^3/sec (440,000 ft^3/sec) would not leave the present channel banks (120 m [390-ft] mean sea level contour), while the 100-year flood waters from the Cold Creek would not approach the site. Therefore, the probability of flood-induced, erosional damage to the final cover is very low.
- Wind – The monthly average wind speeds for the Hanford Site range from about 13.7 km/h (8.5 m/h) in the summer to 10 km/h (6.4 m/h) in the winter. The prevailing regional winds are from the northwest. High/intense winds are typically from the southwest. Wind storms do occasionally occur on the Hanford Site and peak gusts can commonly exceed 80 km/h (50 m/h). The highest wind speed recorded at Hanford Meteorological Tower was 120 km/h (80 m/h) at the 15 m (50 ft) level (January 1972). The average number of days in a year where gusts can exceed 80 km/h (50 m/h) is five. In the spring, early summer, and late fall, the local floral community helps control wind erosion. When the floral communities begin to dry out in late summer, the probability of wind erosion remains low because winds usually tend to decrease during this period. One half of the annual precipitation typically falls during the four months of late fall and winter, when the lowest average wind speeds occur. This, coupled with a low ET rate, decreases the potential for winter wind erosional damage.

Surface erosion pins will be strategically placed throughout the landfill cover to provide a general indication of surface deflation and/or deposition. If the erosion pins indicate an undue amount of soil movement during the inspections, the affected area will be surveyed using one of several methodologies available to develop a surface contour map with vertical accuracy to 0.15 m [0.5 ft] (e.g., Global Positioning System grid or Light Detection and Ranging). Appropriate actions will be taken based on the results of the survey. If erosion greater than or equal to 0.3 m (1 ft) in the run-on and runoff control systems areas or that results in the development of gullies in an excess of 0.3 m (1 ft) deep is identified; an evaluation will be performed to determine a corrective action.

Because of the low probability of serious damage caused by wind or storm-water erosion, preventative measures beyond those described in Chapter 7 are considered unnecessary. However, erosion damage will be properly noted and reported to the responsible maintenance organization. Minor damage will be repaired with hand tools. Major erosion damage repairs will be made using grading equipment and fill soils, as appropriate. Repairs will return all site surfaces to pre-damaged conditions. Maintenance activities will be noted in the inspection logbook.

8.1.3 Cover Integrity

Cover integrity will be assessed by evaluation of subsidence (which is a term for any surface breach or depressions on the exterior of the final cover) and animal intrusion. Also, regular cover integrity inspections will look for any major disruption caused by animals burrowing or wallowing on the surface (digging large depressions) that might breach or otherwise impact the performance of the final cover. Significant breaches or depressions will require an investigation to determine the root cause, evaluate the long-term environmental impacts, and provide a corrective solution.

Subsidence will be assessed by the use of periodic elevation surveys (by conventional survey instruments, Light Detection and Ranging, or aerial phototopography) of control points. Control points (survey markers) will be set around the perimeter and at critical points on the cover. To support postclosure monitoring, the number of control points will be assessed to determine how many additional points will be needed to annually monitor the subsidence. If subsidence greater than 0.3 m (1 ft) is observed, an evaluation will be performed to determine a corrective action. Proposed maintenance action will be to fill in the depression with silt/silt-loam soil and reestablish the vegetative cover as needed [WAC 173-303-390(3), "Facility Reporting"]. One advantage of ET barriers over geomembranes are that they are generally self-healing (i.e., there are no critical engineered interfaces between multiple soil layers that, if disrupted, could compromise the functionality of the cover). Filling in any depression that may develop allows the surface to continue to drain to the landfill perimeter.

In anticipation of minor subsidence that will likely occur, a small stockpile (approximately 10 yd^3 [7.6 m^3]) of silt loam soil will be stored on site to repair the barrier. The stockpile will be created during construction of the barrier and will be stabilized with the seed mix used in the vegetative cover.

8.1.4 Vegetative Cover Integrity

Immediately after closure, the area of the NRDWL will be seeded to initiate growth of a native vegetative cover. The vegetative cover is a very important factor for the long-term stability of the site and performance of the ET cover. After evaluation, maintenance action may include replacement of the fine soil top layer at the affected area, reseeding, and other tasks that were performed during closure (such as the application of pea-gravel admix) to ensure an erosion resistant surface. No cover damage is expected from inspectors walking over the site during the inspections.

Maintenance actions might be required if the vegetation on the final cover fails to progress towards a plant density similar to that of the surrounding undisturbed native vegetation. Maintenance action will include reseeding and the possible application of soil amendments. The inspection of the vegetative cover will follow the same procedures as outlined for erosion damage.

8.1.5 Cover Drainage System Functioning

The integrity of the run-on and runoff precipitation control systems, and the gravel stabilized perimeter of the final cover will be evaluated periodically. The probability of serious damage to the NRDWL because of flooding or storm-water runoff/run-on is low. Run-on and runoff damage are expected to be minimal as a result of the combination of porous soils, arid regional climate, high ET rates, localized collection or drainage areas and minimal local slope in the surrounding area. Specific run-on prevention structures are not necessary in the final cover design for the NRDWL because of the elevated profile.

If erosion greater than or equal to 0.3 m (1 ft) in the areas of the run-on and runoff control systems or that results in the development of gullies in an excess of 0.3 m (1 ft) deep is identified, an evaluation will be performed to determine a corrective action. Proposed maintenance action will be to fill and armor the eroded area with 10 cm (4 in.) minus gravel or rip-rap. Damage to runoff control structures (ditches surrounding the cover) noted during periodic inspection periods will be reported to the responsible maintenance organization for action. All suspected blockages will be eliminated. Minor damage to ditches will be repaired with shovels and other hand tools and/or other appropriate equipment, while minimizing disturbance of the landfill cover.

8.1.6 Inspection Recordkeeping

A logbook will be kept by the personnel conducting inspections. The logbook records may be kept in an electronic format; however, all logbook information will be maintained for examination by the regulatory agency for the entire postclosure period. The inspector will record any damage to the cover and/or other maintenance needs, as well as the weather conditions at the time of inspection, and will sign and date the logbook. The logbook will document the correction of noted problems, in accordance with WAC 173-303-320(2)(d), "General Inspection."

8.2 Postclosure Contact

The following office will be the official contact for the NRDWL during the postclosure care period.

Director, Environmental Management Division
U.S. Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352
(509) 376-0879

8.3 Amendment to Plan

The postclosure plan will be amended by WAC 173-303-610 when required by changes in the postclosure operating plans or facility design. The plan may be amended any time during the active life of the facility or during the postclosure care period. The approved postclosure plan will be amended by submitting a written request to Ecology and the EPA to authorize a change to the approved postclosure plan. The written request will include a copy of the amended postclosure plan for approval.

8.4 Certification of Postclosure Care

No later than 60 days after completion of the established postclosure care period, the RL will submit to Ecology a certification of postclosure care. This certification will be signed by both the RL and an independent professional engineer registered in the State of Washington, stating that postclosure care for the facility was performed in accordance with the approved postclosure plan. The certification will be submitted by registered mail. Documentation supporting the postclosure certification will be retained and furnished to Ecology upon request.

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Appendix A

Reprint of 91-EAB-078, *Report on the Excavation and Inventory of Trench 19N at the Nonradioactive Dangerous Waste Landfill, Hanford Site,* published April 25, 1991

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

91-EAB-078

APR 25 1991

RECEIVED APR 30 1991 CORRESPONDENCE CONTROL

Mr. Paul T. Day
Hanford Project Manager
U.S. Environmental Protection Agency
Region 10
712 Swift Boulevard, Suite 5
MSIN: B5-01
Richland, Washington 99352

Mr. Timothy L. Nord
Hanford Project Manager
State of Washington
Department of Ecology
Mail Stop PV-11
Olympia, Washington 98504-8711

Dear Messrs. Day and Nord:

REPORT ON THE EXCAVATION AND INVENTORY OF TRENCH 19N AT THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL, HANFORD SITE

The enclosed report and Chemical Waste Inventory are being forwarded to the U.S. Environmental Protection Agency and the State of Washington Department of Ecology, in accordance with agreements made at the February 14, 1991, Unit Managers' Meeting.

MAY 1991 RECEIVED EDMC

91-EAB-078

Messrs. Day and Nord -2- APR 25 1991

If you have questions regarding these documents, please contact Ms. S. L. Trine of the U.S. Department of Energy, Richland Operations Office on (509) 376-6943, or Ms. C. J. Geier of the Westinghouse Hanford Company on (509) 376-2237.

Sincerely,

E. A. Bracken, Director
Environmental Restoration Division
Richland Operations Office

ERD:SLT

R. E. Lerch, Manager
Environmental Division
Westinghouse Hanford Company

Enclosure:
Excavation Report/Chemical Waste Inventory

cc w/o encl.:
D. L. Duncan, EPA
R. E. Lerch, WHC
P. Stasch, Ecology, w/encl.

REPORT ON THE EXCAVATION AND INVENTORY OF TRENCH 19N AT THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL, HANFORD SITE

INTRODUCTION

The Nonradioactive Dangerous Waste Landfill (NRDWL) is an isolated, operationally closed, land disposal unit located near the geographic center of the Hanford Site in the 600 Area. The landfill received nonradioactive dangerous chemicals regulated under WAC 173-303 in six trenches from 1975 through May 1985. On November 8, 1985, one of the six chemical trenches (Figure 1), designated 19N, was excavated to retrieve several drums containing regulated dangerous waste.

The purpose of this paper is to document the November 8, 1985 Trench 19N excavation activity in response to an action item identified during the January 15, 1991 Unit Managers Meeting for the NRDWL. Specifically, this paper describes the excavation process and conditions encountered during the retrieval process, and reconciles pre- and post-excavation inventories. Information concerning the excavation process was acquired from interviews with Hanford Site personnel that were directly involved with the activity.

DESCRIPTION OF THE TRENCH 19N EXCAVATION ACTIVITY

Background Information

A 150-foot section of Trench 19N was opened in March 1984 to dispose of oxidizer chemicals. The trench was approximately 14 feet deep and 16 feet wide at the base. An access ramp on the south end of the trench allowed transfer vehicles to access the working face. An 8- to 12-inch layer of cobble/gravel was placed over the bottom of the trench to form a temporary roadbed. A representative cross section of the trench is shown in Figure 2.

Trench 19N received its first shipment of waste in April 1984 consisting of nonregulated empty containers. The first receipt of chemical waste occurred in June 1984. A total of 4 shipments of chemical waste where placed in Trench 19N, the last of which was received in May 1985. The trench also received 7 shipments of empty containers not regulated under WAC 173-303. Each shipment of waste was catalogued using a disposal request number. All containers disposed of in Trench 19N were covered by an approximately 10-foot thick operational cover consisting of local sand.

On November 8, 1985, Trench 19N was excavated to retrieve drums containing sodium nitrite which had been mistakenly disposed of in the trench. Sodium nitrite which is designated as an extremely hazardous waste was prohibited from being disposed of in the NRDWL. In the process of retrieving the sodium nitrite drums, all other waste containers that were disposed of in Trench 19N also were removed. Approximately 120 feet of available trench space had been filled prior to the Trench 19N excavation activity.

OPEN 1-76	SANITARY TRASH	CLOSED 9-76	1N
OPEN 5-85	ASBESTOS	CLOSED 10-86	2N
OPEN 7-79	ASBESTOS	CLOSED 7-81	20
OPEN 1-84	ASBESTOS	CLOSED 5-85	21
OPEN 10-86	ASBESTOS	CLOSED 5-88	22
OPEN 7-81	ASBESTOS	CLOSED 9-82	23
	UNUSED		24
OPEN 9-82	ASBESTOS	CLOSED 3-84	25
OPEN 1-85	CORROSIVES	OPEN	26
OPEN 1-75	ASBESTOS	CLOSED 7-76	27
OPEN 2-84	CORROSIVES	CLOSED 1-85	28
OPEN 9-76	ASBESTOS	CLOSED 6-79	29
OPEN 8-76	ASBESTOS	CLOSED 9-78	30
OPEN 9-82	CHEMICAL	CLOSED 4-84	31
	UNUSED		32
OPEN 11-80	CHEMICAL	CLOSED 9-82	33
OPEN 1-75	CHEMICAL	CLOSED 11-80	34
	UNUSED		18N
OPEN 3-84	OXIDIZERS	OPEN	19N

Figure 1. Nonradioactive Dangerous Waste Landfill Trench Plan.

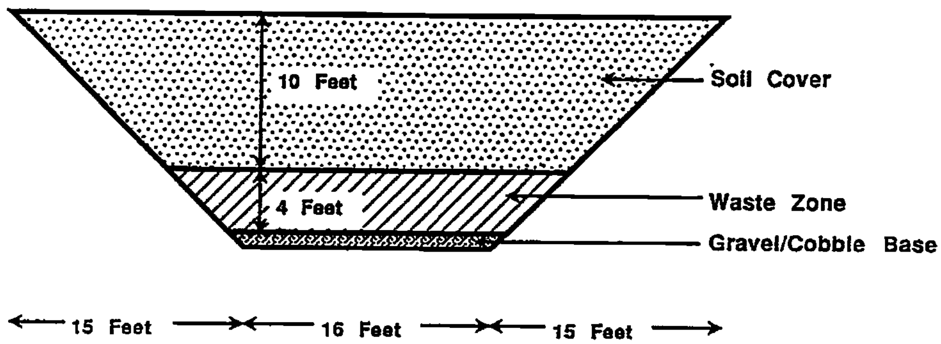

Figure 2. Representative Cross Section of a Nonradioactive Dangerous Waste Landfill Chemical Trench.

Excavation Methodology

The excavation of Trench 19N and retrieval of drums was performed by NRDWL landfill operating personnel including a work supervisor, a heavy equipment operator, and two laborers. Equipment used included a front end wheel loader and hand shovels. No written work plan was prepared.

The excavation activity began by scraping off a portion of the operational cover using a front wheel loader to decrease the amount of overburden. The depth of material removed in this manner was limited to a few feet to prevent damaging the underlying containers. Cover material that was removed was piled along the sides of the trench.

After the upper portion of the cover was removed, the front end loader was then used to locate the buried containers. Working in the bottom of the trench, the loader operator carefully exposed containers by driving the loader bucket into the base of the waste layer and then tilting or lifting the bucket. By following the coarse gravel/cobble layer (Figure 2), which defined the base of the waste layer, the operator was successful in positioning the bucket beneath the containers. Excavated soil was piled along the edges of the trench.

After a container was located with the front end loader, laborers would complete the excavation using hand shovels and place the container in the loader bucket. The container would then be transported out of the trench. Retrieved containers were segregated by shipment (i.e. disposal request number) and staged along the east side of the trench. The method of excavation was considered to be effective in finding and retrieving containers without damage.

The retrieval process started on the south side (open side) of the Trench 19N and progressed in manner opposite to the original disposal sequence. The activity took two days to complete at a cost of approximately $2,000. Thirty metal drums containing regulated waste, and numerous empty containers were retrieved. No leaking containers or evidence of soil contamination was observed. The metal drums containing regulated waste were found to be in good shape with no damage from the excavation process. Container labels; however, were often illegible, which added some uncertainty to the identification process. This was further complicated by the finding that a number of shipments, which were thought to have been placed in Trench 19N were actually not present. The matching of containers to a particular disposal request number was often based on the arrangement in which they were found in the trench.

On November 11, 1985 containers with regulated waste were either loaded onto a flat-bed for transportation to the 2727S Nonradioactive Dangerous Waste Storage Facility or returned back to Trench 19N and covered. No attempt was made to open retrieved containers at the NRDWL to verify their contents. No waste or soil sampling was performed. Empty containers which were not regulated under WAC 173-303 were transferred to the adjacent Solid Waste Landfill for disposal as sanitary waste.

WASTE DESCRIPTION AND INVENTORY

Three distinct inventory lists for Trench 19N have been provided in RCRA regulatory documents. The first inventory list was provided in Appendix D-1 of the 1985 Part B Permit Application for the Nonradioactive Dangerous Landfill and Storage Facility. In August 1990, a closure and postclosure plan was prepared for the NRDWL (DOE/RL-90-17) that contained two other lists including a revision of 1985 inventory (Appendix 4C) and a post-excavation inventory (Appendix 4A). The following discussion explains the differences between these three inventory lists.

Appendix D-1 contained in the 1985 Part B permit Application was compiled before November 1985, and did not take into account the findings and results of the November 8, 1985 excavation activity. During the excavation of Trench 19N, several shipments that were thought to have been placed in Trench 19N were not found. It was deduced that the missing containers had actually been disposed of in another NRDWL trench (28 or 26) which happened to be open at the same time as Trench 19N. Appendix D-1 was revised accordingly and issued as an appendix (4C) in the closure/postclosure plan. Several discrepancies with the original records were also corrected in Appendix 4C. The inventory for Trench 19N was then revised a second time (Appendix 4A) to reflect the containers that where removed during the excavation activity and transferred elsewhere (e.g. 2727S Facility).

Table 1 summarizes the differences in the three inventory lists, and provides specific comments governing why changes were made to the inventory. In addition, Table 1 identifies several remaining errors. These errors have been corrected in the attached inventory lists for Trench 19N and 28. Effected inventory lists in the NRDWL Closure/Postclosure Plan will also be revised accordingly in the next revision of the document.

TABLE 1. CHEMICAL WASTE INVENTORIES FOR NONRADIOACTIVE DANGEROUS WASTE LANDFILL TRENCH 19N

1985 Part B Permit Application Inventory (Appendix D-1)			Disposal Request #	Comments/Disposition	1990 Closure/PostClosure Plan (DOE/RL-90-17)	
Date	Quantity	Chemical			Pre-Excavation Inventory (Appendix 4C)	Post-Excavation Inventory (Appendix 4A)
04-17-84	10 gal 20 gal 55 gal 55 gal 55 gal 30 gal 5 gal 5 gal 5 gal	Ferric nitrate Lithium nitrate Ferric phosphate Neodymium nitrate Aluminum nitrate Rare earth nitrate Magnesium nitrate Kesel Manganese nitrate	5-17	•Original record indicates that all containers were empty •Empty containers were transferred to SWL	•Deleted	•Deleted
06-13-84	2 lb 20 lb	Sodium nitrate Sodium nitrate	9-33	•Original record indicates that the total quantity should read 20 lbs not 22 lbs •Returned to Trench 19N following excavation	•Included	•Included
07-05-84	100 lb 25 lb 13 gal 225 lb	Versene EDTA Thiourea Ethylene glycol Ammonium persulfate	9-41	•Not found during excavation of Trench 19N •Assumed to be disposed of in corrosive Trench 28	•Deleted	•Deleted, but not added to Trench 28 inventory
07-19-84	18 drums 10 drums	Sodium nitrite Nickel, hydrated	6-9	•18 drums sodium nitrite transferred to 2727S •1 drum nickel transferred to 2727S; 9 other drums nickel were not found during excavation of Trench 19N •Assumed that 9 drums nickel are disposed of in corrosive Trench 28	•Included; however quantity is incorrect	•Deleted and added to Trench 28 inventory, but quantity is incorrect
09-05-84	400 lb	Metal alloy - 40% Al and 60% Ca	10-9	•Not found during excavation of Trench 19N •Assumed to be disposed of in corrosive Trench 28	•Deleted	•Deleted, but not added to Trench 28 inventory
09-24-84	10 gal	Dioctyl sebacate	10-43	•Nonregulated Waste •Not found during excavation of Trench 19N	•Deleted	•Deleted
11-09-84	75 gal	Paint related material	11-39B	•Original record indicates that waste was actually placed in corrosive Trench 28	•Deleted	•Deleted, but not added to Trench 28 inventory

9 1 1 2 1 ' 3 0 2 5 6

TABLE 1. CHEMICAL WASTE INVENTORIES FOR NONRADIOACTIVE DANGEROUS WASTE LANDFILL TRENCH 19N

1985 Part B Permit Application Inventory (Appendix D-1)			Disposal Request #	Comments/Disposition	1990 Closure/PostClosure Plan (DOE/RL-90-17)	
Date	Quantity	Chemical			Pre-Excavation Inventory (Appendix 4C)	Post-Excavation Inventory (Appendix 4A)
12-05-84	1 lb 1 lb 1 lb 5 lb 1 pt 1 pt 1 qt 1 gal 1 lb 1 lb 1 qt 2 qt	Potassium permanganate Sodium nitrate Sodium chromate Sodium hydroxide Ethyl acetate Methanol Isopropanol Naphtha Ammonium nitrate Ammonium chloride Ammonium hydroxide Ammonium oxalate	12-15B	•Returned to Trench 19N following excavation	•Included	•Included; however several additional chemicals were mistakenly added
12-20-84	69 mL 230 mL	Refill CQC for Fyrite Oxygen Indicator Methanol	10-23	•Original record indicates that waste was actually placed in corrosive Trench 28	•Deleted	•Deleted, but not added to Trench 28 inventory
01-11-85	13 drums	Salt cake	5-31	•Not found during excavation of Trench 19N •Assumed to be disposed of in corrosive Trench 26; however, corrosive Trench 28 may have been used, because it was also open during this period	•Included, but should have been deleted	•Deleted and added to Trench 26 inventory
05-14-85	3 drums 1 drum	Calcium nitrate Sodium nitrate	7-23	•Returned to Trench 19N following excavation	•Included	•Included

ATTACHMENT 1

REVISED INVENTORY LISTS FOR TRENCH 19N AND 28

APPENDIX 4A
CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #19N

Date	Quantity	Chemical
11-08-85	3 drums, 55 gal	Waste calcium nitrate
11-11-85	1 drum, 55 gal	Waste sodium nitrate
	~~22~~ 20 lb	Sodium nitrate
	1 pt	Ethyl acetate
	~~8 pt~~	~~Toluene~~
	~~1 pt~~	~~Xylene~~
	~~3~~ 1 pt	Methyl alcohol
	~~5 pt~~	~~Benzene~~
	~~2~~ 1 qt	Isopropanol
	1 lb	Potassium permanganate
	1 lb	Ammonium nitrate
	~~3~~ 1 lb	Sodium nitrate
	1 lb	Ammonium chloride
	1 lb	Sodium chromate
	~~1 qt~~	~~1-1-1-Trichloroethane~~
	~~2~~ 1 qt	Ammonium hydroxide
	~~1 pt~~	~~37% Formaldehyde solution~~
	5 lb	Sodium hydroxide, dry solid
	1 gal	Naphtha
	2 qt	Ammonium oxalate (TURCO 4521*)

ATT 1-1

APPENDIX 4A
CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #28

Date	Quantity	Chemical
02-03-84	6 lb	Sodium hydrogen sulfide
	1 lb	Sodium chromate
	1 lb	Sodium bichromate
	0.5 lb	Potassium chromate
	10 oz	1-Ethylquinelinium iodide
	1 lb	Sodium metabisulfite
	1 lb	Ferrous sulfate
	0.5 lb	Nickel chloride
	1 kg	Calgon*
	1 lb	Gelatine powder
	1 pt	Flexible collodion
	1 L	Polyelectrolytes
	1 lb	Ammonium sulfate
	1 lb	Aluminum oxide
	32 oz	Glycenyl triacetate
	800 g	Weldon 28 component C
	32 oz	Ammonium sulfide
	250 mL	Castor oil
	1 pt	Photo-flo 200
	100 g	Creosote
02-09-84	110 gal	Anhydrous borax
	255 gal	Sodium nitrate
	170 gal	Boric acid
	240 gal	Sodium nitrite
	145 gal	Sodium nitrite, borax, frit, sand, gravel
	22 gal	Boric acid, frit, soda ash, silica, and warehouse sweepings
	120 gal	Boric acid, anhydrous borax, brown sand
	175 gal	Boric acid, borax, potassium nitrate
	165 gal	Boric acid, sand, fine frit, borax, sodium nitrate
	220 gal	Boric acid, frit, borax, sodium nitrate
	195 gal	Borax, sand, frit, empty chemical bags
	55 gal	Low sodium nitrate sludge
	55 gal	Normal sodium nitrate sludge
	275 gal	Sodium carbonate sludge spiked
02-22-84	18 gal	Ammonium hydroxide
03-16-84	200 mL	Butyl alcohol
	1 pt	2-Propanol

ATT 1-2

APPENDIX 4A
CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #28

Date	Quantity	Chemical
03-16-84	0.5 pt	Butyl ether
(cont)	1 L	Amyl alcohol
	0.5 kg	n-Octylalcohol
	0.5 pt	Normal paraffin hydrocarbon
	1,000 mL	Plexiglass* cement
	1 pt	Iodobenzene
	2/3 pt	Combustible liquid, n.o.s.
	0.5 L	Phosphenylchloride, dichlorophenyl phosphine
	500 mL	Indene
	1/8 pt	Diazald
	1 L	Tris (hydroxymethyl) amino-methane
	1 pt	Hypophosphorus acid
	250 g	Antimonypentachloride
	1 L	Bromine
	1 pt	Hydriodic acid
	1 pt	Dinoylnapthalenesulfonic acid
	450 g	Benzoyl peroxide
	1 L	2,2-A$_2$O-bis-2-Methyl propionitrile
	315 kg	Ceric oxide
	54 ft^3	Cerous oxalate
	1 pt	Butyl ether
	11 qt	Sulfurous acid
	250 lb	Magnesium nitrate
	100 lb	Bismuth nitrate
	75 lb	Sodium nitrate
	950 lb	Sodium nitrite
	75 lb	Disodium phosphate
	96 lb	Cesium carbonate
	25 lb	Soda ash
	5 gal	Kaowool* cement
	100 lb	Activated aluminum
	30 lb	Sodium fluoride
05-01-84	2 gal	Urethane component A
	1 pt	Urethane component B
	2 gal	Concentrated chemical A/B
05-23-84	20 gal	Waste corrosive liquid, n.o.s. (Picrolonic acid, formic acid, and vanadous formate all absorbed)
06-13-84	10 lb	Sodium hydroxide

ATT 1-3

APPENDIX 4A
CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #28

Date	Quantity	Chemical
06-14-84	17 gal	Ammonium hydroxide
06-20-84	0.5 kg	Zirconium hydride
06-22-84	1,140 gal	Lanthanum nitrate
	825 gal	Trichloroethane
07-05-84	100 lb	Versene EDTA
	25 lb	Thiourea
	13 gal	Ethylene glycol
	225 lb	Ammonium persulfate
07-19-84	~~90 lb~~ 9 drums, 55 gal	Nickel, hydrated
08-23-84	1 pt	Ammonium sulfide
	1 pt	Ethylacetate
	0.5 gal	Hexone
	6 pt	Butyl alcohol
	1 qt	Hexone
	1 qt	Collodion
	1 pt	Amyl acetate
	1 pt	Ethyl acetate
	3 kg	Methyl ethyl ketone
	1 pt	Hexone
	1 qt	Tetrahydrofuran
	1 pt	Perchloric acid (70%)
	1 pt	Hydrogen peroxide (30%)
	5 gal	Dichloromethane
	1 qt	Bis(2-ethylhexyl)2-hexylphosphonate
	1 qt	Mono-2-ethyl hexylacid orthophosphate
	1 pt	Glycerine
	1 kg	Octyl alcohol
	5 L	Isopentyl alcohol
	1 qt	Acetyl acetone
	1 gal	Dimethyl formamide
	1 L	Hexanol
	5 lb	Lactic acid
	1 qt	Diisopropyl ketone
	1 gal	Sulfuric acid (93%)
09-05-84	400 lb	Metal alloy - 40% Al and 60% Ca

ATT 1-4

APPENDIX 4A
CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #28

Date	Quantity	Chemical
11-09-84	75 gal	Paint related material
12-20-84	69 mL 230 mL	Refill for CQC for fyrite oxygen indicator Methanol
01-11-85	520 gal	Dry salt cake: $NaNO_3$, $NaNO_2$, NaOH

ATT 1-5

APPENDIX 4C

PRE-NOVEMBER 1985 CHEMICAL WASTE INVENTORY FOR THE NONRADIOACTIVE DANGEROUS WASTE LANDFILL

Trench #19N

Date	Quantity	Chemical
06-13-84	~~2 lb~~	~~Sodium nitrate~~
	20 lb	Sodium nitrate
07-19-84	~~990 gal~~ 18 drums, 55 gal	Sodium nitrite
	~~550 gal~~ 1 drum, 55 gal	Nickel, hydrated
12-05-84	1 lb	Potassium permanganate
	1 lb	Sodium nitrate
	1 lb	Sodium chromate
	5 lb	Sodium hydroxide
	1 pt	Ethyl acetate
	1 pt	Methanol
	1 qt	Isopropanol
	1 gal	Naphtha
	1 lb	Ammonium nitrate
	1 lb	Ammonium chloride
	1 qt	Ammonium hydroxide
	2 qt	Ammonium oxalate
~~01-11-85~~	~~13 drums, 55 gal~~	~~Salt cake~~
05-14-85	3 drums, 55 gal	Waste calcium nitrate
	1 drum, 55 gal	Waste sodium nitrate

ATT 1-6

Appendix B

Waste Inventory

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Contents

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Waste inventory consists of a listing of the chemical waste placed in the Nonradioactive Dangerous Waste Landfill. The inventory is organized by trench number, date of disposal, and type and quantity.

