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Attachment B	Well Boring Logs
Attachment C	Vadose Zone Monitoring Report
Attachment D	Dose Analysis

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Attachment E	Facility Closure Cap Design Drawings
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EXECUTIVE SUMMARY

This "Site Stabilization and Closure Plan" (Closure Plan) describes the means to assure that the Low-Level Radioactive Waste Disposal Facility (Facility) operated by US Ecology is closed in accordance with Washington State (State) and U.S. Nuclear Regulatory Commission (NRC) requirements. The Closure Plan meets the regulatory requirements specifically contained in WN-I019 (License) Condition 66, and uses the best presently available technology.

This Closure Plan facilitates long-term planning and demonstrates facility performance, and is consistent with and complimentary to ongoing site operations. The Plan incorporates current technology to achieve final site closure. After approval by the Washington Department of Health (WDOH), it will be reviewed periodically and amended as required. This review process will ensure that facility design and operations remain consistent with long-term performance requirements and are current with prevailing technology and site information. The review process also provides for periodic assessment of the adequacy of available closure and perpetual maintenance funds.

The objectives of the Closure Plan are to provide a sound and realistic plan to close the facility, to demonstrate that the closed facility will meet the dose limits contained in WAC-246-250-170, and to develop realistic estimates of time, materials, and costs associated with closure and future site monitoring.

This Closure Plan makes certain assumptions concerning institutional controls and site and Facility characteristics. These assumptions include commonly accepted regulatory concepts from 10 CFR Part 61, as well as site specific physical, geologic, and climatologic characteristics.

Consistent with these assumptions, the Plan establishes design goals necessary to meet closure objectives. These include limiting infiltration, constructing the cover from natural non-degrading materials, maximizing use of vegetation and flat slopes to control erosion, and emphasizing both compliance and performance monitoring.

The key component of the Closure Plan is a continuous, multilayer, multifunctional cover over the disposal unit. The final cover will be the primary barrier between the disposed waste and the surrounding environment, and will replace the 6-inch cobble interim covers presently in place over closed trenches. The final cover will isolate the wastes, will provide the required erosion protection and intruder barrier, will limit infiltration into the trenches, and will limit gaseous emissions to the atmosphere. The multilayer cover will have a minimum total thickness of 16.4 feet (5 meters). Cover components contribute individually and collectively to achieve Facility performance objectives.

The plan proposes immediate final closure of several older trenches. This will demonstrate the adequacy of the proposed cover design, while the remainder of the site continues to operate. This closure will be performed with the placement of the partial cap, and will be integrated into the overall, final cap at cessation of operations in 2056. US Ecology will

monitor physical and radiological parameters of the partial cap to verify performance and assess the need for design modifications. A performance monitoring access tunnel will facilitate these studies.

The constructed disposal unit cover will be higher than the surrounding ground surface to prevent the flow of water onto the disposal cover. The cover surface will be sloped to both encourage surface-water runoff and limit the erosive force of precipitation. Cover interfaces with natural terrain will be protected from raveling by vegetation.

The Closure Plan provides an environmental monitoring program to confirm that waste materials which were disposed of during the operational phase of the Facility remain in a stable and safe condition. The primary objective of the monitoring program is to assure that the Facility meets pertinent requirements for the protection of the public and the environment throughout the operating and post closure life of the Facility.

The monitoring program includes compliance monitoring of groundwater, air, vegetation and soil pathways as well as direct radiation. The program also will include performance monitoring of the vadose zone disposal units and observation of the physical condition of the cap and vegetation.

Ongoing operations must lend themselves to proper closure of the facility. During the continuing operation period, US Ecology will maintain records conducive to orderly transfer according to current procedures. US Ecology will continue to maintain accurate and detailed site surveys and documentation thereof. The Closure Plan addresses how specific closure requirements contained in the License are met during ongoing operations and eventual closure.

The dose analysis included in the Closure Plan demonstrates that the Facility will meet the requirements in License Condition 66 and all applicable State and Federal regulations. Analyses focus on direct exposure and groundwater transport as bounding pathways. Other pathway scenarios did not yield measurable exposures to hypothetical individuals from the disposal waste. Even with the conservative assumptions incorporated into the model, the results of dose calculations for a hypothetical individual indicate that, with the infiltration limiting cover, the maximum calculated dose is 1.16 millirem/year to the thyroid and 0.73 millirem/year to the lower intestine. These doses, well within prescribed regulatory limits, are projected thousands of years in the future.

The Closure Plan presents cost estimates for three closure scenarios. The first scenario projects a cost of $23 million to construct a partial cap over Trenches 1 through 6 and the Chemical Trench beginning in 1996 and a cap over the remainder of the site at scheduled closure in 2056. The second scenario estimates a cost of $24 million for an unscheduled closure of the entire site in December 1996. The final scenario identifies a cost of $16 million for closure of the entire site in 2056. Currently, there is approximately $23 million in the Site Closure Account and $23 million in the Perpetual Care and Maintenance Account. These balances, along with accrued interest on unexpended funds, assure adequate funds are available for all three closure scenarios.

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1. INTRODUCTION

This document is the plan for the stabilization and closure of the Richland, Washington Low-Level Radioactive Waste (LLRW) Disposal Facility. This plan describes the specific natural site features, engineered facility closure components, and the modeling and analyses that demonstrate that the closed facility will meet the requirements of the Washington State Radioactive Materials License No. WN-I019-2 (Amendment No. 20), and the U.S. Nuclear Regulatory Commission (NRC) Special Nuclear Materials (SNM) License No. 16-19204-01 (Amendment No. 11). Since the site is dually licensed, references to Federal waste disposal regulations in applicable parts of 10 CFR are assumed to also reference equivalent state regulations codified in Washington Administrative Code (WAC) 246-249 and 250.

This Closure Plan is comprised of seven principal sections and fifteen supporting attachments. The principal sections include (1) Introduction, (2) Facility Characteristics, (3) Closure Plan, (4) Condition 66 Performance Criteria, (5) Dose Analysis, (6) Facility Closure, Stabilization and Perpetual Care and Maintenance Costs , and (7) References.

Section 1 describes the design goals of the Closure Plan and summarizes the site and Facility characteristics, the proposed closure design and the performance assessment.

Section 2 describes the Facility characteristics and the surrounding environment. Facility and environmental data are presented and summarized in this section. Supporting information is provided either by reference or through attachments.

Section 3 outlines the conceptual Facility Closure Plan. The conceptual plan is presented in sufficient detail to assess the future performance of the closed facility and to make reliable estimates of closure costs. The plan includes closure of a portion of the Facility within the next year, a program to monitor and maintain this part of the facility during the remainder of the Facility operating period, and a plan for closing the remainder of the disposal Facility.

Section 4 discusses each of the 16 performance objectives contained in Condition 66 of US Ecology's State of Washington Radioactive Materials License and referenced by Condition 37 of the NRC SNM License. Condition 66 contains the regulatory criteria the Closure Plan must meet. The discussions in Section 4 summarize the specific features of the Closure Plan that address the individual requirements, and reference the locations in this Plan where compliance with each requirement is demonstrated.

Section 5 presents the facility's dose analysis, including the pathways and scenarios. This section describes the physical system being analyzed, the conceptualization of the scenario models, the mathematical representation of these models, and the conclusions of the calculations.

Section 6 outlines projected costs for closure, stabilization, and perpetual care and maintenance of the LLRW Disposal Facility, including: early closure of a portion of the Facility on December 31, 1996, and scheduled closure in September 2056, herein referred to as closure in 2056. Stabilization is scheduled to be completed by September 2063.

Section 7 contains a list of the references used in the development of this Closure Plan.

1.1 OBJECTIVES OF THE CLOSURE PLAN

A Closure Plan has been developed to facilitate long-term planning and demonstrate facility performance at the Richland facility. The plan is based on utilizing current technology. After initial approval by the Washington Department of Health (WDOH), it will be reviewed every five years for possible plan revisions or amendment in accordance with license requirements. This review process will ensure that facility design and operation remain consistent with long-term performance requirements. It will incorporate additional information that may be obtained during installation of new wells, excavation of new trenches and particularly, the construction and monitoring of the final cap over Trenches 1 through 6 (Trenches 1-6) and the Chemical Trench. It will also provide an opportunity for periodic assessment of the adequacy of funds dedicated to closure and long-term monitoring of the facility. WDOH will continue to review the financial status of the Closure funds annually.

Specifically, the objectives of this Closure Plan are:

- to provide a sound and realistic plan to close the facility utilizing presently available technology,
- to develop estimates of closure and post-closure costs based upon the proposed Closure Plan, and
- to demonstrate that the closed facility will meet the dose limits contained in WAC-246-250-170.

In addition to meeting these general criteria, the proposed plan recommends immediate final closure and capping of a portion of the facility. The first phase of the final cap (referred to herein as the partial cap) is to be constructed over Trenches 1-6, and the Chemical Trench. The partial cap will further minimize the potential for releases to the environment from wastes buried in these trenches. Monitoring and assessment of the closed and capped area will aid in evaluating the effectiveness of the entire Closure Plan and will allow actual physical performance data to be incorporated in the closure of the remainder of the facility.

1.2 REGULATIONS, REQUIREMENTS, AND GUIDANCE

The proposed Closure Plan meets all the regulatory requirements that are applicable to this Facility. The design features included and the performance criteria met are based on sound engineering design principles and regulatory guidance. The regulatory guidance and requirements are described in Sections 1.2.1, 1.2.2, and 1.2.3.

1.2.1 WDOH License Condition 66

Condition 66 of the Facility license, issued to US Ecology by the WDOH, dictates the primary criteria governing the Closure Plan. These criteria are summarized in Table 1-1 and are addressed in detail in Section 4 of this plan.

The requirements in Table 1-1 that influence the operation and closure of the Facility can be grouped into basic categories of Administrative (Conditions 66.C and J), Operational (Conditions 66.A, B, and L), and Performance and Design (all remaining conditions). The design elements of this Closure Plan are primarily addressed in the latter category.

Condition 66.E (Performance Assessment) and Condition 66.H (Erosion and Site Integrity) have the greatest influence upon the Facility performance after closure and consequently, on the design of the Closure Plan. The proposed Closure Plan addresses in detail the requirements of these two conditions.

1.2.2 WAC 246-249:250 and 10 CFR Part 61

Seventeen years after the Richland facility was issued a license in 1964, the NRC promulgated regulations under 10 CFR Part 61 that included specific requirements applicable to future low-level radioactive waste disposal facilities. These regulations have been codified in Chapters 246-249 and 246-250 of the Washington Administrative Code (WAC). Since the Richland Facility was constructed and in operation before these regulations were promulgated, not all of the regulations are directly applicable. However, as a matter of practice, they have been used as guidance in developing specific operational procedures at the Richland Facility and in designing this Closure Plan. The provisions of WAC 246-249 and 246-250 are applicable on a case-by-case basis at the discretion of the Department.

US Ecology currently operates the Richland Facility in conformance with the underlying principles of the WAC and applicable parts of 10 CFR Part 61. In particular, the Facility manages and disposes of radioactive wastes in accordance with the WAC and applicable parts of 10 CFR Part 61 waste classification system. The purpose of the waste classification system is described in the WAC and in 10 CFR 61.55 (a)(1):

> Determination of the classification of radioactive waste involves two considerations. First, consideration must be given to the concentration of long-lived radionuclides (and their shorter-lived precursors) whose

> potential hazard will persist long after such precautions as institutional controls, improved waste form, and deeper disposal have ceased to be effective. These precautions delay the time when long-lived radionuclides could cause exposures. In addition, the magnitude of the potential dose is limited by the concentration and availability of the radionuclide at the time of exposure. Second, consideration must be given to the concentration of shorter-lived radionuclides for which requirements on institutional controls, waste form, and disposal methods are effective.

Operational practices prior to the implementation of 10 CFR 61 differ markedly in some respects from those currently used. Recognition of these differences does impact closure of the facility. In particular, current operating procedures require segregation of incoming waste according to the Part 61 waste classification system. Class B and C waste must be in a form that resists deterioration (i.e. is structurally stable) and must be disposed at least 5 meters below grade. Class A waste may be buried at any depth, however, it must be in a stable form if it is disposed with Class B or C waste. In the past, wastes were not segregated in this manner, consequently the older trenches contain a mixture of wastes that were not classified in accordance with present regulations.

The mixing of the waste classes in the older trenches may lead to subsidence as the physically unstable wastes deteriorate and the waste volume decreases due to deterioration. US Ecology studied the implications of possible future subsidence. It determined that the consequences of long-term subsidence are not as serious as potential problems associated with in-situ densification or other means of stabilization of the wastes in the older trenches.[1] The Closure Plan cover design will fulfill the burial depth requirements for Class B and C wastes. Thus, subsidence that may occur is mitigated to the extent practicable.

1.2.3 Guidance

Regulatory guidance from several sources was used during the preparation of this Closure Plan. These guidance documents were acknowledged in the development of the Closure Plan to assure that the plan is consistent with current technology and regulatory thinking; however, the documents were not explicitly followed. The following lists the primary guidance documents consulted during the preparation of this plan.

- NUREG 1199. "Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility," January 1991.

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[1] Grant Environmental, 1994, Phase 1 Cap Design, Subsidence Evaluation, and Initial Source Term Presentation, Richland, Washington Low-Level Radioactive Waste Disposal Site.

- NRC Final Staff Technical Position on the Design of Erosion-Resistant Covers for Stabilization of Uranium Mill Tailings Sites, August, 1990.
- NUREG 1200. "Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility," January 1987.
- NRC Regulatory Guide 1.109. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50," Appendix I, 1977.

1.3 ASSUMPTIONS

This Closure Plan was prepared based upon certain assumptions. These assumptions, their justification, and their consequences are summarized in the following paragraphs.

1.3.1 Institutional Controls

These assumptions relate to the institutional requirements and control to which the Facility will be subjected after closure.

1. Design Life: The design life is the period of time after closure that the Facility must continue to isolate the disposed wastes. The design life of the closed facility determines the required durability of materials used to construct the cover and the magnitude of natural events the Facility must be designed to withstand. Under 10 CFR Part 61, waste designated as Class C must be disposed of so that the top of the waste is a minimum of 5 meters (16.4 ft) below the top surface of the cover or must be disposed of with intruder barriers that are designed to protect against an inadvertent intrusion for at least 500 years. Regulations previous to 10 CFR Part 61 did not classify wastes in this manner. However, to match the intent of 10 CFR 61, this plan proposes to cover all waste with a minimum of 5 meters (16.4 ft) of soil and to also utilize the 500-year minimum design life specified for intruder protection as a guide. Based upon this minimum time period, US Ecology selected a conservative design life of 1,000 years for the cap design.

2. Period of Institutional Control: The period of institutional control refers to that period after closure and stabilization that the State of Washington will monitor, maintain, and control access to the closed facility. Such activities are outlined in 10 CFR Part 61, as evidenced by the requirement that low-level radioactive waste disposal facilities be located on land owned by a sovereign. Consistent with 10 CFR Part 61, US Ecology has assumed a 100-year institutional control period (also referred to as the perpetual care and maintenance period). Three different levels of monitoring, maintenance, and control are assumed during and after closure. The first comprises rather intensive monitoring and maintenance by US Ecology over a two-year period as the Facility is closed. The second is a period of monitoring during stabilization, with repairs being made only as necessary to prevent damage to the Facility. US Ecology will conduct these activities during the five-year stabilization period. The

third level is the 100-year institutional control period required by 10 CFR Part 61. Activities during this time will be confined to minimal monitoring, and maintenance only as necessary to prevent the loss of integrity or function of the Facility. The Facility Closure Plan is structured to minimize the maintenance required during the institutional control period. Activities during this period will be implemented by the State custodian using Perpetual Surveillance/Maintenance funds. A timeline of the period after closure is included as Figure 1-1.

3. Federal Institutional Control: The Richland Facility is located on the 200 Area Plateau on the Hanford Reservation. The U.S. Department of Energy has selected this area as the central repository for low-level and mixed wastes derived from the decommissioning of the Reservation. Due to the volume and character of these decommissioning wastes, it is likely that the Department of Energy will maintain control of the entire 200 Area Plateau far longer than the 100-year period of institutional control described in the previous assumption[2] (Hanford Work Group, 1992).

4. Site Inventory: The site inventory refers to the volume and radioactivity of the wastes disposed at the site at the time of closure. This inventory was determined to be the present inventory augmented by extrapolating the current waste receipts through closure in 2056. The projected waste receipts were adjusted based on changes to waste streams expected to occur in the future. These changes are itemized in Attachment I.

5. Potential Exposure Scenarios: Exposure scenarios used to evaluate the conformance of the closed Facility with License Condition 66.E were selected in accordance with standard practices. It was assumed that there would be no control of the Facility after the 100-year institutional period, and that potential intruders would have the desire and the technology to construct a residence and farm on or adjacent to the site. Exposure scenarios are described in detail in Section 5.4.

1.3.2 Site and Facility Characteristics

This section discusses the site and Facility characteristics that were assumed in the development of the Closure Plan.

- Site: The site is the 100 acres subleased from the State of Washington, including the subsurface geology and hydrology.

- Disposal Facility: The disposal facility (Facility) is comprised of the disposal trenches, the area between the trenches and the edge of the site, the vadose zone extending from ground surface to the water table, and the uppermost aquifer within

[2] Hanford Future Site Uses Working Group, 1991, Future for Hanford: Uses and Cleanup

the site boundaries. This definition of the facility comports with 10 CFR Part 61, and with the original Facility design and operational concepts.

- Disposal Unit: The portion of the Facility within the boundaries of the disposal trenches, including the ground surface and the underlying vadose zone.

- Aridity: The site is located within the rain shadow of the Cascade Mountains. As a consequence, it receives little rainfall. Potential annual evapotranspiration exceeds annual precipitation in every year. Recharge studies (discussed in Section 2) on the 200 Area Plateau repeatedly have shown that, so long as a modicum of vegetation is maintained on the soil surface, the zone of moisture circulation is limited to the top few meters of the vadose zone. The zone of circulation, the active zone, expands and contracts in response to short-term climatic variations, but this expansion is limited. Infrequent events with intense or large volumes of rainfall do not significantly affect the zone of circulation, since most such precipitation becomes surface runoff. The depth of circulation is more influenced by persistent periods of precipitation or low evapotranspiration, and by the amount and timing of snowmelt in the spring. If it occurs at all, percolation below the zone of circulation occurs at relatively constant and small rates. In the analyses of subsurface radionuclide migration done to support this Closure Plan, it was assumed that percolation below the zone of circulation is constant and equal to 0.2 inches per year (0.5 cm/yr) (discussed in detail in Section 2.7.2).

- Large Floods: The design of all safety-related hydraulic components of the closed Facility are based upon episodic runoff derived from the probable maximum precipitation appropriate for this area. Probable maximum precipitation is determined from Hydrometeorological Report No. 57[3] (Attachment M).

- Wind Erosion: The design of components to protect the Facility against wind erosion is based upon cumulative erosion by exposure to normal and extreme winds that might be expected during the design life of the facility. Erosion is calculated with a version of the universal soil loss equation[4] (Attachment M).

- Role of Vegetation: The closure design recognizes the importance of vegetation in limiting infiltration and controlling erosion. In this sense, closure of an arid environment low-level radioactive waste disposal facility is different than closure of other radioactive waste management facilities. The Closure Plan includes provisions for establishing and supporting vegetation over the closed trenches. Analysis of the performance of the closed Facility presumes the presence of

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[3] US Department of Commerce, National Oceanic and Atmospheric Administration, 1994, Probable Maximum Precipitation - Pacific Northwest States, Hydrometeorological Report No. 57.

[4] US EPA, 1979, Design and Construction of Covers for Hazardous Waste Landfills, EPA-608/2-79-165

vegetation consistent with the natural vegetation of the surrounding area. Thus the infiltration rate through the cap is the same or less than undisturbed areas.

- Subsidence: Subsidence refers to the formation of depressions in the surface of the closed Facility by the consolidation of backfill or deterioration of the disposed wastes. This Closure Plan assumes that subsidence will occur during the period of institutional control and will continue at reduced rates thereafter. The closure design minimizes the effects of subsidence on the cap by preventing storm water run-on to the extent practicable, and by incorporating infiltration-limiting features that do not depend upon precise alignment of internal components.

- Packaging Containment: No credit was taken for radionuclide containment that may be provided by waste packaging.

1.4 DESIGN GOALS

This section summarizes the design goals of this Closure Plan.

- Infiltration: Percolation through the disposed wastes should be limited to amounts no larger than ambient percolation over the 200 Area Plateau, and should be further minimized to the extent consistent with other design goals.

- Critical materials: Critical components, including infiltration-limiting components of the cover, should be constructed of naturally-occurring materials. The proper functioning of these components should not depend upon man-made materials with uncertain service lifetimes.

- Erosion Stability: The closed Facility should be capable of withstanding runoff resulting from any probable maximum precipitation event without loss of function or integrity. Erosion resistance is provided by rock armor, vegetation, and limiting cover slopes.

- Vegetation: The Closure Plan should include components to enhance and protect vegetation over the trench covers.

- Simple Repairs and Easy Monitoring: The closed Facility should be capable of being easily repaired and monitored.

- Robust: The closed Facility should be robust. Minor damage that might occur from erosion or subsidence should be self-healing to the extent practical, and should not lead to continued deterioration or loss of function. This consideration suggests that stability should be provided by regenerative and self-healing components such as vegetation rather than by engineered features that might require repair.

1.5 SUMMARY OF CLOSURE PLAN DESIGN

This section describes the major components of the closed Facility. The Facility cover, waste, and the monitoring system are discussed.

1.5.1 Cover

The Closure Plan includes a multilayer, multifunctional cover (also referred to as a cap) over the disposal trenches. The volume encompassing the disposal trenches and extending from ground surface to the upper aquifer is identified as the disposal unit. In general, one continuous cover is provided over the entire surface of the disposal unit.

The disposal unit cover will be the primary barrier between the disposed waste and the surrounding environment, and will replace the interim cover presently in place over closed trenches. This cover isolates the waste, enhances the required intruder barrier, limits infiltration into the trenches, and limits gaseous emissions to the atmosphere. The cover is designed to withstand extreme climatic events and to discourage inadvertent human intrusion.

The disposal unit cover is constructed in several layers. Each layer contributes to the ability of the cover to limit infiltration and gaseous emissions, and to resist erosion. The cover components are described briefly below, beginning with the cover surface and ending at the bottom of the cover. A detailed description of the cover is contained in Section 3 and is depicted in Figure 3-1.

1. Vegetation: The uppermost component of the disposal unit cover is vegetation. Vegetation enhances transpiration from the cover, and protects the cover from erosion by wind or water.

2. Gravel Mulch Layer (Layer 1): The surface of the cover is formed by a four-inch layer of gravel mulch. This layer is constructed of a mixture of gravel and silty soil. This layer provides an erosion-resistant surface to the cover, and improves the ability of the cover to capture and retain moisture. The gravel mulch layer increases the amount of moisture available to support vegetation. The increased moisture allows more dense vegetation to grow on the cover. The more dense vegetation increases potential evaporation from the cover, and thus decreases the amount of percolation that can infiltrate the wastes. The vegetation also serves to minimize wind erosion.

3. Capillary Barrier Layer (Layer 2): The capillary barrier layer is a three-foot thick layer of silt mixed with pea gravel. This layer forms the upper part of the zone of active moisture circulation. This layer stores infiltrating moisture and provides the moisture and nutrients for vegetation. This layer comprises most of the root zone of the vegetation growing on the cover.

4. Site Sand Layer (Layer 3): The site sand layer consists of three-feet of site sands. The function of this layer is identical to the capillary barrier layer above, however, it

is constructed of fine to medium grained site sands, thus contains decidedly less fine grained soil and nutrients than the overlying layers. This layer forms the bottom of the zone of active moisture circulation and vegetative root growth.

5. Capillary Break Layer (Layer 4): The capillary break is a one-foot thick layer of gravel (ranging from one to three inches in size). This layer has essentially no moisture-holding capacity or nutrients, discourages the downward penetration and growth of roots, and interrupts the capillary tension in the overlying layers. This increases the water-storage capability of the overlying layers, and decreases percolation into the wastes. A geotextile filter fabric is placed above and below the gravels to facilitate construction. The geotextile is a construction artifact that is not a part of the capillary break and does not serve any protective function in the design of the cover.

6. Low Permeability Barrier Layer (Layer 5): The barrier layer is a one-foot thick layer composed of site sands mixed with clay. This layer minimizes infiltration should the storage capacity of the overlying layers be exceeded. This layer also enhances the ability of the cover to limit upward migration of gases.

7. Fill Layer (Layer 6): The fill layer is constructed of site soils and varies in thickness. This layer is placed prior to placement of the cover, provides part of the ability of the cover to limit upward migration of gases, and will be varied to shape the cover surface.

The disposal unit cover is elevated above the surrounding ground surface to prevent the flow of water onto the disposal unit cover. The cover surface slopes at a minimum one percent to encourage surface water runoff and limit the erosive force of incident precipitation. Steeper cover edges (maximum of 20 percent) are protected by vegetation.

1.5.2 Waste

The physical, chemical, and radioactive characteristics of the wastes and backfill within the disposal unit are important to the proper closure of the Facility. This section summarizes these waste characteristics, and describes how waste properties were considered with respect to closure design and performance analyses.

1.5.2.1 Waste Placement and Segregation

The characteristics of the wastes and backfill differs from trench to trench at the Facility. Wastes in Trenches 1 through 8 and 10 were disposed by random placement and backfilled with sandy site soil. Wastes in the later trenches are segregated according to 10 CFR Part 61 waste classification. Unstable Class A wastes are disposed separately from Classes B and C wastes. The wastes are placed randomly in layers, and backfilled with sandy site soil.

Class A waste may be either structurally stable or unstable, but Classes B and C wastes must be structurally stable or be encased in approved containers designed to provide stability for at least 300 years. Only structurally stable Class A waste may be disposed with Class B and C wastes.

Intuitively, the wastes in the newer trenches should be less susceptible to deterioration and consolidation; however, the earlier and later trenches were not distinguished in the site performance analyses, and no credit was taken for any containment that may be provided by waste packaging.

1.5.3 Performance Monitoring

It is anticipated that operations will stop and final closure of the Facility will commence in the year 2056. This plan describes closure of Trenches 1-6 and the Chemical Trench in the near future with the partial cap and final closure of the remaining trenches in 2056. The placement of the partial cap will allow the performance of the closed part of the Facility to be observed and documented for more than 60 years. Additionally, US Ecology regards performance monitoring as an integral part of the Closure Plan, and believes that significant alterations in the Closure Plan will be made over time as a result of this monitoring and technological advances.

Accordingly, the Closure Plan incorporates multiple components to facilitate monitoring the closed part of the Facility. This monitoring includes both performance and compliance components described in the following sections.

1.5.3.1 Performance Monitoring

Current site operating procedures include diverse monitoring of site performance. This monitoring includes observing and recording subsidence, revegetation, and erosion of completed trenches. Also, groundwater is monitored, along with the monitoring of gases in the vadose zone around the trenches. US Ecology has proposed, and WDOH is reviewing, a program to expand the vadose zone monitoring program around the completed trenches. These programs will continue throughout the operational life of the Facility.

The Closure Plan includes components to monitor movement of moisture in the disposal unit cover for the partial cap. The plan also envisions implementing the institutional control monitoring and maintenance program described in Section 3 on the closed portion of the Facility through final Facility closure.

1.5.3.2 Compliance Monitoring

This Closure Plan includes a program to continue monitoring Facility compliance during the closure and institutional control periods. This program, designed to be an extension of the current compliance monitoring program, is described in Section 3. This program

includes air, soil, vegetation and ground-water monitoring and trench cap radiation surveys.

1.6 PERFORMANCE ASSESSMENT

This section summarizes the analyses completed to assess the closure design and the future performance of the closed Facility.

1.6.1 Stability

The ability of the closed Facility to sequester the wastes from the environment during the design life is a critical closure requirement. Stability of the closed Facility means the ability of the Facility to withstand the anticipated stresses without progressive failure or loss of function.

Design stresses include erosive forces of wind and water, and potential damage to the disposal unit cover by waste deterioration and subsequent subsidence.

1.6.1.1 Erosion

1.6.1.1.1 Wind Erosion

Potential damage to the disposal unit cover from wind erosion was assessed by considering the cumulative damage by wind over the design life of the cover. Wind erosion was calculated using a variant of the Universal Soil Loss Equation, considering winds, soil, and soil moisture conditions that will exist on the cover.

Saltation, or the episodic movement by wind of particles on the disposal unit cover, was evaluated by calculating the lift on critical particles using aerodynamic formulae and a design wind speed of 139 feet per second. These calculations were used to size the gravel mulch to be placed on the cover to resist erosion during high winds.

The wind erosion analyses demonstrated that erosion protection sufficient to withstand water erosion is more than sufficient to prevent erosion by wind. The analyses showed that damage to the disposal unit cover by wind over the design life of the cover will be negligible.

These calculations are discussed in detail in Attachment M.

1.6.1.1.2 Water Erosion

The disposal unit cover was designed to resist stormwater runoff resulting from a probable maximum precipitation event at the site. The analyses followed the guidance in the US NRC Final Staff Technical Position on the Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites, August, 1990 (NRC STP).

Credit was taken in the analyses for the resistance provided by vegetation that will grow on the top and side slopes of the disposal unit cover. This departs from the usual application of the NRC STP guidance for reasons discussed in Section 1.3.2 above. However, this assumption is appropriate for analyzing this disposal unit cover, since the cover includes components to promote the growth of vegetation. If sufficient vegetation is not maintained, other erosion control mechanisms will be examined for the side slopes.

The analyses demonstrate that the cover can withstand a probable maximum precipitation event without significant damage or loss of function.

These calculations are discussed in detail in Attachment M.

1.6.1.2 Subsidence

US Ecology studied the potential for subsidence in the waste disposal trenches, the probable effects of this subsidence on the disposal unit cover, and methods by which subsidence might be reduced or eliminated. US Ecology reported the conclusions to WDOH in February, 1994[5]. Potential damage by subsidence is not serious enough to warrant direct measures to reduce or eliminate the subsidence. WDOH directed US Ecology to provide a closure design that can accommodate the expected subsidence.

The proposed closure design includes a layered cover that can accommodate expected subsidence and also limit infiltration. The proper functioning of this cover does not depend upon drainage, but rather uses the moisture storage properties of the cover soils to retain infiltrating moisture until it can be returned to the atmosphere by evaporation and transpiration.

The arid climate and the ability of the cover to store moisture temporarily limits increases in ground-water recharge that might otherwise result from infiltration in small subsidence depressions. This is because excess moisture in such depressions will tend to move laterally in response to unbalanced capillary forces between the moister soils in the depression and the drier surrounding soils.

1.6.2 Dose Analysis

Pathways analysis and dose modeling were performed to identify potential exposures to humans and to determine that the performance objectives for the Low-Level Radioactive Waste Disposal Facility will be met. Specifically, the release of radioactive material to the general environment, including groundwater, surface water, air, soil, plants or animals cannot result in an annual dose exceeding an equivalent of 25

[5] Grant Environmental, 1994, Phase 1 Cap Design, Subsidence Evaluation, and Initial Source Term Presentation, Richland, Washington Low-Level Radioactive Waste Disposal Site.

millirem/year (mrem/yr) to the whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ (WAC-246-250-170).

The dose analysis examined the possible release of radionuclides from subsurface wastes disposed presently and from projected future operations. Potential pathways that were examined for this analysis included ingestion, direct exposure, and inhalation. These pathways were examined for three scenarios including: an agricultural scenario, a construction scenario, and a residential (basement) scenario. A detailed description of each of the scenarios and pathways is provided in Section 5 of this Closure Plan.

Only the groundwater portion of the ingestion pathway was determined to be a significant mechanism for transport of waste constituents to the environment. The groundwater portion of the ingestion pathway examines the cumulative effects of using contaminated groundwater as drinking water for man and a cow, and as a source of irrigation water for crops and pasture land. The groundwater is assumed to come from a hypothetical well located adjacent to and downgradient of the Facility.

The dose modeling for a hypothetical individual as described above was performed for an ambient infiltration rate of 0.2 in/yr (0.5 cm/yr) and an infiltration rate through the designed cover of 0.05 in/yr (0.13 cm/yr). The ingestion pathway dose modeling for the designed cover infiltration rate indicates that the maximum calculated dose is 1.16 mrem/year to the thyroid. This represents a value of about 1.5 percent of the WAC limit. A maximum total body dose of 0.19 mrem/year represents about 0.8 percent of the WAC performance objective. The next largest organ dose, 0.73 mrem/year to the lower intestine, represents about 2.9 percent of the WAC performance objective. Therefore, the performance objective is being met.

TABLE 1-1

SUMMARY OF CLOSURE PLAN REQUIREMENTS

	License Condition - General Subject	Specific Requirement
NO	66.A - Burying waste	Bury all waste in accordance with the requirements of the license.
NO	66.B - Dismantling and Decontamination	Dismantle, decontaminate as required and dispose of all structures, equipment, and materials that are not to be transferred to the site custodian.
NO	66.C - Orderly Site Transfer	Document the arrangements and the status of the arrangements for orderly transfer of site control and for long-term care by the government custodian. Also document the agreement, if any, of state or federal governments to participate in, or accomplish, performance objectives. Specific arrangements to assure availability of funds to complete the site closure and stabilization plan shall be documented.
yes	66.D - Direct Gamma Radiation Levels	Direct gamma radiation from buried wastes shall be essentially background at any accessible above-ground location, as determined by evaluation of environmental data from the licensee, U.S. Department of Energy and its contractors.

TABLE 1-1

SUMMARY OF CLOSURE PLAN REQUIREMENTS

66.E - Performance Assessment	Demonstrate by measurement and model during operations and after site closure that concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals will not result in any member of the public receiving an annual dose equivalent of 25 millirems (0.25 mSv) to the whole body, 75 millirems (0.75 mSv) to the thyroid and 25 millirems (0.25 mSv) to any other organ of any member of the public.
66.F - Rendering Site Suitable for Surface Activities	Render the site suitable for surface activities without resort to custodial care exceeding vegetation control, minor maintenance, and environmental monitoring. No active on-going maintenance shall be necessary. Final conditions at the site must be acceptable to the government custodian and compatible with its plan for the site.
66.G - Trench Elevations	Demonstrate that all trench elevations are above water table levels taking into account the complete history of seasonal fluctuations.
66.H - Erosion and Site Integrity	Eliminate the potential for erosion or loss of site or trench integrity due to factors such as groundwater, surface water, wind, subsidence, and frost action. All slopes shall be sufficiently gentle to prevent slumping or gullying. The surface shall be stabilized to minimize erosion, settling, or slumping of caps.

TABLE 1-1

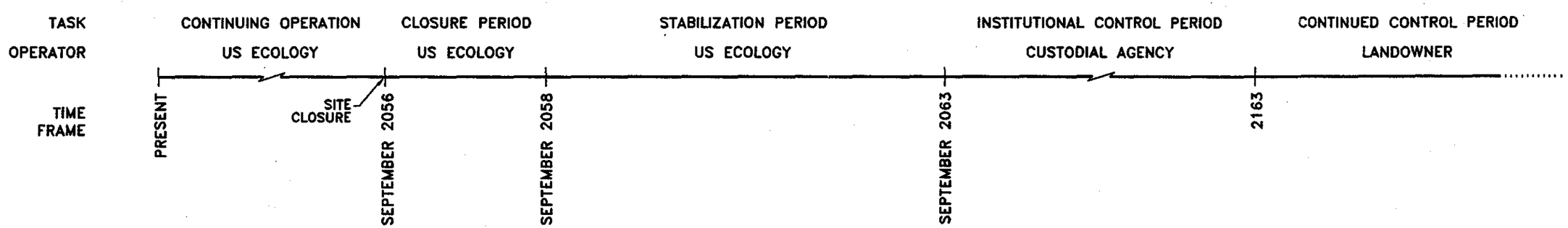
SUMMARY OF CLOSURE PLAN REQUIREMENTS

66.I - Permanent Trench Markers	Demonstrate that permanent trench markers are in place, stable, and keyed to benchmarks. Identifying information shall be clearly and permanently marked as required by Condition 65 of this license.
66.J - Records	Compile and transfer to the Department complete records of site maintenance and stabilization activities, trench elevation and locations, trench inventories, and monitoring data for use during custodial care for unexpected corrective measures and data interpretation.
66.K - Buffer Zone	Maintain a buffer zone to provide space to stabilize slopes, incorporate off-site surface water management features, assure that any future excavation on adjoining areas shall be evaluated as to its potential to compromise trench or site integrity, and provide working space for unexpected mitigating measures, if needed, in the future. The buffer zone may be within the subleasehold or on adjacent land, provided written agreements are secured with persons owning or controlling adjacent lands which shall allow the licensee or custodial agency the required access and actions.
66.L - Passive Site Security System	Provide a secure passive site security system (e.g., a fence) that requires minimum maintenance.

TABLE 1-1

SUMMARY OF CLOSURE PLAN REQUIREMENTS

66.M and N - Site Stabilization	Stabilize the site in a manner to minimize environmental monitoring requirements for the long-term custodial phase and develop a monitoring program based on the stabilization plan. Investigate the causes of any statistically significant levels of radioactive or hazardous materials in environmental samples taken during operation and stabilization. In particular, any evidence of unusual or unexpected rates or levels of radionuclide migration in or with the groundwater shall be analyzed and corrective measures implemented.
66.O - Elimination of Active Water Management Measures	Eliminate the need for active water management measures, such as sump or trench pumping and treatment of water, to assure that wastes are not leached by standing water in the trenches.
66.P - Evaluation of Present and Proposed Activities	Evaluate present and proposed activities on adjoining areas to determine their impact on the long-term performances of the site and take reasonable action to identify and minimize the effects.



GRANT ENVIRONMENTAL consulting and engineering DENVER, COLORADO

FIGURE 1-1

FACILITY CLOSURE TIME LINE

5018

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2. FACILITY CHARACTERISTICS

2.1 OVERVIEW

This section describes the physical characteristics of the Facility. These physical characteristics are the controlling mechanisms that determine the suitability and durability of the Facility for the long-term isolation of low-level radioactive waste from the environment. This section presents the physical data that are used in the development of Section 3, "Closure Plan;" Section 4, "Condition 66 Performance Criteria;" and Section 5 "Dose Analysis." This section also presents estimated values for those physical parameters for which data are limited and identifies data values that could benefit from additional supporting information.

Section 2 is organized under the following major headings:

- 2.1 Overview:
  Presents the purpose and organization of Section 2.

- 2.2 Description of the Facility:
  Describes the location and brief history of the US Ecology Facility and the surrounding Hanford Reservation area.

- 2.3 Climatology:
  Presents data on wind, precipitation, evapo-transpiration, temperature and severe weather events at the Hanford Reservation.

- 2.4 Geology:
  Presents data on the regional and facility geology, and relates the information to those values required for cover design and dose analysis.

- 2.5 Seismicity:
  Presents data on expected regional seismic activity, and relates the seismic activity to the Facility.

- 2.6 Terrestrial Ecology:
  Presents information on native vegetation and animals at the Facility.

- 2.7 Hydrology:
  Describes the controlling hydrologic features of the site, including infiltration and recharge, the vadose zone and the saturated zone.

- 2.8 Flooding Potential:
  Presents information on the potential for surface water to affect the Facility.

- 2.9 Topography:
  Presents information on the topographic features of the Facility.

The information presented under these headings are summaries of recent available information. Additional detail on this information can be found in the references listed in Section 7, "References" for the Closure Plan.

2.2 DESCRIPTION OF FACILITY

2.2.1 Location

The US Ecology Low Level Radioactive Waste (LLRW) Disposal Facility (herein referred to as "Facility") is located in Benton County, Washington, latitude N46°32'17", longitude W119°33'29", near the center of the Hanford Reservation (herein referred to as "Reservation") in the southeastern Washington desert. It is more than 6.2 miles (10 kilometers) from the Facility to the nearest Reservation boundary. The 100 acre (40 hectares) Facility is bounded on all sides by federal land controlled by the DOE.

The Reservation is located within the Pasco Basin area of southern Washington, near the confluence of the Columbia and Yakima Rivers, as shown in Figures 2-1 and 2-2. The nearest population center is Richland, Washington, which is located about three miles (4.8 km) from the southernmost boundary of the Reservation. There are no permanent residents on the Reservation. The Pasco Basin is surrounded by the Rocky Mountains to the east and the Cascade Mountains to the west and south. There are several basalt ridges within the basin.

The Facility is located south of Gable Mountain and Gable Butte, east of Yakima Ridge, and north of Rattlesnake Hills and Red Mountain in the Separations Area. The Separations Area covers 82 square miles (212 square km) near the center of the Reservation. The Separations Area encompasses the 200-East and 200-West Areas where irradiated uranium fuel processing facilities, plutonium separation facilities, and major radioactive waste storage and disposal facilities are located. The Facility is immediately southwest of the 200-East Area and about 2.5 miles (4 km) east of the 200-West Area. The US Department of Energy Environmental Restoration Disposal Facility (ERDF) is being constructed immediately west of the Facility, and east of the 200-West Area. The Columbia River, the natural surface water body nearest to the Facility, is about 7 miles (11 km) east at its closest point or approximately 16 miles (26 km) in the direction of groundwater flow.

2.2.2 History

The Reservation began operation in the 1940s as part of the Manhattan Project. It is presently the site of several nuclear reactors, research facilities and waste disposal facilities. The Reservation was a critical component of the nation's nuclear weapons complex operated by the U.S. Department of Energy (DOE). The DOE's mission for the Reservation has recently changed from weapons production to environmental

restoration, and includes the development of the ERDF. Data collected in recent investigations associated with the ERDF are incorporated into this Closure Plan.

The State of Washington is currently the prime lease holder from the DOE for the 100 acre tract occupied by the Facility. US Ecology subleases the area from the State of Washington. Detailed description of the lease arrangements is included in Section 4 of this Closure Plan. The Facility began operating in 1965 and through 1995 has received approximately 13 million cubic feet (3.7×10^5 cubic meters) of low-level radioactive waste. Additional low-level radioactive waste is expected to be received until Facility closure in 2056.

2.3 CLIMATOLOGY

2.3.1 General

Climatological data are available from the Hanford Meteorological Station, which is located between the 200 Areas near the Facility, and are assumed to be representative of the general climatic conditions for the region[1]. Data have been collected at the Hanford Meteorological Station since 1945; temperature and precipitation data are available from nearby locations for the time period 1912-1943. A compilation of meteorological data published for the Hanford Reservation through 1994[2,3] is used in this Closure Plan.

2.3.2 Wind

The prevailing winds in the vicinity of the Facility are from the northwest. Seasonally, the wind speed is lower during the winter (monthly averages of 6 to 7 mph)(9.6 to 11.3 kph) than during the summer (8 to 10 mph)(12.9 to 16.1 kph) (Table 2-1). Wind direction from the southwest is more common for above average windspeeds. Monthly wind roses for the Hanford Meteorological Station (HMS) are presented in Figure 2-3.

Winds with speeds that are well above average are usually from the southwest (Table 2-1). In the summer, high-speed winds from the southwest cause most of the dust storms experienced in the region. High winds also can occur during all seasons in the afternoon and during thunderstorms. An estimate of extreme winds at the Hanford Station is included in Table 2-2.

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[1] Stone, W. A., J. M. Thorp, O. P. Gifford and D. J. Hoitink, 1983, Climatological Summary for the Hanford Area, PNL-4622, Pacific Northwest Laboratory, Richland, Washington, p. I-1, Introduction.

[2] Stone, et al., 1983, op. cit.

[3] Hoitink, D.J., and K.W. Burk, 1995, Climatological Data Summary 1994 with Historical Data: PNL-10553, Pacific Northwest Laboratory, Richland, Washington.

Peak gust records for 1949 through 1991 are included in Table 2-3. A graph of the peak gust records is presented in Figure 2-4[4].

2.3.3 Precipitation

The Pasco Basin is located within the rain shadow of the Cascade Mountains and receives about 6.3 inches (16 cm) of precipitation each year. Most of this precipitation occurs during the winter, with about 38 percent of annual precipitation occurring as snowfall between December and March[5]. Monthly average precipitation amounts are shown on Figure 2-5[6]. There are an average of 125 days per year when precipitation occurs; however, only 24 days per year have totals of 0.10 inch (0.25 cm) or more. Only three times during the period of record has daily precipitation equaled or exceeded one inch (2.54 cm).

Recorded periods through 1994 when precipitation was abnormally high[7] are included in Table 2-4.

An unusual amount of precipitation fell in 1973. Total precipitation for the year was 8.27 inches (21 cm), or 132% of normal (6.25 inches, or 15.9 cm). The record snowfall for the Hanford reservation occurred during the winter of 1992-1993, with 56 inches (142 cm) of snow[8].

The area is classified as a mid-latitude semiarid desert; therefore there have been many dry periods. The record number of consecutive days without measurable precipitation occurred in 1919 (102 days). The driest year of record was 1976. Total precipitation for that year was 2.99 inches (7.60 cm).

2.3.4 Evapotranspiration

Potential evapotranspiration (PET) in the area is between 28 and 33 inches per year (71 to 84 cm per year). Water balance computations, performed as part of the Basalt Waste Isolation Project (BWIP), indicate that the average annual PET is about 29.4 inches (74.7 cm). Figure 2-6 is a graphical representation of the computed water balance and shows that evapotranspiration exceeds precipitation during nine months of

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[4] Ligotke, M. W., 1993, Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel: PNL-8478, Pacific Northwest Laboratory, Richland, Washington, p. 3.5, Figure 3.2.

[5] Department of Energy (DOE), 1994, Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility, U.S. DOE, Revision 1, DOE/RL-93-99.

[6] Stone, et al., 1983, op. cit., p. IV-3, Figure 3.2.

[7] Stone, et al., 1983, op. cit., p. IV-6, second paragraph.

[8] Hoitink, D.J., and Burk, 1995, Climatological Data Summary 1994 with Historical Data, PNL-10553.

the year. Infiltration generally occurs during the period between November and January when precipitation exceeds evapotranspiration. The net moisture deficit is found by subtracting the annual average rainfall from the PET. The net deficit for the Facility is 23.1 inches (58.7 cm). Other reports yield similar values, with average annual rainfall of about 6 inches per year (15 cm per year), and potential evapotranspiration of more than 39 inches per year (100 cm per year)[9].

2.3.5 Temperature and Humidity

Temperature and humidity data are summarized by DOE[10]. During the period from 1946 through 1993, average monthly temperatures at the Facility varied from 30°F (-1°C) in January to 76°F (24°C) in July. There are normally about 115 days a year (from mid-November through mid-March) with minimum temperatures below freezing and about 12 summer days with maximum temperatures above 100°F (38°C).

Relative humidity is measured at the Hanford Meteorological Station. Annual average relative humidity is about 54%, with winter averages of about 75% and summer averages of about 35%. The effects of humidity at the Facility control the diurnal temperature range. The higher humidity in the winter reduces the average diurnal temperature range to about 14°F (8°C). The lower humidity in the summer allows the average diurnal temperature range to increase to about 27°F (15°C)[11].

2.3.6 Severe Weather Events

Thunderstorms occur on about ten days during an average year, but the total has varied from 3 in 1949 to 23 in 1948. Tornadoes are unlikely. One tornado and two other funnel clouds which did not touch ground were observed on the Reservation during a 36-year observation period.

2.4 GEOLOGY

2.4.1 Physiography

The Facility is located near the center of the Pasco Basin, one of numerous structural and topographic depressions in the Columbia Plateau physiographic province, a broad basin characterized by thick accumulation of basaltic lava flows. The Pasco Basin is bounded on the north by the Saddle Mountains; on the west by Umtanum Ridge, Yakima Ridge and Rattlesnake Hills; on the south by Rattlesnake Mountain and Horse

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[9] Gee, G.W., Heller, P.R., 1985, Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography, PNL-5428, Pacific Northwest Laboratory, Richland, Washington.

[10] Department of Energy, 1994, op. cit.

[11] Department of Energy, 1994, op. cit.

Heaven Hills; and on the east by the Palouse Slope. A few bedrock outcrops occur, most notably Gable Mountain and Gable Butte, above the terrace lands in the central portion of the Pasco Basin, near the Facility. The central portion of the Pasco Basin is relatively flat, but the terrain is steep along the basaltic ridges.

2.4.2 Regional Geology

The regional geology of the Reservation is described as a basalt plateau overlain by thick layers of unconsolidated to partially consolidated sediments which are Miocene to Recent in age.

2.4.2.1 Suprabasalt Sediments

Within the Reservation, the suprabasalt sediments consist of (from youngest to oldest): surficial soils, Hanford Formation, Pre-Hanford/Post Ringold sediments and the Ringold Formation. Each of these formations is described below; additional information is available in published reports[12]. The regional surficial geology is illustrated on Figure 2-7.

2.4.2.1.1 Surficial Soils

The surficial soil at the Reservation is a thin veneer of eolian-deposited silts and sands, alluvium, colluvium, talus and landslide deposits. In places, human activities at the Reservation have disturbed, excavated, or covered this veneer.

2.4.2.1.2 Hanford Formation

The Hanford Formation consists of unconsolidated sands, silts, clays and some gravels deposited by glacial flood waters, with the last deposition sequence about 13,000 years

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[12] Energy Research & Development Administration (ERDA), 1975, Waste Management Operations: Hanford Reservation

Bergeron, M. P., G. V, Last, A .E. Reisenauer, 1987a, Geohydrology of a Commercial Low-Level Radioactive Waste Disposal Facility near Richland, Washington: Battelle Pacific Northwest Laboratories, 1987.

Last, G.V., Bjornstad, B.N., Bergeron, M.P., Wallace, D.W., Newcomer, D.R., Schramke, J.A., Chamness, M.A., Cline, C.S., Airhart, S.P., Wilbur, J.S., 1989, Hydrogeology of the 200 Areas Low-Level Burial Grounds - An Interim Report, PNL-6820 Vol. 1, Pacific Northwest Laboratory, Richland, Washington

Department of Energy, 1994, op. cit.

Weekes, D.C., Jaeger, G.K., Ford, B.H., 1995, Preoperational Baseline and Site Characterization Report for the Environmental Restoration Disposal Facility, U.S. DOE, Revision 00, BHI-00270, Volume 1.

ago[13]. The Hanford Formation is divided in the literature into gravel-dominated, sand-dominated, or silt-dominated facies. The gravel-dominated facies is referred to as the Pasco Gravels facies and consists of poorly sorted clasts deposited in high energy environments. The silt-dominated facies is referred to as Touchet Beds facies of graded silt, sand and minor gravel units deposited in a slack water environment[14]. The sand-dominated and silt-dominated facies predominate beneath the Facility. The Hanford Formation is thickest (up to 350 feet (107 m)) underneath the Separations Area (200 Areas).[15].

2.4.2.1.3 Pre-Hanford/Post-Ringold Sediments

Thin alluvial deposits are located between the Hanford Formation and the underlying Ringold Formation. These alluvial deposits have been sub-divided into three informally-defined units consisting of the Plio-Pleistocene unit, the early Palouse soil unit and the pre-Missoula gravels. The Plio-Pleistocene unit, consisting of eolian silt and fine sand with a relatively high caliche content, overlies the Ringold Formation in the western portion of the Reservation. These alluvial deposits were eroded towards the east, and are absent beneath the Facility.

2.4.2.1.4 Ringold Formation

The fluvial-lacustrine Ringold Formation was deposited over the basalts in generally east-west trending valleys by the ancestral Columbia River and its tributaries[16]. The Ringold Formation is interpreted to be late Miocene to late Pliocene in age[17] between 3.7 to 8.5 million years before present[18]. Within the Pasco Basin, the Ringold Formation is classified into facies associations based upon variations in depositional environment. Ringold deposits within the central portion of the Pasco Basin are dominated by gravel and associated sand and silt representing migrating channel deposits of the ancestral Columbia and/or Snake River systems. Within the Reservation, the literature divides the sediments of the Ringold Formation into four textural units: a sand and gravel basal unit; a lower unit consisting of clay, silt and fine

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[13] Department of Energy (DOE), 1987, Final Environmental Impact Statement - Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, Hanford Site, Washington: DOE/EIS-0113, Vols. 1 through 5, U.S. Department of Energy, Washington, D.C., p. 4.7, first and second paragraphs.

[14] Department of Energy, 1987, op. cit., p. 4.7, second paragraph.

[15] Department of Energy, 1994, op. cit.

[16] Department of Energy, 1988, Site Characterization Plan and Reference Repository Location, Hanford Site, Washington, DOE/RW-0164 (Vol. 1 of 9), p. 1.2-64.

[17] Department of Energy, 1988, op. cit., p. 1.2-65.

[18] Bergeron et al., 1987a, op. cit., p. 11 first paragraph.

sand with minor gravel lenses; a middle unit of occasionally indurated sand and gravel; and an upper unit of silt and fine sand. The upper Ringold unit was eroded toward the east and is absent beneath the Facility where the middle Ringold unit underlies the Hanford Formation. The middle Ringold unit is comprised of occasionally cemented sands and gravels, and is bounded by a lower Ringold unit comprised of clay, silt and fine sand with minor gravel lenses[19]. The middle Ringold unit contains some calcium carbonate[20]; data from US Ecology boring logs[21] support the conclusion that cementation is limited and sporadic in the vicinity of the Facility.

2.4.2.2 Basalts

Beneath the unconsolidated sediments, the Pasco Basin is underlain by basalt flows of the Columbia River Basalt Group. The basalt sequences are interbedded with erosional sediments, and are more than 700 feet (213 meters) thick. The basalt outcrops are within the Hanford Reservation and near the Facility. Figure 2-7 is a regional surficial geology map that identifies the basalt outcrops in the area of the Hanford reservation. Figure 2-8 is a cross-section extending southwest to northeast across the Hanford reservation that passes near the Facility. The cross-section illustrates the relationship of the suprabasalt sediments overlying the Columbia River Basalt Group. Figure 2-9 is a stratigraphic column of the Pasco basin area that presents the general stratigraphy and nomenclature of the suprabasalt sediments and the underlying basalt flow sequences. Figure 2-9 also identifies the suprabasalt stratigraphic units that underlie the Facility.

2.4.3 Facility Geology

The Facility is located in the Separations Area (200 Areas), near the southern end of the Gable Mountains. Site-specific geologic information is available from excavations and monitoring wells located within the Facility boundaries, borings located in the 200-East and 200-West Areas, and borings made for the ERDF facility.

At the Facility, the suprabasalt sediments consist of the surficial soils, the Hanford Formation and the middle member of the Ringold Formation. These deposits exhibit a wide range of particle sizes and mineralogy, and consist of unconsolidated to partly indurated sand, silt, clay, and gravel sediments. Geologic information has been derived from disposal unit trenches up to approximately 50 feet (15.2 meters) in depth and the

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[19] Bergeron et al., 1987a, op. cit., p. 11 second paragraph.

[20] Tallman, A. M., K. R. Fecht, M. C. Marratt and G. V. Last, 1979, Geology of the Separation Areas, Hanford Site, South-Central Washington, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington, p. vi, first paragraph.

[21] CH2M-Hill, Inc., 1985, Monitoring Well Installation Report and Laboratory Testing Program Results for US Ecology, Inc., Richland, Washington, January 16, 1985.

boring logs of five monitoring wells that extend as deep as 360 feet (110 meters) below ground surface. The trenches and borings logs are discussed in a previous report[22].

The surficial soils consist of about 10 to 20 feet (3 to 6 meters) of glaciofluvial, alluvial and dune sands with occasional layers of volcanic ash. The Hanford Formation is about 250 feet (76 meters) thick beneath the Facility, and rests unconformably on the middle member of the Ringold Formation. The Hanford Formation consists of fluvial and colluvial materials with alternating layers of silt, fine sand and medium to coarse sand over poorly-sorted sands, silts and gravels. Below that, the middle member of the Ringold Formation is a silty, sandy gravel consisting of well-rounded pebbles and small cobbles with interstitial spaces filled with coarse to fine sand and silt with variable amounts of cementation[23]. Drilling has advanced about 80 feet (24 meters) into the middle member of the Ringold Formation beneath the Facility without reaching the underlying strata. The middle member of the Ringold Formation is separated from the sands and gravels of the basal member of the Ringold by 50 to 70 feet (15 to 21 meters) of sandy silts of the lower member.

The outcrop of the middle member of the Ringold Formation along the White Bluffs is a conglomerate which is matrix supported and massive in appearance with minor imbrication of the gravel clasts. Drilling cuttings from the middle member of the Ringold Formation, obtained during installation of five monitoring wells at the Facility[24], were described as well-graded gravel with medium to fine sand in seams. The gravels were well rounded, ranging from 0.25 inch to 3 inches (0.6 to 7.6 cm) with occasional cobbles. Silt comprised less than 5% of this soil by weight. The middle member of the Ringold Formation contains some soil cemented with calcium carbonate[25]; however, data from US Ecology boring logs indicate the cementation is sporadic and limited in the vicinity of the Facility. Consistency of low soil moisture contents above and below instances of cementation indicate the shallow cemented soils do not retard water significantly. Thus, these layers would not be a moisture barrier which could provide a shallow horizontal pathway for migration.

Drillings in the 200-West Area and 200-East Area indicate that the suprabasalt sediments thicken to the west and south, and thin to the north and east with proximity to Gable Mountain. Several boreholes have been drilled through the middle member of the Ringold Formation in the 200-East and 200-West Area. In the 200-West Area, the

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[22] Bergeron et al., 1987, op. cit.

[23] Tallman et al., 1979, op. cit., p. vi, first paragraph.

[24] Bergeron et al., 1987, op. cit., p. 25, second paragraph.

[25] Tallman et al., 1979, op. cit., p. vi, first paragraph.

borings terminate in the clay/silt lower member of the Ringold Formation. Borings in the northern part of the 200-East Area terminate in the basalt[26].

None of the five borings drilled at the Facility have been extended through the middle member of the Ringold Formation. Two additional upgradient characterization monitoring wells are proposed to be installed at the Facility in 1996; one of these borings is planned to be advanced through the middle member of the Ringold to the underlying strata. Six characterization borings and three borings for monitoring wells have been drilled at the ERDF site; none of the nine borings extended through the middle member of the Ringold Formation. Two additional monitoring wells are proposed to be installed at the ERDF site in 1996; neither of the borings are to be advanced through the middle member of the Ringold Formation[27].

Driller's logs for the monitoring wells 003, 005, 008, 010 and 013 installed at the Facility are included in a report prepared by CH2M Hill entitled, "Monitoring Well Installation Report and Laboratory Testing Program Results for US Ecology, Inc., Richland, Washington" and included as Attachment B of this Closure Plan. Well logs for the three vadose monitoring wells VW100, VW101 and VW102 are included in Attachment C of this Closure Plan.

2.5 SEISMICITY

Seismicity in the Columbia Plateau is attributed to a north-south oriented compressional stress regime that has resulted in thrust or reverse dip-slip faulting. Recent seismic data and observations since 1872 show that most large earthquakes have occurred further than about 124 miles (200 kilometers) from the Pasco Basin. Earthquake activity in the Hanford Reservation region has been monitored since 1969. Seismic events in the central Columbia Plateau, including the Pasco Basin, generally are short in duration and low in magnitude (less than 3.5 Richter Scale). The earthquakes tend to occur in swarms with limited areal extent[28].

Conservative studies performed to support the use of nuclear reactors on the Reservation estimated the maximum credible earthquake for the next fifty years. The estimated largest earthquake associated with a known geologic structure would be a Richter magnitude 6.7 event located at the northwestern end of the Rattlesnake-Wallula alignment of deformation (see Figure 2-10). The maximum earthquake not associated

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[26] Last et al., 1989, op. cit.

[27] Weekes, 1995, personal communication.

[28] Department of Energy (DOE), 1986, Draft Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, DOE/EIS-0013 (Vol. 3), Washington, D.C., p. R.95, fourth paragraph.

with a fault structure is estimated to be of Richter magnitude 5.75[29]. These values are applicable to the Facility because of its location within the Reservation.

Historical information indicates the Facility is within an area of relatively low seismicity. The effects of infrequent volcanic activity associated with the Cascade Range would not affect waste disposal[30].

Other seismic-related activity such as fault rupture, reservoir induced seismicity, subsidence and liquefaction are either of low probability or not likely to adversely affect waste disposal. The high relative density of the Hanford Formation sands combined with the large depth to groundwater provides suitable soils for supporting heavy foundation loads and eliminates the possibility of liquefaction[31].

2.6 TERRESTRIAL ECOLOGY

2.6.1 Vegetation

The environment of the Facility is characterized as a shrub-steppe ecosystem typical of the Reservation and the semiarid Columbia Basin. A sagebrush/cheatgrass/Sandberg's bluegrass plant community dominates, while several other shrub-grassland communities occur nearby. Trees on the Reservation grow in riverbank communities adjacent to the Columbia River, in several ponds, and in abandoned towns or military compounds. When the vegetation of the shrub-grassland community is removed by excavation or fire, the Reservation becomes dominated by the invasive cheatgrass (*Bromus tectorum*). The cheatgrass is an annual species that grows in dense turf, is dead and dry by late summer, and is very susceptible to fire. Cheatgrass produces large amounts of seed, some of which remains in the soil from year to year, and survives to the gradual exclusion of most native species which are more sensitive to fire or other disturbances.

2.6.1.1 Site Vegetation

The vegetation that exists on the Hanford Reservation is described in a previous report[32]. The vegetation discussed includes desert shrubs, (i.e., sagebrush, rabbitbrush, and bitterbrush) and bunch grasses (i.e., bluegrass and wheat grasses).

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[29] Department of Energy, 1986, op. cit., p. R.95, Section R.10, third paragraph.

[30] Department of Energy, 1986, op. cit., p. R.93, fifth paragraph.

[31] Department of Energy, 1986, op. cit., p. R.95, fifth paragraph.

[32] Brandt, C.A., W.H. Rickard, Jr., and M.G. Hefty, 1989, Interim Reclamation Report: Basalt Waste Isolation Project Exploratory Boreholes Site, PNL-7280, Richland, Washington.

The report explains that native plants important to revegetation of a site are comprised mainly of cool-season species, namely big sagebrush and spiny hopsage. Vegetative growth occurs primarily during the late fall after the first rains and during spring before the extreme temperatures of summer. The primary shrub species, big sagebrush, is capable of photosynthesis year-round, provided sufficient water is present in the soil and air temperatures are between 50°F and 68°F (10°C and 20°C). Usually, however, growth is greatest in the cool season. Flowering and seed set occurs between late November and early December. Germination of big sagebrush seeds is inhibited by continuous temperatures below 41°F (5°C) and is highest when warm-period temperatures exceed 59°F (15°C).

Spiny hopsage is the most difficult shrub species to reestablish at the Facility. Spiny hopsage drops its leaves at the onset of hot weather and remains dormant until late winter. Its peak growth period is thus limited to the cool, moist conditions of the spring. Spiny hopsage flowers in early spring and sets seed just before leaf-drop. Germination of seeds under laboratory conditions reaches optimum levels when exposed to 41°F (5°C) nights and 50°F to 86°F (10°C to 30°C) days.

The principal native grasses important to revegetation at the Facility are Sandberg's bluegrass, bottlebrush squirreltail, and needle-and-thread grass. Cheatgrass is an important non-native component of most habitats on the Reservation. Cheatgrass, an annual, is a highly competitive species, especially on disturbed areas. Both cheatgrass and Sandberg's bluegrass germinate after the first significant rains in fall. Sandberg's bluegrass sets seed during early spring, then becomes dormant until fall. Cheatgrass sets its seed slightly later, then dies. Sandberg bluegrass seeds have low germinability until six months after dehiscence.

Germination of Sandberg's bluegrass seeds is highest at daytime temperatures of 59°F (15°C) and overnight temperatures of 41°F to 59°F (5°C to 15°C). Needle-and-thread grass seeds germinate in early winter; bottlebrush squirreltail germinates in late fall and early winter. Bottlebrush squirreltail seed germination is highest under conditions of warm days 50°F to 68°F (10°C to 20°C) and cool nights 41°F (5°C) but, like all the grasses, may be inhibited by low soil moisture.

A number of alien annual species occur on the Reservation. Most of these are early successional varieties that rapidly colonize areas of soil disturbance. Such colonizers include prickly lettuce, tansy mustard, tumble mustard, Russian thistle, and cheatgrass. The most aggressive and ubiquitous of these is cheatgrass. Areas occupied by cheatgrass are resistant to invasion by native species. Cheatgrass is an Eurasian native that was introduced to Washington State in the 1890s.

The first plants to colonize a disrupted (e.g., plowed) area are usually Russian thistle and tumble mustard, though these are completely eliminated in a few years by cheatgrass without appropriate management. In semiarid areas such as the Reservation, cheatgrass occurs in nearly pure stands on formerly disturbed ground.

Old fields abandoned on the Site in the early 1940s continue to be dominated by cheatgrass, to the exclusion of native species. Other areas outside the Hanford Site have remained as nearly pure stands of cheatgrass despite the elimination of human-caused disturbances at least as far back as 1911.[33]

2.6.1.2 Site Revegetation

Two considerations for reclamation derived from the above discussion are significant for revegetating the site with native vegetation. First, the native grasses all germinate during the early fall period after the first significant rains, a period when soil temperatures are still high but occasional freezing air temperatures may be expected. Because native grasses are cool-season species, they perform most of their growth and nutrient storage during the winter before the ground freezes and in the spring between ground thaw and summer heat. Grasses planted too close in time to ground freeze or in the spring may not have sufficient time to establish an adequate nutrient and moisture base to carry them successfully through summer dormancy. Irrigation may enhance the rate of survival should planting be performed late, but if dormancy is triggered by day length or temperature, such actions will be futile.

The second consideration for reclamation deals with competition from cheatgrass. As a component of nearly all communities on the Reservation, cheatgrass can be expected to invade the Facility at some point.

Plant community information presented in the Basalt Isolation Project Exploratory Shaft Site Report (200 West Area), and summarized above, is applicable to the Facility. The strategy employed at the Exploratory Shaft Facility was to introduce as many species as possible from seed, supplement them with nutrients, irrigate for approximately one year, and establish spiny hopsage by planting tubeling stock. The site was irrigated from March through June at a rate of about one inch (2.5 cm) per month. This program appears to have been successful in restoring vegetation[34].

2.6.1.3 Root Depth

The DOE, through its subcontractor Pacific Northwest Laboratory (PNL), has performed studies documenting rooting depths and distributions of deep-rooted plants common to the Reservation's 200 Areas (Separations Area). PNL concentrated on excavating plant species suspected of having deep root systems and species that have been reported in previous studies to contain radionuclides in above-ground parts.

Fourteen species, including 58 individual plants were excavated to measure maximum rooting depth and to determine root density through the root zone. Eight of the fourteen

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[33] Brandt et al., 1989, op. cit.

[34] Brandt et al., 1989, op. cit.

species excavated had average rooting depths of about 59 inches (150 cm) or more. The two deepest rooted plants were antelope bitterbrush and big sagebrush with average depths of about 116.5 and 78.7 inches, respectively (296 and 200 cm). These are commonly found throughout the 200 East Area. Gray rabbitbrush, another persistent shrub found in this area had an average rooting depth of about 72 inches (183 cm). The summer annuals Russian thistle and bursage are common to sandy areas of the Hanford site, including the 200-Area plateau. They have average rooting depths of about 67.7 and 63.8 inches, respectively (172 and 162 cm)[35].

2.6.1.4 Threatened or Endangered Plant Species

The Washington Natural Heritage Program, administered by the Department of Natural Resources, is tasked with monitoring the status of vascular plants in the state of Washington. Plant species are designated as endangered, threatened, sensitive, or monitored according to the species' status in Washington state. Columbia milkvetch (*Astragalus columbianus*) and Hoover's desert parsley (*Lomatium tuberosum*) are listed as threatened, and persistent sepal yellowcress (*Rorippa columbiae*) and northern wormwood (*Artemisia campestris borealis* var. *wormskioldii*) are designated as endangered. These four plant species are also listed as candidate species by the Federal government. The Dwarf evening primrose (*Oenothera pygmaea*) is listed as threatened by Washington State. Columbia milkvetch occurs on dry land benches along the Columbia River in the vicinity of Priest Rapids Dam, Midway, and Vernita; it also has been found on top of Umtanum Ridge and in Cold Creek Valley near the present vineyards. Hoover's desert parsley grows on steep talus slopes in the vicinity of Priest Rapids Dam, Midway, and Vernita. Yellowcress occurs in the wetted zone of the water's edge along the Columbia River. Northern wormwood is known to occur near Beverley and could inhabit the northern shoreline of the Columbia River across from the 100 Areas.

Thompson's sandwort (*Arenaria franklinii v. thompsonii*) is listed as a monitored species and is known to occur in stabilized sand dunes in the vicinity of the 200 Areas. Other plant species designated as sensitive by the Washington State National Heritage program and likely to be found in the dryland areas of the Hanford Site are Piper's daisy (*Erigeron piperianus*) and gray cryptantha (*Cryptantha leucophaea*). False yarrow (*Chaenactis douglassii* var. *glandulosa*) is also likely to be found in these areas, but it has been re-classified from a sensitive species to a monitored species. A recent survey of the proposed ERDF site identified stalked-pod milkvetch (*Astragalus sclerocarpus*), a Washington State monitored species, as the only state-listed plant present.[36]

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[35] Klepper, E.L., Gano, K.A., and L.L. Cadwell, 1985, Rooting Depth and Distributions of Deep Rooted Plants in the 200 Area Control Zone of the Hanford Site, PNL-5247, Pacific Northwest Laboratory, Richland, Washington, p. iii, second paragraph.

[36] Department of Energy, 1994, op. cit., p. 2-37 and 2-38

2.6.1.5 Wildlife

2.6.1.5.1 Birds.

The horned lark and western meadowlark are the most abundant nesting birds in the shrub-steppe found on the Reservation[37]. The game birds found on the Reservation are the chukar, gray partridge, and mourning dove. The chukar and gray partridge are year-round residents, while mourning doves are migrants. Mourning doves nest on the ground and in trees all across the Hanford Reservation. Chukars are most numerous on Rattlesnake Mountain, Yakima Ridge, Umtanum Ridge, Saddle Mountains, and Gable Mountain areas and are somewhat rare on the 200 Areas Plateau (Separations Area); however, a few birds are known to inhabit the plateau. Gray partridges are not as numerous as chukars; their numbers also vary greatly from year to year.

In recent years, the number of nesting ferruginous hawks has increased, at least in part because the hawks have accepted steel powerline towers as nesting sites. Only about 50 pairs are believed to be nesting in the state of Washington. Other raptors that nest on the Reservation are the prairie falcon, northern harrier, red-tailed hawk, Swainson's hawk, and kestrel. Burrowing owls, great horned owls, barn owls, and long-eared owls also nest on the Reservation but in smaller numbers.

2.6.1.5.2 Mammals

Approximately 39 species of mammals have been identified on the Reservation. The largest vertebrate predator found on the Reservation is the coyote, which ranges across the site. Bobcats and badgers also inhabit the Reservation in low numbers. Black-tailed jackrabbits are common, mostly associated with mature stands of sagebrush. Cottontails are also common but appear to be more closely associated with the buildings, debris piles, and equipment laydown areas associated with laboratory and industrial facilities.

Townsend's ground squirrels occur in colonies of various sizes scattered across the Reservation, and marmots are scarce. The most abundant mammal inhabiting the Site is the Great Basin pocket mouse. It occurs all across the Columbia River plain and on the slopes of the surrounding ridges. Other small mammals include the deer mouse, harvest mouse, grasshopper mouse, montane vole, vagrant shrew, and Merriam's shrew.

Seven species of bats inhabit the Reservation, occurring mostly as fall or winter migrants. The pallid bat frequents deserted buildings and is thought to be the most abundant of the various species. Other species include the hoary bat, silver-haired bat, California brown bat, little brown bat, Yuma brown bat, and Townsend's big-eared bat.

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[37] Department of Energy, 1994, op. cit., p. 2-36, Section 2.8.1.4.

2.6.1.6 Burrowing Animal Depth

Burrowing animals, ranging in size from small invertebrates (such as ants) to medium size mammals (including badgers) have the potential to dig through soil covers and move contaminants to the surface after contacting buried waste. A 1982 Pacific Northwest Laboratory Report recorded badger excavation depths to 5 feet (1.5 m). The Westinghouse Hanford 1990 "Animal Intrusion Status Report" reported maximum depth of burrows for small mammals like the pocket mouse, pocket gopher and ground squirrel of approximately 5 feet (1.5 m). Since badgers prey almost entirely on burrowing rodents, their excavations are similar in depth to rodents.

The depth of burrow construction, in general, is influenced by the depth of the average frost line in the area. The frost line for the Reservation is 3.5 feet (1.1 m)[38]. This depth penetrates only the upper portion of the design cap described in Section 3.

2.6.1.7 Threatened or Endangered Animal Species

No federally designated threatened or endangered animal species are known to inhabit the Facility. However, the bald eagle (*Haliaeetus leucocephalus*), a threatened species, and the peregrine falcon (*Falco peregrinus*), an endangered species, have been seen on the Reservation and may pass over the Facility. No critical habitat is designated in the region, and no suitable habitat exists on the Facility to attract them. Three additional species considered as candidates for listing as threatened or endangered species may use the Reservation. The ferruginous hawk (*Buteo regalis*) and the Swainson's hawk (*Buteo swainsoni*) may hunt for prey on the Facility (no nest sites are known or expected on the Facility), and the long-billed curlew (*Numenius Americanus*) probably nests on or near the Facility in small numbers. The ferruginous hawk is classified as threatened by the State of Washington Department of Game. The same department also lists several species of animals common to the Hanford Reservation as "sensitive," although it is not known if they are found on the leasehold. Examples include the Swainson's hawk, golden eagle, prairie falcon, burrowing owl, and loggerhead shrike.

2.7 HYDROLOGY

The hydrology of the Reservation, including the Facility and the surrounding Separations Area (200 Areas), has been the subject of many investigations and summaries over a period of about 40 years.

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[38] Sowers, G. F., 1979, Introductory Soil Mechanics and Foundations: Geotechnical Engineering, fourth edition, Macmillan Publishing Company, New York, New York., p. 141, Figure 3.30.

2.7.1 Regional Hydrology

The regional hydrology of the Hanford Reservation is directly related to the semiarid climate. Small amounts of precipitation (about 6.3 inches (16 cm) per year) and an active zone of evapotranspiration limit infiltration and groundwater recharge. With the exception of the Columbia and Yakima Rivers, and several man-made disposal ponds, surface water at the Reservation is ephemeral.

Away from the Columbia and Yakima Rivers, a thick vadose zone overlies the saturated zones at the Reservation. Groundwater at the Reservation occurs under both unconfined and confined conditions. Each of these components is discussed in the following sections.

2.7.1.1 Vadose Zone

The vadose zone at the Reservation thickens away from the rivers. The depth to water ranges from one foot (0.3 m), near the Columbia River, to 350 feet (107 m) near the center of the Reservation. The vadose zone may consist of the surficial soils, Hanford Formation, pre-Hanford/post-Ringold units, or the upper and middle portions of the Ringold Formation, depending on the location and the water table elevation. The low soil moisture content, low precipitation and high evapotranspiration reduces the potential infiltration through the unsaturated sediments in the basin.

2.7.1.2 Unconfined Aquifer

2.7.1.2.1 Extent

The unconfined aquifer is contained within the Hanford and Ringold formations and is bounded below by either the basalt surface or, in places, by the relatively impermeable clays and silts of the lower unit of the Ringold Formation. The unconfined aquifer is bounded laterally by the anticlinal basalt ridges and by the Yakima and Columbia Rivers.

2.7.1.2.2 Infiltration and Recharge

The unconfined aquifer is recharged by the infiltration of precipitation along the flanks of the basalt ridges and from runoff in ephemeral streams, such as Cold Creek and Dry Creek. The Yakima River recharges the unconfined aquifer as it flows along the southwest boundary of the Hanford Reservation. The unconfined aquifer is also subject to recharge from man-made sources. Artificial recharge occurs from the infiltration of irrigation water. The irrigation occurs on property outside the boundaries of the Reservation and does not impact the water levels at the Facility. The nearest Reservation property line is 6.2 miles (10 km) away.

The major source of artificial recharge was wastewater disposal by the DOE. This liquid waste was generated by fuel reprocessing activities in the 200 East and 200 West

Areas. The wastewater generated in these areas was disposed of in infiltration basins. Wastewater disposal altered the groundwater flow directions and gradients at the Reservation. Figure 2-11 shows the water table configuration prior to wastewater disposal operations. Beneath the liquid infiltration basins, groundwater mounds developed in response to the artificial recharge (Figure 2-12). The water table within the 200 West Area has risen 80 feet (24 m) since inception of disposal operations in 1944[39]. The rate of increase in the water table was most rapid from 1950 to 1960. Small increases in the water table elevation occurred from 1970 to 1980 with water levels data from 1988 most nearly corresponding to the highest groundwater levels measured in the recent past[40].

Studies have shown that the existing groundwater flow pattern may reverse and return to the pre-operational pattern if the artificial recharge were discontinued. This recharge has apparently been discontinued. A general lowering of the water table is occurring beneath the 200 Areas in response to pond closures and a decrease in wastewater infiltration[41].

2.7.1.2.3 Previous Studies

During the past two decades, ongoing projects have been conducted by Rockwell, Westinghouse, and Battelle to characterize water balance on the Hanford Reservation. Most of these projects have utilized weighing and other types of lysimeters to gather data on changes in soil water storage, evapotranspiration, recharge, and net overland flow. Studies have been conducted at facilities near the 200 and 300 Areas, which were designed to study variations in soil type, barrier material type, vegetation, surface layer configuration, and precipitation[42]. These studies bound the climatic, soil, vegetation, and hydrogeologic conditions expected throughout the Reservation. The differing characteristics at the various facilities yield a range of recharge rates; however, the results are similar and indicate little recharge occurs at the Separations Area (200 Areas). Some of these studies are discussed below.

Large-scale lysimeter studies and soil moisture studies have been performed in the 200 Areas of the Hanford Reservation. These studies were performed over a number of years to collect field data representative of typical infiltration and recharge rates over a period of time. The 200 Areas are within the Separations Area, which includes the US

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[39] Department of Energy, 1994, op. cit., p. 2-19, second paragraph.

[40] Department of Energy, 1994, op. cit., p. 2-19, second and third paragraphs.

[41] Department of Energy, 1994, op. cit., p. 2-19, third paragraph.

[42] Rockhold, M. L., M. J. Fayer, G. W. Gee, and M. J. Kanyid, 1990, Natural Groundwater Recharge and Water Balance at the Hanford Site, PNL-7215, Pacific Northwest Laboratory, Richland, Washington, January, 1990, p. iii.

Ecology Facility and the ERDF site. These sites are close to each other, and study results yield similar findings. The conceptual model of the Closure Plan identifies an upper zone of active moisture movement, and a deeper zone of steady-state moisture movement. The studies presented below similarly recognize an upper zone where infiltrating water is removed by evapotranspiration, overlying a steady state zone where recharge rates are stable. The studies indicate that the infiltration rates measured in the upper zone are larger than the steady-state recharge rates.

Thermocouple psychrometers, which measure the vapor pressure (humidity) of soil air, were installed in 1969 in a deep well (699-32-490) located about 0.6 mile (1 km) south of the 200-East Area. Matric potential data were collected over a four-year period to depths of 295 feet (90 meters)[43]. The soil humidity can be related to the matric potential of the soil water via calibration. A comparison of the data collected with the equilibrium matric potential values for the unsaturated zone was interpreted to indicate that recharge was occurring. However, the rate of recharge could only be estimated, because the in-situ unsaturated hydraulic conductivity was not measured. In-situ unsaturated hydraulic conductivities were estimated from laboratory measurements, and used to calculate that the recharge rate could vary between 0.1 to 0.4 in/yr (0.3 to 1 cm/yr). Additional calculations using matric potential gradients and estimated hydraulic conductivities indicated recharge rates could vary between 0.01 and 1.6 in/yr (0.03 and 4 cm/yr). These values are estimates of the low recharge rates that move through the vadose zone.

Two 59 feet (18 m) deep, non-weighing lysimeters were constructed in 1971 about 0.6 mile (1 km) south of the 200-East Area. Vegetation was allowed to grow on non-weighing lysimeter surfaces. Measurements were made with neutron probes, thermocouples and thermocouple psychrometers. Calculated rates of recharge ranged from 0.1 to 1.2 in/yr (0.3 to 3.0 cm/yr); however, because of the uncertainty in the neutron probe measurements in estimating water content, the average recharge rate between 16.4 and 59 feet (5 and 18 meters) was estimated to vary between 0 and 0.4 in/yr (0 and 1 cm/yr). At the 200 East lysimeter facility, Westinghouse found no measurable accumulation of moisture at the base of the closed-bottom lysimeter after 13 years[44]. These results match the conceptual model developed for the site, which suggests low to undetectable amounts of recharge in the steady-state zone of moisture movement.

Groundwater infiltration rates have been estimated from tritium concentrations in the vadose zone in the 200 Areas. Nuclear weapons testing, started in 1952, resulted in

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[43] Brownell, L.E., Backer, J.G., Isaacson, R.E., Brown, D.J., 1975, Soil Moisture Transport in Arid Site Vadose Zones, ARH-ST-123, Atlantic Richfield Hanford Company, Richland, Washington.

[44] Routson, R. C., M. R. Fuchs, and W. A. Jordan, 1988, Recharge Estimates for the Hanford Site 200 Areas Plateau, WHC-EP-0046, Westinghouse Hanford Company, Richland, Washington.

elevated tritium concentrations in precipitation around the world. Measurements of the depth of penetration of infiltrating water from rainfall and snowmelt were examined near the 200 Area in well 12-B using tritium in soil moisture as a tracer. Tritium concentrations in core samples collected in 1969 indicated that the infiltrating water had migrated to 16.4 feet (5 meters) below the ground surface. One interpretation was that precipitation water had migrated steadily downward over a period of 20 years; assuming an average moisture content of 5%, an infiltration rate of 0.8 in/yr (2 cm/yr) was estimated[45]. Recharge values were not estimated from this study.

Unsaturated hydraulic conductivity measurements were made on soil samples from boreholes drilled at the ERDF. These samples were analyzed over a range of moisture contents, starting from saturated conditions, and gradually desaturating the samples. At the lowest moisture contents tested for each of the samples, unsaturated hydraulic conductivity values were less than 2.8×10^{-6} ft/day (1×10^{-9} cm/sec). For the same soil samples at the field moisture content, the estimated recharge rates for samples collected from the vadose zone ranged from 0.01 in/yr (0.025 cm/yr) to less than 0.0001 in/yr (0.0003 cm/yr). The authors determined from the results that the samples from the vadose zone show very low, if not zero, estimated recharge rates[46].

Soil moisture curves developed for soil samples collected in borings drilled to install monitoring wells at the US Ecology Facility[47], and soil moisture measurements made in lysimeters located about 0.6 mile (1 km) south of the 200-East Area were used to calculate groundwater recharge at the Facility. Typical moisture contents of 5 to 6 percent were estimated from the 200 Area lysimeters. Using these values for moisture content, an average unsaturated hydraulic conductivity of 4.25×10^{-5} ft/day (1.5×10^{-8} cm/sec) was estimated for the Facility. Applying a unit gradient to the unsaturated hydraulic conductivity yields a recharge rate of about 0.2 in/yr (0.5 cm/yr).

Soil moisture data for soil samples collected in the borings for the Facility wells indicate that the moisture content in the vadose zone at the Facility is similar to that measured at the 200 Area lysimeters. Although larger soil moisture contents are recorded in the near surface soil samples, the moisture content drops to levels of 2 to 3% (by weight) below 25 feet (7.6 m). This data is presented on the boring logs included in Attachment B of this Closure Plan. Converting to volumetric moisture yields a volumetric moisture content of about 4 to 5%, which is similar to the moisture content at the 200 Area

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[45] Heller, P.R., Gee, G.W., and Myers, D.A., 1985, Moisture and Textural Variations in Unsaturated Soils/Sediments Near the Hanford Wye Barricade, PNL-5377, Pacific Northwest Laboratory, Richland, Washington

[46] Conca, J. and Mockler, T.J., 1994, Measurement of unsaturated transport properties in soils from the ERDF site, included as Appendix B to Preoperational Baseline and Site Characterization Report for the Environmental Restoration Disposal Facility, Weekes, D.C., Ford, B.H., and Jaeger, G.K., 1995.

[47] Bergeron et al., 1987a, op. cit.

lysimeters. An average soil moisture content of 5.5% was selected from the Facility data and studies in the 200 Area lysimeter. This value is a conservative estimate that represents the current upper bound of moisture content at the Facility. A moisture content in this range would support a recharge rate of about 0.2 in/yr (0.5 cm/yr), similar to previous studies in the area.

2.7.1.2.4 Groundwater Movement

Groundwater in the regional unconfined aquifer moves from west to east (Figure 2-13) and discharges at perennial springs along the Columbia and Yakima Rivers, except during periods of high river stage. During periods of high river stage, water enters the aquifer from the rivers and is held as bank storage until the rivers return to normal pool elevations.

2.7.1.3 Confined Aquifers

The confined aquifers consist of sedimentary interbeds between basalt units. The basalt and some clay-rich interbeds serve as aquitards. Because of the physical and hydrologic separation from the unconfined aquifer, the confined aquifers are not significant to the regional or Facility hydrology and are not described in detail in this Closure Plan.

2.7.2 Facility Hydrology

2.7.2.1 Vadose Zone

Based on monitoring wells installed at the Facility, the vadose zone beneath the trenches is about 265 feet (81 m) thick, or extends to about 315 feet (96 m) below the ground surface. The boring logs for monitoring wells MW-5 and MW-10 are examined in detail in Section 4 of Attachment D. Using water levels recorded in the boring logs yielded a vadose zone thickness of 266 feet (81 m) at MW-5 and 265 feet (81 m) at MW-10. This yields a vadose zone thickness of about 265 feet (81 m). This value was selected as the vadose zone thickness for Closure Plan calculations.

The vadose zone consists of sediments with variable hydraulic properties and generally is composed of poorly-sorted sand with local admixtures of gravel, silt, and clay. Because of the low infiltration rates and low soil moisture content, water movement through the vadose zone is slow. The following Facility-specific discussion of infiltration and recharge focus on the estimated movement of water through the vadose zone.

2.7.2.1.1 Infiltration and Recharge

Infiltration, as discussed in this plan, is the amount of water that enters the ground surface. It differs from precipitation in that it does not include the amount of water that is removed by evaporation from the ground surface or leaf area, or the amount of water that runs off. Recharge, for the purpose of this study, is the amount of infiltration that

eventually reaches the water table. Recharge does not include the amount of infiltrated water that is removed by evaporation or transpiration, or the amount that is stored and reflected as changes in moisture content in the soil. Infiltration at the Facility is assumed to move predominantly downward, and not to migrate significantly laterally. The assessment of recharge at arid sites is often difficult because of the low moisture contents and the difficulty of calibrating measurement instruments. At low soil moisture contents, the calibration error can be a large part of the measured moisture content.

Recharge at the Facility is discussed in detail in various reports[48]. The recharge studies described in Section 2.7.1.2.3 generally support the low recharge rates expected in the 200 Areas. Several of the studies reflect the uncertainty in measuring the rate or even the direction of moisture movement at depths below 32.8 feet (10 meters), where moisture contents are very low, and when the hydraulic conductivity value is estimated, rather than measured. Most moisture movement occurred within the upper 13 to 20 feet (4 to 6 meters), and included the infiltration of water, and subsequent removal because of evapotranspiration[49].

Natural recharge was estimated based on current site conditions, using a unit hydraulic gradient approach, with moisture contents measured in the 200 East Area closed-bottom lysimeter and in soil samples from borings drilled at the Facility, and soil characteristic curves developed from soil samples collected from borings drilled at the Facility. The unsaturated hydraulic conductivity values for the Facility are measured in soil samples collected from monitoring wells installed on the Facility. Installation of three vadose zone wells at the Facility in 1991 has allowed a correlation between Facility hydraulic properties and those at the 200 East Area lysimeter, as determined by a comparison of soil sample data. Data from soil samples collected during the drilling and installation of those vadose zone wells include site-specific moisture content, grain-size analysis, bulk density, porosity, hydraulic conductivities, and soil characteristic curves. These data are contained in the report "Vadose Zone Monitoring Program for

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[48] Gee, G.W., Kirkham, R.R., 1984, Arid Site Water Balance: Evapotranspiration Modeling and Measurements, PNL-5177, Pacific Northwest Laboratory, Richland, Washington

Gee et al., 1985, op. cit.

Bergeron et al., 1987a, op. cit.

Gee, G.W., Wierenga, P.J., Andraski, B.J., Young, M.H., Fayer, M.J., Rockhold, M.L., 1994, Variations in Water Balance and Recharge Potential at Three Western Desert Sites.

Weekes et al., 1995, op. cit.

[49] Gee, G.W., and Heller, P.R., 1985, op. cit.

Low-Level Radioactive Waste Management Facility, US Ecology, Inc. Richland, Washington"[50].

The previous studies that were presented describe estimates of infiltration rates and recharge rates in the 200 Areas (Separations Area). An infiltration rate in the active moisture zone was estimated from the tritium study to be about 0.8 in/yr (2 cm/yr)[51]. Recharge rates in the deeper, steady-state moisture zone, have been estimated from tests in which the unsaturated hydraulic conductivity was measured, rather than estimated. These measurements ranged from 0 to 0.2 in/yr (0 to 0.5 cm/yr)[52]. Higher recharge rates were presented in other studies, but included estimated unsaturated hydraulic conductivity values. Based on the various recharge studies in the 200 Area, and supporting data collected from wells installed at the Facility, the natural recharge at the Facility is conservatively estimated to be 0.2 in/yr (0.5 cm/yr). This value was used for dose analysis calculations, in addition to the less conservative value 0.05 in/yr (0.13 cm/yr) which takes credit for closure cap performance.

2.7.2.1.2 HELP Model Studies

The HELP model was used to calculate the percolation of water through the designed cover for the Facility. The HELP model was used to compare different cover designs, and to examine the effects of increased precipitation on the amount of water that percolated through the cover. The implementation of the HELP model is discussed in greater detail in Section 3 "Cover Design" of this Closure Plan.

Two separate scenarios illustrate the modeled behavior of the cover over time. The HELP model was used to estimate the percolation through the cover using the typical annual precipitation of about 6.3 in/yr (16 cm/yr), and including one year of greater than normal precipitation of about 12.6 in/yr (32 cm/yr). An average annual recharge rate through the cap of 0.05 in/yr (0.13 cm/yr) was estimated by the HELP model for the proposed cover design. The HELP model also was modified to allow simulations over longer time periods. The HELP model was run for a period of 100 years, with multiple large storm events. The average recharge rate was calculated to be about 0.06 in/yr (0.15 cm/yr). The modeling results indicate that an arid site may experience increased infiltration during periods of abnormal rainfall, but the infiltration is removed by evapotranspiration during subsequent years of normal precipitation. Storage in the finer-grained sediments will hold excess infiltration, and release that water during

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[50] US Ecology, 1992, Vadose Zone Monitoring Program, March 1992.

[51] Gee, G.W., and Heller, P.R., 1985, op. cit.

[52] Bergeron et al, 1987a, op. cit.

Conca, J., and Mockler, T.J., 1994, op. cit.

periods of normal precipitation. Short periods of higher than average precipitation do not materially affect the average recharge to the groundwater.

For the dose analysis described in Section 5, two cases are considered. For the scenario of an intact cover (e.g., a cover which has not been altered beyond its design parameters through erosion or excavation), the percolation through the cover is expected to be less than 0.05 inches per year (0.13 cm/yr). For the scenario of natural recharge, the percolation rate is expected to be about 0.2 inches per year (0.5 cm/yr).

2.7.2.2 Saturated Zone

The water table at the Facility is encountered at a depth of approximately 315 feet (96 m) below the ground surface, or at elevations ranging from about 403 to 410 feet (123 to 125 m) mean sea level based upon Facility groundwater depth measurements. This is about 265 feet (81 m) below the trench bottoms. The water table beneath the US Ecology site is in the upper part of the silty sands and gravels of the middle member of the Ringold Formation.

Aquifer parameters that are necessary for the dose analysis include aquifer thickness, aquifer recharge, infiltration, and hydraulic properties. Each of these items is discussed in the following sections.

2.7.2.2.1 Aquifer Thickness

Geologic data from characterization borings and wells drilled at the Facility and within the Separations Area (200 Areas) were used to characterize the saturated thickness of the unconfined aquifer. Borings that do not penetrate the entire saturated thickness (such as the five monitoring wells installed at the Facility) provide minimum bounds on the saturated thickness, while borings that penetrate the entire saturated thickness at locations near the Facility provide approximate aquifer thickness.

Recent information gathered at the nearby ERDF site also yields an estimate of the aquifer thickness near the Facility[53]. This report describes the unconfined aquifer beneath the Hanford Site as being laterally extensive with saturated thicknesses ranging up to 295 feet (90 m) beneath the 200 West Area. The report indicates that the unconfined aquifer thins and is locally absent along the flanks of anticlinal structures in the area. This discussion on estimation of aquifer thickness has been further divided into Direct Measurements and Indirect Measurements.

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[53] Department of Energy, 1994, op. cit.

2.7.2.2.1.1 Direct Measurements

A hydrologic study of the Separations Area (200 Areas) resulted in the installation of 35 monitoring wells in the 200 East and 200 West Areas[54]. In the 200 West Area, four of nineteen borings penetrated the unconfined aquifer and reached the clay unit of the Lower Member of the Ringold Formation. Saturated thickness of the unconfined aquifer in this location ranged from 215 to 274 feet (65 to 83 m). Twelve of sixteen borings drilled in the 200 East Area also penetrated the unconfined aquifer. These borings were drilled in the northern portion of the 200 East Area, and terminated in basalt. Saturated thickness of the unconfined aquifer ranged from 0 to 46 feet (0 to 14 m). Well locations are shown on Figure 2-14.

Additional drilling has been performed at the ERDF site[55] adjacent to the Facility. Six deep characterization borings, two shallow characterization borings, and three monitoring wells were drilled at the ERDF site. The six deep characterization borings were advanced until the saturated zone was encountered. The two shallow characterization borings were stopped in the vadose zone. The three groundwater monitoring wells were advanced about 20 to 30 feet (6 to 9 m) into the unconfined aquifer, and screened in the upper 20 to 30 feet (6 to 9 m) of the unconfined aquifer. None of the nine borings (six deep soil borings, three monitoring wells) fully penetrated the unconfined aquifer. Two additional monitoring wells are planned to be installed in 1996 at the ERDF, but neither is to be drilled through the unconfined aquifer.

An upgradient well, number 699-36-70A, was installed at the ERDF site. The boring for this well was advanced through the unconfined aquifer to the underlying clay layer that forms the lower member of the Ringold Formation. A saturated thickness of about 180 feet (55 m) was estimated from a cross-section incorporating this boring[56]. The boring was subsequently backfilled to a depth about 20 to 30 feet (6 to 9 m) into the unconfined aquifer, and the well was screened in the upper portion of the aquifer.

Another upgradient well, number 699-32-72A, was installed at the ERDF site. The boring for this well was advanced through the unconfined aquifer to an underlying confined aquifer. A saturated thickness of about 190 feet (58 m) was estimated for the unconfined aquifer from a cross-section incorporating this boring[57]. The boring was completed in the unconfined aquifer with perforated casing, and in the confined aquifer with a well screen.

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[54] Last et al., 1989, op. cit.

[55] Weekes et al., 1995, op,. cit.

[56] Department of Energy, 1994, op. cit.

[57] Weekes et al., 1995, op. cit.

2.7.2.2.1.2 Indirect Measurements

A hydrologic characterization report of the Separations Area (200 Areas) presents a summary of pump test results in the unconfined aquifer between 1945 and 1976[58]. The summary presents transmissivity and hydraulic conductivity results for wells in the unconfined aquifer; from these values, the saturated thickness can be calculated.

Three wells listed in the summary of pump test results are located within a 0.9 mile (1.5 km) radius of the center of the Facility. These wells are numbers 699-31-53, 699-33-56, and 699-36-61. The calculated saturated aquifer thicknesses for these wells are 117 feet (35.7 m), 91 feet (27.7 m), and 67 feet (20.4 m)(average of two tests that yielded 65 feet (19.8 m) and 69 feet (21 m)), respectively. These values are indicated on Figure 2-14. The average of these three values yields a saturated thickness of 92 feet (28 m) for the unconfined aquifer in the vicinity of the Facility. This average is within the range of 90 to 110 feet (27.4 to 33.5 m) saturated thickness for the middle member of the Ringold Formation[59].

Another report[60] presents aquifer test results for the same three wells in the unconfined aquifer. The text identifies test results for three wells located near the Facility, 699-31-53, 699-33-56, and 699-36-61. The saturated thickness for the unconfined aquifer at these three wells is listed as 127 feet (38.7 m), 88 (26.8 m), and 65 feet (19.8 m), respectively. The average of these three values yields a saturated thickness of 93 feet (28.3 m) for the unconfined aquifer in the vicinity of the Facility.

Based upon the average value of these three wells the thickness of the unconfined aquifer beneath the Facility is about 100 feet (30.5 m). This value is used as the aquifer thickness value in calculations.

2.7.2.3 Hydraulic Gradient of Saturated Zone

Groundwater flow determined from water levels measured at the Facility has been shown to be in an easterly to northeasterly direction. Measured hydraulic gradients have been of the order of 0.003-0.004 foot per foot (ft/ft) (Figure 2-15). The groundwater gradient at the site corresponds to the gradient determined from DOE wells in the vicinity of the site as indicated in Figure 2-16. The regional hydraulic gradient for the Hanford Reservation is steeper near Rattlesnake Mountain and flattens towards the Columbia River to the east. An average hydraulic gradient of about 0.003 ft/ft was measured from Facility potentiometric maps (Figure 2-15).

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[58] Graham, M.J., Hall, M.D., Strait, S.R., Brown, W.R., 1981, Hydrology of the Separations Area, RHO-St-42, Rockwell International, Richland, Washington

[59] Bergeron et al., 1987a, op. cit.

[60] Energy Research & Development Administration, 1975, op. cit.

Groundwater recharge from wastewater infiltration basins within the Reservation have altered the configuration of the water table[61]. Water level elevation data from DOE wells near the Facility indicate a water table rise of about 18 feet (5.5 m) between 1949 and the mid 1980s, and a small decrease since the mid 1980s (Figure 2-17). The recent decline is attributed to the discontinuation of some waste disposal operations in the late 1980s. These operations are not expected to resume. This will alter the configuration of artificial recharge and cause water levels to continue to decrease. Groundwater elevation measurements taken from the wells at the Facility confirm a decreasing trend of about 0.4 feet per year (0.12 m/yr) since their installation in 1986. Figure 2-18 is a hydrograph of Facility monitoring well water levels that reflect this trend.

2.7.2.4 Hydraulic Properties of Vadose and Saturated Zone

Hydraulic properties of the saturated and unsaturated zones and summaries of site-specific data are presented in several reports[62]. During the installation of US Ecology monitoring wells and trench construction, soil and sediment characterization data were obtained including particle size analysis, moisture retention curves, moisture contents, measured saturated hydraulic conductivities, calculated unsaturated hydraulic conductivities as a function of water content, and total porosity determinations. Geophysical data in the form of neutron, natural gamma, and density logs were also obtained. These data and descriptions of the methods and calculations performed in the data analyses are included in Appendix A of this Closure Plan.

Similar data have been collected recently at the ERDF site[63]. This location is adjacent to the Facility, has similar geology and hydrology, and can be considered to yield representative, site-specific hydraulic property values for the Facility. These hydraulic properties are further discussed below.

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[61] Department of Energy, 1987, op. cit., p. 4.20, second paragraph.

[62] Energy Research & Development Administration, 1975, op. cit.

Graham, M.J., Hall, M.D., Strait, S.R., Brown, W.R., 1981, Hydrology of the Separations Area, RHO-St-42, Rockwell International, Richland, Washington

Bergeron et al, 1987a, op. cit.

Last et al., 1989, op. cit.

Department of Energy, 1994, op. cit.

Weekes et al., 1995, op. cit.

[63] Weekes et al., 1995, op. cit.

2.7.2.4.1 Horizontal Hydraulic Conductivity of Saturated Zone

Saturated hydraulic conductivities of the middle member of the Ringold Formation have been measured from aquifer tests performed in the Separations Area (200 Areas), and the results have been reported in various reports[64]. The horizontal saturated hydraulic conductivities of the middle member of the Ringold Formation range from 9 to 230 feet per day (ft/day)(2.7 to 70 m/day)[65].

An aquifer pump test and slug test was performed in well 699-32-72B at the ERDF[66]. The well is located about 2.75 miles (4.4 km) west of the US Ecology Facility. The saturated hydraulic conductivity results ranged from 15 ft/day (4.6 m/day) to 50 ft/day (15.2 m/day).

Two wells located near the Facility (wells 699-36-61A and 699-33-56) had reported saturated hydraulic conductivity values of 43 ft/day (13 m/day) and 250 ft/day (76 m/day). These wells are located about 0.5 mile (0.8 km) west and southeast, respectively, of the Facility. These values are less than an order of magnitude different from each other; for a parameter that can vary as widely as hydraulic conductivity, these values are similar. The geometric average of the hydraulic conductivity values of the two wells yields a saturated hydraulic conductivity value of 100 ft/day (30.5 m/day). This value falls within the reported range of hydraulic conductivity values for the middle member of the Ringold Formation of 9 to 230 ft/day (2.7 to 70 m/day), and was used as the saturated hydraulic conductivity value for the unconfined aquifer.

2.7.2.4.2 Porosity of Vadose and Saturated Zones

The total porosity of a material is the percentage of the soil material that is comprised of voids; the effective porosity of a material is the percentage of interconnected void spaces. Total porosity values have been measured from soil samples collected from the borings drilled for the monitoring wells installed at the Facility[67], and from soil

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[64] Energy Research & Development Administration, 1975, op. cit.

Graham, M.J., Hall, M.D., Strait, S.R., Brown, W.R., 1981, Hydrology of the Separations Area, RHO-St-42, Rockwell International, Richland, Washington

[65] Energy Research & Development Administration, 1975, op. cit.

Graham, M.J., Hall, M.D., Strait, S.R., Brown, W.R., 1981, Hydrology of the Separations Area, RHO-St-42, Rockwell International, Richland, Washington

Bergeron et al., 1987a, op. cit.

[66] Weekes et al., 1995, op. cit.

[67] Bergeron et al., 1987a, op. cit.

samples collected from borings drilled at the ERDF site[68]. Effective porosity of sands and gravels can be estimated to be less than total porosity. The data from the Facility and the ERDF are discussed below.

An average total porosity value was calculated from the total porosity values calculated for soil samples from monitoring wells MW-5, MW-8 and MW-10 installed at the Facility[69]. This yields an average value of 43% for samples collected from the Hanford Formation. The report indicates the total porosity values were calculated from analyses of re-packed samples. Thus, these values may only approximate *in-situ* site values.

Data from soil samples collected from the Hanford Formation at the ERDF site yield a lower average total porosity value; these values are presented in Table B-1 of the ERDF Characterization Report[70]. An average of the reported total porosity for soil samples collected from the three groundwater monitoring wells, six deep characterization borings, and two shallow characterization borings yield a value of 37%.

Based on these values calculated from site-specific data, effective porosity values were estimated for the finer-grained materials above the water table (consisting primarily of the Hanford Formation). The average total porosity measured in the vadose zone ranged from 37 to 43%. From these values, the effective porosity of the vadose zone was estimated to be 30%.

Lower total porosity values were measured for the coarser-grained middle member of the Ringold Formation (ranging typically from about 11 to 19%, with a larger single value of 32%). Soil moisture curves developed from the coarser-grained soil samples collected from the middle member of the Ringold Formation support the smaller total porosity values with moisture retention ranging from 7.5 to 20.5%. Lower total porosity values are typical where finer-grained material in-fills the larger pore spaces[71].

An aquifer pump test and slug test was performed in well 699-32-72B at the ERDF[72]. This well screens the middle member of the Ringold Formation. A calculated specific yield value (which can be used as an approximation of effective or drainable porosity) was between 5 and 9%.

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[68] Weekes et al., 1995, op. cit.

[69] Bergeron et al., 1987a, op. cit.

[70] Weekes et al., 1995, op. cit., p. B-19.

[71] Freeze, R.A. and J.A. Cherry, 1979, Groundwater, Prentice-Hall, Englewood Cliff, N.J., p. 38.

[72] Weekes et al., 1995, op. cit.

From these values, a mid-range value of 10% will be used for the saturated zone effective porosity.

2.8 FLOODING POTENTIAL

Potential flooding in the vicinity of the Facility has been analyzed both on a local and regional basis. A detailed evaluation of local flooding in Cold Creek, a small ephemeral stream which flows through the Reservation, was performed using empirically derived methodologies[73]. The evaluation included development of maximum annual flood frequency curves, probable maximum flood peak discharges, and computation of water surface profiles.

2.8.1 Regional Flooding

Associated with evaluating maximum flooding is the concept of the probable maximum flood (PMF), which is determined from the upper limit of precipitation falling on a drainage area and other hydrologic factors (such as antecedent moisture conditions, snowmelt and tributary conditions) that would result in maximum runoff. The PMF for the Columbia River below Priest Rapids Dam is calculated as 1,400,000 ft^3/s (40,000 m^3/s)[74]. The floodplain associated with the PMF is shown in Figure 2-19. This magnitude flood would inundate the 100 Areas of the Reservation and large areas within the City of Richland. The 200 and 300 Areas as well as the central portion of the Hanford Site would remain unaffected.

The effects of a hypothetical 50% breach of Grand Coulee Dam were studied by the U.S. Army Corps of Engineers[75]. The resulting flow would be 8,000,000 ft^3/s (230,000 m^3/s)[76]. The resulting inundations from the 50% breach scenario are shown in Figure 2-20. In addition to the areas inundated by the PMF, the remainder of the 100 Areas, nearly all of the City of Richland, the 300 Areas, and the Washington State Public Power Supply System, Inc. reactor sites would be flooded. The Facility would not be affected by this event.

A third catastrophic event which was studied is river blockage and flooding due to landslides along the Columbia River. Calculations indicate that a 1 million-yd^3 (770,000 m^3) landslide concurrent with a flood flow of 600,000 ft^3/s (17,000 m^3/s) (200-year flood)

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[73] Skaggs, R. L. and W. H. Walters, 1981, Flood Risk and Analysis of Cold Creek Near the Hanford Site, PNL-4219, Pacific Northwest Laboratory, Richland, Washington, p. iii, second paragraph.

[74] Skaggs et al., 1981, op. cit., p. 14, second paragraph.

[75] U.S. Army Corps of Engineers, 1951, Artificial Flood Possibilities on the Columbia River, Washington District, Washington, D.C.

[76] Skaggs et al., 1981, op. cit., p. 14, second paragraph.

would result in a flood wave crest elevation of 400 ft MSL. A PMF of 1,400,000 ft^3/s (40,000 m^3/s) would result in a flood wave crest of 410 ft (125 m) MSL[77]. In both cases the Facility would be unaffected.

2.8.2 Local Flooding

The only major potential source of local flooding in the vicinity of the Facility from an off-site source is the Cold Creek watershed. The results of the hydraulic analysis[78] utilizing Probable Maximum Precipitation (PMP) and PMF peak discharge are illustrated in Figure 2-21. The analysis indicates the Facility would not be affected by this event.

2.9 TOPOGRAPHY

The central Reservation forms a gentle rise covered with dunes and small closed basins. Regional topography around the Facility is shown on the map included as Figure 2-22, the portion of the U.S. Geological Survey (USGS) Coyote Rapids, Washington, Quadrangle which includes the Facility at a scale of 1:62,500 with 20-foot contour intervals.

The existing topography of the Facility is shown on the Facility topographic map in Figure 2-23. The original topographic surface was a series of dunes and small closed basins typical of the surrounding area. However, surface features have been altered as a result of Facility development. The Facility has a general slope from north to south of approximately one percent.

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[77] Skaggs et al., 1981, op. cit., p. 17, first paragraph.

[78] Skaggs et al., op. cit., p. 20.

TABLE 2-1 MONTHLY & ANNUAL PREVAILING WIND DIRECTION, AVE SPEEDS & PEAK GUSTS AT 50 FT: 1945-1994

MONTH	PREVAILING DIRECTION	AVERAGE SPEED		HIGHEST AVERAGE		YEAR	LOWEST AVERAGE		YEAR	PEAK GUSTS			
		MPH	M/S	MPH	M/S		MPH	M/S		SPEED (mph)	SPEED (m/s)	DIRECTION	YEAR
JANUARY	NW	6.2	2.77	10.3	4.60	1972	2.9	1.30	1985	80	35.76	SW	1972
FEBRUARY	NW	7.0	3.13	10.8	4.83	1976	4.6	2.06	1963	65	29.06	SW	1971
MARCH	WNW	8.2	3.67	10.7	4.78	1977+	5.9	2.64	1958	70	31.29	SW	1956
APRIL	WNW	8.9	3.98	11.1	4.96	1972+	7.4	3.31	1989+	73	32.63	SSW	1972
MAY	WNW	8.8	3.93	10.7	4.78	1983	5.8	2.59	1957	71	31.74	SSW	1948
JUNE	WNW	9.1	4.07	10.7	4.78	1983+	7.7	3.44	1950+	72	32.18	SW	1957
JULY	WNW	8.6	3.84	10.7	4.78	1983	6.8	3.04	1955	69	30.84	WSW	1979
AUGUST	WNW	7.9	3.53	9.1	4.07	1946	6.0	2.68	1956	66	29.50	SW	1961
SEPTEMBER	WNW	7.5	3.35	9.2	4.11	1961	5.4	2.41	1957	65	29.06	SSW	1953
OCTOBER	WNW	6.5	2.91	9.1	4.07	1946	4.4	1.97	1952	63	28.16	SSW	1950
NOVEMBER	NW	6.3	2.82	10.0	4.47	1990	2.9	1.30	1956	67	29.95	WSW	1993
DECEMBER	NW	5.9	2.64	8.3	3.71	1968	3.3	1.48	1985	71	31.74	SW	1955
ANNUAL	NW	7.6	3.40	8.4	3.75	1983	6.2	2.77	1989	80	35.76	SW	JAN 1972

+ Also in earlier years

Source: Hoitink, D.J., and Burk, K.W., 1995, Climatological Summary 1994 with Historical Data, PNL-10554, Richland, Washington

TABLE 2-2

ESTIMATES OF EXTREME WINDS AT THE HANFORD STATION

	PEAK GUSTS mile /hr	
	50 ft	200 ft
Return Period, yr	Above Ground	Above Ground
2	60	68
10	71	80
100	85	94
1,000	99	109

(Source: DOE, 1987, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, p. 4.28, Table 4.9)

TABLE 2-3
PEAK 15-M (49 FEET) GUST RETURN PERIOD RECORD FOR THE HANFORD METEOROLOGICAL STATION (1949 THROUGH 1991)

		PEAK GUST			RETURN PERIOD		
YEAR	MONTH	(MPH)	(M/S)	DIRECTION	RANK	(YEARS)	ANNUAL PROBABILITY
1949	NOV	63	28.2	SSW	19	2.32	0.43
1950	OCT	63	28.2	SSW	19	2.32	0.43
1951	JAN	62	27.7	SSW	21	2.10	0.48
1952	DEC	52	23.2	SSE	41	1.07	0.93
1953	SEP	65	29.0	SSW	14	3.14	0.32
1954	NOV	56	25.0	SW	34	1.29	0.77
1955	MAR	58	25.9	SW	30	1.47	0.68
1956	MAR	70	31.3	SW	4	11.00	0.09
1957	JUN	72	32.2	SW	3	14.67	0.07
1958	NOV	58	25.9	WSW	30	1.47	0.68
1959	DEC	55	24.6	SSW	36	1.22	0.82
1960	NOV	59	26.4	SSW	27	1.63	0.61
1961	JUL	66	29.5	SW	8	5.50	0.18
1962	NOV	57	25.5	SSW	32	1.38	0.73
1963	MAR	65	29.0	SW	14	3.14	0.32
1964	MAR	53	23.7	WSW	40	1.10	0.91
1965	FEB	63	28.2	SW	19	2.32	0.43
1966	JAN	57	25.5	SSW	32	1.38	0.73
1967	JAN	65	29.0	SSW	14	3.14	0.32
1968	DEC	55	24.6	SW	36	1.22	0.82
1969	APR	60	26.8	WSW	25	1.76	0.57
1970	JUL	53	23.7	SSW	40	1.10	0.91
1971	FEB	65	29.0	SW	14	3.14	0.32
1972	JAN	80	35.8	SW	1	44.00	0.02
1973	DEC	51	22.8	SSW	42	1.05	0.95
1974	DEC	61	27.3	SW	23	1.91	0.52
1975	DEC	68	30.4	SSW	6	7.33	0.14
1976	MAR	65	29.0	SW	14	3.14	0.32
1977	NOV	59	26.4	SSW	27	1.63	0.61
1978	APR	64	28.6	SW	15	2.93	0.34
1979	JUL	69	30.8	WSW	5	8.80	0.11
1980	JAN	56	25.0	SW	34	1.29	0.77
1981	NOV	66	29.5	SW	8	5.50	0.18
1982	DEC	60	26.8	SSW	25	1.76	0.57
1983	MAR	65	29.0	W	14	3.14	0.32
1984	DEC	62	27.7	S	21	2.10	0.48
1985	JUL	48	21.5	NW	43	1.02	0.98
1986	MAR	54	24.1	S	38	1.16	0.86
1987	DEC	54	24.1	SSW	38	1.16	0.86
1988	APR	63	28.2	SW	19	2.32	0.43
1989	JAN	58	25.9	SW	30	1.47	0.68
1990	JAN	73	32.6	SW	2	22.00	0.05
1991	JAN	61	27.3	SW	23	1.91	0.52

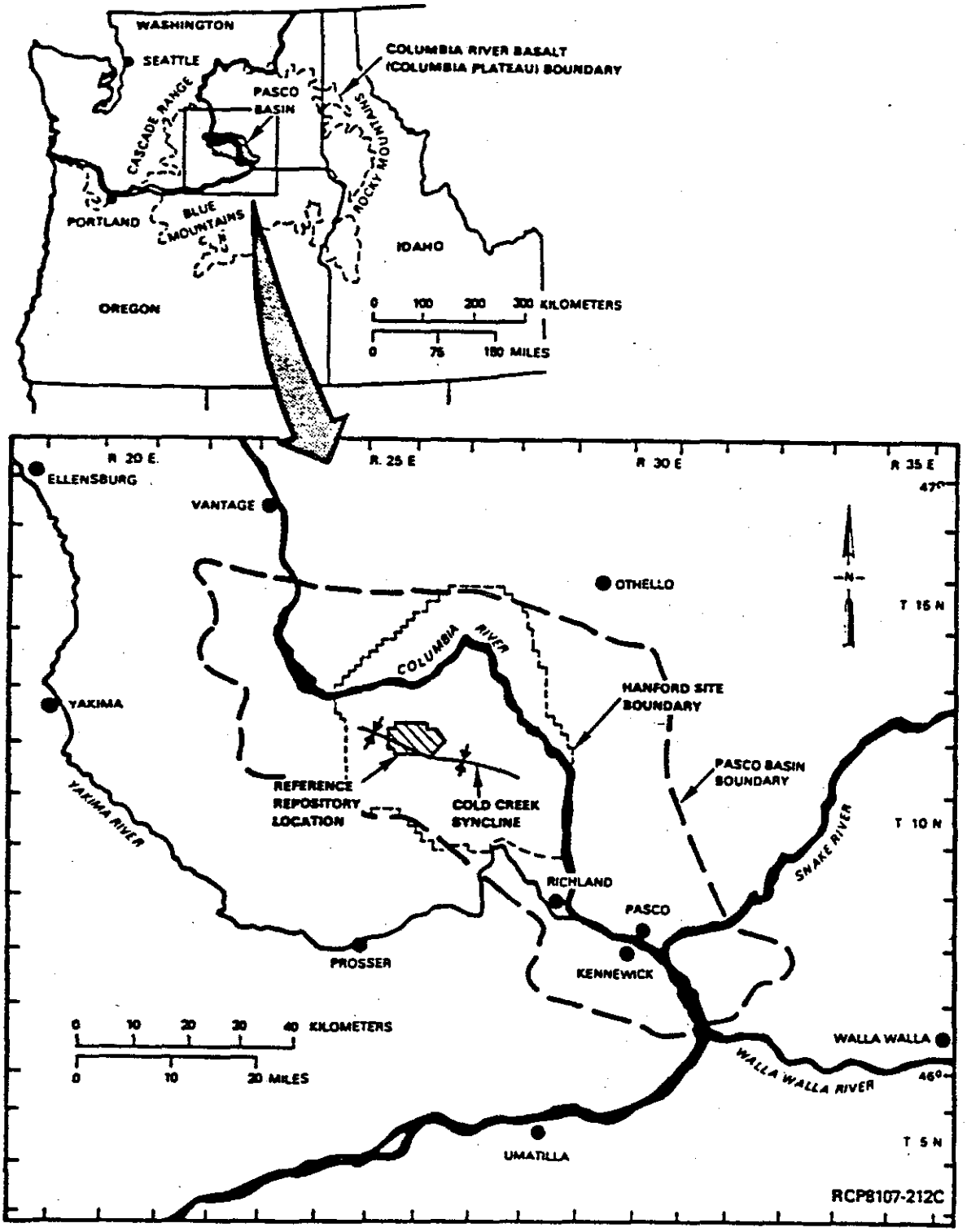
Source: Ligotke, 1993

TABLE 2-4

PRECIPITATION ABOVE AVERAGE

Period	No. Days w/Measurable Precipitation	Total Amount (inches) Water Equiv	Snowfall
Oct. 7-Nov. 4, 1947	17	2.21	0
Jan. 3-28, 1950	15	1.80	23.4
Nov. 11-Dec. 19, 1950	20	1.37	3.7
Nov. 16-Dec. 22, 1955	24	3.19	22.7
Oct. 31-Dec. 7, 1973	20	3.45	8.1
Nov. 15-Dec. 7, 1985	14	1.96	25.2
Dec. 27, 1992-Jan. 22, 1993	19	2.02	26.8

Source: Hoitink, D.J., and Burk, K.W., 1995, Climatological Summary 1994 with Historical Data, PNL-10554, Richland, Washington



SOURCE: DOE/RW-0164 1988 pp 2, Fig . 1

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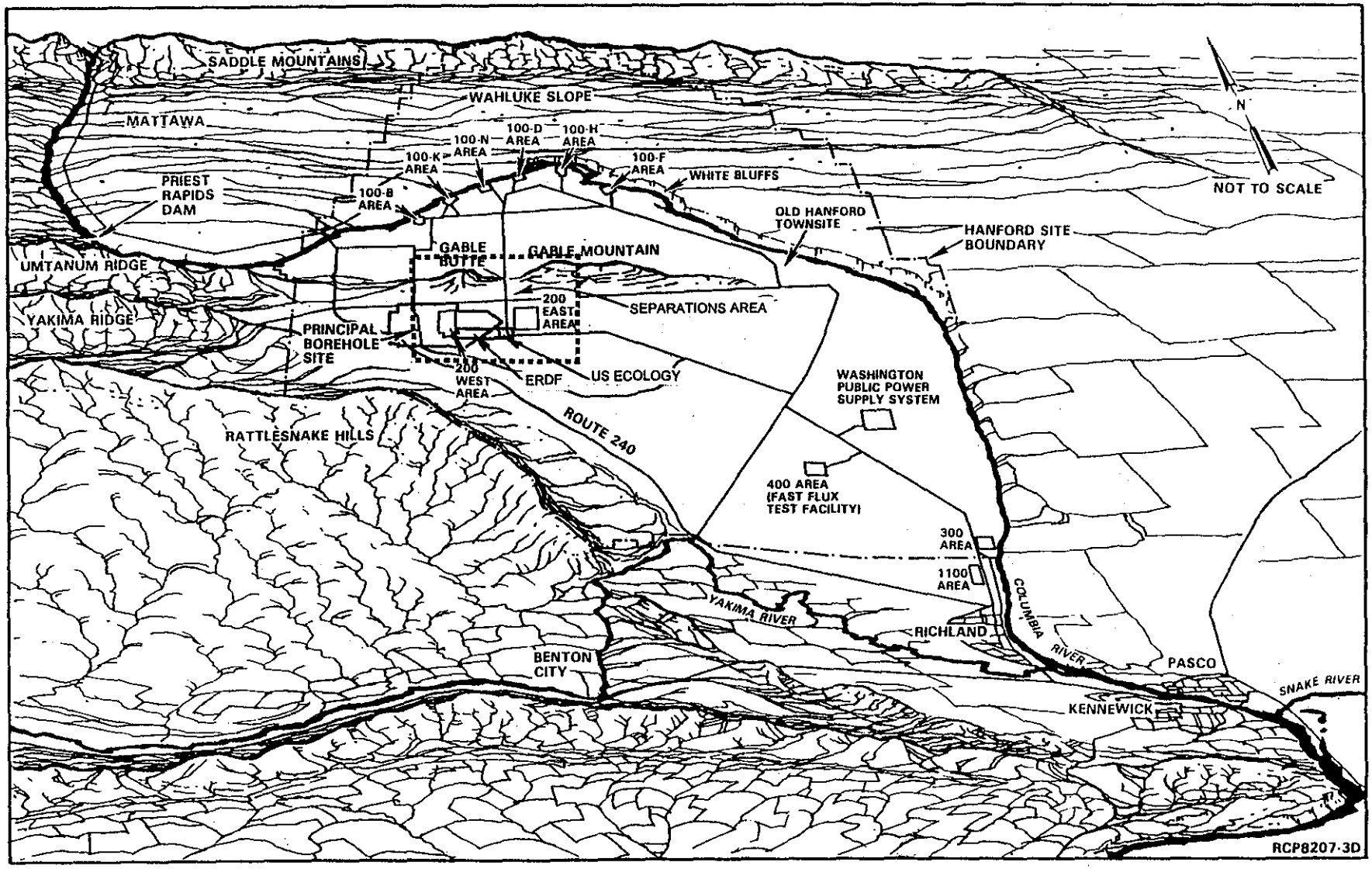
FIGURE 2-1

GEOGRAPHIC SETTING OF THE PASCO BASIN



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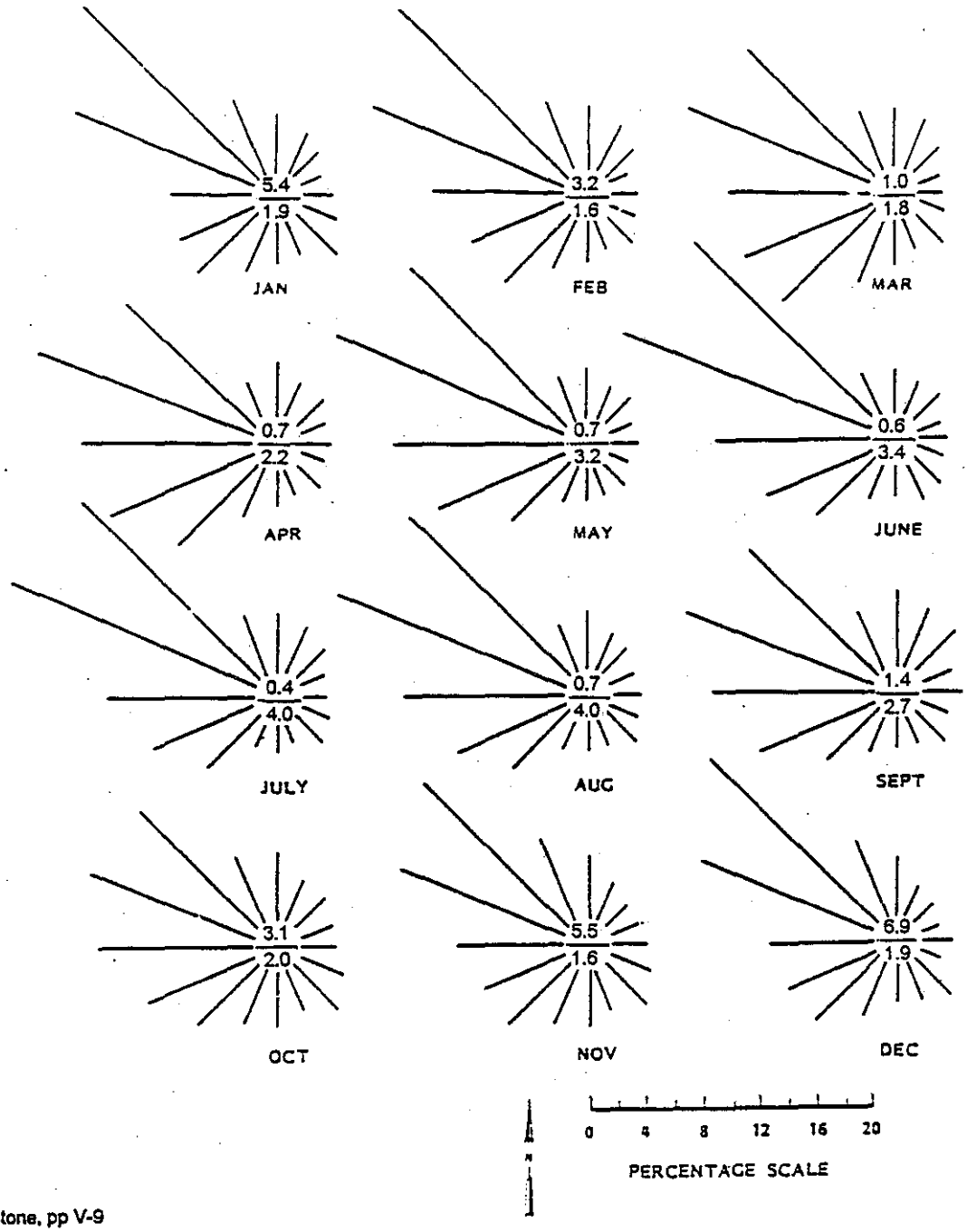
SOURCE: DOE 1988 (Site Char. Plan) pp 5, Fig. 3

FIGURE 2-2

DOE'S HANFORD SITE



SOURCE: Stone, pp V-9

Note: The numbers in the centers are the percentages of calm (top numbers) and variable (bottom numbers) winds. The points of the rose represent the directions from which the winds blow.