Trench 19N

Date	Quantity	Chemical
11-08-85	3 drums, 55 gal	Waste calcium nitrate
	1 drum, 55 gal	Waste sodium nitrate
	22 lb	Sodium nitrate
	1 pt	Ethyl acetate
	8 pt	Toluene
	1 pt	Xylene
	3 pt	Methyl alcohol
	5 pt	Benzene
	2 qt	Isopropanol
	1 lb	Potassium permanganate
	1 lb	Ammonium nitrate
	3 lb	Sodium nitrate
	1 lb	Ammonium chloride
	1 lb	Sodium chromate
	1 qt	1-1-I Trichloroethane
	2 qt	Ammonium hydroxide
	1 pt	37% Formaldehyde solution
	5 lb	Sodium hydroxide, dry solid
	1 gal	Naphtha
	2 qt	Ammonium oxalate (TURCO 4521*)

Trench 26

Date	Quantity	Chemical
01-11-85	13 drums, 55 gal	Sodium nitrite
04-17-85	114 drums, 55 gal 8 drums, 55 gal	Oil soaked sand

Trench 28

Date	Quantity	Chemical
02-03-84	6 lb	Sodium hydrogen sulfide
	1 lb	Sodium chromate
	1 lb	Sodium bichromate
	0.5 lb	Potassium chromate
	10 oz	1-Ethylquinelinium iodide
	1 lb	Sodium metabisulfite
	1 lb	Ferrous sulfate
	0.5 lb	Nickel chloride
	1 kg	Calgon*
	1 lb	Gelatine powder
	1 pt	Flexible collodion
	1 L	Polyelectrolytes
	1 lb	Ammonium sulfate
	1 lb	Aluminum oxide
	32 oz	Glycenyl triacetate
	800 g	Weldon 28 component C
	32 oz	Ammonium sulfide
	250 mL	Castor oil
	1 pt	Photo-flo 200
	100 g	Creosote
02-09-84	110 gal	Anhydrous borax
	255 gal	Sodium nitrate
	170 gal	Boric acid
	240 gal	Sodium nitrite
	145 gal	Sodium nitrite, borax, frit, sand, gravel
	22 gal	Boric acid, frit, soda ash, silica, and warehouse sweepings
	120 gal	Boric acid, anhydrous borax, brown sand
	175 gal	Boric acid, borax, potassium nitrate
	165 gal	Boric acid, sand, fine frit, borax, sodium nitrate
	220 gal	Boric acid, frit, borax, sodium nitrate
	195 gal	Borax, sand, frit, empty chemical bags
	55 gal	Low sodium nitrate sludge
	55 gal	Normal sodium nitrate sludge
	275 gal	Sodium carbonate sludge spiked
02-22-84	18 gal	Ammonium hydroxide
03-16-84	200 mL	Butyl alcohol
	1 pt	2-Propanol

Date	Quantity	Chemical
03-16-84 (cont)	0.5 pt	Butyl ether
	1 L	Amyl alcohol
	0.5 kg	n-Octylalcohol
	0.5 pt	Normal paraffin hydrocarbon
	1,000 mL	Plexiglass* cement
	1 pt	Iodobenzene
	2/3 pt	Combustible liquid, n.o.s.
	0.5 L	Phosphenylchloride, dichlorophenyl phosphine
	500 mL	Indene
	1/8 pt	Diazald
	1 L	Tris (hydroxymethyl) amino-methane
	1 pt	Hypophosphorus acid
	250 g	Antimonypentachloride
	1 L	Bromine
	1 pt	Hydriodic acid
	1 pt	Dinoylnapthalenesulfonic acid
	450 g	Benzoyl peroxide
	1 L	2,2-$A_2$0-bis-2-Methyl propionitrile
	315 kg	Ceric oxide
	54 ft^3	Cerous oxalate
	1 pt	Butyl ether
	11 qt	Sulfurous acid
	250 lb	Magnesium nitrate
	100 lb	Bismuth nitrate
	75 lb	Sodium nitrate
	950 lb	Sodium nitrite
	75 lb	Disodium phosphate
	96 lb	Cesium carbonate
	25 lb	Soda ash
	5 gal	Kaowool* cement
	100 lb	Activated aluminum
	30 lb	Sodium fluoride
05-01-84	2 gal	Urethane component A
	1 pt	Urethane component B
	2 gal	Concentrated chemical A/B
05-23-84	20 gal	Waste corrosive liquid, n.o.s. (Picrolonic acid, formic acid, and vanadous formate all absorbed)
06-13-84	10 lb	Sodium hydroxide

Date	Quantity	Chemical
06-14-84	17 gal	Ammonium hydroxide
06-20-84	0.5 kg	Zirconium hydride
06-22-84	1,140 gal	Lanthanum nitrate
	825 gal	Trichloroethane
07-19-84	90 lb	Nickel, hydrated
08-23-84	1 pt	Ammonium sulfide
	1 pt	Ehtylacetate
	0.5 gal	Hexone
	6 pt	Butyl alcohol
	1 qt	Hexone
	1 pt	Amyl acetate
	1 pt	Ethyl acetate
	3 kg	Methyl ethyl ketone
	1 pt	Hexone
	1 qt	Tetrahydrofuran
	1 pt	Perchloric acid (70%)
	1 pt	Hydrogen peroxide (30%)
	5 gal	Dichloromethane
	1 qt	Bis(2-ethylhexyl)2-hexylphosphonate
	1 qt	Mono-2-ethyl hexylacid orthophosphate
	1 kg	Octyl alcohol
	5 L	Isopentyl alcohol
	1 qt	Acetyl acetone
	1 gal	Dimethyl formamide
	1 L	Hexanol
	5 lb	Lactic acid
	1 qt	Diisopropyl ketone
	1 gal	Sulfuric acid (93%)
01-11-85	520 gal	Dry salt cake: $NaNO_3$, $NaNO_2$, NaOH

Trench 31

Date	Quantity	Chemical
11-05-82	210 lb	Lead acid gel in battery
12-10-82	1 lb	Mercury absorbed and contained
12-17-82	4 ft^3	Beryllium copper
02-03-83	1,440 lb	Lithium nitrite and reaction debris
03-21-83	10 lb	Phosphoric acid
	170 mL	Gasoline
	4,000 mL	Xylene
	1,000 mL	Toluene
	1,000 mL	Cyclohexane
	40 mL	tetra-N-Propyl ammonium hydroxide
	400 mL	di-N-Butyl sulfoxide
	100 mL	2,4-D Amine
	200 mL	Dicamba
	200 mL	Teflon*
	200 mL	Tordon*
	500 mL	50% hydrogen peroxide
	200 mL	Type B polymer
	200 mL	Type A polymer
	2 gal	Ammonium fluoride
04-12-83	2 bags	Misc. (herbicide contaminated rags, respirator cartridges, etc.)
04-14-83	11 lb	Sulfanilic acid
	4 kg	Sulfanilamide
	500 g	Potassium persulfate reduced
	250 g	Chloramine T
05-04-83	5 gal	Muriatic acid
	1 gal	Hydrofluoric acid
05-05-83	2 gal	p-Dioxane
	4 kg	1-Octanol
	2 qt	Triton x-100 (alkyl-lanyl-polyether alcohol)
	20 kg	1,2,4-Trichlorobenzene
	10 pts	Tetrachloroethylene

Date	Quantity	Chemical
05-12-83	48 lb	Ammonium bifluoride
	25 lb	Calcium fluoride
	600 lb	(Chel. DTPA 41) sodium salt*
	200 lb	Sodium salt
	1,200 lb	Rare earth carbonate
	250 lb	Sodium sulfate
	300 lb	Strontium carbonate
	300 lb	Floculant
	15 gal	Tol floc coag. floculant
	350 lb	Powdered clay olin 5004* coagulant aid
	55 gal	Magnesium nitrate
		Crystal oxidizer
	55 gal	Nitrilotriacetic acid
	55 gal	Nalco 5* - sodium
		Aluminate
	55 gal	Nickelous nitrate
		oxidizer
	55 gal	Silica gel - actuated
		desiccant
	100 lbs	Silica gel
06-01-83	1 lb	Oxalic acid
	1 lb	Sodium hydroxide
	1 lb	Aluminum chloride
	1 lb	Aluminum nitrate
	3 pt	Hypo-phosphorus acid
	1 lb	Magnesium perchlorate
	1 lb	Arsenic acid
	25 mL	Petroleum ether
	3 lb	Magnesium perchlorate
	10 pt	Hydroodic acid
	20 pt	Hydroodic acid
	0.25 lb	Potassium hydrogen phthalate
	1 lb	Potassium persulfate
	1 lb	Bromine
	1 pt	Cerric sulfate in sulfuric acid
	1 lb	Sodium hydroxide
	1 lb	Sodium acetate
	5 lb	Ammonium oxalate
	1 lb	Potassium iodide
	1 lb	Potassium chloride
	1 lb	Potassium carbonate

Date	Quantity	Chemical
06-01-83 (cont)	6.25 lb	Potassium sodium tartrate
	1 lb	Potassium bromide
	1 lb	Potassium carbonate
	2 lb	Potassium phosphate
	5 lb	Cupric sulfate
	500 mL	Ferric ammonium sulfate
	0.25 lb	Ammonium iodide
	8 lb	Barium chloride
	0.25 lb	Cerium nitrate
	0.25 lb	Lanthanum nitrate
	1 lb	Mercuric thiocyanate
	1 lb	Ammonium oxalite
	12 lb, 1 lb	Sodium meta bisulfate
	10 lb	Sodium bisulfate monohydrate
	1 oz	Cupferron
	1 gal	Propylene carbonate
	1 lb	Sodium bicarbonate
	1 lb	Sodium arsenite
	1 lb	Sodium sulfate
	3 lb	Sodium metasilicate
	1 lb	Sodium phosphate
	0.25 lb, 0.25 lb	Sodium iodide
	1 lb	Sodium hydrosulfate
	4 lb	Sodium dithionite
	1 lb	Sodium bromate
	1 lb, 1 lb	Sodium oxalate
	1 lb	Sodium chloride
	250 mL	Sodium acetate
	1 lb, 7 lb	Sodium fluoride
	1 lb	Sodium sulfite
	1 lb	Ferrous ammonium sulfate
	2 lb	Ammonium acetate
	1 lb	Ammonium bifluoride
	2 lb	Ammonium molybdate
	1 lb	Ammonium phosphate
	2 lb	Ammonium sulfate
	9 lb	Ascorbic acid powder
	1 lb	Sodium acetate
	1 lb	Ferric chloride
	1 lb	Cerric nitrate
	1 lb	Sodium carbonate
	2 lb	Ferrous ammonium sulfate

Date	Quantity	Chemical
06-01-83	25 mL	Tri-Sil Z*
(cont)	50 mL	Ferrous sulfamate
	1 qt	Potassium permangate
	1 qt	Potassium hydrogen sulfate
	1 qt	Potassium hydrogen sulfate
	3 lb	Potassium nitrate
	1 lb	Potassium chloride
	1 lb	Potassium carbonate
	0.25 lb	Cupric nitrate
	1 lb, 0.25 lb	Ferric nitrate
	1 lb	Sodium oxalate
	250 mL	Potassium permanganate
	5 g	Bromo cresol purple sodium
	2 lb	Ammonium citrate
	25 g	Tetrapropylammonium hydroxide
	1 lb	Sodium bisulfate
	3 lb	Sodium bisulfate monohydrate
	1 lb	Sodium carbonate
	6 lb	Sodium chloride
	1 lb	Sodium chromate
	15 lb	Sodium nitrate
	0.25 lb	Sodium tartrate
	1 lb	Sodium thiosulfate
	1 lb	Urea
	0.25 lb	Acid potassium phthalate
	1 lb	Cuprous chloride
	6 lb	Ferrous ammonium sulfate
	2 lb	Lithium fluoride
	1 lb	Magnesium chloride
	1 lb	Nickel nitrate
	3 lb	Potassium bromate
	1 lb	Potassium fluoride
	250 g	Potassium iodide
	100 g (top of drum)	Sulfamic acid
	115 g	Hydroxylamine hydrochloride
	125 mL	Dibutyl phosphonate
	250 mL	Collodion
	1 pt	Methyl isobutyl ketone
	1 pt	Agle sulanilic acid in acetic acid
	125 mL	Lithium-10-phenanthroline ferrous sulfate

Date	Quantity	Chemical
06-01-83 (cont)	5 lb (top of drum)	Sulfamic acid
	1 lb	o-Tolidine dihydrochloride
	12 lb	Ascarite
	0.25 lb (top of drum)	Glycolic acid
	8 lb	Hydroxylamine hydrochloride
	0.25 lb	Diethylene-triamine-penta-acetic acid
	1 lb	Hydroxylamine hydrochloride
	200 mL, 500 mL	Dibutyl phosphonate
	200 mL	Dichlorodimethylsilane
	125 mL	n-Tridecane
	250 mL, 250 mL (bottom of barrel)	Formic acid
	1 pt	Isoamyl alcohol
	1 pt	Amyl acetate
	1 gal	Methymethocylate
	1 gal	Tributylphosphate
	2 gal	Butylstearate
	1 pt	Isoamyl alcohol
	5 pt	Methylisobutyl ketone
06-06-83	46 lb	Dioctyl sebacate (absorbed)
	8,835 g	Petroleum distillates
	1,500 cc	Ethyl acetate
	16.5 oz	Petroleum solvent and alcohol
	12 oz	Metal check remover E-59
	3 oz	Petroleum distillate and diethyl ether
06-22-83	125 lb	TURCO 4502
06-27-83	24 oz	Sulfuric acid
	8 oz	Potassium hydroxide solution
	8 oz	Sulfate solution
07-10-83	125 lb	Ferrous sulfamate
	325 lb	Painters' waste (rags, thinner, etc.)
07-27-83	735 gal	Ferrous hydroxide
	230 gal	Floor sweepings [calcium carbonate, silica, lithium hydroxide (solid)]

Date	Quantity	Chemical
07-27-83 (cont)	75 lb	Cupric nitrate
09-08-83	4.5 gal	Retort water [organic carbon 30,000-40,000 ppm C inorganic carbon 1,000-3,000 ppm C ammonium ion 36,000 ppm (as ammonium ion)] Ammonium Anions: Sulfate = 23,000 ppm Disulfite = 46,000 ppm Sulfite = up to 2,000 ppm Elements: (ppm) Arsenic - 7 Boron - 45 Barium - 0.2 Calcium - 35 Cadmium - 0.4 Chromium - 0.1 Cobalt - 0.25 Copper - 2 to 24 Iron - 1 Lithium - 4 Magnesium - 1,000 Manganese - 0.1 Molybdenum - 0.5 Potassium - up to 70 Sodium - 520 Silicone - 20 Strontium - 1.5 Zinc - 3.5
	3 pt	1,4 Dioxane
	1 pt	Nitromethane
	2 pt	Methylene chloride
	1 lb	Anhydrone
	4,500 mL	2-Butoxyethanol
	2 gal	Ethylene dichloride
	5 kg	1,1,2,2-Tetrabromo-methane
	1 gal	Micro resist rinse (N-butyl acetate)
	1 gal	Micro resist developer (petroleum distillates)
	0.5 pt	Ditridecyl amine
	0.5 pt	Malachite Green hydrochloride
	0.25 pt	Cobalt molybdenate

Date	Quantity	Chemical
09-08-83 (cont)	0.25 pt	Calcium sulfate
	1 pt	Quinizarin
	0.5 pt	Copper oleate
	1 pt	Ethoxyquin
	1 lb	Dipentamethylene thiuram hexasulfide
	0.5 pt	Ethylene glycol
	500 g	Tetramethyl thiceram disulfide
	1.5 kg	Guaiacol
	1 lb	Citric acid crystals
	0.5 gal	Sorbitan monooleate
	0.5 lb	Diphenyl-phosphoric sulfide
	3 lb	Hydroxylamine hydrochloride
	0.25 pt	N,N-Dimethyl-p-phenylene diamine sulfate
	160 lb	Copper sulfate crystals
	1 pt	Heptane
	1 pt	1-Butanol
	1 gal	Tetrahydrofuran
	1,500 g	Ethanolamine
	0.25 pt	Benzaldehyde
	1 kg	Acrylonitrile 99%
	5 pt	Aniline
	2 L	Sodium amide
	1 gal	Chloroform
	1 gal	Formaldehyde
	1 gal	Carbon tetrachloride
	1 pt	Aluminum cleaner
	1 kg	Crotonaldehyde
	11 lbs	2, 4-Dinitrophenol
09-20-83	1 pt	Acetone
	1 lb	Butyl alcohol
	1 pt	Glycerine (alcohol n.o.s.)
	1 lb	Dextrose anhydrous
	1 lb	Potassium dichloride
	5 lb	Sodium chloride
	1 lb	Sodium silica
	1 lb	Hydrofluoric acid
	100 g	Sulfamic acid (corrosive solid n.o.s.)
	1 lb	Trichloroacetate (corrosive solid n.o.s.)
	1 lb	Lithium hydroxide (corrosive solid n.o.s.)
	5 lb	Sodium hydroxide
	1 lb	Aluminum nitrate

Date	Quantity	Chemical
09-20-83 (cont)	0.25 lb	Cupric nitrate
	1 lb	Magnesium nitrate
	1 lb	Magnesium oxide
	1 lb	Potassium nitrate
	1 lb	Potassium permanganate
	4 oz	Silver nitrate
	1 lb	Sodium nitrate
	1 lb	Strontium nitrate
	1 oz	Zirconium nitrate
	1 lb	Calcium carbonate
	1 lb	Ferric oxide
	1 lb	Potassium phosphate
	1 lb	Potassium phosphate
	1 lb	Sodium acetate
	1 lb	Sodium bicarbonate
	1 lb	Aluminum oxide (ORMA n.o.s.)
	1 lb	Ammonium carbonate
	1 lb	Potassium hydrogen sulfate
	1 lb	Ammonium chloride
	1 lb	Sodium phosphate
10-04-83	6,375 lb	Altrex* metal cleaner
10-17-83	50 gal	Doctyl sebacate (absorbed)
10-27-83	2 pt	Trichloroacetic acid
	9 pt	Methyl alcohol
	6 lbs	Chloroform

Trench 33

Date	Quantity	Chemical
11-07-80	110 gal	Copper beryllium
11-13-80	110 gal	Chemical solution: Acetone, Touluene Methylene chloride and Pyrolytic compounds
11-26-80	4 gal	Waste organic solvents: Methyl isobutyl ketone, Hexane, Methylene chloride (absorbed on vermiculite)
12-26-80	4 gal	Waste solvents: Methyl isobutyl ketone, Hexane Methylene chloride, Ethanol double canned on vermiculite in 25- and 50-lb tin cans (could be absorbed)
12-29-80	Small quantity laboratory reagents, quantity less than 1 kg	Oxalate reagent Rhodium Sulfa salt Hydroquinone Cadmium oxide Potassium sulfate Ammonium compound Ammonium oxalate Versenol 120* Dibutyl hydrogen phosphate N-phenylbenzoyl-dioxanic-acid Dicyandiamide 5-sulfosalicylic acid Quinaldine Bathophenarthvoline disalfonic acid, disodium salt Alizarin Ammonium molybdate Potassium hydroxyacetate Potassium chloride Ammonium citrate Ammonium persulfate Sodium hydrogen carbonate Oxalic acid

Date	Quantity	Chemical
12-29-80 (cont)		Cesium nitrate Sodium nitrate Ethyldianthic acid Ferrous ammonium sulfate Benzoic oxaine Potassium nitrate N-phenylbenzo hydroxamic acid Sodium nitrate Sodium iodide α-Benzoic oxime Potassium sodium tartrate Sodium bromide Sodium nitrate Sodium suflate Phosphorous acid Sodium bisulfate Potassium cyanide Potassium periodate Potassium citrate 2-Potassium permanganate Magnesium sulfate .7 water Bismuth metal Strontium nitrate Lead nitrate Phosphomolybdic acid, 48 hydrate Potassium colbalticycubude Acid tungstic Potassium iodide Ceric sulfate Dimethylglyoxime Barium chloride Barium chloride Diphenylthiocarbenzone Mercuric sulfate Sodium fluoride Ammonium persulfate Diethyldithiocarbonic acid Lead hydrate Antimony potassium tartrate Na_2SO_4 8-Quinolinal-8-hydroxyquinoline Ammonium persulfate

Date	Quantity	Chemical
12-29-80 (cont)		Ammonium carbonate
		Calcium carbonate
		Citric acid
		Potassium sodium tartrate
		Potassium hydroxide
		Cupric nitrate
		Potassium hydroxide flakes
		Cupric sulfate
		Kaolin
		Sodium phosphate, monobasic
		Copper metal
		Hydrous citric acid
		Sodium bismuthate
		Ammonium chloride
		Cupric sulfate
		Ammonium sulfate
		Calcium chloride
		Anhydrone
		Cesium sulfate
		Cesium nitrate
		Beryllium nitrate
		Cesium chloride
		Lithium sulfate
		Potassium bichromate
		Potassium pyrosulfate
		Iodine
		Potassium nitrate
		Lead iodide
		Potassium iodide
		Iodic acid
		Silica tungsten acid
		Potassium pyrosulfate
		Potassium bisulfate
		Sodium sulfide
		Sodium tungstate
		Sodium bromate
		Tin metal
		Sodium nitrate
		Sodium formate
		Sodium phosphate, tribasic
		Acid tungstic
		Sodium phosphate, dibasic

Date	Quantity	Chemical
12-29-80 (cont)		Sodium phosphate
		Sodium vanadate
		Sodium thiocyanate
		Zirconyl nitrate
		Tungstic acid
		Chromium chloride
		Versenex 80*
		Versenex 120
		2-Versenex 100
		4-Hydroxylamine . hydrochloric acid
		Sodium acetate
		Citric acid
		Vinyl spray
		Zinc oxide
		2-Thionyltrifluoroacetone
		Alizarine
		Benzoin-oxime
		2,4-Dinotrodrphenylamine
		Thymolphthalein
		2-Dimethylgloxime
		M-Cresolsulfonthalien -hydroxy-isohatynic acid
		Acid sulfosulicylic
		3,5-Diiodo-4-pyriodone-N-acetic acid
		5-Cp-dimethylammobenzyladine rhodamine
		Quinalizarin
		4,7-Dibromo-8-hydroxyquinoline
		Violuric acid hydroxy-iso-butyric acid
		2-Carminin acid
		Rhodizonic acid potassium salt
		Phosphorus acid
		Sodium nitrate
		Nitric acid
		Titanium chloride
		Ammonium bifluoride
		Potassium iron (III) cyanide
		Hydroquinone
		Hydroxyethylethylenediaminetriacetic acid
		DOWEX-2*
		Potassium permanganate

Date	Quantity	Chemical
12-29-80 (cont)		Lanthanum nitrate
		Sodium suflate
		Manganese metal chips
		Nickel carbonate
		DOWEX SOW-X8
		Sodium sulfide
		Potassium permanganate
		Calcium nitrate
		Mercury nitrate
		Diisobutylphthalate
		10% Ammonium persulfate
		Dimethylglyoxime in ethanol
		0.1N Sodium hydroxide
		pH 4.4 buffer
		Potassium hydride phthalate buffer
		Acetic acid in trichloromethane
		Water extracted with PCT
		2:1 n-Butanol/ethyl acetate
		0.05% Xylenol orange in methanol
		10% Ammonium molybdate
		DDTC in carbon tetrachloride
		Iron in methanol
		0.1N Trichlorochromate
		3 g Cobalt nitrate - nitric acid
		1N-2N 22.1 mg Water
		1% Triethanol
		E3426
		P2246
		W-2N Methanol
		TTA acetone
		4450 in methanol
		Par water
		"AKS"
		E2942
		RO in water
		Spent methanol
		E238
		Ortho-Phenol
		E3092
		EBT
		E2106
		0.5% PAN in ethanol

Date	Quantity	Chemical
12-29-80 (cont)		P7302 in water
		PAN in hexane
		PAN in ethanol
		5.69N Tributyl phosphate
		Eosin
		KD
		P+PA
		Mercury solution
		Phenyl acetate
		10% DIEPPA
		TTA solution 5M in xylene
		Hydroxyethylethylenediaminetriacetic acid
		TTA in benzene
		Amyl acetate spent
		Ethylene dichloride
		Hydrochloric acid and ammonium hydroxide
		0.1% Carminic acid
		0.4M D12 EHPA
		Ammonium carbonate strong in DDH_2O
		TOPO wash
		Benzene spent
		Sulfamic acid
		Dimethylglyoxime
		Methyl orange
		d-Tartaric acid
		Periodic acid
		Hydroxylamine hydrochloride
		pH 10 buffer
		Chloran hydrate
		1% APDC
		$(NH_4)_2\ C_6H_5O_7$
		8N Sodium hydroxide
		1% Sodium hydrogen sulfate
		50% Sodium hydroxide
		6M Sulfuric acid
		6N Ammonium hydroxide
		Methyl orange
		Ammonium hydroxide
		Hydrogen peroxide
		50% Sodium hydroxide
		0.5M Ammonium sulfate
		0.2N Hydrochloric acid

Date	Quantity	Chemical
12-29-80 (cont)		10.0 g/L iron
		1% Citric acid
		-N Nitric acid
		pH 2.5 acid spent
		2N Nitric acid
		0.45M HDEHP in isooctane
		1N Sulfuric acid
		12M Nitric acid
		DTPP
		Concentrated phosphoric acid
		1N Nitric acid
		8M Ammonium nitrate and 0.1M nitric acid
		Di2 EHPA
		0.4M Nitric acid
		Acetic acid
		3N Hydrochloric acid
		1M Phosphoric acid
		0.5M Hydrochloric acid
		0.6M Nitrate and sulfate
		100 g/L Sodium sulfate
		10M Nitric acid
		Saturated oxalic acid
		10% Ammonium hydroxide . hydrochloric acid
		Concentrated hydrochloric acid
		Hydrogen peroxide
		0.2N Nitric acid
		Sodium acetal and acetic acid
		Hydrogen peroxide
		0.05M Sulfuric acid
		0.05M Ammonium formate
		Nitric acid
		0.1M KHC_8O_4
		2M Ammonium acetate
		8N Hydrochloric acid
		Butyl alcohol
		0.05% Quinalizarin
		0.01M Nitric acid
		4N Nitric acid
		pH 3.5 Chromium-tungsten
		8.5M Perchloric acid + 0.5M hydrochloric acid
		1N Nitric acid + 90% H_3ON
		0.2M Hydrochloric acid + 40% ethanol

Date	Quantity	Chemical
12-29-80 (cont)		Bromcresol green in 0.1% ethanol 3M Hydrochloric acid 20% ethanol Bromcresol purple 0.1M Ammonium chloride 1 g/L Boron 0.5 g/L Boron 50% Phosphoric acid 1N Phosphoric acid 2M Ammonium hydrogen citrate 0.1M Ortho-phenol 8.5M Perchloric acid + 0.5M hydrochloric acid + 0.1M hydrofluoric acid 3M Acetic acid 0.01% Methyl orange Sulfuric acid 0.5M Nitric acid - 70% methanol Lead 1 g/L 8.5M Perchloric acid + 0.5M hydrochloric acid + 0.1M hydrofluoric acid 3M Acetic acid 0.01% Methyl orange Sulfuric acid 0.5M Nitric acid - 70% methanol Lead 1 g/L Dorex 50 acetate 1 ppm lead 10 g/L Ammonium molybdate in 10% sulfuric acid . 5 mL 8N Sodium hydroxide - 20% sodium oxygen hydroxide 0.1N Sulfuric acid 10M Hydrochloric acid 0.2M Ammonium chloride 0.2N Hydrochloric acid 30% Ammonium tartrate 8 - Hydroxyquinoline (8-HQ) 5% Hydroxyquinoline in water 1% Niobium + acetic acid in chloroform Diphenylthiocarbazone (dithizone) in carbontectrachloride 0.005M Azure carbon 1M Hydrochloride acid + 0.1M hydriodic acid

Date	Quantity	Chemical
12-29-80 (cont)		APDC in hydrochloric acid
		5% Na Tungsten
		Hydroquinone solution
		Hydrogen peroxide
		Benzene
		1% Methyl glyoxime in ammonium hydroxide
		Solutions:
		Gold
		Copper
		Europium
		Potassium iron (III) cyanide
		Aluminum
		Barium chloride
		Bromocresol purple
		Cromium (III) cation
		8-Hydroxyquinoline
		Selenium 10 mg/L
		Aluminum 1 g/L
		Selenium (VI) cation in 10 g/L
		Butyl cellosolve
		1M Sulfasulacylic acid
		0.1% Alizarine in hexanol
		0.2% PCT in hexane
		30.7 g Manganese chloride hydrate/1 L water
		11.1N Phosphoric acid
		0.5N Phosphoric acid
		TTA 0.5N in Xylene
		DDTC in chloroform
		Hydroxide of hyamin 1M
		10% Acetylacetate in hexanol
		15% Potassium cyanide
		Ethylene glycol
		D,D 1N Hydrochloric acid
		Ludox* stock solution
		2.5M Dimethylglyoxime
		20% TOPO in benzene
		1.6N Nitrilotriacetic acid
		5% TOPO in cyclohexane
		Dowex, chloroform
		Phosphoric acid in water
		DHDECMP
		33% in cyclohexane

Date	Quantity	Chemical
12-29-80 (cont)		1% Boron
		Selenium (VI) in tap water
		Tin (dilute)
		Cold saturated niobium 1 g/L
		Silver 10 mg/mL
		Manganese g/L
		Iron (III) cation
		Methyl violet
		Titanium saturated 1 g/L
		Nickel (II) ion 10 mg/mL
		0.1% Phenyl red
		1% NPHA in chloroform
		Barium (II) ion 10 g/L
		Mercury
		Thymol phthalein
		Zinc (II) ion
		La Carrier 5 mg/mL
		Copper selenium oxide hydrate 1.001 g selenium/l
		3% APDC
		11 ppm titanium in sulfuric acid
		Titanium 1 mg/mL
		3.3 ppm Cadmium and 6.7 ppm cadmium and beryllium 10 mg/mL
		Strontium (II) ion 10 mg/mL
		1 g/L Nickel
		Saturated ammonium carbonate
		Carbamic acid
		$Na_4P_2O_2.10H_2O$ 200 g/L
	4 L	1N Sodium hydroxide solution
	1 pt	Triethanolamine
	1 pt	Dimethyl formamide
	1 L	Piperidime
	2 L	Diisobutyl phthalate
	1 L	Biofluor
	1 L	10% T10A
	1 pt	1/1 by volume ethoxyethanol - ethanol
	1 pt	Anisole
	1 L	2-Ethyl hexylamine
	1 pt	p-Cymene
	1 pt	Ethylene glycol
	1 pt	Benzonitrile

Date	Quantity	Chemical
12-29-80 (cont)	1 pt	Chlorobenzene
	1 pt	Monobromobenzene
	1 gal	Aropol WEP 666P*
	1 gal	Ready-Solv solution VI
	5 L	p-Dioxane
	1 pt	Hyamine hydroxide
	1 pt	Aquosol
	1 gal	Unknown
	1 gal	Unknown
	1 gal	Oil
	1 pt	Formaldehyde solution
01-02-81	15 gal (90 lb)	Dioctyl phthalate on vermiculite
01-02-81	20 gal (120 lb)	Monoplex DOS, dioctyl sebacate
01-02-81	90 lb	Dioctyl phthalate absorbed with vermiculite
01-02-81	120 lb	Dioctyl sebacate in vermiculite
01-06-81	4 lb	Ethyl ether
	2 pt	Toluene
	12 gal	Tetrahydrofuran mixture
	4 kg	Tetrahydrofuran
02-0 -81	1 gal (10 lb)	DTPA in water absorbed on vermiculite
02-11-81	1 gal (10 lb)	Nitrilotriacetic acid in water on vermiculite
02-11-81	1 gal (4 lb)	1AX solvent NPH/tributyl phosphate on vermiculite
02-11-81	1 gal (8 lb)	Used mineral oil on vermiculite
02-11-81	2 gal (10 lb)	Used transformer oil on vermiculite
02-11-81	1 gal	Polyethylene glycol
02-11-81	4 lb	NPH/tributyl phosphate in vermiculite
02-11-81	10 lb	DTPA in water in vermiculite

Date	Quantity	Chemical
02-11-81	10 lb	Nitrilotriacetic acid in water in vermiculite
02-16-81	1 L	10 ppm beryllium liquid
02-25-81	1 L	Oil
	500 mL	TTA, tributyl phosphate
02-25-81	2.5 L	Methylene chloride Tetrahydrofuran Xylenes Chloroform hexane
03-05-81	1 lb	Potassium chloride solution
	1 pt	Dimethyl amino benzaldehyde solution
	0.5 pt	Hexone
	3 lb	Dibenzoyl peroxide
	125 lb	Dioctyl sebacate with vermiculite
	500 mL	TTA and tributyl phosphate mixtures
	2500 mL	Mixture: Methylene chloride, Tetrahydrofuran, Xylene's, Chloroform, Hexane
03-12-81	12.5 gal (125 lb)	Monoplex* DOS dioctyle sebacate
03-16-81	4 lb	Potassium dichromate
	24 pt	Methyl alcohol
	0.5 lb	Silver nitrate
	0.25 lb	Ferrous sulfate
	1 lb	Iodine
	2 lb	Potassium iodate
	250 g	Dimethylamine benzaldehyde
	0.25 lb	Starch
	2 lb	Sodium metavanadate
	2 lb	Potassium iodide
	1 lb	Aluminum metal
	75 g	Resorcinol
	1.5 lb	Sodium hydroxide (pellets)
	40 lb	Sodium hydroxide
	70 lb	Flake caustic soda
	1 lb	Potassium chloride saturate with silver chloride

Date	Quantity	Chemical
03-16-81 (cont)	0.5 pt	p-Dimethylamine benzaldehyde
	0.5 pt	Hexone
	400 g	Hydrazine dihydrochloride
	1 lb	Aluminum nitrate
	1 lb	Potassium permanganate
	1.25 lb	Sodium sulfate
	2 lb	Sodium thiosulfate
	2 oz	Cerium nitrate
	2 oz	Sulfamic acid
	0.25 lb	Strontium nitrate
	0.5 lb	Sodium acetate
	3 lb	Boric acid
	1 lb	Sodium chloride
	4 lb	Sodium sulfite
	1 lb	Magnesium
	5 lb	Calcium chloride
	250 lb	Boric acid
	560 lb	Orocol*
04-01-81	350 lb	Alkaline metal cleaner
	1 pt	pH 7 butter solution
04-01-81	350 lb	Alkaline metal cleaner
	22 lb	Sodium hydroxide
	6 lb	Sodium hydroxide pellets
	4 lb	Sodium nitrite
	9 lb	Sulfuric acid
04-15-81	105 lb	Cupric sulfate
	7 lb	Chromium nitrate
	14 lb	Potassium sulfide
	8 lb	Sodium acetate
	10 lb	Sodium nitrate
	1 lb	Ammonium nitrate
	1 lb	Potassium fluoride
	12 oz	Sodium peroxide
	2 qt	Hydrazine (64% in water)
	1 L	Acetaldehyde
	1 pt	Perchloric acid
	1 pt	Methyl iodide
	1 kg	Chlorosulfamic acid

Date	Quantity	Chemical
04-16-81	1 L	Acetaldehyde
	45 lb	Cupric sulfate
	7 lb	Chromium nitrate
	14 lb	Potassium iodide
	8 lb	Sodium acetate
	10 lb	Sodium nitrate
	1 lb	Ammonium nitrate
	1 lb	Potassium fluoride
	1 lb	Sodium peroxide
	1 lb	Potassium fluoride
	12 oz	Sodium peroxide
	2 qt	Hydrazine (65% in water)
	1 L	Acetaldehyde
	1 pt	Perchloric acid
	1 pt	Methyl iodide
	1 kg	Chlorosulfamic acid
04-21-81	240 lb	Dioctyl sebacate with vermiculite
	40 gal (240 lb)	Monoplex DOS dioctyl sebacate
07-09-81	1 pt	Hydrogen peroxide
	few drops	Chlorotrimethylsilane
	4 oz	Unknown
	50 mL	Unknown
	100 mL	Hydrofluoric acid
	1 pt	Ethyl acetoacetate
	1 qt	Methyl silane (leaking bottle)
	100 mL	Ultrex nitric acid
	1 L	Sulfuric acid
	250 mL	
	500-1000 mL	Perchloric acid
	700 mL & 1 pt	Sodium hypochlorite
	300 mL	Hydrochloric acid
	150 mL	Hydriodic acid
	500 mL	Hydriodic acid
	400 mL	Sulfuric acid
	2 pt	Trichloroethylene
	0.75 gal	Ethyl ether
	5 pt	Ethylene glycol
	0.5 pt	Chloroform

Date	Quantity	Chemical
07-09-81 (cont)	1 gal	Methylformamide
	1 pt	Benzene
	8 lb	Ammonium fluoride
	6 lb	Ammonium oxalate
	7 lb	Magnesium chloride
	45 gal	Benzyl-para-aminophenol
	1,200 mLs	Mercury
	250 mL	Formalydehyde
	500 mL	Iodine solution
	250 mL	Formalin
	0.5 pt	Iodine solution
07-16-81	8 kg	Beryllium-liquid-10 ppm
	1200 mL	Mercury
	30 gal	Solvent refined coal
	45 gal	Benzalphapyrene
07-21-81	2,772 lb total	Reacted lithium & sodium products
08-13-81	30 g	Mercuric nitrate
	1 L	Molybdate reagent
	0.75 L	Phosphorous acid
	0.75 L	Phosphorous acid
	0.5 L	Phorphorous trichloride
	0.75 L	Ethone N: enplate solution (electroless plating)
	1 L	Ethone NL-62 enplate solution (electroless plating)
	1 L	NA hypobromite solution
	0.66 lb	Molybdic acid
	1 lb	Barium hydroxide
	70 g	Bismuth nitrate
	1 g	Elemental boron
	70 g	Cadmium nitrate (hydrate)
	0.33 lb	Cadmium chloride
	45 g	Cerium nitrate (hydrate)
	0.33 lb	Chromium chloride
	40 g	Chromium oxide
	760 g	Cobalt nitrate (hydrate)
	0.8 lb	Ammonium nitrate
	1 lb	Cupric chloride (hydrate)
	0.4 lb	Cupric sulfate (hydrate)

Date	Quantity	Chemical
08-13-81 (cont)	70 g	Cuprous oxide
	75 g	Lithium fluoride
	3 lb	Lanthanium ammonium nitrate . water
	0.9 lb	Magnesium sulfate
	100 g	Manganese chloride
	30 g	Mercuric nitrate
	1 lb	Nickel acetate
	160 g	Magnesium base alloy (chips)
	75 g	Lead acetate . 3 water
	0.9 lb	Lead dioxide
	80 g	Acid phosphomolybdic
	1 L	Molybdate reagent
	0.25 lb	Phosphorus
	0.75 lb	Phosphorous acid
	0.75 lb	Phosphorous acid
	0.75 lb	Phosphorous trichloride
	0.8 lb	Ammonium hydrogen phosphate
	1 lb	Potassium hydrogen phosphate
	1 lb	Sodium hydrogen phosphate
	1 lb	Disodium hydrogen phosphate
	0.75 lb	Trisodium phosphate (tribasic)
	0.66 lb	Sodium hypophosphite
	0.33 lb	Potassium chloride
	0.66 lb	Potassium fluoride
	0.9 lb	Potassium bromate
	0.2 lb	Potassium hydroxide
	0.5 lb	Potassium iodide
	0.66 lb	Potassium nitrate
	70 g	Potassium meta-periodate
	0.75 lb	Potassium thiocyanate
	1 L	Enthone NL-62
	0.4 lb	Sodium bismuthate
	1 lb	Sodium bromide
	1 lb	Sodium fluoride
	1 L	Sodium hypobromite solution
	1 lb	Sodium iodide
	1 lb	Sodium nitrite
	0.75 lb	Sodium nitrate
	15 g	Sodium stannate
	1 lb	Sodium thiosulfate
	70 g	Sodium vanadate
	100 g	Selenious acid

Date	Quantity	Chemical
08-13-81 (cont)	35 g	Silver nitrate
	1 lb	Sulfur
	0.75 lb	Zinc metal
	10 g	Thallous acetate
	40 g	Stannic chloride
	0.75 lb	Trichloroacetic acid
	1 lb	Zinc nitrate
	1 lb	Barium nitrate
	0.5 lb	Oakite*
	4 lb	Ammonium persulfate
	0.75 lb	Ceric sulfate
	1 lb	Magnesium perchlorate
	0.75 lb	Manganese dioxide
08-24-81	200 gal (20 lb)	Fenemine
09-17-81	19,350 lb (~45 drums)	Solvents, oils, paint, and paint thinner mixed and unknown names. Material absorbed with speedy dry
	1 pt	Methyl chloroform
	13 L	Benzene
	5 pt	Dye in methanol
	1 pt	Ether
	Small bottle	Chloroform
	200 mL	Mercury
	500 mL	Formaldehyde
	6 pt	Benzene
	7 pt	Benzene/chlorotrimethyl silane
	1 pt	p-Dioxane
	1 pt	Methylchloroform
	2 gal	Potassium permanganate/sodium hydroxide
	13 L	Benzene
	5 pt	Dye in methanol
	1 pt	Ether
	1 pt	Chloroform (methyl chloroform)
	Petri dish	Iodine crystals
	Empty bottle	Dye grains
	5 gal	Chromium-aluminum-manganese-sulfur-iron powder
	3 gal	Nickel powder
	200 mL	Mercury (in concrete)
	500 mL	Formaldehyde
	6 pt	Benzene

Date	Quantity	Chemical
09-17-81 (cont)	7 pt	Benzene/chlorotrimethylsilone mix
	1 pt	p-Dioxane
	0.25 ft^3	Mercury batteries (in concrete)
	0.5 ft^3	Mercury contaminated material (in concrete)
09-21-81	1 metal container	Banvel* herbicide
	1 metal container	2-4-D Amine, dimethylamine
	1 metal container	Greenshield adjuvant
09-24-81	200 lb	Feremire
10-22-81	1 55 gal drum (350 lb)	Solvent refined cool (clean up from chemical spill) heavy fraction
	0.25 lb	Silver chloride
	0.25 lb	Silica powder
	0.25 lb	Chromic oxide
	0.25 lb	Iron (II) oxide
	1 lb	Potassium cyanide (P098)
	0.25 lb	Sodium arsenate
	1 lb	Mercury chloride
	1 lb	Sodium perchlorate
	1 lb	Arsenic oxide (P012)
	1 lb	Borium perchlorate
	0.25 lb	Thallous formate
	2 lb	Nickel chloride
	1 lb	Mercuric chloride
11-16-81	4 gal	Nitric acid
	5 L	Lead nitrate
	1 qt	Benzene
	8 gal	Dioxone & water
	0.5 gal	Misc. unlabeled reagents
11-23-81	0.5 pt	Benzene
	500 mL	Hexane
	8 gal	Dioxane mixture
	5 gal	40% nitric acid
	1 L	72% perchloric acid
12-17-81	4 lb	Ethyl ether
	2 pt	Toluene
	12 gal	Tetrahydrofuran with pump oil

Date	Quantity	Chemical
12-17-81 (cont)	10 gal	Wood for derivatives
	3 lb	Potassium bromide
	10 lb	Sodium sulfite
	7 gal	Union fluid LO500
	1 qt	Paraffin oil
	1 pt	Perchloric acid
	5 gal	Pump oil
	1 pt	Xylene
12-23-81	1 55 gal drum	Dioctyl sebacate with vermiculite
	40 gal (150 lb)	Dioctyl sebacate with vermiculite
	40 gal (150 lb)	Dioctyl sebacate (Monoplex DOS)
	20 gal (120 lb)	Dioctyl sebacate (DOS) Monoplex DOS plasticizer
01-07-82	14 pkg	Afrin nasal spray
	4 pkg	Wycillin suspension
01-12-82	80 L 24 lb ea.	Iron (II) nitrate liquid
	272 lb	Ferric nitrate
	1 pkg	APC compound
01-25-82	6 g	Bisdihydroxy phosphinyl
	10 g	Glyoxal-bis-(2-hydroxyanil)
	6 g	Erio Chrome* blue black R
	5 g	Acid alizarin black
	15 g	Eriochromschwarz T
02-03-82	4 gal (36 lb)	CALCI-Solve
	5 gal (35 lb)	Perchloroethylene
	1 gal (9 lb)	H_2SO_4 liq
	1 gal (8 lb)	Unknown liquid
	0.66 gal (5 lb)	Ferric chloride etch solution
	0.5 gal (3.5 lb)	Nitric acid
	55 gal	50/50 35% hydrazine in sorbed absorbent
02-12-82	400 lb	Kodak* rapid fixer and hardner (contains sulfuric acid) and liquid developer (potassium hydroxide solution) that has been absorbed.

Date	Quantity	Chemical
02-12-82 (cont)	0.5 gal (3.5 lb)	Nitric acid
03-09-82	225 g	Ferrous sulfide
	0.75 lb	Lead nitrate
	1 lb	Ferrous sulfate
	0.5 lb	Magnesium sulfate
	1 lb	Mercuric oxide
	2 oz	Mercuric chloride
	0.75 lb	Magnesium chloride
	1 lb	Mercurous chloride
	1 lb	Lead oxide (low silver)
	3 oz	Tin metal
	75 g	T-O-Folylazo-o-toliudine
	5 g	L-trypotophane
	1 lb	Trypticase soy agar
	0.75 lb	Lead acetate
	0.25 lb	Zinc oxide
	100 g	Special vanadium oxytrichbride corrosive material
	8 lb & 1 pt	Sodium sulfite
	0.5 lb	Charcoal bone
	1 lb	Diphenylamine
		Desoxycholic acid
	0.7 lb	Ethylenediamine, tetraacetic acid
	0.7 lb	Salicylic acid
	0.13 lb	Magnesium carbonate
	0.6 lb	Sodium dichromate
	0.6 lb	Sodium dichromate
		Iodine
	200 g	Triethanolamine
	0.5 lb	Sodium salicylate
	0.5 lb	Sodium dichromate
	0.7 lb	Resorcinol
	0.75 lb	Sodium bisulfite, meta dry
	0.25 lb	Sodium bisulfite, meta dry
	1 lb	Sodium fluoride
	1 lb	Sodium bromate crystal
	0.5 lb	Sodium sulfite, meta
	2 oz	Sodium iodide
	0.25 lb	Sodium oxalate
	1 lb	Sodium fluoride

Date	Quantity	Chemical
03-09-82 (cont)	0.75 lb	Sodium bisulfite, meta dry
	0.75 lb	Sodium sulfite
	10 g	Sodium sulfite
	30 g	Potassium oxalate
	12 oz	Potassium permanganate
	12 oz	Potassium iodide
	12 oz	Potassium iodide
	12 oz	Potassium permanganate
	14 oz	Potassium bromide
	2 oz	Sand sea
	0.14 lb	Potassium citrate
	0.2 lb	Potassium
	2 lb	Potassium permanganate
	12 oz	Potassium chromate
	1 lb	Potassium pyrosulfate
	2 oz	Potassium periodate
	12 oz	Potassium iodate
	1 lb	Attasol
	25 g	Anion exch. FLOC DE 50
	25 g	Anion exch. FLOC AE 50
	15 g	Cation exch. CM 70, powder
	250 g	Maleic acid (pellet)
	475 g	Isopentylacetate
	0.25 lb	Hexadecyltrimethylammonium bromide
	75 g	Isoelectric casein
	500 g	Maleic anhydride
	60 g	Isoelectric casein
	100 g	n-Methylglucamine
	90 g	Glycerophosphate sodium 5-1/2 water
	100 g	Iodacetamide
	8 g	1-Inositoc
	3.5 oz	Methyl-salicylaete
	70 g	Hood mercaptoacetic acid
	100 g	2-Mercaptoethane
	25 g	n-n-Methylenebisacrylamide
	108 g	Ethyl chloride
	15 g	n-n-Methylenebisacryilamide
	25 g	Hexamethyldisilane reagent
	15 g	DL-Disodium glycerophosphate
	4 g	Sodium glycerophosphate
	95 g	Hydrazine sulfate
	2.5 g	Glycogen

Date	Quantity	Chemical
03-09-82 (cont)	50 g	Glucuronolacetone
	450 g	Diphenylamine hydrobromide
	90 g	Disodium salt
	90 g	Butylated hydroxytoluene
	0.8 k	Chloramine-T
	0.25 lb	Ascarite
	0.4 g	1-(-1-cystin)
	40 g	Bromphenylhydrazine hydrochloride
	6 g	Anthydrol
	90 g	Cholinchloride
	75 g	p-Dimethamino-benzaldehyde
	100 g	p-Nitroaniline
	12 oz	Nordihydroguaiaretic acid
	12 oz	Oxyethylated-tert-octyl-phenol formaldehyde polymer
	100 g	Phosphatidylethanotamine
	113 g	(Hood) picric acid
	44 g	(Hood) potassium cyanide
	18 g	Orcinol
	50 g	(Hood) picric acid
	25 g	4-Nitroquinolin N-oxide
	0.25 lb	Pyridine
	430 g	Oxalic acid
	450 g	Propionic acid
	15 gm	Picryl sulfonic
	0.66 lb	Phosphorus tungsten acid
	0.33 g	DL-norcuecine
	0.5 g	1-Proline
	5 g	Propylthiouracil
	4 g	DL-alanin-methyester-dihydro-chloride
	4 g	Alloxan
	g	Ammopyrine
	g	1-Amino-2-naphthol-4-sulfur
	1 lb	Ammonium persulfate
	1 L	Ammonium thiocyanate
	0.75 lb	Arsenic trioxide
	0.13 lb	Barium acetate
	1 lb	Barium hydroxide
	0.75 lb	Barium hydroxide
	0.5 lb	Barium hydroxide
	1 lb	Barium chloride
	10 g	Benzidine clare

Date	Quantity	Chemical
03-09-82 (cont)	14 oz	Chromium trioxide
	8 oz	Calcium carbonate
	8 oz	Calcium hydroxide
	12 oz	Chromium trioxide
	10 oz	Chromium trioxide
	0.13 lb	Cadmium chloride anhydrous
	2 oz	Cupric oxide
	0.13 lb	Calcium chloride
	2.5 oz	Cupric carbonate
	12 oz	Calcium chloride
	2 oz	Calcium chloride
	2 oz	Calcium chloride
	10 oz	Calcium sulfate
	1 L	1N sulfuric acid
	0.1 L	1/10N NA4SCN
	1 pt	2-Nessler's solution
	500 mL	2 folin and ciocalteus phenal reagent
	100 mL	Polyoxerelene sorbitan mono-oleate
	100 mL	Solvene-350
	500 mL	2 protosol
	50 mL each	Trizmal buffer 10 (bottles)
	100 g	Acetaldehyde
	1 qt	Ethylene glycol monomethyl ether
	1 L	Kodak rapid fix solution
	0.75 lb	Phosphorous trichloride
	0.5 lb	Glycerine
	0.75 lb	Ethyl acetate
	100 mL	X-100
	50 mL	5% polystyrene in benzene
	0.75 lb	Hydriodic acid
	1 mL	Beckman filter solvent
	90 g	Sebacyl chloride
	3.5 oz	Contrad 70
	1 pt	Aerosol OT cleaner
	.75 pt	Collodion
	10 vials, 1 mL each	Di-sil-prep
	2 lb	Triphenyltetrazolium chloride 2 ferrous sulfate solution
	3 oz	Methyl salicylate
	27 mL	U-DTPA 32 mg/mL

Date	Quantity	Chemical
03-09-82 (cont)	2 bottles, 420 mL each	Electrolyte
	175 gm	10% DTPA
	20 mL	Tris-tetra methylene-phosphoric-triamide
	0.1 mmol	manganese sodium DTPA
	25 mL	Foto-flo*
		Fluoro surfactant
	2 vials, 15 mL each	Latex particles - polystyrene
	4 vials, 10 mL each	Grobax* - sodium polyanethol sulfonate 5%
	10 mL	Hydrogen-gold DTPA
	10 cc ampule	Calcium gluconate - glucoheptonate
	9 ampules, 10 mL each	Calcium gluconate - gluceptate
	50 g	d-Limonene
	6 vials, 5 cc each	Madribon 10% (sulfur)*
	0.5 lb	Phosphorus trichloride
	8 oz	Acrylamide
	0.25 lb	Aluminum oxide powder
	0.5 lb	Aluminum potassium sulfate crystal
	75 gm	Agarose
	0.75 lb	Ammonium sulfate granular
	0.5 lb	Amberlite IRC-50
	0.25 lb	2-bromoethylamineltycrobromide
	8 oz	Boiling chips micro-porous
	0.25 lb	Ferric ammonium sulfate crystal
	0.25 lb	Fluorescein sodium salt
	0.13 lb	Hydrazine sulfate
	1 lb	Hydrazine sulfate
	0.25 lb	Lead nitrate crystal
	0.25 lb	Trichloroacetic acid crystals
	0.25 lb	Potassium citrate crystal
	2 oz	Merculic chloride crystal
	0.13 lb	Potassium bromate
	4 oz	Potassium biphthalate
	4 oz	Sequlene
	0.75 lb	Resorcinol crystals
	1 lb	Trishydroxymethylamine (TRIs) methane
	1 lb	Zeokarb H*
	100 gm	An O

Date	Quantity	Chemical
03-09-82 (cont)	1 lb	Z10 Cl
	3 oz	Acid tungsten powder
	0.25 lb	Sodium pyrophosphate
	0.25 lb	Sodium phosphate dibasic crystal
	0.5 lb	Sodium acetate
	0.5 lb	Citric acid granular
	0.5 lb	Hydroxylamine hydrochloride crystals
	2 oz	Iodine crystals (resublimed)
	1 lb	Sodium diethyldithiocarbonate
	10 gm	1-Lysine ethyl ester dihydro-chloride
	10 gm	S-carboxyethyl-1-cysteine
	10 gm	S-carboxyethyl-1-cysteine
	10 g	S-carboxyethyl-1-cysteine
	10 g	S-carboxyethyl-1-cysteine
	0.25 lb	Cesium chloride
	5 vials	Methyl bis/b-chlorethyl
	1 jar	Calcium sodium
	1 jar	Calcium DTPA
	0.25 lb	Methyl metharylale
	0.13 lb	Sodium hydrogen ethylenediaminetetra-acetic acid
	90 g	Chelidamic acid monohydrate
	45 g	Sodium taurochelate
	90 g	Sodium DTDA
	90 g	1-Ethylenedinitriloldi-o-cred
	45 g	n,n-Dicyclohexylcarbodiimide
	1 g	2,4,6-Triethyleneamino triazin
	25 g	Salicylhydroxyamic acid
	25 g	Aces
	125 g	DTPA
	90 g	Triethylene tetraamine tetrachloride
	50 g	Thielated gelatin
	10 oz	Isocinchomeronic acid
	8 oz	Microporous boiling chips
	25 g	2 Thiophenecarboxylic acid
	oz	Cit-A 1 water
	oz	DTPA acid
	20 g	2-3 dimethoxybenzoic
	g	Zirconium DTPA
	g	Zinc hydrogen DTPA
	0.25 lb	Sulfur compound
	45 g	Palmitic acid

Date	Quantity	Chemical
03-09-82	5 g	PDT disulfonate
(cont)	2 g	Phthaleincomplexore
	10 g	Phloridzin
	oz	5-amino-3-sulphosalicylic-acid
	5 g	Thymine-5-methyluracil
	g	Sodium polystyrenesulfonate
	100 g	Sodium chelate MA
	50 g	Eriochromschwarz +
	60 g	Brenzkatechin
	50 g	Ethyl glycine
		623 dimethyloxybenzoil
	430 g	Procaine hydrochloride
	90 g	Proplygaliate
	100 g	Polyvinyl pyrrolidone aiceut
	14 oz	Pyromellitic acid
	75 g	2,5 Diphenyloxazole
	90 g	MPTT K+
	50 g	Polyvinyl pyrrolidone
	90 g	Sodium desoxycholate
	1 kg	Poly-oxyethejiene-23-lavrylether
	14 oz	Hydroquinone
	12 oz	Sorbitan monolavrate
	1 lb	Dextrose
	50 g	Fat black (microscope)
	450 g	Hexamethyenetetramine
	100 g	Dimethydithiacarbamic acid sodium salt dihydrate
	100 g	Dextran
	14 lb	Calcium phytate
	90 g	5 Sulfosalicylic acid
	25 g	n-Acytyl-di-penicillamine
	4 g	Neutral red
	8 oz	Gelatin powder
	100 g	5B Cholanic acid 3, 7, 12 tricue
	75 g	Acridine orange
	20 g	POPOP
	90 g	Ethylenedinitrilo tetraacetic acid epsom salt
	100 g	Pl Dimethylamino
	75 g	4,4-diamino-2,2-biphenyl-disulfate acid
	100 g	Sodium glocuranate
	100 g	N,N-Ethylennis (forraini de)
		Acridine orange

Date	Quantity	Chemical
03-09-82 (cont)	4 g	Gramine
	10 g	Aurnic acid natural
	25 g	2,6 dicarbonypyridine-n-oside
	5 g	Butyl alcohol
	oz	Chel. 300 acid
	oz	Cyclohexamine-N,N,N,N,L-tetraficetic acid
	48 g	8 ace + oxyquinoline
	9 g	Dithizone
	20 g	Alizarin reds
	10 g	Ammonium rhodanilate
	90 g	25 Dimercapto-1,3,4-thiadiazole
	1 lb	Fleischmann's* pure dry yeast
	0.25 oz	Calcium chloride crystal
	5 g	Ammonium perrhenate
	2 oz	Bismuth trioxide
	1 g	Calcium fluoride
	1 lb	Ammonium tetrasulfate cerate
	1 g	Calcium fluoride
	1 lb	Ammonium tetrasulfate cerate
	1 g	Calcium fluoride
	1 lb	Ammonium tetrasulfate cerate
	1 g	Fluorescein isothiocyanate
	1 g	Benzenesulfohydroxamic acid
	0.25 lb	Barium permanganate
	8 mL	Ferrous surfactant
	5 g	Murexide
	10 g	8-Mercaptopurine
	4 gm	3-Hydroxyflacene
	5 g	1-(2-pyridylaze) 2-naphthol indicator grade
	10 g	f-Mercaytopurine
	0.25 lb	Nickle oxide powder
	200 g	Calcium sulfamate
	5 g	Periodic acid H5IO
	1 g	Acetyl-D-phenylalanine
	1 gm	1-Thyrexine sodium salt
	0.75 oz	Titanium oxide anhydrous
	0.75 lb	Copper-iron
	20 g	Silicon-carbon
	0.2 lb	Potassium acid phthalate crystals
	1 lb	Manganese dioxide powder
	50 mg	Calcium chloride