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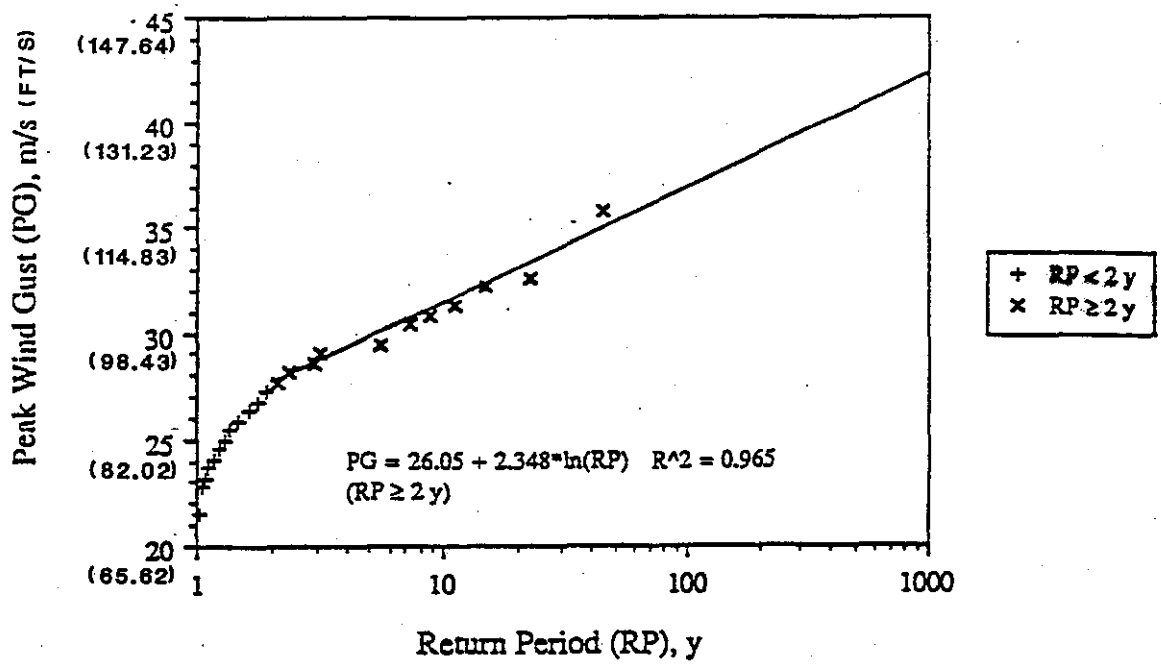
FIGURE 2-3

Monthly Wind Roses for HMS Based on 50-Foot Wind Data 1955 Through 1980



Peak 15-m Wind Gust Return Period for the Hanford Meteorological Station (1949 through 1991) - (Ligotke, 1993)

SOURCE: Ligotke 1993, pp 3.5, Fig. 3.2

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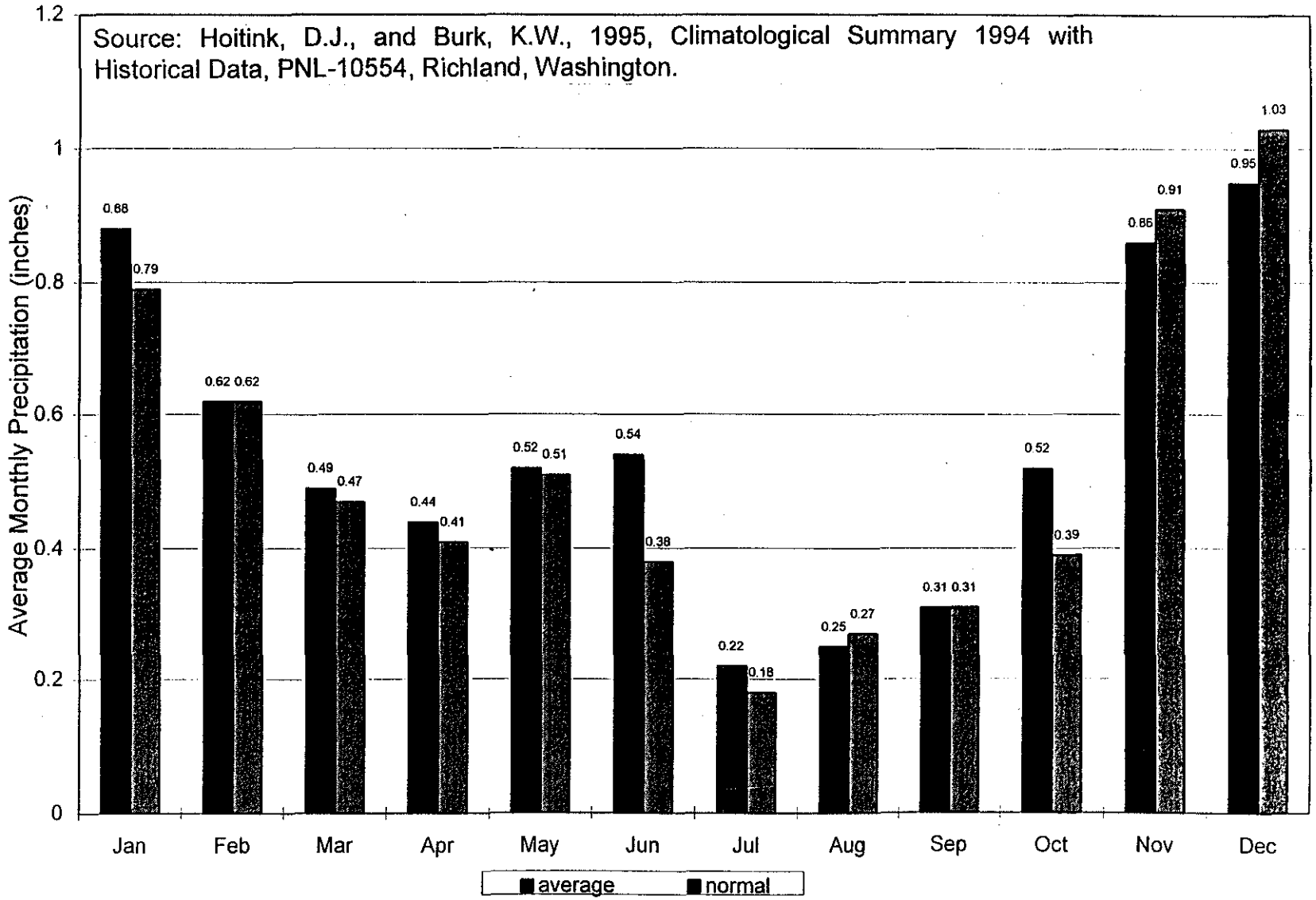
FIGURE 2-4

Peak 15-m Wind Gust Return Period for the Hanford Meteorological Station (1949-1991)



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Average is calculated for period 1946 - 1994.

Normal is calculated for period 1961 - 1994.

FIGURE 2-5

MONTHLY AVERAGE PRECIPITATION AMOUNTS: 1945-1994

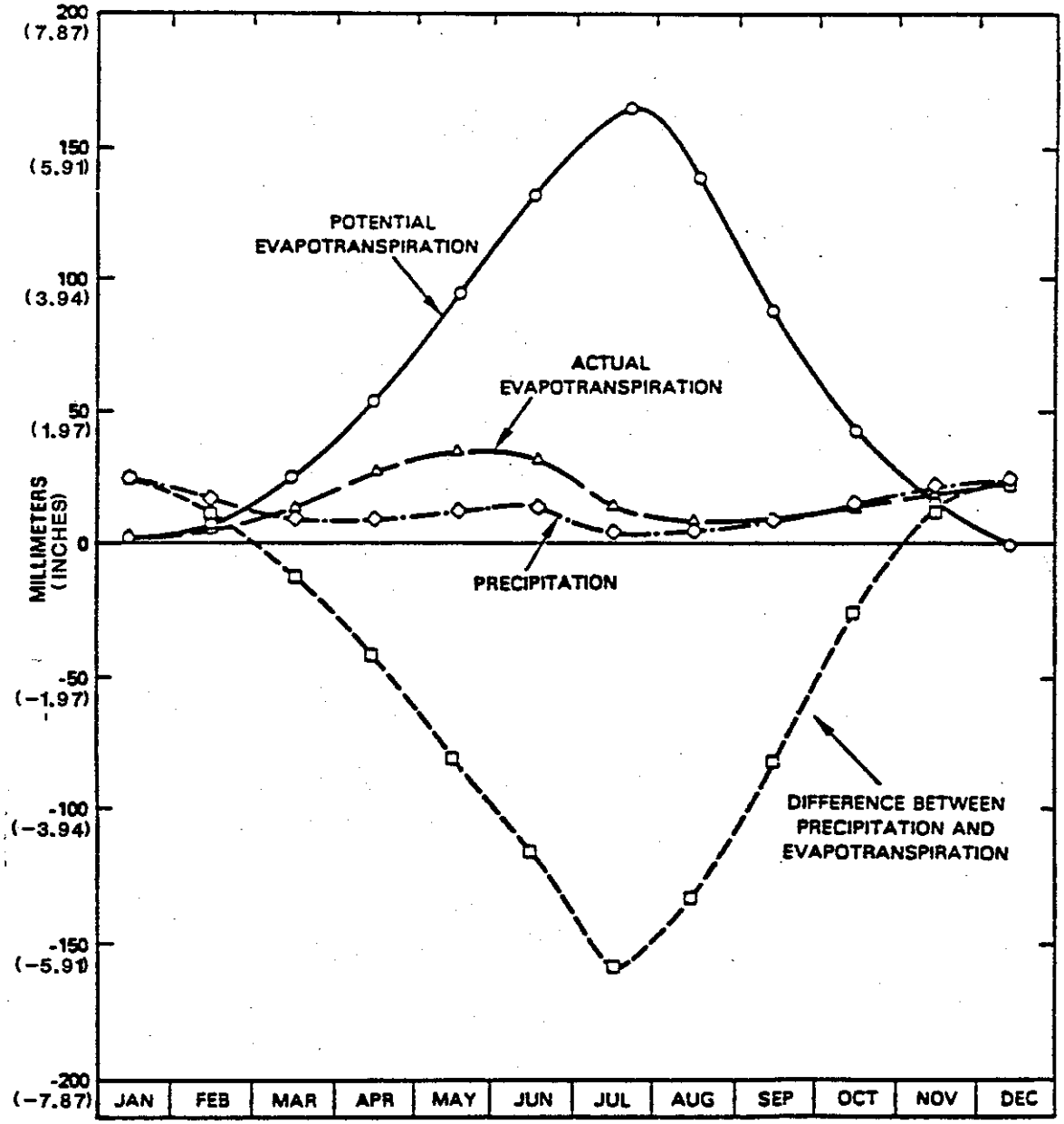

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FIGURE 2-6

WATER BALANCE AT HANFORD

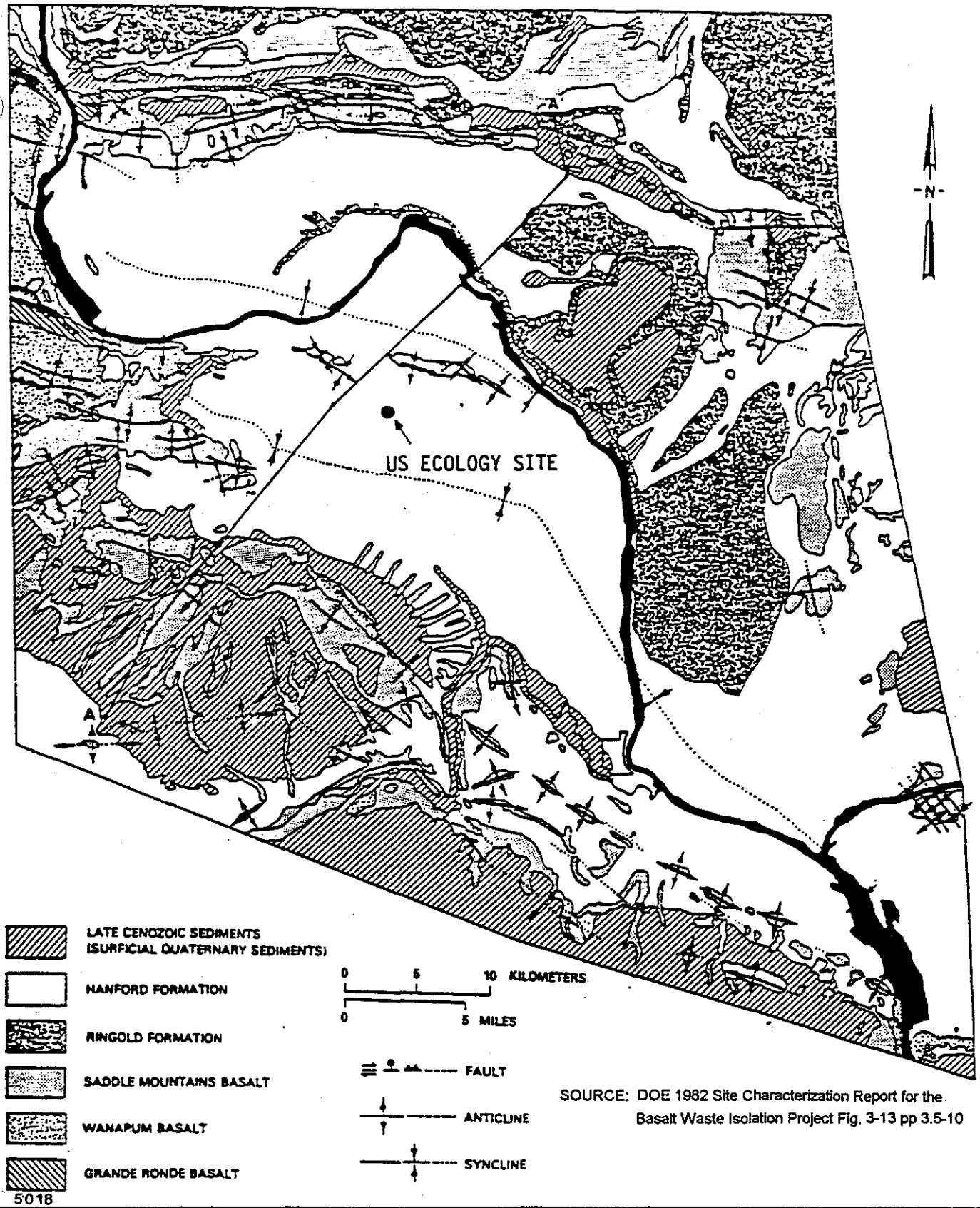

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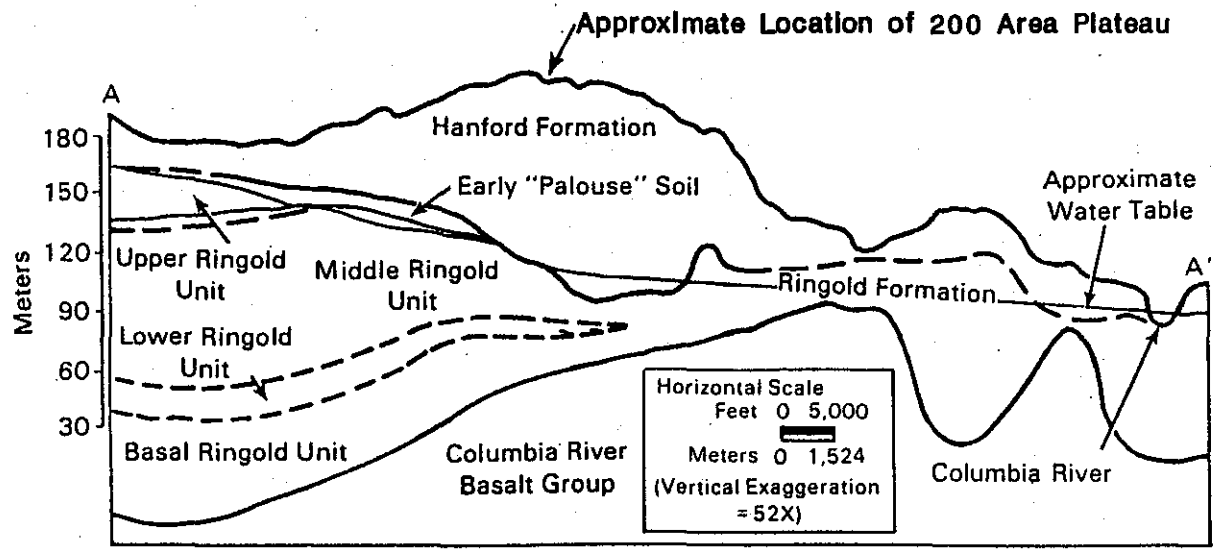
FIGURE 2-7

REGIONAL SURFICIAL GEOLOGY



SOURCE: DOE 1982 Site Characterization Report for the Basalt Waste Isolation Project Fig. 3-14 pp 3.5-11

5018

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FIGURE 2-8

GENERALIZED STRUCTURE CROSS-SECTION

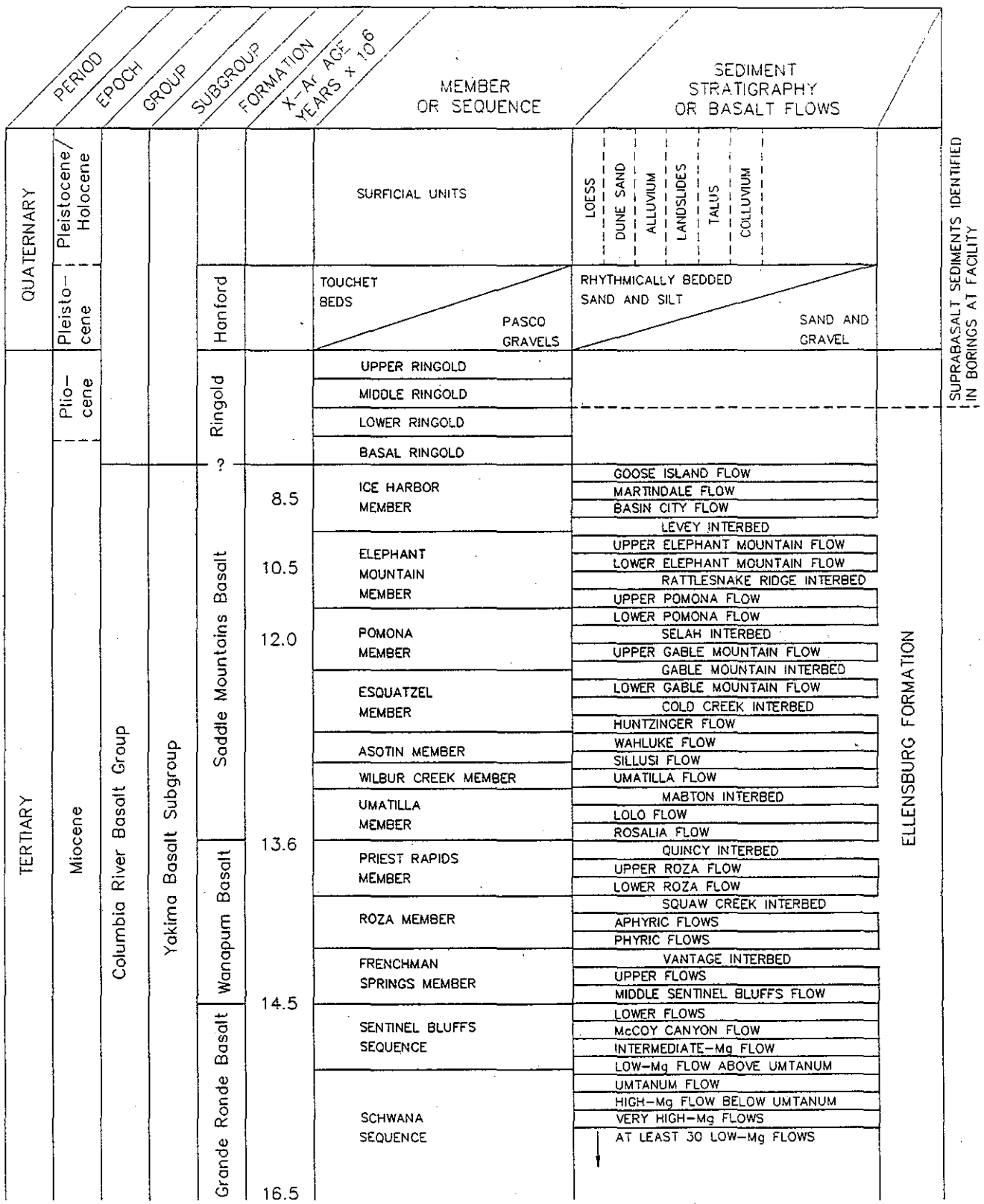

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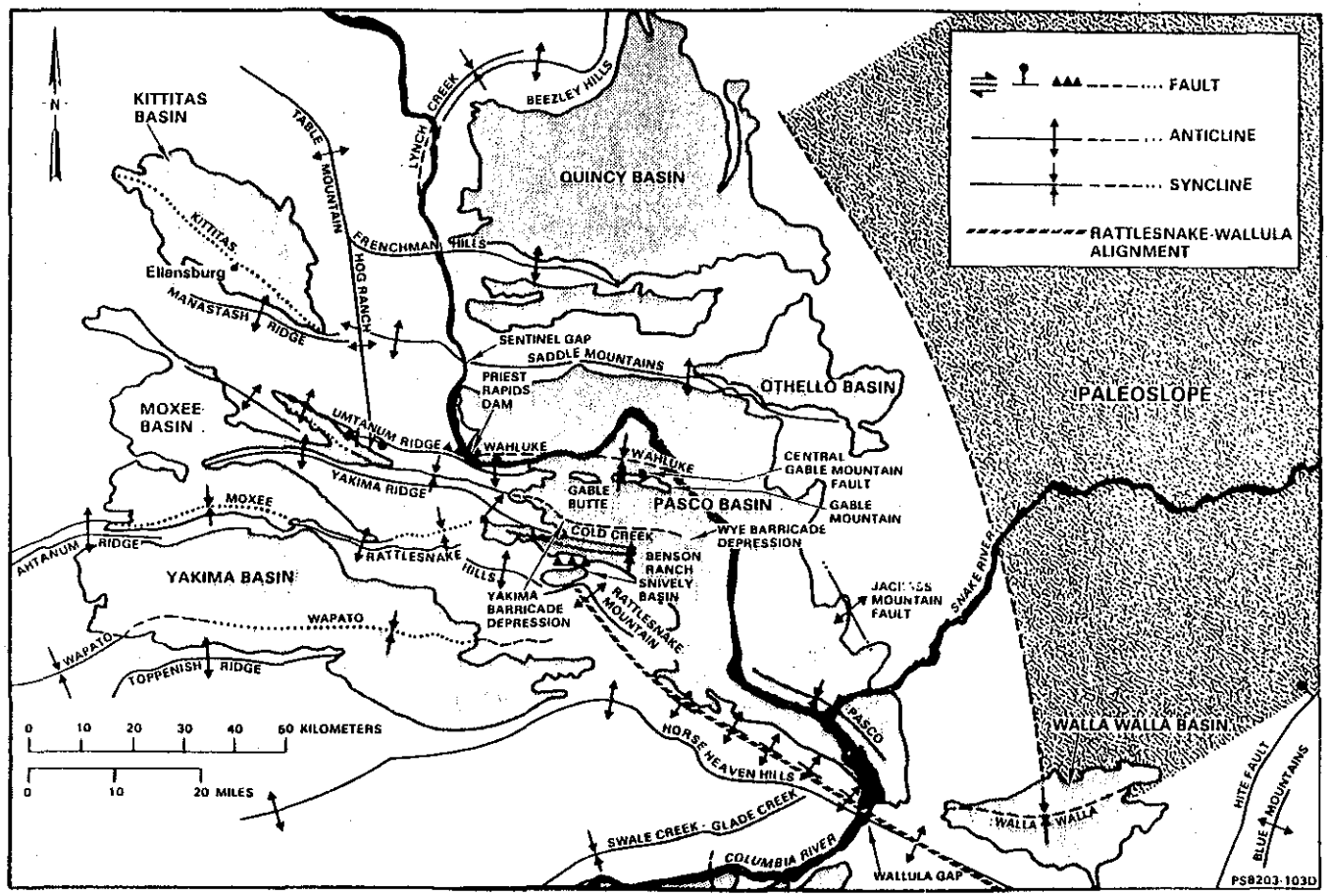
FIGURE 2-9

STRATIGRAPHIC NOMENCLATURE

5018\04\F... -9.DWG; 12/19/95



Source: DOE 1987, Fig. 4.5, pp. 4.11

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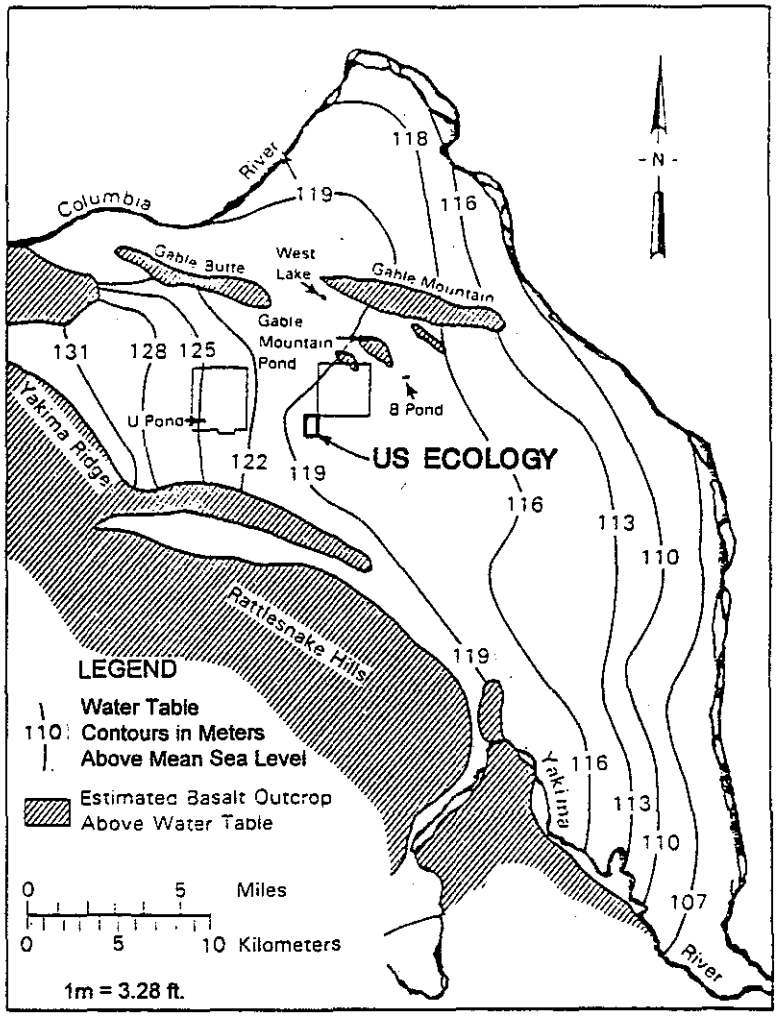
FIGURE 2-10

GENERALIZED STRUCTURE MAP OF CENTRAL PLATEAU



SOURCE: DOE 1987 Fig. 4.11, pp 4.21

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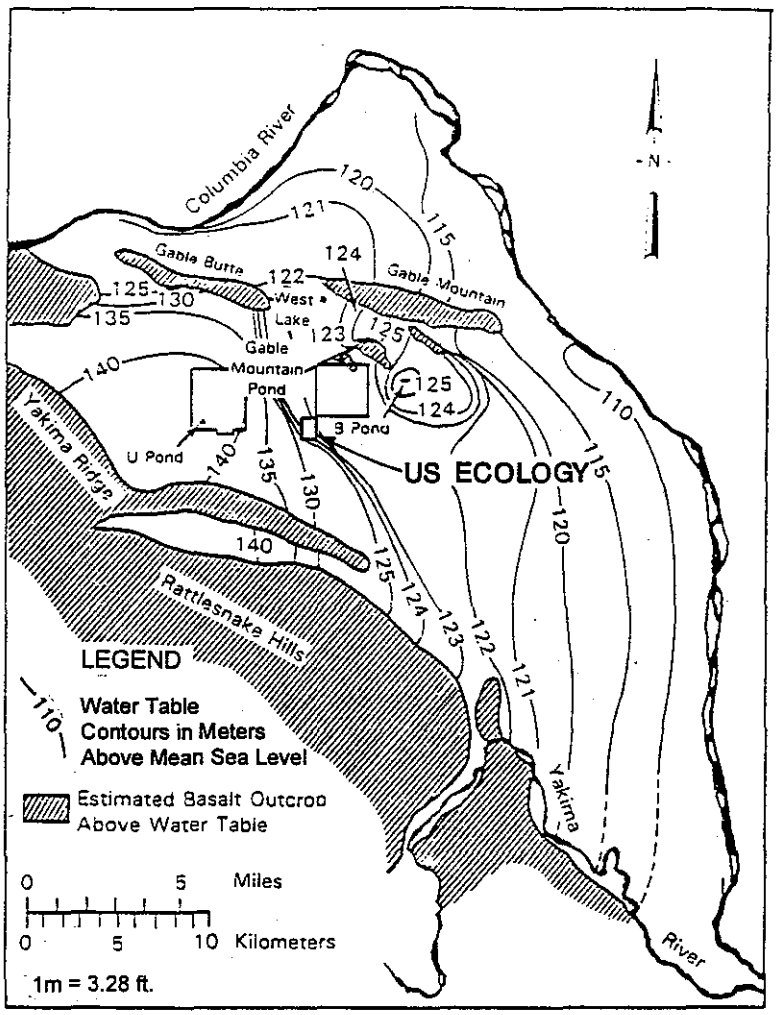
FIGURE 2-11

REGIONAL WATER TABLE ELEVATION MAP - JANUARY 1944



SOURCE: DOE 1987 Fig. 4.10, pp 4.20

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FIGURE 2-12

REGIONAL WATER TABLE ELEVATION MAP - DECEMBER 1982

Figure 3-2

HELP MODEL

100-Year Synthetically Generated Precipitation

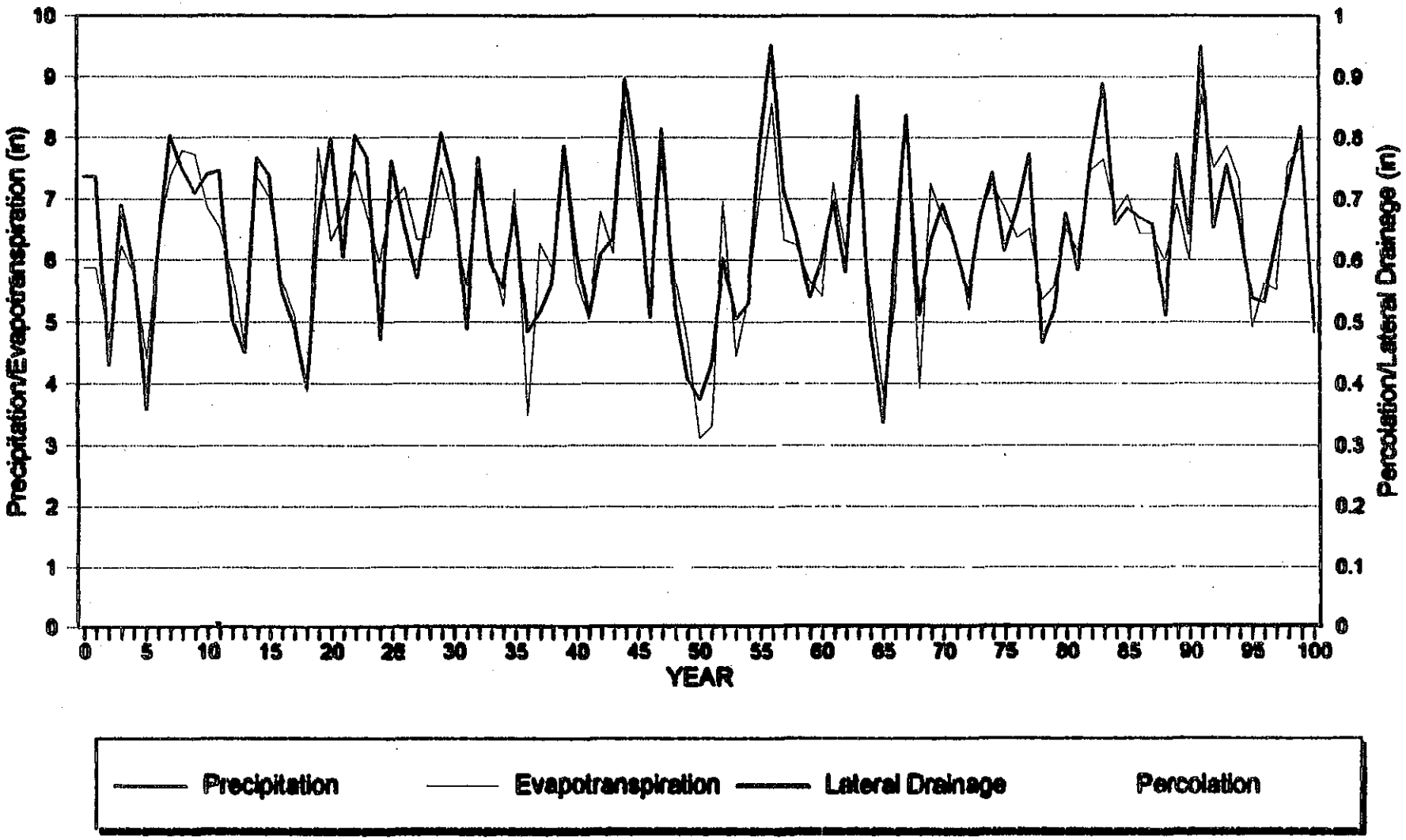
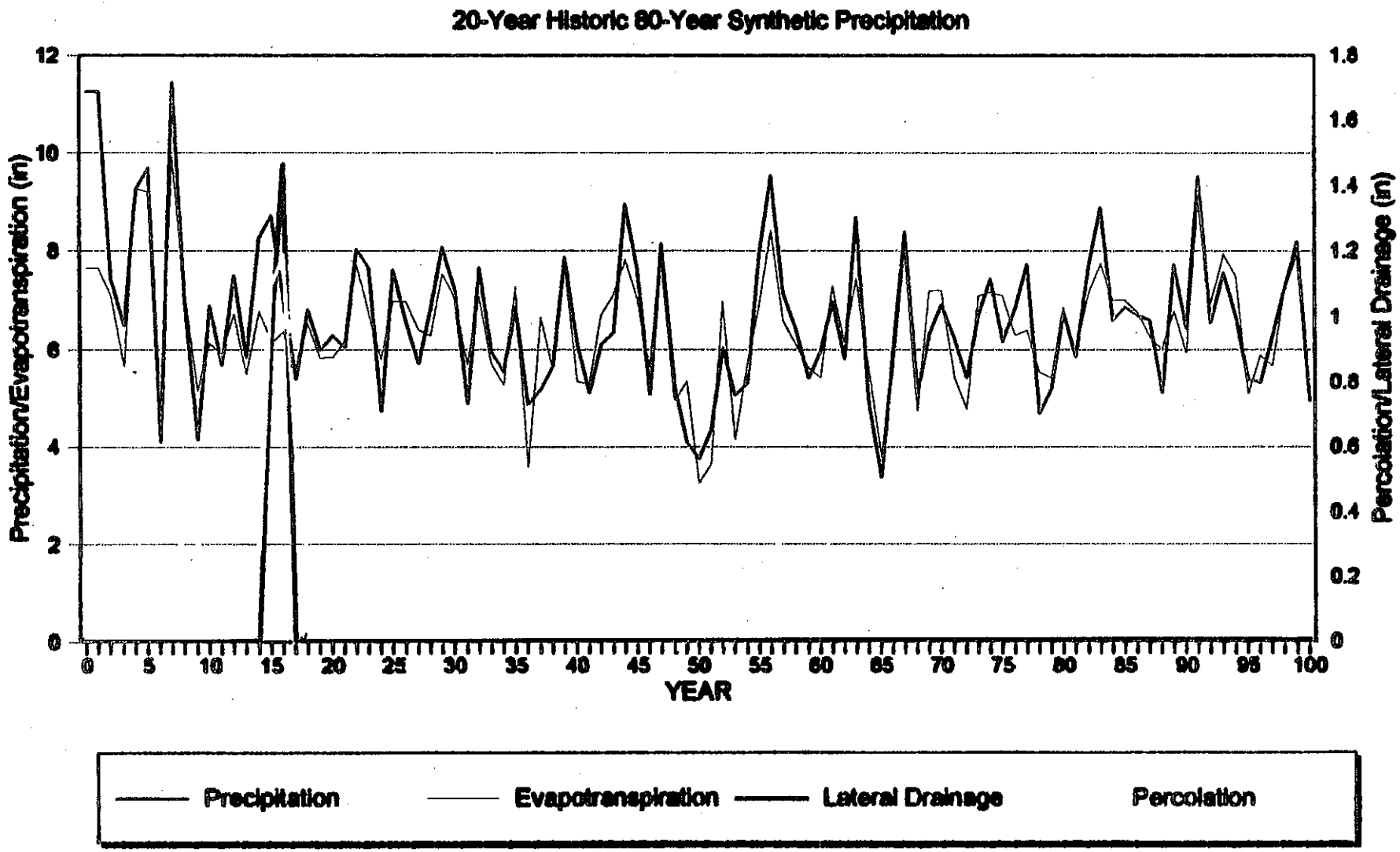


Figure 3-3

HELP MODEL



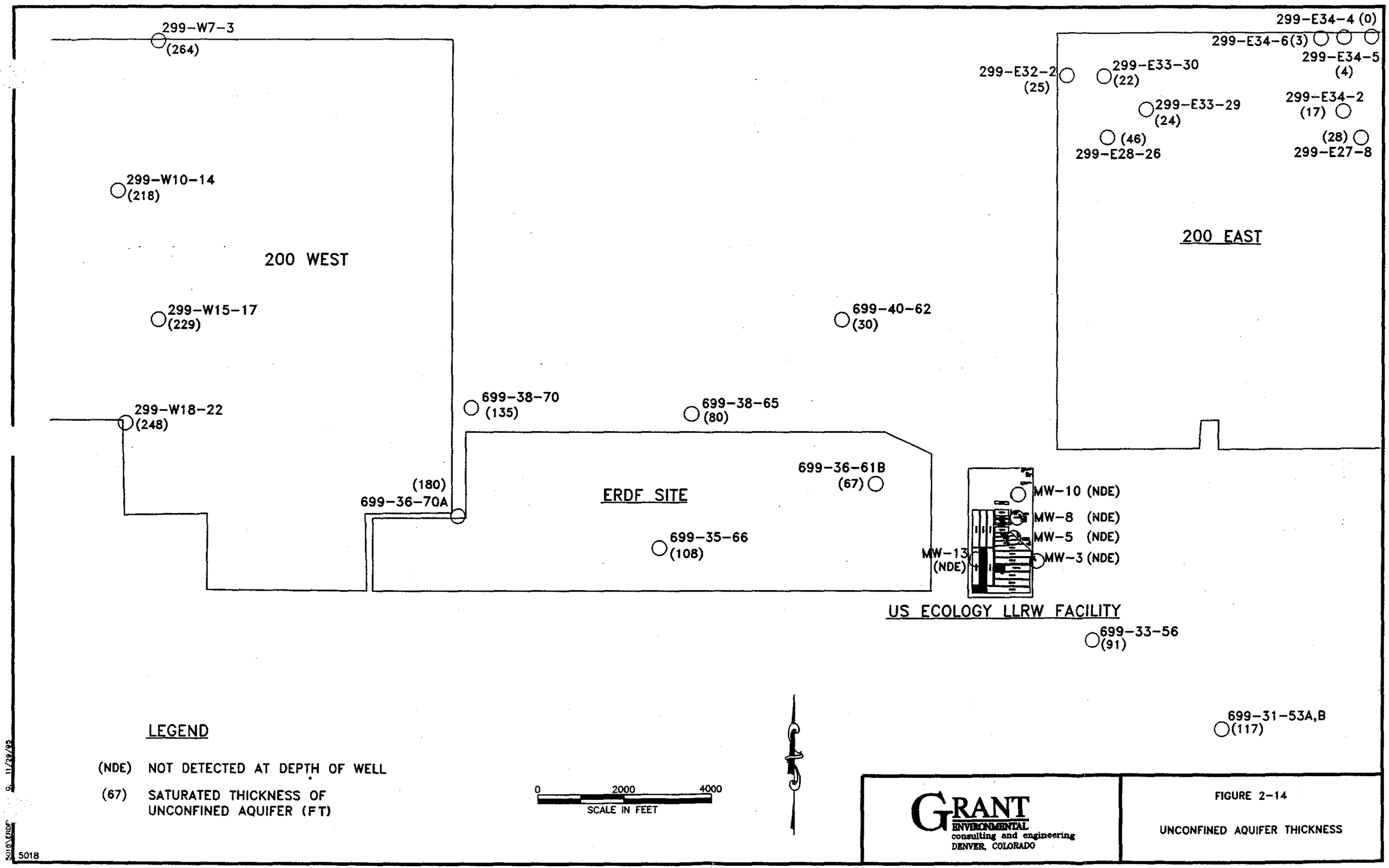

299-W7-3
(264)
299-W10-14
(218)
200 WEST
299-W15-17
(229)
299-W18-22
(248)
(180)
699-36-70A
699-38-70
(135)
699-38-65
(80)
699-40-62
(30)
ERDF SITE
699-36-61B
(67)
699-35-66
(108)
299-E34-4 (0)
299-E34-6(3)
299-E34-5
(4)
299-E32-2
(25)
299-E33-30
(22)
299-E33-29
(24)
299-E34-2
(17)
(46)
299-E28-26
(28)
299-E27-8
200 EAST
MW-10 (NDE)
MW-8 (NDE)
MW-5 (NDE)
MW-3 (NDE)
MW-13
(NDE)
US ECOLOGY LLRW FACILITY
699-33-56
(91)
699-31-53A,B
(117)
LEGEND
(NDE) NOT DETECTED AT DEPTH OF WELL
(67) SATURATED THICKNESS OF UNCONFINED AQUIFER (FT)
0
2000
4000
SCALE IN FEET
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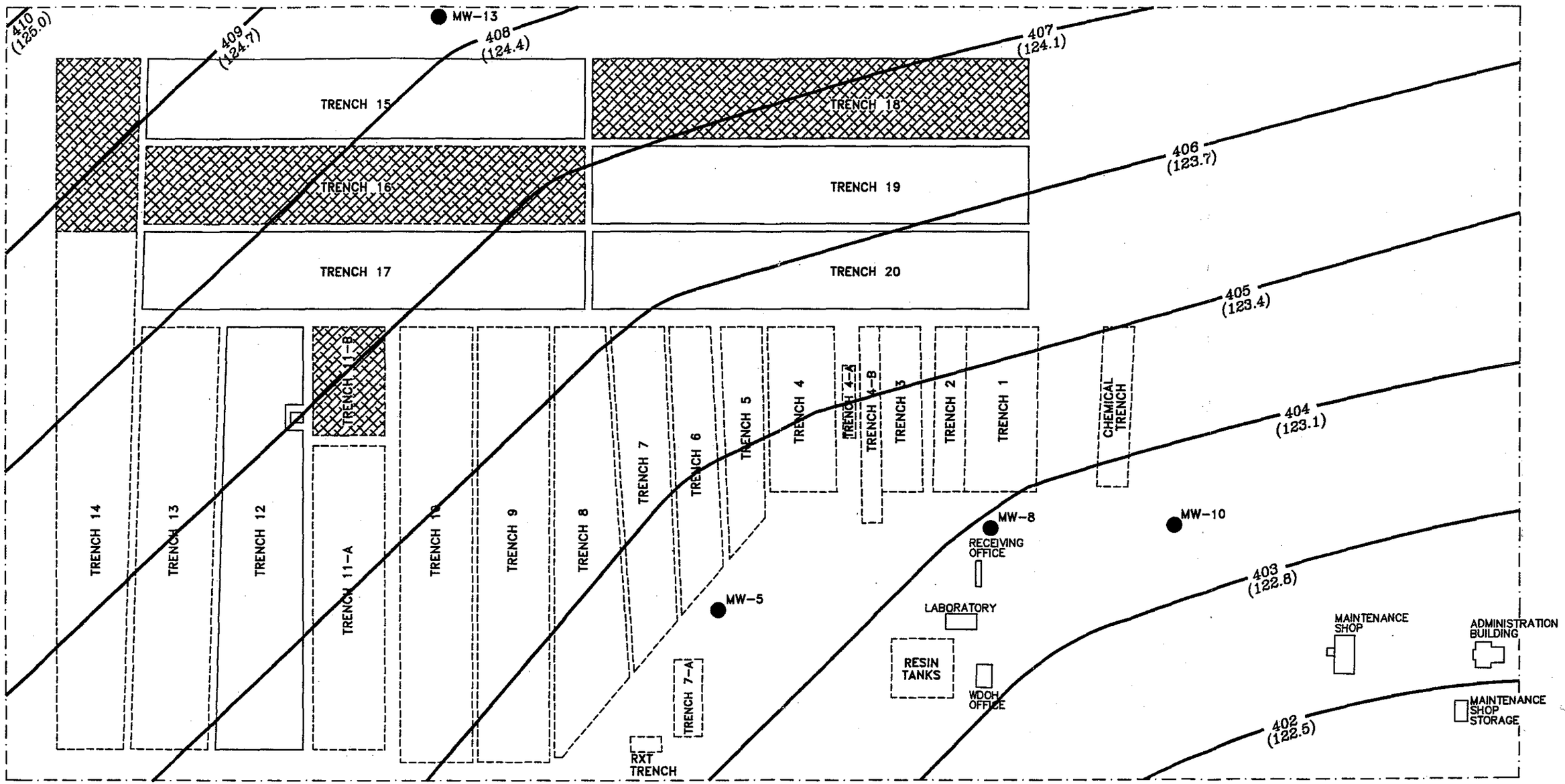
FIGURE 2-14
UNCONFINED AQUIFER THICKNESS
5018



LEGEND

- 402 (122.5) — GROUND-WATER ELEVATION CONTOUR IN FEET MSL (METERS)
- ● MONITORING WELL LOCATION
- PROPERTY LINE
- CLOSED TRENCH
- FUTURE TRENCH
- ACTIVE TRENCH

SOURCE:
GROUND-WATER CONTOURS PROVIDED BY US ECOLOGY
US ECOLOGY 1993 ANNUAL REPORT.

0 200 400
SCALE IN FEET

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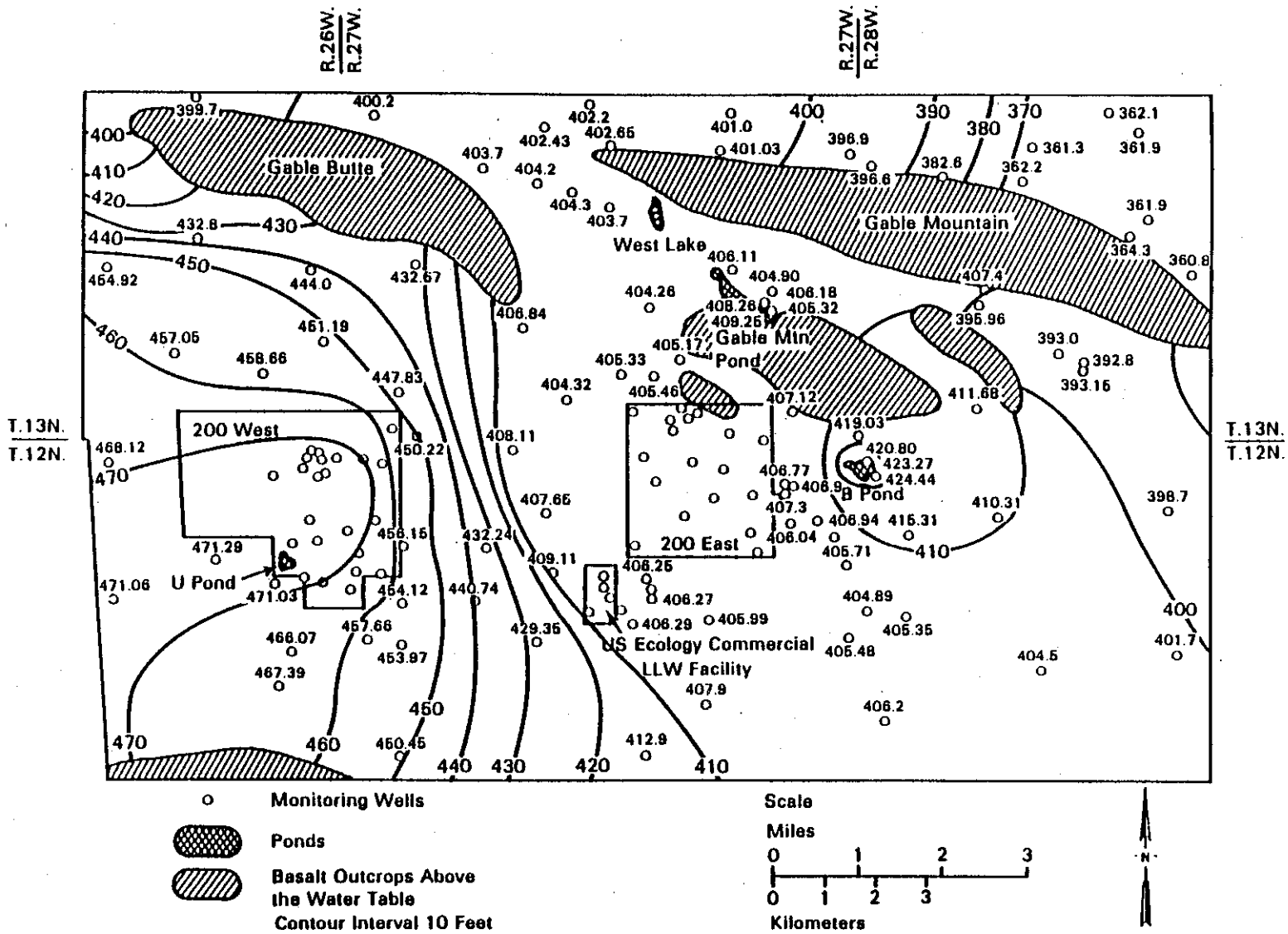
FIGURE 2-15
SITE WATER TABLE ELEVATION MAP
MAY 1992

5018\MAY92 7/15/96



SOURCE: Bergeron, 1987, pp 55, Fig. 20

5018

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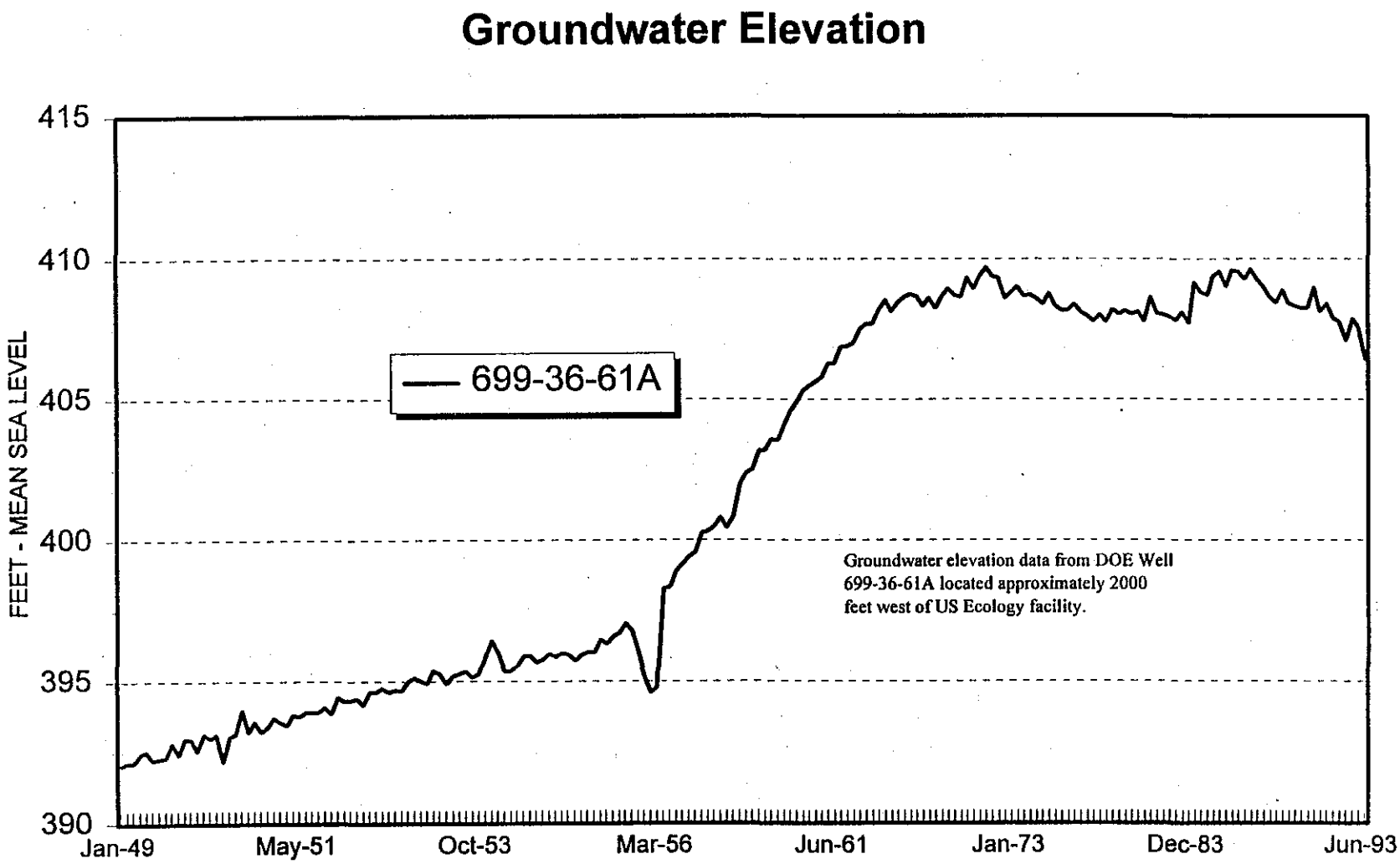
FIGURE 2-16
SITE GROUNDWATER TABLE ELEVATION MAP - JUNE 1986



SOURCE: Grant, Data obtained from U.S. DOE Hanford Site groundwater monitoring data

5018

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FIGURE 2-17
REGIONAL GROUNDWATER ELEVATION TREND GRAPH
JANUARY 1949 - JUNE 1993

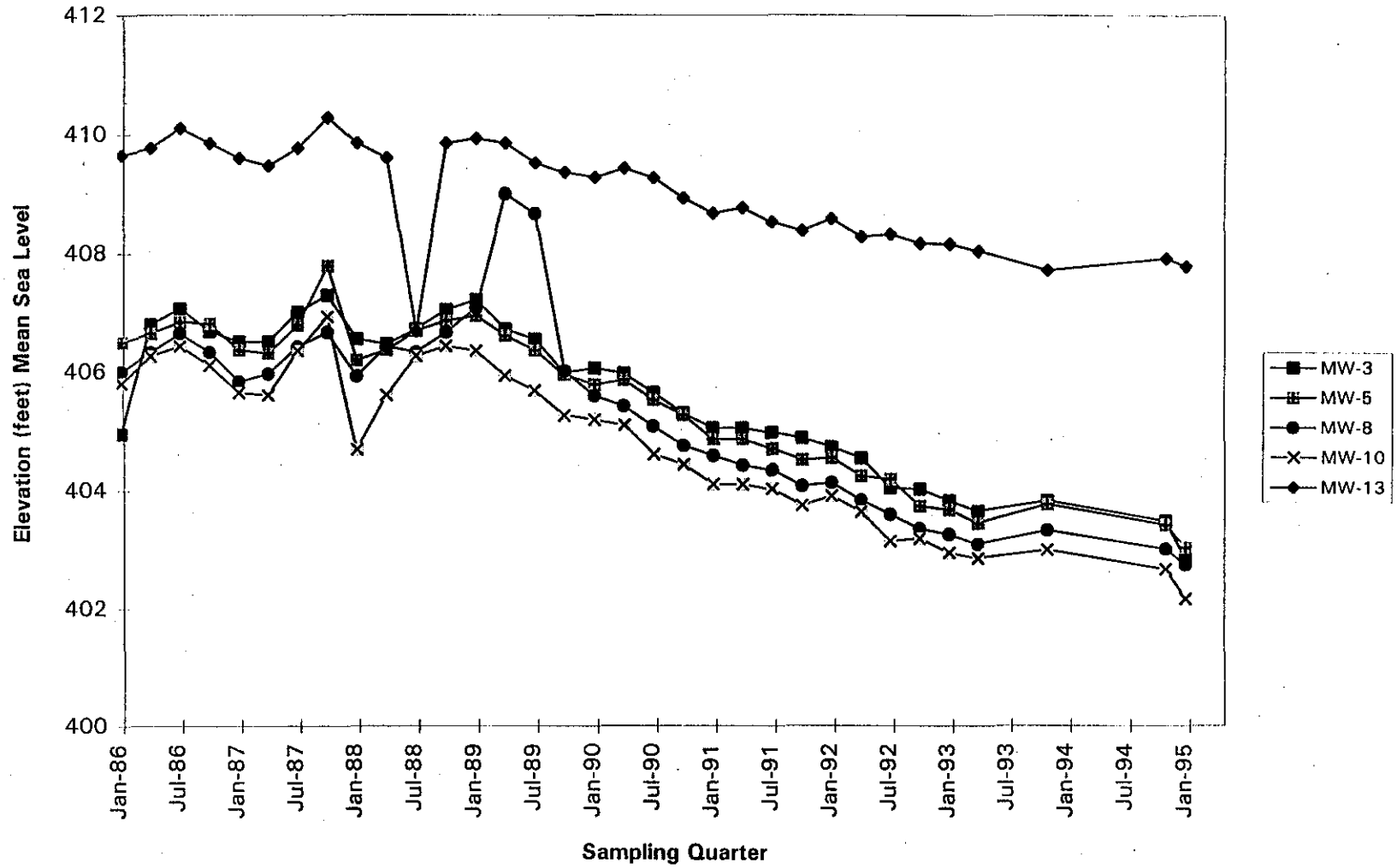

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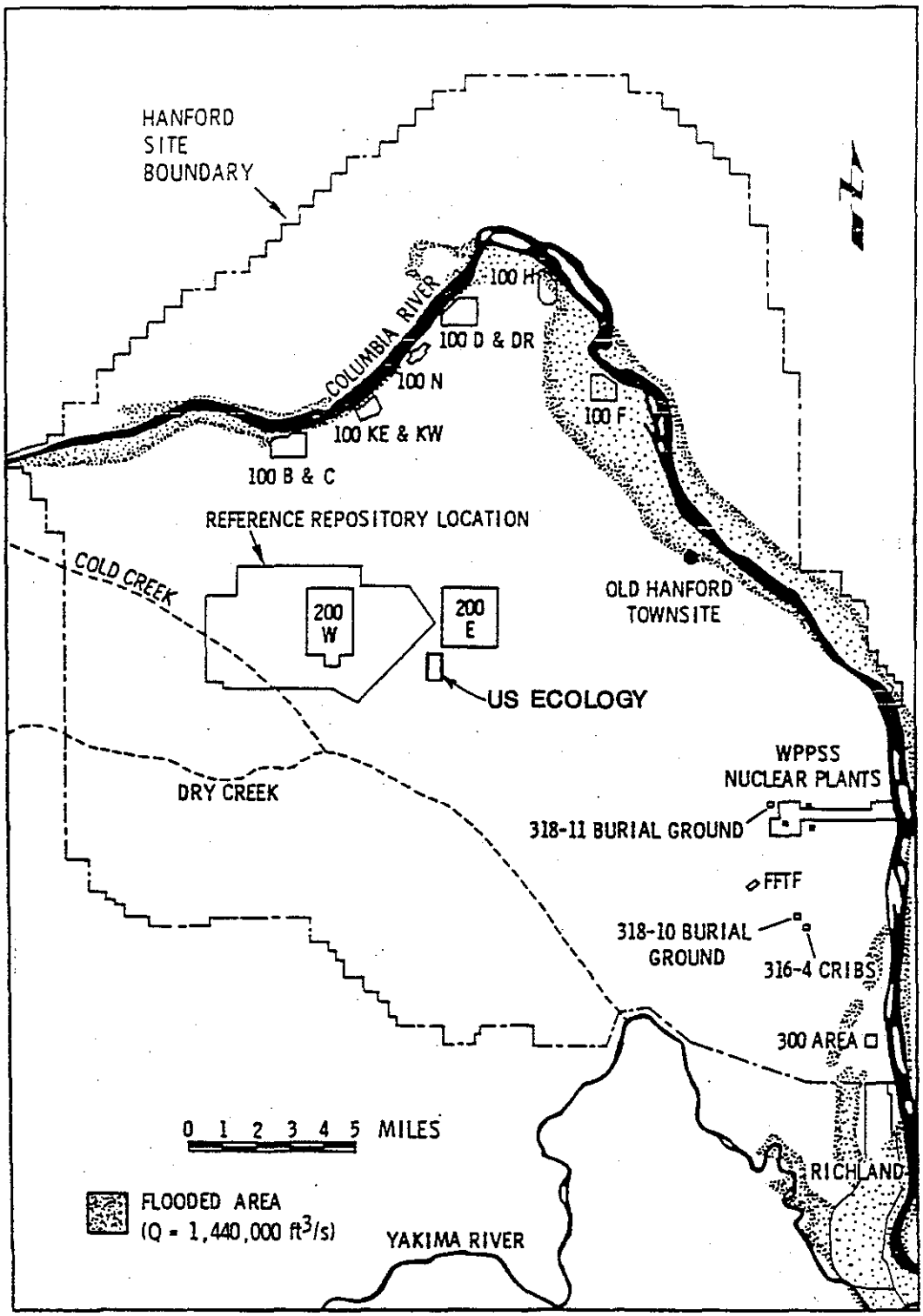
FIGURE 2-18

FACILITY GROUNDWATER ELEVATION TREND GRAPH
JANUARY 1986 - JANUARY 1995



SOURCE: Skaggs, Walters, 1981, pp 15, Fig. 5 (After ERDA, 1976)

5018

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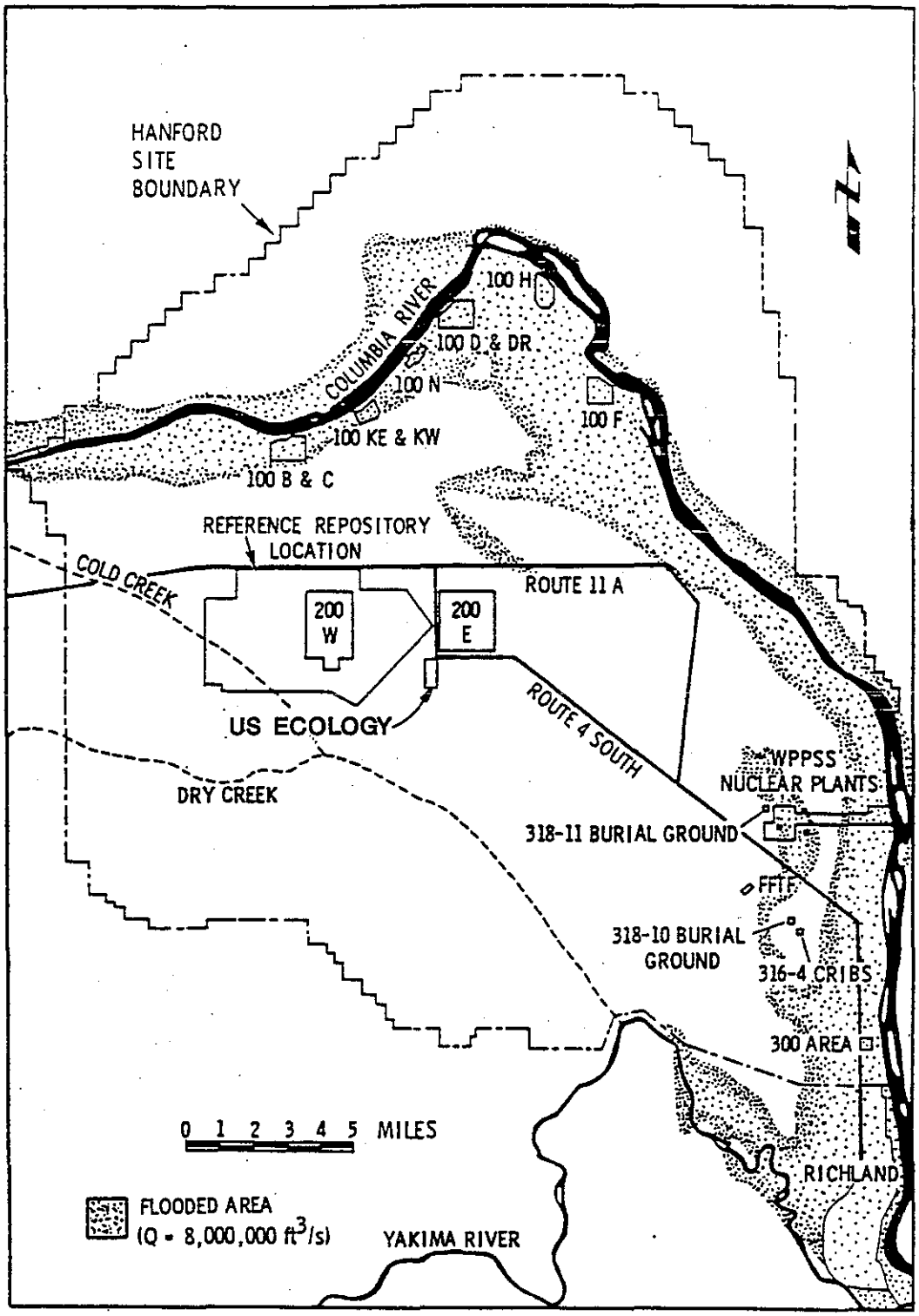
FIGURE 2-19
PROBABLE MAXIMUM FLOOD
HANFORD RESERVATION



SOURCE: Skaggs, Walters, 1981, pp 16, Fig. 6 (After ERDA, 1976)

5018

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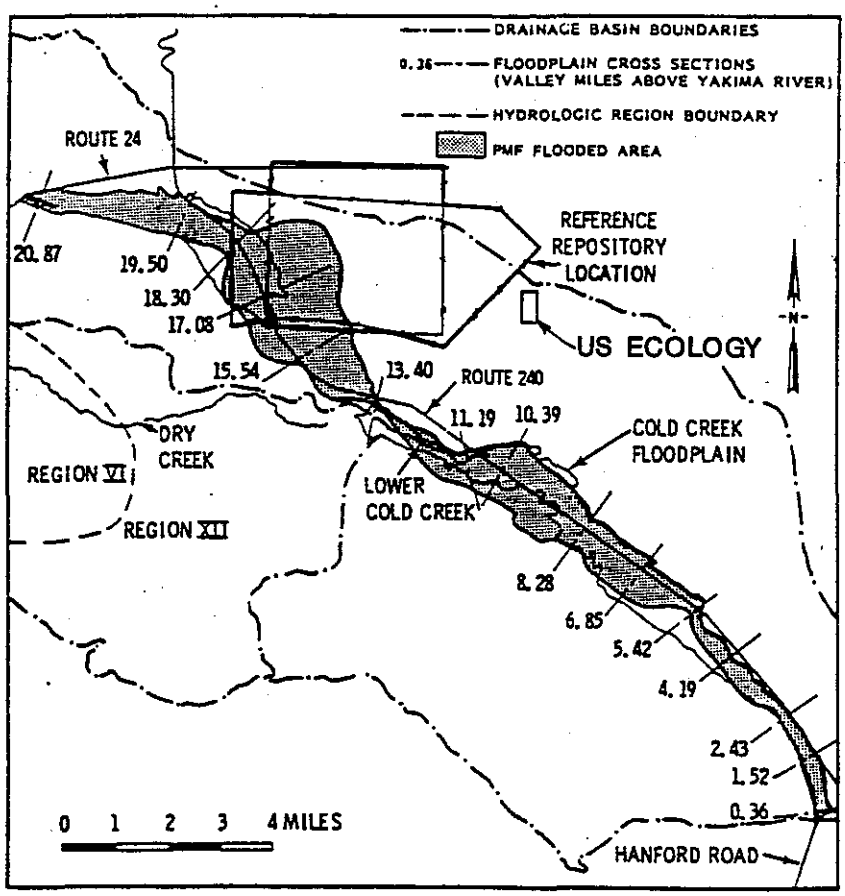
FIGURE 2-20

FLOODED AREA IN THE VICINITY OF THE REFERENCE REPOSITORY



SOURCE: Skaggs, Walters, 1981, pp 32, Fig. 12

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FIGURE 2-21

COLD CREEK PMF FLOODED AREA

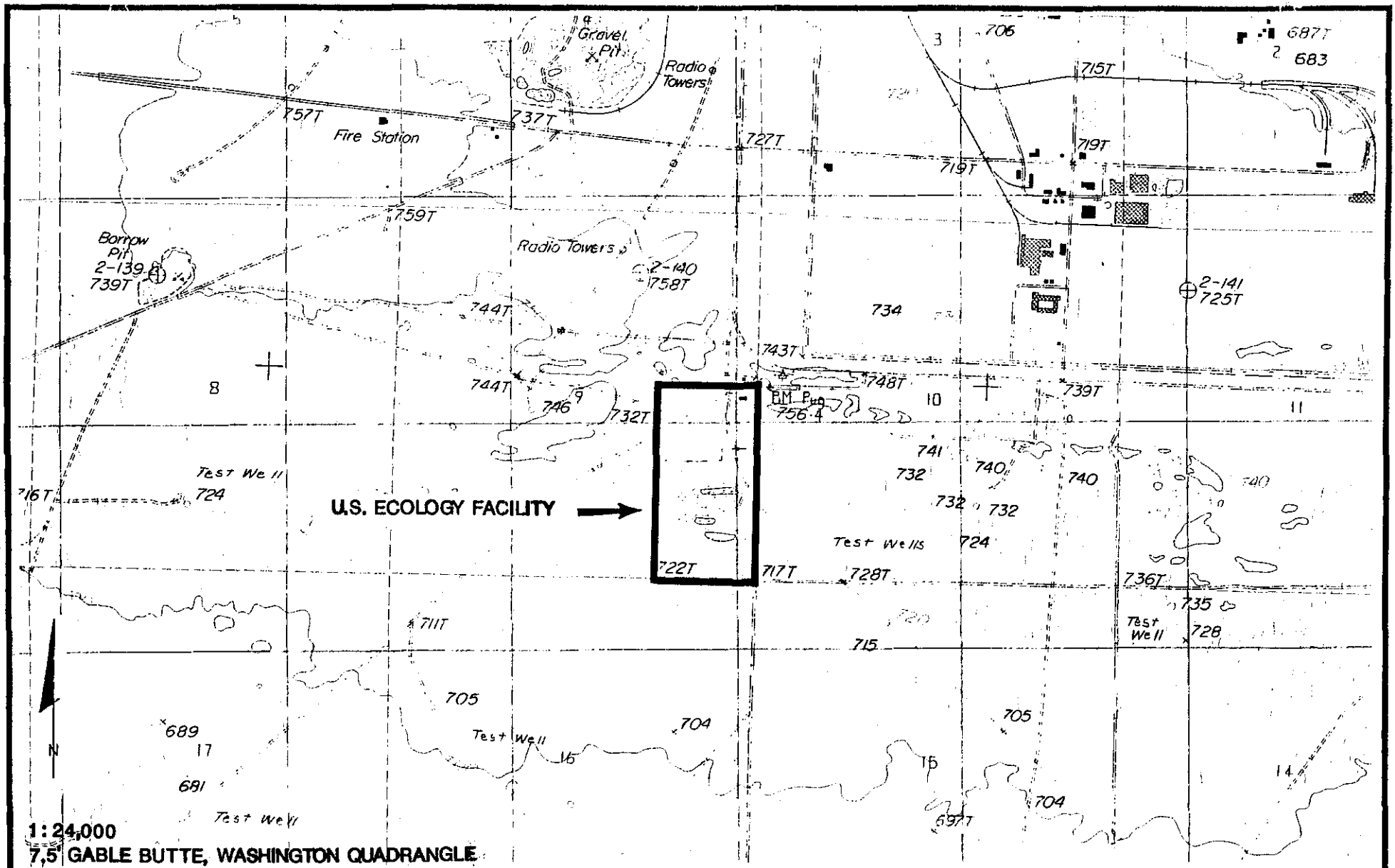

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FIGURE 2-22
SECTION OF USGS QUAD
HIGHLIGHTING AREA

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3. CLOSURE PLAN

3.1 GENERAL

This plan describes closure activities for the Richland, Washington LLRW Disposal Facility to ensure compliance with Washington License WN-I019-2 Condition 66, and NRC SNM License 16-19204-2. Key elements of the proposed Richland Closure Plan include:

- environmental monitoring of soil, vegetation, groundwater, vadose zone, and air;
- dose analysis based on adequate characterization of the waste source term, soil characteristics of the host material which will attenuate migration, and engineered features to enhance the site natural characteristics;
- implementation of design features including grading, site drainage and erosion control features to maintain site surface stability;
- installation of a multipurpose integrated disposal unit cover to provide a barrier to infiltration, a barrier to biointrusion, and a deterrent to inadvertent human intrusion;
- implementation of institutional controls to ensure continuity of knowledge of every aspect of site operations and closure - including provisions for orderly records transfer, detailed site surveys and documentation, physical marking of trench boundaries;
- radiological surveys confirming that the site has been decommissioned in accordance with regulatory standards; and
- periodic updates of analyses contained herein to ensure knowledge remains current.