Date	Quantity	Chemical
03-09-82 (cont)	1 oz	C-chloromercuriphenol
	0.25 lb	Potassium iodate granular
	0.25 lb	Potassium persulfate
	0.25 lb	Sodium cobalt nitrate powder
	2 oz	Lead sulfide powder
	1 lb	Zinc metal granular
	4 oz	Sodium cyanide granular
	20 g	Stannic oxide
	1 lb	Silica pow (200 mesh)
	0.25 lb	Sodium permanganate
	0.25 lb	Cesium chloride
	5 g	1-Threchin-methylester
	0.25 lb	Acid tungsten
	10 g	Dextran
	10 g	Vitastain
	1 g	DL-O-tyucsinc
	1 g	DL-C-phosphosenine
	1 g	Hydrocortisone alcohol
	1 g	Palmitic acid
	5 g	Phenol red
	5 g	Alizanin complexane
	5 g	Phenol red
	10 g	Easin Y
	10 g	Calcein W
	5 g	Phenol red
	2 vials, 15 mL ea.	Polystyrene - latex particles
	1 g	Fuchsin basic
	4 vials, 10 mL ea.	Grobax (sodium polyanethol sulfonate 5%)
	90 g	Butylated hydroxyanisole pellets
	2 g	Aluminum CP
	21 g	Girard's P
	100 g	Arsanalic acid
	2 g	Isatin-3-oxime
	25 g	N-acetyl-DL-penicillamine
	5 g	Diphenic acid
	100 g	1-Thiazolidine-4-carboxylic acid
	50 g	2-Guanidino-4-ammonium bromide
	60 g	Buffalo black NBR
	0.25 lb	Beef blood serum
	mL	1-Dyenkolic acid

Date	Quantity	Chemical
03-09-82	mL	Glucoronolaetone
(cont)	25 g	D-(-)-penicillamine
	25 g	Dimethyl big vanide hydrochloric acid
	20 g	Erio glaucine
	12 g	Glycocyamine
	20 g	EMPC
	5 g	Dihydro-ketoquinoxaline carboxylic acid
	10 g	Synthetic arbotin
	Almost empty	Osmium tetoxide
	5 g	2,6-Dihydroxy-isonicotinic acid
	5 g	4,4-Bis-Dimethylamino-diphenylcarbinol
	500 mg	Deferal
	4 g	3,4-DL-Dihydroxyphenylalanine
	25 g	Diothylstibesterol
	5 g	Ethoxzolamide
	5 g	Dibenzoyl-diamino ethylene
	2 g	29-Dimethyl-1, 10-pherantnrolire
	2 g	4,7-Diphenyl-1,10-phenanthraline
	5 g	Dihydronaphtlool naphthofurofuran
	1 g	Neocuproine
	10 g	2-Nitrosolnaphtlool-4-sulfuric acid
	5 g	Beta-alanine
	9 g	Calciferol
	5 g	Chondroitin sulfate
	oz	N-(4-amino 3-carboxyphenyl sulfonyl)
	oz	Calmagite
	15 g	Calcein
	1 oz	Benzotriazol purified
	5 g	Diazine green
	2 g	Pan indicator
	25 g	Imidazole-4,5-dicarboxylic acid
	25 g	Isatin
	2 g	Dipotassium pentacalcium dicalcein
	8 g	Sulfaethidole
	oz	Thio-Michler's ketone
	1 oz	Pepsin
	5 g	N-acetyl-DC-penicillamine
	25 g	2-mercaptocihydrouracil propionic acid
	10 g	Nile blue A
	0.5 g	DL-proline
	10 g	2-Nitrosolnaphth-4-sulfonic acid
	5 g	2,4,6-Tripyridyl-S-triazine

Date	Quantity	Chemical
03-09-82 (cont)	5 g	DL-penicillamine
	5 g	D-penicillamine disulfide
	5 b	2-(DL-penicillamine acetone adduct hydrachloride)
	8 g, 10 g	2-(a,a-dicarboxy-n,n-diformyl-4-piperazinediaianine-tetreathylester)
	0.25 lb	Thiazolilidine-4-carboxylic acid
	0.2 g	Polyaspartic acid
	5 g	Hodizonic acid, potassium salt
	0.2	dl-homocystine
	5 g	D-penicillamin puriss
	0.1 g	4,7-diphenyl-1, 10-phenanthroline
	5 g	7-aminocephalosporanic acid
	5 g	Potassium chromium sulfate
	5 g	1,2,3-Triketohydrinolene
	4 g	2,4,6,8-Tetrahydroxypyrimido pyrimidine (54)
	1 g	Zincon*
	10 g	Eri Chrome blue black
	8 g	p-Nitrobenzeneazocrornal
	1 g	Acetazolamide
	1 g	D-serine
	2 g	Enemethyl blue
	1.75 g	Poly-L-glutamic acid sodium salt
	0.5 lb	Sodium anthraquinone sulfenate
	8 g	Uric acid
	85 g	4-N-maleysulfanilamide
	100 g	2-Meraptobenzothiazolylbutyric acid
	50 g	5-Salicylsulfonic acid
	4 g	Naphthol-beta
	75 g	1-(p-sulfophhenyl)-5-pyrazdene-3 carboxylicaad
	g	4-dimethylamino-azobarizene
	0.33 lb	Hydroxylamine hydrochloride
	0.5 lb	De-acutite anich exchanger
	0.5 lb	Ferric nitrate crystals
	0.5 lb	Acid citric monohydrate crystal
	1 lb	Jaguar A-20-A
	0.25 lb	Hydroxylamine hydrochloride
	1 lb	Cupric sulfate
	0.75 lb	Ferric ammonium sulfate
	0.25 lb	Pyrogallol
	4 oz	Phenylhydrazine hydrochloride
	1 lb	Potassium phosphate monobasic

Date	Quantity	Chemical
03-09-82 (cont)	10 g	Siractan AF #2 (arabinogalactin)
	0.75 lb	Potassium iodide
	0.75 lb	beta-Methylumbelliferone
	1 lb	Paraformaldehyde
	1 lb	Potassium permanganate crystals
	1 lb	Ferrous ammonium sulfate crystals
	200 g	Monogram ink (black)
	5 g	Guantec E-2
	5 g	2-Mercaptoacetanilide
	5 g	2-Mercaptoacetanilide
	5 g	2-Mercaptoacetanilide
	5 g	2-Mercaptoacetanilide
	5 g	2-Mercaptoacetanilide
	0.5 lb	Ferrous ammonium sulfate crystals
	20 g	Fluroescent zinc sulfide
	1 lb	Sodium fluoride powder
	0.25 lb	Schooghan
	100 g	2-Mercaptoacetanilide carbonate
	1 lb	Potassium chloride crystals
	200 g	Rexyn RG 50* (H)
	0.5 lb	Magnesium perchlorate
	1 lb	Purulic chloride
	0.75 lb	Lead carbonate
	0.5 lb	Sodium titanate
	1 lb	Seelex-C
	1 lb	Seelex-A-100
	1 lb	Morclire white petroleum jelly
	0.5 lb	Potassium hydroxide
	1 lg	Phenol
	40 g	Zinc oxide
	0.25 lb	Hood potassium cyanide
	1 lb	Sulfur powder
	0.5 lb	Potassium thiocyanate
	1 lb	Ammonium carbonate
	0.25 lb	Calcium gluconate
	0.75 lb	Potassium thiocyanate
	15 g	2-Aminoethan-1-hydrochloride
	0.25 lb	Sodium malonate water
	0.13 lb	Sulfamic acid
	0.25 lb	Nitroso R salt
	15 g	Phloriazin
	45 g	2-Mercaptoorotic acid

Date	Quantity	Chemical
03-09-82 (cont)	3.5 oz	Sarkosyl* N1-100
	20 g	Sudan black B
	6 g	Crio glaocine
	5 g	Violursavre
	oz	Calco* oil red N-1700
	3 g	Sialic acid concentrate assay
	8 oz	Calco alizarine cyanine green base
	22 g	Quinacrine dihydrochloride
	8 oz	Alcofast spirit yellow zirconium
	40 g	Thioacetamide
	8 g	Persantin active ingredient
	0.2 g	Piperic acid
	50 g	Insulin
	10 g	4-Methylumbelliferone
	10 g	Phenoxymethyl-Pencilloic acid
	50 g	Luxol hydrate
	1 g	2,4,6-Triamino-pyrimidine
	4 g	Taurine
	2 g	2-Mercaptothiazoline
	10 g	Pheroxymethyl-penicilloic acid hydrate
	1 oz	Thymol USP
	20 g	Alloxan
	15 g	Brilliant ponceau
	0.5 lb	Zinc chloride
	0.5 lb	Magnesium chloride
	1 lb	Sodium hydroxide
	0.5 lb	Sodium bicarbonate
	1 lb	Potassium chloride
	0.5 lb	Sodium bisulfate meta
	0.75 lb	Potassium iodide
	1 lb	Sodium hydroxide
	1 lb	Surfylnol 104
	30 mL	Chromerce
	1 lb	Calcium gluconate
	0.25 lb	Potassium cyanide
	1 lb	Sodium thiosulfate
	1 lb	Calcium chloridecihydrate
	1 lb	Sodium bicarbonate
	0.5 lb	Sodium phosphate
	1 lb	Potassium carbonate
	0.25 lb	Cupric sulfate
	0.13 lb	Potassium cyanide

Date	Quantity	Chemical
03-09-82 (cont)	0.75 lb	Boric acid
	0.5 lb	Ammonium acetate
	1 oz	Titanium oxide anhydrous
	0.75 lb	3 Zinc carbonate
	0.75 lb	Ammonium thiocyanate
	0.33 lb	Anhydrone
	0.5 lb	Calcium powder
	0.75 lb	Potassium sodium tartrate
	0.5 lb	Zinc oxide
	1 lb	Kojic acid
	25 g	Used drierite
	44 lb	Car bopol 941
	4.5 lb	Drierite*
		Cesium hydrogen sulfate
	125 mL	Hydrazine
	1-100 mL boxes	Procaine penicillin G
	3	Batteries AA
	10 g	Spermidin
	2	Service batteries
	1	Duracell* battery
	500 mg	Lecithin
	100 mg	Deferrichrome
	1 g	Rhodotorulic acid
	50 mL	Barentrifluoride-methanol
	10 g	Cyclopentadlenylthallium
		Chloroacetontrile
	50 g	Glutanaldehyde
	50 cc	Iron-dextran injectible
	100 g	t-Pyriclidinecarbodithicic acid ammonium salt
	2.1 oz	Acufine developer
	4 oz	Soluble powder-terramycin
	0.33 lb	Scotchcast* electrical resin
	0.67 lb	Scotchcast electrical resin
	0.75 lb	Nitric acid
	200 g	CH-USP cholesterol
	1 lb	Bromine
	500 g	Ethylchloroformate
	1 pt	Ammonium sulfide solution
	1 g	B(2FVRYL)-acrylic acid
	1 g	Colchicine

Date	Quantity	Chemical
03-09-82 (cont)	1 g	Ethyl-3-indole acetate
	1 g	Maleic acid hydrazide
	1 g	D-Napthalen-acetamide
	0.1 g	Traumatic acid
	10 g	Lysozyme 3X
	1 g	Carbonyl bis (L-methionine) -nutraphenyl este
	1 g	Carbonyl bis (L-methionine) -nutraphenyl este
	5 g each 2 bottles	Cleland's reagent (dithiothreitol)
	1 g	Keflin*
	1 g	DL-tallo-crystathionine
	10 g	Histamine-dihydrochloride
	1 g	Lysozyme
	5 g	B-aminoproplanitrile, B
	50 g	Desferriaxamine B-metharesulfonate
	5 g	Thiagel
	5 g	Thiagel
	0.25 lb	Trypticase soy agar
	125 cc	LC 124 liquid crystals in petroleum ether solution
	125 cc	LC 124 liquid crystals in petroleum ether solution
	3 g	Desferrioxamine-B-methanesulfonate
	1 g	Pourlese ecatalase 30 1 g standard 750 mg
	50 g	L-a-phosphatidyl choline [L-a-lecithin]
	25 g	Lecithin egg (highly purified)
	25 g	Lecithin egg (highly purified)
	250 mL	Toluene spent
	100 g	Dizalmitin (1,2,41,3 mixture of isomers) (Sigma)
	2 vials ea. 0.1 g solid	Rebonuclease-A from bovinepancreas
	0.25 mg	Phosphatidyl ethanolamine
	500 mg	BIS-DHB-1, 3-propane diamine
	500 mg	DIS-DHB-ethyenediamine
	25 mg	TS-6
	500 mg	DIS-DHB putrescline
	500 mg	BIS-DHB octanedamive
	4 vials 100 mg ea.	Cytochrome-C from horse heart

Date	Quantity	Chemical
03-09-82 (cont)	4 vials 100 mg ea.	Cytochrome-C from horse heart
	500 mg	Cytochrome-C from horse heart
	100 mg	Cytochrome-C, type 11-A, horse H
	100 mg	Cytochrome-C, type 11-A, horse H
	0.1 g	Methyl palmitoleate
	3 vials, 1 g ea.	DL-isocitric lactone
	25 g	Tributyrin
	5 mL	Transaminase chem. control sch.
	3 vials, 1 g ea.	N,N-Bis-(2-carboximidoethyl) tantarmide dimethyl estea dihydlicchloride
	10 mg	Hemoglobin standard
	2 vials, 1 g ea.	Pepsin 3X cyst (parcine stomach mucous)
	1 g	Pepsin
	2 vials 25 mg ea.	Gangliosides
	25 mg	N-acetyl neuraminic acid
	2.5 mL	Lactic dehydrogenase enzyme
	2 vials, 5 mL (3 ug/mL)	N-4-nitrobenzo-Z-iva 1,3 diazide phosphetidyl ethanolamine
	1 g	Pepsin crystallizer
	100 mg	Cholesteryl oleate
	1 g	4-fluoro-3-nitro-phenylazide
	1 g	O-phenyl
	500 mg	Peroxidase
	mg	Cyto-C
	2 vials 0.1 g ea.	Cytidine-5-diphospho choline
	500 mg	Cytochrome-C, type III
	<1 kg	NEC-084H sodium acetuate-1-C (1 mCi C^{14})
	10 caps 25 mg ea.	Fast blue RR salt
	5 g	2-acetamido-2-deoxy-1,2,3,4-tetra--acetyl-b-diglueopyrabose
	0.1 g	Methyl palmitoleate
	3 vials, 1 g ea.	DL-isocitric lactone
	25 g	Tributyrin
	5 mL	Transaminase chem control sch.
	3 vials, 1 g ea.	N,N-Bis-(2-carboximidoethyl) tantarmide dimethyl estea dihydlicchloride

Date	Quantity	Chemical
03-09-82 (cont)	10 mg	Hemoglobin standard
	6 g	Bisdihydroxy phosphinyl
	10 g	Glyoxal bis(2 hydroxyanil)
	6 g	Eriochrome blue black
	15 gs	Spermidine
03-11-82	185 g powder	Nalco 66-B-619-5
	5 gal liquid	H-230 calgon biocide
	1 gal	Pozzalon 300
	25 lb dry	Bromocide
	250 g	Sterotex-K*
	70 lb	TURCO 4502
	110 lb	TURCO 4521
	300 lb	Nalclean-68* scale remover
	45 gal	Amerzine-TM-35* catalyzed hydrazine
	28 gal	Hydrazine 35% sonbed
	5 lb	Sample #3, Project #1086
	15 lb	Sample #1, Project #1086
	100 lb	Nalclean 68
	30 lb	Bromicide
	55 gal	Calgon CL-77
	4 gal	Rodine* 82A acid inhibitor
	44 lb	Calgon D-26 deposit inhibitor
	38 lb	Calgon H230 water microbiocide
	1 gal	Betz 403
	2 gal	Betz 403
	0.5 gal	35% hydrazine
	1 gal	Amerzine
	1 qt	Malco 310(B-6126)*
	3 qt	Calgon CL-162
	1 qt	Calgon CL-246
	1 pt	10% methylene Bis thiocyanate
	0.66 pt	Nalco 7323 (B-8118)
	0.66 pt	Nalco 7326 (B-8251)
	0.66 pt	Nalco 7326 (B-8264)
	0.13 pt	15% Amerzine
	0.25 pt	Nional
	3 15	CL-246
	1 pt	Biosperse-201*
	3 qt	CL-162
	1 qt	310-B-6126

Date	Quantity	Chemical
03-11-82 (cont)	1 qt	7328 B-8251
	1 qt	7326 B-8264
	1 pt	7323 B-8118
	1 pt	Methylene Bis thiocyanate 10%
	0.5 pt	Nional
	10 oz	Nalco 7324
	20 mL	Cat-Floc T*
	0.75 gal	Bentonite
	2 gal	Rodine 82-A
	25 mL	Amerzine
	1 gal	Pozzalon 300
	5 gal	D-26 inhibitor
	5 gal	H-230 biocide
	4 L	Betz 403
	2 gal	Rodine 82-A
	40 lb	TURCO 4502
	6 L	Betz 403
	80 lb (est.)	TURCO 4521
	30 lb (est.)	Oxalic acid
	250 g	Sterotex - K
	185 g	Nalco 66 B-169-5
04-15-82	1 gal	Jenny Coil Cond. Compound #80 (has hydrochloric acid)
	11 pt	Lactated Ringer's solution
	57 pt	Donnagel suspension
	67 tbe	Neosporin*-antibiotic
	12 box	Band-Aid*, butterfly
	16 tbe	Cordran .05%*
	7 box	Coricidin* tablets
	1 btl	Gantrisin* tablet
	3 btl	Medrol* tablets 4 mg
	16 tbe	Neo-Cortef* ointment 5%
	4 tbe	Neo-Cortef ointment 1%
	8 btl	Novahistine* L.P.
	1 btl	Apc Compound, tablets
	6 tbe	Polysporin* ointment
	5 ea	Ger-o-foam
04-29-82	1.5 lb	Ferric chloride
	2 lb	Carbon powder
	4 lb	Cesium chloride

Date	Quantity	Chemical
04-29-82 (cont)	1.5 lb	Cuprous chloride
	5 lb	Sodium dithionate
	4.25 lb	Calcium carbonate
	4.25 lb	Barium hydroxide
	1 lb	Aluminum nitrate
	2 lb	Barium nitrate
	2 lb	Stannous chloride
	1 lb	Lead acetate
	2 lb	Magnesium sulfate
	1 lb	Aluminum silicate
	1 lb	Sodium oxalate
	1 lb	Magnesium sulfate
	4 oz	Cobalt nitrate
	8 oz	Ammonium thiocyanate
	3 lb	Hydroxylamine hydrochloride
	1.25 lb	Sodium acetate
	0.5 g	Potassium chromate
	2 lb	Lithium hydrochloride
	1.5 oz	Mercuric nitrate
	1 lb	Potassium iodate
	1 lb	Potassium phosphate
	2 lb	Potassium chloride
	3 lb	Ammonium acetate
	10 oz	Cobalt nitrate
	2 lb	Calcium chloride
	4 oz	Barium chloride
	8 oz	Sodium bisulfite, meta
	1 pt	Carmine
	3 oz	Magnifloc
	4 oz	Aurintricarboxylic acid
	2 lb	8-Hydroxyquinoline
	5 lb	Potassium thiocyanate
	5 lb	Pyrogalic acid
	0.5 lb	Potassium acid phthalate
	8 oz	Boric acid
	1 lb	Salicylic acid
	8 oz	Anti foam 60
	3/8 lb	Dimethylgloxime
	1 lb	Hydrin-K*
	2 oz	Sodium cyanide
	2 lb	8-Hydroxyquinoline
	2.75 lb	Phenol

Date	Quantity	Chemical
04-29-82 (cont)	10 g	C_5H_4NN:NC10H_6OH pan powder
	2 oz	Potassium ferrocyanide
	4 oz	Ammonium citrate dibasic
	12 oz	Aluminum
	1 kg	Sodium gluconate
	12 oz	Separan*
	4.5 lb	Sodium sulfate
	4.5 lb	Sodium phosphate
	5 lb	Sodium sulfite
	7 lb	Ammonium sulfate
	0.4 lb	Cuprous chloride
	8 pt	Perchloric acid
	4 pt	Formic acid
	1 pt	Zinc chloride
	2 pt	Carbon tetrachloride
	1 pt	Chloroform
	500 mL	Phenol carbolic acid
	0.75 kg	50% gluconic acid
	1 pt	Formaldehyde
	2 gal	Acid
	1 L	ORSAT solution
05-04-82	55 gal	Spent trichloroethyline absorbed in vermiculite
05-05-82	3 L (12 lb)	Perchloric acid
05-23-82	10 gal	Corrosive mixture
	500 gm	Kepone
	1 gal	Heaxane
05-27-82	1 pt	Dry 1,4-dioxane-diethylene oxide tec. grape
06-25-82	550 gal	Ferrous hydroxide (solid)
	30 gal	Chromic nitrate
	10 gal	Corrosive mixtures
	500 g	Kepone
	15 lb	Phosphoric acid
	1 gal	Hexane
	1 lb	Potassium cyanide
	1 lb	Sodium cyanide

Date	Quantity	Chemical
08-17-82	1 gal	Nitric acid
	1 gal	Glacial acetic acid
	1 gal	Hydrochloric acid
	1 gal	Chloroform
	4 lb	Ether
	1 L	Dimethyl formamide
	9 gal	Mixed solvents (Tetrahydrofuran, acetone, methylene chloride)
	50 lb	Mercury-concreted
	13 gal	Benzene-concreted
	3 gal	Mixed carcinogens-concreted

Trench 34

Date	Quantity	Chemical
11-08-75	48,875 lb	DECON-4306c (TURCO)
11-13-75	3-55 gal overpacks	Lab pack of misc. small quantity laboratory chemicals
12-11-75	2 yds	Battery acid contaminated soil
	50 lbs in a 55 gal overpack	Lab pack of misc. small quantity laboratory chemicals
	(8) jars	unknown liquids
	100 ml	phenyl isocyanate
	1 jar	2,7,Dichloroflorescein spray reagent
	1 plastic	NHy MB
	21,600 ml	Solvent extracts
	10 L	Scintilation vials
	12 chunks	Sediment
	100 vials	Unknown
	1 L	Formamide liquid
	1 L	Hydrochloric acid in metal container
	15 lb	Phosphorous pentoxide (granular)
	13.0 lb	Aluminum (powder)
	1.0 lb	Calcium chloride
	1.0 lb	Soda lime
	19.0 lb	Phosphoric acid (granular)
	11.0 lb	Sodium oxalate
	0.8 lb	Pentasodium diethylenetriamine pentaacetate
	0.5 lb	Ethylenediaminetetraacetic acid
	2.5 lb	Oxalic acid (granular)
	1.0 lb	Manganous sulfate
	0.75 lb	Magnesium sulfate (anhydrous)
	25.0 lb	Silica gel
	4.0 lb	Sodium carbonate
	1.0 lb	Acridine
	1.0 lb	8-Quinolinol
	0.1 lb	8-Hydroxy-7-iodo-5-quinoline sulfonic acid
	0.5 lb	Sulfamic acid
	0.75 lb	Magnesium oxide
	0.75 lb	Potassium dichromate
	1.0 lb	Potassium iodide
	3.0 lb	Potassium permanganate
	0.5 lb	Thenoxitrifluoracetone
	1.0 lb	Calcium carbonate
	0.25 lb	Phosphorous acid (granular)

Date	Quantity	Chemical
12-11-75	10.0 lb	Unknown liquid
(cont)	0.1 lb	Unknown liquid
	1 gal	Electrolyte
	2 gal	Crude sludge
	4 bottles	Crude oil
12-22-75	55 gal	Trichloroethylene
01-05-76	1,400 gal	Septic tank sludge
04-76	3 lb	Bromo-napthalene
	5 gal	Carbon tetrachloride
04-21-76	25-55 gal drums	Sodium oxide film on scrap metal
05-76	6 lbs	Hydrochloric acid 37%
	7 lbs	Nitric acid 70%
05-01-76	3 lbs	Bromo-naphthalene
	5 gal	Carbon tetrachloride
05-19-76	250 g	Acid aminonaphinol-sulfonic
	0.5 lb	Aluminum sulfate
	50 g	1-Amino-2-napthol-4-sulfonic acid
	50 g	Ammonium acetate
	200 g	Ammonium formate
	0.5 lb	Ammonium phosphate-dibasic
	500 g	Amonium sulfamate
	100 g	Aniline hydrochloride
	100 g	p-Bromaniline
	70 g	Brucine sulfate
	0.5 lb	Calcium nitrate
	50 g	Chloroanilic acid
	25 g	DL-Citrulline
		p-Dimethylamino benzaldehyde
	500 g	Ethylenediamine dihydrochloride
	50 g	1-Hydroxy-2-acetonapthone
	400 g	1-Hydroxy-2-napthoic acid
	0.5 lb	Lithium nitrate crystal
	0.5 lb	Lloyd reagent alkaloid
	1 lb	Magnesium nitrate
	0.5 lb	Manganous sulfate

Date	Quantity	Chemical
05-19-76 (cont)	100 g	Napthol
	100 g	p-Nitroaniline
	0.25 lb	Phenyl mercury chloride
	0.25 lb	Potassium citrate
	1 oz	Quinidine sulfate
	0.5 lb	Rosin
	0.5 lb	Sodium bromide
	0.25 lb	Sodium formate
	2 0.5 lb	Sodium molybdate
	200 g	Succinic acid disodium salt
	g	Sulfosalicylic acid
	5 g	Triketohydrindene hydrate
	2 g	Tripyridine
	100 g	2,4-D
	0.25 lb	Ferric chloride
	100 g	1-10-(ortho) phenanthralin monohydrate
	250 g	p-Toluene sulfonic acid
06-24-76	100 lbs	Paraffin
07-76	500 g	Cyclopentane
07-12-76	100 lbs	Cadmium nitrate solution 50% contaminate cleanup items
08-20-76	10 gal	Foam concentrate
	120 lb	Butvar BR 50%
	10 gal	Pluconic acid
	55 gal	Versenex 80
	100 lb	Sodium cluconate
	10 gal	Rodine #214
	2 L	Rodine #92-A
	10 lb	Methyl violet
	15 lb	Oil blue A (dye)
	1.5 gal	Zef-pure
	5 lb	Fire-sord
	7 gal	Petrogon
09-76	500 lbs	Sodium oxide contaminated shipping containers
	10 g	Mercury
	110 gal	TURCO 4521

Date	Quantity	Chemical
09-76 (cont)	2,500 lb	TURCO 4521
	430 lb	Sodium carbonate
	10 gal	Rodine #214
	55 gal	Hi-EX foam
10-28-76	300 lbs	Sodium hudroxide
	55 gal	TURCO fabrifilm
	55 gal	TURCO 430GC
	100 lbs	TURCO 430GB
	1,700 lbs	TURCO 430GD
	1,300 lbs	Sodium sulfate, borax sweepings
	800 lbs	Sodium persulfate sweepings
	600 lbs	Sodium sulfite sweepings
10-29-76	173 gal	Misc. paint
	1 pt	Epoxy hardener
12-76	10 L	Hydrazine solution depleted
	630 lbs	Poly-vinyl sulfonated Benzene cation exchange Resion
12-15-76	55 gal	Dibutyl carbitol
01-03-77	25 g	1,3,5-Trinitrobenzene mixed with 100 parts sand
02-07-77	0.75 gal	2,4-D dilute
	50 L	Coal tar/water
02-10-77	990 gals	Toluene/Isopropyl 50/50
02-11-77	30 lb	Sodium oxide waste
03-77	30 L	Unknown organics
	55 gal	Tetrachloroethylene 90% ethylene glycol 10%
03-29-77	3 lbs	Potassium permanganaate
	10 lbs	Sodium hydroxide
	5 lbs	Nickel chloride
	5 lbs	Nickel sulfate
	1 lb	Collodion flexible

Date	Quantity	Chemical
03-29-77 (cont)	1 lb	Sodium phosphate
	1 lb	Sodium borate
	1 lb	Boric acid
	1 lb	Cuprous cyanide
	6 lbs	Cupric sulfate
	1 lb	Lithium fluoride
	1 lb	Aluminum chloride
	1 lb	Lithium carbonate
	1 lb	Sodium fluoride
	13 cans	Spray paint (pressurized)
	1 pt	Dow Corning* fluid 200
	1/3 gal	Paper cement
	1 qt	Dowanol*
	3.05 gal	2-propanol
	6 lbs	Calcium carbonate
	0.25 pt	Unknown
	1 lb	Sodium cyanide
	1 pt	Dimethyl formamide
	1 qt	Cyclohexane
	4 pt	Ethylene dichloride
	1 gal	Carboline thinner 2J
	2 oz	Fine sulphide
	1 qt	Mineral oil
	1 pt	Chloroform
	1 pt	Collodion
	1 pt	Ethylene glycol
	1 pt	Diethylene glycol
	6 pt	Butyl alcohol
	14 pt	Benzene
04-77	165 gal	Paint/solvent
	0.2 kg	Hydrochloric acid gas
	1.4 kg	Hydrobromic acid gas
04-19-77	NA	Sodium oxide contaminated equipment including two 2-inch valves and one 6-inch-diameter and 18-inch-long tank
04-24-77	26 gal	Liquid penetrants
05-77	40 lb	Ion-exchange cleaner
	100 lb	Sodium phosphate tribasic

Date	Quantity	Chemical
05-77 (cont)	100 lb	Scale cleaner
	10 lb	Caustic
	50 lb	Nitrogen fertilizer
	4 gal	Alfa bromonaphthalene
05-04-77	40 lb	Amberlyst A-26* anion strong base resin
06-77	5 gal	Unknown liquid
06-06-77	48 ft^3	Sodium oxide contaminated pipe
06-15-77	5 gal	Phenoline 300 catalyst
06-22-77	5 gal	Phenoline 300 catalyst
	3 lb	Bird-X
08-77	7.2 kg	Cupric oxide
	4.5 kg	Ferric oxide
	36.3 kg	Ferric oxide
09-30-77	30 lb	Dimethylsalf oxide (DMSO)
10-12-77	Small quantity less than 1 lb	Litharige lead monoxide
		Cobaltous nitrate
		Potassium nitrate
		Sodium nitrate
		Sodium cobaltous nitrate
		Nickelous nitrate
		Zirconium nitrate
		Zinc oxide
		Sodium molybdate
		Trisodium phosphate
		Black ferric oxide
		Red ferric oxide
		Ferric chloride
		Ferric oxide
		Cupric oxide
		Sodium phosphate
		Tin metal
		Lead
		Strontium chloride
		Sodium peroxide

Date	Quantity	Chemical
10-12-77 (cont)		Potassium chloride
		Magnesium metal
10-19-77	110 gal	Solvent refined coal and solvent
	20 gal	Waste oil/solvents
10-31-77	10 ft^3	Oil shale (rock)
11-11-77	8 oz	Beryllium metal
	500 lbs	Concreted carcinogen (benzene, pyrene)
	12 kg	Mercury in solution with hydrochloric acid, sodium chloride and organics
12-01-77	3 gal	Organic solvents--methyl isobutyl ketone, benzene, pyridine, carbondisulfide, pesticides and beryllium
12-12-77	540 lbs	Sodium oxide contaminated equipment
01-78	30 gal	Boiler treatment solution
	15 gal	NINALK B acid
	2.5 gal	Produce #135 (contains chromate)
02-15-78	55 gal	Aluminum nitrate
	55 gal	DTPA
	100 lb	Sodium nitrate
	100 lb	Sairset bonding mortar
	5 gal	Manganese nitrate
	5 gal	Sodium silicate
	100 gal	Ferric nitrate
	18 L	DTPA
	1 L	Unknown solution
	4 L	HEDTA-hydroxyethylethylenediametriacetic acid
	3 L	100% TBA
	2 L	NPH
	1	15% Aliquot 336/xylene
	500 ml	5% Aliquot 336/chloroform
	1 L	30% Aliquot 336/xylene
	1 L	DI (secondary-butyl) phenol phosphonate
	250 ml	5% TOPO/cyclohexane
	250 ml	1.3 m HDEHP/cyclohexane

Date	Quantity	Chemical
02-15-78 (cont)	200 ml	30% DI (secondary butyl) phenol phosphonate/xylene
	150 ml	100% Di butyl N,N-diethylcarbamoyl-phosphonate
	500 ml	Chloroform
	250 ml	5% TOPO/cyclohexane
	130 ml	D_2 EHPA
	150 ml	Hexone
	400 ml	.1m TOPO/cyclohexane
	400 ml	15% Aliquot 336/xylene
	200 ml	30% Aliquot 336/xylene
	500 ml	Soap i isopropano
	500 ml	Cyclohexane
	500 ml	Hexone
	700 ml	Nitroethane
	300 ml	Chevron dispersant NI-W*
	100 ml	.05 M Br-PADAP/hexanol
	100 mt	.05 M BR-PADAP/cyclohexane
	3 L	HOPPES #9 solvent
	1 lb	Barium perchlorate
	2 oz	Zirconyl nitrate
	36 oz	Mercuric nitrate
	0.75 lb	Silver nitrate
	1 lb	Lead nitrate
	2 lb	Lead dioxide
	2 lb	Larnthanium nitrate
	2.5 lb	Mercuric nitrate
	1 lb	Magnesium perchlorate
	5 lb	Sodium perchlorate
	5 lb	Phosphorous pentoxide
	1 lb	Potassium oxalate
	2 lb	Larthanum nitrate crystals
	1 lb	Sodium bisulfate
	1 lb	Graphite powder
	0.25 lb	Lithium fluoride
	5 g	Ferric sulfate
	1 lb	Potassium bromide
	100 g	Reinecke salt $NH_4(Cr(NH_3)_2(SCH))\cdot H_2O$
	4 oz	Sodium stearate
	6 lb	Sodium sulfate, anhydrous
	0.25 lb	Turgatic anhydride
	1 lb	Sodium silicate
	1 lb	Potassium carbonate

Date	Quantity	Chemical
02-15-78 (cont)	5 g	Hexachloric dihydrager platinum IV
	1 gal	Ferric sulfate
	10 lb	Cresco sulphur
	1 lb	Iron chip accelerator
	1 lb	Potassium ferrocyanide
	1 lb	Lithium hydroxide, anhydrous
	1 lb	Sodium hydrochlorite
	1 lb	Potassium fluoride
	10 g	Zinc sulfate
	25 g	Zinc sulfide
	4 oz	Mercuric chloride
	10 g	Meta sodium bisulfate
	1 lb	Sulfamic acid
	10 g	Sodium tetra borate
	10 g	Magnesium chloride
	10 g	Nickel sulfate
	25 g	Sodium perchlorate
	50 g	Black K salt (Nation Anvine Divison)
	25 g	Potassium ferricyanide
	0.25 lb	Lithium chloride
	100 g	Sodium azide
	100 g	Nitroso R salt
	250 ml	Hydroxylamine hydrochloride
	0.5 lb	Manganous chloride
	2 lb	Manganous chloride
	6 pt	Ceric ammonium, sulfate (0.04N)
	1 pt	Titanium trichloride
	10 g	Phenol red
	0.5 lb	TTA
	1 lb	Hydroquinone
	100 g	2,5-Diphenyl oxazole
	25 g	1,5-Diphenyl carbohydrazide
	10 g	Cholesteryl escuate
	5 g	Glyoxol-bis (2-hydroxyanil)
	15 ml	Benzalkorium CL(zephiron), 2.8% (rexall phum.)
	100 g	Dodecyl alcohol
	100 g	4,5-Dihydroxyl-3-(p-sulfophenylazo)- 3,7-napthalene disulfonic acid in sodium salt
	5 g	Bis (1-phenyl-1,3-butaine dicro)copper
	10 g	N-phenrylberzo hydroxamis acid
	160 oz	1,10-pherathrolie ferrous sulfate, solution (ferrous)

Date	Quantity	Chemical
02-15-78 (cont)	5 g	Aluminum (2-ethylhexaroate)
	100 g	1-Nitroso-1-naphthol
	10 g	6-Methyl-2,4-heptanedione
	1 lb	Ammonium sulfide
	1 lb	Aerosol OT solution, 25% (Verwalters & Rogers)
	5 g	Nickel cyclohexane butyrate
	10 lb	Trilauryl testing amine (alamine 304)
	250 ml	2-Ethylhexylamine
	500 g	o-Aminophenol
	1 kg	Di-N-butyl phosphate
	5 g	Tris (-phenyl-1,3-butanedione) iron
	2 g	Bathopherzathroline, sulfonated, sodium salt
	2 g	Thymol blue indicator
	10 g	Hematoxylin.
	5 g	2-Napthylamine
	40 g	Bromothymol blue
	20 g	Methyl violet 2B
	10 g	Diphenylthiocasbazone
	25 g	2,4-Dimethyl pharol
	10 g	Cargo red
	1 pt	Kad fisdur reagent
	25 g	1-Nitroso-2-napthol-3,6-disulfours acid disodium salt
	25 g	1-Pyfolidine carbonithior acid, ammonium salt
	5 g	POPOP 1,4-bis (2-(5-phenyloxazolyl))-benzene
	25 g	Premix 'P' 2% POPOP; 98% PPO(PPO-aphenoazide)
	20 g	Methyl red
	100 g	Trioctylphosphine oxide
	10 g	Oxime
	100 g	Sulfosalicylic acid
	4 oz	Potassium biphthalate
	21 g	CDTA (1,2-cyolohexylene-dinitirile)-tetraacetric acid
	10 g	Potassium fluoride
	200 g	Amadac-F (Besdiet/Jackson Laboratories)
	1 pt	'Aerosol' OT clear, 25% (American Cyanimid Co.)
	1 oz	Methyl red
	1 lb	Anion exchange resin (chloride form)
	20 g	Dithizone
	50 g	Petrol black 'A'
	12 pt	Ehrlich reagent solution (p-dimethylamino benaldehyde)

Date	Quantity	Chemical
02-15-78 (cont)	1 lb	Silica powder
	250 ml	Collodion in ethylether
	14 pt	Formaldehyde
	1 pt	Benzene
	1 gal	Special thinner #92 (alcohol derivative)
	1 L	Chclohexane
	1 gal	N-butyl acetate
	1 gal	Ketone
	250 ml	24.7% Aromatic solvent 30.0% M-purol 25.0% O-dichlorobenzene 12.5 % Crysylic acid 5.0% Monoethandamine 2.8% Igepal* CO 210% by volume
	1 kg	Butylacetate
	5 pt	Carbon tetrachloride
	600 ml	Organic gelatin & dye
	1 gal	Flammable organic
	4 gal	Ammonia
02-24-78	4 gal	Ammonia
03-78	30 gal	TURCO DESEN IT II
	40 lb	Microdoiocide
06-01-78	110 gal	Sulfamic acid
03-09-79	30 lb (6 gal)	Hydrofluoric acid
	30 lb (15 L)	Hydriodic acid
03-27-79	5 gal	Sodium hydroxide
	4 gal	Ammonium hydroxide
	10 gal	Chloroform, hexane, tetrahydrofuran acetone
	6 gal	Carbon tetrachloride, hexane, tetrahydrofuran
	1 L	Phosphorous pentoxide
04-23-79	55 gal drum	Methyl ethyl ketone, mineral spirits and absorbent
06-08-79	600 ml	Benzene

Date	Quantity	Chemical
07-19-79	55 gal drum with absorbent & individual containers	Flammable organic solvents
		Corrosive liquid
		Ammonia
		Phosphoric acid (1.5 gal)
		Epoxy resin (1 gal)
		Catalyst (1 qt)
		Xylene (2 qt)
		Fixing agent (2.25 gal)
		'Photo resist' (2 qt)
07-24-79	4 L	Dibromobutane
	3 qt	Dibutyl phthalate
	1 kg	Dichloromethane
	75 g	2-Methylamino ethanol
	1 L	.1M TTA, 0.01M tributyl phosphate in hexane
	1 lb	Aquafluor
	1 qt	White oil (mineral oil)
	2 lb	Glycerine
	1 gal	Glycerine
	500 g	2,4-Pentane.
	4 kg	2,6-Dimethyl-4-heptanol
	5 pt	Triethanolamine
	2 L	Isooctane
	12 kg	2,2,4-Trimethyl pentane
	11 pt	Amyl acetate
	4 qt	Isoamyl acetate
	19 pt	Cylohexanone
	30 pt	Carbon tetrachloride
	24 pt	Carbon tetrachloride
	5 gal	Ethylene glycol monoethyl ether
	45 pt	Xylene
	15 pt	Isoamyl alcohol
	500 g	Bis(2-ethoxyethyl) ether
	645 g	Bis(2-ethylhexyl) hydrogen phosphate
	10 pt	Ethyl acetate
	9 pt	Bromobenzene
	12 pt	Butyl alcohol
	5 pt	Pyridine
	4 kg	Nitrobenzene
	5 pt	Chloroform
	24 pt	Chloroform
	3 pt	Petroleum ether

Date	Quantity	Chemical
07-24-79 (cont)	10 pt	Isopropyl ether
	5 gal	Heptane
	1 gal	Butyl cellosolve
	16 pt	Hexanol
	1 gal	Salicylaldehyde
	5 gal	Transformer oil
	1 gal	Flammable liquid NOS
	18 lb	Hydrofluoric acid
	1 gal	Freon*
08-28-79	25 lb	Ammonium hydroxide
	8 lb	Hydrogen peroxide
	0.75 gal	Dimethyl formamide
	0.66 gal	Heptane
	1 gal	Formaldehyde
	1 gal	Acetonitrile
	0.75 gal	Dichloroethane
	1 gal	Butyl ethyl acetate
	5 pt	Carbon tetrachloride
	0.5 gal	Methanol
	0.75 gal	Propanol
	4 lb	Glacial acetic acid
	13 lb	Sulfuric acid
	6 lb	Hydrochloric acid
	20 lb	Oxalic acid
	30 lb	Potassium hydroxide
09-11-79	4 gal	Petroleum ether, hexane, benzene, pyridine, pesticide, beryllium
10-25-79	5 gal	Cine 2 reversal bleach solution developer reprenisher
11-28-79	2-5 gal cans	Mixed liquid carcinogens (benzene, benzyl-para-aminophenol, etc.) absorbed into Discasorb, placed into 5-gallon cans and concreted into 55-gallon drums
	125 lb	Mercury with 'discasorb'
03-05-80	6 pt	Isoamyl alcohol
	500 ml	50% Isoamyl alcohol

Date	Quantity	Chemical
03-05-80 (cont)	2 L	Isooctane
	2 kg	Mesityl oxide
	4 kg	Triethanolamine
	2 kg	Nitrobenzene
	4 pt	Nitrobenzene
	16 oz	Phenol reagent
	500 g	Propylene carbonate
	9 pt	Pyridine
	1 L	1 g/L Rhodium
	5 kg	1,1,2,2-tetra-bromo-ethane
	1 kg	Tetrahydrofuran
	16 pt	Trichloro-ethylene
	2 bottles	Triisooctylamine
	4 L	2,2,4-Trimethyl pentane
	8 pt	Tri-n-octylamine
	2 pt	Octyl alcohol
	3 lb	Cadmium
	3 oz	Cadmium nitrate
	1 lb	Cadmium chloride
	5 lb	Cryolite
	5 lb	Calcium hydroxide
	500 g	2-(2-hydroxyl-1-naphtylazo)-2-naphthol-4-sulfonic acid zinc salt
	9 oz	Iodine
	750 g	Hydroxylamine sulfate
	500 g	Hydrazine sulfate
	2 lb	Lead nitrate
	4 lb	Iron metal wire
	1 lb	Magnesium acetate
	0.25 lb	Lead iodide
	1 lb	lead chloride
	0.5 lb	Lithium aluminum oxide
	1 lb	Magnesium chloride
	0.25 lb	Manganous chloride
	25 g	2-Mercaptobenzathiazole
	10 g	2-Mercapto-N-2-naphthylacetamide
	0.25 lb	Mercuric oxide red
	10 g	3-Methylindole
	100 g	3-Methyl-1-phenyl-2-pyrazoline-5-one
	200 g	1-Naphthylamine hydrochloride

Date	Quantity	Chemical
03-05-80	100 g	1-Naphthalamine
(cont)	5 g	di-β-naphthylthiocarbazone
	4 oz	Nickelous sulfate
	0.25 lb	Nickelous nitrate
	4 oz	Nickel metal powder
	4 oz	Oxalic acid
	200 g	Pararosaniline hydrochloride
	25 g	3.3'-dimethyl-1,1'-diphenyl [4,4'-bi-2-pyrazoline]-5,5'-dione]
	25 g	Phenylazoaniline
	3 lb	Potassium carbonate
	0.25 lb	Potassium bromate
	1 lb	Potassium chlorate
	25 g	Potassium dithio-oxalate
	100 g	Potassium ferrocyanide
	0.25 lb	Potassium chloride
	1 lb	Potassium biohydrate
	1 lb	Potassium ferricyanide
	1 lb	Potassium nitrate
	0.25 lb	Potassium periodate
	1 lb	Potassium phosphate dibasic
	2 lb	Potassium phosphate monobasic
	2.25 lb	Potassium sodium tartrate
	1 oz	Quinine sulfate
	10 g	Quinalizarin
	1 lb	Pumice
	100 g	8-Quinolinol
	1 lb	Potassium sulfate
	1 lb	Potassium thiocyanate
	4 oz	Pyrogallic acid
	0.25 lb	Silver nitrate
	0.25 lb	Saponin
	0.25 lb	Sequestrene NA2*
	1 lb	Sodium arsenate
	2.25 lb	Potassium sodium tartrate
	1 oz	Quinine sulfate
	10 g	Quinalizarin
	1 lb	Pumice
	100 g	8-Quinolinol
	1 lb	Potassium sulfate
	1 lb	Potassium thiocyanate
	4 oz	Pyrogallic acid

Date	Quantity	Chemical
03-05-80 (cont)	0.25 lb	Silver nitrate
	0.25 lb	Saponin
	0.25 lb	Sequestrene NA2
	1 lb	Sodium arsenate
	0.25 lb	Sodium bismuthate
	0.25 lb	Sodium cyanide
	3 lb	Sodium dichromate
	100 g	Sodium diethyldithiocarbamate
	2 lb	Sodium dithionate
	1 kg	Sodium formaldehyde bisulfite
	2 lb	Sodium formate
	1 lb	Soda lime
	4 oz	Sodium oxalate
	1 lb	Sodium nitrite
	1 lb	Sodium phosphate tribasic
	1 lb	Sodium phosphate tera
	1 lb	Sodium sulfide
	4 oz	Strontium bromide
	4 oz	Strontium carbonate
	4 oz	Strontium hydroxide
	2 lb	Stannous sulfate
	2 lb	Sulfur
	10 lb	Sulfanilic acid
	700 g	N-1-naphthylethylenediamine dihydrochloride
	5 lb	Sodium sulfite
	0.25 lb	Strontium nitrate
	1 g	Thymolsulfonephthalein
	1 g	Tartaric acid
	1 g	Tetrahydroxyquinone
	1 lb	Thymol
	1 lb	o-Toluidine
	4 oz	Zinc
	3 oz	Calcium nitrate
	3 lb	Calcium chloride
	1.25 lb	Chromium potassium sulfate
	2 lb	Chromium trioxide
	1 lb	Copper turnings
	1 lb	Cobalt chloride
	0.25 lb	Cobalt nitrate
	1 lb	Cobalt sulfate
	4 oz	Cupric nitrate

Date	Quantity	Chemical
03-05-80 (cont)	4 oz	Cupferron
	5 lb	Ceric sulfate
	1 lb	Talc
	1 lb	Magnesium turnings
	6 lb	Potassium dichromate
	2 lb	Dextrose
	100 g	Diazole
	25 g	1,8-dihydrosynaphthalene-, 6-disulfonic acid
	200 g	M-dinitrobenzene
	45 g	Diphenylthiocarbazone
	1 lb	Ethylenediamine tetraacetic acid
	1 lb	Ferric nitrate
	1 lb	Ferrous sulfide
	100 g	Fluorescein disodium salt
	2 lb	Gelatin
	500 g	L-(t)-Glutamic acid
	1 lb	Zinc sulfate
	1 lb	Zinc oxide
	2 lb	Zinc acetate
	1 lb	Zinc chloride
	1 lb	zinc nitrate
	1 oz	Zirconium chloride
	500 g	Zirconyl chloride
	1 oz	Zirconyl nitrate
	100 g	Acetyl choline chloride
	1 lb	Aluminum chloride
	1.5 lb	Aluminum sulfate
	6 oz	Asbestos
	0.5 lb	Agar agar
	2 oz	Ammonium chromate
	4 oz	Ammonium iodide
	0.25 lb	Ammonium oxalate
	4 oz	Ammonium phosphate
	2 lb	Ammonium thiocyanate
	4 oz	Arsenic trioxide
	4 oz	Arsenic acid
	5 lb	Ammonium persufate
	0.25 lb	Barium hydroxide
	1 lb	Barium nitrate
	0.5 lb	Beryllium sulfate
03-15-80	500 g	Acetonitrile

Date	Quantity	Chemical
03-15-80 (cont)	3 pt	Aniline
	1 pt	Ammonium sulfide
	1 kg	2-Butoxyethyl acetate
	1 kg	Butyl acetate
	500 ml	N-butyl acetate
	500 g	Butylamine
	1 kg	o-Dichlorobenzene
	250 g	2-Dimethylamino ethanol
	100 g	n,n-Dimethyl-1-naphthylame
	2 pt	Dimethylsulfoxide
	1 pt	1,4 Dioxane
	2 pt	Ethylene glycol
	500 g	Formamide
	2 pt	1 Hexanol
04-10-80	0.4 lb	Benzene reagent
04-15-80	5 lb	Glycerol
	10 lb	Hydrogen peroxide
	20 lb	Mercury - double contained + concrete
	2 oz	Methanol
	6 oz	D-tartaric acid
	10 g	Dimethyl amino ethanol
	3 qt	Ethylene glycol
	4 lb	Easy Off* oven cleaner
	1.5 gal	OSPHO acid metal prepcint conditioner
	1 pt	68% Ammonium nitrate monohydrate
	1 gal	potassium-permanganate
	1 pt	25% Oxalic acid
	0.5 pt	Sodium hydroxide
	1 gal	Glycerol
	0.5 pt	Murokami etchart
	0.13 pt	Nitric acid, hydrofluoric acid, water
	0.5 pt	20% Acetic acid, water
	0.25 pt	Kellign's reagent
	0.25 pt	Nitric acid, hydrofluoric acid, water
	1 pt	Liquid paraffin
	1 gal	Diethylene glycol monoethyl ether
	1 qt	Norcune 3416
	2 gal	Hypersol lubricant
	3 cans	OS lubricant
	2 qt	Hypalube 'Hyprez'*

Date	Quantity	Chemical
04-15-80 (cont)	1 pt	1% Chromium trioxide
	1 qt	2% Chromium trioxide
	0.5 pt	25% Sodium hydroxide
	0.5 pt	10% Oxalic
	2 glass containers	Ballards triple-distilled mercury
	1 lb	Magnesium oxide
	14 lb	Fluorochemical inert
	2 lb	Cupric sulfate
	1 gal	Dimethyl phosphate
	1 lb	Dimethylformamide
	4 gal	Zinc bromide
	2 lb	Ammonium citrate dibasic
	4 lb	Aluminum oxide
	1 lb	Aluminum metal
	6 lb	Aluminum nitrate
	5 lb	Ammonium persulfate
	3 lb	Acid citric
	1 lb	Ammonium fluoride
	1 lb	Cesium nitrate
	1 lb	Copper metal
	1 lb	Cupric chloride
	2 lb	Chromium oxide
	9 lb	Chromium trioxide
	8 lb	Cupric sulfate
	4 lb	Disodium dihydrogen ethylene diaminetetracetate dihydrate
	2 lb	Ferric chloride
	4 oz	$Fe(NO_3)_3$
	1 oz	Fluorescein sodium
	2 lb	Iron metal
	6 lb	Lead metal
	4 lb	Mercuric nitrate
	10 lb	Oxalic acid dihydrate
	4 lb	Magnesium permanganate
	4 lb	Potassium permanganate
	4 lb	Potassium ferricyanide
	1 lb	Potassium thiocyanate
	5 lb	Sodium sulfite anhydrous
	0.25 lb	Sodium iodide
	1.25 lb	Sodium metabisulfite
	4 oz	Sodium cyanide

Date	Quantity	Chemical
04-15-80 (cont)	3 lb	Sodium dichromate
	44 lb	Sodium nitrite
	5 lb	Calcium sulfate
	100 gms	Diclycidl ether of polypropylene glycol
	1 lb	Magnesium oxide
04-25-80	3 plastic jars in 5 gal metal drums	Paraquat
	2 glass containers	Ballard's mercury triple distilled
05-07-80	1,500-1,700 gal	Dilute 2,4-D amine
05-14-80	15 gal (90 lb)	Dow Corning 710 silicone fluid mixed with 'Dry Floor': stiff paste
06-04-80	2 L	Hydrochloric acid
	1 gal	Carbon tetrachloride
	1 gal	Unknown resin
	3 L	Formamide
	5 oz	Methylene iodide
	200 ml	Mercury
	10 gal	Liquid heat mixture: 52.5% $BaCl_2$ 14.2% NaCl 33.3% KCl
	9 L	Rhodium
	2 gal	Chromium compounds
	1 qt	Potassium gold cyanide
06-17-80	72 pkg (100 lb)	Neomycin sulfate antibiotic
	16 plastic containers 1 in. x 3 in.	Lactated ringer solution
	15 gal (130 lb)	Calcium hypochlorite liquid
	60 gal (500 lb)	Yellow dye

Date	Quantity	Chemical
06-17-80 (cont)	132 jars 11 lbs each	Sodium dithionite
	100 lbs	Oxalic acid
07-30-80	1 L (4 lb)	Lead perchlorate perchloric acid

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Appendix C

Conceptual Design of the Final Cover for the Nonradioactive Dangerous Waste Landfill

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Contents

Figures

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Terms

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
HELP	*Hydrologic Evaluation of Landfill Performance*
ITRC	Interstate Technology Regulatory Council
LAI	leaf area index
LANL	Los Alamos National Laboratory
NRDWL	Nonradioactive Dangerous Waste Landfill
RCN	Runoff Curve Number
RCRA	*Resource Conservation and Recovery Act of 1976*
SCS	Soil Conservation Service
SWL	Solid Waste Landfill
WAC	*Washington Administrative Code*

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C1 Introduction

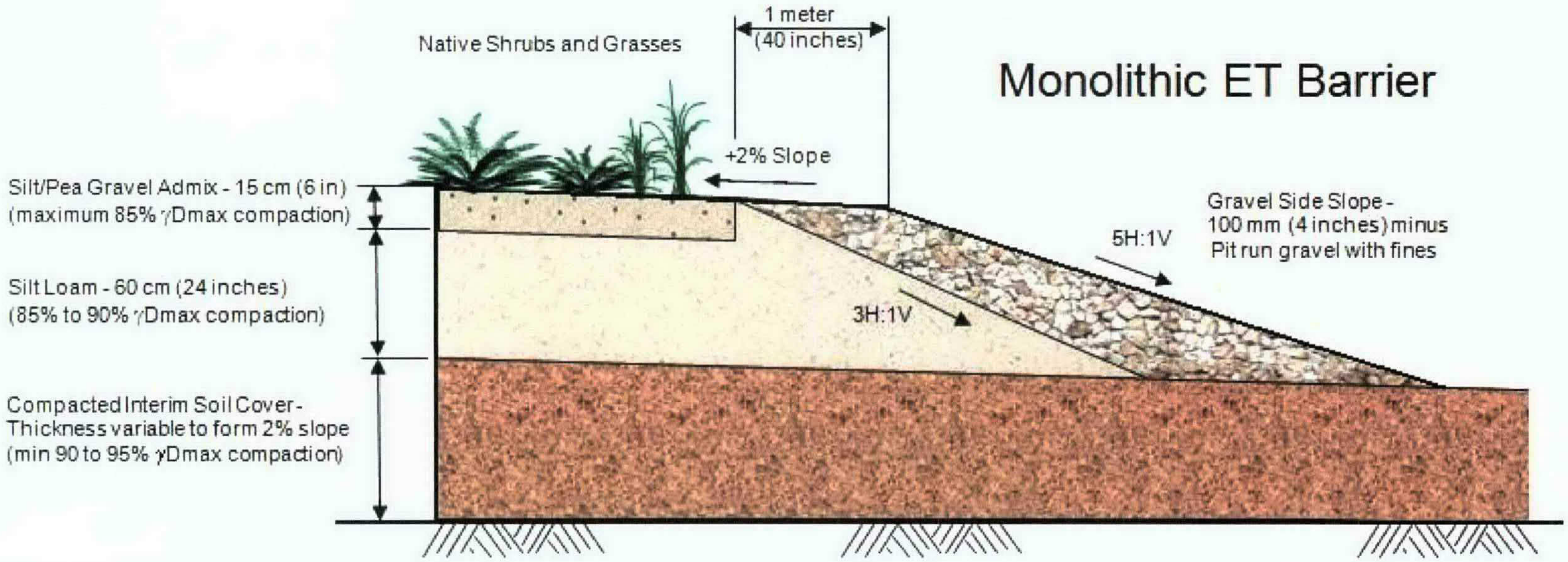
The conceptual design of the final cover for the Nonradioactive Dangerous Waste Landfill (NRDWL) is based on conformance to the requirements of WAC 173-303-610, "Closure and Post-Closure," and WAC 173-303-665(6) "Closure and Post-Closure Care." These requirements will be met by specifying a 75 cm (30 in.) thick evapotranspiration (ET) final cover with a general slope of approximately 2 percent, planted with a variety of native shrubs, grasses, and forbs. An interim soil cover is already in place, but in some areas of the landfill it may require some reshaping and/or placement of additional soil fill in preparation for the installation of the ET final cover in order to achieve a general 2 percent slope so that the cover surface drains to the perimeter of the landfill. The ET final cover will consist of 60 cm (24 in.) of a fine-grained, low permeability soil and 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion-resistant top soil (Figure C-1). The slope of the final cover will be maintained at approximately 2 percent as fine-grained soils (e.g., silt-loam) are more susceptible to erosional forces when the slope is greater than 2 percent (PNL-8478, *Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel*). The entire cover will be planted with a variety of native shrubs, grasses, and forbs.