Groundwater, vegetation and soil monitoring will provide continuity with the on-going operational monitoring program and verify continued site performance.

Dose analyses (Section 5 and Attachment D) suggest that given the current knowledge of the site, the design, and the source term, the site will maintain doses below regulatory limits. This dose analysis will be updated with each periodic update of this Closure Plan in accordance with Facility license requirements.

Integrated design features for post-closure drainage and erosion control will be implemented at final closure of the entire site in 2056. Features required for interim

Radiological surveys necessary to close the site will be performed as discussed herein.

These tasks that constitute closure are discussed individually in more detail in this Section and are discussed collectively in Section 4 to demonstrate compliance with all requirements of License Condition 66.

3.2 INTERIM CLOSURE

Interim closure of the Facility is accomplished by placing site soil above the waste to grade after each trench or trench section is filled with waste. Trenches 1, 2, 3, 4, 5, 6 and the Chemical Trench have waste placed to within three feet (0.9 meters) below-grade. The trenches constructed after Trench 6 have waste placement terminating eight feet (2.4 meters) or more below-grade. The backfill material consists of mostly silty sands and gravels which were previously excavated and stockpiled during trench construction.

If available, excess site soils displaced by waste may be added to the top of the closed trenches for surcharging. The depth of this material shall not exceed 10 feet (3 meters) over closed trenches which contain high integrity containers unless approved by the Washington Department of Health (WDOH); however, analysis of available structural information on high integrity containers indicates that greater soil overburden can be withstood[1]. The excess material so placed will surcharge the waste until final closure activities are performed or the soils are needed for backfilling or site grading. Excess material is graded such that the surface slope will enhance drainage. All trenches will be surcharged following interim closure for a period of at least 30 days prior to final closure.

The site soils that are used as backfill consist, in general, of dry, granular materials (i.e., sands). When granular materials are compressed, which is the process occurring during surcharging activities, any settlement that is going to occur will occur almost immediately. This is due to the relatively high permeability of the granular soils.[2] It is very easy for the water (and air) in the voids to be displaced (i.e., squeezed out). The purpose of the surcharging is to load the trench prior to capping to an elevation greater than that expected for the final cap. This preloading will facilitate any preliminary settlement prior to capping. However, it is not intended to eliminate future subsidence due to package and waste deterioration, which occurs over the long term.

---

[1] Grant Environmental, 1995, High Integrity Containers, A letter report dated July 25, 1995, submitted to WDOH.

[2] Holtz, R. D. and Kovacs, W. D., 1981, An Introduction to Geotechnical Engineering, Prentice-Hall, Inc.

control of drainage and erosion are similar to those provided during operations. The key design feature of the Closure Plan is a multifunctional disposal unit cover.

The primary objective of the cap design is to provide a low-maintenance barrier that isolates wastes for a minimum of 1,000 years. The cap should limit water percolation to amounts less than amounts through natural soil profiles; reduce the likelihood of plant, animal, and human intrusion; and minimize erosion-related problems.

The cap design was selected to minimize erosion and infiltration and to allow for easy detection of subsidence. The design uses a gravel mulch layer to support vegetation and store meteoric water. Water is removed from this layer by runoff and evapotranspiration. A capillary break (drainage) and a low-permeability barrier layer are included to complement the function of the vegetative layer. The capillary break layer and barrier layer, combined with the natural aridity of the site, will limit percolation of surface water through the cap and into the waste to negligible amounts.

This Closure Plan describes the final cap design, a first phase closure of several older trenches (with what is herein referred to as the partial cap) as well as the placement of the remaining cap. Because several older trenches are filled and have not been operated for several years, it is practical to implement final closure for these trenches now in order to demonstrate the adequacy of this Closure Plan, while the remainder of the site continues to operate throughout the lease agreement period. The partial cap will be constructed over Trenches 1-6 and the Chemical Trench, and will be integrated into the final cap at site closure. Studies of physical and radiological parameters will be made to verify performance or suggest design modifications. Finally, at conclusion of Facility operations, an integrated version of the cover will be constructed atop the entire Facility not previously covered.

All work completed will comply with the US Ecology Corporate Quality Assurance Manual, QA-MA-1. This manual and its sub-tier procedures are designed to implement the requirements of ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities."

The cap Quality Assurance Plan will define the quality objectives and requirements of the project, as well as the procedures to be followed in meeting those requirements and the organization responsible for ensuring proper implementation of the plan. The plan will address the organization and responsibilities associated with testing, sampling, analyses, inspection, chain of custody and documentation. The overall organization of the project includes representatives from US Ecology operations, the construction contractor (US Ecology or subcontractor), US Ecology Quality Assurance personnel and additional subcontractor personnel.

During the continuing operation period, US Ecology will maintain records conducive to orderly transfer according to current procedures. US Ecology will continue to maintain accurate and detailed site surveys and documentation thereof. Furthermore, US Ecology will maintain physical monuments marking disposal trench locations.

3.3 FINAL CLOSURE

The closure cap has been designed to isolate wastes disposed of at the Facility. The cap design has been evaluated with respect to several criteria including minimizing erosion at the cap surface, and limiting infiltration and biointrusion through the cap.

Because of the goal for the cap to perform for at least 1,000 years without active maintenance, natural construction materials have been selected to optimize barrier performance and longevity. The cap components and design criteria are described in detail in the following sections.

3.3.1 Cap Design Components

The design of the closure cover includes (see Figure 3-1):

1. Vegetation - vegetation will be reestablished at the earliest time practicable after construction is completed.
2. Gravel Mulch Layer (Layer 1) - above the capillary barrier layer, four inches (10 cm) thick, consisting of a mixture of gravel and site soils.
3. Capillary Barrier Layer (Layer 2) - below the gravel mulch layer, three feet (0.9 m) of fine-grained soil mixed with pea gravel. This layer functions as a storage layer for moisture which is used by vegetation for growth.
4. Site Sand Layer (Layer 3) - below the capillary barrier layer, three feet (0.9 m) thick, consisting of fine-to medium-grained sands.
5. Capillary Break Layer (Layer 4) - below the site sand layer, one foot thick (0.3 m), consisting of gravels (materials ranging from one to three inches (2.5 to 7.6 cm) in size), and geotextile filter fabric placed above and below this layer to facilitate construction. The capillary break provides a discontinuity in the moisture-tension characteristics of the layers above and limits downward unsaturated flow from the overlying finer-grained soils.
6. Low Permeability Barrier Layer (Layer 5) - below capillary break layer, one foot thick (0.3 m), composed of site sands mixed with clay.
7. Fill layer (Layer 6) - site soil added to surface of interim caps to meet required design elevation prior to construction of barrier layer; Trenches 1 through 6 (Trenches 1-6) and the Chemical Trench Cap will have fill layer placed on top of interim cover a minimum of five feet (1.5 m) thick.

It should be noted that the thickness of the layers discussed above, and through this plan, are minimum values. At construction, the layer thicknesses as placed will be at or above the minimum specified, resulting in a total thickness of the cap and backfill of at least 5 m (16.4 ft).

3.3.1.1 Trench Cover

The following sections describe the various components of the trench cover. Reduced versions of the conceptual cap drawings are included as Plates at the end of this Closure Plan. The full-size drawings are included in Attachment E. A typical cross-section is shown on Figure 3-1, and identifies the trench cover components.

3.3.1.1.1 Vegetation

Vegetation is an integral component of an effective cap. Plants can reduce soil loss and may enhance deposition of wind blown particles. The most important role of an effective vegetative cover is removing infiltrated moisture by transpiration.

A mixture of seeds will be used to establish vegetation. The seeds have been recommended for use based on the Barrier Erosion Control Test Plan[3]. The seed types were selected for their ability to produce vegetation that resists drought, develops dense roots, and extracts water from the soil profile. Over the course of the 1,000 year design life, the plant community established by the vegetation planted at the time of closure will likely converge with the surrounding plant community[4].

A mixture of native and exotic grasses, listed in Table 3-1, was selected for the following reasons[5]:

(1) it includes indigenous species found in mature plant communities at the 200 Areas,
(2) it includes commercially available cultivars that are most like certain native species for which cultivars are not available, and
(3) it includes relatively easy-to-establish cultivars having characteristics similar to native species that are difficult to establish in the Pasco Basin.

Should other species invade the Facility, including common species like cheatgrass, they will be allowed to propagate undisturbed. Species such as cheatgrass, although not originally native to the area, have become common in the arid environments of the West. These plants also provide erosion protection.

The WDOH has expressed concern about the growth of vegetation on the cap and slopes. US Ecology will perform a literature study of vegetation growth for barrier covers and disturbed areas in the vicinity of the Facility. The literature study will be

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[3] Waugh, W.J. and S.O. Link, 1988, Barrier Erosion Control Test Plan: Gravel Mulch, Vegetation, and Soil Water Interactions: WHC-EP-0067, PNL, Richland, Washington, p. 10, Section 4.3.2.

[4] Waugh, W.J. and S.O. Link, 1988, op. cit., p. 4, Section 2.2.

[5] Waugh, W.J. and S.O. Link, 1988, op. cit., p. 10, Section 4.3.2.1.

used to confirm that suitable vegetation has been selected for the Facility. Additionally, the growth of vegetation on the partial cap will be observed as part of the monitoring described in Section 3.3.6.

3.3.1.1.2 Gravel Mulch Layer (Layer 1)

Several studies have been performed testing combinations of gravel mulches and admixtures[6]. Preliminary analysis has shown that gravel admixture surfaces enhance plant establishment and growth.

A four-inch thick layer of a mixture of 50 percent site soils and 50 percent gravel will be placed on the surface of the cap to encourage rapid establishment of vegetation. The gravel to be added to the soil to form the mulch is planned to have D_{50} = 1 inch.

4"

3.3.1.1.3 Capillary Barrier Layer (Layer 2)

A 36-inch (91 cm) thick capillary barrier will be beneath the gravel mulch. The capillary barrier will be a layer of soil capable of supporting vegetation and storing moisture. The function of this layer is to provide a medium in which vegetation can grow, and to retain meteoric water within the plant root system and soil matrix until evaporation and transpiration return the stored water back to the atmosphere. The capillary barrier layer minimizes infiltration in this manner. The capillary barrier will be comprised of a mixture of 70% silt and 30% pea gravel. This is comparable to the Hanford Prototype Barrier which was comprised of 85% silt loam and 15% gravel[7]. The source for the silt is assumed to be from stockpiles of excavated material and overburden placed on the trenches during interim closure, or from soil mined on- or off-site. The mixture that will be utilized for the silt will consist of approximately 60% silt and 40% sand. The capillary barrier material will be placed with trucks or scrapers. This layer will not be compacted.

36"

Capillary barrier layer performance has been studied for several years by Battelle at the Field Lysimeter Test Facility (FLTF)[8]. Results from these tests indicate that capillary barriers are effective in promoting evapotranspiration and reducing infiltration. During the first three years of testing, twice the annual average precipitation (about 12.1 inches, or 31 cm) was added to lysimeters simulating a wetter climate. During the next two years, three times the annual average precipitation (about 18.75 inches or 48 cm) was added to the same lysimeters. During this entire five-year testing period, water

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[6] Cadwell, L.L., S.O. Link, and G.W. Gee, 1993, Hanford Site Permanent Isolation Surface Barrier Development Program: Fiscal Year 1992 and 1993 Highlights, PNL-8741, Richland, Washington, p. 2.17.

[7] Gee, G.W., A.L. Ward, B.G. Gilmore, M.W. Ligotke, and S.O. Link, 1995, Hanford Prototype-Barrier Status Report: FY 1995.

[8] Wing, N.R., 1993, Permanent Isolation Surface Barrier: Functional Performance, WHC-EP-0650, Westinghouse Hanford Company.

losses by evaporation and transpiration exceeded water gains by precipitation and irrigation, even for the lysimeters receiving treatments representative of wetter climatic conditions. It also should be noted that these results were observed for both vegetated and unvegetated lysimeters. Even though the vegetated lysimeters were most effective at removing soil moisture, the soil water stored in the unvegetated lysimeters also decreased during the five-year test period.

An extreme condition (rapid snowmelt irrigated lysimeter) occurred in early spring 1993 causing temporary breakthrough of water through bare soil lysimeters. No other lysimeters exhibited drainage.

3.3.1.1.4 Site Sand Layer (Layer 3) - Acts as a matrix potential barrier

What is benefit

36"

Thirty-six inches (91 cm) of fine- to medium-grained site sands will be beneath the capillary barrier layer. This layer will aid in water storage, provide an additional barrier to animal intrusion, and provide additional protection from roots and frost to the underlying drainage and low-permeability layers.

The site sands are placed from dump trucks and scrapers, and spread in 12 to 18-inch (30.5 to 45.7 cm) lifts with a bulldozer or grader, but with no other compactive effort.

3.3.1.1.5 Capillary Break Layer (Layer 4)

12" ?

Although it is an extremely unlikely event, during periods of unusually heavy, intense, or prolonged precipitation, the water-holding capacity of the capillary barrier layer and sand layer could be exceeded, allowing water to drain into the capillary break layer. The capillary break provides a discontinuity in the moisture-tension characteristics of the cap and limits downward unsaturated flow from the overlying finer-grained soils. For this reason, a 12-inch (30.5 cm) thick gravel capillary break will be placed beneath the site sand layer. The gravel used in the capillary break layer will be classified as "GW" based upon the Unified Soil Classification System designation. The gravel will be obtained from off-site sources. The gravel will be end-dumped from trucks, and spread in a 12-inch (30.5 cm) minimum lift with a bulldozer or grader.

Geotextile filter fabric will be installed above and below this layer to prevent gravel from mixing with the underlying and overlying soils during construction.

88"!

3.3.1.1.6 Low Permeability Barrier Layer (Layer 5)

Storage Capacity? It will move from higher to lower potential once it gets past root zone!

Beneath the capillary break layer, a 12-inch (30.5 cm) thick low-permeability barrier will be constructed. Should the storage capacity of the site sand and overlying layers be exceeded, and water move into the capillary break, the low-permeability layer will confine the water to the capillary break layer. The water that drains through the capillary break will migrate along the top of the low permeability layer. The capillary break layer "daylights" at the cap edge which directs drainage away from the cap and underlying waste layer.

The low permeability barrier layer also serves to reduce radon migration through the cap. The increased travel time allows time for the radon to decay, thereby reducing the emanation of radon.

The low permeability barrier layer material will be formed by mixing site sands stockpiled during trench excavation, or imported from local sources, with clay (or sodium bentonite) obtained from off-site sources. Approximately 12 percent clay will be used in the barrier layer. This mixture is resistant to shrinkage and cracking typically found in a conventional clay liner. Studies performed for the closure of the 183-H Barriers located on the Reservation determined the optimum mixture of clay and silty sand to be approximately 10 to 15 percent clay. Only enough clay is used to plug the void spaces between sand particles. This mixture provides a low permeability matrix with sufficient strength to resist tension and compression stresses caused by drying and wetting.

this will be hard to do!

A number of shrinkage, cracking, and permeability tests were performed on a range of clay and sand mixes including Wyoming bentonite and Los Alamos silty sand. The data indicate that compactive effort, compaction water content, and percent of silty sand influenced the soil matrix shrinkage potential[9]. The test samples compacted at 12 percent moisture shrunk less than one percent. The permeabilities of all the samples were less than 3.94×10^{-8} in/sec (1×10^{-7} cm/sec).

The clay and the site soil will be mixed together in a pug mill to achieve uniformity. The mixture will be spread in six to twelve-inch (15 to 30.5 cm) lifts on the cap and compacted to 95% of Standard Proctor value. Moisture will be maintained within three percent of optimum as determined by the Standard Proctor test.

3.3.1.1.7 Fill Layer (Layer 6)

10 CFR 61.52 requires Class C waste to be disposed a minimum of 16.4 feet (5 meters) below final grade. Since the 10 CFR 61 waste classification system was not in place during the initial operation of the Facility, the waste received during that time was not classified as Class A, B or C waste. To achieve the waste depth requirement, at least five feet (1.5 m) of site soils will be placed over Trenches 1-6 and Chemical Trench areas. This fill, along with the eight feet four inches (2.5 m) of cap thickness and three feet (0.9 m) or more of soil originally placed below-grade, will ensure compliance with the depth requirements in 10 CFR 61. For the remaining trenches, since waste placement stops eight feet (2.4 m) below-grade and the remaining space is backfilled with site soil, the depth requirement will be met without additional fill.

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[9] Department of Energy (DOE), 1990, Closure/Post Closure Plan, 183-H Basins, Rev. 2, DOE/RL-93-99, Appendix D-5.

Additional site soil will be placed on the interim caps as necessary to achieve the desired design grades. The upper foot of this layer will be rough graded to within 0.3 feet (0.1 m) of nominal grade and compacted to a minimum density of 90 percent of Standard Proctor density. The compaction will provide a firm base upon which to begin construction of the final cap layers.

3.3.2 Design Criteria

The following disposal cell cover design criteria implement the requirements of License Condition 66.

3.3.2.1 Design Life

Criterion: The disposal cell cover should have a design life of 1,000 years or more.

Low-level radioactive waste as categorized and managed under 10 CFR Part 61 is hazardous only for a limited time. Class A waste will decay to innocuous levels within about 100 years. In approximately 500 years, Class B and C wastes will decay to levels that do not pose an unacceptable hazard to an intruder or to public health and safety. A 1,000-year design life is chosen for Class B and C wastes; a shorter design lifetime of 200 years is adequate for Class A wastes. These design lifetimes provide ample time for the buried wastes to decay to innocuous levels.

Because some of the wastes were placed before the classification system contained in 10 CFR Part 61 was instituted in 1983, some trenches are comprised of a mixture of waste which was unclassified. Consequently, a trench-cover design lifetime of 1,000 years was selected for the entire site. This criterion is adequate to isolate the longest-lived wastes in these trenches.

A minimum thickness of 5 m (16.4 ft) is required over Class C wastes. The final cover, including the fill layer and interim cover thickness, will be a minimum of 16.4 feet (5 m) thick over the wastes. The design cover meets the thickness requirement.

3.3.2.2 Resistance to Water Infiltration

Criterion: An effective disposal cell cover should minimize water infiltration consistent with other design constraints.

Water that infiltrates through the waste can leach and transport radionuclides and other contaminants from the trench.

The cap has been designed with a minimum one percent slope to facilitate runoff of meteoric water. Maximizing runoff while keeping erosion to a minimum will limit the amount of water available for infiltration. The amount of water available for infiltration is a function of the amount of precipitation that falls on the cap surface less the amount of water that runs off the cap surface and away from the cap.

Vegetation will be established as early as possible to encourage evapotranspiration and reduce the amount of water stored in the cap.

3.3.2.3 Resistance to Bio-Intrusion

Criterion: An effective disposal cell cover should eliminate or minimize the possibility of intrusion by plants and animals into the waste.

Bio-intrusion is the penetration of deep-rooted plants or burrowing animals into the waste zone. Plant roots in the waste could mobilize waste constituents and move the contaminants to the ground surface. At the surface, the waste constituents could be dispersed.

Animals burrowing directly into the waste zone could contact the waste and transport waste constituents to the earth's surface as soil castings where the constituents could be dispersed by physical or biological agents. The animal burrows might increase infiltration by creating preferential migration pathways through the soil cover.

The final closure cap has been designed to protect wastes from the intrusion of deep rooting plants and burrowing animals. Plant rooting depth and animal burrowing depths are described in Section 2.6.1.3 and Section 2.6.1.6, respectively. Protection against intrusion is provided by including bio-barriers comprising coarse-grained layers, low-permeability layers, or simply by providing a soil cover thick enough to prohibit such intrusion. A minimum of 16.4 feet (5 m) of soil will be provided between the trench cap surface and the top of the waste.

The effectiveness of coarse-grained barriers has been demonstrated at the Field Lysimeter Test Facility (FLTF), located east of the 200-West Area and north of the ERDF. In 1988, a deep-rooting sagebrush was planted in the surface soils of the clear-tube lysimeter. As the sagebrush matured, the root system of the plant developed into a network that penetrated the fine-soil layer. However, as the roots reached the textural interface between the fine soils and the coarser sands below, their growth was stopped. Plant root growth is discouraged in the coarse drainage layers because of the lack of available moisture for root growth found in these layers. The roots next to the inside wall of the clear-tube lysimeter were observed to penetrate just a few millimeters into the sand. No plant roots penetrated the sand layer and the graded filter.[10]

The control of plant-root intrusion is accomplished by the capillary break layer. This layer discourages plant-root intrusion by limiting water available to plants.

As with plant intrusion, the intrusion of burrowing animals could adversely affect barrier performance. Literature surveys indicate that most animals that currently inhabit or are

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[10] Wing, N. R., 1993, Permanent Isolation Surface Barrier: Functional Performance, WHC-EP-0650, Westinghouse Hanford Company.

expected to inhabit the Hanford Reservation during the design life of the barrier do not burrow deeper than five feet (1.5 m)[11]. Favorable biological conditions (i.e., food, shelter, moisture, soil temperature, etc.) for most of the animals are found within the top 1.6 to 3.3 feet (0.5 to 1 m) of the earth's surface. Because there is no need or incentive for these animals to burrow deeper and because the layers below the capillary barrier layer are "hostile" (e.g., dry, sterile, composed of rocks, etc.), the animals will not expend the additional energy required to dig deeper into the cap.

Extensive field tests have been performed to study the effect of large-mammal (e.g., badgers, coyotes) burrows and small-mammal (e.g., squirrels, mice, gophers) burrows on the cap materials. From the results of the testing performed to date, the presence of small-mammal burrows does not appear to have a significant effect on the deep percolation of water through the barrier. Large mammals do appear to cause increased deep penetration of water in the fine-soil layer, but it was observed that much of this water was removed by increased vegetative growth and evaporation during the following growing season[12].

3.3.2.4 Resistance to Erosion

Criterion: An effective disposal cell cover should eliminate or minimize erosion by wind and water.

Wind or water erosion could remove the surface soils and expose the buried waste. Erosion can inhibit the proper function of a cell cover by removing a part of the cap.

The cap has been designed to minimize the effects of wind and water erosion on the surface and side slopes. Throughout the majority of its design life, vegetation will be growing on the surface of the cap. Section 3.3.1.1.1 discusses specific types of vegetation. Vegetation of the cap surface will significantly reduce the amount of the capillary barrier layer lost due to wind and water erosion. However, to protect the cap surface during periods of time when the vegetative cover may be disturbed by range fires, drought, disease or other phenomena, a gravel mulch layer will cover the capillary barrier layer. This surface layer will be resistant to wind erosion.

Eolian erosive forces will have the greatest effect on the long-term performance of the cap. These forces wear down the existing particles and deposit sand particles which will act as an abrasive force on the existing cap structure.

A wind tunnel was used to apply controlled wind and saltating sand erosive stresses to various mixtures of soil types. Mixed soil, sand and soil, and gravel and soil surfaces

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[11] Gano, K.A., and J.B. States, 1982, Habitat Requirements and Burrowing Depths of Rodents in Relation to Shallow Waste Burial Sites, PNL-4140, Pacific Northwest Laboratory, Richland, Washington.

[12] Gano and States, 1982, op. cit.

were prepared and tested in the wind tunnel of the Pacific Northwest Laboratory (PNL) Aerosol Wind Tunnel Research Facility. The tests studied surface deflation rates under simulated worst-case conditions. Meteorological data from Hanford were updated, and peak wind gust return periods were estimated in the wind tunnel tests. Although peak gusts are by definition intermittent and not sustained, as are mean wind speeds, their capacity to cause erosion is substantial (Attachment M).

Peak wind gust meteorological data are included in Section 2.3.2. A graphical presentation of peak wind gust return period is shown in Figure 2-4. Extrapolating from known data gives a value of 139 ft/s (42 m/s) for the 1,000-year peak gust.

Wind speeds recorded during wind tunnel tests provide surface shear stress levels greater than those recorded by equal wind speeds in the field. This is because wind tunnel air velocities are often measured closer to the surface, and in the wind tunnel significant surface features such as vegetation are generally absent.

Test data provide evidence supporting the use of pea-gravel admixtures to protect the capillary barrier layer[13]. Although the gravel may tend to become buried by plants and surface deposits during normal climatic periods, periods of dry stress may lead to deflationary conditions and cause the gravel to appear on the surface. The armor thus formed will protect the capillary barrier layer from erosion.

The above studies show that, compared with rates caused by applied wind stresses and measured from unprotected soil surfaces, pea-gravel armors reduced deflation rates by 93 percent at 34 mph (15 m/s) and by at least 96.5 percent to more than 99.4 percent at wind speeds of 45, 56, and 67 mph (20, 25, and 30 m/s). For the greater wind speeds, this result is equivalent to at least a 29-fold to more than a 170-fold reduction in deflation rate. Importantly, surface protection afforded by pea gravel also extended to applied sand saltation erosive stresses. Exposed gravel absorbed the impact energy of saltating sand grains and resulted in deflation rates at least 45±6 times less than those from unprotected soil surfaces.

3.3.2.5 Resistance to Temporal Degradation

Criterion: An effective disposal cell cover should be stable, and not subject to deterioration over the design life of the cover.

Deterioration refers to the breakdown of cap materials with time. The disposal cell cover uses natural materials, the permanence of which is demonstrated by their survival over geologic time. The gravel mulch layer is sufficiently thick to protect against gully development and erosion.

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[13] Ligotke, M.W., 1993, Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel: PNL-8478, Pacific Northwest Laboratory, Richland, Washington, p. iii.

3.3.2.6 Resistance to Subsidence

Criterion: The design of an effective disposal cell cover should be coordinated with the design of the underlying trench, and should be able to withstand normally-expected subsidence without loss of function.

Only minor subsidence has been noted in the trenches during interim closure. Subsidence can create localized depressed areas on the cap that may damage the stability of the cap, and provide preferential pathways for infiltrating water. The preferential pathways may be formed by cap thinning or cracking, or by disrupting critical layers within a multi-layered cap. ~~The proposed cap does not depend upon internal drainage nor impermeable barriers as the primary mechanism by which infiltration is minimized. Therefore, the covers will resist the minor amounts of subsidence that may occur after closure.~~ Large subsidence features are mostly associated with near-term consolidation and waste deterioration. Such subsidence should occur mostly before closure, and can be repaired during the closure and stabilization periods if necessary.

Explain how?

The wastes that are placed in the trenches are dry, and the backfill is dry and sandy. Long-term consolidation is a phenomenon related to the slow drainage of saturated fine-grained soil. Any subsidence resulting from backfill consolidation will occur essentially simultaneously with the consolidating load. Long-term consolidation, if it occurs, would result from deterioration of wastes or waste containers. Even this consolidation would likely occur relatively quickly (on the order of years or decades) after the waste is placed because the chemical and biological processes that cause the deterioration act rather quickly. – Timing?

Subsidence has been observed primarily at humid sites where waste deterioration or unstable voids in backfill soils have led to waste consolidation. Raveling of fine-grained soil into voids in the backfill is caused, or initiated, by internal erosion by infiltrating water.

For several reasons, this is a humid area phenomenon. Voids in moist, fine-grained backfill typically are much larger than those in dry, granular backfill, and the amount of water moving through a trench in an arid environment is much less than that infiltrating a trench in a humid area. Consequently, significant subsidence has been observed at humid sites, and very little subsidence has been documented at arid sites.

Additional discussion is included in Attachment L of the Closure Plan and Section 5.3 of the "Phase 1 Cap Design, Subsidence Evaluation and Initial Source Term Presentation," dated April 14, 1994.

3.3.3 Cap Design Features

3.3.3.1 Slope Stability

The steepest cap slopes will be the 3:1 (horizontal:vertical) temporary cap outslope on the western edge of the partial cover. The maximum outslope on the final cap will be a 5:1 slope. Experience has shown that at these slopes, the cap is not subject to slope failure or creep.

3.3.3.2 Freeze-Thaw Resistance

Typically, discussions on frost damage are concerned with damage to structures and utilities which are most susceptible to the actions of frost heave. The layer of the cap which would be most affected by frost damage is the low permeability barrier layer.

In the Hanford area, the depth of frost damage is approximately 3.5 feet (1.1 m)[14]. The minimum thickness of the cap above the low-permeability layer is 7.5 feet (2.3 m). Historical measurements of the lowest recorded subsoil temperatures at a depth of 36 inches (91 cm) are above freezing (Table 3-2). Long-term effects of freeze-thaw damage will not adversely affect the cap performance.

Surface effects of freeze-thaw (e.g. gully formation and erosion) are minimal because of the design and function of the cap layers. Freeze/thaw movement in the gravel mulch layer may actually enhance vegetation growth. Additionally, the upper two layers are uncompacted, and will not be adversely affected by freeze/thaw.

3.3.3.3 Cap Maintenance Requirements

The primary objective of the cap design is to provide an effective, low maintenance barrier between the waste and the environment. The long design life necessitates the use of passive systems for achieving the performance objectives. Active systems were not considered for the cap design because they require human involvement for operation and maintenance.

The passive systems used in the cap design incorporate natural materials to achieve the design objectives. For example, by selecting proper drainage gradients and capillary break material types, the need for an active system, such as the removal of infiltrating water by pumps or other mechanical means, was eliminated.

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[14] Sowers, G.F., 1979, Introductory Soil Mechanics and Foundations: Geotechnical Engineering, fourth edition, Macmillan Publishing Company, New York, New York, p. 141, Figure 3.30.

3.3.4 Cap Infiltration Modeling

3.3.4.1 Model Application

The final closure cap design was evaluated to estimate the amount of moisture that could be expected to migrate through the cap. The Hydrologic Evaluation of Landfill Performance (HELP) (Version 2.05) computer program developed by the U.S. Army Engineer Waterways Experiment Station was used for the evaluation. The HELP model was developed to provide landfill designers and regulators with a tool for rapid, economical screening of alternative designs. The program uses climatologic, soil and design data to produce daily estimates of water movement across, into, through and out of landfill covers.

The model uses a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. The user provides climatological data for the cap area. The climatological input data used are described below. The model input and output for the cap are presented in Attachment F of this Closure Plan and are discussed below. This model was used for comparative purposes and not as an absolute prediction of the degree of percolation for a specific design.

The hydrologic processes modeled by the program can be divided into two categories: surface processes and subsurface processes. The surface processes modeled are snowmelt, interception of rainfall by vegetation, surface runoff and surface evaporation. The subsurface processes modeled are soil evaporation, plant transpiration, vertical unsaturated drainage, barrier-layer percolation and lateral saturated drainage. The gravel mulch layer, capillary barrier layer, and site sand layer comprise the active moisture zone and are modeled as vertical percolation layers. The capillary break layer is modeled as a lateral drainage layer, and the low permeability barrier layer is modeled as a barrier soil layer.

Daily infiltration into the landfill cap is determined indirectly from a surface-water balance. Each day, infiltration is assumed to equal the sum of rainfall and snowmelt, minus the sum of runoff and surface evaporation. No liquid water is held in surface storage from one day to the next. The daily surface-water accounting process utilizes the Soil Conservation Service (SCS) rainfall-runoff relationship to determine the runoff resulting from the rainfall and snowmelt. Surface evaporation is then computed. Surface evaporation is not allowed to exceed the sum of surface snow storage and intercepted rainfall. The rainfall that does not run off or evaporate is assumed to infiltrate into the landfill cap.

The first subsurface processes considered are moisture evaporation from soil surfaces and plant transpiration from the evaporative zone of the upper subprofile. A vegetative growth model accounts for the daily growth and decay of the surface vegetation. The other subsurface processes are modeled one subprofile at a time, from top to bottom, using a six-hour time step. A storage-routing procedure is used to redistribute the soil

water among the modeling segments that comprise the subprofile. This procedure accounts for infiltration or percolation into the subprofile and evapotranspiration from the evaporative zone. Since the subprofile contains a low permeability barrier layer (i.e., Layer 5 of the cap), the program computes the head on the barrier layer, the percolation rate through it and the lateral drainage rate.

3.3.4.2 Maximum Value of Leaf Area Index (LAI)

This parameter defines the type of vegetative cover on the cap surface, and is used as input into the HELP model. LAI is defined as the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing. A value of 0.4 [15], representative of a shrub-steppe ecosystem, was used. A sensitivity analysis was completed using different LAI values.

3.3.4.3 Evaporative Zone Depth

This parameter is the maximum depth from which water may be removed from the soil by evapotranspiration. For the cap design, the capillary barrier layer corresponds to the evaporative zone depth since the function of the capillary barrier layer is to store moisture within the root zone and in the unsaturated soil matrix until evapotranspirative processes recycle any excess water back to the atmosphere.

In the unsaturated capillary barrier layer, the capillary pressures are much less than atmospheric pressure. For significant quantities of water to flow into and through the coarser sublayer, water pressure must be raised to nearly equal atmospheric pressure. The fine-grained material present in the capillary barrier layer must become nearly saturated for the water pressure to approach atmospheric pressure and thus allow flow into the sublayers. In the semi-arid environment found at the Facility, moisture present in the capillary barrier layer does not readily drain, thus providing moisture storage capacity within this layer. The increased moisture storage capacity of the capillary barrier layer enhances the ability to establish plants which are necessary for evapotranspiration to occur.

In order to select the final thickness of the cap layers, several combinations were evaluated using the HELP model. As discussed in Section 3.3.4.5, varying the thickness of the capillary barrier layer (Layer 2) affected the results more than varying any other parameter. The final design uses the optimum thickness of 36 inches (91 cm) which resulted in a minimal amount of percolation. Increasing the capillary barrier layer thickness to greater than 36 inches (91 cm) did not result in an appreciable decrease in percolation.

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[15] Link, S.O., G.W. Gee, and Thiede, M.E., 1989, Response of a Shrub-Steppe Ecosystem to Fire: Soil Water and Vegetational Change, Arid Soil Research and Rehabilitation, p. 169.

3.3.4.4 Climatic Data

There are three available alternatives for precipitation input into the model. The user may input site-specific data, use default rainfall data from a select list of cities, or use synthetically generated precipitation data. The synthetic daily precipitation generation option was used. The WGEN synthetic Weather Generator developed by the USDA Agricultural Research Service produces daily values of precipitation, temperature, and solar radiation for determining snowmelt and evapotranspiration for selected cities.

A 100-year climatic period was synthesized using the synthetic precipitation generator in the HELP model. Climatological parameters were derived from Yakima, Washington data. Yakima is about eighty miles west of the Facility. The average annual precipitation at Yakima is 7.92 inches (20 cm) while the average annual precipitation for Hanford is 6.25 inches (16 cm)[16]. Precipitation values generated by the synthetic precipitation option for Yakima were modified using an Edit feature of the HELP model so that the monthly average precipitation values incorporated into the model (Figure 2-5) were representative of historical data at the Hanford Facility. The synthetically generated precipitation and evapotranspiration values are shown in Figure 3-2.

After the design was finalized, several years of actual rainfall data were utilized as input to the model to evaluate the cap performance. The data are graphed on Figure 3-3. Twenty years of precipitation data from 1940 to 1963 (data were not recorded from 1943 to 1946) replaced the first twenty years of synthetically generated data.

The growing season used in the model ran from the end of March to the end of August[17].

3.3.4.5 Sensitivity Analyses and Results

The thicknesses and layer composition were determined as a result of the 1994 Richland Closure Plan Phase I Study[18] which evaluated various cap designs in order to determine the optimum cost-effective design.

The HELP model was used to simulate different design features such as material properties, layer thickness, slope, and drainage layer characteristics. The drainage

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[16] Stone, W.A, J.M. Thorp, O.P. Gilford, and D.J. Hoitink, 1983, Climatological Summary for the Hanford Site, PNL-4219, Pacific Northwest Laboratory, Richland, Washington, p. IV-2, Table 10.

[17] Rikard, W.H., L.E. Rogers, B.E. Vaughan, and S.F. Liebetrau, 1988, Shrub-Steppe Balance and Change in a Semi-Arid Terrestrial Ecosystem, Developments in Agricultural and Managed-Forest Ecology 20, Pacific Northwest Laboratory, Richland, Washington, p. 123, figure 6.6.

[18] Grant Environmental and Chase Environmental Group, Inc., 1994, Phase 1 Cap Design, Subsidence Evaluation and Initial Source Term Presentation, Richland, Washington Low-Level radioactive Waste Disposal Site, April 14, 1994.

layer is the capillary break layer (Layer 4). The calculated infiltration verified that the capillary barrier layer is the critical layer for limiting infiltration in this semi-arid environment. Varying the thickness of this layer affected percolation estimates more than varying any other soil parameter.

Other variables that were evaluated were the capillary break layer (drainage layer) slopes and the hydraulic conductivity of the drainage material. Decreasing the drainage layer slope from two percent to one percent caused no change in the amount of percolation from the bottom of the cap.

The hydraulic conductivity of the capillary break layer (drainage layer) was reduced from approximately 39.4 to 0.4 in/sec (100 cm/sec to 1 cm/sec) to simulate the effects of a gradual clogging of the drainage layer. The average annual percolation amounts increased from 0.01 in/yr (0.025 cm/yr) at 39.4 in/sec (100 cm/sec) to 0.06 in/yr (0.15 cm/yr) for 0.4 in/sec (1 cm/sec). As indicated by the model run results, the amount of water that is transported vertically through the drainage layer is negligible.

The effects of varying the amount of vegetative cover (the leaf area index) were evaluated. Increasing the LAI from 0.4 to 0.5 (40 to 50%) decreased the average amount of percolation through the bottom of the cap from 0.06 in/yr to 0.004 in/yr (0.15 to 0.01 cm/yr), a decrease of more than 93%.

The results of these analyses provided guidance in evaluating the cap layer performance (see Attachment F for model runs). A summary of the soil parameters used for each layer type is shown on Table 3-3.

3.3.4.6 Model Results

Summary model results were evaluated to finalize the cap design. The summary runs list the average annual values for the hundred-year time period modeled. To evaluate the effects of precipitation on an annual basis, a detailed model run was obtained for the final design cross-section. The data are graphed on Figure 3-2. It appears from the data that the percolation values remain essentially zero. Several years of above-average rainfall increased the amount of percolation from the bottom of the cap. The percolation amount peaks where the model calculates the annual percolation to be 0.48 inches (1.2 cm). When the precipitation values return to average values (around 6.3 inches, or 16 cm), the percolation values decrease to approximately 0.08 in/yr (0.2 cm/yr). The overall average percolation for the 100-year simulation is approximately 0.06 in/yr (0.15 cm/yr).

Model results using the historic data were reviewed to evaluate the cap performance. Percolation values are graphed on Figure 3-3. Two years of precipitation in excess of 11 inches (28 cm) at the beginning of the simulation resulted in high percolation values around year 15, but the percolation decreased to approximately 0.06 in/yr (0.15 cm/yr) when precipitation returned to average or slightly above average. The overall average percolation was estimated to be approximately 0.14 in/yr (0.36 cm/yr). It appears that

several consecutive years of higher than normal precipitation affect percolation values more than a single rainfall "spike."

In all cases, the effects of large precipitation events or unusual coincidences of wetter than average years are not persistent, and have relatively little effect on long-term average percolation.

The detailed model runs are included as Attachment F.

3.3.5 Cap Construction

3.3.5.1 Trenches 1-6 and the Chemical Trench Cap

Trenches 1-6 and the Chemical Trench will be capped with the partial cap after the approval of the Closure Plan and after final funding approval. The cost of the partial cap will be funded from the dedicated Site Closure Account administrated by the State. The drawings depicting the preliminary partial cap design for these trenches are included as plates at the end of this Closure Plan and in Drawing Set Number 1 in Attachment E. A final design will be prepared after the final Closure Plan is approved, and the State has provided input into the design. The purpose of constructing the partial cap is to monitor the cap performance prior to final site closure so that any modifications to improve cap performance may be incorporated into the design during subsequent revisions to the Closure Plan.

3.3.5.2 Facility Cap at Site Closure

The stability of the partial cap will be observed and measured during a period of active monitoring for not less than 10 years. This active site monitoring includes the water infiltration study and the less complex subsidence study. Vegetation growth and erosion impacts will also be monitored during this period. At the end of this 10-year period, an evaluation will be performed to determine if the assumptions made during cap design and construction were acceptable. If changes or modifications are required, they will be incorporated into future closure plans for final site closure in 2056.

The cap design drawings included as plates at the end of this Closure Plan and in Drawing Set 2 in Attachment E show the final cap elevations and indicates the areas where the partial cap will tie into the final cap. The tie-in areas were designed so that cap material placed over the disposal area would not be disturbed.

3.3.6 Cap Performance Monitoring for Trenches 1-6 and Chemical Trench

US Ecology will begin a monitoring program to document the performance of the partial cap after this cover is constructed. The monitoring program is described below. The program is designed to collect data to demonstrate the performance and stability of the closed Facility.

The program will be staged. The first stage will entail monitoring and repairs as necessary to stabilize the cap. This stage of the program is expected to extend for two to four years after the cap is completed. The second stage will consist of monitoring the stabilized Facility and documenting any deterioration that is observed. During this stage of the program, repairs will be made only when necessary to maintain the integrity of the Facility. US Ecology will obtain WDOH approval prior to making any repairs. Minor deterioration will be noted and observed to determine whether the deterioration stops or continues. This program should allow the cover to be stabilized, and provide a direct demonstration of the long-term stability of the Facility.

Data gathered during this program will include observations of trench cap condition, measurements of trench subsidence and settlement, measurements of moisture within the trench cover, and monitoring for certain organic gases and radionuclides in the trench cover and the vadose zone beneath the trenches. An access tunnel is proposed to be installed between Trenches 4 and 4B. This tunnel will be used to allow the inspection, repair and replacement of trench cover monitoring equipment without disruptive activities over the trenches.

Upon final closure, US Ecology will institute a Facility-wide inspection and repair program developed under the partial cap monitoring project. Information gathered during this project will be used to improve the closure program.

Although post-closure monitoring and maintenance will be the responsibility of the Custodial Agent, US Ecology assumes that a program similar to the second stage monitoring and maintenance program will be continued throughout the Custodial Care period.

3.3.6.1 Qualitative Observations

As described above, the cap observations will be divided into two phases. During the first phase of the partial cap monitoring program, the closed trench caps will be inspected for evidence of subsidence, settlement, cracking, animal burrows and erosion. Cracks and depressions caused by settlement and subsidence, animal burrows, and erosion gullies deeper than about four inches will be filled with soil from the site stockpile and will be compacted by construction equipment or hand-operated tampers as soon as weather or surface conditions allow traffic over the area without causing additional damage. Minor erosion, such as rills and gullies less than four inches deep, will be filled and compacted as required to prevent them from becoming more serious.

During the second phase of the program, the closed trench caps will be inspected and records kept of any erosion or subsidence. Repairs will be made only as necessary to prevent cap loss of function. Information gathered during this phase of the monitoring program will be reviewed periodically to identify any deficiencies in the design and maintenance program for the cap. Improvements to the cap and the maintenance program will be based upon the results of this monitoring.

3.3.6.2 Settlement and Subsidence Monitoring

US Ecology will install settlement plates in the partial cap. The plates will be installed in the cap below the maximum expected frost depth. A metal rod fastened to the plate will extend above the ground surface. The elevation of the top of this rod will be measured to identify any movement of the settlement plate. Two plates will be placed in each trench, at about the one-third distance points from the end of each trench. The elevation of the measuring point on each plate will be recorded when the plates are installed. Ground elevations will be measured at each plate and about five feet (1.5 m) from the plate at the same time. These elevations will be measured semi-annually thereafter during the monitoring period. Measurements of the settlement plates will allow the subsidence and settlement of the trench cap to be quantified. These measurements and the adjacent ground elevation measurements will allow estimates of erosion and/or deposition to be made.

US Ecology will measure and quantify any observed subsidence at locations other than at the settlement plates. These measurements will be made during the trench cover inspections, and before any repairs are made to subsidence or erosion features. The extent and location of the feature will be recorded, as will a description of any repairs. Additional settlement plates will be installed on two of the newer trenches to monitor subsidence. The location of these settlement plates will be determined by US Ecology and WDOH.

3.3.6.3 Infiltration Monitoring of Surface Barrier

3.3.6.3.1 Disposal Unit Cover Performance Monitoring

The premise upon which the design of the disposal unit is based is that the disposal unit should be compatible with, and complementary to, the natural conditions at the disposal site. The characteristics of the disposal site that are most significant to the ability of the disposal unit to isolate the radioactive waste are those characteristics related to the site aridity. The thick vadose zone is the most important aspect of the site, since disposal occurs in this zone, and it represents the primary barrier to uncontrolled migration of radionuclides. The presence and effectiveness of this zone depends in part upon the climate of the area, and in part upon the drainage and vegetation of the surface of the site.

The disposal cover has been designed to complement the features of the natural system which produces the very dry conditions in the near-surface soils. The disposal unit cap is designed to convey surface water away from the disposal unit. The cover is designed to retain most water which infiltrates into the cover within a zone where it can be removed by evaporation and transpiration. For a sensitivity analysis, the dose model was run assuming the moisture infiltration characteristics of the completed disposal unit will not differ appreciably from those of the natural system. This assumption represents a worst-case scenario, and any migration of waste constituents from the disposal unit will be less when the final cap is installed.

As a part of disposal cap design, characteristics of the natural system have been measured. Those characteristics have been adapted to analysis of the disposal unit using a variety of models. The closure cap monitoring program is designed to collect data to evaluate the performance of the cap. The program includes measuring moisture potentials at various points within the disposal unit cover to indicate whether there is movement of soil moisture in the cap. This monitoring system is described in more detail in the following sections.

3.3.6.3.2 Trench Cover Monitoring

Monitoring the disposal unit cap requires installing numerous moisture-sensing devices in the cover. These devices are sensitive and fragile. Inspection and replacement of the monitoring devices requires continuing traffic over the cover, and in some instances requires drilling or digging into the cover. To avoid conducting these disruptive activities on the disposal trenches, US Ecology proposes to construct a tunnel extending between Trenches 4B and 4 (see Figure 3-4) from which monitoring can be done without disturbing the trench cover surface.

The tunnel will be constructed from a corrugated metal pipe arch about six feet (1.8 m) high and ten feet (3 m) wide (a standard shape will be used). Provisions for access, lighting, power, and ventilation in the tunnel will be made. Monitoring devices can be installed by removing a small section of the metal wall, installing the monitoring device by drilling, jacking, or other appropriate means, and then patching the metal wall around the monitoring device.

The tunnel will be placed as the trench cap is constructed, and can be removed at or before final site closure. Figure 3-5 provides conceptual details of the monitoring tunnel.

The trench cap monitoring includes sampling and observations of water vapor, matric potential, and moisture content. The program for monitoring water vapor is similar to that presented in Section 4.5.1.2 for vadose zone monitoring beneath the trenches. The monitoring program for matric potential and moisture content is described below.

3.3.6.3.3 Instrumentation

The cap to be monitored will be instrumented as shown in Figure 3-5. The monitoring sensors are placed in clusters at various depths to allow measurement of moisture changes at different depths within the cover. Neutron access tubes will be installed near the instrumentation to monitor moisture movement in the cover materials.

Clusters of instruments are located within the cap, and along the interface between the cover and the excavation sidewall. The vertical positions of the sensors are indicated schematically on Figure 3-5. Within the trench covers, the sensors are located in the active moisture zone (the upper six feet (1.8 m) of the cover) and at interfaces between the various deeper layers. It is anticipated that heat dissipation probes (HDPs) and

thermocouple psychrometers (TCPs) will be used within the upper six feet (1.8 m) of the cover where a wide range of moisture potentials are anticipated. TCPs will be used for monitoring the deeper portion of the cover where moisture changes are expected to be smaller and matric potentials more negative. Neutron logging is used to track moisture movement and verify the operation of the other instruments. Neutron probes can indicate soil volumetric moisture content when properly calibrated.

The discussion that follows assumes that HDPs and TCPs will be used to instrument the trench cover. However, newer instrumentation will be examined when the partial cap is designed. One such instrument that will be considered as a replacement for both the HDPs and the TCPs is a Time Domain Reflectometry (TDR) system. The TDR system can provide direct measures of soil moisture content over a range of conditions from very dry to saturated.

3.3.6.3.4 Installation and Maintenance of Instrumentation

HDPs will be installed in borings extended from the tunnel. The probe will be placed in a small bag of silica flour to which enough moisture has been added to bring the moisture potential of the flour to a value slightly higher than that of the soil. The HDP probe and the silica flour will be inserted into the borehole. The borehole will be backfilled with soil from the boring. The backfill will be placed in thin (about 6 inch, or 15 cm) layers. Each layer will be compacted to the approximate density of the in-situ soil. Figure 3-6 is a detail of a typical HDP installation.

TCPs will be installed in one-inch (2.5 cm) diameter PVC casings that are slotted at the location at which the TCP is to be placed. Two TCPs, the readings from which are used as internal checks on the calibration of the sensors, will be placed at each location in the casing. A 0.25-inch (0.6 cm) air line extending to the approximate location of the TCPs is placed in the casing and used to purge the installation. A suction applied to this line will remove air from around the TCPs and replace the air with air from the surrounding soil. Figure 3-7 is a detail of a typical TCP installation in the trench cover.

The neutron access tubes will comprise aluminum casings, two inches (5.1 cm) in diameter, installed as shown on Figure 3-8. The surface where the casings enter the tunnel will be sealed with bentonite cement. The casings will be capped to prevent moisture from entering the tubes.

It is anticipated that the disposal unit cover monitoring will employ moisture sensors as presented in Table 3-4. However, should a different device be used (for example, TDRs), then the number of sensors will be modified according to the capabilities of the device used.

Experience with these types of sensors in other applications has shown that the failure rate of both types of sensors is high. US Ecology anticipates that approximately one-half of the HDPs and approximately 30 percent of the TCPs will fail during each year. The TCPs are installed in casings which allow them to be replaced without

replacing the casing or significantly damaging the trench cover. These sensors can be replaced by drilling new holes and installing new sensors. Because of the shallow installations of these sensors, replacement will be reasonably straightforward. The utility of the HDP sensors will be evaluated early in the program. These sensors may be eliminated from the monitoring arrays if early experience shows that the TCPs provide equivalent data. Logging the neutron access holes will require availability of properly trained personnel.

3.3.6.3.5 Measurements

The TCPs and HDPs will be connected to an Integrated Data Acquisition System (IDAS) (Figure 3-9). The IDAS facilitates Quality Assurance for the data collected. This computerized system collects data from the sensors at frequencies depending upon the depth of the sensor. Initially, data will be collected at the following intervals. Shallow sensors, those installed five feet (2.4 cm) or less below the surface of the cover, will be scanned every hour. Deeper sensors will be scanned twice each day. These frequencies may be changed as data are collected and the rates of moisture movement are quantified.

The neutron access holes will be logged immediately after every major storm or snowmelt event (0.5 inch (1.3 cm) or greater). Logging will be done thereafter once a day for six days. Logging will be done at least once a month. Point measurements will be made at locations near the moisture sensors.

The frequencies at which data are collected from the various sensors will be adjusted during the program depending upon observed time rates of change of matric potential and rate of moisture movement in the material.

The sensors measure matric potentials in the soils around the probes. These measurements are correlated with soil moisture characteristics curves developed from laboratory tests on samples from soils sampled near the probes when the probes are installed. The moisture characteristics curves will allow the matric potential data to be converted to moisture content and hydraulic conductivities from which percolation rates are estimated. The moisture content is also directly estimated from neutron logging.

3.3.6.3.6 Analysis of Data

The matric potential data and the derived moisture content data will be used to track the movement of moisture within the trench cover and to develop estimates of infiltration and percolation associated with particular precipitation events. Tracking the rate of infiltration from distinct events usually will be possible, since significant precipitation events usually will be widely spaced.

The ultimate purpose of the monitoring is to provide data regarding the quantity of moisture moving through the trench covers. Limited site performance evaluations have been made on the basis of infiltration after partial or total cover failure. Intact trench covers are expected to be at least as effective in limiting infiltration and percolation as

the natural soil profile. It is unlikely that measured infiltration rates will exceed the conservative rates used in the performance evaluation.

No particular levels of infiltration into or percolation through the trench cap can be identified as critical and requiring immediate corrective action. Instead, the data from this monitoring will be used to confirm the expected performance of the trench cover, or as a basis for improving the trench cover design should the data indicate that the cover does not perform as expected.

Annual summaries of the data will be prepared and copies maintained at the Facility. Because this type of monitoring is largely experimental in nature, these summaries will include a brief discussion of the program during the year and any maintenance and special problems encountered. The summary will identify any unusual or notable infiltration events and provide an estimated annual water balance for the trench covers.

A copy of the data summary will be included in an appropriate report to the WDOH. Detailed data printouts and computer records of the data will be kept at the site or another location selected by US Ecology. These data will be available to the WDOH upon request.

3.3.6.4 Vegetation Monitoring

The role of vegetation in the cap design is two-fold: to remove infiltrating water from the active moisture zone, and to reduce erosion on the cover and outslopes. The important characteristics of the vegetative growth with respect to these features are the ability to resist drought, develops dense roots, and extract water from the soil profile. The vegetation monitoring data is particularly important on the outslopes of the cap, where vegetation is subject to the greatest stress.

After the partial or final cap is constructed, vegetation monitoring will consist of observations recorded over time. Vegetation observations should be performed more frequently in the first few years after the partial or final cover is finished, when the vegetation growth is beginning, and then be reduced in frequency as the vegetation becomes more established. At this time, a semi-annual frequency is envisioned for the first two to four years, and then annually afterwards for the remainder of the 10-year observation period described in Section 3.3.5.2. The vegetation observations will be recorded on a site map, as either grids or scanlines, and include such details as growth density, vegetation types (particularly as the expected alien species encroach), and distribution (e.g., even or bunched). Photographs also will be taken to support the observations. If possible, observations of any erosion will be correlated with vegetation observations, and repairs made, if necessary. Vegetation repairs may include additional seeding or plantings, and fertilization or additional watering to promote growth if necessary. US Ecology will obtain WDOH approval prior to making any repairs. The vegetation data will be stored at the Facility for WDOH inspection.

3.4 SITE STRUCTURES

3.4.1 General

The structures that are presently within the 100-acre State leased property are listed in Table 3-5. Aside from the two WDOH office trailers controlled by the State, US Ecology monitors and maintains site structures to control the spread of radioactive materials. The only structure that is within the controlled area is the Inspection Room, adjacent to the Facility Laboratory. Access from the inspection area into the laboratory area requires a whole body frisk. All other site structures are outside of the controlled area and are not considered contaminated or in need of decontamination prior to removal. This conclusion is based upon the existing controls and monitoring in place as part of overall site operating procedures.

The inspection room is also monitored after use to prevent the spread of contamination. Any residual activity noted during these inspections is removed. This would be the only building that may require decontamination and/or dismantling for on-site disposal during the closure period.

At the time of final closure, US Ecology will consult with the custodial agency to decide which buildings are to be removed from the site. US Ecology will dismantle the buildings for off-site disposal as non-radioactive material. The removal of potentially contaminated buildings is discussed in Section 3.4.2.

3.4.2 Decontamination

Decontamination will be performed, if required, in accordance with NRC Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," or successor guidance as appropriate. This will ensure that the decontaminated structure (Inspection/Laboratory Building) meets all unrestricted release criteria. Decontamination operations will be conducted in accordance with the Facility Standards Manual (FSM) and Richland Operations Procedures (ROPs) and as required by any applicable laws, rules or regulations. Current acceptable surface contamination levels for release of materials for unrestricted use are specified in Table 3-6. In lieu of decontamination, the contaminated portions of structures may be disposed of in the operating disposal area. Since the last operating trench will be closed during the Closure Period, the decision to dismantle the Inspection/Laboratory building must be made during the Closure Period.

3.4.3 Equipment and Materials

No materials, equipment or supplies are contemplated to be transferred to the custodial agency. The extent of contamination will be the primary factor for choosing the method for disposal of equipment and materials stored within the controlled area. Contaminated or unsalvageable items will be disposed of in the operating disposal trench prior to final closure. Salvageable items will be removed from the site at no cost

to the custodial agency after radiological control personnel have performed surveys and decontamination, as necessary in accordance with NRC Regulatory Guide 1.86 and US Ecology's FSM and ROPs.

3.5 INSPECTIONS AND SURVEYS

3.5.1 General

This section sets forth the guidelines to be implemented by the Facility Radiological Control and Safety Officer (FRC&SO) or his designee or the custodial agency when performing the gamma surveys and inspections on closed trenches.

Surveys and inspections of filled trenches will be performed on a quarterly basis per applicable operations procedures during the closure and stabilization period. All cap surveys will be conducted as walking surveys.

During the periodic surveys, physical or radiological abnormalities will be clearly and unambiguously marked. Coordinates of the abnormality can be derived by measurement from known points or can be located after the monitoring survey by land surveying methods. A copy of the site map or an overlay of the map will be marked to show the survey pattern and the location and description of abnormalities. Subsequent overlays from later surveys will create a continuous record of survey coverage and will identify any areas of abnormality.

3.5.2 Schedule

Surveys are to be performed during the closure and stabilization periods and are recommended for the custodial period.

A. Interim Closure

During the operational life of the Facility (i.e. that period of time when low-level radioactive waste is being disposed of), trenches which have been closed and capped (interim closure) will have an initial survey and inspection completed as described in Sections 3.6 and 3.7. Subsequent surveys and inspections will be performed on a quarterly basis.

B. Partial Closure

After placement of the cap on Trenches 1-6 and the Chemical Trench, a baseline survey will be performed over this capped area. Subsequent surveys and inspections will be performed in accordance with Sections 3.6 and 3.7. Erosion gullies, subsidence, and animal burrows will be monitored to determine rate of deterioration of the surface for establishing guidance for future repairs at final site closure. Repairs will be made as described in Section 3.3.6.

C. Closure and Stabilization Period

During the final closure phase of Facility operation (i.e. that period of time when the final site closure activities are being carried out), trench cap surveys will be postponed until placement of the final cap has been completed. After completion of site work, a baseline survey will be completed of the entire capped area. During stabilization (i.e. that period after site closure in which observation and maintenance is performed to verify the site is stable and ready for institutional control), trench caps will be surveyed and inspected quarterly per Sections 3.6 and 3.7. At the end of the stabilization period (herein assumed to be five years) the licensee will have applied for a license transfer to the disposal site owner or prime lessee.

D. Custodial Period

During the custodial period, trench cap surveys and inspections are recommended to be performed on a quarterly basis per Sections 3.6 and 3.7. This period also is called the perpetual care and maintenance (PC&M), institutional control, or post-closure period. This is the time after the license has been transferred to the site owner or prime lessee. Under the conditions of the transferred license, the licensee will carry out a program of monitoring to assure continued satisfactory disposal site performance.

3.5.2.1 Records

All inspections, trench cap surveys and maintenance information will be recorded in an inspection/maintenance log. The log will include, at a minimum, the date, name of person performing the inspection or maintenance, weather and site conditions, relevant observations, and a detailed description of maintenance performed. In addition, all areas requiring maintenance, or areas where maintenance has been performed, will be shown on a minimum of an 8-1/2 by 11-inch (21.6 by 28 cm) copy of the site map which will be kept with the log. When maintenance is performed on a date other than the inspection date, the inspection date will be referenced on the maintenance record to ensure that the log is kept current. The master copy of the log will be retained at the Facility and a duplicate copy will be retained at another company location. The log will be transferred to the custodial agency after closure.

3.6 SURFACE INSPECTION

The closed trench caps will be inspected quarterly for evidence of subsidence, settlement, cracking, animal burrows and erosion. A standard for repair of cracks and depressions caused by settlement and subsidence, animal burrows, and erosion gullies will be established during the partial cap observation period and finalized during the

stabilization period. As the criteria are established for cap repair, a procedure will be written for site implementation and submitted to WDOH for approval.

3.7 TRENCH RADIOLOGICAL SURVEYS

3.7.1 Instrumentation

All surveys will be performed utilizing an instrument capable of monitoring in the range of 2 μR/hr. Instruments will be calibrated at six month intervals. The requirements of US Ecology's FSM will be followed during the closure and stabilization, and are recommended for the custodial period.

3.7.2 Radiological Survey Procedures

Per operating procedures, closed and capped trenches are completely surveyed to determine the baseline levels to be used for all future surveys. Significant changes to a trench cap (e.g., the placement of the partial and final cap), will require complete resurvey of the cap to reestablish the baseline levels.

Once the baseline survey has been completed, all trenches will be surveyed quarterly such that 25 percent of each cap is included, and all capped areas are completely surveyed annually during the stabilization period. The survey is to be performed in accordance with approved procedures. Any readings in excess of two times the baseline values established during the closure period are reported to the FRC&SO. Additional fill material will be applied to decrease the direct gamma radiation readings to approximately the baseline values.

3.8 ENVIRONMENTAL MONITORING

3.8.1 General

Monitoring activities which will be performed during the closure, stabilization and custodial periods are described in the following sections. The sampling frequencies are summarized in Table 3-7. The proposed monitoring programs will provide for continuity between measurements obtained during the operational period. Almost seventy years of additional monitoring data will be obtained during the period from 1996 through site closure and stabilization in 2063.

3.8.2 Airborne Radioactive Monitoring

Airborne radioactivity concentrations will be monitored weekly throughout the closure period during cap placement and quarterly thereafter through the first year of the stabilization period. Subsequent to these periods, airborne activity monitoring is unnecessary as the installation of the final cap effectively precludes airborne release of radioactive materials.

It is expected that four airborne activity monitoring stations and one background station will be used during the closure and stabilization periods. The locations of these stations are indicated in Figure 3-10. The background station will be located in the region utilized for background measurements during the last phases of operation. This will provide consistency between the operational and closure monitoring programs.

Airborne particulate monitoring will be performed by drawing air at approximately 1.5 cubic feet per minute through glass fiber filters. Filters will be counted for the presence of gross beta and alpha activity on a weekly basis. Filters collected from each station during each quarter will be composited and analyzed for the presence of gamma-emitting radionuclides.

It is expected that monitoring for radioiodine will be performed using activated charcoal adsorber cartridges in-line with the glass fiber filters. Charcoal cartridges will be analyzed weekly with the particulate air filters.

Airborne tritium samples will be collected from the northwest and southeast stations using silica-gel desiccant columns. Water vapor collected in these canisters will be extracted and measured to determine tritium concentration in air. These samples will be taken quarterly.

3.8.3 Soil Sampling

Soil samples will be taken at the location of each of the four airborne activity monitoring stations. Soil samples will also be taken at the background airborne activity monitoring station to provide a local control sample.

Soil sampling will be done quarterly during the closure and stabilization periods. Soil sampling is recommended to be performed annually during the custodial period. Installation of the permanent site cap will provide a sufficiently thick layer of fill and cover materials to reduce sampling to annual measurement for soil radioactivity concentrations.

Procedures presently used for performing soil sampling will continue to be used for future sampling events. The general procedure for soil sampling is to use dedicated sampling equipment to collect soil from a 12-inch (30.5 cm) square area to a depth of one inch (2.5 cm). An aliquot of this sample is then analyzed by gamma spectroscopy for the presence of gamma emitting radionuclides. Other analyses include gross beta activity, isotopic plutonium concentrations, and total uranium activity.

3.8.4 Vegetation Sampling

Vegetation samples will be collected annually during closure and subsequent periods. Live vegetation will be sampled from the vicinity of each of the air monitoring stations as well as from the background station. Trench cap vegetation samples (if sufficient vegetation is present) also will be taken from each of the three trenches containing the

greatest quantity of tritium. Currently, trenches 9A, 11 and 13 have the greatest tritium activity.

As there are no harvest crops grown within the bounds of the Hanford Reservation, vegetation samples will include various deep-rooted species that are viable in the region.

The general procedure for vegetation sampling is to clip live samples from several plants and place the clippings into sample containers. Samples are subsequently analyzed for gamma emitters, gross beta, total uranium and isotopic plutonium activity. Samples taken from the caps of trenches and the background stations also will be analyzed for tritium activity.

3.8.5 Groundwater Monitoring

Groundwater monitoring beneath the site is currently done in five monitoring wells shown on Figure 3-11. These wells, constructed in the fall of 1985, vary from 350 to 360 feet (107 to 119 m) deep and are screened through the upper 35 to 40 feet (11 to 12 m) of the unconfined aquifer. One well, MW-13, is located up-gradient of the site and the remaining four wells, MW-3, MW-5, MW-8 and MW-10, are located down-gradient of the Facility for current groundwater flow conditions.

These locations monitor the upper portion of the aquifer as the zone most likely to be affected by the Facility, as well as releases from off-site locations, and form an adequate monitoring system. Performance of the wells will be addressed through periodic well evaluations which include quarterly water level and well depth measurements, non-destructive casing inspections every five years, and review of groundwater analytical data.

Water samples are collected on a quarterly basis and are analyzed for the specific constituents given in Table 3-8. Sampling is performed in accordance with Richland Operational Procedures that have been approved by the WDOH.

All analyses of groundwater demonstrate that the concentrations of gross alpha and beta emitters, isotopic plutonium and uranium, and gamma emitters are not significantly greater than the concentrations in groundwater located off the reservation. Tritium concentration in groundwater has been increasing due to the encroachment of a tritium plume from the southwest, i.e., up-gradient of the disposal units[19]. It exceeds the tritium concentration typical of background locations off-site from the Hanford Reservation. Tritium concentrations in the unconfined aquifer exceed 2 $x10^5$ pCi/l in the regions surrounding the 200 East and 200 West Areas. As expected, tritium contamination from these plumes is increasing the tritium levels observed in Facility

[19] Hanford Site Environmental Report for Calendar Year 1992.

monitoring wells. The concentration of tritium in groundwater under the Facility is not greater than that found in the nearby vicinity on the Reservation. Comparisons of groundwater data gathered to date can be found in previous US Ecology Annual Environmental Monitoring reports as well as Hanford Site environmental reports.

As discussed in the US Ecology January 18, 1994 correspondence to Mr. Gary Robertson, WDOH, (included in Attachment G with the proposed Vadose Zone Monitoring Program) and based upon the sequence of site development, US Ecology had proposed that an additional up-gradient well (MW-9) and down-gradient well (MW-1) be installed in the near term. Based on discussions in a meeting held between US Ecology and WDOH on October 26, 1995, the two wells will be installed up-gradient of the Facility, and will screen different depths of the uppermost aquifer. The new wells will be located near the southwest Facility boundary to monitor the encroachment of the contaminated plume emanating from the 200 West Area (see Figures 3-12 and 3-13). Well installation and abandonment will be in accordance with the requirements of the Washington Administrative Code (WAC-173-160-500). These are the only new monitoring well locations proposed to be constructed through site closure. Some existing monitoring wells may require replacement prior to site closure. The proposed well locations are shown on Figure 3-14.

Quarterly monitoring will continue throughout the closure and stabilization periods. Additionally, annual sampling of the wells is recommended throughout the PC&M period. A decrease in the frequency of monitoring during the PC&M periods is justified if levels of contaminants associated with the Facility are not detected during the operational period and various other monitoring phases. Monitoring will be adjusted should groundwater measurements exceed activity levels in Table 6.1 of the FSM, indicating the need for further investigation.

3.8.6 Direct Radiation Monitoring

Thermoluminescent dosimeters (TLDs) placed at locations surrounding the Facility boundary will monitor direct radiation. Eleven dosimeters will be used for quarterly integrated monitoring during the closure and stabilization periods. Quarterly monitoring is justified due to the type of operations to occur at the Facility during the time period of interest, as well as the need for increased sensitivity of the badges exposed for longer periods of time to environmental levels of radioactivity. The direct radiation monitoring program will serve to supplement and reinforce the trench cap radiation survey information which will be gathered on a quarterly basis during the closure and stabilization period and on an annual basis (as recommended) throughout the PC&M period. The monitoring of direct radiation on a quarterly basis also will provide adequate assurance that exposure to direct radiation is within regulatory requirements.

The TLDs will be placed at each corner of the Facility and at the middle of the north and south Facility boundary lines. In addition, two dosimeters will be located on the east and west sides of the Facility boundary as shown in Figure 3-15. A background

dosimeter will determine the relative significance of the Facility with respect to external radiation. This dosimeter will be located at the same location that is in use for background determination at the time of Facility closure.

3.8.7 Vadose Zone Monitoring

3.8.7.1 Current Program

Currently three vadose zone wells installed in the unsaturated soil zone are part of a research program to determine their viability. US Ecology installed the three vadose zone monitoring wells to experiment with soil gas sampling and analytical techniques. The well installation and proposed sampling procedures are detailed in US Ecology's "Vadose Zone Monitoring Program" submitted March 1992[20]. The compounds monitored are toluene, xylene, methane and combustible gases, radon-222, and tritium. Sampling is conducted quarterly. This program will be evaluated along with the expansion program discussed in Section 3.8.7.2 to determine if the program will be modified or terminated as appropriate.

3.8.7.2 Potential Expansions

US Ecology has developed and submitted to WDOH and WDOE a program for approval to further investigate and measure the radionuclides and chemical constituents of the waste that may have moved from the trench into the underlying vadose zone (summarized below in Section 3.8.7.2.1 and described in detail in Attachment G). This program is an enhancement of the present vadose zone monitoring program. The program includes drilling beneath two trenches, Trench 5 and the Chemical Trench. Soil samples will be taken from beneath the trenches and tested to identify and quantify any regulated waste constituents. Based upon the results of this testing, the suite of constituents for which the groundwater is monitored will be modified as appropriate.

At the present time, vadose zone monitoring at other sites, including the Reservation, has been confined to research and development projects conducted by government and academia, not by functional operational programs. There are no ASTM, EPA or NRC standardized procedures for analyzing soil gas constituents. For these reasons, the proposed US Ecology program is of necessity an experimental program designed in part to explore the effect of such monitoring, and to identify and validate techniques by which the program can be implemented and expanded. The proposed expansion to the existing program is outlined below.

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[20] US Ecology, Inc., 1992, Vadose Zone Monitoring Program for Low-Level Radioactive Waste Management Facility, Richland, Washington, March 1992.

3.8.7.2.1 Initial Study

Upon approval, US Ecology will expand the existing experimental vadose zone monitoring program. The following paragraphs briefly outline the proposed expansion, which is oriented toward monitoring existing trenches at the Facility. This expansion is designed to be compatible with, and complimentary to, the existing experimental vadose zone monitoring program. Attachment G explains the expanded vadose zone monitoring program in greater detail.

The purpose of the expanded program is to obtain monitoring data beneath trenches where radionuclides or trace concentrations of hazardous constituents may have migrated into the adjacent vadose zone either as vapor or liquid. Collected data will be studied to determine if they have any probative value. If useful interpretations of the data can be made, then the program may be scaled to monitor other Facility locations as appropriate.

The proposed expansion comprises two separate activities: 1) constructing two monitoring clusters to test the viability of monitoring the vadose zone, and 2) sampling and analyzing from beneath trenches. The locations of the two clusters were selected based upon the results of the existing experimental vadose zone monitoring program, and a desire to monitor the vadose zone beneath the Chemical Trench. Results from the existing experimental vadose zone monitoring show detectable tritium in well VW-101. The first cluster location will facilitate comparison of the expanded program results with the existing experimental program results. Trench 5 has more tritium than any of the other old trenches (1 - 6), and so positive monitoring results are more likely in the vicinity of this trench. The second cluster location beneath the Chemical Trench will allow potential movement of constituents from the Chemical Trench to be identified and assessed.

Each new monitoring cluster in the expanded program will consist of a test boring and three well borings in which vadose zone monitoring wells will be installed. All four borings will be angled to extend beneath the trench. Borings for the wells will be drilled with augers, or by using casing and an air rotary rig. Vertical wells have been installed at the Facility and at other locations in the 200-East Area using augers. If neither augers nor air rotary drilling prove satisfactory for the angle borings, US Ecology will consult with WDOH to choose a more appropriate drilling method. Magnetic or gyroscopic wellbore surveys will be used to monitor drilling angle and determine the proper locations of the sampling points in the new vadose zone monitoring wells.

Continuous or near-continuous split-spoon samples of soils will be taken from the test boring at each cluster. These samples will be logged by a geologist or engineer at the site. Split-spoon samples also will be taken from the well borings in each cluster, but the number and locations of these samples will be at the discretion of the geologist or engineer at the Facility, if such samples are thought necessary to provide a complete picture of the stratigraphy and soil conditions in the well boring. Continuous sampling is

not required in each well boring because of its proximity to the test boring. As a minimum, a sample will be taken from each well boring at the depth corresponding approximately to the bottom of the trench and at the maximum depth of the boring. Samples also will be taken of fine-grained strata thicker than 6 inches (15 cm). If a stratum comprising thin alternating beds of fine and coarse materials is encountered, that stratum will be sampled continuously. Where split-spoon samples are not collected, a sample of drill cuttings will be collected at five-foot (1.5 m) intervals.

The soil samples will be subjected to several suites of tests, including tests to measure physical properties, basic chemical and hydraulic properties, and chemical and radiological contaminants. Chemical and physical properties of the soils will be used to interpret the monitoring data that will be collected from the vadose zone monitoring wells. The specific tests comprising each suite are listed in Table 3-9.

A vadose-zone monitoring well will be installed in each of the three well borings at each cluster. These wells will be screened over the lower five feet. The monitoring well clusters will be sampled quarterly until the program data indicate that a different frequency is appropriate. Gas samples, condensate samples, and sorbent samples will be taken from each sampling well. The gas samples will be tested for volatile organics, the condensate samples will be tested for tritium, and the sorbent samples will be tested for tritium and radon-222.

3.8.7.2.2 Data Interpretation

Vadose zone monitoring is performance monitoring. Some movement, particularly of gaseous constituents, is expected. The design and operation of the Facility is predicated upon the ability of the trench cover and the vadose zone to limit the movement of waste constituents to acceptable levels. Consequently, the vadose zone monitoring program will be managed to attempt to monitor the effectiveness of the site to limit movement of waste constituents.

Factors important to the assessment of site performance include:

- moisture profile, and particularly changes in moisture content,
- identification of transport mode (gaseous or unsaturated water movement),
- identification of major contaminants, and
- measurement of changes in contaminant concentration with depth.

The vadose zone monitoring program will consider these factors. The silica gel and gas sample analyses will be used as indicators of the presence or absence of radionuclides and VOCs. Moisture variations at selected locations will be examined initially from soil samples collected during drilling to identify major changes in moisture content that might signify the passage of a slug of moisture (and presumably waste constituents).

Moisture content will be compared with soil moisture tension curves to determine if the moisture in the soil column is in equilibrium. This comparison is desirable but the extreme non-linearity of the moisture-tension curves at the expected moisture contents make the comparisons subjective at best.

Shapes of waste-constituent plumes, if any, will be examined to determine whether the mechanism by which the plume moves is gaseous diffusion or unsaturated water flow.

Estimates of radionuclide and organic fluxes will be made. The estimates will be based upon measured analyte concentrations and estimates of moisture or gas flux determined from the vadose zone monitoring data. These estimates will be compared with estimates made in previous site assessments to monitor Facility performance.

Radionuclide and organic vapor flux estimates will be compared to the fluxes that would be required to cause the water in the underlying aquifer to exceed established groundwater standards. This comparison will be based upon analyses of movement through the unsaturated zone and mixing in the saturated zone during transit to the site boundary (the groundwater compliance point). Unsaturated flow models and gaseous diffusion models may be used to calculate the constituent flux through the unsaturated zone. Groundwater flow and transport models may be used to calculate the constituent mixing and transport in the groundwater to the site boundary. Hydraulic and chemical information obtained from this program, and information obtained from previous studies by US Ecology and others on the site and site area (described in Section 2.7), will be used to calibrate the various models.

The data obtained from the program will be evaluated to determine whether they are repeatable, and whether they provide a consistent indication of conditions in the vadose zone beneath the trenches. These evaluations will be made of individual components of the program. Data from the various components will be compared to evaluate the internal consistency of the information. For example, if the silica gel samples show elevated concentrations of tritium, then the gas samples should confirm, or at least not contradict, this finding.

Since this program is considered an experimental monitoring program, the final design, number of wells, and locations at closure can not be predicted. Modification to the program will be covered in future closure plans.

3.8.7.2.3 Reports

Monthly progress reports will be prepared during the installation phase to document the progress of the installation, and to formalize discussions between US Ecology, WDOH, and other Washington agencies.

A final installation report will be prepared and submitted to WDOH within three months after the installation of the system is complete. This report will document the

installations, provide complete diagrams of the monitoring wells, and present and summarize the field and laboratory data collected during the installation.

Quarterly monitoring results will be reported thereafter during the program. The Annual Environmental Monitoring Report will contain a synopsis of the data for the entire year, and include a detailed evaluation of the data.

3.8.8 Quality Assurance

Samples taken to implement the environmental monitoring program are analyzed either on-site or by an independent laboratory under contract to US Ecology. Both in-house and contract counting laboratories are subject to the US Ecology Quality Assurance Program (QA-MA-1). This program will be continued through the stabilization period, and US Ecology is recommending that a similar program be implemented by the custodial agency.

Samples analyzed on-site are counted on equipment that is calibrated in accordance with manufacturer's technical manuals using traceable sources. Daily instrument checks also are performed in accordance with manufacturer's technical manuals. All analyses are performed according to written and approved sample analysis procedures.

Samples analyzed at the contract laboratory are transferred under a chain of custody system to ensure representative samples are received by the processor. Field and trip blank samples are included with each shipment.

Samples are processed in accordance with the laboratory's written analytical procedures which are reviewed by US Ecology. Contract laboratories are required to comply with U.S. NRC Regulatory Guide 4.15 and to participate in the U.S. EPA analytical cross-check program. Although National Voluntary Laboratory Accreditation Program (NVLAP) standards have not been developed for environmental direct radiation measurements, contract environmental TLD processors are required to be NVLAP-certified for personnel dosimetry as a demonstration of their competence in the field of dosimetry.

Analytical laboratories used by US Ecology are audited by US Ecology's Quality Assurance Department prior to being placed on US Ecology's Approved Vendors list (AVL). Laboratories are reviewed annually thereafter in order to remain on the AVL.

Contract laboratories are required to notify US Ecology if sample results exceed predetermined "action levels." In addition, they are also required to notify US Ecology of any defects or anomalies in sample receipt or analysis.

3.9 ENVIRONMENTAL MONITORING ANALYSIS

Data will be screened to identify values that deviate greatly from other data or appear to be inaccurate. Outliers will be investigated for validity by reviewing laboratory results,

sample collection practices, and the effect of Reservation operations, e.g., contaminated groundwater plumes from Reservation facilities intercepted by site wells. Examples of inaccurate data are analyses resulting in positive identification of short half-life radionuclides that are not the daughters of long half-lived parents or when parent-daughter activity ratios vary significantly from standard values.

Should statistically significant levels of radioactivity or unusual/unexpected levels of radionuclide migration be detected, those levels of radioactivity or rates of migration will be analyzed with regard to their possible effect on the ability of the facility to meet the annual dose limits in WAC 246-250-170. Should environmental levels result in calculated annual doses greater than 50 percent of these limits, corrective action will be implemented.

The laboratory will report results with an estimate of the uncertainty associated with the 95 percent confidence level of the analytical result. Laboratories typically report the confidence level of a measurement in terms of the standard deviation, or sigma, e.g., a mean value plus the value for two sigma. If the mean value is equal to or greater than three sigma, there is confidence that the radionuclide was detected by the analysis. If the mean value is equal to a value between two sigma and three sigma, the results may be questionable due to statistical variations within the group of samples. Such results may not be reliable because all uncertainties associated with laboratory analysis are not assessed and propagated to yield a total uncertainty value. Thus, the 95 percent confidence value may encompass zero, and the contaminant may not have been detected. Questionable results will be thoroughly evaluated with respect to all available information that may lead to the conclusion that the contaminant was or was not detected. Sample results for volatile organic compounds are reported in the appropriate units for the tested media, and include the laboratory Practical Quantitation Limit (PQL).

3.10 PERMANENT MARKERS

Interim closed trenches are marked with monuments bearing plates inscribed with the identifying information as required by License Condition 65 and Section 5.9.6 of the FSM. These monuments will be removed prior to final closure and placed over the final cap after closure. The existing cap monuments should be satisfactory for final closure. Also, survey records tying these monuments and the disposal area corners to established federal control systems will be transferred to the custodial agency after closure. A site map with a complete list of trench coordinates in the NGS system will be provided to the custodial agency at closure. Records containing the information on the markers will be provided to the custodial agency at closure in the event a destroyed marker requires replacement.

The existing trench markers are installed at each end of the disposal trench and are solid concrete blocks, 12 inches (30.5 cm) thick and 12 inches (30.5 cm) wide and 8 feet (2.4 m) long. The markers are buried with a minimum of 20 inches protruding from

the surface. The data on each marker is inscribed on a brass plate 4 inches (10 cm) by 6.5 inches (16.5 cm) and 0.125 inches (0.3 cm) thick. The brass plate is attached permanently to the marker block by use of brass studs in order to preclude any galvanic action.

The information inscribed on the trench marker is listed below. Any changes required to the markers, which reflect the Company's disposal records, will be made before final installation. The inscribed information is:

1. Total activity of radioactive material in curies, total amount of source material in kilograms, and total amount of special nuclear material in grams in the trench;

2. Trench number;

3. Date of opening and closing of the trench; and

4. Volume of waste in the trench.

3.11 SECURITY

The Facility is located near the center of the 573-square mile (1,480 square km) Reservation within the Central Plateau and has manned entrances, a pass system, and internal security patrols. At closure, security around the Facility will be maintained by the existing eight foot (2.4 m) high galvanized chain-link fence which is topped with three strands of barbed wire. The fence as well as Reservation security measures previously mentioned will continue to protect all closed and capped disposal trenches. The final form and extent of Reservation security measures that will be in-place at the time of Facility closure have not been determined by DOE.

A report from the Hanford Future Site Uses Working Group recommended that "some type of government presence or oversight of the (Central Plateau) Area should be assumed for the foreseeable future due to the anticipated level of residual contamination in the ... (Central Plateau) Area"[21]. Additionally, the report recommended that access to the area be restricted to personnel who are properly trained and monitored. The casual intruder will be prohibited from entering the Facility for the foreseeable future after closure.

3.12 TRANSFER OF RECORDS

The site maintenance and stabilization records generated during the operational phase of the Facility will be catalogued, organized chronologically, and cross-referenced as necessary prior to closure and during closure. The following record categories will be transferred to the custodial agency:

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[21] Hanford Future Site Uses Working Group, 1991, Future for Hanford: Uses and Cleanup.

- Site Characterization Reports and Geotechnical Engineering Studies.
- Engineering Designs and Specifications.
- Construction QA/QC Records.
- Site Maintenance Records.
- Annual Environmental Reports.
- Safety Analysis Reports.
- Shipping Manifests/Radioactive Shipment Records.
- Burial Records.
- Operation Surveys.
- Vehicle Radiation Surveys.
- Environmental Monitoring Reports (Laboratory Results).
- Monitoring Equipment Calibration Records.
- Environmental Monitoring Quality Assurance Records and Audits.
- Copies of all previously issued Licenses, Operations Manuals, Procedures and Regulatory Agency issued License Variances.
- Final Plot Plan, indicating all disposal areas on the Facility.

Copies of records for the location and the quantity of radioactive waste contained at the Facility will be transferred upon license termination to the Governor's Office and other State, local and federal governmental agencies designated by regulatory or custodial entities at the time of license termination.

Table 3-1

Revegetation Grass Species

Species	Accession or cultivar
Siberian wheatgrass (Agropyron sibericum)	P-27
Thickspike wheatgrass (Agropyron dasystachyum)	Critana
Indian ricegrass (Oryzopsis hymedordes)	Nezpar
Sheep fescue (Festuca ovina)	Covar
Canby bluegrass (Poa canbyl)	Canbar

Table 3-2

Subsoil Temperatures

	AVERAGE MONTHLY SUBSOIL TEMPERATURES*			-0.5 INCH				-15 INCHES				-36 INCHES			
	-0.5"	-15"	-36"	HIGHEST MONTHLY AVG	YEAR	LOWEST MONTHLY AVG	YEAR	HIGHEST MONTHLY AVG	YEAR	LOWEST MONTHLY AVG	YEAR	HIGHEST MONTHLY AVG	YEAR	LOWEST MONTHLY AVG	YEAR
JAN	31.1	36.0	42.4	39.4	1967	16.3	1949	41.3	1967	25.5	1979	48.7	1975	36.3	1979
FEB	38.5	39.0	42.1	44.7	1967	30.6	1950	44.9	1967	29.6	1957	46.9	1967	33.5	1957
MAR	48.0	46.4	46.1	54.0	1968	42.4	1955	52.6	1968	40.3	1955	51.7	1968	41.8	1955
APR	60.1	55.2	52.9	69.4	1977	53.2	1970+	62.1	1977	48.7	1955	57.4	1966	47.3	1955
MAY	72.8	65.4	60.7	83.6	1947	65.2	1959	70.4	1966	58.5	1955	64.3	1968	54.8	1955
JUNE	82.0	74.9	68.8	88.1	1974	74.2	1953	84.5	1966	67.2	1953	73.4	1969	64.0	1953
JULY	91.2	81.7	75.5	96.2	1968	84.0	1955	88.1	1967	75.4	1955	81.2	1967	70.9	1955
AUG	87.5	82.3	78.7	94.8	1971	81.6	1960	89.2	1967	77.3	1954	83.9	1967	74.6	1954
SEPT	74.3	74.5	74.8	81.0	1967	67.0	1959	82.2	1967	68.8	1955	81.4	1967	70.1	1978
OCT	56.7	62.6	67.1	62.3	1965	51.7	1946	66.6	1967	57.9	1957	72.3	1967	62.9	1959
NOV	41.4	49.0	56.7	46.2	1949	34.5	1952	54.0	1974	44.6	1978	62.7	1974	52.6	1959+
DEC	33.8	39.7	47.7	39.4	1969	27.1	1978	45.0	1974	34.4	1978	54.6	1974	44.9	1978+
ANNUAL	59.8	58.9	59.5	62.8	1967	57.3	1959	63.0	1967	56.1	1957	63.2	1967	57.6	1957
				ABSOLUTE HIGH AND LOW SUBSOIL TEMPERATURES											
				150.0	1971	-3.0	1949	93.0	1967	16.1	1979	85.3	1967	32.0	1957

* -0.5 INCH PERIOD OF RECORD 1945-1980
-15 INCH AND -36 INCH PERIOD OF RECORD 1952-1980

\+ DENOTES ALSO IN EARLIER YEARS

Table 3-3

Soil Parameters Used in the HELP Model

Layer Type (Figure 3-1)	N Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Initial Moisture Content (%)	Permeability (cm/sec)	Permeability (in/sec)
GRAVEL MULCH (Layer 1)	0.431[e]	0.064[e]	0.265[e]	0.039[e]	$2.7X10^{-2}$[e]	$1.06x10^{-2}$[e]
SILT/PEA GRAVEL (Layer 2)	0.496[a]	0.2585[a]	0.0681[a]	0.071[a]	$1.29x10^{-3}$[d]	$5.08x10^{-4}$[d]
SITE SAND (Layer 3)	0.445[a]	0.083[a]	0.033[a]	0.033[a]	$4.75x10^{-3}$[a]	$1.87x10^{-3}$[a]
GRAVEL (Capillary Break Layer) (Layer 4)	0.417[c]	0.045[c]	0.02[c]	0.045[c]	1.0[b]	0.39[b]
SAND/ BENTONITE (Low Permeability Barrier Layer) (Layer 5)	0.398[c]	0.244[c]	0.136[e]	0.244[c]	$1x10^{-7}$[f]	$3.94x10^{-8}$[f]

a. Nichols, W.E. 1991. Comparative Simulations of a Two-Layer Landfill Barrier Using the HELP Version 2.0 and UNSAT-H Version 2.0 Computer Codes. PNL-7583, Pacific Northwest Laboratory, Richland, Washington.

b. Freeze, R.A., Cherry, J.A., 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, N.J.

c. Schroeder, P.R., R.L. Peyton, B.M. McEnroe, J.W. Sjostrom. 1988. The Hydrologic Evaluation of Landfill Performance (HELP) Model Volume III. User's Guide for Version 2.05 Draft., U.S. Environmental Protection Agency, Washington, D.C.

d Estimated, based on 30 percent gravel/70 percent silt mix.

e. Estimated, based on 50 percent gravel/50 percent fine sand mix.

f. Closure/Post Closure Plan, 183-H Basins, Rev. 2. 1990. DOE/RL 88-04.

Table 3-4

Summary of Moisture Sensors

	HDPs	TCPs
Number of sensors per array	1	2
Number of sensors per installation	4	16
Total number of sensors & casings	5	18

Numbers includes redundant sensor at each probe location

Table 3-5

Facility Structures

Building Name	Approximate Dimensions
Warehouse	24' x 36'
Maintenance Shop	40' x 100'
Office Trailer (Receiving trailer)	10' x 50'
Site Office	48' x 24' (and 26' x 26' addition)
Telephone Building	9.5' x 11.5'
Two Office Trailers (WDOH)	10' x 52' each
Laboratory/Inspection	24' x 52'

Tab -6

Acceptable Surface Contamination Levels

NUCLIDES[a]	AVERAGE[b c f]		MAXIMUM[b d f]		REMOVABLE[b e f]	
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/ 100 cm^2	7.75 dpm α/ 1 in^2	15,000 dpm α/ 100 cm^2	23.25 dpm α/ 1 in^2	1,000 dpm α/ 100 cm^2	1.55 dpm α/ 1 in^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/ 100 cm^2	0.155 dpm/ 1 in^2	300 dpm/ 100 cm^2	0.465 dpm/ 1 in^2	20 dpm/ 100 cm^2	0.031 dpm α/ 1 in^2
Th-nat, Th-232, Sr-90 Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm/ 100 cm^2	1.55 dpm/ 1 in^2	3000 dpm/ 100 cm^2	4.65 dpm/ 1 in^2	200 dpm/ 100 cm^2	0.310 dpm α/ 1 in^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm βγ/ 100 cm^2	7.75 dpm βγ/ 1 in^2	15,000 dpm βγ/ 100 cm^2	23.25 dpm βγ/ 1 in^2	1000 dpm βγ/ 100 cm^2	1.55 dpm α/ 1 in^2

[a]Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b]As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c]Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each object.

[d]The maximum contamination level applies to an area of not more that 100 cm^2.

[e]The amount of removable radioactive material per 100 cm2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

[f]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

Table 3-7

Sampling Frequencies

	CLOSURE Yr 1 - Yr 2	STABILIZATION Yr 3 - Yr 7	PC/M PERIOD Yr 8 - Yr 107
Trench Cap Surface Inspection (Section 3.6)	Quarterly	Quarterly	Annually
Trench Cap Surveys (Radiological Surveys) (Section 3.7.2)	Quarterly	Quarterly	Annually
Air Monitoring (Section 3.8.2)	Weekly/ Quarterly	Quarterly (1 yr only)	
Soil Monitoring (Section 3.8.3)	Quarterly	Quarterly	Annually
Vegetation Monitoring (Section 3.8.4)	Annually	Annually	Annually
Groundwater Monitoring (Section 3.8.5)	Quarterly	Quarterly	Annually
Vadose Zone Monitoring (Section 3.8.7)	Quarterly	Quarterly	Annually

Table 3-8

Constituents Analyzed in the US Ecology Quarterly Sampling Program (Continued Through Closure and PC&M)

Field Parameters	General Range of Measured Concentrations
pH	7.5 to 8.0
Conductivity	350 to 415 umhos/cm
Water Elevation	403-410 feet
Temperature	20-22° C
Radionuclides	
Tritium	MDC to 3600 pCi/L
Carbon-14	MDC to 300 pCi/L
Gross Alpha	
Dissolved	MDC to 5 pCi/L
Gross Beta	
Dissolved	MDC to 10 pCi/L
Uranium	
U-234	MDC to 3 pCi/L
U-235	MDC to 0.8 pCi/L
U-238	MDC to 2 pCi/L
Isotopic Plutonium	
Pu-238	0.1 pCi/L
Pu-239/240	0.1 pCi/L
Gamma Spectral Analysis	
Cobalt-60	< MDC
Cesium-137	< MDC
Ruthenium-106	< MDC
Inorganics	
Nitrates	15 to 45 ppm (mg/L)
Organics	
Total Organic Carbon	Less than 1000 ppb (ug/L)
Total Organic Halogens	Less than 20 ppb (ug/L)
Tetrachloromethane	Less than 10 ppb (ug/L)
Benzene	Less than 10 ppb (ug/L)
Dioxane	Less than 500 ppb (ug/L)
Methylethyl	Less than 10 ppb (ug/L)
Pyridine	Less than 500 ppb (ug/L)
Toluene	Less than 10 ppb (ug/L)
1,1,1-Trichlorethane	Less than 10 ppb (ug/L)
1,1,2-Trichlorethane	Less than 10 ppb (ug/L)
Tetrachlorethene	Less than 10 ppb (ug/L)
Xylene (O,P)	Less than 10 ppb (ug/L)
Xylene (M)	Less than 10 ppb (ug/L)
Formaldehyde	Less than 500 ppb (ug/L)

ppm - parts per million
ppb - parts per billion
MDC - Estimated minimum detectable concentration for five percent risk of Type I (false positive) and Type II (false negative) errors.

Table 3-9

Soil Analyses

Physical Tests		Chemical Tests		Chemical and Radiological Constituents	
Test	Method	Test	Method	Test	Method
moisture content	ASTM D-2216	mineralogy	X-ray Diffraction (No standard procedure)	Appendix IX constituents	Total, per appropriate SW-846 methods
particle size distribution	ASTM D-422	exchangeable ions	SCS - Method in *Diagnosis of Saline and Alkaline Soils*	radiological parameters (uranium, radium, tritium, gross alpha, gross beta, gamma spec)	As specified in the Richland ROP
density	ASTM D-1587 ASTM D-1586	cation exchange capacity	SCS 9081		
hydraulic conductivity	ASTM D-2434	distribution coefficients (uranium, radium)	batch tests		
moisture characteristics	ASTM D-2325 ASTM D-3152	organic content	ASTM D-2974		
Atterberg limits	ASTM D-4318				

ASTM - American Society of Testing Materials
SCS - Soil Conservation Service

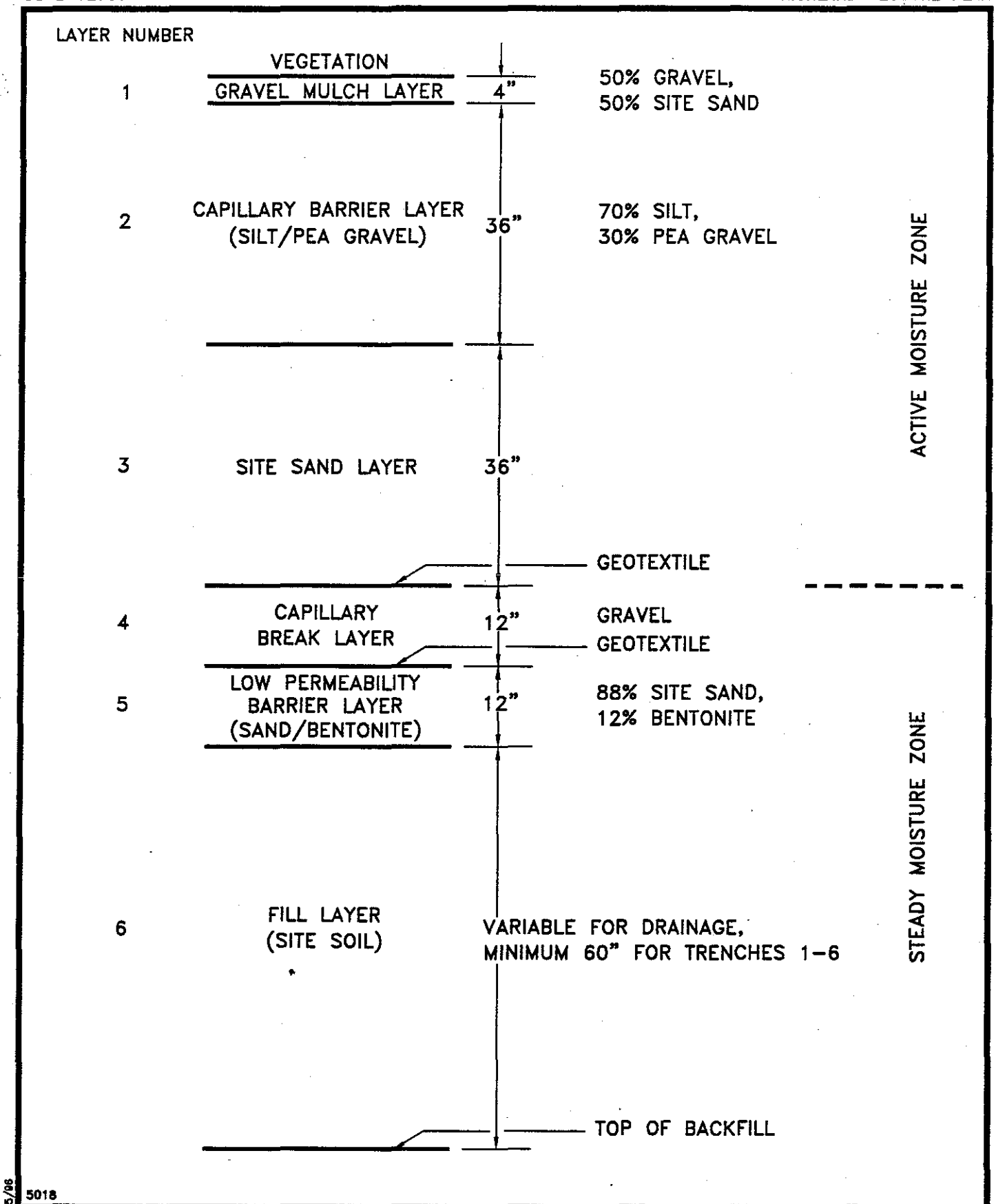

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FIGURE 3-1

CLOSURE CAP
PROPOSED CROSS-SECTION

5018\XSEC_SMP.DWG; 7/15/96

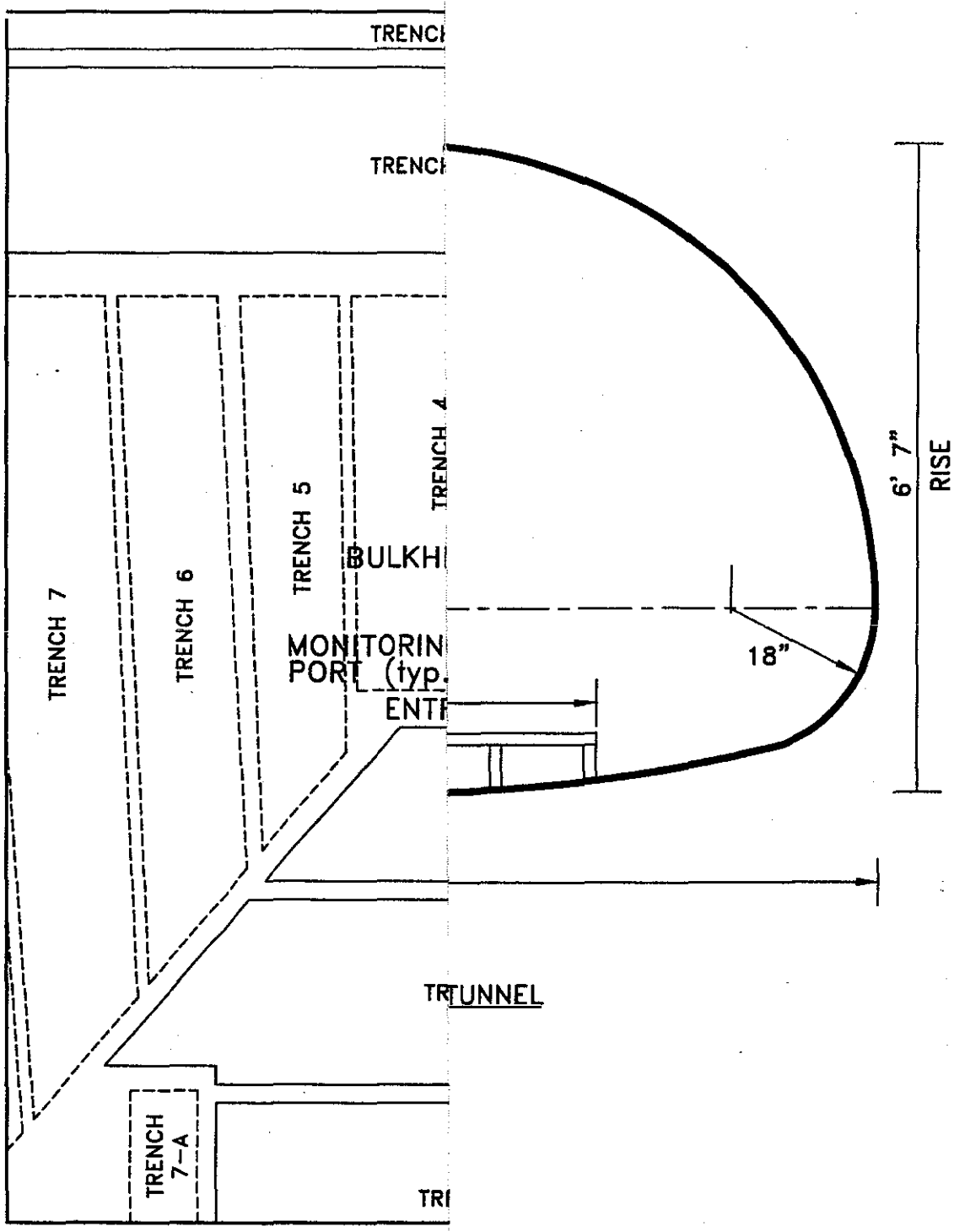

FIGURE 3-4

TRENCH LAYOUT MAP AND MONITORING TUNNEL CROSS-SECTION

7/15/96

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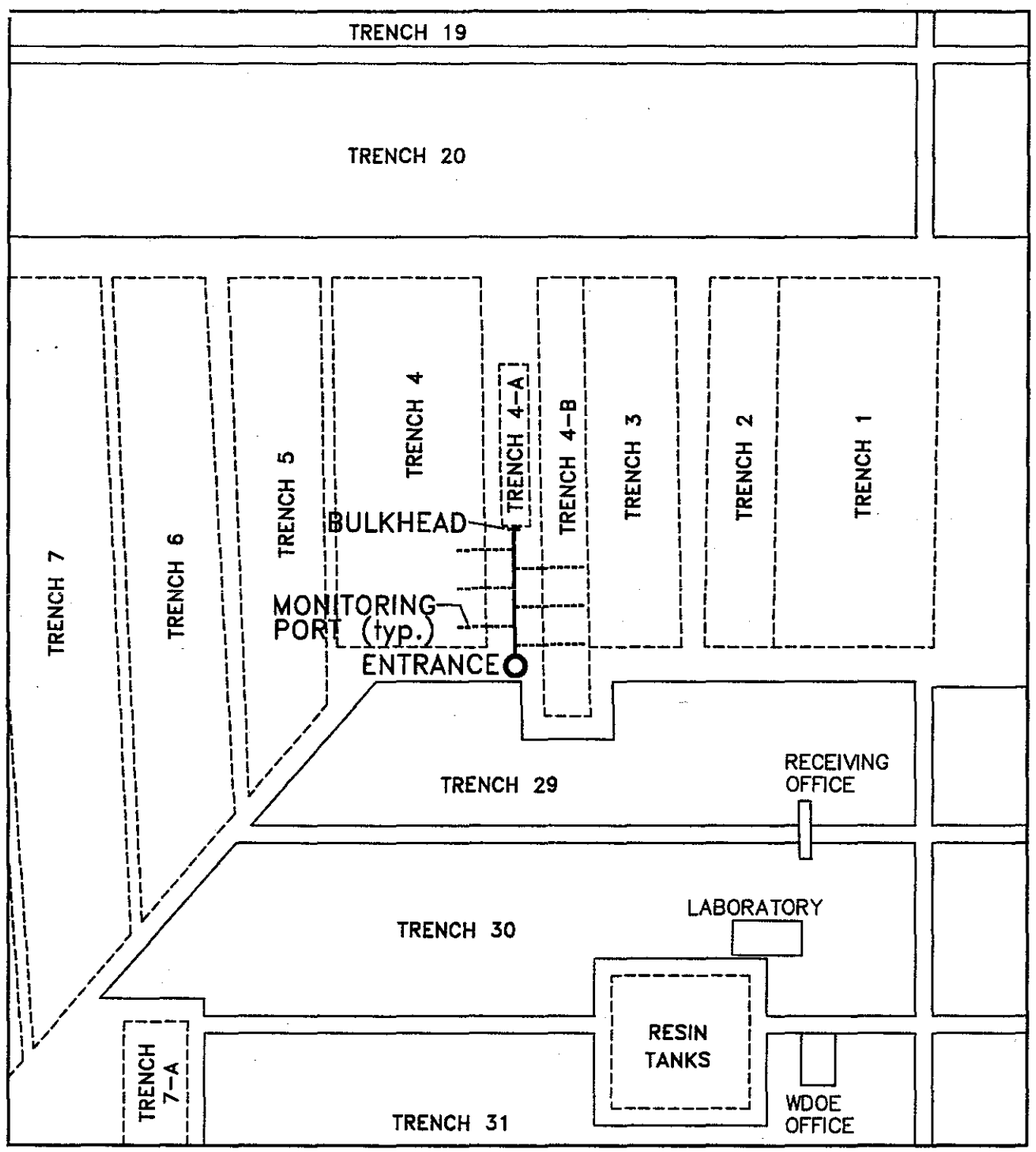

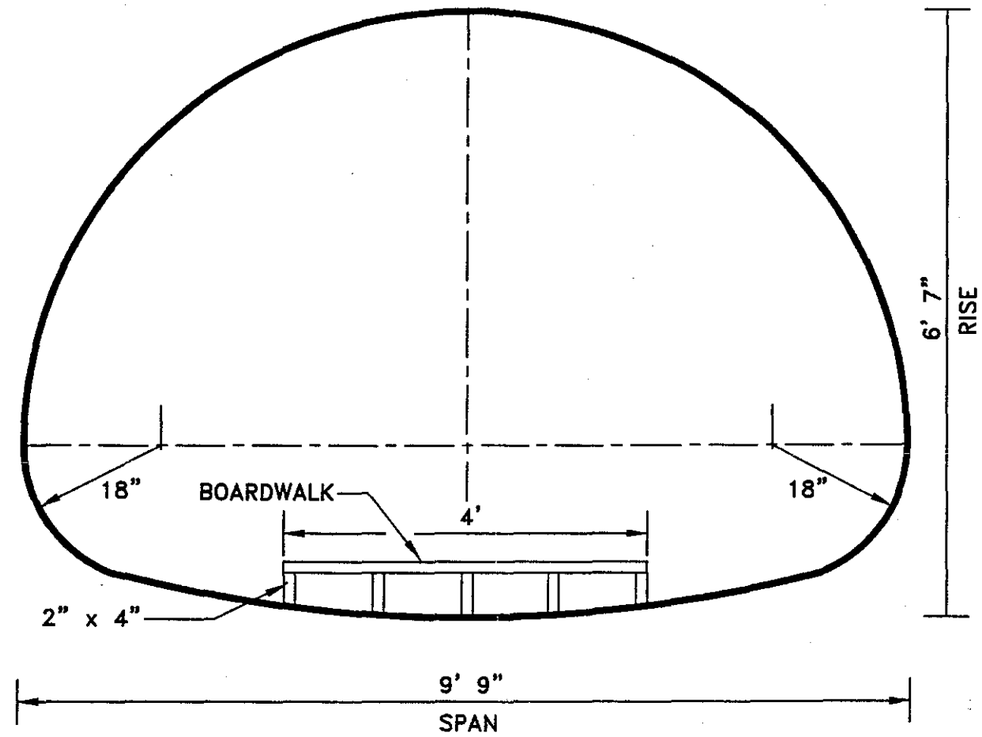

MONITORING TUNNEL

0 300 600
SCALE IN FEET

LEGEND
CLOSED TRENCH
FUTURE TRENCH

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FIGURE 3-4

TRENCH LAYOUT MAP AND MONITORING TUNNEL CROSS-SECTION

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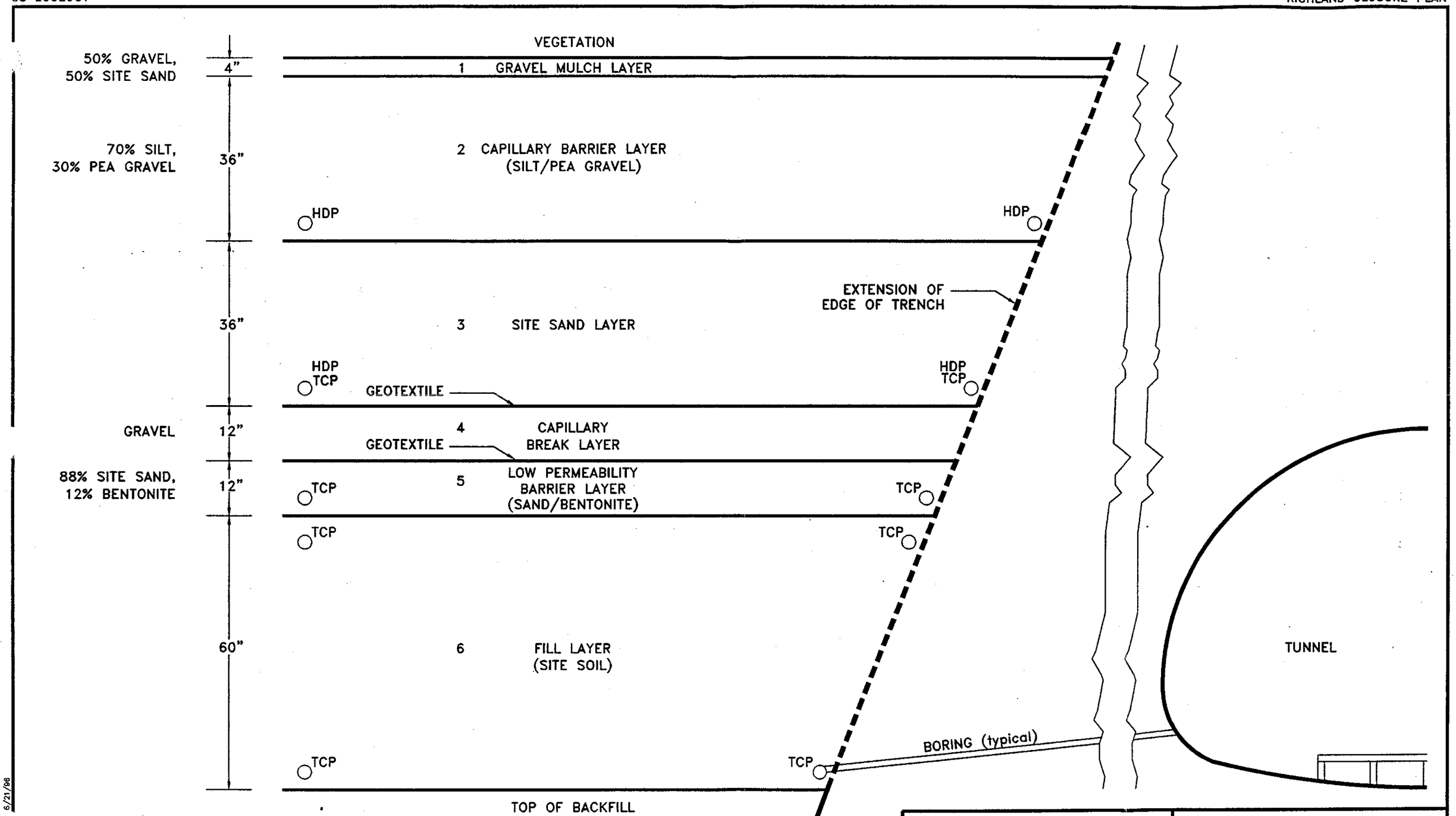

NO SCALE

NOTE:
BORINGS AND CONDUITS FROM TUNNEL TO DETECTORS NOT SHOWN FOR CLARITY.

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FIGURE 3-5
TYPICAL
MONITORING CONFIGURATION

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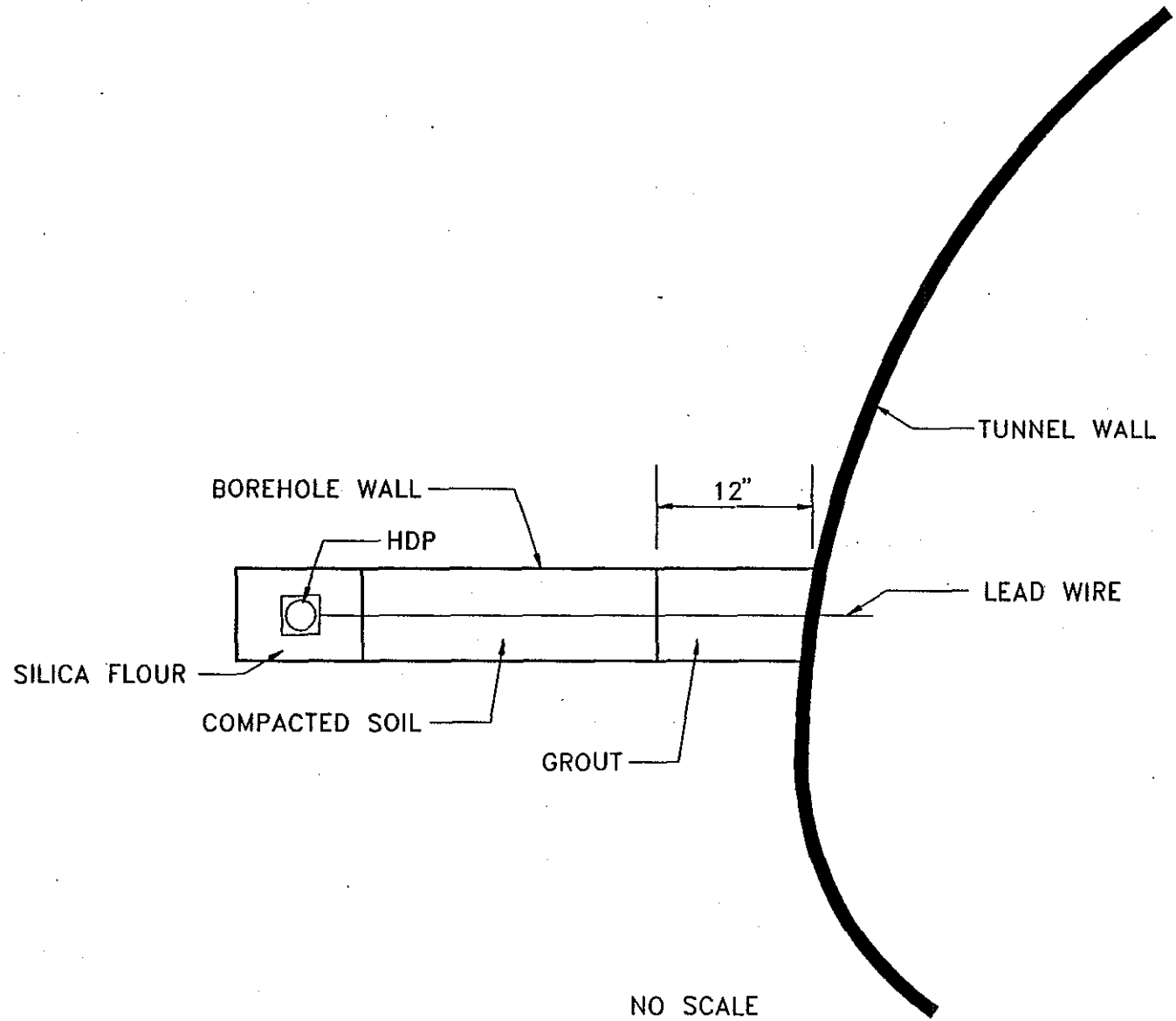