A single soil cover design was developed for the entire area containing asbestos and solid waste trenches. Because of the close proximity to the Solid Waste Landfill (SWL), the cover designs for the NRDWL and SWL are to be fully coordinated and/or integrated. This will eliminate the potential for one design to impact the design and construction costs for the placement of a cover over the other. The need for coordination is evident when noting that the NRDWL and SWL share a common boundary, with less than 8 m (25 ft) separating trenches within the two landfills. In examining the topography, the existing grade will require some rework to minimize the amount of fill required to create a general 2 percent slope for both covers, while at the same time assuring the final covers will drain to runoff/run-on control ditches and basins at the outer perimeter of the landfill. Modeling (see Section C3) indicates that up to 6 % of annual precipitation will be removed as runoff. With the evidence provided at the Hanford Barrier and other study sites, actual runoff is expected to be much less. However, the inclusion of perimeter channels or ditches and low area collection basins is advisable due to the large surface area of the landfill. Additionally, some native material will be required to form the general shape/slope of the cover. By selectively siting local borrow areas, a sufficient runoff/run-on control system could be formed. Siting of borrow areas should also consider the potential for lateral subsurface flow of any percolating runoff water back into waste trenches due to contrasting soil textural boundaries within the underlying soils.

As the interim cover for the NRDWL is documented to be 1.2 to 3.0 m (4.0 to 10 ft) thick and the interim cover of the SWL is documented to be 0.6 to 1.2 m (2.0 to 4.0 ft) thick, an assumption was made that with the expected gradual consolidation of the waste in the trenches the maximum amount of cover that could be safely removed from any particular location during regrading activities, while retaining a minimum thickness interim cover, would be approximately 0.5 m (19 in.). Using these concepts, a set of conceptual integrated final cover design grading plans were generated (Figures C-2 and C-3). The amount of soil removal that could be safely allowed during any regrading activity will be established during definitive design using topographical maps (historical and current), geophysical survey, and/or probes or potholes.

The design of the final cover for the NRDWL will conform to WAC 173-303, "Dangerous Waste Regulations," even though the majority of the trenches within the landfill received waste of a type that is not specifically regulated under this statute. Trench 1N, on the west end of the NRDWL, received municipal solid waste, which is regulated under WAC 173-350, "Solid Waste Handling Standards." In addition to conforming to the requirements of WAC 173-303, the design will conform to the regulatory guidance given in WAC 173-350-400, "Limited Purpose Landfills," which establishes the standards for solid waste landfill final covers. Trenches 2N, 20, 21, 22, 23, 25, 27, 29, and 30 received demolition waste containing asbestos and would normally be regulated under 40 CFR 61, "National Emission

Standards for Hazardous Air Pollutants." According to 40 CFR 61, final closure of the asbestos trenches could have been achieved simply by covering the trenches with a sufficient thickness of soil and rock to provide a simple physical barrier. However, because of the commingling of the trenches that received asbestos waste with the trenches that received solid waste, the entire landfill will be covered with the same cover. Suitable soil material having adequate water storage capacity and rooting thickness must be placed over the asbestos trenches to develop and retain vigorous native perennial cover vegetation at the site.



γDmax = total unit weight density maximum

H:V = horizontal to vertical

Figure C-1. Proposed Final Cover Design for the Hanford Nonradioactive Dangerous Waste Landfill

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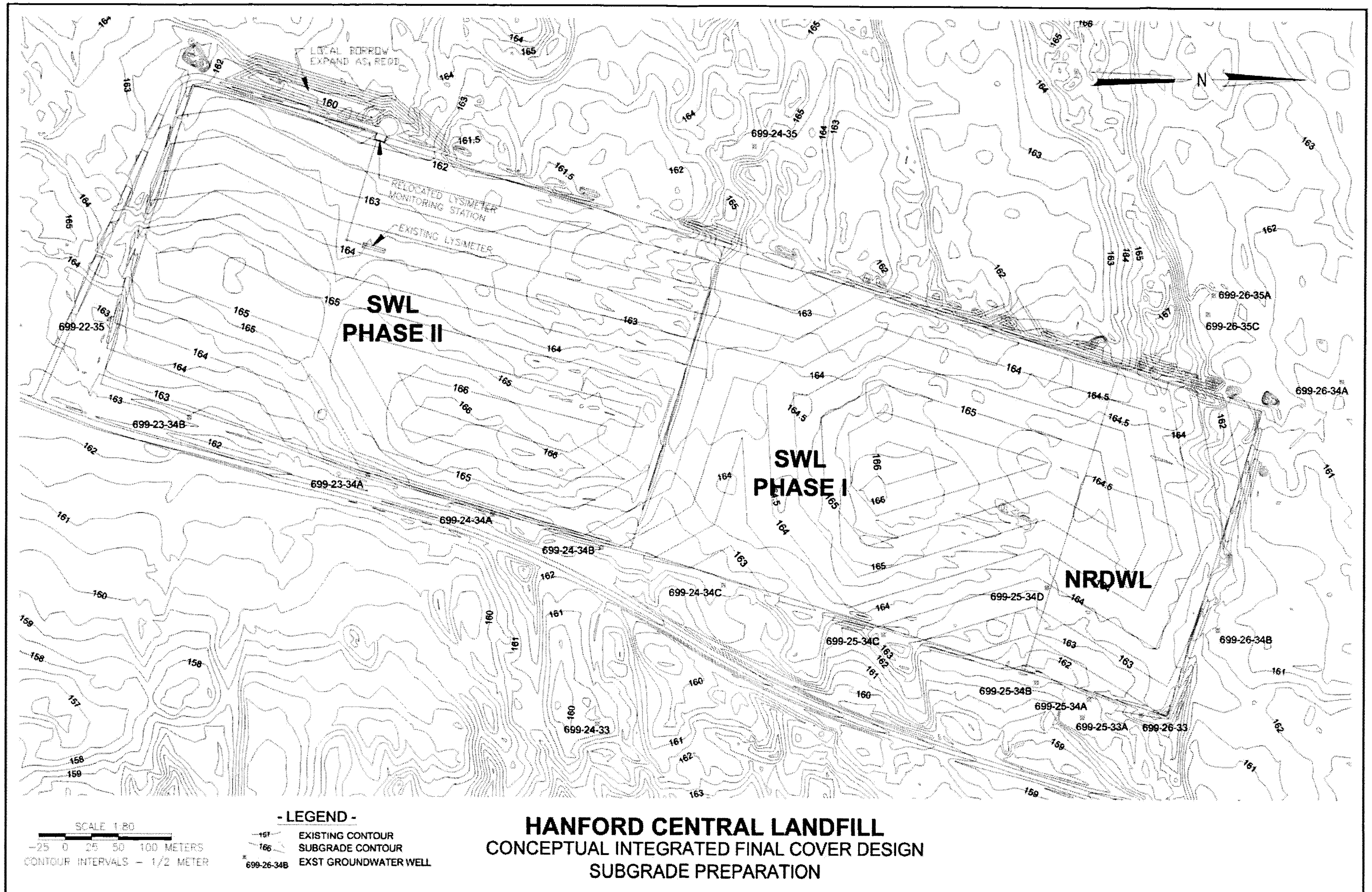

Figure C-2. Conceptual Integrated Final Cover Design Subgrade Preparation

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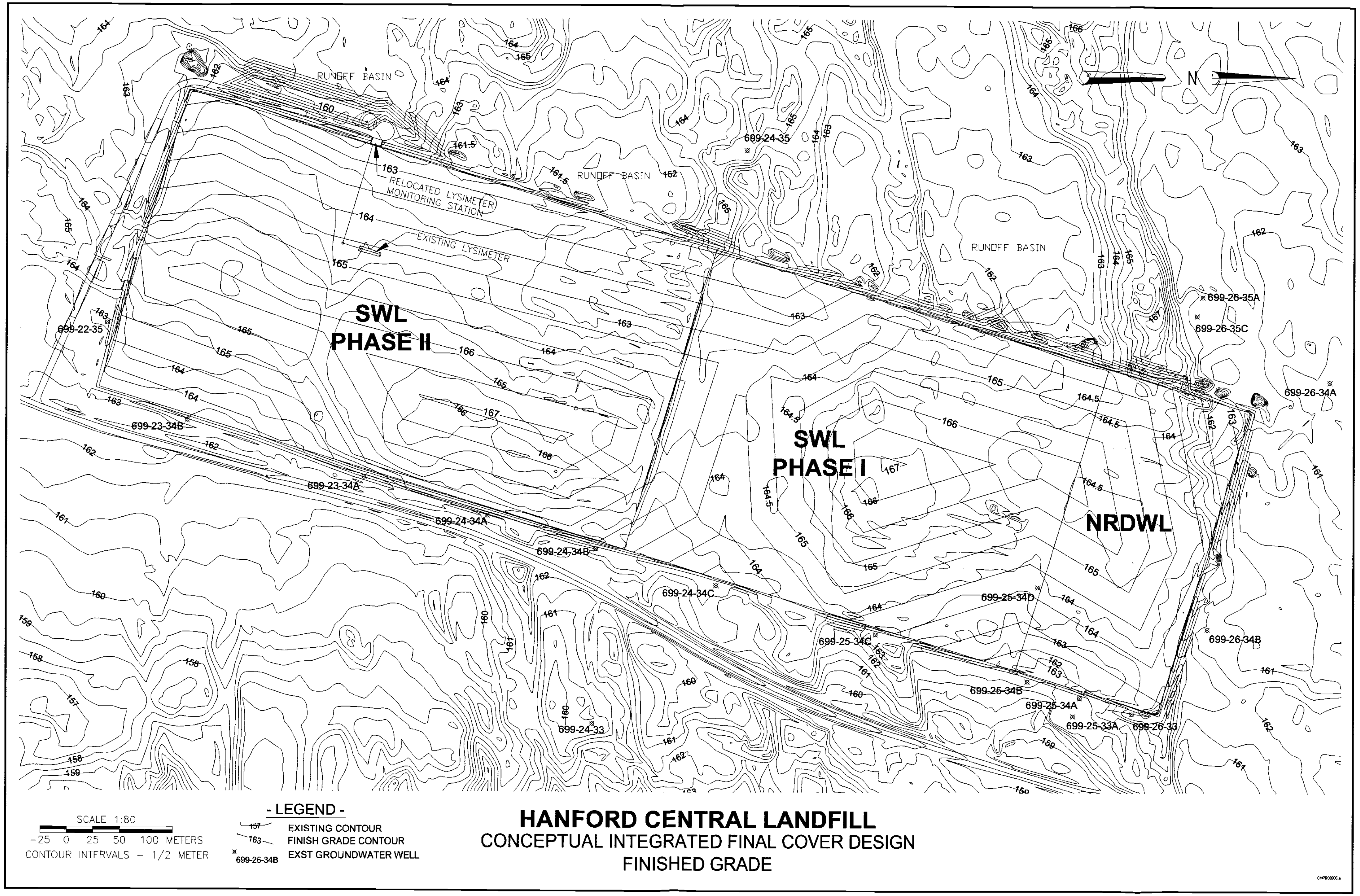

Figure C-3. Conceptual Integrated Final Cover Design Finished Grade

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C2 Selection of Cover Design Concept

Cover design has been studied at the Hanford Site since the 1980's. Since the principal concern at the Hanford Site deals with resolving issues with radioactive waste, the Hanford Barrier Program has focused on extremely long term performance (> 1,000 years). Several natural analogue sites have been evaluated. Numerous laboratory analyses have been performed. Various test plots and lysimeters were constructed and monitored, some for well over a decade. All of these tests and studies have verified that, because of the arid climate, the Hanford Site should employ covers that rely upon the natural processes of ET to control leachate generation (DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*).

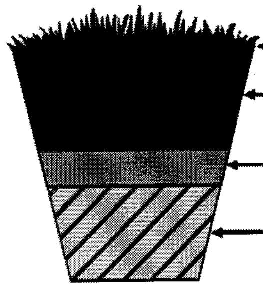
In 1994, a large test barrier was constructed that incorporated a layer of locally available fine-grained soils as the principal component in restricting water movement towards and through the waste. Even though a portion of the test barrier was stressed for the first three years with three times the annual precipitation, as well as an additional simulated precipitation event that exceeded a 1,000-year probability of occurrence, after 8 years of monitoring, drainage through the vegetated fine-soil layer only occurred during the third year. That one year's drainage did not exceed the design goal of 0.5 mm (PNNL-14143, *The Hanford Site 1000-Year Cap Design Test*), demonstrating the ability of the cover to control leachate generation.

Over the past few decades there have been numerous studies performed across the nation, sponsored by regulatory agencies and landfill owners, on the performance of various cover design concepts. One of the more comprehensive studies is being performed under the Alternative Cover Assessment Program, of which the U.S. Environmental Protection Agency (EPA) is one of the principal sponsors. Under this program, large-scale test plots of a set of several cover concepts were constructed at locations throughout the U.S., and the performance at each location compared. Alternative Cover Assessment Program has concluded that covers that rely on the natural process of ET are well suited for application where the climate is arid or semi-arid as long as the type and thickness of the soils used in constructing the cover provide sufficient water storage capacity (DRI, 2002, *Alternative Cover Assessment Project Phase I Report*).

Another comprehensive study on cover concepts is being performed for the U.S. Department of Energy (DOE) at the Los Alamos National Laboratory (LANL), a semi-arid site that receives almost three times the average annual precipitation that the Hanford Site receives. Several test plots were constructed at the LANL that have demonstrated that a simple ET cover will adequately protect the environment. In 2007, the LANL published a design guidance and requirements document that identifies a monolithic ET cover as the typical cover design to be used at the LANL for hazardous and radioactive mixed waste sites (LA-UR-06-4715, *Cover System Design Guidance and Requirements Document*).

The ET cover concept was selected for the NRDWL final cover. The ET covers, or surface barriers, rely on the natural systems of the water-holding "or storage" capacity of a fine-grained soil, evaporation from the near-surface, and plant transpiration to control water movement through the cover. Precipitation is allowed to infiltrate at the surface, where it is retained in the soil until natural ET processes release the water back to the atmosphere. Such designs are particularly suitable for semiarid and arid climates with a low annual amount of precipitation and a relatively high ET potential. When precipitation exceeds ET, water is stored, and when ET exceeds precipitation, water is removed.

One of the more common types of ET cover is the monofill (or monolithic) cover (Figure C-4), which relies on a relatively thick single layer of fine-grained soil to store precipitation for later removal by direct evaporation and/or plant transpiration. Figure C-1 shows a cross-section showing the profile and side-slope design being proposed for the NRDWL.



Source: EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet*

Figure C-4. Conceptual Monofill (Monolithic) ET Cover Design

The thickness of a monofill ET cover is based on soil characteristics (i.e., water-holding capacity) and providing an adequate rooting medium for native plants. Silt-loam soils from the Hanford Site can have a total water storage or holding capacity of up to 30 percent vol/vol [PNNL-14143]). The functional water storage capacity of a 75 cm (30 in.) thick monofill ET cover constructed of Hanford silt-loam soil could therefore be as much as an entire average year of precipitation. Functional water storage capacity is determined by the difference in water content between the field capacity and the wilting point of a given soil, times its thickness. Field capacity (or water-holding capacity) is defined as the amount of water held in a soil after excess moisture has drained away by gravity and the soil is no longer draining (soil pore pressures of negative 1/3 bar). Wilting point is defined as the water content when a common agricultural crop can no longer draw water from the soil (pore pressures of negative 15 bars). This is conservative since it has been demonstrated by numerous studies that desert plants, physiologically adapted to arid climates, can extract water from the soil at pore pressures far below that of a common agricultural crop. Sagebrush can extract water from soils at pore pressures below negative 75 bars (PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*), while some desert plants can extract water at soil pore pressures exceeding negative 200 bars.

The average annual precipitation at the Hanford Site is 173 mm (6.81 in.) (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*). Forty percent of the average annual precipitation at the Hanford Site typically falls during winter, when potential ET is slightly less than precipitation, making the amount of functional water storage provided by a cover an important feature. The field capacity of the fine-grained soil available at a borrow site (Area C) located 10 km (6 mi.) west of the NRDWL is 0.229 vol/vol (mean soil properties for Area C soil [PNNL-17134]). The agricultural crop wilting point for that same soil is 0.056 vol/vol. Field capacity (0.229), minus wilting point (0.056), times 75 cm (30 in.) thickness of soil, equals 130 mm [5.1 in.] of functional water storage capacity. Therefore, a 75 cm (30 in.) thick cover of Area C soil will provide a functional water storage capacity of 188 percent of the precipitation that would fall during an average winter. Since the average annual potential ET is 1,270 mm/yr (50 in./yr) (PNNL-6750, *Status of FY 1988 Soil-Water Balance Studies on the Hanford Site*), during all other times of the year potential ET will greatly exceed precipitation, and the ability of a soil to absorb and store water becomes important to plants. As median root depths for the Hanford Site native perennial forbs and grasses are 60 cm (24 in.) and 70 cm (28 in.) (PNNL-17134, Table 5-10), a 75 cm (30 in.) fine-grained soil layer will provide an adequate rooting medium.

C3 Barrier Performance Modeling

Performance modeling using Schroeder et al., 1994, *Hydrologic Evaluation of Landfill Performance (HELP) Model* (HELP) suggests that 75 cm (30 in.) of Hanford silt-loam will reduce leachate generation within the NRDWL to near zero. The HELP computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. Several HELP model simulations of the NRDWL, with slight variations for a final cover, were run for comparison and to identify sensitivities to certain parameters (e.g., soil type, thickness, and plant community).

Because of the uncertainties and spatial variability in water balance model input parameters, models such as HELP generally should be viewed as a means to compare alternatives rather than to predict performance. Recent studies have compared available numerical models and found that cover design depends on site-specific factors (e.g., climate, cover type, available soils), and that no single model is adequate to predict accurately the performance of an ET cover (EPA/542/F-03/015, *Evapotranspiration Landfill Cover Systems Fact Sheet*). Even when calibrated to a specific site, some models tend to under predict, while others over predict cover performance. The HELP model has been the most widely used water balance model for landfill cover design, however, it tends to over-predict drainage at arid sites, which could lead to a conservative design (DRI, 2002). Also, to minimize processor demands and computational time, the HELP model uses daily average weather, quarterly averaged humidity, and other broadly averaged inputs. With these averaged inputs, the HELP model will sometimes predict cover performance in the small fractions of a percent of the precipitation that historically fell at or near the site. Cover performance predicted by the HELP model should be considered a general approximation. The HELP model was used in this report as a preliminary screening tool.

During definitive or final design, a more rigorous analysis, using a model based on the Richards' equation, will be performed. Models that are based on the Richards' equation are considered more physically correct for characterizing water movement through a surface barrier or cover than models like HELP, which are based on enhanced water balance methods (ITRC, 2003, *Technical and Regulatory Guidance for Design, Installation, and Monitoring of Alternative Final Landfill Covers*). A more complex model (e.g., PNNL, 2007, *STOMP Subsurface Transport over Multiple Phases*) will provide enhanced precision and accuracy in predicting future barrier performance.

C3.1 Model Inputs – Weather

The HELP model requires climate data for daily total precipitation, daily average temperature, daily solar radiation, quarterly average humidity, and annual average wind speed. The model contains a limited database of values that allow the model to synthetically generate weather information for 139 cities within the United States should adequate weather data for the specific site not be available. The Hanford Site has kept weather records since 1912, with hourly temperature, dew point, atmospheric pressure, precipitation, relative humidity, solar radiation, and wind speed and direction recorded since July 1946. Daily maximum and minimum temperatures and total precipitation have been recorded since 1912.

The Alternative Landfill Technologies Team the Interstate Technology Regulatory Council (ITRC) and others have suggested that, when comprehensive weather data is available, a conservative but reasonable approach to modeling cover performance is to use the wettest ten year cycle on record (DRI, 2002). A ten-year span will usually include a combination of wet and dry years so that the cycle is not overly conservative. During the years 1989 through 1998, the Hanford Site received 115 percent of normal precipitation. This period included the two wettest years on record (1995 and 1996), the wettest month on record (December 1996), the wettest winter on record (November 1996 through March 1997), the second highest snow accumulation on record (15 in. from January 15 to 20, 1993, which equates to a 50 year frequency accumulation), and a 150-year frequency, 24-hour storm (November 18 to 19, 1996) (PNNL-15160). The monthly total precipitation for the years 1946 through 2007 is provided in Table C-1. The far right column shows the running ten-year average for the years 1958 through 2007, with the highest ten-year average occurring at the end of 1998.

Hourly total precipitation and solar radiation records for the years 1989 through 1998 at the Hanford Site were summed into daily total values, and an input file created for each. Hourly temperatures for the years 1989 through 1998 were averaged for each given day to create the daily average temperature input file. Quarterly relative humidity values were derived from the monthly averages provided in PNNL-15160, Table 6.3, and the annual average wind speed was taken from PNNL-15160, Table 5.1. All model runs use the same climate data.

Table C-1. Summary of Monthly and Annual Precipitation Totals from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten-Year Running Average
1946	--	--	--	--	--	--	0.15	0.35	0.52	0.65	0.66	0.11	--	--
1947	0.32	0.27	0.42	0.7	0.02	1.07	0.71	0.68	**1.34**	2.2	0.81	0.75	9.29	--
1948	1.36	0.69	0.07	0.95	1.71	1.47	0.4	0.39	0.16	0.45	0.95	1.11	9.71	--
1949	0.13	0.68	1.12	0.02	0.16	0.01	0.01	0.03	0.23	0.1	1.47	0.16	4.12	--
1950	1.8	1.06	0.87	0.47	0.27	**2.92**	0.07	T	0.01	2.46	0.55	0.97	11.45	--
1951	0.84	0.51	0.46	0.53	0.43	1.38	0.37	0.15	0.1	0.71	0.82	0.7	7	--
1952	0.65	0.5	0.06	0.13	0.58	1.07	T	0.08	0.08	0.04	0.2	0.77	4.16	--
1953	2.16	0.25	0.17	0.77	0.28	0.55	T	0.96	0.13	0.2	0.96	0.49	6.92	--
1954	1.48	0.28	0.59	0.07	0.41	0.1	0.22	0.42	0.51	0.42	0.86	0.35	5.71	--
1955	0.56	0.22	0.17	0.4	0.59	0.28	0.57	0	0.77	0.4	1.54	2.03	7.53	--
1956	1.71	0.56	0.1	T	0.22	0.86	T	0.38	0.01	1.03	0.15	0.58	5.6	7.149
1957	0.48	0.23	**1.86**	0.38	0.82	0.47	0.05	0.02	0.34	**2.72**	0.39	0.53	8.29	7.049
1958	1.74	1.48	0.46	0.64	0.74	0.81	0.02	T	0.05	0.19	0.77	1.84	8.74	6.952
1959	2.05	1.17	0.4	0.2	0.5	0.23	T	0.03	1.26	0.56	0.41	0.26	7.07	7.247
1960	0.51	0.58	0.67	0.53	0.71	0.14	T	0.26	0.23	0.23	0.92	0.64	5.42	6.644
1961	0.33	**2.1**	1.02	0.48	0.8	0.42	0.15	0.09	T	0.07	0.49	0.89	6.84	6.628
1962	0.13	0.9	0.14	0.34	1.35	0.12	T	0.5	0.38	0.95	0.65	0.6	6.06	6.818
1963	0.95	0.69	0.53	1.17	0.43	0.28	0.31	0.01	0.02	0.04	0.74	1.14	6.31	6.757
1964	0.37	0.01	0.03	0.11	0.04	0.9	0.04	0.24	0.09	0.28	0.94	2.34	5.39	6.725
1965	0.93	0.14	0.03	0.09	0.15	0.49	0.11	0.03	0.11	0.01	1.17	0.39	3.65	6.337
1966	0.68	0.03	0.39	0.03	0.05	0.43	0.81	T	0.27	0.39	2.25	0.6	5.93	6.37
1967	0.32	T	0.14	0.9	0.56	0.57	T	T	0.05	0.13	0.16	0.43	3.26	5.867
1968	0.88	0.58	**0.02**	0.01	0.06	0.19	0.04	0.51	0.25	0.93	1.23	1.25	5.95	5.588
1969	1.24	0.54	0.1	1.22	0.51	0.75	T	T	0.48	0.1	0.13	1.29	6.36	5.517
1970	**2.47**	0.75	0.27	0.45	0.54	0.25	0.01	T	0.03	0.24	0.71	0.61	6.33	5.608
1971	0.78	0.1	1.02	0.07	0.56	0.71	0.13	0.09	1.13	0.18	0.46	1.07	6.3	5.554
1972	0.19	0.27	0.58	0.1	**2.03**	0.66	0.16	0.56	0.02	T	0.55	1.27	6.39	5.587
1973	0.9	0.21	0.08	T	0.24	0.01	T	0.02	0.43	1.72	2.64	2.02	8.27	5.783

Table C-1. Summary of Monthly and Annual Precipitation Totals from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten-Year Running Average
1974	0.9	0.41	0.52	0.46	0.28	0.12	0.71	T	0.01	0.21	0.71	0.97	5.3	5.774
1975	1.43	0.98	0.33	0.42	0.38	0.24	0.32	1.16	0.03	0.87	0.6	0.7	7.46	6.155
1976	0.56	0.36	0.23	0.41	0.08	0.11	0.13	0.96	T	0.04	**T**	**0.11**	**2.99**	5.861
1977	**0.08**	0.57	0.41	T	0.65	0.37	0.06	**1.36**	0.66	0.15	0.63	1.47	6.41	6.176
1978	1.72	0.92	0.3	0.46	0.41	0.09	0.52	0.57	0.11	T	1.21	0.26	6.57	6.238
1979	0.54	0.17	0.54	0.52	0.1	T	0.09	0.38	0.2	0.67	1.36	0.99	5.56	6.158
1980	1.32	1.3	0.3	0.86	1.41	0.96	T	0.02	0.85	0.33	0.44	1.89	9.68	6.493
1981	0.56	0.6	0.7	0.02	0.99	0.43	0.19	0.03	0.6	0.39	1.08	1.45	7.04	6.567
1982	0.33	0.57	0.3	0.75	0.28	0.75	0.22	0.2	0.55	1.33	0.91	1.79	7.98	6.726
1983	1.44	1.36	1	0.42	0.52	0.68	0.31	0.12	0.46	0.52	2.12	2.12	11.07	7.006
1984	0.23	0.94	1.01	0.6	0.55	0.99	0.06	T	0.42	0.07	1.83	0.57	7.27	7.203
1985	0.34	0.82	0.36	0.01	0.12	0.15	0.12	0.01	0.63	0.46	1.24	0.84	5.1	6.967
1986	1.76	1.37	0.76	T	0.3	T	0.21	0.02	0.96	0.29	0.65	0.77	7.09	7.377
1987	0.8	0.19	1.05	0.14	0.17	0.11	0.5	0.07	0.01	**T**	0.4	1.63	5.07	7.243
1988	0.48	**T**	0.39	1.12	0.33	0.11	0.13	**0**	0.39	0.01	0.82	0.4	4.18	7.004
1989	0.21	1.67	1.56	0.84	0.59	0.01	0.01	0.26	0.02	0.42	1.04	0.29	6.92	7.14
1990	0.77	0.09	0.1	0.4	0.86	0.36	0.14	0.83	T	0.78	0.02	0.72	5.07	6.679
1991	0.33	0.19	1.12	0.45	0.49	1.44	0.29	0.07	0	0.53	1.44	0.4	6.75	6.65
1992	0.44	0.94	0.09	0.94	**T**	1.14	0.38	0.2	0.27	0.61	1.07	1.82	7.9	6.642
1993	1.3	1.17	0.67	0.71	0.6	0.12	**1.76**	0.24	0.04	0.09	0.19	0.94	7.83	6.318
1994	0.44	0.11	0.03	0.61	1.27	0.38	0.15	0.08	0.08	0.93	0.68	1.36	6.12	6.203
1995	2.14	0.69	0.95	1.54	0.79	0.77	0.34	0.07	0.79	0.87	1.04	2.32	**12.31**	6.924
1996	1.42	1.22	0.83	0.43	0.62	0.05	0.14	0.02	0.22	0.88	**2.67**	**3.69**	12.19	7.434
1997	1.51	0.25	0.7	0.33	0.33	0.46	0.19	0.06	0.32	0.92	1.01	0.31	6.39	7.566
1998	1.24	1.15	0.5	0.07	0.52	0.48	0.34	0.04	0.1	0.28	1.29	0.44	6.45	7.793
1999	0.89	0.7	0.06	**T**	0.34	0.31	0.07	0.57	**0**	0.48	0.26	0.07	3.75	7.476
2000	1.09	1.12	0.94	0.57	0.77	0.25	0.46	T	0.56	0.57	1.08	0.67	8.08	7.777
2001	0.29	0.42	0.67	0.83	0.08	1.27	0.05	0.08	0.13	0.37	1.67	0.8	6.66	7.768
2002	0.42	0.67	0.19	0.29	0.16	0.65	0.16	0.01	T	0.12	0.38	2.36	5.41	7.519
2003	1.87	0.82	0.26	**2.23**	0.08	**T**	**0**	0.46	0.24	0.07	0.15	1.96	8.14	7.55
2004	2.12	0.92	0.36	0.21	0.89	0.82	0.03	0.95	0.14	0.86	0.29	0.37	7.96	7.734
2005	0.93	0.04	0.31	0.26	0.79	0.06	0.09	0.06	0.66	0.29	0.89	2.01	6.39	7.142
2006	1.18	0.41	0.24	1.3	0.57	1.33	T	T	0.21	0.76	0.71	1.75	8.46	6.769
2007	0.14	0.76	0.74	0.26	0.3	0.45	0.07	0.32	0.57	0.21	1.13	0.53	5.48	6.678
AVERAGE[a]	0.95	0.64	0.5	0.47	0.52	0.52	0.21	0.24	0.3	0.53	0.88	1.04	6.8	NA
NORMAL[b]	0.87	0.68	0.58	0.44	0.55	0.41	0.27	0.27	0.33	0.49	0.98	1.11	6.98	NA

Table C-1. Summary of Monthly and Annual Precipitation Totals from the Hanford Meteorological Station Record

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	Ten-Year Running Average

a. The average is the mean value of the historic record, 1945-2005.

b. By convention, a climatological normal is the average over a 30-year period, in this case the period 1971-2000.