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FIGURE 3-6

TYPICAL HDP INSTALLATION

853770\TYP_HDP.DWG: 12/3/94

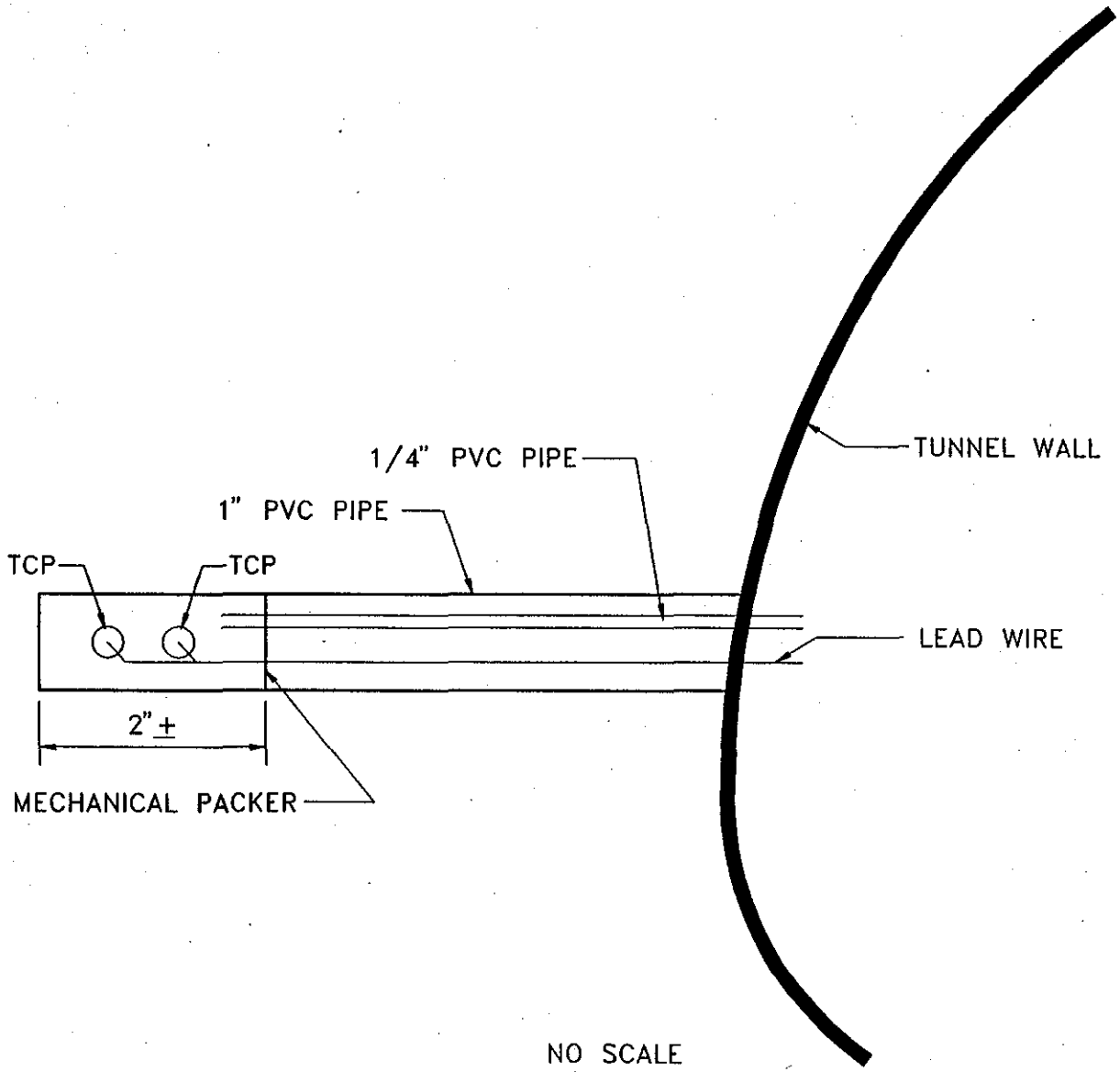

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FIGURE 3-7

TYPICAL TCP INSTALLATION

85377C\TYP_TCP.DWG: 12/3/94

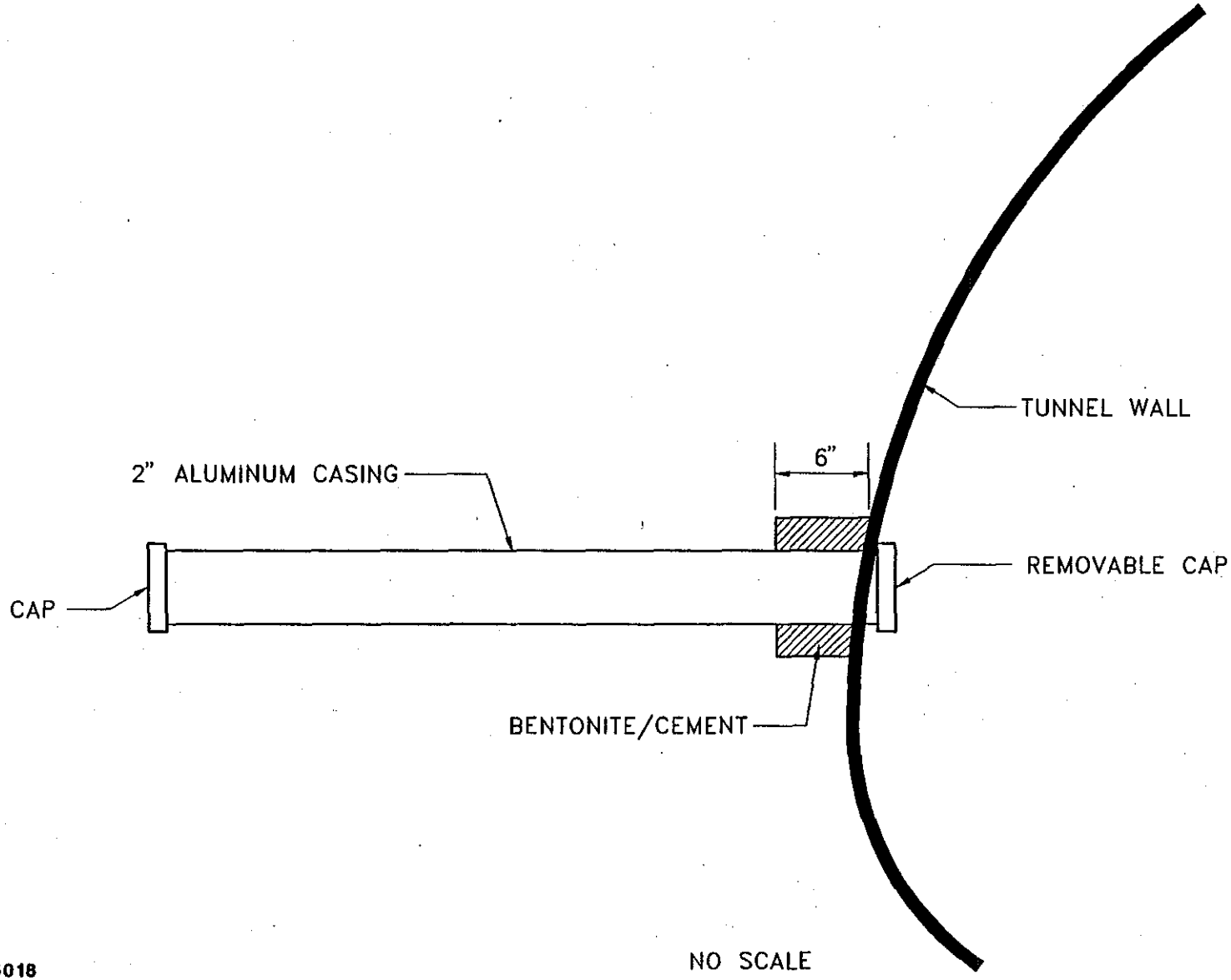

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FIGURE 3-8
TYPICAL NEUTRON ACCESS TUBE INSTALLATION

353770\TYP_NAT.DWG; 12/3/94

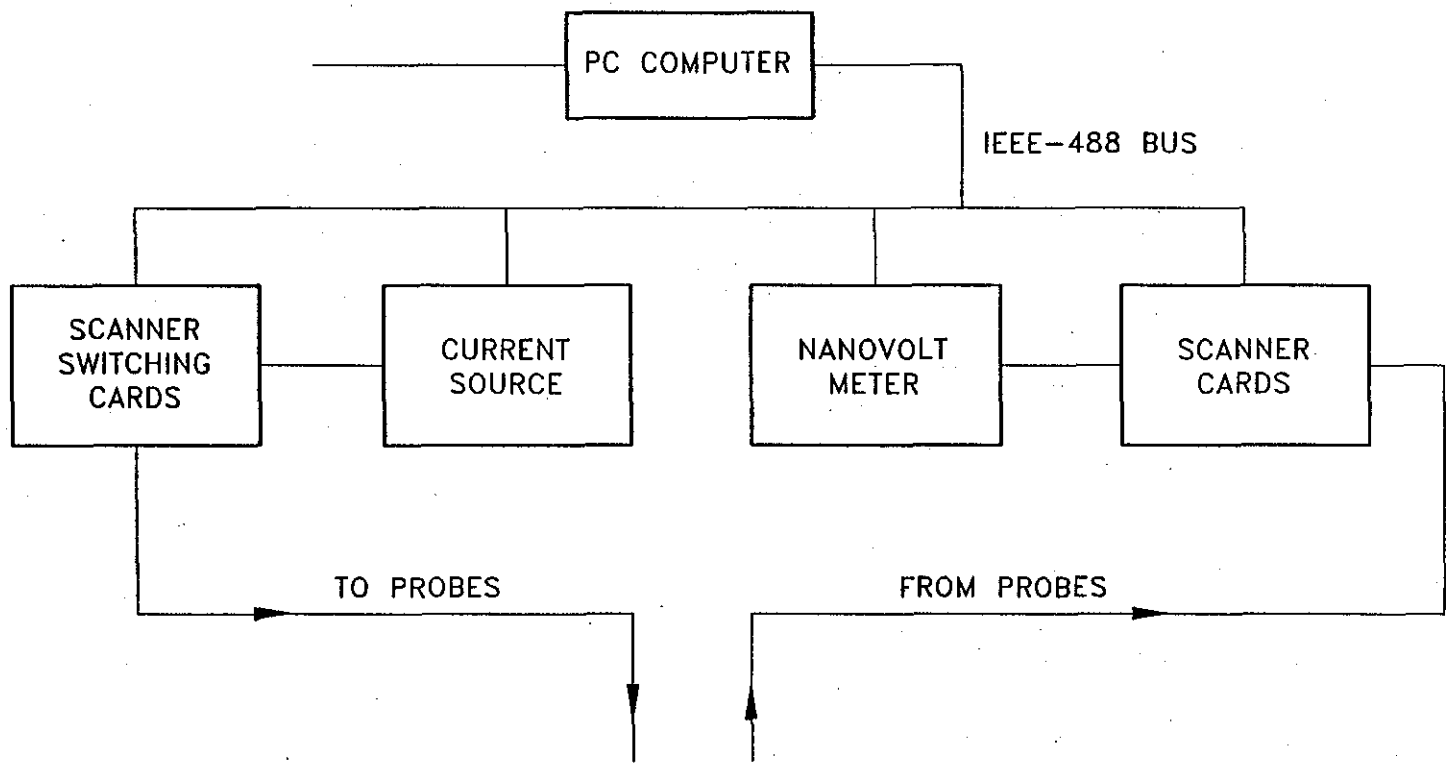

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FIGURE 3-9
SCHEMATIC
DATA ACQUISITION SYSTEM

853770\DATA_AC.DWG: 12/3/94

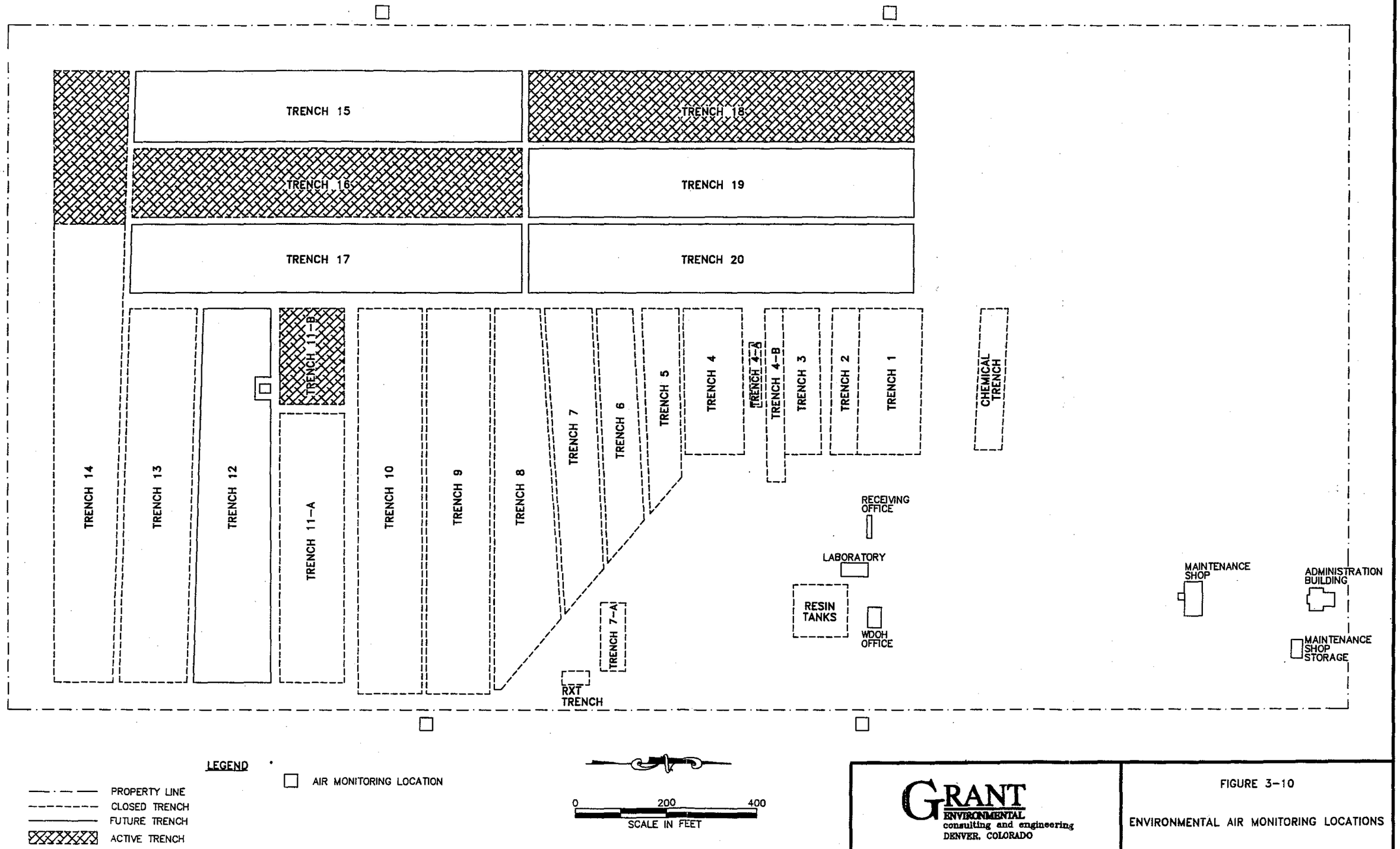

FIGURE 3-10

ENVIRONMENTAL AIR MONITORING LOCATIONS

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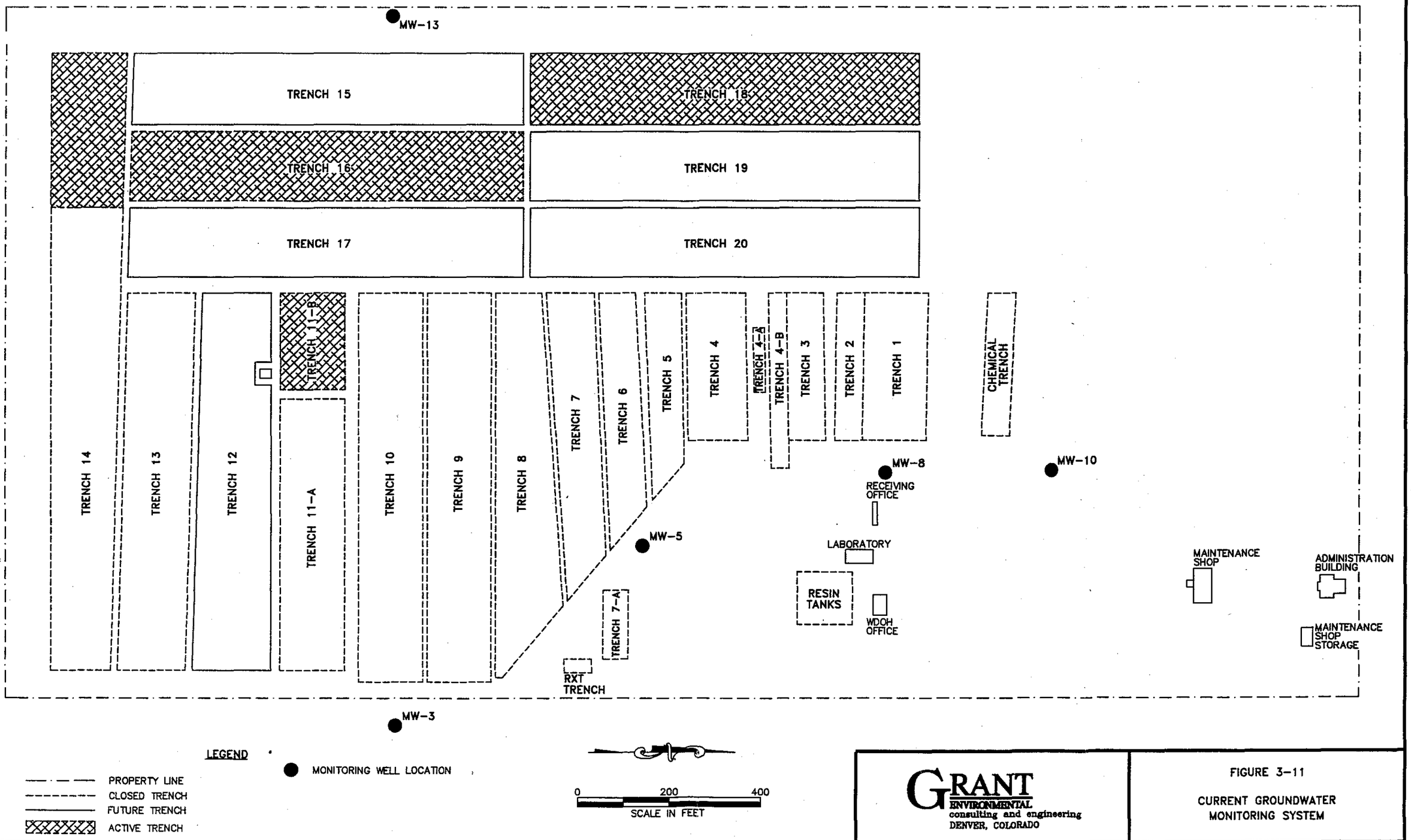

FIGURE 3-11

CURRENT GROUNDWATER MONITORING SYSTEM

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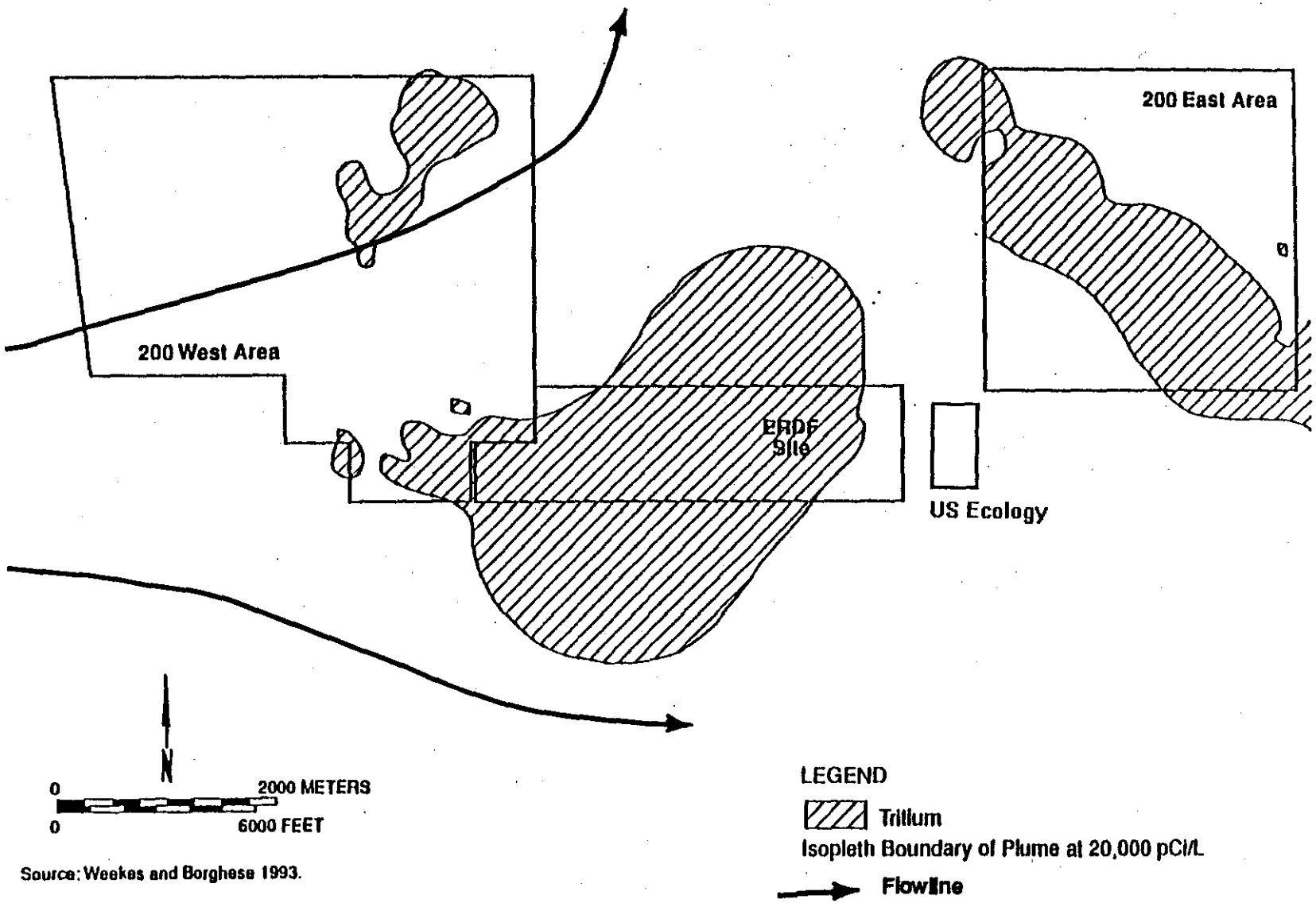

Source: Weekes and Borghese 1993.

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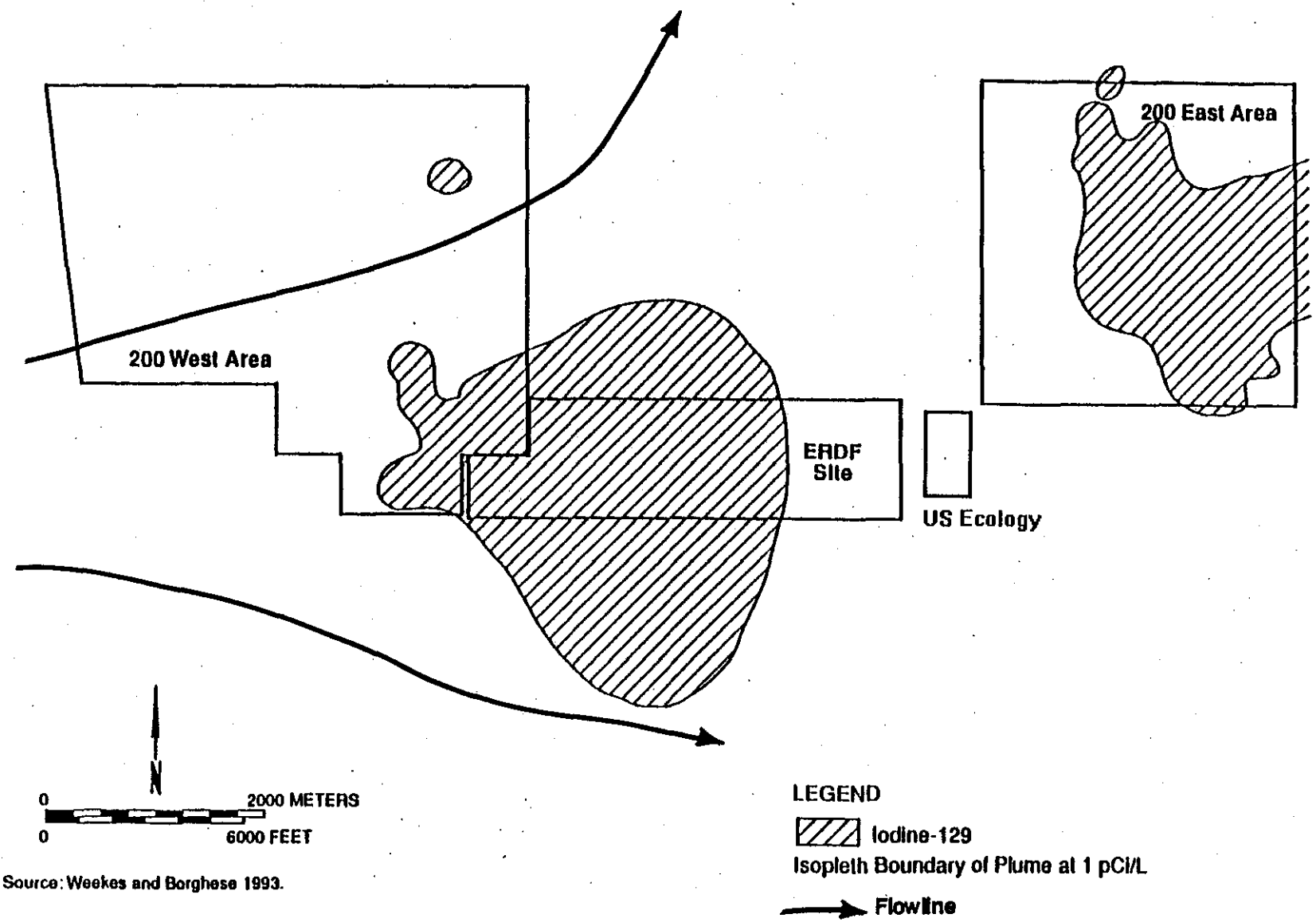
FIGURE 3-12

TRITIUM GROUNDWATER PLUME MAP



Source: Weekes and Borghese 1993.

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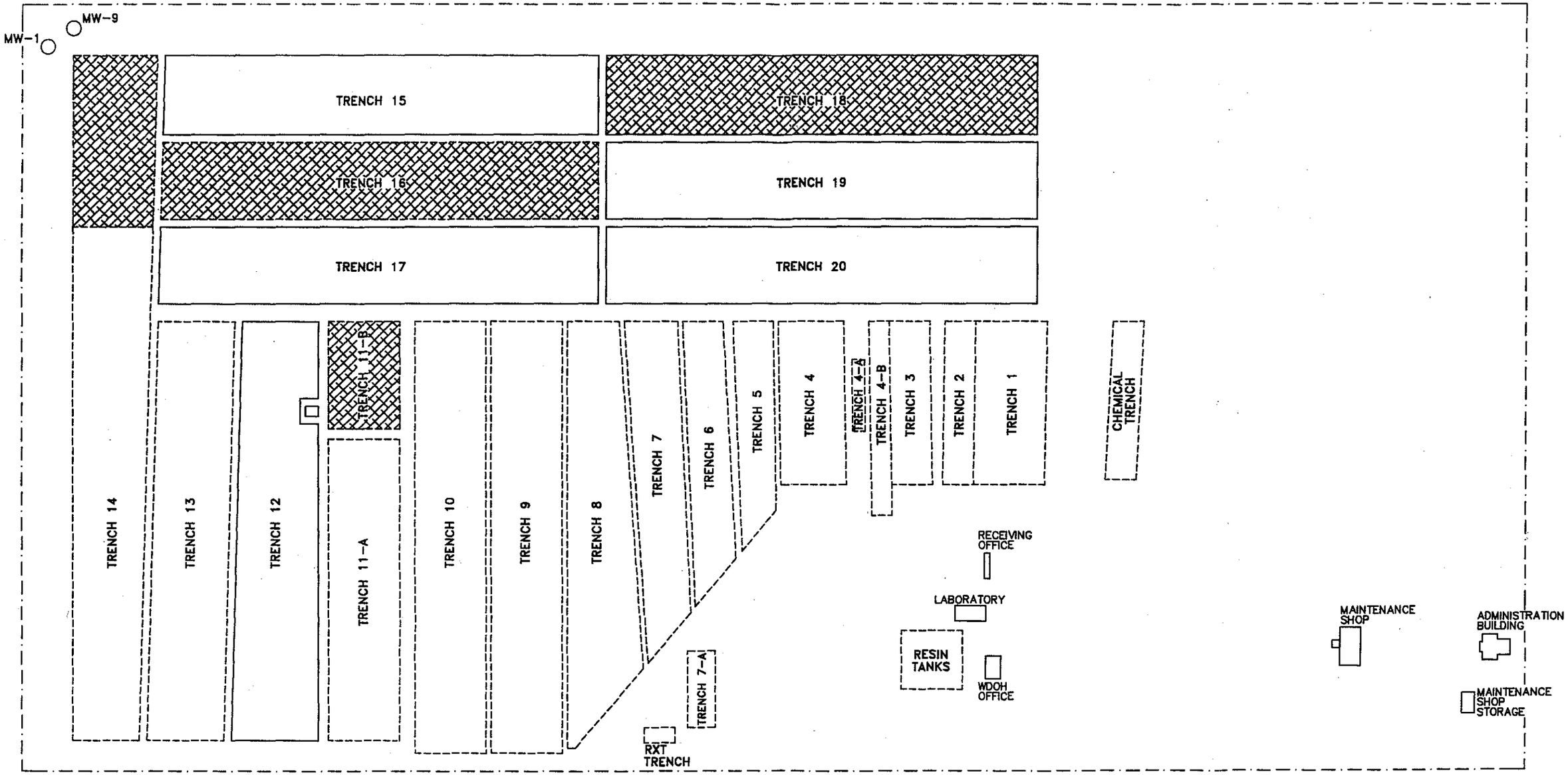
FIGURE 3-13

IODINE-129 GROUNDWATER PLUME MAP



LEGEND

- PROPERTY LINE
- CLOSED TRENCH
- FUTURE TRENCH
- ACTIVE TRENCH
- MONITORING WELL LOCATION

0 200 400
SCALE IN FEET

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FIGURE 3-14

PROPOSED NEW MONITORING WELL LOCATIONS

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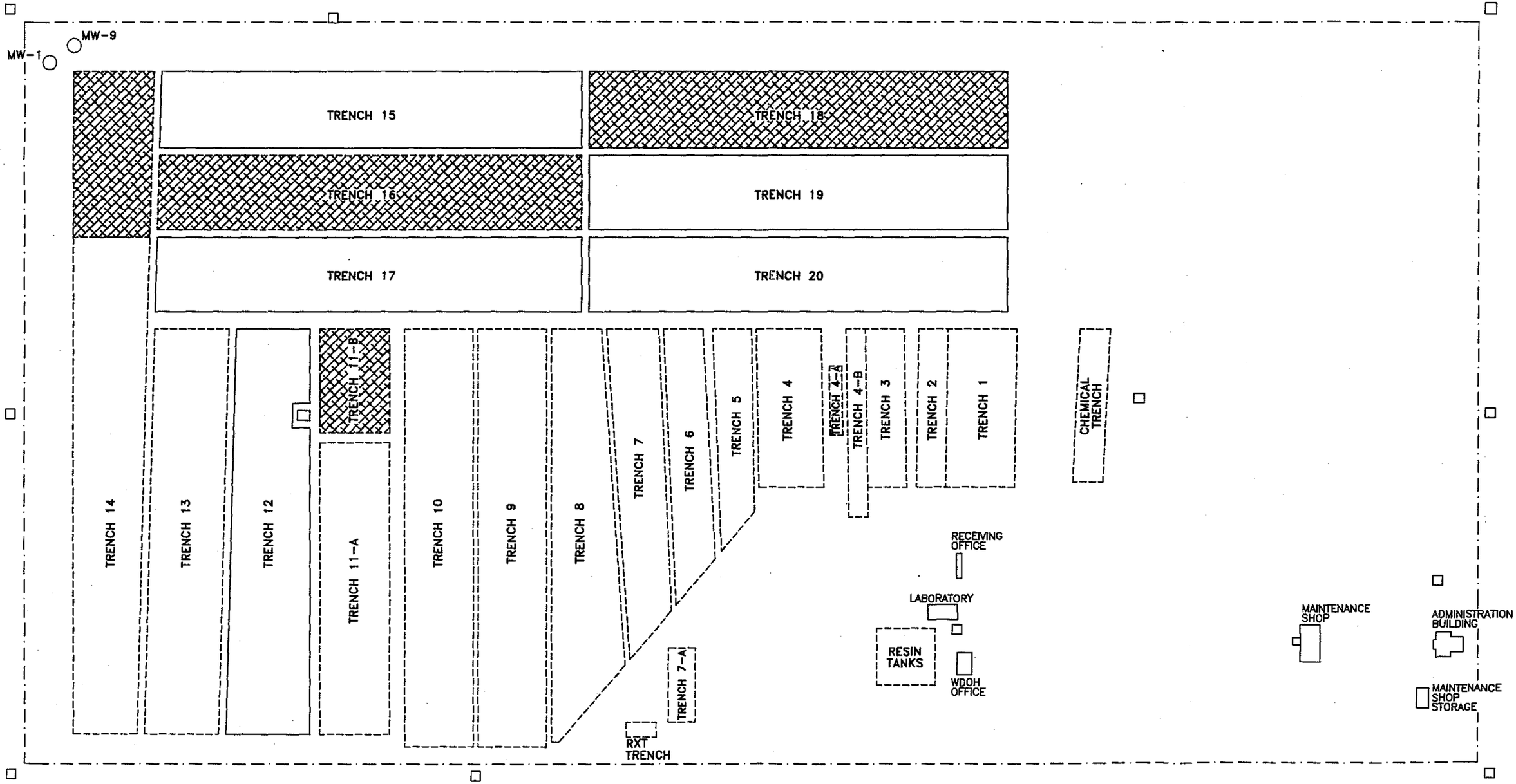

LEGEND

- PROPERTY LINE
- CLOSED TRENCH
- FUTURE TRENCH
- ACTIVE TRENCH
- DOSIMETER MONITORING LOCATION

0 200 400
SCALE IN FEET

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FIGURE 3-15

PROPOSED ENVIRONMENTAL DOSIMETER MONITORING LOCATIONS

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4. CONDITION 66 PERFORMANCE CRITERIA

As required by the Facility's State of Washington Radioactive Materials License (RML), this section addresses the sixteen requirements of License Condition 66. Each requirement is restated in this section in the order presented in the license followed by the response. The response discusses how the Site is operated or at Closure meets or plans to meet the specified requirement. The License Conditions are also included in Section 1, Table 1-1.

4.1 LICENSE CONDITION 66. 1A - BURYING WASTE

Bury all waste in accordance with the requirements of the license.

4.1.1 Response

4.1.1.1 General

Waste has been and will continue to be disposed of in accordance with all regulatory requirements applicable at the time of receipt. To ensure that disposal operations are conducted in full compliance with all applicable rules and regulations, a Facility Standards Manual (FSM) and Richland Operations Procedures (ROPs) have been issued to provide necessary radiological and operational direction to US Ecology Facility personnel. The FSM and ROPs are approved by the WDOH. The current rules, regulations and other applicable requirements are contained in the FSM, ROPs, WDOH License No. WN-I019-2 (Amendment #20), and an NRC issued SNM License No. 16-19204-01 (Amendment #11). US Ecology, the WDOH and the NRC routinely audit facility operations to ensure compliance with all requirements and procedures.

4.1.1.2 License

Waste disposal activities were first licensed at the Facility by the U.S. Atomic Energy Commission (AEC) under License No. 13-10042-1, Amendment 1, issued October 26, 1964. This license initially authorized by-product, source and SNM activities. The State of Washington, upon becoming an Agreement State, in accordance with Section 274 of the Atomic Energy Act 1954, as amended, issued License No. WN-I019-2 on August 28, 1967. This license authorized the receipt, possession and disposal of by-product and source material activities in conjunction with AEC License No. 13-10042-1 which was amended to be limited solely to SNM activities. The AEC issued SNM license was subsequently re-issued by the NRC as No. 16-19204-01 on November 30, 1979.

Copies of the subject licenses, amendments, reference letters and manuals are retained at the Facility. These include:

A. AEC License 13-10042-1 and correspondence relating to the license;

B. NRC License 16-19204-01 and correspondence relating to the license;

C. Washington State License WN-I019-2 and correspondence relating to the license; and

D. US Ecology's FSM and ROPs.

4.1.1.3 Waste Receipt and Burial

Since completion of Trench 6, trenches have been constructed in the following order: Trenches 8, 10, 4A, 7, 9, 4B, 11, 7A, 13, 14, 16, and 18. This Closure Plan is based upon actual site closure in 2056. Projections of waste receipt during future operations have been based upon changes in Northwest and Rocky Mountain compact customers during the years 1996 through 2056. The projected volume was assumed to average 100,000 ft^3/yr. Based upon this projection, in addition to existing trenches, trenches 15, 17, 19, 20, and 12 should accommodate the remaining future disposal requirements. Should trench utilization decrease, or waste volumes increase requiring additional space, additional trenches would be constructed. Waste segregation will be in accordance with the existing Facility license.

Trench size has varied throughout the operating history of the Facility and was determined by the expected rate of receipts and the capabilities of the available construction and operating equipment. Depths of trenches 1, 2, 3, 4, 5 and 6 varied up to a depth of 35 feet; Trench 8 is 40 feet deep with slit trenches down to 48 feet; Trench 10 is 45 feet deep with slit trenches down to 53 feet; and Trenches 11, 13, 14, 16, and 18 are 45 feet deep. All other trenches are less than 45 feet deep.

A. Trenches 1-4

In general, wastes buried in Trenches 1, 2, 3, and 4 were received in metal drums, fiberboard drums and cardboard boxes and were placed in the trench by hand. Liners from casks were handled in one of two ways. The first method, used for liners reading up to approximately 50 R/hr, was to place the liner at or near the bottom of the trench (approximately 35 feet). After confirmation of the radiation levels, the liner was shielded with other waste or sand until the radiation level was acceptable. The second method, used with liners reading in excess of 50 R/hr, was to place the liner in a slit trench cut in the sloping wall of the trench and then cover the liner with three to five feet of site soil. Most liners in slit trenches are 20 feet or more below grade. The shallowest liner was buried approximately 10 to 15 feet deep in the extreme west end of Trench 4.

Some boxes were placed in the trenches by cranes using box hooks or slings. If the box weight exceeded the capacity of the crane, the boxes were maneuvered down the operating face of the trench until the trench bottom was reached. The utilization of these trenches (defined as the total volume of waste placed in the trench divided by the total volume of the excavation with no adjustment for the cap) was approximately 25 to 30 percent. The other 70 to 75 percent is sandy backfill. Backfilling was completed by bulldozing the native sandy soil over the working face as the face reached its final height of three feet below the ground surface. Additional soil was placed to ground surface and mounded over the closed trenches to a height of two feet above the ground surface at the trench center line. This was covered by a layer of six inches of pit-run gravel.

B. Trench 5

Starting with Trench 5, drums were placed in the trench by crane, two at a time. However, these containers were still considered to be randomly placed. This practice is still being utilized. Cardboard containers were no longer accepted for burial. Acquisition of a larger crane made box-stacking possible, although a low box inventory generally held box stacks to two high and two deep. Trench utilization increased to approximately 35 percent. Cask liner handling, backfilling, mounding and gravel cover were the same as before.

C. Trench 6

Starting with Trench 6, box hooks were no longer used. Boxes were handled exclusively with slings and were used to construct stacks or cells by stacking them two to three high and two to three deep with an open space in the center. Cask liners with high radiation levels are placed in these cells and then covered with sand to reduce radiation levels. All other activities remained the same as described for Trenches 1, 2, 3, 4 and 5.

D. Later Trenches

Subsequent trenches, which include 8, 10, 4A, 7, 9, 4B, 11, 7A, 13, 14, 16, and 18 have had waste selectively placed in the trench at depths commensurate with the on-contact radiation reading. Type B quantity (a Department of Transportation classification) waste packages and waste packages having greater than 10 R/hr readings have been placed at least 20 feet below-grade (i.e. deeper than the 5 meter, or 16.4 feet, regulatory requirement) beginning January 21, 1987. Waste having a reading greater than 100 R/hr has been placed at least 30 feet below-grade (approximately 9 meters) beginning January 21, 1987. With more recent changes to the FSM, only Class C waste and waste with a surface contact dose rate greater than 10 R/hr are required to be disposed 5 meters (16.4 feet) below natural grade.

Additional site soils have been placed over closed trenches as part of interim closure activities. (See Closure, Section 3).

4.1.1.4 Records Involved in Receipt of Waste

Prior to acceptance of a waste shipment for disposal at the Facility, a Radioactive Waste Shipment and Disposal Manifest (RSM) must have been completed in its entirety.

A vehicle radiological survey is performed by a qualified Radiological Control and Safety Technician to ensure compliance with all applicable federal, state and company rules, regulations and guidelines. Documentation of these surveys was required by US Ecology's Radiological Control and Safety Manual, Site Operations Manual and work procedures and is currently required by the FSM and ROPs.

Other documents required by Washington License No. WN-I019-2 are reviewed for availability and completeness prior to acceptance of a shipment for disposal. These additional forms include:

- Washington State Indemnification Form (RHF-31);
- Washington Utilities and Transportation Commission vehicle inspection certificate or sticker;
- And if applicable to the specific shipment:
  - DOE/NRC 741 Form (As of October 11, 1994, this information is being electronically transferred; however hard copies are still required during a transition period).
  - Inspection certificate on SNM performed 48 hours prior to shipment.
  - Exclusive-Use instructions.

4.1.1.5 Records/Audit

The following records are maintained at the Facility for review by the WDOH, NRC, US Ecology Management and the Chief Radiological Control and Safety Officer (CRC&SO).

A. Radioactive Waste Shipment and Disposal Manifest Forms (RSM)

A review of the RSM files indicates that these forms have been received and reviewed by a qualified individual since June 21, 1965. The form has been revised over the years but the information is basically the same, (i.e. isotope, activity, radiation levels). Copies of versions of the RSM are included with this plan as Attachment H. Since January 1977, the trench number in which the

waste was buried has been recorded on the RSM. Other associated documentation concerning the waste shipment have been assigned the same sequential receipt number. The most recent version of the RSM is dated April 1991. The Naturally Occurring Radioactive Material (NORM) manifest was completed in September 1994. A summary of the disposal history and waste activity at the Facility is shown in Table 4-1.

The values recorded in Table 4-1 reflect the manifest information contained in the Company's electronic data system including the latest revisions. The revisions to the data systems are reflected in a revised License Condition 58 which was originally submitted June 28, 1990. This condition required US Ecology to report the location and description of all waste disposed, with the total trench content of each radionuclide listed. The revised report is included as Attachment I.

B. Vehicle Survey

Records involving the surveys of vehicles for radiation and contamination levels date back to August 15, 1975. These forms have been revised over the years and copies of these forms are included with this plan as Attachment J. These reports are filed also by the sequential receipt number.

C. Burial Reports

Burial reports available at the Facility date back to mid-1968. These reports have been submitted to WDOH and filed by month and/or year by US Ecology.

D. 741 Forms

Information on 741 forms, dating back to January 1975, indicate the generator, volume, millicuries, grams of SNM and weight of source material, as required by 10 CFR 70. These reports are available at the Facility.

E. Unusual Occurrence Report

Unusual Occurrence Reports were generated starting January 1, 1979. In general, they include the type of occurrence, pictures (when deemed necessary), generator name, and identify the action taken.

F. Audits

Formal audits performed by the CRC&SO began in early 1977, and are filed chronologically. The first formal audit was conducted on February 3, 1977 and subsequent audits were performed at least quarterly. US Ecology Management Audits began April 10, 1980. These audits are conducted quarterly and also are filed chronologically at the Facility.

Other audits are also performed periodically by American Nuclear Insurers. Audits and responses are filed chronologically at the Facility. WDOH audits (dating back to May 25, 1979), and U.S. NRC audits (dating back to July 6, 1978), are filed chronologically at the Facility.

G. Accident Reports

An Accident Report is required whenever a significant accident occurs at the Facility. These reports indicate the type of accident, personnel involved and what actions were taken. Since January 1, 1979, Unusual Occurrence Reports are now being used to replace Accident Reports.

H. Quarterly Site Inspection

A quarterly site inspection is performed and documented by site radiological control personnel. These inspection reports were begun January 2, 1980, as required by License No. WN-I019-2 Amendment 10.

I. Burial Records

Records are maintained of overburden placement, waste classification (Class A, Class B or Class C), waste stability (Class A, stable or unstable) and burial depth. This information is entered into the US Ecology electronic data base system as waste is received. Information contained on older burial records prior to the installation of the electronic data system has been entered into the Company's database. This work was originally completed on June 29, 1990 with the License Condition 58 (License Amendment #17) submittal to the WDOH. An audit of this information by US Ecology in 1994 resulted in changes being made to the early disposal data that was entered for Condition 58. This revised report was submitted to the WDOH on December 9, 1994, and is included as Attachment I.

4.1.1.6 Radiological Control and Safety Audits

Radiological Control and Safety Audits are performed by the CRC&SO or his designee. Audits include verification of compliance and effectiveness of the Company's ALARA Program; implementation of required procedures, regulations and license provisions; programs for training, retraining, qualification and performance of operating staff; corrective actions taken following abnormal occurrences; and observation of performance of operating and maintenance activities, including associated recordkeeping.

No incidents which would cause a threat to the health and safety of the public, to US Ecology personnel, or to the environment have occurred. Copies of radiological control and safety audits are on file at the Facility.

4.1.1.7 Management Audit Summary

Management Audits are performed quarterly with the following items being covered: safety, equipment status, security, receipts and disposal of waste, inspection of closed trenches, environmental monitoring and surveillance conditions, trench construction and various other activities.

4.1.2 Conclusion

All necessary procedures for waste receipt, handling and documentation are included in US Ecology's FSM and ROPs. These are reviewed periodically and revised when necessary. The WDOH reviews and approves the FSM and the ROPs. Periodic audits are performed by the NRC, WDOH, US Ecology's CRC&SO and US Ecology management to confirm compliance. Therefore, waste buried at the site has always been required to be in compliance with applicable federal and State regulations and all license conditions.

4.2 LICENSE CONDITION 66.B - DISMANTLING AND DECONTAMINATION

Dismantle, decontaminate, as required, and dispose of all structures, equipment, and materials that are not to be transferred to the site custodian.

4.2.1 Response

Refer to Section 3.4 "Site Structures" of this Closure Plan.

4.3 LICENSE CONDITION 66.C - ORDERLY TRANSFER

Document the arrangements and the status of the arrangements for orderly transfer of site control and for long-term care by the government custodian. Also document the agreement, if any, of state or federal governments to participate in, or accomplish, performance objectives. Specific arrangements to assure availability of funds to complete the site closure and stabilization plan shall be documented.

4.3.1 Response

On September 10, 1964, the State of Washington entered into a 99-year lease with the federal government represented by the United States Atomic Energy Commission, for a 1000-acre tract on the Hanford Reservation. The objective of the lease was to encourage the development and utilization of atomic energy for peaceful purposes. In 1965, the State of Washington, represented by the Department of Commerce and Economic Development, and California Nuclear, Inc., negotiated a sublease for 100 acres of the 1000-acre tract to be developed and utilized as a low-level radioactive waste disposal Facility. The term of the sublease was ten years with an option to extend for two additional periods of fifteen years.

Current prime lease responsibilities of the United States and the State of Washington are being administered respectively by the United States Department of Energy (USDOE) and the Washington State Department of Ecology (WDOE). In 1968 Nuclear Engineering Company Inc., presently known as US Ecology, Inc., acquired California Nuclear and the obligations of the sublease.

The prime lease was amended June 24, 1965, and August 19, 1970. Also, a Perpetual Care Agreement between the United States and the State of Washington was signed on July 29, 1965, and amended on July 22, 1976. The sublease was renegotiated on February 26, 1976 and further amended on January 11, 1980, January 14, 1982 and May 3, 1991. The most recent amendment increased the annual rent paid by US Ecology from $6,000 to $50,000 and extended the sublease through July 29, 2005. The prime lease and sublease, as amended, are attached as Attachment K.

In October 1993 the USDOE recalled 900 acres of the 1000-acre leased tract that was not being utilized or subleased by the State. The prime lease therefore currently applies to only the 100 acres subleased to US Ecology.

Both the prime lease between the State and USDOE and the sublease between the State and US Ecology provide for the continuing obligation of the parties during closure and post closure periods. In accordance with the terms of the prime lease, unless terminated earlier by USDOE, the State would remain in possession of the properties after closure for the remaining portion of the 99-year lease. Thereafter the properties would revert to USDOE and all unexpended funds acquired for perpetual care and maintenance by the State transferred to USDOE for their continued custodial management of the Facility.

Under the July 29, 1965 Perpetual Care Agreement, USDOE may elect to sell the 100-acre subleased site to the State in lieu of requiring the transfer of the perpetual maintenance funds to the federal government. If so, the State would continue to assume perpetual care responsibilities.

4.3.1.1 Site Closure and Stabilization Funding

The State, acting through its Energy Office and in further recognition of its post closure responsibilities, executed the Third Amendment to the sublease on January 14, 1982. This Amendment provided in Article VII that a fund of $6 million, as measured in 1982 dollars, was necessary for the Perpetual Care and Maintenance (PC&M) fund. A mechanism for bringing the existing balance to the $6 million amount was implemented at the rate of one dollar and seventy-five cents ($1.75) per cubic foot of LLRW disposed at the Facility. Upon acquisition of the $6 million, US Ecology and the State agreed to reassess the need for further acquisition of post closure funds. The State determined that the $1.75 fee would continue to be collected and paid into the PC&M fund. The fund as of December 31, 1995, contains $22,993,995.

Through Article XXV of the Third Amendment to the sublease, the State additionally determined that $1 million was necessary to ensure all projected closure objectives were funded prior to closure. It implemented, for the first time, a fee of twenty-five cents ($0.25) per cubic foot of LLRW disposed at the Facility. The interim adequacy of the closure fund was ensured by the requirement for US Ecology to post a $500,000 bond for the period of January 30, 1982 through January 30, 1993. For the period of January 30, 1993, through January 30, 1994, US Ecology agreed to post a $250,000 bond. Thereafter, no bond was projected to be required, as the closure fund would contain sufficient moneys to cover closure in the event US Ecology, for whatever reason, defaulted on its lease obligations and the services of an independent contractor had to be obtained to fulfill the closure requirements.

Upon the accumulation of the $1 million fund, the State and US Ecology agreed to a joint technical study to determine whether the collection of additional closure funds would be necessary. In response to the joint technical study, the State of Washington enacted Substitute House Bill 2956, March 13, 1990, allowing the Department of Ecology to divert into the closure fund $10 of the $40 per cubic foot surcharge received under the 1985 federal Low Level Radioactive Waste Policy Act Amendment. The interest from the PC&M account was diverted into the closure fund. This funding mechanism continued through December 31, 1992. The account balance as of December 31, 1995 was $22,818,197. No additional funds, other than interest, are being added to the closure account.

Since the prime lease provides that the purpose of the lease is to promote nuclear activities, and the State in Section 3, thereof ". . . covenants that only those facilities and activities which are compatible with the Commission's (USDOE) operations and programs and which are nuclear related will be permitted on the leased premises. . .", it is expected that there will be no inconsistent State use of the 100-acre subleased lands between the time the Facility closes and the lease terminates on September 9, 2063. No inconsistent uses of the funds in either the Perpetual Care and Maintenance Account or the Site Closure Account are contemplated.

4.3.1.2 Long-Term Care by Custodial Agency

In December 1992, the DOE published a Report titled, "The Future for Hanford: Uses and Cleanup." The document summarized the final report of the Hanford Future Site Uses Working Group. This group was diversely comprised of representatives from federal, State, and local governments, native American tribes, labor groups, economic development groups and public interest groups.

The working group divided the Hanford Reservation into six geographic areas, one of which is the Central Plateau (200 Areas). The Central Plateau is at the center of the Reservation and encompasses 9.4 square miles (approximately 6,000 acres) of land. This geographic area encompasses all of the 200 East and West Areas (including the Facility) the land between these areas, and extends to the north to include an area

informally known as the 200 North Area. The Central Plateau has been used heavily for fuel reprocessing and waste management and disposal activities. The Central Plateau is the most heavily contaminated of the six geographic areas. Most of the contamination and stored wastes on the Hanford site are within the boundaries of this area. A great deal of the stored wastes are contained in single-shell (some of which have leaked into the soil beneath the tanks) and double-shell tanks[1].

The Working Group had the following findings and recommendations:

- "The Central Plateau is unique among the geographic areas in its level of contamination.
- Some type of government presence or oversight of the area should be assumed for the foreseeable future due to the anticipated level or residual contamination in the 200 Area.
- Waste from throughout the Hanford site should be concentrated in the 200 Area; thus wastes would be moving into the 200 Area from across the site.
- Waste management, storage and disposal activities in the 200 Area and immediate vicinity should be concentrated within the 200 Area whenever feasible to minimize the amount of land devoted to or contaminated by waste management activities. When bringing wastes to the area, adverse effects should be minimized, especially to currently uncontaminated areas of the Central Plateau.
- Wastes generated in or coming to the 200 Area from the rest of the site will not necessarily be permanently disposed of here. Off-site shipments are occurring now and might continue for some wastes. Also, new technologies may be applied to wastes at a later date.
- Waste and contaminants within the 200 Area should be treated and managed to prevent migration from the 200 Area to other areas and/or off site. Waste streams resulting from treatment or other activities should not further contaminate or spread contaminants throughout and/or off site.
- Based on the risk emanating from the contaminants and waste management activities in the Central Plateau, a buffer zone around the borders of these contaminants and waste management activities should be established to minimize exposure.
- The Group acknowledges the existing obligations at the Hanford site to dispose of submarine reactor compartments and commercial LLRW (in accordance with the Northwest Low-Level Radioactive Waste Compact) at the US Ecology site on the

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[1] DOE, 1986, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Draft Environmental Impact Statement, DOE/EIS-0113 (Vol. 1).

state-leased lands in this area. Fulfillment of these obligations is assumed when considering other future use options for the Central Plateau.

- Access to the exclusive area, including the buffer area, would be restricted to personnel who were properly trained and monitored for working under these conditions and exposures."

4.3.2 Conclusion

The Central Plateau area, as discussed by the DOE working groups, should remain an area designated for waste disposal activities and be restricted to personnel properly trained and monitored. This area includes the Facility.

The orderly transfer of site control is outlined in the prime lease between the United States and the State of Washington and the sublease between the State of Washington and US Ecology. Specifications for long-term care of the site by either the State of Washington or the federal government have not been negotiated.

Although no informal agreements have been made with the state or federal agencies to participate in or accomplish the performance objectives, the Washington Department of Health (WDOH) has formed a working group to evaluate the closure plan and discuss site related monitoring activities. Included in this working group are representatives of WDOH, the Washington Department of Ecology (WDOE), USDOE-Richland, USEPA, the Yakima Indian Tribe and US Ecology.

Funds totaling over $22.8 million in the Site Closure Account and $23.0 million in the Perpetual Surveillance/Maintenance Account (i.e., PC&M funds) have been collected to date to assure availability of funds to complete the site closure and stabilization plan. Both funds will continue to grow during the remaining Facility operating life.

4.4 LICENSE CONDITION 66.D - DIRECT GAMMA RADIATION

Direct gamma radiation from buried wastes shall be essentially background at any accessible above-ground location, as determined by evaluation of environmental data from the licensee, U.S. Department of Energy and its contractors.

4.4.1 Response

At closure, sufficient fill and cover materials will be used to ensure the dose rate at any accessible above-ground location is not significantly greater than background. Background at the Facility is influenced by the adjacent offsite DOE activities and contaminated soils. Background dose rates for closure activities will be defined based upon the environmental dosimeter measurements for perimeter stations published in the Hanford Site Environmental Report and US Ecology Annual Environmental Reports. From 1983-1988 the dose rates at the Hanford site perimeter stations have been in the range of 9-12 μrem per hour. This is an average hourly dose rate derived from annual

dose measurements. Short-term variations in the natural background and instrument response to changes in the radiation spectra will affect measurements taken with a portable microrem survey instrument. The short-term variations in the radiation dose rate are in the range of 0.5 to 2.0 μrem per hour. Adding the variations in the dose rate to the average dose rate results in an average background dose rate of 14 μrem per hour. The action level for closed cap surveys will be twice background.

US Ecology continuously evaluates on-site activities affecting worker exposures as part of its radiation safety program. ALARA reports are generated annually to provide information to the Radiation Safety Committee for use in minimizing worker dose. Most activities to be performed during closure are identical to those performed during operation of the Facility, except that those activities associated with waste receipt will no longer be performed. Therefore, doses received during closure should be less than those received during operations. In addition, after the initial soil fill layer is placed, doses from closure operations will be reduced significantly.

Review of annual ALARA reports indicates that exposures associated with off-loading of waste were the main contributor to dose at the US Ecology Facility. Non off-loading exposures, such as those to be received during closure, were approximately 0.8 man-rem in 1993. Non off-loading exposures received during 1993 included maintenance operations within the controlled area, backfilling and associated surveys, filling and placement of sandbags used for burial cell construction, trench maintenance/cleanup, waste verification inspections, routine surveys, environmental monitoring surveillances, maintenance of the engineered barrier cell, and exhumation of waste from active trenches.

Reported non off-loading doses for 1989 through 1993 were 0.81, 0.71, 0.46, 0.93, and 0.80 man-rem. The non off-loading dose has remained relatively constant during this period. The data indicate that doses to workers should be less than 0.8 man-rem per year until such time as the waste is covered with soil to grade. US Ecology will continue evaluations of work activities in an effort to maintain doses ALARA.

Decontamination and decommissioning activities at the Facility are not expected to impact worker doses. Decontamination activities are performed as necessary during operations, and will be performed during closure. There are no areas or buildings currently known to be contaminated that will have significant impact on worker doses. Accidents that may occur during closure activities are those normally associated with facilities employing heavy equipment and field activities. Appropriate industrial hygiene, radiological control, and worker safety measures will be employed to ensure that such accidents are minimized. In addition, US Ecology has an Emergency Plan that is activated when required to ensure appropriate response is taken.

US Ecology performs trench radiation surveys on a quarterly basis. These surveys indicate that skyshine is the main factor impacting doses and that covering of the wastes to normal grade with eight feet of soil reduces penetrating radiation to levels

consistent with normal background. As an example, surveys performed in 1992 over Trench 14 show exposures at the western end of the trench to be approximately 10 μR/h. Exposure rates gradually increased to 180 μR/h as the surveyor moved eastward across the trench toward the then active portion. Surveys performed over backfilled trenches in other areas of the Facility that are removed from current disposal operations also indicate levels near normal background. For example, surveys at the Tank Farm Trench indicated 20 μR/h or less, and Reactor Vessel Head trench surveys indicated 30 μR/h or less during 1992. The results from thermoluminescent dosimeters placed as part of the environmental monitoring program also support these observations. With the cessation of site operations and cap placement, the direct gamma radiation should approach the background of 14 μR/hr noted for the Hanford site perimeter stations.

To further evaluate the potential impact and significance of penetrating radiation as a pathway of concern (direct exposure pathway), the site was modeled using the MicroShield[2] computer code. Modeling results confirm that the radiation dose from penetrating radiation through the cap is insignificant due to the attenuating effects of the overlying soils and cap materials. Calculations indicate doses produced by buried waste at the cap surface, assuming 8 feet of backfill soil and an 8-foot cap thickness, to be less than 1×10^{-12} μR/h. This can be compared to background gamma in the vicinity of the Hanford Reservation, which is approximately 13 orders of magnitude greater. The MicroShield calculation and results are presented in greater detail in Attachment D.

Environmental thermoluminescent dosimeters (TLDs) are presently placed at the background station adjacent to the site administrative offices. Site administrative offices and the background station should not require relocation as the site approaches scheduled closure in 2056. Although not anticipated, if trenches are built adjacent to the presently occupied administration/office area, the TLDs will be relocated. The location of the background TLDs will depend on the sequence of site development. In any case, TLDs will be located sufficiently far away from operating trenches to be representative of the natural background in the surrounding area.

4.4.2 Conclusion

A final survey of the cap will be performed as part of the overall site closure. Based upon the fill to be placed above the waste and historic data available for interim closed trenches, gamma radiation from buried waste should be essentially background.

4.5 LICENSE CONDITION 66.E - DOSE MODEL

Demonstrate by measurement and model during operations and after site closure that concentrations of radioactive material which may be released to the general

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[2] Negin, C.A., and G. Worku, 1993, MicroShield, Version 4.10, User's Manual, Grove Engineering, Inc. Rockville, Maryland.

environment in groundwater, surface water, air, soil, plants, or animals will not result in any member of the public receiving an annual dose equivalent of 25 millirems (2.5 x 10^{-4} Sv) to the whole body, 75 millirems (7.5 x 10^{-4} Sv) to the thyroid and 25 millirems (2.5 x 10^{-4} Sv) to any other organ of any member of the public.

4.5.1 Response

4.5.1.1 Facility Dose Model and Pathway Analysis

A pathway analysis and dose modeling study was completed to provide reasonable estimates of the maximum credible impacts the Facility might have on the surrounding environment. The study evaluates the potential exposure to a hypothetical individual living at the Facility boundary some time in the future, and to ascertain if calculated exposures to this individual are within limits established as performance objectives for the Richland LLRW Facility. Exposure pathways evaluated include direct radiation, groundwater, surface water, air (gaseous release), soil, and biotic intrusion.

The results of this pathway analysis indicate the closed Facility will sequester the waste from the environment in the future, and prevent exposure to the buried waste. Radiological exposures from surface water, soil, and biotic intrusion were found not to be credible and were analyzed in a qualitative manner only.

The dose analysis is outlined in Section 1.6 of this Closure Plan. A detailed description of the dose analysis, including assumptions, data, references, calculations, sensitivity analyses, and model input and output files are included in Section 5 and Attachment D.

4.5.1.2 Summary of Current Environmental Monitoring

The Richland Facility is required to perform environmental monitoring to show that it is in compliance with the Washington Administrative Code WAC 246-250-170 and the Code of Federal Regulations, 10 CFR, Part 61.41 (License Condition 66.E). These regulations require that effluents to the general environment be maintained ALARA and that annual doses due to effluents not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public.

The environmental monitoring program at the Richland Facility monitors all pathways which could result in measurable off-site doses. The pathways also include direct radiation. Due to the location of the Facility within the Hanford Reservation, there is extremely low probability of any effluents reaching the general population. Monitoring of the milk pathway is not possible as there are no farms or cattle near the Facility. Wildlife is not monitored as hunting on the Hanford Reservation is not permitted. Analysis of vegetation samples serves to provide an indication of any radionuclides which could be included in the diet of wildlife.

Table 4-2 describes the environmental monitoring program presently in place at the Facility and the action levels as required by the Facility licenses. Actions required whenever environmental action levels are exceeded are given in Table 4-3. Table 4-4 summarizes the requirements of minimum detectable concentrations for gamma spectroscopy of environmental samples. Figure 4-1 shows all environmental monitoring stations and locations which are described in Table 4-2. US Ecology's Annual Environmental Monitoring Reports contain a complete compilation of environmental data for each calendar year up to the present.

A. Atmospheric Concentration Monitoring

Current monitoring of atmospheric environmental concentrations is described in Table 4-2. As indicated by current monitoring data, disposal operations at the Facility have not resulted in the release of radionuclides which cause any statistically measurable or significant difference between the radioactive air concentrations in the vicinity of the Facility and the Hanford site average background concentrations.

B. Soil and Vegetation Monitoring

Routine monitoring of radioactivity in both soil and vegetation (when available), is described in Table 4-2.

Current data from soil and vegetation monitoring confirms the conclusions of the pathway analysis. Routine disposal operations do not result in radioactivity in the soil or vegetation surrounding the Facility which is statistically measurable or significantly different from ambient concentrations on the Reservation. Elevated levels of tritium in vegetation have been measured on and off the Facility; these levels are being investigated by US Ecology, the State, and the Department of Energy. At this time, tritium monitoring of vegetation is an experimental program and there is not a consensus opinion as to the interpretation of the analytical results.

C. Direct Gamma Exposure

Direct gamma exposure at the Facility fenceline is monitored by use of environmental thermoluminescence dosimeters (TLDs) as well as by use of portable radiation survey instrumentation.

The TLDs are located in areas chosen to monitor the highest radiation levels resulting from Facility operations (i.e. nearest the active disposal unit). These TLDs are exchanged monthly. Sets of TLDs exchanged monthly as well as other sets of TLDs exchanged on a quarterly frequency are located on the north fenceline, south fenceline, east fenceline and west fenceline. Other TLDs, which are exchanged on a quarterly frequency, are located at all site corners.

A review of 1991 through 1993 results obtained from the TLD monitoring program confirms compliance with the regulatory limits contained in Washington Administrative Code WAC 246-221-050 and equivalent NRC regulations. For example, the highest annual total occurred at the south fence adjacent to Trench 14. The net annual exposure for this location varied from 168 to 270 millirem. These totals were under the unrestricted area exposure limit of 500 millirem per year in accordance with regulations.

D. Groundwater Monitoring

Current monitoring of the groundwater system beneath the site is summarized in Table 4-2. Water levels in the wells are measured on a quarterly basis so that the direction of groundwater movement beneath the site can be evaluated.

Water quality beneath the site is monitored also. Under the current program, water samples are collected on a quarterly basis and are analyzed for the specific constituents described in Table 4-2.

The gross alpha, gross beta results for 1993 compare favorably with those for previous years. Results from up-gradient and down-gradient wells were also similar.

Tritium is present in groundwater at the Hanford site from both natural processes and tritium-contaminated liquid waste discharged to the ground from DOE facilities in the past. Tritium concentrations measured in groundwater samples in 1993 ranged from 1,230±130 pCi/l to 3,110±187 pCi/l (Well 13). As the investigation level for tritium in groundwater well samples is 3,600 pCi/l, no analytical results exceeded investigation levels. Tritium in groundwater sample results for 1992 ranged from 849±527 pCi/l to 2,450±160 pCi/l.

It should be noted that the Facility is located adjacent to the 200 East and 200 West Areas of the Department of Energy Hanford Reservation. As presented in DOE's "Hanford Site Environmental Report 1992," tritium concentrations in the unconfined aquifer exceed 200,000 pCi/l in the regions surrounding the 200 East and 200 West Areas. As expected, tritium contamination from these plumes is increasing the levels observed in US Ecology monitoring wells.

E. Special Sampling

US Ecology added two new elements to its environmental monitoring program in 1993. These were radon monitoring at Air Monitoring Stations 1, 2, and 5 and radon monitoring at the trench cap surface.

The program to monitor radon soil gas near the surface of Trenches 7 and 5 is ongoing. Measurements are made by placing soil gas track etch detectors at three locations along the long axis of each trench. A background detector is

placed in soil at the site background monitoring station. There are no environmental standards or limits applicable to soil gas radon concentrations for the US Ecology site. This experimental program is on-going.

The present vadose zone monitoring system, which was installed in late 1991, is part of a research program on unsaturated soil zone monitoring. The program includes monitoring three wells: one background and two adjacent to Trenches 4 and 10. The wells are sampled for tritium, radon, methane, toluene and xylene.

Organic vapor sampling entails withdrawing a gas sample from the well into an evacuated chamber. The chamber is then sent to an off-site laboratory for analysis. Sampling for tritium vapor is performed by placing silica gel in a perforated cylinder into the well so that it can absorb water vapor present in the vadose zone. Radon measurements are made by attaching an airborne radon track etch detector to the cylinder containing the silica gel.

Measured vadose zone radon for 1993 ranged from a low of 306 pCi/l at VW 102 in the second quarter to a high of 879 pCi/l at VW 101 in the fourth quarter. The average concentration ranged from 343 pCi/l to 795 pCi/l. The average concentration measured at the background well was 313 pCi/l.

Vadose zone tritium concentrations ranged from a low of 2.03×10^{-4} μCi/cc at VW 101 during the first quarter to a high of 4.5×10^{-4} μCi/cc at VW 102 during the first quarter. The average concentration ranged from 2.18×10^{-4} μCi/cc to 4.25×10^{-4} μCi/cc. The background well average concentration was 3.87×10^{-7} μCi/cc.

As with the trench cap radon concentrations, there are no applicable environmental standards or limits for vadose zone radon or tritium.

4.5.2 Conclusion

As indicated by current monitoring data, disposal operations at the Facility have not resulted in releases of radionuclides which cause statistically significant concentrations above average background concentrations on the Reservation. The ongoing monitoring program demonstrates that the Facility meets License Condition 66.E.

The results of the dose analysis, presented in Section 5 and Attachment D, also demonstrate compliance with License Condition 66.E.

4.6 LICENSE CONDITION 66.F - RENDERING SITE SUITABLE FOR SURFACE ACTIVITIES

Render the site suitable for surface activities without resort to custodial care exceeding vegetation control, minor maintenance, and environmental monitoring. No active on-going maintenance will be necessary. Final conditions at the site must be acceptable to the government custodian and compatible with its plan for the site.

4.6.1 Response

Section 3 outlines the final cap design. Included as an integral part of the closure is the construction of a partial cover over Trenches 1-6 and the Chemical Trench. This partial cover will be constructed to the same design and according to the same specifications as the proposed cover for the entire disposal site. The partial cover will be monitored for ten years, as described in Section 3.3.6, and then evaluated to determine if sufficient data has been generated to demonstrate cap performance. The ability of the proposed design to meet the above requirement will be determined from evaluation of the partial cover. Any modifications found necessary or desirable can be implemented when designing the final disposal cover, and will be noted during periodic updates of the Closure Plan. The partial cover and the associated monitoring are part of Facility closure, and will be funded from the closure fund.

This cap will return the land surface to a condition compatible with natural conditions, and will limit direct exposure over the trenches to insignificant levels.

The proposed disposal unit cover is consistent with current state-of-the-art practice as defined by studies on the Hanford Reservation[3] and at Los Alamos National Laboratory[4], and should be acceptable to the government custodian today. The closure monitoring of the site performance during the remaining years of operations will allow the cover design to be improved in response to monitoring results and to advances in the state-of-the-art. The present design was selected so that only minimal maintenance would be required. In general, only natural materials found on site or transported from off-site will be used to construct the cap, rather than incorporating materials such as concrete or asphalt into the design.

DOE has designated a large part of the 200-Area Plateau as a waste disposal area for the Hanford Reservation. The ERDF is proposed for the 200 Area. The ERDF would serve as the receiving Facility for most of the waste excavated during the site-wide remediation (DOE/RL-93-99 Rev.1). The final condition of the Facility will be consistent with this planned land use, and will accommodate compatible incidental uses. Incidental uses are assumed to include transient occupation of the area, but not permanent habitation. Transient occupation would allow such activities as hunting, hiking, and similar temporary surface uses. It would not include such permanent activities as constructing dwellings or drilling wells.

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[3] Gee, G.W., A.L. Ward, B.G. Gilmore, M.W. Ligotke, and S.O. Link, 1995, Hanford Prototype -Barrier Status Report: FY 1995.

[4] Nyhan, J., and F. Barnes, 1989, Development of a Prototype Plan for the Effective Closure of a Waste Disposal Site in Los Alamos, NM, LANL-LA-11282-MS.

4.6.1.1 Subsidence Potential

Prior to final site closure, all active trenches will have been surcharged with site soils for at least 30 days to consolidate void space within the waste to the extent practicable. Some of this surcharge material will be removed during cap construction. The cap is designed so that water infiltrating through the surface gravel mulch is stored in the capillary barrier layer (Layer 2) and returned to the atmosphere by evapotranspirative forces. There are no pumps required in the drainage layer design, since there is no leachate being generated that would require treatment or disposal. The gravel mulch (Layer 1) on the cap will minimize erosion while vegetation is being established on the cap surface.

Although surcharged prior to closure, any LLRW disposal facility is subject to some varying degree of long-term subsidence due to the physical nature of the waste and its handling requirements during disposal. The potential for subsidence is discussed in greater detail in Section 3.3.2.6 and in Attachment L.

Backfill practices have changed over the site life. For Trenches 1-6, backfill was principally used for radiation shielding. Commencing with Trench 7 and continuing through subsequent trenches, backfill has been used for shielding and to fill void spaces between packages as waste is placed.

Beginning with disposal activities in Trench 7, consolidation of trench materials (backfill and waste) has been achieved by surcharging a filled disposal area with Facility soil excavated from newly-constructed disposal trenches and also by the passage of heavy wheeled and tracked equipment over the backfill. Due to the consolidation characteristics of the sands, effective settlement and reduction of void space is achieved during surcharging. Trenches 1-6, filled from 1965 to 1980, were compacted by surcharge commencing in 1985.

More recently, the Facility initiated a procedure (ROP 42) to further minimize potential void spaces between packages while maintaining good trench utilization. As layers of packages are stacked or randomly placed in the trench, backfill is applied to fill the voids between packages. In the case of unstable waste, backfilling is accomplished frequently enough so that the maximum unburied depth of waste is less than two times the maximum package dimension of the packages being disposed. At no time is the uncovered depth of packages to exceed six feet. In the case where the waste is stacked in a regular fashion, this requirement does not apply. The backfill materials are dry, freeflowing, cohesionless site soils that are stockpiled specifically for the purpose of covering waste. During periods of precipitation, the damp or wet upper portion of the soil stockpile is set aside and dry soil beneath is used.

Class B and C wastes, other waste disposed of as stable waste, and wastes which have specific package segregation or orientation requirements, also are backfilled per ROP 42. Each waste layer is covered prior to subsequent waste placement, or more frequently as directed by the FRC&SO to minimize radiation exposures.

Compaction of soil placed between packages is not practical. However, some densification is expected to occur as some of the waste, especially Class A unstable waste, consolidates with the application of overlying layers of waste, backfill, and cover.

Above the upper limit for waste placement, eight feet of backfill is placed with scrapers and dozers. Some compaction is achieved by the compactive action of the rubber-tired scrapers and the vibration caused by the equipment. Additional consolidation of packages occurs when the trench is subjected to loading from surcharging and soil placement for the interim cap.

4.6.1.2 Waste Form

In addition to backfilling, waste forms have changed to reduce package void space. A data study completed by US Ecology indicates that waste densities have increased substantially over the history of the Facility operations. This indicates a reduction in package void space. This increase is also due to a reduction in biodegradable waste being sent for disposal, as these wastes are now incinerated. The following table shows the increase in average waste density by year.

YEAR	DENSITY
prior to 1982	20-30 lbs/ft^3 (estimated)
1982	42 lbs/ft^3
1983	42 lbs/ft^3
1988	58 lbs/ft^3
1989	59 lbs/ft^3
1990	63 lbs/ft^3
1991	66 lbs/ft^3
1992	68 lbs/ft^3
1993	86 lbs/ft^3

The enhanced backfill, the reduction in package void space, and the decrease in the percentage of biodegradable material disposed, will reduce the potential for long-term subsidence.

4.6.1.3 Partial Cap Monitoring

The partial cap will be monitored for subsidence; the monitoring program is discussed in Section 3.3.6. Since these trenches predated the requirements of 10 CFR Part 61 they contain waste disposed in metal drums, metal boxes, fiber board drums, wooden boxes and cardboard boxes. Also, earlier packaging yielded lower density wastes (e.g. greater void spaces), which are more susceptible to subsidence. For these reasons, these trenches should have the higher subsidence potential of any at the facility.

4.6.1.4 Site History

The surface of the Pasco basin is mantled with loess and sand dunes. These deposits are primarily reworked sediments of the Hanford Formation from surrounding areas. The thickness of these wind-blown sediments varies considerably, ranging from zero to more that 30 feet in some dunes. The physical evidence of sand dunes present on the Reservation suggests this phenomenon of wind blown particles depositing on the surface will continue.[5]

The climate, geology, trench surcharging, and cap design will combine to render the site suitable for custodial care with only minor maintenance required. The inspection of the closed trenches (interim closure) by site personnel during site operation has found minor depressions, cracks and erosion gullies requiring fill. No significant subsidence has been noted in any trenches after interim closure. With proper implementation of closure, the site should be suitable to the custodian for long-term care (the 100-year PC&M period). Additionally, as discussed in Section 4.3.1, the Central Plateau Region of the Reservation of which the Facility is a part, will have some type of government presence or oversight for the foreseeable future. The Hanford Working Group has defined "foreseeable future" as the 100 years from the decommissioning of the 200 Areas waste management facilities and the closure of the waste disposal areas.

Because of present and future waste disposal within the Plateau Region by DOE and US Ecology, this area should not be subject to deep excavation or extensive irrigation. However, hunting, gathering of foods and medicines, and religious practices by Native Americans should be possible if DOE allows. As has been discussed throughout, this area will probably always be under some type of government control.

4.7 LICENSE CONDITION 66.G - TRENCH ELEVATIONS

Demonstrate that all trench elevations are above water table levels, taking into account the complete history of seasonable fluctuations.

4.7.1 Response

Groundwater beneath the site is at a depth of approximately 315 feet (elevations of approximately 405 to 410 feet above mean sea level), whereas the deepest trench constructed to date is approximately 45 feet with a slit trench down to 53 feet. Future trenches will be constructed to a depth of about 45 feet below-grade. Seasonal fluctuations in the groundwater tables would amount to only a few feet at most. Groundwater elevations in the five monitoring wells taken in 1993 varied from 317 feet to 334 below top of casing. Artificial recharge on the Reservation resulting from processing activities has impacted the unconfined aquifer and has created large

[5] Tallman, A.M. et al, 1979, Geology of the Separation Areas, Hanford Site, South-Central Washington, Rockwell International, p. 21.

groundwater mounds beneath the Reservation. This has increased groundwater elevation under the site by approximately 20 feet. Recent decommissioning of the liquid waste infiltration basins will result in a reduction in groundwater recharge beneath the site and a gradual lowering of the water table elevations to natural levels.

4.8 LICENSE CONDITION 66.H - EROSION AND SITE INTEGRITY

Eliminate the potential for erosion or loss of site or trench integrity due to factors such as ground water, surface water, wind, subsidence, and frost action. All slopes shall be sufficiently gentle to prevent slumping or gullying. The surface shall be stabilized to minimize erosion, settling, or slumping of caps.

4.8.1 Response

4.8.1.1 Waste Disposal Operations

As mentioned in Section 4.6, the Facility is being operated to minimize the potential voids between packages during disposal activities. Additionally, the waste form has been changed over the years to reduce void space within the waste package. The potential for subsidence is discussed in detail in Section 3.3.6.2 and Attachment L.

4.8.1.2 Surcharging

Prior to final closure, all closed (interim) trenches will have been surcharged with ten to fifteen feet of site soil for at least 30 days. The purpose of placing additional site soils over closed trenches (surcharging) is to reduce the amount of voids that may have formed during the operational life of a disposal trench, which minimizes subsidence occurring after closure.

4.8.1.3 Final Closure

After final closure activities have been completed, the soil cover over waste will range from approximately eight to sixteen feet in thickness above-grade and sloped at a minimum of one percent. The amount of rainfall at the site is about six inches annually. Therefore, erosion mitigation rather than infiltration reduction will be the most critical measure of cap performance. Erosion will be minimized with the placement of the gravel mulch and propagation of vegetation. The trench cap has been designed to be stable for the design life of 1,000 years.

The outside slopes at the edges of the final cap fill will be a maximum of 5:1. Although some minor erosion on these outer slopes is both expected and acceptable, the gravel mulch and the natural propagation of vegetation (see Section 3.3.1.1.1) will stabilize these areas soon after Facility closure.

The potential for erosion or loss of site or trench integrity due to the effects of surface water and wind is detailed in Attachment M. The one-hour PMP from Hydrometeorological Report #57 (US Department of Commerce, 1994, p.157) is used as the design flood.

4.8.1.4 Infiltration

The potential for moisture recharge and the projected travel times for moisture through the unsaturated zone at the site were investigated in a study by Bergeron et al.[6]. The study is included for review in Attachment A. Bergeron estimated recharge at the site to be about 0.2 inches per year. Calculations based on the current water table position and this rate of recharge resulted in vadose zone travel time of about 1060 years. A 38-foot drop in the water table anticipated for post-Hanford conditions, combined with the report's recharge estimate, would add an additional 350 years of travel time in the vadose zone[7].

The addition of the closure cap will further limit infiltration into the groundwater. HELP Model studies described in Section 3.3.4 estimate the average percolation rate from the bottom of the trench cap as about 0.06 inches per year, which increases the travel time. Both the travel time and recharge rate of ambient conditions (e.g. assuming no cap) and of the final closure cap were used for the dose analysis.

4.8.1.5 Rainfall Run-On/Runoff

Since the Facility is located near the crest of a gentle rise, the Facility is subject to only localized run-on (see Topographical Map, Figure 2-22). Drainage is generally away from the Facility.

The final closure cap has been designed to elevate the cap above natural grade with a minimum of one percent slope over the entire surface. This will divert surface water off the cap. The cap design will create a topographic "mound" over the Facility which will prevent run-on from draining onto the Facility.

4.8.2 Conclusion

The combination of elevated cap, sloped at one percent and covered with a gravel mulch, will minimize the potential for erosion or loss of trench integrity. The waste form, backfill and surcharging prior to final capping will minimize the potential for long-term subsidence.

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[6] Bergeron, M.P. et al., 1987a, Geohydrology of a Commercial Low-Level Radioactive Waste Disposal Facility near Richland, Washington. Battelle Pacific Northwest Laboratories.

[7] Bergeron, M.P., et al., 1987a, Geohydrology of a Commercial Low-Level Radioactive Waste Disposal Facility near Richland, Washington: Battelle Pacific Northwest Laboratories.

4.9 LICENSE CONDITION 66.I - PERMANENT TRENCH MARKERS

Demonstrate that permanent trench markers are in place, stable, and keyed to benchmarks. Identifying information shall be clearly and permanently marked as required by Condition 65 of this license.

4.9.1 Response

Refer to Section 3.10 of this plan.

4.10 LICENSE CONDITION 66.J - RECORDS

Compile and transfer to the department complete records of site maintenance and stabilization activities, trench elevation and locations, trench inventories, and monitoring data for use during custodial care for unexpected corrective measures and data interpretation.

4.10.1 Response

Refer to Section 3.12 of this plan.

4.11 LICENSE CONDITION 66.K - BUFFER ZONE

Maintain a buffer zone to provide space to stabilize slopes, incorporate off-site surface water management features, assure that any future excavation on adjoining areas shall be evaluated as to its potential to compromise trench or site integrity, and provide working space for unexpected mitigating measures, if needed, in the future. The buffer zone may be within the subleasehold or on adjacent land, provided written agreements are secured with persons owning or controlling adjacent lands which shall allow the licensee or custodial agency the required access and actions.

4.11.1 Response

The State of Washington Radioactive Materials License requires that a specified buffer zone be maintained on site per License Condition No. 58, which reads:

"Until an agreement is secured with agencies controlling adjacent lands which meets the requirements of Condition 66(k) of this license, disposal units constructed after the effective date of this license will be placed at least 100 feet away from the North, South and West subleasehold boundaries. The set back distance for the East boundary will be no less than 50 feet."

The required buffer zones are being maintained. To the extent possible, the final trench capping and drainage channels will be constructed within these buffer zones. The final slopes are shown on the design drawings included in Attachment E.

The land use for the Central Plateau is projected to remain basically unchanged for the foreseeable future from that of today. This is a conclusion of the Hanford Future Site Uses Working Group. Working Group findings and recommendations are discussed in Section 4.15. The entire 1,500 km^2 of the Reservation is a controlled area, for security and public health and safety reasons, and is expected to remain so for the foreseeable future. Thus, the DOE land surrounding the Facility could be used if necessary for remediation beyond the buffer zone. The only agency controlling the land surrounding the Facility is DOE, who is expected to be the ultimate custodial agency for the property. However, per the lease arrangement, the DOE may transfer title to the State of Washington for the 100 acres.

US Ecology has petitioned US DOE - Richland for an easement up to its 500 feet on all sides to construct the outslope of the closure cover and perform monitoring activities, if necessary, in the future. The US Ecology letter to the DOE dated March 25, 1996 requesting the easement is included as Attachment N. The DOE accepted US Ecology's petition in a letter dated June 10, 1996. The letter also is included in Attachment N.

4.12 LICENSE CONDITION 66.L - PASSIVE SITE SECURITY SYSTEM

Provide a secure passive site security system (e.g., a fence) that requires minimum maintenance.

4.12.1 Response

Refer to Section 3.11 of this plan. The controlled area of the Facility is presently surrounded by an eight-foot chain link fence. At site closure, the fence will be inspected and repaired as necessary to verify its integrity prior to the Facility land being returned to the custodial agency.

4.13 LICENSE CONDITION 66.M - SITE STABILIZATION

LICENSE CONDITION 66.M

Stabilize the site in a manner to minimize environmental monitoring requirements for the long-term custodial phase and develop a monitoring program based on the stabilization plan.

AND LICENSE CONDITION 66.N

Investigate the causes of any statistically significant levels of radioactive or hazardous materials in environmental samples taken during operation and stabilization. In particular, any evidence of unusual or unexpected rates or levels of radionuclide migration in or with the groundwater shall be analyzed and corrective measures implemented.

4.13.1 Response

The disposal procedures, surcharging efforts, and final cap are designed so that maximum physical stability is achieved during the operational and closure phases of the Facility's life. The environmental monitoring program that will be implemented during closure, stabilization and custodial care periods is described in Section 3.8 of this plan. The existing monitoring program will be continued through closure. This will provide almost an additional 70 years of data. Based upon continued compliance with performance objectives, the environmental monitoring program could be reduced during the Facility closure phase. Should statistically significant levels of radioactivity, or unusual unexpected levels of radionuclide migration be detected, those levels of radioactivity or rates of migration will be analyzed to assess the affect on the ability of the Facility to meet performance objectives. Should any performance objective be at risk, corrective action will be implemented.

The environmental monitoring plan proposed in Section 3.8 of this plan may be revised during closure to reflect any changes in the sampling and assessment regimen. Included in the plan will be the recommended actions for the custodial agency to follow to investigate statistically significant levels of radioactivity or other indicator parameters. A prepared corrective action plan also will be included for the most plausible scenario for radioactive migration to the groundwater. The procedure for evaluating data is described in Section 3.9 of this plan.

A summary of the current environmental monitoring program is discussed in Section 4.5.1.2. As discussed in that section, and as required by the FSM, any statistically significant levels of radioactive materials found in environmental samples are investigated. This program will be continued through the closure and stabilization periods. The present monitoring program indicates that site operations have had no measurable effect upon the surrounding environment[8].

4.14 LICENSE CONDITION 66.O - ELIMINATION OF ACTIVE WATER MANAGEMENT MEASURES

Eliminate the need for active water management measures, such as sump or trench pumping and treatment of water, to assure that wastes are not leached by standing water in the trenches.

4.14.1 Response

The potential for liquid migration through the cap/vadose zone and into the trenches in sufficient volume to create a need for active water management is minimal. The potential for deep percolation on the Reservation has been examined in detail by

[8] US Ecology, 1995, Environmental Monitoring Annual Report.

numerous researchers discussed elsewhere and herein. One such research project is the FLTF.

As discussed in Section 3.3.1.1.3, the FLTF was designed to test the performance of a capillary barrier system under arid site conditions. Twelve lysimeters contain silt loam and two contain a gravel admix. The gravel admix used in two of the lysimeters is similar to the silt/pea gravel admix used in the capillary barrier layer (Layer 2) in the Closure Plan cap design. Below the capillary barrier mixture is a graded filter. The critical component of the capillary barrier layer is the fine soil, which retains infiltrating precipitation until evapotranspirative processes recycle the water back to the atmosphere.[9] The final cap design includes the fine soil component in the capillary barrier.

Natural groundwater recharge has been evaluated by collecting water-balance data from three areas on the Reservation.[10] One area studied consisted of two lysimeters approximately 0.6 miles (1 kilometer) south of the 200 East Area. These lysimeters are 59 feet (18 meters) deep. Over the 16 year study period, water contents below the 16 foot (4.88 m) depth in the closed-bottom lysimeter have not changed measurably, implying that significant recharge has not occurred. Recharge and infiltration studies are described in greater detail in Sections 2.7.1.2.2 and 2.7.2.1.1.

In the 200 Areas plateau, contaminated soil was placed in a solid-waste burial ground.[11] Ten years later, core samples were analyzed to determine the depth of radionuclide migration. Below the bottom of the trench, no measurable Cs-137 activity was found. Additional data indicated that the net recharge was zero and probably negative over the 10 year burial period.

US Ecology will continue to track the status of various studies of unsaturated zone recharge, water balance, and contaminant transport as part of its effort to demonstrate the adequacy of closure implementation.

Additionally, laboratory measurement data on the matric potential shows that the pore water has low mobility given the high levels of tension. Site-specific data from the installation of groundwater monitoring wells at the Facility have been evaluated by US

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[9] Gee, G.W., et al., 1993, Field Lysimeter Test Facility Status Report IV, FY 1993, Battelle Pacific Northwest Laboratory.

[10] Rockhold, M.L., M.J. Fayer, G.W. Gee and M.J. Kanyid, 1990, Natural Groundwater Recharge and Water Balance at the Hanford Site, PNL-7215, Pacific Northwest Laboratories, Richland, Washington.

[11] Routson, R.C., M.R. Fuchs, and W.R. Jordan, 1988, Recharge estimates for the Hanford Site 200 Areas Plateau, WHC-EP-0046, Westinghouse Hanford Company, Richland, Washington.

Ecology and compared to similar values obtained by Jones (1978)[12]. These data show a uniform soil moisture content below 30 to 40 feet of 2%[13]. Analyses of samples by B.F. Hajek Consulting Services[14] for soil water retention showed that an average of 3.8% moisture was retained in samples under a pressure of 4000 cm-H_2O (3.8 atmospheres). From these data, it is concluded that the matric potential (soil suction) of the deposits at the Facility with moisture contents of 2% is nearly 4 atmospheres. The potential for liquid migration is discussed in detail by Bergeron[15].

The cap design includes a capillary break layer (Layer 4) which is composed of coarse-grained materials. The primary function of the capillary break is to provide a coarse-grained interface which will keep moisture in the finer layers above for removal by evapotranspirative forces. The minimal amount of percolation anticipated will be further impeded by the performance of the low permeability barrier layer (Layer 5), constructed of the sand-bentonite admix.

The numerous infiltration studies performed to date indicate the difficulties involved with monitoring for liquids in the arid environment present at the Facility. Suction lysimeters cannot function above approximately 0.75 atm of soil suction, and there is no other technology at this time which would circumvent that limitation.

4.15 LICENSE CONDITION 66.P - EVALUATION OF PRESENT AND PROPOSED ACTIVITIES

Evaluate present and proposed activities on adjoining areas to determine their impact on the long-term performances of the site, and take reasonable action to identify and minimize the effects.

4.15.1 Response

The land use for the 200 Areas is projected to remain basically unchanged from that of today. As discussed in the "Final Report of the Hanford Future Site Uses Working Group" published in 1992, the 200 East and West Areas will require some type of government presence or oversight for the foreseeable future. This report also recommended that "wastes from throughout the Hanford site should be concentrated in the 200 Area; thus wastes would be moving into the 200 Area from across the site." Additionally, the Reservation future was discussed in the "Final Hanford Facility

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[12] Jones, T.L., 1978, Sediment Moisture Relations, Rockwell Hanford Operations, RHO-ST-15.

[13] CH2M Hill, 1985, Monitoring Well Installation Report and Laboratory Testing Program Results for US Ecology, Inc., Richland, Washington.

[14] Hajek, B.F., 1986, Soil Analysis for the US Ecology LLRW Disposal Facility, Richland, Washington.

[15] Bergeron, M.P. et al., 1987a, op. cit.

Environmental Impact Statement for Tank Wastes" (DOE/EIS-0113 Vol. 1). In the first paragraph of Section 4.7(Land Use), p.4.40 of that report, the statement was made, "[t]he entire 1,500 km^2 of the Hanford site is a controlled area, for security and public health and safety reasons, and is expected to remain so for the foreseeable future."

Also, the 900 acres that had been leased to the State of Washington adjacent to the Facility have been returned to the DOE and are being used for disposal of DOE waste. The "Remedial Investigation and Feasibility Study Report" for the ERDF, dated October 1994, includes a landfill for receiving waste excavated during remediation of other sites on the Reservation. The ERDF is under construction on the 900-acre site. As discussed in that Report, Section 2.7.1.2 (Hanford Site Land Use), the 200 Area is designated for waste disposal:

> *The 200 West and 200 East areas are located on a plateau about 8 and 11 km (5 and 7 mi) respectively from the Columbia River. These areas have been dedicated to waste management and disposal activities. The 200 areas cover about 16 km^2 (6.2 mi^2).*

Environmental monitoring presently in place around the site (or planned for the future) and that proposed to continue through closure should determine what effect, if any, the surrounding 200 Areas activities have on the Facility.

4.15.1.1 Potential Future On-Site Monitoring

A Work Plan developed by US Ecology for comprehensive investigation of Solid Waste Management Units (SWMUs) identified in a 1994 Department of Energy Hanford Facility Resource Conservation and Recovery Act (RCRA) permit has been submitted to and approved by the Washington Department of Ecology.[16] The purposes of this investigation are to assess the presence of hazardous waste constituents in the vadose zone beneath thirteen SWMUs at the US Ecology Low-Level Radioactive Waste Disposal Site and to confirm the performance of disposal trenches within the Facility with respect to the protection of groundwater from small amounts of hazardous material associated with some low-level radioactive waste. The investigation is designed to complement and possibly replace the vadose zone monitoring expansion outlined in Section 3.8.7 of this Closure Plan. The Work Plan will be immediately implemented upon the authorization of funding by the Washington State Legislature.

The investigation consists of three separate phases. Under Phase 1, additional analyses will be incorporated in the scheduled sampling of existing and planned groundwater wells (two upgradient wells) and existing vadose zone wells on site. The groundwater wells will be analyzed for volatile organic compounds and a suite of

[16] US Ecology, Inc. Work Plan - Comprehensive Investigation US Ecology - Hanford Operations, prepared by Landau Associates, Inc. March, 1996.

metals, including barium, chromium, vanadium and lead. The vadose zone soil gas will be analyzed for a broad suite of volatile organic compounds.

During Phase 2, two additional soil gas monitoring installations are proposed to be collated with two angle soil borings under the Chemical Trench and Trench 5. Soil and soil gas samples will be collected from the vertical monitoring installations. The angled borings will provide soil for analysis. Depending on the implications of the chemical and geological data from Phase 2, a contaminant transport model may be developed. US Ecology is hopeful agreement between WDOH and WDOE can be reached and funding will be authorized to enable a single vadose monitoring plan to be adopted for sampling and monitoring for potential releases from the Chemical Trench and Trench 5.

Phase 3 consists of constructing fourteen additional soil gas sampling installations. These installations will be located between the identified SWMUs at the Chemical Trench and trenches 1 through 11A (Figure 4.2). Soil and soil gas samples will be collected from all these installations (Figure 4.3). Design and placement of the Phase 3 installation will be finalized and will incorporate refinements based on data generated from Phase 2.

4.15.1.1.1 Contaminants of Interest

The waste disposed of in Trench 1 through 11A are not well documented with respect to chemical constituents. Available records reveal the total amount of radioactivity that was disposed of in each trench, but do not reveal either the kind or volumes of hazardous waste constituents that may have been incorporated with the radiological wastes.

The Work Plan's 3-Phase investigation will focus on the volatile organic compounds because some of these compounds are thought to have been disposed of and because they are likely to be the most mobile. Limited testing for Appendix IX constituents will also be conducted.

Subsurface contaminant migration is expected to occur by vapor or liquid migration. Vapor migration is anticipated to be easy to detect. Released liquids are anticipated to migrate horizontally in the fine-grained strata as well as vertically downward. Liquid migration would be detected with the proposed vertical and angle borings during visual inspection and field screening of soil samples. Otherwise, a liquid release would be detected if volatile hazardous waste or radioactive constituents are present in the liquid.

All contaminants of interest will be identified based on the findings of the investigation. No detection of hazardous waste constituents in concentrations that can be attributed to materials disposed of in the SWMU trenches have been documented at the site to date. If detection of hazardous waste constituents occurs during this investigation, they will be evaluated sufficiently to develop an assessment of their potential to migrate to and impact groundwater (Figure 4.4). Contaminants that may present a potential risk to groundwater will be incorporated into the existing monitoring programs, and an

evaluation of the need for and feasibility of remedial action will be conducted. While results from the comprehensive investigation will be used to amend, if appropriate, the current groundwater monitoring program for the facility such that potential releases of hazardous constituents to groundwater can be monitored, no on-going periodic monitoring is provided for in the Work Plan.

TABLE 4-1

SUMMARY OF DISPOSAL HISTORY AND WASTE ACTIVITY AT US ECOLOGY RICHLAND, WASHINGTON LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY (As of December 31, 1995)

Trench	Date Opened	Date Closed	Activity (mCi)
1	Sept. 16, 1965	Sept. 12, 1966	1,092,778
2	Aug. 18, 1966	Nov. 30. 1971	402,437
3	Dec. 01, 1971	Mar. 31, 1975	102,519,867
4	Apr. 01, 1975	Aug. 10, 1978	313,805,821
4A	Apr. 30, 1982	June 18, 1982	4,357
4B	July 09, 1984	Aug. 23, 1985	251,797,244
5	Apr. 29, 1978	Sept. 05, 1979	320,467,842
6	Aug, 22, 1979	June 10, 1980	74,408,010
7	Oct. 29, 1982	Oct. 12, 1983	43,007,197
7A	June 03, 1985	July 16, 1985	63,609
8	May 05, 1980	May 22, 1981	15,537,521
9A	Sept. 09, 1983	Nov. 30, 1984	86,536,080
9B	Sept. 09, 1983	Nov. 30, 1984	39,028,536
10	May 05, 1981	Dec. 20, 1982	85,066,310
Resin Tanks	June 12, 1972	May 04, 1987	580
Reactor Head	Apr. 22, 1976	Apr. 22, 1976	49,400
11A	Oct. 29, 1984	Nov. 07,1985	8,642,000
11B	Oct. 29, 1984	(Open)	548,230,800
13	July 29, 1985	March 31, 1995	243,160,790
14	Feb. 02, 1987	(Open)	57,982,517
16	Jan. 08, 1992	(Open)	24,966,455
18	Nov. 21, 1995	(Open)	18,810

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TABLE 4-2

Environmental/Occupational Monitoring Requirements

Medium	Location	Type, Frequency	Analysis	ACTION LEVELS: Investigation Level[1]	ACTION LEVELS: Reporting Level	Action Category[1]
Environmental Air	Envir. Monitoring Stations 1-9	Continuous, changed weekly	Gross Alpha	1×10^{-14} uCi/cc	1.7×10^{-14} uCi/cc	3, 4
			Gross Beta	1×10^{-13} uCi/cc	2.6×10^{-11} uCi/cc	3, 4
			I-125	3.5×10^{-14} uCi/cc	2.3×10^{-10} uCi/cc	3, 4
	Envir. Monitoring Stations 1-9	Continuous, Monthly; Composite of weekly samples	Co-60	5×10^{-14} uCi/cc	2.6×10^{-11} uCi/cc	3, 4
			Cs-137	5×10^{-14} uCi/cc	1.9×10^{-10} uCi/cc	3, 4
			Gamma Spec	5 X MDC[3]	5 X MDC[3]	3, 4
	Envir. Monitoring Stations 1, 2, 5	Continuous, Changed monthly	H-3	2×10^{-11} uCi/cc	6.1×10^{-8} uCi/cc	3, 4
Occupational Air	One downwind plus one at each location of potential exposure	Continuous during operations or 1 hour/day; whichever is greater	Gross Alpha	NA[4]	3×10^{-13} uCi/cc	1
			Gross Beta	NA[4]	1×10^{-12} uCi/cc[2]	1
			I-125	NA[4]	5×10^{-10} uCi/cc	1

TABLE 4-2

Medium	Location	Type, Frequency	Analysis	ACTION LEVELS Investigation Level	Reporting Level	Action Category[1]
Groundwater	Wells	Grab, Quarterly	Gross Alpha	12 pCi/L	15 pCi/L	3,4
	#013 (upgradient)		Gross Beta	12 pCi/L	50 pCi/L	3,4
	#010		H-3	3,600 pCi/L	20,000 pCi/L	3,4
	#008		C-14	250 pCi/L	2,000 pCi/L	3,4
	#005		Total Uranium[6]	4.5 pCi/L	30 pCi/L	3,4
	#003		Pu-238	0.03 pCi/L	See Pu-239/240	3,4
			Pu-239/240	0.03 pCi/L	40 pCi/L (Total Pu)	3,4
			Co-60	6 pCi/L	100 pCi/L	3,4
			Cs-137	7 pCi/L	200 pCi/L	3,4
			Gamma Spec	5 X MDC[3]	5 X MDC[3,7]	3,4
			Specific Conductance	NA[4,8]	NA[4,8]	NA[4]
			TDS	NA[4,8]	NA[4,8]	NA[4]
			TOC	NA[4,8]	NA[4,8]	NA[4]
			Nitrates	NA[4,8]	NA[4,8]	NA[4]
			Temperature	NA[4,8]	NA[4,8]	NA[4]
Field Blank Deionized Water		1 blank per 10 samples collected	Note[9]	NA[4,10]	NA[4,10]	NA[4]

TABLE 4-2

Medium	Location	Type, Frequency	Analysis	ACTION LEVELS: Investigation Level	ACTION LEVELS: Reporting Level	Action Category[1]
Soil[5]	Envir. Monitoring Stations 1-9 and NE, NW Corners	Grab, Quarterly	Gross Beta	35 pCi/g (dry)	35 pCi/g (dry)[7]	3, 4
			Total Uranium[6]	1 pCi/g (dry)	1 pCi/g (dry)[7]	3, 4
			Pu-238	0.03 pCi/g (dry)	0.03 pCi/g (dry)[7]	3, 4
			Pu-239/240	0.03 pCi/g (dry)	0.03 pCi/g (dry)[7]	3, 4
			Co-60	0.3 pCi/g (dry)	0.3 pCi/g (dry)[7]	3, 4
			Cs-137	0.25 pCi/g (dry)	0.25 pCi/g (dry)[7]	3, 4
			Gamma Spec	5 X MDC[3]	5 X MDC[3,7]	3, 4
Vegetation[5]	Envir. Monitoring Stations 1-9 and NE, NW Corners	Grab, Quarterly for deep rooted	Gross Beta	100 pCi/g (dry)	100 pCi/g (dry)[7]	3, 4
			Total Uranium[6]	0.25 pCi/g (dry)	0.25 pCi/g (dry)[7]	3, 4
			Pu-238	0.02 pCi/g (dry)	0.02 pCi/g (dry)[7]	3, 4
			Pu-239/240	0.02 pCi/g (dry)	0.02 pCi/g (dry)[7]	3, 4
			Co-60	0.1 pCi/g (dry)	0.1 pCi/g (dry)[7]	3, 4
			Cs-137	0.2 pCi/g (dry)	0.2 pCi/g (dry)[7]	3, 4
			Gamma Spec	5 X MDC[3]	5 X MDC[3,7]	3, 4
	Filled and capped trenches	Grab, Annually	Gross Beta	100 pCi/g (dry)	100 pCi/g (dry)[7]	3, 4
			Total Uranium[6]	0.25 pCi/g (dry)	0.25 pCi/g (dry)[7]	3, 4
			Pu-238	0.02 pCi/g (dry)	0.02 pCi/g (dry)[7]	3, 4
			Pu-239/240	0.02 pCi/g (dry)	0.02 pCi/g (dry)[7]	3, 4
			Co-60	0.1 pCi/g (dry)	0.1 pCi/g (dry)[7]	3, 4
			Cs-137	0.2 pCi/g (dry)	0.2 pCi/g (dry)[7]	3, 4
			Gamma Spec	5 X MDC[3]	5 X MDC[3,7]	3, 4
			H-3	NA[4,8]	NA[4,8]	3, 4

TABLE 4-2

Medium	Location	Type, Frequency	Analysis	ACTION LEVELS Investigation Level	Reporting Level	Action Category[1]
Direct Gamma Dose (TLD)	NW, NE, SW, SE Corners and N, S, E, W Fencelines	Continuous, Quarterly	Tissue dose using thermoluminescent dosimeter	90 mrem/qtr	400 mrem/year	3, 4
	N, S, E, W Fencelines and Fenceline position(s) nearest each active disposal trench	Continuous, Monthly	Tissue dose using thermoluminescent dosimeters	30 mrem/month	400 mrem/year	3, 4

NOTES:
1. Table 4-3 presents the action required based upon action categories.
2. IF Ac-227 is listed on manifest or known to be present, the reporting level is 2.0×10^{-13} uCi/cc.
3. The required minimum detection concentrations (MDC's) are listed in Table 4-4.
4. NA = Not applicable or none established.
5. Dry to wet ratio will be obtained.
6. Total uranium analysis is defined as the sum of the concentrations of uranium isotopes reported.
7. These are interim reporting levels.
8. Concentrations will be evaluated and reported annually in the environmental report.
9. Field blank analysis is the same as well sample analysis.
10. Used for sample QA.

TABLE 4-3

Action Categories

Actions Required When Action Level Met or Exceeded

1. Type 1 Event
   Follow Reporting Level requirements
   Potential for bioassay examined by FRC&SO.

2. Type 2 Event
   Immediate notification of on-site inspector
   Take corrective action

3. Investigation Level
   Notify the FRC&SO and the CRC&SO
   Take corrective actions described in FSM 6.1.5

4. Report Level
   Notify the FRC&SO, CRC&SO, the Department, the US NRC within 24 hours upon confirmation
   Take corrective actions described in FSM 6.1.5
   Make reports in accordance with FSM 6.1.4.C

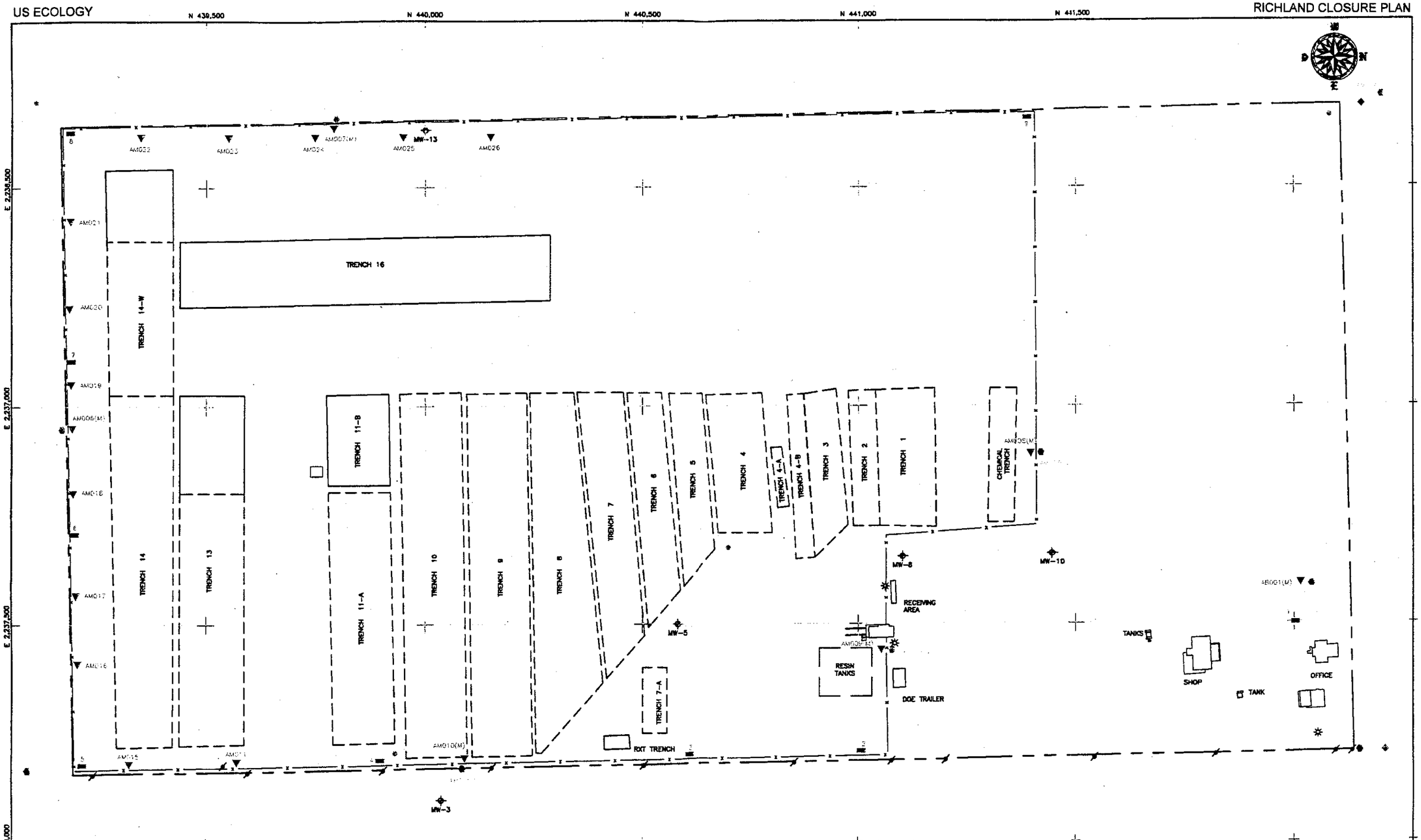
5. Resurvey with dose rate instrument for fixed contamination/radiation level and smears for loose contamination. If dose rate < 0.1 mR/hr and loose contamination < 220 dpm/100 cm^2, no further action is required. If dose rate is ≥ 0.1 mR/hr or loose contamination is ≥ 220 dpm/100 cm^2, then take action per #2 above.

TABLE 4-4

Required Minimum Detectable Concentration (MDC's) for Gamma Spectroscopy Analyses of Environmental Samples

Radionuclide	Water (pCi/l)	Airborne Activity (pCi/m^3)	Soil (pCi/g - dry)	Vegetation (pCi/g - dry)
As-76	16	0.02	0.03	0.05
Ba/La-140	24	0.02	0.05	0.07
Ce-141	10	0.01	0.02	0.03
Ce/Pr-144	92	0.09	0.18	0.10
Co-58	10	0.01	0.02	0.03
Co-60	11	0.01	0.02	0.03
Cs-134	11	0.01	0.02	0.03
Cs-137	10	0.01	0.02	0.03
Eu-152	56	0.06	0.11	0.17
Eu-154	27	0.03	0.05	0.08
Eu-155	24	0.02	0.05	0.07
Fe-59	17	0.02	0.03	0.05
I-131	10	0.02	0.02	0.03
I-133	11	0.01	0.02	0.03
Mn-54	10	0.01	0.02	0.03
Mo-99	69	0.07	0.14	0.21
Na-22	10	0.01	0.02	0.03
Ru-103	10	0.01	0.02	0.03
Ru-106	85	0.09	0.17	0.26
Sb-124	10	0.01	0.02	0.03
Sb-125	24	0.02	0.05	0.07
Zn-65	21	0.02	0.04	0.06
Zr/Nb-95	17	0.02	0.03	0.05

NOTE: The gamma nuclide library used by the analytical laboratory will contain additional radionuclides as specified by US Ecology. Naturally occurring gamma ray emitters which will be monitored and reported in the annual environmental report are not included in this listing.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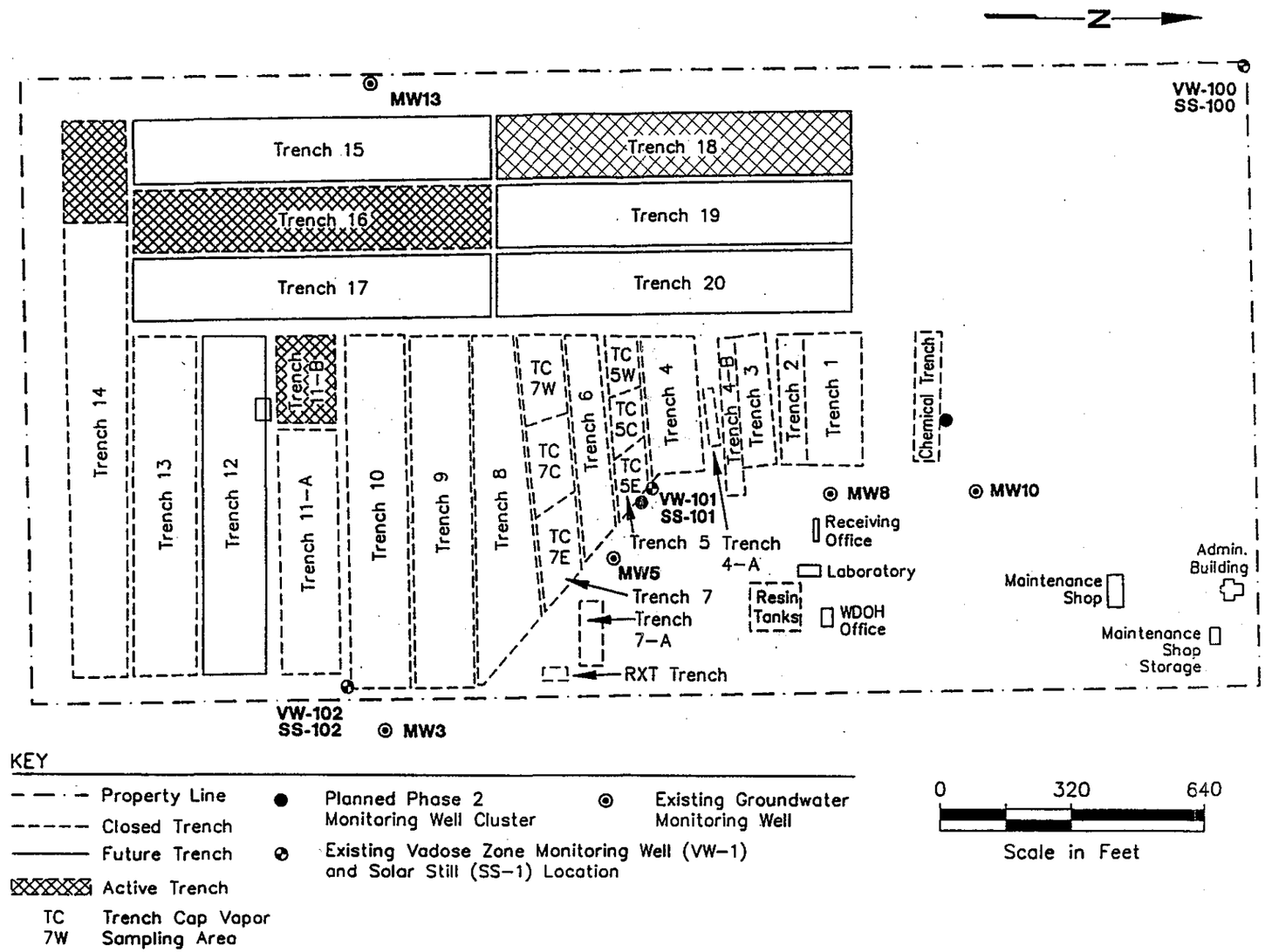
E 2,237,000
E 2,237,500
E 2,236,000
AM022
AM023
AM024
AM007(M)
MW-13
AM025
AM026
AM021
AM020
AM019
AM006(M)
AM018
AM017
AM016
AM015
AM011
AM010(M)
AM009(M)
AM005(M)
AB001(M)
MW-3
MW-5
MW-6
MW-10
TRENCH 16
TRENCH 14-W
TRENCH 14
TRENCH 13
TRENCH 11-B
TRENCH 11-A
TRENCH 10
TRENCH 9
TRENCH 8
TRENCH 7
TRENCH 7-A
TRENCH 6
TRENCH 5
TRENCH 4
TRENCH 4-A
TRENCH 4-B
TRENCH 3
TRENCH 2
TRENCH 1
CHEMICAL TRENCH
RXT TRENCH
RECEIVING AREA
RESIN TANKS
DOE TRAILER
TANKS
SHOP
TANK
OFFICE
LEGEND
PROPERTY LINE
FENCE LINE
ACTIVE DISPOSAL AREA
CLOSED DISPOSAL AREA
EXISTING MONITOR WELL LOCATION AND NUMBER
VADOSE ZONE LOCATION AND NUMBER (UNSATURATED)
POWER POLE
LIGHT
SOIL, VEGETATION, AIR MONITOR STATION LOCATION AND NUMBER
SOIL AND VEGETATION MONITOR STATION
MONTHLY TLD LOCATION AND NUMBER
QUARTERLY TLD LOCATION AND NUMBER
100 50 0 100
SCALE FEET
Rev Drawn Check Appr Date Description
REVISIONS
US Ecology
an American Ecology company
US Ecology Inc.
5333 WESTHEIMER
Suite 1000
Houston, Texas 77056
Drawn By: GKB
Checked By:
Appr. By:
Date: 5/94
Scale: AS NOTED
Project No.: WA-125
Reference Drawings WN-200-TOP-000-R2
ENVIRONMENTAL MONITORING STATIONS
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US Ecology, Inc.
RICHLAND, WASHINGTON
Drawing No. WA-125-TOP-003
Figure 4-1



Modified from:

Landau Associates, Inc.; Work Plan - Comprehensive Investigation, US Ecology - Hanford Operations, March 29, 1996

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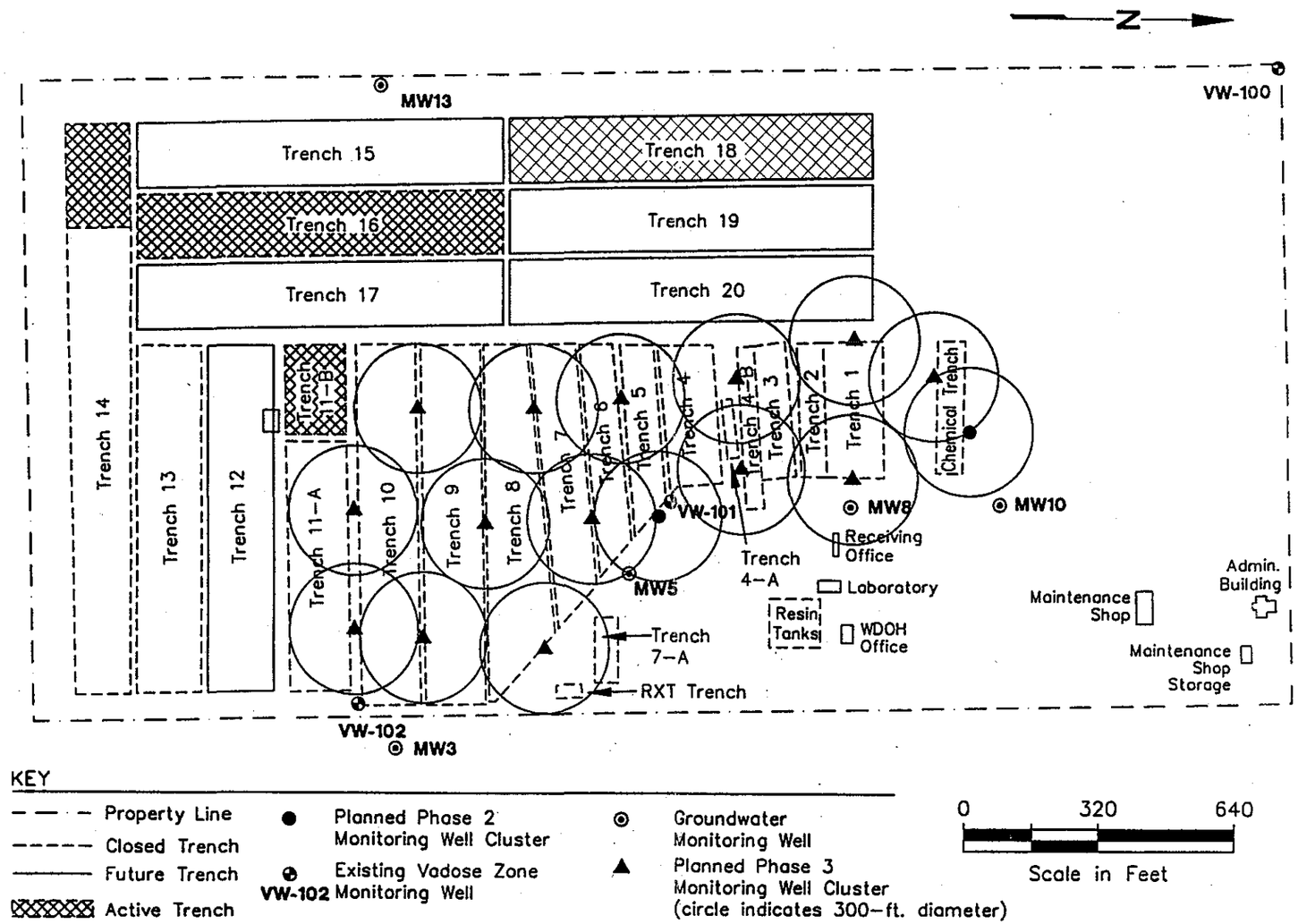
FIGURE 4-2

SITE MAP SHOWING EXISTING WELLS AND PLANNED PHASE 2 WELLS



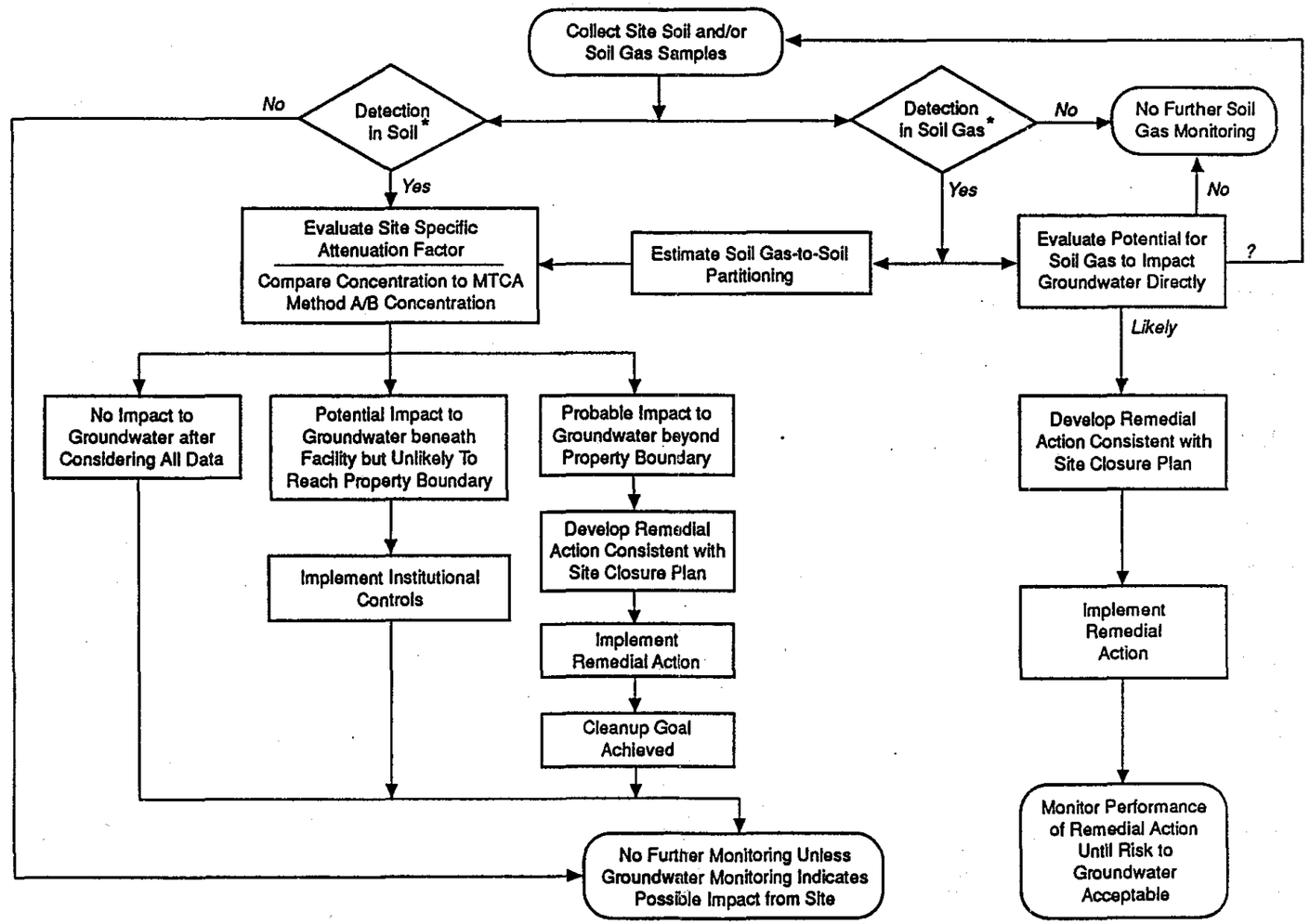
Modified from:

Landau Associates, Inc.; Work Plan - Comprehensive Investigation, US Ecology - Hanford Operations, March 29, 1996

GRANT ENVIRONMENTAL consulting and engineering DENVER, COLORADO

FIGURE 4-3

PLANNED PHASE 3 VADOSE ZONE MONITORING WELL CLUSTERS



* "Detection" is defined as a concentration above background.

Source:

Landau Associates, Inc.; Work Plan - Comprehensive Investigation, US Ecology - Hanford Operations, March 29, 1996

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FIGURE 4-4

IMPACT ASSESSMENT DECISION METHODOLOGY - US ECOLOGY- HANFORD

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5. DOSE ANALYSIS

5.1 OVERVIEW

This chapter summarizes the dose analysis for the Richland Facility. The summary demonstrates that, when closed according to the plan presented in this document, the Facility will meet the requirements stated in License Condition 66. Specifically, the analysis demonstrates that the potential exposure to the maximally exposed individual will not exceed 25 millirem per year to the whole body, 75 millirem per year to the thyroid, or 25 millirem per year to any organ other than the thyroid.

This section is organized as follows:

- Pathway Identification
- Transport Mechanism Identification
- Scenario Identification
- Description of the Site Conceptual Model
- Details of Scenario Models including:
  - selection,
  - mathematical codes,
  - analytical formulas,
  - sensitivity analysis, and
  - results
- Conclusion

Potential exposures were analyzed for agricultural, construction and residential scenarios. The agricultural scenario includes doses due to groundwater, crop, and milk ingestion, direct radiation from buried waste and radioactive gases released from the waste. The construction scenario includes doses due to direct radiation from buried waste and gases released from waste. The residential scenario includes doses due to direct radiation from buried waste and gases released from the waste into a basement. These scenarios are assumed to be possible only after the 100-year institutional control period.

Radiological exposures due to cap erosion and biotic intrusion transport mechanisms were analyzed qualitatively and found to be insignificant. The erosion transport mechanism includes the effects of both wind and water erosion. Similarly, the biotic intrusion transport considered the effects of both animal and vegetation intrusion. The closed Facility will isolate the waste from these transport mechanisms in the future.

The dose analysis focuses on the direct exposure and groundwater transport pathways. Scenarios that do not involve these pathways do not represent credible exposures from the buried waste. The potential for infiltration of water through the buried waste and the generation of leachate at this Facility is shown to be minimal. However, the potential does exist for radionuclides to migrate to groundwater and then travel to a hypothetical well located at the boundary of the Facility. An individual could use the well as a source of drinking and irrigation water. This mechanism is shown to produce the highest cumulative dose of any pathway considered.

Different source terms were developed for each scenario based on the pathways being analyzed. For example, only long-lived isotopes and progeny were considered in the groundwater ingestion pathway. This is because short-lived radionuclides will decay before being able to migrate to groundwater. Similarly, the source term for the basement portion of the residential scenario specifically addresses sources of radon and progeny.

5.1.1 Summary of Site and Facility

The Richland LLRW Disposal Facility occupies approximately 100 acres of land on the Hanford Reservation. The land is owned by the U.S. Department of Energy (DOE) and is leased to the State of Washington, who subleases the property to US Ecology. The Facility was licensed in 1964 and began operations in 1965.

The Facility disposes of LLRW in shallow trenches. Trench sizes and volumes vary. The earlier trenches typically are smaller and shallower than the later trenches. About 13 million cubic feet of wastes have been disposed of in the existing trenches. The waste disposed, in general, was dry and solid. Future trenches are expected to be similar in depth and size to Trench 18, which has a maximum depth of about 45 feet. Predicted future disposal volumes are expected to total approximately 7 million cubic feet. The total waste volume projected to be disposed at the Facility at closure in 2056 is approximately 20 million cubic feet.

The Facility is located on the 200 Area Plateau which is comprised of a thick sequence of sands, gravel, and silt overlying basalt. Groundwater occurs in fractures in the basalt and within the overlying clastics. Groundwater at the Facility is found first at a depth of about 315 feet below ground surface in the clastic deposits. This saturated zone and the overlying vadose zone are comprised of poorly-sorted sand with local admixtures of gravel, silt, and clay. Water moves slowly through the vadose zone. Calculated unsaturated hydraulic conductivity values ranged from less than 10^{-11} centimeters per

second (cm/s) to about 8 x 10^{-7} cm/s at an ambient volumetric moisture content of about 0.055[1].

5.2 PATHWAYS

Pathways are the means by which an individual could receive radiation exposure from waste disposed at the site. The three pathways of exposure are ingestion, direct gamma exposure, and inhalation. The agricultural, construction, and residential scenarios are comprised of, and may be evaluated in terms of, one or more of these pathways.

5.2.1 Ingestion

The ingestion pathway consists of radionuclides taken into the body with food and water. Included are groundwater used for drinking, and irrigated crops grown in the vicinity of the site and milk from a dairy cow pastured near the site. This pathway usually includes doses that may be received through ingestion of food contaminated through the deposition of air- and water-born radioactive material on crops through wind and water erosion. Since the Facility closure cap is designed to limit wind and water erosion, waste is not expected to be re-deposited via this transport mechanism. Consequently, doses due to erosion mechanisms are not evaluated in this analysis.

5.2.2 Direct Gamma Exposure

Direct gamma exposure represents that dose which may be received from radiation emitted directly by buried waste. This exposure pathway is applicable to individuals actually present on the site. The direct exposure pathway generally includes doses due to waste that is exposed through wind and water erosion. However, erosion transport mechanisms are not included in dose calculations since the closure plan cap is designed to preclude waste being exposed by erosion.

5.2.3 Inhalation

The inhalation pathway includes doses received through inhalation of gaseous and particulate radionuclides. Gaseous radionuclides include tritium (H-3), carbon 14 (C-14), noble gases (e.g., Kr-85) and radon. The transport mechanism for these radionuclides is gaseous diffusion through the cover from the waste.

The inhalation pathway also includes doses from airborne radioactive particulates. Airborne radioactive particulates would be generated through wind or water erosion

---

[1] Bergeron, M.P., B.A. Napier, A.E. Reisenaur, and D.R. Sherwood, 1987a, Geohydrology of a Commercial Low-Level Radioactive Waste Disposal Facility Near Richland, Washington: Battelle Pacific Northwest Laboratories, 79 p.

exposing buried waste. The Facility closure cap is designed to prevent airborne radioactive material generation due to erosion. Consequently, this transport mechanism is not included in the dose calculations.

5.3 TRANSPORT MECHANISMS

Transport mechanisms are the means by which radioactive material moves from the disposal trenches to a location where a radiation dose may be received by a receptor. Transport mechanisms include groundwater, surface water, biotic intrusion, wind, and direct radiation. For purposes of this analysis, direct radiation is considered both the pathway of exposure and the transport mechanism.

5.3.1 Groundwater

The groundwater is assumed to transport radionuclides to a well used as a drinking water supply for a resident and livestock and as an irrigation water supply for growing crops. The groundwater transport mechanism requires precipitation to infiltrate the cover and traverse the waste, causing radionuclide migration from the waste through the vadose zone into groundwater. This process is modeled in the agricultural scenario.

Exposure by groundwater transport could also occur if radionuclides reached the groundwater and ultimately moved to the Columbia River. Since the Columbia River is approximately 7 miles (11.3 km) from the site at its closest point[2] (and over 16 miles (26 km) in the direction of groundwater flow)[3], this pathway is bounded by the agricultural scenario and was not modeled.

5.3.2 Surface Water

Exposure to a hypothetical individual located at the Facility boundary may result from precipitation run-off or a perennial stream transporting radioactive material to an off-site location. However, the closed Facility's elevated cap will withstand large floods with minimum erosion. Consequently, this transport mechanism is not credible and was not modeled.

5.3.3 Biotic Intrusion

Burrowing animals or deep-rooted plants potentially could lead to a release to the environment of radioactive materials and subsequent exposure to a receptor. The following exposure models were considered in the performance analyses:

---

[2] Record of Decision, U.S. DOE Hanford Environmental Restoration Disposal Facility, January 1995, p. 2.

[3] Bergeron, M.P., B.A. Napier, A.E. Reisenaur, and D.R. Sherwood, 1987a, op. cit.

1. Intruding plants or animals might transport buried radionuclides to the surface. The radionuclides brought to the surface could be transported to an off-site location by wind or water, and result in exposure to a hypothetical individual located at the Facility boundary.

2. Plants or animals might uptake radionuclides from the waste and then be consumed by humans.

3. Animal burrows in the trench cover might lead to increased percolation of rainwater and increased leaching through the waste.

The closed Facility is designed to minimize plant and animal intrusion by providing a thick, erosion resistant soil cap over the wastes. Since the cap will minimize intrusion, Scenarios 1 and 2 above are not credible, and were not modeled. Also, Scenario 3 was not separately modeled because the ground-water pathway analysis addresses increased percolation resulting from cover damage.[4]

5.3.3.1 Plants

Plant rooting depth on the Reservation's 200 Area Plateau has been studied by the US Department of Energy. The two deepest rooted plants are antelope bitterbrush and big sagebrush with average depths of 296 and 200 cm, respectively (about 116.5 and 78.7 inches). These plants are common throughout the 200 Area and are further described in Section 2.6.1.

The trench cap as designed incorporates a thick multilayer cover with a capillary break to discourage plant root intrusion. Cover layers and thicknesses are illustrated in Figure 3-1. The cover thickness is a minimum of 6.3 ft. (193 cm) over the capillary break layer (Layer 4). Although deep rooted plants may penetrate deeper than 6.3 ft. in undisturbed soils, the presence of the capillary break layer in the cover will prevent further root intrusion because of lack of moisture (discussed in Section 3.3.2.3). Deep rooted plant transport is not considered further because of this design.

5.3.3.2 Animals

Burrowing animals, ranging in size from small invertebrates (such as ants) to medium sized mammals (such as badgers) were considered as potential transport mechanisms. Such a mechanism would include burrowing through the trench cover into the waste and then transporting the waste back to the surface.

---

[4] Potential increases in infiltration are incorporated by using an area-wide infiltration value in the analyses of the ground-water pathway. The use of this value is equivalent to assuming that the engineered features of the cap are not present. The selection of this value is discussed in Section 2.7.1.2. The discussion of the hydrologic model in Section 5.5.1 describes why small surface defects will not have a significant influence on deep infiltration.

A survey of burrowing animals on the Hanford Reservation recorded maximum excavations to a depth of approximately 5 feet (1.5 m). Since the closure plan incorporates both backfill and a cap with a combined depth of about 16.4 feet (5 m), this transport mechanism is not considered further in the dose analysis.

5.3.4 Wind

5.3.4.1 Wind - Erosion

Wind erosion of the trench cap could allow direct release of particulate radionuclides from the waste materials to a hypothetical individual located at the Facility boundary.

This pathway is not credible because the trench cover is designed to minimize erosion such that the opportunity for waste to be directly exposed to the atmosphere is insignificant. Wind erosion of the trench cover will be limited by the vegetation expected to grow on the top and sides of the cap, and also by the uppermost gravel mulch layer. Additionally, the Facility is located in an area of net deposition.

Since the closure plan design limits the potential for direct exposure of the waste to the atmosphere, dose via this transport mechanism is not considered credible and was not modeled.

5.3.4.3 Wind - Gases

Gaseous radionuclides are released as wastes and containers decay. These radionuclides may migrate to the surface of the closed Facility and be transported by wind to a receptor downwind of the Facility. This transport mechanism was evaluated as part of the agricultural scenario.

5.3.4.2 Wind - Resuspension

Large-scale farming operations requiring irrigation are improbable because of the proposed future use of the surrounding Separations Area as a waste storage area for the on-going cleanup operations on the Hanford Reservation. However, as part of the agricultural scenario for single family subsistence farming, the potential effects of re-suspension of radionuclides deposited as a result of irrigation are considered in the groundwater pathway analysis.