Source: PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*, Table 4.1, with 2005, 2006, and 2007 updates.

The shaded portion is the wettest ten years on record. Values in bold type are greatest and least records for the period.

Measurements are in inches.

– = not available T = trace

NA = not applicable

C3.2 Model inputs – Soil Properties

The HELP model requires input values for cover layer thickness, porosity, field capacity, wilting point, initial soil water content, and effective saturated hydraulic conductivity. The model contains a small database containing the physical properties of a number of default soil types, however, it is preferred to use properties of the soils that are or will be part of the cover.

The most likely source for the fine-grained soil that would be used in constructing the final cover for the SWL will be Area C, which is approximately 9.7 km (6 mi.) west-southwest of the Central Landfill. An extensive study of the soils contained within the southeast portion of Area C was performed recently to support the design of surface barriers or covers for several waste sites within the 200-UW-1 Operable Unit as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* remedial action. A set of best-estimate parameter values for modeling the performance of the Area C soils was developed and documented in PNNL-17134.

During the 1990's, a set of studies were performed on the erosion resistance of a typical silt-loam soil under the Hanford Barrier Program. The mission was to identify components of a long-term (1,000 years) surface barrier design. Several of the studies concluded that to enhance resistance of a bare fine-grained soil to erosion, 10 mm (3/8 in.) pea-gravel should be blended or tilled into the upper 30 cm (12 in.) of the surface (PNL-8478). As a bare soil surface deflates over time, more of the pea-gravel becomes exposed, eventually creating what is termed as a desert pavement, which would be highly resistant to wind and water erosion. These studies also determined that a mixture of 15 percent by weight 10 mm pea-gravel and silt would not inhibit native plant germination or growth. Recent analysis, using agricultural industry standard methods, predict that at a 2 percent slope, the gravel admix would be sufficient to limit erosion to an average of less than 6 mm (1/4 in.) every 100 years (200-UW1-C-001, *Engineered Surface Barrier Design-Soil Losses Due to Water Erosion* and 200-UW1-C-002, *Engineered Surface Barrier Design-Soil Losses Due to Wind Erosion*).

To provide a life expectancy of at least 100 years, the top 15 cm (6 in.) of the final cover (Layer 1) for the NRDWL will consist of Area C silt-loam with 10 mm (3/8 in.) pea-gravel blended/tilled into it at 15 percent by weight. Layer 2 will consist of 60 cm (24 in.) of Area C silt-loam soil. Most of the best-estimate parameters for the silt-loam soil and silt-loam soil gravel admix are found in PNNL-17134, Tables 3.4 and 3.5. Saturated hydraulic conductivity for the mean silt-loam soil and silt-loam admix is taken directly from the tables. The density values (particle density [ρ_s] and dry bulk density [ρ_b]) for the mean soil parameters were used to derive the porosity (ϕ_s) of the soil using the equation:

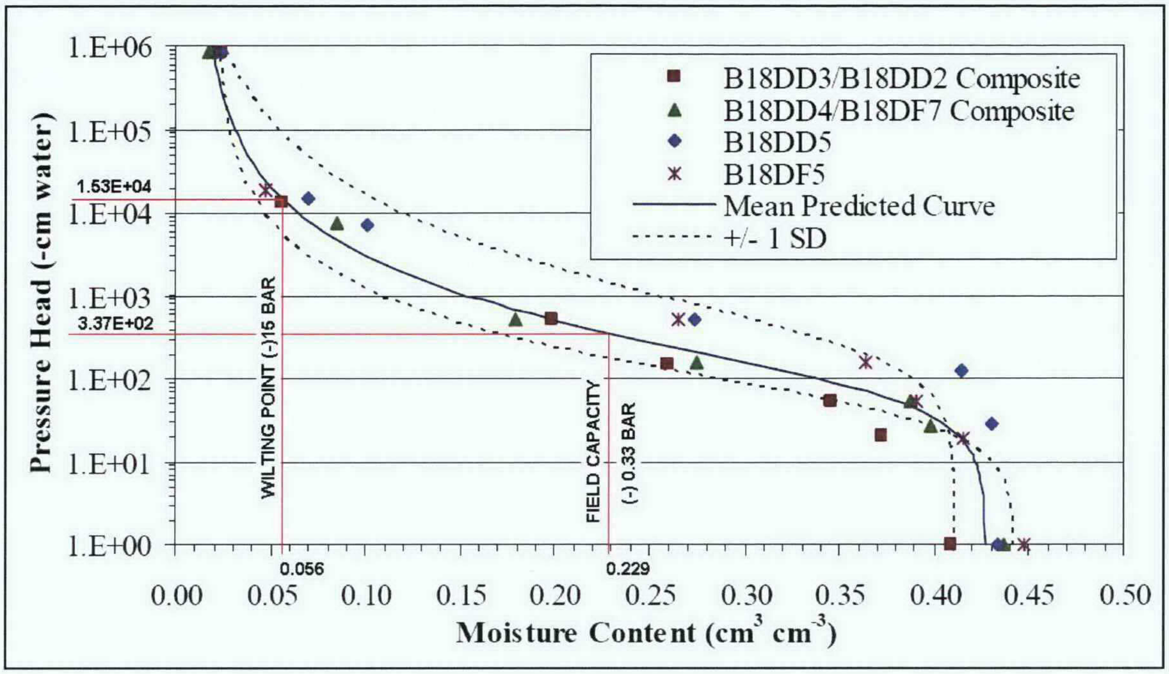
$$\phi_s = 1 - \frac{\rho_b}{\rho_s}$$

All of the values used, including porosity, for the cover soil in all of the model cases were either taken or derived from Area C sample data documented in D&D-25575, *Silt Borrow Source Field Investigation Report*, and expanded on in PNNL-17134.

Field capacity and wilting point for the silt-loam admix and the silt-loam soil were derived by interpolating the pore pressure and moisture content values provided in PNNL-17134, Table B5 for the sample B18DD3/B18DD2 Composite. Pore pressures between field capacity (-3.37×10^2 cm of water [-0.33 BAR]) and wilting point (-1.53×10^4 cm of water [-15 BAR]) for composite blend B18DD3/B18DD2 plot on, or very close to, the "Mean Predicted Curve" shown in PNNL-17134, Figure 3.3. Interpolating from PNNL-17134, Table B5 provided values to three significant figures. Intersects were plotted on the "Mean Predicted Curve" shown on PNNL-17134, Figure 3.3 for pore pressures of -3.37×10^2 cm for field capacity and -1.53×10^4 cm for wilting point to confirm the interpolated results (Figure C-5). This process provided the resultant moisture content parameters of 0.229 vol/vol for field capacity and 0.056 vol/vol for the wilting point for the mean Area C silt-loam. A similar process, using Figure 3.4 of PNNL-17134, was performed to determine the field capacity and wilting point for the silt-loam soil gravel admix (see Figure C-6).

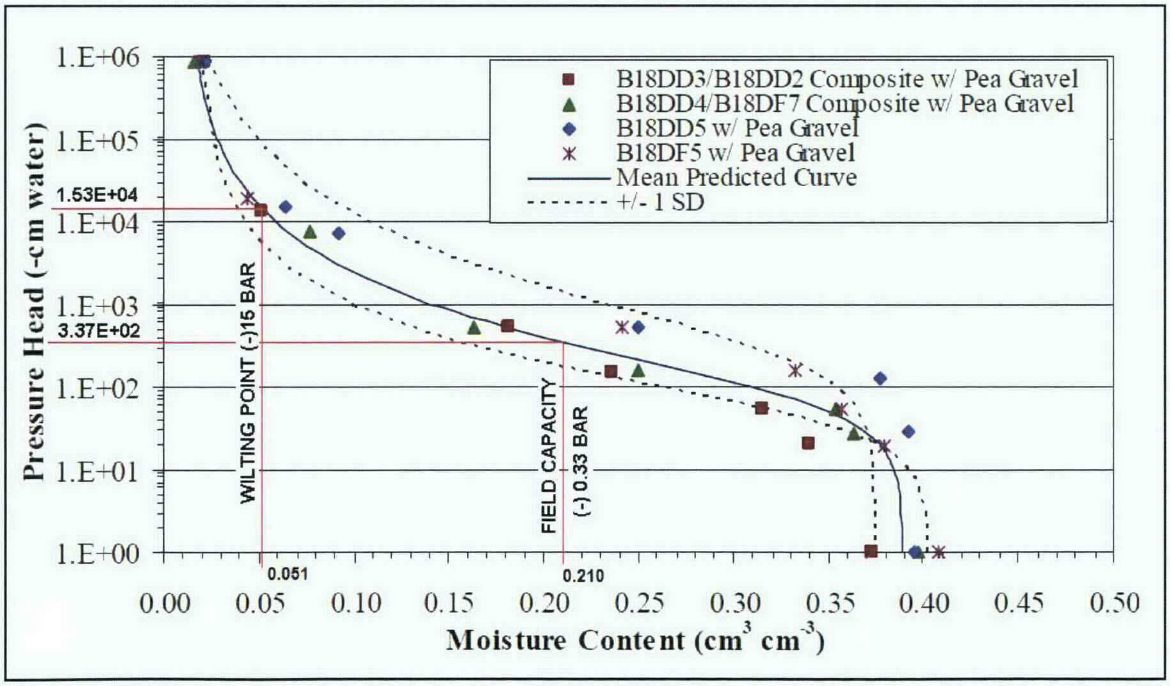
The initial moisture content was developed through an iterative process of repeatedly running the model to identify the water storage at the end of the ten-year period, then entering that value as the initial soil water content until the two sets of values were essentially the same. This equilibrates the model to infinite repeated wettest ten-year weather cycles.

Other than thickness, the properties for the interim soil cover (Layer 3) and the waste layer (Layer 4) were entered by selecting generic materials from the HELP database that best approximate the NRDWL. The NRDWL interim cover is documented to be 1.2 to 3.0 m (4.0 to 10 ft) in thickness and consists mostly of a coarse to fine sand, with gravel. For simplicity, and to address probable re-grading efforts, Layer 3 will be modeled in all simulations as a 1.2 m (4.0 ft) layer of soil having properties best described by HELP as Material Texture Number 3 (a well graded, gravelly sand with few fines, defined by the Unified Soil Classification System as SW). The 3.65 m (12 ft) thick waste layer will be defined as Layer 4, and will be modeled in all simulations as a waste layer having properties best described by HELP as Material Texture Number 18, Municipal Waste.



Source: PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*, Figure 3.3, modified to show field capacity and wilting point.

Figure C-5. Measured and Predicted Water Characteristics and Moisture Content Curve for the Silt-loam Soil at Area C



Source: PNNL-17134, *Geotechnical, Hydrogeologic, and Vegetation Data Package for 200-UW-1 Waste Site Engineered Surface Barrier Design*, Figure 3.4, modified to show field capacity and wilting point.

Figure C-6. Predicted Water Characteristics and Moisture Content Curve for the Area C Silt-loam Soil with Gravel Admix

As a sensitivity analysis on Area C soil properties, several comparative HELP model runs were made using the properties for a blend of some of the more coarse soil samples taken at Area C. Using the same process identified above for determining the properties for the mean Area C soil, properties for the sample blend B18DD3/B18DD2 were input into the model. A soil represented by sample blend B18DD3/B18DD2 will have a slightly lower porosity (0.402 verses 0.409) and a slightly higher saturated hydraulic conductivity (3.96×10^{-5} cm/sec verses 1.53×10^{-5} cm/sec) than the mean for Area C silt-loam soil, but will have very close to the same water storage capacity.

C3.3 Model inputs – General Design and Evaporation Data

The HELP model requires the inputs for Soil Conservation Service (SCS) Runoff Curve Number (RCN), the fraction of the cover that will allow runoff (the portion of the area that is sloped in a manner that would permit drainage off the surface [EPA/600/R-94/168a, *The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3*]), the area of the cover, the Latitude of the site, the maximum leaf area index (LAI), the Julian date for the start of the growing season, the Julian date of the end of the growing season, and the depth of the evaporative zone.

The HELP model has a routine that assists in calculating the SCS RCN. The RCN is a widely used method in determining the approximate amount of runoff from a rainfall or snowmelt event over a particular area, and is based on that area's hydrologic soil group, land use, treatment (e.g., plant community), and hydrologic condition. The HELP model will only calculate the RCN when one of the default soils contained in the HELP database is used as the surface soil. To use the properties for an Area C soil for Layer 1 in the model, an iterative process was employed using the HELP default soils to identify an RCN that would be appropriate for a 147 m (480 ft) long, 2 percent slope consisting of a general Hanford silt-loam type of soil. A conservative value of 75 was selected for the majority of comparative runs with a value of 85 used in a sensitivity analysis. The lower RCN would produce less runoff; therefore, more water would be available to infiltrate the final cover. This correlates well with what has been observed at the Hanford Prototype Barrier (i.e., little runoff).

The HELP model also calculates when the temperature is near or below freezing and holds precipitation at the surface, simulating snow. When the model calculates the temperature has risen above freezing, it releases the stored water, inducing snow melt events to the simulation. A separate routine calculates when the ground could be frozen and, when it is, automatically changes the RCN to 95 for surfaces where the RCN is set to 80 or lower, and 98 when set above 80 (EPA/600/R-94/168b, *The Hydrologic Evaluation Of Landfill Performance (Help) Model: Engineering Documentation For Version 3*). These RCN values are typical for a tight clay soil surface and the model will derive significantly more runoff. This feature cannot be turned off or adjusted by the user, and may result in the over-prediction of runoff. With the exception of one day in one of the sensitivity runs, the only times the model predicted there would be runoff at the NRDWL were during snowmelt events on frozen soil. In actuality, when the surface has not been compacted, and native vegetation is present, runoff very rarely occurs on the Hanford Site.

As the entire surface of the final cover will be sloped a nominal 2 percent towards the landfill perimeter the fraction of landfill cover allowing runoff was set to 100 percent for all model runs, with the exception of a runoff area sensitivity run, in which the variable was set to a conservative 10 percent. The area of the cover will be approximately 4 ha (10 a).

The start and end of the growing season was derived by subjectively (and conservatively) averaging the growth state dates contained in PNNL-17134, Tables 5.15 (Leafy Spurge as a typical perennial forb), 5.16 (Indian Rice Grass), 5.17 (Thickspike Wheatgrass), 5.18 (Needle-and-Thread Grass), 5.19 (Sandberg Bluegrass), 5.21 (Big Sagebrush), and 5.22 (Rabbitbrush). These native species are predominant in the area that surrounds the NRDWL. Leaf growth for the grasses typically starts around day 91 to day 98, earlier for the shrubs and perennial forbs. For conservatism, the start of the growing season was set to day 98. The end of the growing season is based on seed dissemination for the deeper-rooted shrubs, which occurs between day 278 (Rabbitbrush) and day 327 (sagebrush), and plant senescence for the typical deep-rooted forb, which occurs near day 328. Dormancy occurs much earlier for the grasses because of the dry summer and the lack of shallow soil moisture. Day 304 was selected as the end of the growing season as a conservative average for the deeper-rooted plants.

For the maximum leaf area index, a poor stand of grass (LAI=1.0) was conservatively selected as the base case per the guidance given in the HELP users guide (EPA/600/R-94/168a). The HELP model uses a single input parameter labeled "Evaporative Zone Depth" for both rooting (transpiration) depth and active evaporation depth. The depth of the evaporative zone was conservatively set at the bottom of the final cover, even though PNNL-17134, Table 5.11 notes that root depths for a majority of plant species native to the area could extend deeper, with certain species extending as far as 3 m (10 ft) deep.

Additional model runs using an LAI equal to 0 (bare soil) and an LAI of 2.14 were made as part of a sensitivity analysis. The LAI of 2.14 was derived from PNNL-17134, Tables 5.6 and 5.9, for a mature vegetation area at the Hanford Site (the BC Crib area, which is roughly 4.8 km [3 mi.] northwest of the NRDWL). PNNL-17134, Table 5.9, provides the Plant-Area Index for various plant groupings at selected areas at the Hanford Site; Table 5.6 provides empirical relationship equations for estimating leaf-area index from the plant-area index. Inputting the values for plant area index from PNNL-17134, Table 5.9 into the respective equation in Table 5.6 for forbs, grasses, and shrubs, and summing the results provides an LAI=2.14.

C3.4 HELP Model Simulation Results

Simulations were run for the proposed design (or base case) and six sensitivity cases. The sensitivity cases identify the variations that would occur in the results because of a change of a single input variable from that of the proposed design (i.e., the quality of vegetation) (two cases), cover thickness, cover soil properties (i.e., gradation), runoff factors (two cases), and a sensitivity case that looks at the effects of a combination of a coarser soil and increased cover soil thickness.

C3.4.1 Proposed Design (Base Case)

The base case final cover consists of 60 cm (24 in.) of a typical (mean) Area C fine-grained soil plus 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 75 cm (30 in.). The cover has an assumed poor stand of grass (LAI=1.0). The evaporative zone depth is the thickness of the final cover (75 cm [30 in.]).

Model results for the proposed design are provided in output file NRDWL-30.OUT (Section C5.1). Average annual percolation through the landfill is predicted to be 0.18 mm (0.007 in.) of leachate, or approximately 0.09 percent of annual precipitation. Over 94 percent of the annual precipitation will be removed by ET and slightly less than 6 percent removed as runoff. The model predicted runoff would only occur during periods when there was snowmelt on frozen ground and that there would be no runoff in six of the ten years of the wettest ten years on record. The model also predicted that there would be no runoff during a 150-year frequency precipitation event (November 18 to 19, 1996). With a flux of 0.18 mm/yr the proposed design would be expected to achieve performance equal to or better than EPA's prescriptive design for a *Resource Conservation and Recovery Act of 1976* (RCRA) Subtitle C (hazardous/dangerous waste) final cover (EPA/542/F-03/015). In an arid to semi-arid climate, such as at Hanford, a conventional RCRA Subtitle C cover would be expected to produce a flux of 1.5 mm/yr (Albright et al., 2004, "Field Water Balance of Landfill Final Covers").

C3.4.2 Sensitivity Case 1 Bare Soil (No Plants)

Sensitivity case 1 is the same as the base case except with bare soil (LAI=0.0) and slight differences in initial moisture content of each layer due to the iterative process for developing these values. Model results for the bare soil sensitivity case are provided in output file NRDWL-NV.OUT (Section C5.2). Though such a case is highly unlikely (repeated ten year cycles of bare cover), the average annual percolation through the landfill is predicted to be slightly under 16 mm (0.62 in.) of leachate, which is 8 percent of the annual average precipitation that fell during the wettest ten years on record (1989 through 1998), and less than a third of the average annual leachate collected in the SWL lysimeter from 1996 to 2007 under the current interim cover conditions (i.e., coarse sand with sparse vegetation). Runoff was predicted to be slightly more than 6 percent of the annual precipitation, indicating that vegetation with an LAI=1.0 has only a slight impact to the amount of runoff generated. With an increase in percolation of two orders of magnitude over that of the base case, this sensitivity case does indicate the importance of maintaining the cover vegetation.

C3.4.3 Sensitivity Case 2 Increase in Plant Density

Sensitivity case 2 is the same as the base case except with a good stand of shrubs and grass (LAI=2.14) and slight differences in initial moisture content of each layer due to the iterative process for developing these values. Model results are provided in output file AS-GV-30.OUT (Section C5.3). The average annual percolation through the landfill is predicted to be 0.17 mm (0.0066 in.). This is an extremely slight reduction in water flux over that allowed by a poor stand of grass. Coupled with the results of sensitivity case 1 (bare soil), the results indicate that a nominal stand of vegetation would be sufficient for the proposed cover to function optimally. Runoff was predicted to be essentially the same as with the proposed design (5.7 percent of the annual precipitation) indicating that an LAI=2.14 is still too sparse to have a noticeable impact on the amount of runoff generated.

C3.4.4 Sensitivity Case 3 Increase in Cover Thickness

Sensitivity case 3 is the same as the base case except for an additional 25 cm (10 in.) in thickness of cover and slight differences in initial moisture content of each layer due to the iterative process for developing these values. This case consists of 85 cm (34 in.) of a typical (mean) Area C fine-grained soil plus 15 cm (6 in.) of the same fine-grained soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 100 cm (40 in.). Evaporative zone is increased to the thickness of the fine-grained soil. The leaf area index is set to the same as the base case, or an LAI=1.0. Model results are provided in output file NRDWL-40.OUT (Section C5.4). The average annual percolation through the landfill is predicted to be 0.02 mm (0.0008 in.), or less than 0.01 percent of annual precipitation. Runoff and ET values between the base case and this sensitivity case have a variance of less than 0.2 percent. This demonstrates that additional water storage capacity would, as expected, reduce the amount of leachate generated. However, though the numbers indicate that this sensitivity case would result in a flux that is almost an order of magnitude lower than the proposed design; both values are so small that they are essentially zero.

Sensitivity case 3 (increased thickness of cover) was expanded to provide an indication of the optimum thickness for a Monofill Barrier or cover at the NRDWL. A number of simulations were run with Layer 2 varying in thickness from 30 to 90 cm (12 to 36 in.). All other parameters were maintained the same in each simulation, including Layer 1 remaining as 15 cm (6 in.) of modified/blended Area C silt/silt-loam. The evaporative zone was set to 1 m (40 in.) in all simulations based on the typical rooting depth of sagebrush and some of the native bunch grasses (PNNL-17134), and for consistency in approach. All simulations used the mean properties for Area C silt/silt-loam soil for layers 1 and 2, and a leaf area index set at 1.0 (poor grass cover). Simulations were run for total final cover thicknesses (Layers 1 and 2) of 45 cm (18 in.), 60 cm (24 in.), 75 cm (30 in.), 90 cm (36 in.), 100 cm (40 in.), and 106 cm (42 in.). Each simulation was repeated numerous times, reinitializing initial moisture conditions until the initial and final moisture values for all layers became as close to invariant as was possible. The results were used to produce a graph (Figure C-7) that compares the performance of the Monofill Barrier or cover based solely on cover thickness and annual flux, or leachate generation. The graph clearly indicates that the point of diminishing returns for the thickness of the monofill barrier is 75 cm (30 in.) (where additional soil material will not noticeably improve performance).

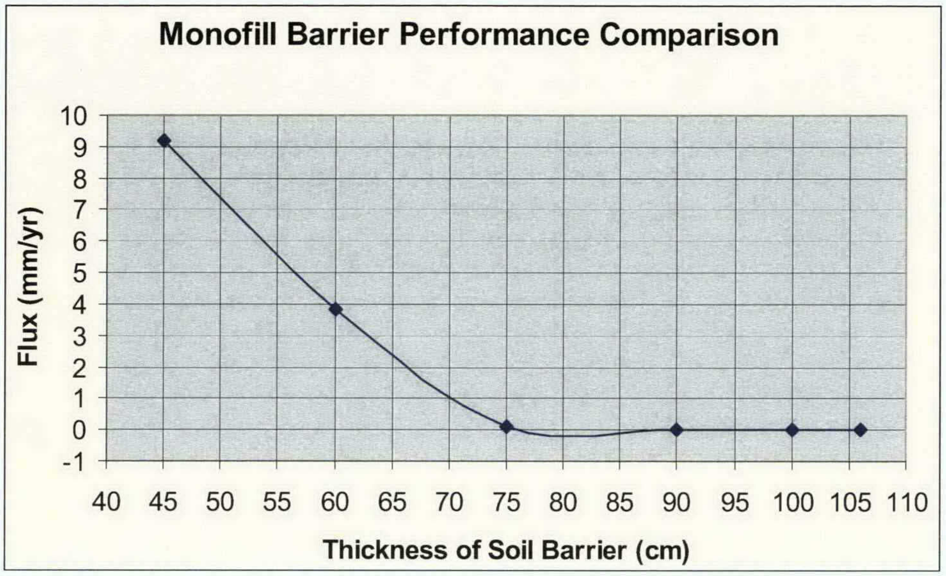


Figure C-7. Monofill Barrier Performance Based on Cover Thickness and Annual Flux

C3.4.5 Sensitivity Case 4 Coarser Soil

Sensitivity case 4 is the same as the base case except for using a coarse blend of Area C soil (sample blend B18DD3/ B18DD2) and slight differences in initial moisture content of each layer due to the iterative process for developing these values. The sample B18DD3/DD2 was a blend of two of the coarsest soil samples taken from the candidate borrow site at Area C, and was selected as a representative upper bounding case for borrow source production. The porosity values noted were verified using the values provided in PNNL-17134, Tables DA3.4 and DA3.5 and found to be correct. This soil has a slightly lower porosity (0.402 verses 0.409) and a slightly higher saturated hydraulic conductivity (3.96×10^{-5} cm/sec verses 1.53×10^{-5} cm/sec) than the mean for Area C silt-loam soil, yet has almost the same water storage capacity (Figure C-5). All other inputs are the same as the proposed design. Model results are provided in output file NCOMP-30.OUT (Section C5.5). The average annual percolation through the landfill is predicted to be 2.0 mm (0.08 in.), or approximately one percent of annual precipitation. The performance of this sensitivity case is more than an order of magnitude higher than that of the base case. This sensitivity case demonstrates the importance in selecting the appropriate barrier soil and establishing adequate construction quality controls. Variations in soil gradation beyond design limits could reduce performance. Even then, this sensitivity case predicts performance of a cover using the coarsest soil blends discovered at Area C would still be basically equivalent to the theoretical performance of EPA's prescriptive design for a RCRA Subtitle C (hazardous/dangerous waste) final cover (EPA/542/F-03/015). In an arid to semi-arid climate, such as at Hanford, a conventional RCRA Subtitle C cover would be expected to produce a flux of 1.5 mm/yr (Albright et al., 2004).

C3.4.6 Sensitivity Case 5 Coarser Soil and Increase in Cover Thickness

Sensitivity Case 5 is the same as the base case except for using a coarse blend of Area C soil (sample blend B18DD3/B18DD2) and an additional 25 cm (10 in.) in thickness of cover and slight differences in initial moisture content of each layer due to the iterative process for developing these values. This case consists of 85 cm (34 in.) of the coarse blend of Area C soil plus 15 cm (6 in.) of the same soil modified with 15 percent by weight pea-gravel as a top soil, for a total thickness of 100 cm (40 in.). Evaporative zone is increased to the thickness of the fine-grained soil. All other inputs are the same as the proposed design. Model results provided in output file NCOMP-40.OUT (Section C5.6). The average annual percolation through the landfill is predicted to be 0.04 mm (0.002 in.), or 0.02 percent of annual precipitation illustrating that added thickness could be used to overcome having to use a coarser soil.

C3.4.7 Sensitivity Case 6 – Higher Runoff Curve Number

Sensitivity Case 6 is the same as the base case except for using an RCN of 85 instead of 75 and slight differences in initial moisture content of each layer due to the iterative process for developing these values. All other input values remained the same, including the amount of surface area that will allow runoff (set to 100 percent). Model results are provided in Section C5.7. As expected, the model calculated the amount of runoff would be greater than when a lower runoff curve number is used. Runoff increased from 5.7 percent to 8.0 percent of the annual precipitation with a corresponding decrease in ET from 94.2 percent for the base case to 92.0 percent. It also predicted almost half the leachate that the base case model predicted when a RCN of 75 is used (0.07 mm/yr [0.003 in./yr] verses 0.18 mm/yr [0.007 in./yr]). With the exception of a single day in the entire ten-year cycle, the model predicted that runoff would only occur during periods where the model also predicted that the soil would be frozen. In all the other cases (i.e., proposed design and sensitivity cases), the model predicted that runoff would only occur when there was snow melt on frozen ground.

C3.4.8 Sensitivity Case 7 – Less Area Allowing Runoff

Sensitivity Case 7 is the same as the base case except for reducing the amount of surface area that will allow runoff from 100 percent to 10 percent and slight differences in initial moisture content of each layer due to the iterative process for developing these values. All other input values remained the same as used in the proposed design model, including using an RCN of 75. Model results are provided in Section C5.8. Even though the potential area contributing to runoff was decreased by 90 percent, the model predicted that runoff would still be over 70 percent of the base case value, or 4.2 percent of annual precipitation. The ET increased to 95.7 percent of annual precipitation from the 94.2 percent predicted in the proposed design model. Flux (leachate generation) increased to 0.25 mm/yr (0.01 in./yr) from the 0.18 mm/yr (0.007 in./yr) predicted for the base case. Even so, flux is still only 0.13 percent of annual precipitation.

C4 Conclusion

During the past couple of decades, there have been numerous studies and evaluations performed on cover system design that have demonstrated the benefits of employing a simple cover system that utilizes fine-grained soils coupled with the natural forces of ET (DOE/RL-93-33; DRI, 2002; EPA/542/F-03/015; ITRC, 2003; LA-UR-06-4715). At arid or semi-arid sites, the use of ET covers for final covers at both dangerous and municipal waste sites is becoming the standard.

Performance modeling, using EPA's HELP model with site-specific weather data and soil information, indicates that a 75 cm (30 in.) thick monofill ET cover, employed as a final cover at the NRDWL (Section C5.7), will severely limit the generation of leachate. The modeling also shows that a 75 cm (30 in.) thick monofill ET cover (consisting of 60 cm [24 in.] of uncompacted, fine-grained, low permeability soil, 15 cm [6 in.] of the same fine-grained soil modified with 15 percent by weight pea-gravel to form an erosion resistant top soil, constructed at a general slope of 2 percent, and planted with native vegetation) will meet the closure requirements of WAC 173-303-610 and WAC 173-303-665(6). A thorough discussion of how the proposed design meets these requirements is provided in Chapter 6.

C5 Model Input/Output Files

This section provides the output file for each of the simulations summarized in Section C3.4.

C5.1 Output File: Proposed Design (Base Case)

Section C3.4.1 summarizes the following output file for the proposed design.

NRDWL-30.OUT

```
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\AS-PV-30.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\NRDWL-30.OUT


TIME:    8:28      DATE:    7/ 6/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (AVE.[Mean] AREA C SILT PROP w/ POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                      =     6.00   INCHES
           POROSITY                       =     0.3750 VOL/VOL
           FIELD CAPACITY                 =     0.2100 VOL/VOL
           WILTING POINT                  =     0.0510 VOL/VOL
           INITIAL SOIL WATER CONTENT     =     0.2107 VOL/VOL
           EFFECTIVE SAT. HYD. COND.      =  0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                                    Page 1
```

NRDWL-30.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4090	VOL/VOL
FIELD CAPACITY	=	0.2290	VOL/VOL
WILTING POINT	=	0.0560	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0737	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.0830	VOL/VOL
WILTING POINT	=	0.0330	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0841	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2917	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.033	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.066	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	49.075	INCHES
TOTAL INITIAL WATER	=	49.075	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

NRDWL-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

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ANNUAL TOTALS FOR YEAR 1989

	MM	CU. METERS	PERCENT
PRECIPITATION	175.77	7113.235	100.00
RUNOFF	17.219	696.829	9.80
EVAPOTRANSPIRATION	164.406	6653.413	93.54
PERC./LEAKAGE THROUGH LAYER 4	0.595025	24.080	0.34
CHANGE IN WATER STORAGE	-6.452	-261.090	-3.67
SOIL WATER AT START OF YEAR	1246.495	50444.945	
SOIL WATER AT END OF YEAR	1240.043	50183.852	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.004	0.00

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Page 3

NRDWL-30.OUT

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ANNUAL TOTALS FOR YEAR 1990

	MM	CU. METERS	PERCENT
PRECIPITATION	128.78	5211.574	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	142.934	5784.462	110.99
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-14.156	-572.887	-10.99
SOIL WATER AT START OF YEAR	1240.043	50183.852	
SOIL WATER AT END OF YEAR	1221.906	49449.852	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	3.981	161.114	3.09
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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ANNUAL TOTALS FOR YEAR 1991

	MM	CU. METERS	PERCENT
PRECIPITATION	171.45	6938.487	100.00
RUNOFF	0.056	2.263	0.03
EVAPOTRANSPIRATION	150.170	6077.296	87.59
PERC./LEAKAGE THROUGH LAYER 4	0.595463	24.098	0.35
CHANGE IN WATER STORAGE	20.629	834.824	12.03
SOIL WATER AT START OF YEAR	1221.906	49449.855	
SOIL WATER AT END OF YEAR	1246.516	50445.793	
SNOW WATER AT START OF YEAR	3.981	161.114	2.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.005	0.00

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NRDWL-30.OUT

ANNUAL TOTALS FOR YEAR 1992

	MM	CU. METERS	PERCENT
PRECIPITATION	200.66	8120.600	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	174.520	7062.715	86.97
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	26.140	1057.882	13.03
SOIL WATER AT START OF YEAR	1246.516	50445.789	
SOIL WATER AT END OF YEAR	1257.072	50872.996	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	15.584	630.677	7.77
ANNUAL WATER BUDGET BALANCE	0.0001	0.003	0.00

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ANNUAL TOTALS FOR YEAR 1993

	MM	CU. METERS	PERCENT
PRECIPITATION	198.88	8048.645	100.00
RUNOFF	15.458	625.575	7.77
EVAPOTRANSPIRATION	228.161	9233.562	114.72
PERC./LEAKAGE THROUGH LAYER 4	0.596142	24.126	0.30
CHANGE IN WATER STORAGE	-45.333	-1834.614	-22.79
SOIL WATER AT START OF YEAR	1257.072	50872.996	
SOIL WATER AT END OF YEAR	1226.505	49635.996	
SNOW WATER AT START OF YEAR	15.584	630.677	7.84
SNOW WATER AT END OF YEAR	0.817	33.062	0.41
ANNUAL WATER BUDGET BALANCE	-0.0001	-0.004	0.00

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NRDWL-30.OUT
ANNUAL TOTALS FOR YEAR 1994

	MM	CU. METERS	PERCENT
PRECIPITATION	155.45	6290.896	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	123.065	4980.369	79.17
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	32.383	1310.524	20.83
SOIL WATER AT START OF YEAR	1226.505	49635.996	
SOIL WATER AT END OF YEAR	1259.705	50979.582	
SNOW WATER AT START OF YEAR	0.817	33.062	0.53
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.004	0.00

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ANNUAL TOTALS FOR YEAR 1995

	MM	CU. METERS	PERCENT
PRECIPITATION	312.67	12653.746	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	278.375	11265.676	89.03
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	34.299	1388.071	10.97
SOIL WATER AT START OF YEAR	1259.705	50979.582	
SOIL WATER AT END OF YEAR	1292.849	52320.871	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.156	46.782	0.37
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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ANNUAL TOTALS FOR YEAR 1996

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NRDWL-30.OUT

	MM	CU. METERS	PERCENT
PRECIPITATION	309.63	12530.396	100.00
RUNOFF	66.864	2705.940	21.60
EVAPOTRANSPIRATION	224.084	9068.563	72.37
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	18.678	755.890	6.03
SOIL WATER AT START OF YEAR	1292.849	52320.867	
SOIL WATER AT END OF YEAR	1305.526	52833.910	
SNOW WATER AT START OF YEAR	1.156	46.782	0.37
SNOW WATER AT END OF YEAR	7.157	289.628	2.31
ANNUAL WATER BUDGET BALANCE	0.0001	0.002	0.00

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ANNUAL TOTALS FOR YEAR 1997

	MM	CU. METERS	PERCENT
PRECIPITATION	162.31	6568.435	100.00
RUNOFF	12.768	516.734	7.87
EVAPOTRANSPIRATION	214.208	8668.859	131.98
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-64.670	-2617.161	-39.84
SOIL WATER AT START OF YEAR	1305.526	52833.910	
SOIL WATER AT END OF YEAR	1248.013	50506.379	
SNOW WATER AT START OF YEAR	7.157	289.628	4.41
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.003	0.00

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ANNUAL TOTALS FOR YEAR 1998

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NRDWL-30.OUT

	MM	CU. METERS	PERCENT
PRECIPITATION	163.83	6630.110	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	165.215	6686.150	100.85
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
CHANGE IN WATER STORAGE	-1.385	-56.038	-0.85
SOIL WATER AT START OF YEAR	1248.013	50506.379	
SOIL WATER AT END OF YEAR	1246.628	50450.340	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.791	2.651	1.183	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.612
STD. DEVIATIONS	3.911	5.453	2.754	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.748
EVAPOTRANSPIRATION						
TOTALS	9.690	10.237	24.053	27.311	20.174	26.405
	35.770	5.236	4.368	5.788	8.864	8.619
STD. DEVIATIONS	4.793	5.817	9.337	17.177	10.732	6.213
	18.349	5.750	4.159	2.481	3.319	1.505
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0595	0.0596	0.0000	0.0000	0.0000	0.0000

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0595
STD. DEVIATIONS	0.1882	0.1885	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1883

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	11.236	(20.8344)	454.73	5.677
EVAPOTRANSPIRATION	186.514	(47.9393)	7548.11	94.226
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.17866	(0.28767)	7.230	0.09026
CHANGE IN WATER STORAGE	0.013	(1.3231)	0.54	0.007

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****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	56.123	2271.2717
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.596142	24.12555
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2250
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0550

****

****

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.2115	0.2107

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NRDWL-30.OUT

2	4.4943	0.0737
3	10.2488	0.0841
4	106.7082	0.2917
SNOW WATER	0.000	

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C5.2 Output File: Sensitivity Case 1

Section C3.4.2 summarizes the following output file for the sensitivity case 1.

```
                              NRDWL-NV.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HNV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\AS-NV-30.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\NRDWL-NV.OUT


TIME:    8:53      DATE:    7/ 6/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (AVE.[Mean] AREA C SILT PROP w/ NO VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3750 VOL/VOL
            FIELD CAPACITY             =      0.2100 VOL/VOL
            WILTING POINT              =      0.0510 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2287 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                                   Page 1
```

NRDWL-NV.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4090	VOL/VOL
FIELD CAPACITY	=	0.2290	VOL/VOL
WILTING POINT	=	0.0560	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1792	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.0830	VOL/VOL
WILTING POINT	=	0.0330	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1117	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2912	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.672	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.064	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	52.967	INCHES
TOTAL INITIAL WATER	=	52.967	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

NRDWL-NV.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	2.383	2.772	1.756	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.676
STD. DEVIATIONS	5.043	5.521	4.207	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.904
EVAPOTRANSPIRATION						
TOTALS	14.436	13.648	28.325	21.021	15.130	12.581
	11.865	8.779	7.242	9.426	13.406	13.623
STD. DEVIATIONS	8.618	12.505	17.730	13.654	8.851	9.359

Page 3

	10.329	3.077	2.182	8.088	7.557	5.623

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.8860	1.0060	0.8273	2.1713	1.9153	1.4352
	1.9157	1.2290	1.4901	1.1261	0.8246	1.0672
STD. DEVIATIONS	1.1801	0.7805	1.1112	3.9962	4.6214	2.1376
	3.0130	1.7469	2.1181	1.1306	1.0403	0.8696

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	12.587	(21.5383)	509.41	6.359
EVAPOTRANSPIRATION	169.482	(42.5210)	6858.83	85.622
PERCOLATION/LEAKAGE THROUGH LAYER 4	15.89388	(21.51371)	643.216	8.02955
CHANGE IN WATER STORAGE	-0.021	(1.6180)	-0.84	-0.010

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	56.632	2291.8713
PERCOLATION/LEAKAGE THROUGH LAYER 4	1.254587	50.77244
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3223	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1352	

****

****

NRDWL-NV.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.4859	0.2287
2	10.9215	0.1792
3	13.6198	0.1117
4	106.4892	0.2911
SNOW WATER	0.000	

****
****

C5.3 Output File: Sensitivity Case 2

Section C3.4.3 summarizes the following output file for the sensitivity case 2.

```
                                 AS-GV-30.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:       C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\NRDWL\HGV-ET30.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\NRDWL\AS-GV-30.D10
OUTPUT DATA FILE:            C:\HELP3\NRDWL\AS-GV-30.OUT


TIME:    8:58      DATE:    7/ 6/2009


******************************************************************************

    TITLE:  30-INCH SOIL COVER (AVE.[Mean] AREA C SILT PROP w/ GOOD VEG)

******************************************************************************


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                                LAYER  1
                                --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00    INCHES
          POROSITY                   =      0.3750 VOL/VOL
          FIELD CAPACITY             =      0.2100 VOL/VOL
          WILTING POINT              =      0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2079 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =   0.130999997000E-04 CM/SEC


                                LAYER  2
                                --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                                 Page 1
```

AS-GV-30.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4090 VOL/VOL
FIELD CAPACITY	=	0.2290 VOL/VOL
WILTING POINT	=	0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0717 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.0830 VOL/VOL
WILTING POINT	=	0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0837 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2902 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.968	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.064	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	48.775	INCHES
TOTAL INITIAL WATER	=	48.775	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

AS-GV-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.14
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.811	2.642	1.179	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.612
STD. DEVIATIONS	3.920	5.444	2.765	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.745
EVAPOTRANSPIRATION						
TOTALS	8.412	8.297	21.375	29.230	32.340	45.755
	10.289	4.724	4.518	5.773	8.050	7.747
STD. DEVIATIONS	3.766	4.737	10.446	15.992	12.374	18.019

Page 3

AS-GV-30.OUT

12.844	4.853	5.441	2.346	3.159	1.332

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0571	0.0000	0.0000	0.0000	0.0572	0.0000
	0.0000	0.0571	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1805	0.0000	0.0000	0.0000	0.1808	0.0000
	0.0000	0.1806	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	11.243	(20.8017)	454.99	5.680
EVAPOTRANSPIRATION	186.511	(49.0033)	7547.98	94.225
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.17135	(0.27590)	6.934	0.08656
CHANGE IN WATER STORAGE	0.017	(1.2779)	0.70	0.009

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	56.115	2270.9478
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.571609	23.13269
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2231
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0550

AS-GV-30.OUT

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.1681	0.2079
2	4.3751	0.0718
3	10.2006	0.0837
4	106.1610	0.2902
SNOW WATER	0.000	

****
****

C5.4 Output File: Sensitivity Case 3

Section C3.4.4 summarizes the following output file for the sensitivity case 3.

```
                              NRDWL-40.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET40.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\AS-PV-40.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\NRDWL-40.OUT


TIME:   9: 9     DATE:   7/ 6/2009


******************************************************************************

     TITLE:  40-INCH SOIL COVER (AVE.[mean] AREA C SILT PROP W/ POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3750 VOL/VOL
            FIELD CAPACITY             =      0.2100 VOL/VOL
            WILTING POINT              =      0.0510 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2232 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                                  Page 1
```

NRDWL-40.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	34.00 INCHES
POROSITY	=	0.4090 VOL/VOL
FIELD CAPACITY	=	0.2290 VOL/VOL
WILTING POINT	=	0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0673 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.0830 VOL/VOL
WILTING POINT	=	0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0643 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1638 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	40.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.627	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	16.156	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.210	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	30.301	INCHES
TOTAL INITIAL WATER	=	30.301	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

NRDWL-40.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	101.6 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.431	3.637	0.822	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	5.592
STD. DEVIATIONS	3.161	7.466	2.046	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	17.683
EVAPOTRANSPIRATION						
TOTALS	7.771	7.064	17.498	28.629	23.448	25.897
	44.446	7.012	4.620	5.989	7.235	6.831
STD. DEVIATIONS	2.547	3.135	9.152	14.833	11.762	5.328

NRDWL-40.OUT

	17.300	5.564	4.416	2.348	2.858	2.412

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0033	0.0004	0.0013	0.0029	0.0017	0.0004
	0.0029	0.0021	0.0004	0.0033	0.0008	0.0008
STD. DEVIATIONS	0.0018	0.0013	0.0020	0.0020	0.0022	0.0013
	0.0020	0.0022	0.0013	0.0018	0.0018	0.0018

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	11.482	(23.6136)	464.67	5.801
EVAPOTRANSPIRATION	186.441	(48.0410)	7545.16	94.189
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.02048	(0.00725)	0.829	0.01035
CHANGE IN WATER STORAGE	-0.001	(1.2796)	-0.05	-0.001

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	55.918	2262.9683
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.004195	0.16978
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.1898	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0552	

****

****

Page 4

NRDWL-40.OUT

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.4021	0.2232
2	5.8112	0.0673
3	7.8393	0.0643
4	59.9108	0.1638
SNOW WATER	0.000	

C5.5 Output File: Sensitivity Case 4

Section C3.4.5 summarizes the following output file for the sensitivity case 4.

```
                                   NCOMP-30.OUT

******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\COMP-30.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\NCOMP-30.OUT


TIME:    9:14      DATE:    7/ 6/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (Area C Composite Blend D3/D2 - POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3630 VOL/VOL
          FIELD CAPACITY             =      0.2100 VOL/VOL
          WILTING POINT              =      0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.1937 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.341000014000E-04 CM/SEC


                                  LAYER  2
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                                    Page 1
```

```
                          NCOMP-30.OUT
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                          =      24.00    INCHES
POROSITY                           =       0.4020 VOL/VOL
FIELD CAPACITY                     =       0.2290 VOL/VOL
WILTING POINT                      =       0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT         =       0.0799 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.395999996000E-04 CM/SEC


                          LAYER  3
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   3
THICKNESS                          =      48.00    INCHES
POROSITY                           =       0.4570 VOL/VOL
FIELD CAPACITY                     =       0.0830 VOL/VOL
WILTING POINT                      =       0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT         =       0.1046 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.310000009000E-02 CM/SEC


                          LAYER  4
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  18
THICKNESS                          =     144.00    INCHES
POROSITY                           =       0.6710 VOL/VOL
FIELD CAPACITY                     =       0.2920 VOL/VOL
WILTING POINT                      =       0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT         =       0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.100000005000E-02 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER              =     75.00
FRACTION OF AREA ALLOWING RUNOFF     =    100.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =     10.000   ACRES
EVAPORATIVE ZONE DEPTH               =     30.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      3.080   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     11.826   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.650   INCHES
INITIAL SNOW WATER                   =      0.000   INCHES
INITIAL WATER IN LAYER MATERIALS     =     50.149   INCHES
TOTAL INITIAL WATER                  =     50.149   INCHES
TOTAL SUBSURFACE INFLOW              =      0.00    INCHES/YEAR


          EVAPOTRANSPIRATION AND WEATHER DATA
                        Page 2
```

NCOMP-30.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	2.047	1.317	1.241	0.000	0.012	0.016
	0.000	0.000	0.000	0.011	0.006	3.992
STD. DEVIATIONS	4.682	2.489	2.772	0.000	0.038	0.051
	0.000	0.000	0.000	0.036	0.019	12.604
EVAPOTRANSPIRATION						
TOTALS	10.550	11.289	25.111	24.855	17.748	26.627
	36.878	4.021	4.278	6.423	9.691	9.840
STD. DEVIATIONS	5.694	7.199	13.144	16.696	9.096	6.719

Page 3

	16.345	2.772	4.027	4.487	3.993	2.324

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1215	0.3035	0.1214	0.0607	0.2427	0.1215
	0.3643	0.0000	0.0606	0.3036	0.1215	0.1821
STD. DEVIATIONS	0.2562	0.3199	0.2560	0.1919	0.3133	0.2562
	0.3135	0.0000	0.1918	0.3200	0.2561	0.2932

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	8.642	(15.4752)	349.74	4.366
EVAPOTRANSPIRATION	187.312	(49.4770)	7580.39	94.629
PERCOLATION/LEAKAGE THROUGH LAYER 4	2.00342	(0.90679)	81.077	1.01212
CHANGE IN WATER STORAGE	-0.015	(1.4453)	-0.60	-0.007

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	39.864	1613.2582
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.608010	24.60582
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2423	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

****

NCOMP-30.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	2.9513	0.1937
2	4.8717	0.0799
3	12.7500	0.1046
4	106.7896	0.2920
SNOW WATER	0.000	

****
****

C5.6 Output File: Sensitivity Case 5

Section C3.4.6 summarizes the following output file for the sensitivity case 5.

```
                                  NCOMP-40.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET40.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\COMP-40.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\NCOMP-40.OUT


TIME:    9:38      DATE:    7/ 6/2009


******************************************************************************

     TITLE:  40-INCH SOIL COVER (Area C Composite Blend D3/D2 - POOR VEG)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3630 VOL/VOL
            FIELD CAPACITY             =      0.2100 VOL/VOL
            WILTING POINT              =      0.0510 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.1896 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   0.341000014000E-04 CM/SEC


                                  LAYER  2
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                                     Page 1
```

NCOMP-40.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	34.00	INCHES
POROSITY	=	0.4020	VOL/VOL
FIELD CAPACITY	=	0.2290	VOL/VOL
WILTING POINT	=	0.0560	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0657	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.395999996000E-04	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.0830	VOL/VOL
WILTING POINT	=	0.0330	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0804	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2801	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	40.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.371	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	15.846	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.210	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	47.565	INCHES
TOTAL INITIAL WATER	=	47.565	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

NCOMP-40.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	101.6 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	1.564	1.090	0.805	0.000	0.000	0.008
	0.000	0.000	0.000	0.000	0.000	3.925
STD. DEVIATIONS	3.628	2.241	1.930	0.000	0.000	0.024
	0.000	0.000	0.000	0.000	0.000	12.413
EVAPOTRANSPIRATION						
TOTALS	13.357	12.652	25.393	28.219	21.698	23.514
	25.847	7.732	3.601	6.218	11.862	10.430
STD. DEVIATIONS	6.185	7.233	12.074	16.132	13.750	7.405

NCOMP-40.OUT

	24.774	7.754	3.943	3.870	4.010	3.145

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0428	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1352	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	7.392	(14.7916)	299.16	3.735
EVAPOTRANSPIRATION	190.523	(49.1611)	7710.38	96.252
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.04277	(0.13525)	1.731	0.02161
CHANGE IN WATER STORAGE	-0.016	(1.5582)	-0.65	-0.008

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	39.255	1588.6217
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.427682	17.30807
SNOW WATER	49.93	2020.6846

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.1989
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0552

****

****

NCOMP-40.OUT
FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	2.8893	0.1896
2	5.6725	0.0657
3	9.8053	0.0804
4	102.4318	0.2801
SNOW WATER	0.000	

****
****

C5.7 Output File: Sensitivity Case 6

Section C3.4.7 summarizes the following output file for the sensitivity case 6.

```
                              30PVRC85.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\30PVRC85.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\30PVRC85.OUT


TIME:    9:49      DATE:    7/ 6/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER, M.AREA C SILT, P.VEG, 100% RUNOFF SCS 85

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      6.00    INCHES
          POROSITY                     =      0.3750  VOL/VOL
          FIELD CAPACITY               =      0.2100  VOL/VOL
          WILTING POINT                =      0.0510  VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2092  VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.130999997000E-04 CM/SEC


                                  LAYER  2
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                                    Page 1
```

30PVRC85.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4090	VOL/VOL
FIELD CAPACITY	=	0.2290	VOL/VOL
WILTING POINT	=	0.0560	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0727	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.0830	VOL/VOL
WILTING POINT	=	0.0330	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0796	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2754	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	85.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.000	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.066	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	46.478	INCHES
TOTAL INITIAL WATER	=	46.478	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

30PVRC85.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	4.126	3.430	2.707	0.000	0.000	0.000
	0.001	0.000	0.000	0.000	0.000	5.508
STD. DEVIATIONS	8.359	6.570	5.194	0.000	0.000	0.000
	0.002	0.000	0.000	0.000	0.000	16.479
EVAPOTRANSPIRATION						
TOTALS	9.575	10.348	23.190	27.266	20.283	26.285
	31.955	5.488	4.390	5.881	8.986	8.464
STD. DEVIATIONS	4.510	6.052	8.623	16.762	10.794	6.304

30PVRC85.OUT

15.402	6.539	4.165	2.488	3.279	1.290

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0372	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0372
STD. DEVIATIONS	0.1177	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1178

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	15.771	(24.1662)	638.23	7.967
EVAPOTRANSPIRATION	182.111	(45.2530)	7369.94	92.002
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.07445	(0.15696)	3.013	0.03761
CHANGE IN WATER STORAGE	-0.014	(1.3608)	-0.57	-0.007

****

****

PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	52.346	2118.4270
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.372373	15.06972
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2123	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

****

****

Page 4

30PVRC85.OUT

FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.1885	0.2092
2	4.4320	0.0727
3	9.7059	0.0796
4	100.7145	0.2754
SNOW WATER	0.000	

****
****

Page 5

C5.8 Output File: Sensitivity Case 7

Section C3.4.8 summarizes the following output file for the sensitivity case 7.

```
                              30ASPV10.OUT
□
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\NRDWL\HANFORDP.D4
TEMPERATURE DATA FILE:        C:\HELP3\NRDWL\HANFORDT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\NRDWL\DATA13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\NRDWL\HPV-ET30.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\NRDWL\30ASPV10.D10
OUTPUT DATA FILE:             C:\HELP3\NRDWL\30ASPV10.OUT


TIME:    9:54       DATE:    7/ 6/2009


******************************************************************************

     TITLE:  30-INCH SOIL COVER (Mean AREA C SILT, POOR VEG, 10% RUNOFF)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3750 VOL/VOL
          FIELD CAPACITY             =      0.2100 VOL/VOL
          WILTING POINT              =      0.0510 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2105 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.130999997000E-04 CM/SEC


                              LAYER  2
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                                Page 1
```

30ASPV10.OUT

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4090 VOL/VOL
FIELD CAPACITY	=	0.2290 VOL/VOL
WILTING POINT	=	0.0560 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0736 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.153000001000E-04 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4570 VOL/VOL
FIELD CAPACITY	=	0.0830 VOL/VOL
WILTING POINT	=	0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0841 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.310000009000E-02 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 18

THICKNESS	=	144.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2852 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	75.00	
FRACTION OF AREA ALLOWING RUNOFF	=	10.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	10.000	ACRES
EVAPORATIVE ZONE DEPTH	=	30.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.029	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.066	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.650	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	48.135	INCHES
TOTAL INITIAL WATER	=	48.135	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

Page 2

30ASPV10.OUT

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HANFORD CP WASHINGTON

STATION LATITUDE	=	46.51 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	98
END OF GROWING SEASON (JULIAN DATE)	=	304
EVAPORATIVE ZONE DEPTH	=	76.2 CM
AVERAGE ANNUAL WIND SPEED	=	12.16 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	43.30 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	37.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA FOR Hanford CP Washington
WAS ENTERED BY THE USER.

NOTE: SOLAR RADIATION DATA FOR Hanford CP Washington

WAS ENTERED BY THE USER.

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1989 THROUGH 1998

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	24.89	19.00	16.64	16.05	15.42	13.23
	9.50	4.75	4.67	16.03	26.54	31.22
STD. DEVIATIONS	16.14	14.30	12.55	10.38	8.48	11.93
	12.72	6.14	6.15	7.50	18.50	28.07
RUNOFF						
TOTALS	4.438	2.215	0.683	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.955
STD. DEVIATIONS	12.353	4.338	2.069	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	3.019
EVAPOTRANSPIRATION						
TOTALS	11.102	11.707	24.466	27.267	20.231	26.421
	34.961	5.585	4.373	5.812	8.878	8.590
STD. DEVIATIONS	4.747	5.744	9.154	17.013	10.719	6.221

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	17.943	5.616	4.170	2.478	3.299	1.444

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0495	0.0000	0.0496	0.0000	0.0000	0.0497
	0.0000	0.0496	0.0496	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.1566	0.0000	0.1570	0.0000	0.0000	0.1571
	0.0000	0.1568	0.1568	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1989 THROUGH 1998

	MM		CU. METERS	PERCENT
PRECIPITATION	197.94	(63.124)	8010.6	100.00
RUNOFF	8.290	(13.5152)	335.50	4.188
EVAPOTRANSPIRATION	189.395	(49.4326)	7664.73	95.682
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.24798	(0.26139)	10.036	0.12528
CHANGE IN WATER STORAGE	0.009	(1.9458)	0.35	0.004

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PEAK DAILY VALUES FOR YEARS 1989 THROUGH 1998

	(MM)	(CU. METERS)
PRECIPITATION	35.31	1428.814
RUNOFF	9.545	386.2992
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.496654	20.09930
SNOW WATER	49.93	2020.6846
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2289	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0550	

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FINAL WATER STORAGE AT END OF YEAR 1998

LAYER	(CM)	(VOL/VOL)
1	3.2082	0.2105
2	4.4856	0.0736
3	10.2530	0.0841
4	104.3246	0.2852
SNOW WATER	0.000	

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