5.4 SCENARIOS

The Richland Facility dose analysis includes both land uses and radioactive material transport mechanisms that together could result in dose to a receptor or individual via ingestion, inhalation, and direct exposure pathways. Three land use scenarios were considered to evaluate the efficacy of Facility closure: the agricultural scenario, the construction scenario, and the residential scenario. All scenarios are expected to occur after the 100-year institutional control period has lapsed.

As previously discussed, wind and water erosion, and biotic intrusion transport mechanisms were eliminated from further consideration in each specific land use scenario. Only groundwater transport was evaluated in all three land use scenarios.

5.4.1 Agricultural Scenario

The agricultural scenario assumes a family resides adjacent to the site and consumes crops, milk, and groundwater potentially impacted by site operations. This scenario includes doses resulting from the ingestion of groundwater from a farm well located at the edge of the Facility, ingestion of crops grown adjacent to the site irrigated with groundwater from the site well, consumption of dairy products produced on the family farm, and radioactive gases released by the buried waste.

Since this scenario assumes the activity takes place at the edge of the Facility, the direct exposure pathway assessment is bounded by the direct exposure pathway analysis performed for the construction scenario in Section 5.6.2. That is, individual exposure estimates for the construction scenario are expected to be higher since workers are assumed to work directly above the waste. Results from the construction scenario are well below applicable dose limits. Consequently, the agricultural scenario impacts are limited to analysis of only the ingestion and inhalation pathways.

5.4.2 Construction Scenario

The construction scenario includes doses which occur due to construction activities on the site. The exposure pathways considered include direct radiation exposure while excavating for building foundations and inhalation of radioactive gases released from disposed waste. In the construction scenario, a worker is assumed to come on-site, work for the day on-site, and leave at the end of the day. The construction worker is assumed not to eat or drink any foodstuffs produced on the closed Facility.

5.4.3 Residential (Basement) Scenario

The residential scenario includes doses only due to direct radiation and inhalation pathways. This scenario assesses the radiological impacts associated with occupying a residence with a basement constructed into the Facility's final closure cap. The residential scenario assumes that the resident lives part of the time in the basement, but does not assume that the resident eats or drinks any foodstuffs produced on the closed Facility.

5.5 SITE CONCEPTUAL MODELS

5.5.1 Site Hydrological Model

The site subsurface for purposes of the performance assessment is considered to be comprised of approximately a 315-foot thick vadose zone overlying an unconfined 100-foot thick aquifer. Both the saturated zone and the vadose zone are assumed to be

formed in unconsolidated soils comprised of sands and silts with varying amounts of gravel. The soils are assumed to be variable, but statistically homogeneous. The lithology and characteristics of the soils vary from point to point, and the average properties of the soil over any sufficiently large volume are constant with depth and position.

Studies of the hydraulic characteristics of the vadose zone at the Facility indicate that movement of soil moisture at depth is controlled by low precipitation and larger evapotranspiration values[5]. This behavior is a consequence of an arid climate where annual precipitation is substantially less than the annual potential evapotranspiration[6].

5.5.1.1 Vadose Zone

The vadose zone is separated into a zone of active moisture fluctuation and an underlying zone of steady-state moisture flow. The active zone acts as a reservoir which stores water after rainfall and snow melt. Moisture is transferred out of this reservoir by plant uptake and evaporation during dry periods. The moisture content of the active zone varies seasonally and with variations in climate. Climatic and seasonal variations in moisture supplied to, and withdrawn from, the active moisture zone result in variations in the thickness and moisture content of the zone.

Moisture in the active moisture zone is conceptualized as varying between a lower limit, designated as the "wilting point," and an upper limit, designated as the "field capacity," of the soil. The wilting point depends upon both the soil and the vegetation cover, and represents the soil moisture content below which plants cannot extract water. The field capacity is a property of the soil alone, and represents the soil moisture content above which water drains freely from the soil. When the moisture content of a soil is greater than the field capacity, water drains downward, wetting the underlying soil. When the moisture content of a soil is less than the field capacity, gravity drainage is negligible.[7] The trench covers are considered to contain the active moisture zone. Figure 5-1 presents the juxtaposition of the active moisture and the steady state zones as compared to the trench cover.

The steady state zone is located beneath the active moisture zone. This zone is assumed always to drain vertically in response to the gravitational force. The rate of drainage is equal to the rate of ground-water recharge, which is calculated from the

---

[5] Gee, G.W. and P.R. Heller, 1985, Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography: Battelle Pacific Northwest Laboratories PNL-5428, 42 p.

[6] Gee, G.W. and P.R. Heller, 1985, *op. cit*

[7] This model is based upon concepts from agronomy. For example, see Kirkham and Powers (1972)

unsaturated hydraulic conductivity at the ambient moisture content of the zone. Differing hydraulic properties of the soil are indicated by differing moisture contents. The rate of drainage in this zone is assumed always to be constant.

The hydraulics of the active moisture and steady-state zones are not consistently represented in the hydrologic model. While slow drainage occurs in the steady-state zone, only gross moisture movement is considered in the active zone. The active moisture zone is represented as a reservoir that supplies moisture at a constant rate to the steady-state zone.

There are two key aspects of this hydrologic model that are important to the dose analyses and to the closure design. First, the active zone acts as a regulator of groundwater recharge. It smoothes the effects of short-term meteorologic variations and allows moisture and leachate movement below the active zone to be considered a steady-state phenomenon. Second, the active moisture zone acts to eliminate deep effects of areally-variable infiltration.

In the active moisture zone, capillary force is the dominant force acting on free water due to significantly varying moisture contents. Consequently, moisture will move laterally as well as vertically to minimize moisture variations within this zone. In the steady state zone, gravity is the dominant force. Capillarity is not important in the steady-state zone because moisture contents are assumed to be at equilibrium.

5.5.1.2 Saturated Zone

Moisture moving downward in the vadose zone becomes groundwater recharge when it reaches the saturated zone. Water in the saturated zone is assumed to move uniformly throughout the thickness of the zone, following the direction of the downgradient slope of the piezometric surface.

The saturated zone is important to the dose analyses because waste constituents that may leach from the Facility wastes could traverse downward through the unsaturated zone to the saturated zone. The saturated zone supplies groundwater that may be withdrawn and used by human receptors.

Travel time in the saturated zone is considered to be minimal because the presumed receptor is located near the disposal trenches at the edge of the Facility. Consequently, radioactive decay during transit in the groundwater is also minimal. Essentially all decreases in radionuclide concentrations result from mixing and dilution within the saturated zone.

5.5.1.3 Moisture Movement

Moisture in both the saturated and unsaturated zones is assumed to move in accordance with D'Arcy's law. This law states that the amount of water moving through

a unit area of soil measured normal to the direction of flow is proportional to the piezometric gradient in the soil volume. Symbolically,

$$q = k * i$$

where

i is the hydraulic gradient,

k is the constant of proportionality (called the permeability or hydraulic conductivity), and

q is the flow per unit area in the soil.

The apparent speed of the water is calculated by the formula

$$v = \frac{q}{\theta}$$

where

q is the flow per unit area,

θ is the volumetric moisture content (unsaturated flow) or effective porosity (saturated flow), and

v is the apparent speed of the water.

Any consistent set of units can be used in the above equations.

The apparent speed of solutes in the water depends upon the speed of the water, modulated by any chemical or physical reactions between the solute and the soil matrix. The effects of reactions are incorporated into a lumped parameter called an equilibrium distribution coefficient. This coefficient, which is a function of the soil, the water chemistry, and the solute, represents the fraction of a solute in a soil-water mixture that is in or attached to the solid phase. In symbols,

$$k_d = \frac{C_s}{C_w}$$

where

k_d is the equilibrium distribution coefficient,

C_s is the concentration of the solute in the solid phase, and

C_w is the concentration of the solute in the liquid phase.

Any consistent set of units can be used in the above equation; typically, distribution coefficient values are expressed in units of milliliters per gram.

A non-zero distribution coefficient retards the movement of a solute in a soil-water system according to the equation,

$$v_s = \frac{v_w}{R_d}$$

where

v_s is the apparent speed of the solute,

R_d is the retardation coefficient, and

v_w is the apparent speed of the water.

In the above equation,

$$R_d = 1 + \rho * \frac{k_d}{\theta}$$

where ρ is the soil bulk density, and the other symbols are as defined before.

5.5.2 Wastes and Leaching

Water infiltrating into the waste disposal trenches may leach radionuclides from the waste, and ultimately transport these radionuclides to the water table. The amount of radionuclides leached and the radionuclide concentrations in the leachate depend upon the physical and chemical characteristics of the wastes. It is also dependent upon the chemistry and volume of leachate, and the properties of the soil in the disposal trenches.

Leaching from low-level radioactive wastes is too complex to be calculated from analytical solutions. Consequently, current practice is to base leaching calculations empirically on radionuclide concentrations observed in trench leachate at humid-area sites. Researchers at Brookhaven National Laboratories have studied leaching at commercial low-level radioactive waste disposal facilities since 1976. These studies culminated in the DUST[8] computer code that calculates dissolution of radionuclides in low-level radioactive wastes. This code uses waste solubility, container durability, and

[8] Sullivan, T. M. 1993. *Disposal Unit Source Term (DUST) Data Input Guide*. NUREG/CR-6041. Nuclear Regulatory Commission.

ion exchange between dissolved ions and trench backfill to simulate leaching in waste disposal trenches.

Baes and Sharp[9] proposed a leaching model that assumed that the liquid and solid phases of radionuclides in trench leachate are in equilibrium, and that the equilibrium distribution coefficient is that of the soil backfill in the trench. This model works reasonably well for radionuclides that are soluble, and for which ion exchange is the predominant mechanism by which the dissolved ions associate with the solid phase. The model does not work well for those radionuclides that are only slightly soluble in the trench leachate.

In this dose assessment, leaching was simulated using a modification of the Baes and Sharp model. The modification calculates leachate concentrations as the minimum of the equilibrium concentration calculated by the Baes and Sharp model, and a maximum solubility determined from measurements of radionuclide concentrations in humid-area disposal trenches. No credit is taken for either the integrity of waste containers or the time required to leach radionuclides from the waste form.

5.6 SCENARIO MODELS

Separate agricultural, construction and residential (basement) scenarios were developed for the dose analysis. The pathways considered in each scenario and the modeling assumptions are discussed in the following sections.

5.6.1 Agriculture Scenario Model

The agricultural model considers the radiological impacts associated with a family maintaining a residence at the edge of the Facility. Exposure pathways associated with this scenario include ingestion of food and water impacted by past site operations and inhalation of airborne radioactive gases released from buried waste.

5.6.1.1 Ingestion Pathway

The conceptual model for the groundwater ingestion pathway includes the use of contaminated groundwater as both a source of drinking water for man and animals, and as a source of irrigation water for crops and pasture grass. This scenario assumes the following:

- The family maintains a subsistence farm lifestyle at the edge of the Facility, and derives all of its dietary produce from the garden. The family will consume milk from a cow that is pastured next to the Facility. Due to

[9] Baes, C. F., and R. D. Sharp. 1983. "A Proposal for Estimation of Soil Leaching and Leaching Constants for Use in Assessment Models." Journal of Environmental Quality. Vol. 12. No. 1. pp 17-24.

the restrictions required for DOE's use of the land surrounding the Facility, this assumption is extremely conservative .

- The family uses contaminated groundwater for its sole source of drinking and irrigation water for the garden and the pasture.

This approach maximizes the expected possible dose and provides a level of conservatism in the radiological impacts predicted by the dose model.

5.6.1.1.1 Codes and Discussion

Site Hydrologic Model

The conceptual hydrologic model upon which performance analyses in this closure plan are based is described in Section 5.5. The model comprises the following components illustrated graphically on Figure 5-1.

- A vadose zone, comprised of a zone of active moisture fluctuation and an underlying zone in which moisture conditions are relatively steady. The active moisture zone is essentially the vegetative root zone.

- A saturated zone, comprised of the uppermost aquifer. At the Facility, the saturated zone is first encountered at a depth of about 315 feet below ground surface.

The Facility model is comprised of the following components, which also are illustrated in Figure 5-1.

- A trench cover, which includes the active moisture zone and a part of the steady-state zone.

- A trench or group of trenches, which are located within the steady-state part of the vadose zone. Low-level radioactive wastes are disposed in the trenches.

- The remainder of the steady-state zone.

- The saturated zone.

The Facility model is represented computationally as a series of separate equations or computer codes that are linked in the same way as the components they represent. The linkages between the various parts of the model are illustrated on Figure 5-2.

Trench Cover

The trench cover is modeled as separate, but linked, active and steady-state zones. The active moisture zone is fully contained within the trench cover, while the steady-state zone extends from within the trench cover through the disposal trenches and into the site soils beneath the waste trenches to the saturated zone.

Active Moisture Zone

The active moisture zone is a storage-depletion area where moisture is stored in the soil during periods when infiltration exceeds evaporation and transpiration, and is removed from storage at other times. Soil storage capacity (or maximum moisture content) is a function of the soil's physical properties. The soil's moisture content fluctuates in response to changes in infiltration and evapotranspiration between minimum and maximum values.

The model above was first formulated by Thornthwaite[10], and is the basis of most lumped-parameter moisture balance models currently used. For example, this model is incorporated into the EPA HELP computer code, the USDA CREAMS and GLEAMS codes, and the USGS VS2D code.

The behavior of the active moisture zone was not simulated in the performance analyses demonstrating the effectiveness of the Facility closure plan. The HELP model was used to qualitatively assess the behavior of various possible cover designs. Average values for infiltration from the active zone were used to calculate transport and potential exposures from the Facility. Average infiltration values were also calculated from moisture contents and hydraulic properties of the steady-state zone.

Steady-State Zone

The active moisture zone forms the upper part of the trench cover. The remainder of the cover is considered a part of the steady-state zone. Moisture content and infiltration in the steady-state zone are assumed to be constant. The steady-state zone drains by gravity. Moisture entering the steady-state zone is assumed equal to the infiltration leaving the active moisture zone. Infiltration rates of 0.2 in/yr (0.5 cm/yr) and 0.05 in/yr (0.13 cm/yr) were used in the dose assessment.

Trenches and Low-Level Radioactive Wastes

The low-level radioactive wastes are conceptualized as uncontained materials through which moisture moves rapidly. The wastes are comprised of inert radioactive materials and soil backfill.

Radioactive materials are assumed to leach according to the solubility of the waste. No credit is taken in the leachate model for the isolating effects of the waste containers. Radionuclide leaching is assumed to be either solubility controlled or sorption controlled. The dissolved concentrations of radionuclides that are solubility controlled are assumed to be in equilibrium with the waste. The dissolved concentrations of

[10] Thornthwaite. C.W., 1948. Toward a Rational System for Classifying Climate. Journal of Geographic Review.

radionuclides that are sorption controlled are assumed to be in equilibrium with the trench backfill.

This leaching model is a modification of a sorption-controlled leaching model described by Baes and Sharp (1983). The model can be customized to a particular facility when the distribution coefficients of the radionuclide-backfill-leachate system are known, such as at the US Ecology Richland site.

The TRANSS computer code[11] was used to calculate leachate concentrations from the Richland Facility wastes for both solubility and sorption controlled radionuclides. The TRANSS code also can route the radionuclides leached from the waste through an unsaturated zone, incorporating the effects of sorption, decay, and dispersion during the transit. This feature of the TRANSS code was used to translocate the radionuclides through the vadose zone from the trench bottom to the saturated zone.

The DUST code was also used to calculate radionuclide concentrations in the Facility leachate. These calculations produced radionuclide concentrations comparable to, but less than, the concentrations calculated with TRANSS. These values were not used in the performance analyses but provided a point of validation for the TRANSS code.

Vadose Zone

The vadose zone is represented as a soil column where moisture is always at steady state. Gravity is the only force causing moisture drainage. No changes in soil moisture storage occur within the vadose zone.

Flow in the vadose zone is represented by the equation,

$$q = k * i$$

In this equation, k is the hydraulic conductivity, which is a function of moisture content and the saturated hydraulic conductivity. Because gravity is the only unbalanced force acting on the moisture, the gradient *i* is unity. Van Genuchten's equation[12] was used to calculate unsaturated hydraulic conductivity from measured saturated hydraulic conductivity and the soil moisture characteristics curve. Van Genuchten's equation is,

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[11] Simmons, C. S., and C. T. Kincaid, and A. E. Reisenauer. 1986. A Simplified Model for Radioactive Contaminant Transport: The TRANSS Code. Pacific Northwest Laboratory. PNL-6029.

[12] van Genuchten, M. Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Journal of the Soil Science Society of America. No. 44. p 892-898.

$$K_r(\Theta) = \Theta^{\frac{1}{2}}\left[1-\left(1-\Theta^{\frac{1}{m}}\right)^m\right]^2$$

where:

$K_r(\Theta)$ is the unsaturated hydraulic conductivity relative to the saturated hydraulic conductivity

$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r}$ is the relative volumetric moisture content, and

θ is the ambient moisture content of the soil,

θ_r is the residual moisture content of the soil,

θ_s is the saturated moisture content of the soil,

$m = 1 - \frac{1}{n}$, and

n is a parameter determined from the soil moisture characteristics data.

If the ambient moisture content and the hydraulic conductivity of the vadose zone soils are known, then the percolation through the vadose zone is equal to the hydraulic conductivity at the measured moisture content. This equation was used to estimate average ground-water recharge at the Facility.

The apparent speed of moisture movement in the vadose zone is calculated from the equation

$$v = \frac{q}{\theta}$$

where:

θ is the ambient moisture content of the soil, and

v is the apparent speed of moisture movement.

This equation was solved for the various unsaturated hydraulic conductivity curves calculated from Facility measurements and the average calculated ground-water recharge at the Facility.

The retarding effect of sorption on the movement of dissolved solutes was incorporated using the equation:

$$R_d = 1 + \rho * \frac{k_d}{\theta}$$

In the above equation, R_d is the retardation coefficient. The speed of a dissolved solute is related to the speed of the moisture in which it is dissolved by the equation

$$v_s = \frac{v_w}{R_d}$$

The velocity of the solute is less than the velocity of the water by an amount equal to the retardation coefficient.

Saturated Zone

The conceptual model for flow in the saturated zone below the Facility is steady-state flow of an incompressible fluid in an incompressible soil matrix. Transport of dissolved solutes is by convection and dispersion; transport is inhibited by the first-order sorption reaction described in the previous subsection. The saturated zone was modeled as a streamtube in a constant-thickness aquifer beneath the Facility. Leachate from the vadose zone was introduced beneath the Facility, and allowed to mix with aquifer water.

The geometry of the conceptual model allowed hand-calculation of the transport and mixing in the groundwater of radionuclides from the Facility to a hypothetical well located at the Facility boundary. The concentrations and timing of radionuclides introduced into the groundwater were calculated by the TRANSS code as described above.

Ingestion Model

Ingestion exposure was calculated using the methods of NRC Regulatory Guide 1.109, "Calculation of Annual Doses To Man From Routine Releases of Reactor Effluents For The Purpose Of Evaluating Compliance With 10 CFR Part 50, Appendix I". This model relates potential exposure and habits of people in standard age groups: adults, children, and infants. Potential exposure to persons in these age groups is based upon typical group habits. For example, exposure of infants to contaminants in milk is higher than exposure to children and adults in the same family.

A typical garden scenario, where well water is used as the sole source of drinking and irrigation water for a subsistence family farm, was used as the conceptual model for ingestion. Crops were grown for family consumption, and pasture land was irrigated for grazing of a dairy cow.

Pathway Calculations

Ingestion exposures include those due to the ingestion of contaminated soil, water, or foodstuffs. The ingestion pathway for the Richland Facility is comprised of direct and indirect exposure to contaminated groundwater. Other media that might terminate in ingestion are insignificant at this Facility. Calculations of potential exposure via

ingestion are predicated upon calculations of migration of radionuclides to and in the groundwater. These calculations are presented in Attachment D to this Closure Plan.

The groundwater transport mechanism was analyzed as a series of connected calculations. The output of one calculation became the input to the next (e.g. the influx of leachate from the vadose zone entering the groundwater). A flow chart of this process is presented in Figure 5-2. This process seeks to:

- Identify infiltration rate and calculate travel time through the vadose zone using vadose zone soil parameters (e.g. soil moisture, porosity, unsaturated hydraulic conductivity);
- Identify source term from waste inventory;
- Calculate concentration of radionuclides in leachate at the water table after movement through the vadose zone, while accounting for decay and dispersion;
- Calculate dilution of radionuclides in leachate in the saturated zone at the point of extraction by a ground-water well; and
- Calculate exposure doses to humans via the ingestion pathway, including drinking water and use of water for irrigation of crops and dairy pastures.

Infiltration Rate and Travel Time

The travel time calculation used an infiltration value of 0.2 in/yr. This simulates the estimated natural recharge that occurs at the Facility. The development of this value is based on site-specific data and studies performed in the 200 Area, and is described in Section 2.7.2.1.1, Infiltration and Recharge. The travel time calculation also used an infiltration value of 0.05 in/yr, to simulate the additional decrease in infiltration expected to result from the final cap placement.

Using a vadose zone thickness of 265 feet beneath the trench bottom, the travel time calculation yielded travel times of approximately 1,040 years for an infiltration rate of 0.2 in/yr and 3,575 years for infiltration of 0.05 in/yr (Attachment D, Section 4).

Source Term

A Facility radionuclide inventory was developed which included actual waste receipts through 1993. This inventory included trenches 1, 2, 3, 4, 4A, 4B, 5, 6, 7, 7A, 8, 9A, 9B, 10, 11, 13, 14, 16, and the "Rx Head" trench. For some waste received early in the Facility life, the disposal trench was not recorded or determined. These wastes were assigned to the "Unknown Trench". This inventory is presented in Attachment I.

Projected radionuclide receipts for the years 1994 to 2056 were developed based upon disposal activity received from Northwest Compact generators for the years 1988

through 1993. Source term calculations were performed through 2063 (end of lease) to accommodate closure in 2056.

Current receipts through 1993 and projections for 1994 through 2056 were combined. To determine the total activity for each radionuclide, since each trench does not contain identical wastes, the data were manipulated to allow total radionuclide activity to be summed by trench and by radionuclide. These values were then summed to yield the total source term activity for the Facility by individual radionuclide.

The following assumptions were used in developing the performance assessment source term from the waste inventory:

- Decay is the screening tool selected for use in the pathways analysis.
- A radionuclide with a half-life equal to 10% of the travel time (about 100 years) through the vadose zone is reduced through decay by a factor of 1,000 after the travel time elapses.
- Progeny ingrowth from actinides does not contribute significant doses to the performance assessment. True

A radionuclide was included in the analyses if the total activity or half-life was large enough that the radionuclide might reach the groundwater in measurable concentrations. Analysis of the predicted travel time through the vadose zone yielded a minimum value, based on current conditions and expected recharge, of at least 1,000 years. As a screening rule, the radionuclides to be modeled were selected based on two criteria:

- activity greater than 1 Curie (Ci), and
- half-life in excess of 0.1 times the migration time of water through the vadose zone (about 100 years).

Radioisotopes not meeting these criteria were evaluated individually to determine if the radioisotope should be included because of an unusually long half-life or unusually high dose conversion factor.

The source term for the ingestion pathway analysis is presented in Table 5-1.

Leachate Concentration

The movement of radionuclides from the trenches through the vadose zone is controlled by two release rate mechanisms:

- Solubility controlled (retardation ≅ 0), and

- Sorption (K_d) controlled, where a retardation factor is calculated for each isotope.

The solubility controlled release occurs where the K_d values are relatively low (adsorption is small). The K_d controlled release is an adsorption controlled release rate. The determination of the most appropriate release type was made for each of the radionuclides modeled. Solubility and sorption coefficients were taken from previous pathways analysis performed for the Facility[13], or at other low-level radioactive waste sites in humid regions[14].

The release rate mechanisms affect how each isotope migrates to the groundwater. Solubility-controlled releases are not greatly influenced by the quantity or concentration of the material. The isotope is released at the rate of solubility until the waste is exhausted. Changes in the source term are not expected to cause significant changes in the concentration in the groundwater. However, an increase in waste amount would change how long the radionuclides are released.

Adsorption controlled releases are governed by the concentration of the isotope in the soil versus the concentration in the leachate. Because the adsorption coefficient is the ratio between the concentration in the solid phase versus the concentration in the liquid phase, a change (either increase or decrease) in the source term (concentration in the solid phase) would be expected to yield a like change in the leachate concentration.

The TRANSS code was selected to conservatively estimate leaching rates through the vadose zone for solubility and sorption controlled radionuclides. The TRANSS code models transport as one-dimensional migration along flow lines. The advantage of a one-dimensional analysis is that it requires less information about the physical setting than three-dimensional analytical solutions. However, the user must recognize that the model is a simplification of physical reality, and that the results of the code are dependent on the input parameter values. The TRANSS does not include the delay time for the disintegration of the burial containers.

The TRANSS code yields a curve which indicates the fraction of radionuclide activity remaining in the source at any time. This is discussed in detail in Section 5 of Attachment D. Radioactivity is removed from the source by two mechanisms:

- radioactive decay, and
- activity flux into the system (transport away from source).

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[13] Bergeron, M.P., B.A. Napier, A.E. Reisenauer, and D.R. Sherwood, 1987b, Environmental Pathways Analysis of the US Ecology Low-Level Waste Disposal Facility, Richland, Washington.

[14] Fields et al., 1986, op. cit.; Baes and Sharp, 1983, op. cit.

That portion of the radioactive waste inventory that leaves the trenches is further transported through the vadose zone and into groundwater. TRANSS projects the concentration over time, in pCi/L, for each radionuclide in leachate reaching groundwater. These values are calculated for each radionuclide in the source term. Leachate concentrations entering the saturated zone are listed in Table 5-2.

Mixing and Dilution

Mixing and dilution occur as radionuclides move from the location where they enter the groundwater from the unsaturated zone and travel to a well located on the Facility boundary. The mixing and dilution analysis accounts for the dilution of the radionuclides in leachate by the aquifer and is calculated separately from the TRANSS computations. This, in turn, supports calculating radionuclide concentrations in groundwater at the well over time.

The following assumptions were used in this calculation:

- The hypothetical well screens the uppermost unconfined aquifer (bottom of the Hanford Formation through middle member of the Ringold Formation). The amount of water in the aquifer that is available for dilution is limited.
- Complete and instantaneous mixing of leachate water and aquifer water occurs. Although the aquifer may be up to 100 feet thick, the mechanics of well intake structures in an unconfined aquifer provide necessary mixing action. Thus, even if the leachate is not completely mixed within the aquifer, mixing occurs within the hypothetical well.

Method Summary

The dilution effect is calculated by estimating the amount of water that would be recharged to the aquifer from the leachate, and the amount of water flowing through the aquifer. The calculation assumes groundwater flows along a streamtube and leachate can enter the groundwater along the length of the aquifer underneath the Facility.

Flow through the aquifer is calculated using D'Arcy's Law (discussed in Section 5.5.1.3). The hydraulic conductivity (K) and aquifer thickness (b) values discussed in Section 2.7 of the Facility Closure Plan are K = 100 ft/day and b=100 feet, respectively. These values yield a transmissivity of:

$$T = K*b = (100 \text{ ft/day})(100 \text{ ft}) = 10{,}000 \text{ ft}^2\text{/day}.$$

The gradient at the Facility appears to be relatively uniform. Values are discussed in Section 2.7, and yield a typical value of about 0.003 ft/ft. Effective porosity of the aquifer is estimated to be about 10%. Therefore, the groundwater seepage velocity is,

$$v = \frac{K * i}{n_e} = \frac{(100 ft / day)(0.003 ft / ft)}{0.10}$$

v = 3 ft/day = 1,095 ft/year

This indicates that within 1 years time, a non-sorbing contaminant could travel with the velocity of groundwater to a distance of about 1,095 ft. Radionuclides that have sorption-controlled releases will have slower travel times. The velocity of sorbed radionuclides can be calculated by dividing the groundwater seepage velocity by the retardation factor.

Calculation for Dilution

The infiltration (recharge) is 0.2 in/yr, or 0.017 ft/year (as discussed in Section 2.7).

The amount of recharge is the infiltration amount times the streamtube length, times the width, or

Leachate Recharge = (0.017 ft/year)(1,900 ft)(1 ft) = 31.7 ft^3/year

The aquifer through-flow can be calculated as,

$Q = K*i*A$

where:

K = hydraulic conductivity

i = gradient,

A = cross-sectional area of aquifer or streamtube.

This yields:

Q = (100 ft/day) (365 days/year)(0.003 feet/foot)(1ft)(100ft)

Q = 10,950 ft^3/year

The dilution factor, then, is

D.F. = (31.7)/(10,950) = 0.003.

The dilution factor is multiplied by the leachate values to estimate the concentration of leachate that will enter the well. Details of this calculation are included in Section 6 of Attachment D.

Exposure and Dose

Exposures to body organs are examined using the PRESTO-II computer code[15] for the expected radiological dose, and a weighted sum for the whole body dose. PRESTO-II output includes information on the dose rates to the organs, and calculates the dose rate to each organ as the sum of the modeled radionuclides, or by individual radionuclide. Radionuclides that contribute the predominant dose can be identified from this output.

The PRESTO-II computer code was not used to compute the dose rates for the radionuclides Cl-36 or Nb-94 because these radionuclides are not included in the model's internal database. Dose due to Nb-94 was not calculated, as the concentration at the groundwater well was low (6.85×10^{-12} pCi/l in the worst case). This was considered to be insignificant for this analysis. Dose factors for the ingestion of Cl-36 were taken from Federal Guidance Report No. 11[16], and used in hand calculations for the dose. Since ingestion yielded almost all of the incurred dose in the groundwater pathways analysis, only ingestion was considered for Cl-36. Details of this calculation are included in Section 9 of Attachment D.

5.6.1.1.2 Sensitivity Analysis

Sensitivity analyses on generated exposure and dose calculations consisted of varying the input values for trench cover infiltration rates, soil porosity and saturated zone horizontal hydraulic conductivity.

Infiltration rates of 0.05, 0.2, and 2.0 in/yr were run. The value of 0.05 in/yr reflects the anticipated design performance of the cover. The value 0.2 in/yr represents the infiltration under the condition that the cap is not effective. This value is based on measured infiltration rates of native soils surrounding the Facility. The value of 2.0 in/yr was used only to determine the sensitivity of travel time results to infiltration rate. It specifically does not represent an expected realistic value of infiltration at the Facility,

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[15] Fields, D.E., C.J. Emerson, R.O. Chester, C.A. Little, G. Hiromoto, 1986, PRESTO-II: A Low-Level Waste Environmental Transport and Risk Assessment Code: Oak Ridge National Laboratory, ORNL-5970.

[16] Eckerman, K.F., A.B. Wolbarst, and A.C.B. Richardson, 1988, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion: Federal Guidance Report No. 11, Oak Ridge National Laboratory.

based on recharge studies summarized in Section 2.7. A discussion of the basis for selection of values for infiltration is provided in Section 4 of Appendix D.

Soil porosity values of 0.30 and 0.43 were considered. The value 0.30 is based on expected values for silt, sand, and gravel. The value of 0.43 is a calculated porosity from a repacked sample of site soils obtained during monitoring well installation. Section 5.6.2 of Appendix D provides further discussion of the basis for selection of these values.

The third parameter varied in the sensitivity analysis was horizontal hydraulic conductivity of the unconfined aquifer. Groundwater well concentrations were calculated for hydraulic conductivities of 100 and 1,000 ft/day. The 100 ft/day figure is the value expected to be representative of conditions at the Facility. Use of a 100 ft/day hydraulic conductivity results in less dilution of radionuclides but a longer travel time to the hypothetical well. The 1,000 ft/day figure results in shorter travel time and therefore less radioactive decay than the 100 ft/day value. Selection of these values is also described in detail in Section 6.4.3 of Appendix D.

5.6.1.1.3 Results

Potential exposures were calculated under two infiltration assumptions: 0.2 in/yr and 0.05 in/yr. The dose rates calculated for all cases run were less than the limits prescribed by WAC and the Facility Radioactive Material License. Projected doses are presented in Table 5-3.

For the case where infiltration was equal to 0.2 in/yr, the largest organ dose, 6.90 mrem/yr, was delivered to the thyroid. The principal contributor to the thyroid dose was I-129. This value is roughly 9% of the WAC regulatory limit of 75 mrem/yr for this organ. The next largest calculated organ dose was 4.05 mrem/yr to the lower intestine. This value is approximately 16% of the WAC limit of 25 mrem/yr for this organ. U-238 is the primary contributor to this exposure. The whole body dose for this infiltration rate was 1.17 mrem/yr. This dose rate is approximately 4.7% of the WAC limit of 25 mrem/yr for a total body dose. The principal contributor for the whole body was C-14.

Potential exposures were also calculated for an infiltration rate of 0.05 in/yr through the final closure cap. This calculation assumes that the cap is more effective in limiting infiltration than the natural soil profile, and illustrates the reduction in calculated exposure with a reduction in recharge. The largest organ dose, 1.16 mrem/yr, was delivered to the thyroid. This value is about 1.5% of the WAC regulatory limit of 75 mrem/yr for this organ. The principal contributor for thyroid dose was I-129. The next largest calculated organ dose, 0.73 mrem/yr, is to the lower intestine. U-238 is the primary contributor to this exposure. This value is approximately 2.9% of the WAC limit of 25 mrem/yr to this organ. The whole body dose for this infiltration rate was 0.19 mrem/yr. This dose rate is roughly 0.8% of the WAC limit of 25 mrem/yr for whole body dose. The principal contributor for the whole body was C-14.

All of the calculated radiological exposures for the groundwater pathway are below regulatory limits. Moreover, since the exposure scenario assumes an individual to be exposed to radionuclides in the drinking water, milk, and garden crops irrigated by the well water, the predicted dose to the hypothetical individual is highly conservative. Additional conservative factors in this pathway analysis include: 1) the receptor consumes only crops produced on-site, 2) the transport time through the vadose zone was based on non-sorptive radionuclides; 3) the cap design infiltration rate of 0.05 in/yr and the worst case scenario of 0.2 in/yr infiltration rate for no cap were both used in the dose modeling and yielded doses below regulatory limits; and 4) peak radionuclide concentrations (i.e. the maximum calculated values) were used as input to the dose calculation code.

5.6.1.2 Inhalation Pathway

The agricultural scenario assumes the resident farmer lives on the edge of the Facility. Consequently, doses to a hypothetical individual were calculated for H-3 and C-14 at various distances from the trench cap, beginning at the cap boundary. For the case of radon, comparison is made with ambient environmental radon concentrations, with allowable flux for uranium tailing impoundments, and with the effluent concentration limits in the Washington Administrative Code (WAC).

The evaluations are performed for the year following final closure in 2056. Radioactive decay will serve to reduce doses to individuals due to H-3 in the diffusion pathway after 2056 to levels below those calculated in this evaluation.

5.6.1.2.1 Codes and Discussion

Diffusion of radionuclides is modeled using Fick's Law of Diffusion. The RADON computer code evaluates one-dimensional diffusion in the upward direction only. The methods described in Nuclear Regulatory Commission Regulatory Guide 3.64[17] are used to obtain the activity flux (in pCi m^{-2} s^{-1}) from the trench cap surface. Regulatory Guide 3.64 contains a computer code listing for the "RADON" code that was used in evaluating the Rn-222 activity flux. This code was modified slightly to calculate diffusive flux source terms for H-3 and C-14.

Atmospheric dispersion and dose modeling was performed using the "CAP88PC" (Clean Air Act Assessment Package-1988) computer code and the diffusive flux source terms to calculate exposures to a hypothetical individual at various distances from the Facility trench cap. The CAP88PC code utilizes Gaussian plume modeling techniques and applies dose conversion factors to the results of the plume model to obtain dose estimates. CAP88PC input includes population and weather data.

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[17] Nuclear Regulatory Commission (NRC), 1989, Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers, Regulatory Guide 3.64.

For the trench cap diffusion cases outlined here, the trench cap area is modeled as a circular area over all closed trenches. The maximum exposed individual is assumed to be located at the edge of the trench cap. The individual is assumed to reside in the area and perform normal rural activities including farming and ingestion of vegetables grown near the Facility.

CAP88PC computes radionuclide concentrations in air, rates of deposition on soil and vegetation, concentrations in food, and intake rates to individuals from inhalation of air and ingestion of food produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, and milk consumed by humans are made by coupling the output of the atmospheric transport model with the NRC Regulatory Guide 1.109 "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I" terrestrial food chain models.

In the case of radon, the daughter products from decay are not included in calculations of dose. Radon is compared with normal environmental levels, with regulatory flux limits for uranium mill tailings impoundments, and with effluent concentration limits for licensees.

The assumptions and parameters used in the computer code runs, and calculated results, are presented below. Projected values were used in calculations when necessary to incorporate assumptions regarding future disposal activities.

RADON MODEL PARAMETERS

Layer Thickness

The thickness of the waste is equivalent to the trench depth minus the thickness of the layer of backfill between the top of the waste and Facility grade. Different trenches at Richland have different depths and thickness of waste and backfill. An average waste thickness for the Facility was obtained by multiplying the waste thickness in each trench times the waste volume disposed. This calculation weighted the waste thickness in each trench according to the volume of waste disposed. The average waste thickness at Facility closure was estimated to be 34.6 feet (10.6 m).

For purposes of these diffusion calculations, the backfill between the top layer of waste and grade, and the trench cap, will be modeled as a single layer consisting of Facility soils. Each trench will have at least 8 feet (2.4 m) of backfill soil and a trench cap with a thickness of 8.3 feet (2.5 m). It should be noted that the thickness of the layers discussed above, and through this plan, are minimum values. At construction, the layer thicknesses as placed will be at or above the minimum specified, resulting in a total thickness of the cap and backfill of at least 5 m (16.4 ft).

Layer Densities, Specific Gravities, and Porosities

An average trench density was determined by averaging the actual or projected waste and backfill densities. Each trench was assigned an average waste density based upon year of closure and calculations performed for calendar years 1982, 1983, and 1988 through 1993. Wastes disposed prior to 1982 were assigned an average density of 25 lb/ft^3 (0.4 g/cm^3) based on an estimated density range of 20 to 30 lb/ft^3 (0.3 to 0.5 g/cm^3). Trenches 11 and 13 were assigned closure years of 1985 and 1991, respectively, since essentially all trench volume was utilized by those dates. Backfill density of 94 lb/ft^3 (1.5 g/cm^3) was assumed for the applicable fraction in each trench not utilized for waste burial. Volume averaging was performed to obtain effective (average) trench densities for each trench and for the Facility as a whole. The average Facility density for all disposal trenches, at time of Facility closure, was estimated as 79 lb/ft^3 (1.26 g/cm^3)(Table 2-2, Section 2 of Attachment D)

The porosity of materials buried in the trenches was assumed to be 40 percent. This value could not be confirmed but is thought to be reasonable based upon the fraction of material in the trenches comprised of Facility soils (with a porosity of 44 percent) and the compacted nature of much of the waste. The specific gravity of the trench disposal area is calculated as 2.1 using the above parameters.

A value of 1.5 g/cm^3 was chosen as a reasonable estimate for the dry bulk mass density of the backfill, cover, and cap material. An average porosity of 0.44 was chosen for the cover and cap soils for this analysis. The specific gravity of the cover was assigned a value of 2.68 based upon calculations using the density of 1.5 and a porosity of 0.44.

The RADON computer code output shows the specific gravity of cover and waste as 2.65. This value is not used in code calculations when the values for density and porosity are input by the user, as was the case for the calculations to follow.

Long Term Average Moisture

The moisture content of soils near the Facility ranged between five and six percent by volume at 200 Area lysimeters[18]. The value used in these analyses was 5.5 percent. This value is below the wilting point and is conservative, and also is the lower bound for measurements performed at the 200 Area lysimeters.

It is assumed that the long-term average moisture content of buried waste will be the same as in the surrounding soils. Therefore, w_{waste} and w_{cover} are calculated as 3.4 and 3.7, respectively, since the density of water (ρ_{water}) is equal to 1.

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[18] Bergeron, M.P., B.A. Napier, A.E. Reisenaur, and D.R. Sherwood, 1987a, op. cit.

Radionuclide Concentrations

The projected source term activities of Ra-226 and C-14 at closure are 207,623 mCi and 3,880,700 mCi, respectively. Average Facility source term concentrations for each radionuclide were calculated by dividing the Facility activity by the total mass of waste and backfill.

Total Backfill and Waste Mass = 50,604,765 ft^3 x 28,317 cm^3/ft^3 x 1.26 g/cm^3
= 1.8×10^{12} grams

Using this mass the Facility average source term concentrations are 115 pCi/g for Ra-226 and 2,150 pCi/g for C-14.

The projected source term activity for H-3 at closure was calculated to be 1.26×10^7 mCi by summing the activity in each trench and adding future disposal projections. For purposes of calculating the impact of H-3 decay, Trench 11 was assumed to have been closed in 1985 and Trench 13 in 1991. This is based on the small quantity of wastes placed in each of these trenches since those dates and the small remaining available volume in each trench. In addition, no credit for radioactive decay was taken for trench closures subsequent to Trench 16, or for wastes disposed prior to the actual date of trench closure. Therefore, the calculated Facility inventory of H-3 at closure is considered to be conservative. The Facility average concentration of H-3 at closure in 2056 was calculated as 7×10^3 pCi/g.

Diffusion Coefficients

Measurements for diffusion coefficients are not available for Rn-222, H-3, and C-14 at the Richland Facility. Therefore, Regulatory Guide 3.64 methodology was used to obtain a conservative estimate of the radon diffusion coefficients in waste and cap/cover materials.

The radon diffusion coefficient is related to the moisture saturation fraction and the porosity as described by equation 7 in Section 1.1.5 of RG 3.64. The diffusion coefficients in waste and cap/cover are calculated to be 0.049 cm^2s^{-1} and 0.047 cm^2s^{-1}, respectively.

Diffusion coefficients for H-3 in soils, agar gel, and glass beads were evaluated by Nakayama and Jackson[19]. They reported diffusion coefficients of tritiated water in Pachappa loam at moisture contents ranging from several percent up to approximately 40 percent by volume. The diffusion coefficient was almost constant in the water content region between 10 and 40 percent by volume. A maximum diffusion coefficient

[19] Nakayama, F.S. and R.D. Jackson, 1963, Diffusion of Tritiated Water in Soils, Soil Sci Soc. Am. Proc. Vol. 27, No. 3, p. 255.

of 4.16×10^{-5} cm^2s^{-1} was observed at about 4% water content. Diffusion coefficients decreased for water contents above and below 4% by volume.

Site soils have been previously reported to contain approximately 5.5% water by volume. Based upon this information and the research of Nakayama and Jackson, the diffusion coefficient for H-3 is estimated to be 3×10^{-5} cm^2s^{-1}.

The diffusion coefficient for C-14 was calculated using a relationship between the diffusion coefficient in soil and the diffusion coefficient in air as described by Penman[20]. The soil and air diffusion coefficients are taken to be proportional to the porosity of the soil. Penman performed experiments showing that when the number of air filled pores surrounded by water is negligible, then the soil/air diffusion coefficient ratio can be approximated as 0.66 times the porosity.

A conservative assumption that all C-14 is in the form of gaseous CO_2 was made. In reality, much of the C-14 will be fixed onto surfaces or otherwise bound into the waste matrix. The CRC Handbook of Chemistry and Physics[21] gives the coefficient of diffusion for CO_2 gas into air at 0°C as 0.139 cm^2s^{-1}. Penman also used this value, stating that it is a mean of the values taken from standard works of reference. The reference values ranged from 0.134 to 0.142 cm^2s^{-1}. Using the ratio previously described results in calculated soil diffusion coefficients for $^{14}CO_2$ in waste and cap/cover materials of 3.7×10^{-2} cm^2s^{-1} and 4.0×10^{-2} cm^2s^{-1} (both at 0 °C). Correction for temperature effects to an assumed average ground temperature of 12 °C results in calculated diffusion coefficients for $^{14}CO_2$ of 4×10^{-2} cm^2s^{-1} and 4.4×10^{-2} cm^2s^{-1} for waste and cap/cover materials, respectively.

Emanation Coefficients

Regulatory Guide 3.64 defines the radon emanation coefficient as "the fraction of radon that is released from the tailings or soil matrix into the pore space." The NRC uses a reference value of 0.35 for all materials. No references to specific emanation coefficients were found for H-3 or C-14 in the literature. The NRC reference value of 0.35 was used for all isotopes in this investigation. The NRC reference value for the emanation coefficient is larger than most measured coefficients.

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[20] Penman, H.L. 1940, Gas and Vapor Movements in the Soil I. The Diffusion of Vapors through Porous Solids", J.Agr. Sci, Vol 30, No. 3, p. 437-462.

Penman, H.L. 1940, Gas and Vapor Movements in the Soil II. The Diffusion of Carbon Dioxide through Porous Solids", J.Agr. Sci, Vol 30, No. 4, p. 570-581.

[21] Chemical Rubber Company, Handbook of Chemistry and Physics, 57th edition, p. F-62.

Other Fundamental Parameters

Values for the decay constants are based upon the half-life of the radionuclides. The RADON computer code was modified to incorporate the necessary changes.

The equilibrium distribution coefficient used for radon between water and air was 0.26 pCi/cm^3 water per pCi/cm^3 air, as referenced in RG 3.64. This value was also used for CO_2. Sepall and Mason[22] studied the ratio of tritium and hydrogen in vapor and liquid phases at different temperatures and reported it as varying from 0.86 at 0 °C to 0.97 at 90 °C. Since this evaluation is for diffusion in soils, a temperature of approximately 12 to 15 °C is appropriate. Sepall and Mason[23] measured the vapor to liquid partition coefficient for tritiated water as 0.90 at 14 °C. The liquid to vapor ratio is the inverse of this value. Therefore, an equilibrium distribution coefficient of 1.1 was used in the evaluation of H-3 flux.

Results of the Diffusion Calculations

The fluxes penetrating the trench cap were calculated to be approximately 6.3, 0.17, and 0.038 pCi m^{-2}s^{-1} for Rn-222, H-3, and C-14, respectively.

CAP88PC PARAMETERS

Some manipulation of the output source term from the RADON code was necessary in order to obtain a source term for input into the CAP88PC code. The following sections discuss assumptions and methods used in generating the dose estimates for individuals, results of the CAP88PC computer code, and comparison of radon effluents from the diffusion pathway.

Source Term

Source terms for H-3, C-14, and Rn-222 in terms of total curies penetrating the trench cap per year were estimated by multiplying the activity flux (pCi m^{-2}s^{-1}) times the area of the trenches (1.912x10^6 ft^2) and various conversion factors to obtain the emission rate in Ci per year. The source terms for H-3, C-14, and Rn-222 were calculated as 0.97, 0.21, and 35.3 Ci per year, respectively.

---

[22] Sepall, O. and S.G. Mason, 1961, Vapor/Liquid Partition of Tritium in Tritiated Water: Can. J. Chem., Vol. 23, p. 2024

[23] Sepall and Mason, 1961, op. cit.

Meteorological and Agricultural Data

Weather data were based upon information generated at Hanford 200 Area meteorological stations. Since there is no mechanical force driving the emission, the plume rise was assumed to be zero.

CAP88PC default food array data were used in estimating exposure to the individual from ingestion of contaminated food items. The default food array identifies the amount and type of food ingested to calculate exposure.

5.6.1.2.3 Sensitivity Analysis

The sensitivity analysis for the inhalation pathway consisted of running the dose projections at a number of downwind distances from the center of the trench cover. The trench cap and area of emission was modeled as a circular area. The area of the trench cap is projected to be 3.64×10^6 ft^2, consequently the radius for the modeled trench cap is estimated to be 330 meters (roughly 1,080 feet). The 330 meter distance represents the distance to an individual situated at the edge of the trench cap and was used as the base case for dose projections. Air concentrations and doses to an individual were calculated at distances of 330, 500, 1000, 2000, 5000, and 10,000 meters from the trench cap center.

5.6.1.2.4 Results

Calculated Atmospheric Exposure

The calculated combined total effective dose equivalent from H-3 and C-14 is 5.2×10^{-2} mrem/yr. The location of the maximally exposed individual is shown to be 330 meters in the ESE direction. CAP88PC also calculated a lifetime fatal cancer risk of 1.3×10^{-6}. The dose and risk due to the diffusion of H-3 and C-14 are thus insignificant based upon this assessment. The maximum organ dose due to H-3 and C-14, combined, was 0.2 mrem/year to the endosteal tissue. Again, this dose is insignificant in terms of the allowable dose limit (25 mrem/yr) and doses to individuals from natural background.

Radon Emissions

Radon flux from the cap surface was calculated to be 6.3 pCi $m^{-2}s^{-1}$. Washington Administrative Code (WAC) 402 requires that earthen covers over uranium tailing piles limit atmospheric releases to an average release rate of 20 pCi $m^{-2}s^{-1}$. While the referenced regulations are not specifically applicable to the LLRW disposal Facility, they are indicative of acceptable limits applied to other facilities. The calculated emission from the Facility is below the 20 pCi $m^{-2}s^{-1}$ criterion by a factor of approximately three.

The calculated radon-222 concentration at the most elevated location evaluated in the CAP88PC scenario (330 meters ESE) was 3.2×10^{-2} E-02 pCi/L. This concentration is approximately 20 times less than reported values for ambient radon concentration due

to natural emissions from earthen materials of 0.15 pCi/L (150 pCi/m^3)as reported by NCRP Report No. 45 and is more than two orders of magnitude less than the EPA guidance for radon in homes (4 pCi/L). Comparison can also be made with the effluent concentration in Table 2 of WAC-402 "Standards for Protection Against Radiation," which is 1 E^{-8} μCi/mL (10 pCi/L) for Rn-222 with daughters removed. The concentration at the maximally exposed individual location (330 meters ESE) is 0.32 percent of the effluent concentration limit.

5.6.2 Construction Scenario Modeling

The construction scenario considers and evaluates exposure to workers directly on top of the closed trenches and waste. The two pathways of interest for this scenario include direct gamma exposure and inhalation. The receptor is assumed to be working on top of the closed trenches, and digging into the trench cover a maximum of eight feet to construct a basement.

The inhalation pathway is considered in detail in the Residential (Basement) scenario and is not discussed in this scenario. The ingestion pathway is not considered to be a component of dose received since it is assumed that workers will not consume crops grown on the site nor will they drink water produced from an on-site well. Also, the cover material is considered clean material and not a source of exposure to the workers as they dig.

5.6.2.1 Direct Gamma Exposure Pathway

An intruder could be exposed to direct gamma radiation from the waste material buried in the trenches below the cap and backfill material. For this analysis, consideration is given to four potential scenarios:

1. At closure, a Facility operator/maintenance person may receive direct exposure while standing directly over the trench;

2. After closure, a person standing at the Facility boundary may receive direct exposure from a capped trench;

3. At some future date after closure, an inadvertent intruder may receive direct exposure by standing over a trench; or

4. An intruder could be exposed to direct radiation as a result of constructing and occupying a dwelling over a trench.

The Facility is located in the area identified as the Central Plateau. The findings of the Hanford Future Site Uses Working Group has identified this area as the location for waste storage from cleanup activities from the rest of the Hanford Reservation. Consequently, the Central Plateau, including the Facility, will have restricted access as a result of other larger scale disposal activities.

The direct exposure via a basement construction scenario in the trench cover could be eliminated as a result of the assumption of institutional control exercised outside of the Facility. The limiting case of the three remaining scenarios would be the first scenario, in which a Facility operator/maintenance person received direct exposure while standing over a closed trench at time of closure.

A sensitivity analysis to evaluate potential exposures was run to determine the effect of decreasing the trench cap thickness from 16 feet to 0 feet in two foot thick increments. This sensitivity analysis allows estimation of the radiological impact if institutional controls were lost and the cover was removed or a basement was constructed.

The conceptual model for this pathway considers the radiation source to be a large solid mass, since the source is the waste in the burial trenches. The receptor is assumed to be standing on top of the trench cap, which serves as a shield to direct radiation. This pathway was evaluated using the MicroShield computer code. The analysis performed for the Facility was undertaken to provide conservative radiological impacts to a hypothetical maximally exposed individual. The assumptions and data are conservative for the conditions at the Facility.

5.6.2.1.1 Codes and Discussion

The direct exposure pathway calculations were run using the MicroShield computer code. The Facility was modeled as a cylindrical volume with end shields geometry. In this geometry, the waste is isolated by a series of horizontal shields.

The cap area is 3.64×10^6 square feet (rectangular shape). The radius of an equivalent circular area is estimated to be 1,075 feet.

The following assumptions were used for modeling the direct exposure pathway for the Richland Facility:

1. A maximum trench depth of about 50 feet below ground surface was used in the modeling. A trench depth of 50 feet and a soil layer of 8 feet yields a source height of 42 feet.

2. The present and proposed future radioactive waste trenches are modeled as one large trench.

3. The waste from the present and future trenches is homogeneously distributed in this trench. This assumption is extremely conservative because the waste is not homogeneously distributed. In actuality, waste packages emitting higher radiation fields are disposed at the bottom of the trench. This results in greater shielding for higher dose rate packages.

4. The engineered cover is a minimum 8.3 feet thick. During cap construction, additional site soils will be placed between the cover and the

waste such that the total thickness of cover and fill is at least 16.4 feet above waste after the final cap is constructed.

5. The radioactivity inventory of waste disposed up through 1993 was combined with projected waste receipts for 1994 through 2056 to estimate the source. The effect of radioactive decay of waste received prior to 1994 was ignored as a conservative simplifying assumption. Sensitivity analyses were performed for several decay times following site closure to examine the effects of the in-growth of daughter products.

6. The radiation exposure to an individual is based on a Facility operator/maintenance person who is standing on the trench cap in the center of the Facility. An hourly dose rate was calculated.

7. The trench caps will be maintained such that major soil erosion is repaired. Because of the trench cover design, site location and soil conditions, the soil erosion potential is minimal.

The following data was used in the analysis of the direct exposure pathway.

1. Soil used for trench backfill and trench cap material is SiO_2 (sand) with a density of 100 lb/ft^3 (1.6 g/cm^3).

2. The density of waste is also 100 lb/ft^3 (1.6 g/cm^3).

3. The source term activity (summed over the 15 isotopes with the greatest activity) is about 2 million Ci. This is approximately 96% of the total waste inventory at the time of closure. Progeny in-growth was examined for waste decay times of 4 hours, 1 year and 10 years.

4. The trench cap, including fill material, is a minimum of 16.4 feet thick above the waste.

It should be noted that the minimum thickness of cover and fill material above waste is 16.4 ft. Additional fill material (1 to 10 ft) is placed above most trenches as backfill and to prepare the site for the final cover material. This additional material was not considered in the direct dose calculation, as its depth varies across the Facility. This is an additional conservative factor in the calculation.

The computer code requires the shield and source material be defined. The code contains attenuation information for concrete and several other materials. The material for both the shield and source was assumed to be concrete with a typical soil density of 100 lb/ft^3 (1.6 g/cm^3).

5.6.2.1.2 Sensitivity Analysis

The base model was run for a reference value of 16.3 feet of shield material with a decay time of zero. Sensitivity analyses were performed to consider the effects of varying shield thickness and source decay. The shield thickness sensitivity analysis was performed for values of 0 feet to 16 feet in 2 foot increments. This analysis examines the results of possible cap removal as could occur under the conditions of basement construction on the Facility.

The decay sensitivity analysis considers the effect of source decay over time. The base case assumes a decay time of 0 years. This is a very conservative assumption in that closure and stabilization is expected to be completed in the year 2063 with the majority of waste received in the early portion of the Facility's life. Cases run included decay times of 4 hours, 1 year, and 10 years. The 4 hour case was run to examine the effect of in-growth of daughter radionuclides which are not present in the inventory in the decay = 0 case.

A density sensitivity analysis considers the effect of cover and waste density. The cover density was reduced to 94 lb/ft^3 (1.5 g/cm^3) and the waste density was reduced to 79 lb/ft^3 (1.26 g/cm^3) to match the density values used in the inhalation pathway analysis radon modeling.

5.6.2.1.3 Results

The base case run for the direct exposure model was for a trench cap thickness of 16.3 feet with a source decay time of 0 years. The results of this case project the dose rate to an individual standing over the intact trench cap as 1.46×10^{-15} mrad/hr (3.49×10^{-14} mrad/day). This value is insignificant in comparison to the minimum average gamma exposure rate for the Hanford Reservation 200 Area of 0.30 mR/day[24].

Table 5-4 provides a summary of the results from cases run with various decay times and cap thicknesses. It can be seen from this analysis that even with a decay time of zero, removing up to ten feet of soil from the cap (i.e. basement construction) will result in a dose rate of less than 2.37×10^{-5} mrad/hour. This is equivalent to 0.2 mrad per year assuming a 24 hour per day/365 day per year exposure.

There is no impact on dose rates from increasing decay time from 0 to 4 hours for all cap thicknesses except 0 and 2 feet. The 2 foot cap thickness dose rate increases from 0.601 to 0.605 mrad/hr while the dose rate for a 0 foot cap thickness increases from 162 to 168 mrad/hr. The magnitude of these changes is not significant.

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[24] 1994 Hanford Site Environmental Report

The density sensitvity analysis indicated a slight increase in dose to an individual standing over the intact trench cap as 2.88×10^{-15} mrad/hr (6.91×10^{-14} mrad/day). The change in dose rates is not significant.

Base case and sensitivity analyses results clearly indicate the direct exposure pathway contributes negligible exposure.

5.6.3 Residential (Basement) Model

Since the resident farmer is assumed to live at the edge of the Facility, an additional Residential or Basement scenario was developed to consider the radiological impacts that may result from construction of a residence directly over (or into) the trench cap.

In this scenario an individual is assumed to intrude onto the closed Facility, construct a residence over the trenches and excavate a basement into the trench cover. This individual is then assumed to live in the basement.

Since the Facility is located on the Central Plateau of the Hanford Reservation, and the Hanford Future Site Uses Working Group has identified this area as the location for waste storage from cleanup activities from the rest of the Hanford Reservation, it is likely that institutional control will be exercised outside of the Facility. Consequently, construction of a residence on the waste disposal site is a highly unlikely event.

5.6.3.1 Combined Ingestion, Dust Inhalation and Direct Exposure Pathway

The principal exposure mechanism for this scenario is radon inhalation. All other mechanisms were combined into one dose analysis reflecting soil ingestion, dust inhalation and external gamma radiation dose.

5.6.3.1.1 Codes and Discussion

The combined pathway for soil ingestion, dust inhalation, and external gamma radiation were analyzed using the RESRAD computer code[25]. The RESRAD code was selected because it is an industry standard code which includes a basement scenario. Doses were calculated over a 1,000-year period following a 100-year institutional control period. The physical properties of the Facility were input to the RESRAD code. This analysis was presented to the WDOH in a previous submittal, but is attached to the Closure Plan in Attachment D.

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[25] Yu, C., Zielen, A.J., Cheng, J.-J., Yuan, Y.C., Jones, L.G., LePoire, D.J., Wang, Y.Y., Loureiro, C.O., Gnanapragasam, E., Faillace, E., Wallo III, A., Williams, W.A., and Peterson, H., 1993, Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0, Argonne National Laboratory, Argonne, Illinois.

5.6.3.1.2 Results

The dose calculated using the RESRAD code for soil ingestion, dust inhalation, and external radiation pathways yielded a maximum dose of approximately $7x10^{-13}$ mrem/year over the 1,000-year period. This value is consistent with the calculated value for the direct radiation pathway on top of the cap in the construction scenario.

5.6.3.2 Inhalation (Radon) Pathway

The inhalation pathway was analyzed separately from other pathways and was evaluated against radon flux standards applied to Uranium Mill Closures.

5.6.3.2.1 Codes and Discussion

The basement scenario for radon was modeled using a two-step process. First, the in-growth of daughter products was calculated for the uranium chain from U-238 to Ra-226 throughout the 1,000-year evaluation period. The decay process was assumed to start at the end of the institutional control period at the closure of the Facility. The concentration of Ra-226 was calculated by dividing the Ra-226 activity by the waste mass value. A Ra-226 concentration of 115.3 pCi/g was calculated from the waste inventory. A similar calculation was made considering Ra-226 ingrowth from the decay of U-238 and its daughters at the end of the 1,000 year period described above. This yielded a concentration of 113.4 pCi/g.

The radon flux source through the excavated cover was calculated at the beginning of the 1,000 year period using the calculated Ra-226 concentrations described in the previous paragraph. The flux was calculated using the RADON program. The basement was assumed to be constructed at the top of the bentonite layer in the cover design. The cover thickness beneath the building was calculated to be eight feet of site soils above the waste and one foot of bentonite. Facility data for moisture contents and density values for the soils were used in the RADON program. Additional details of this calculation are presented in Attachment D.

5.6.3.4 Results

The flux into the basement was calculated for the beginning of the evaluation period (0 years) and the end of the evaluation period (1,000 years). The flux was 3.08 pCi/m^2s for the beginning of the evaluation period and 3.03 pCi/m^2s for the end of the evaluation period. This value can be compared to the WAC 402 that requires that earthen covers over uranium tailings limit radon flux to 20 pCi/m^2s.

5.7 CONCLUSION

Pathways analysis and dose modeling have been completed in support of the US Ecology Richland Facility Closure Plan. This evaluation was performed to identify

potential exposures to humans and to ascertain if the performance objectives for a low-level radioactive waste disposal Facility are met (License Condition No. 66).

The dose analysis examined the possible release of radionuclides from subsurface wastes disposed presently and from projected future operations. Potential pathways that were examined for this analysis included ingestion, direct exposure, and inhalation. Only the groundwater portion of the ingestion pathway was determined to be a significant mechanism for transport of waste constituents to the environment.

The results of dose modeling for a hypothetical individual as described above for an infiltration rate of 0.05 in/yr indicate that the maximum calculated dose is 1.16 mrem/yr to the thyroid. This represents a value of about 1.5 percent of the WAC limit. The next largest organ dose, 0.73 mrem/yr to the lower intestine, represents about 2.9 percent of the WAC performance objective. A maximum total body dose of 0.19 mrem/year represents about 0.8 percent of the WAC performance objective. The dose modeling performed was conservative, and the analysis indicates that the performance objective is being met.

TABLE 5-1

RADIONUCLIDE SOURCE TERM

Isotope	Half-Life (years)	Activity (Curies) [1]
Am-241	458	464.3
C-14	5.73E+03	3880.7
Cl-36	3.08E+05	34.5
I-129	1.70E+07	5.77
K-40	1.26E-09	4.7
Nb-94	2.00E+04	0.94
Ni-59	8.00E+04	187.91
Ni-63	92	35,426.5
Pu-238	86.4	11,442.99
Pu-239	2.44E+04	12,945.7
Pu-242	3.79E5	240.48
Ra-226	1.60E+03	207.6
Sr-90	27.7	35,334.4
Tc-99	2.12E+05	65.6
Th-232	1.41E+10	636.5
U-238	4.51E+09	10,938.24

Notes

Pu-239 includes Pu-239 and Pu-240 isotopes

U-238 includes U-233, U-234, U-235, U-238, U-depleted, U-natural, U-unknown

Thorium contains Th-229, Th-230, Th-232 and Th-natural and Hf-181

(1) Includes activity through 1993 and predicted future activity (1994-2063)

TABLE 5-2
LEACHATE CONCENTRATION

Isotope	Leachate Control	Leachate Conc. (pCi/L)* Infiltration = 0.2 in/yr Depth to GW = 265 ft Theta= 0.30 RICH1.DAT	Leachate Conc. (pCi/L)* Infiltration = 0.05 in/yr Depth to GW = 265 ft Theta= 0.30 RICH2.DAT
Am-241	Kd	7.2904E-120	1.07041E-121
C-14	Solubility	13,515.1	8,904.65
Cl-36	Solubility	16.9191	14.4275
I-129	Solubility	16.8499	14.4718
K-40	Solubility	22.7167	19.0128
Nb-94	Kd	6.85361E-12	1.64673E-13
Ni-59	Kd	0.211916	0.0161502
Ni-63	Kd	9.10708E-92	1.35750E-93
Pu-238	Kd	1.09453E-79	1.64522E-81
Pu-239	Kd	3.57054	0.197315
Pu-242	Kd	40.7807	15.7687
Ra-226	Kd	3.11091E-31	5.24996E-33
Sr-90	Kd	8.01797E-10	1.91827E-35
Tc-99	Solubility	8251.5	4763.6
Th-232	Kd	373.686	295.853
U-238	Solubility	852.955	731.697

*Peak concentration for each isotope.

TABLE 5-3
DOSE SUMMARY

Ingestion Pathway

Infiltration = 0.2 in/yr

Organ	Dose Rate (millirem/year)	WAC Limit (millirem/year)	Dominant Radionuclide	Percent of Total Radiological Exposure
Whole Body	1.17*	25	C-14	52
Critical Dose (Bone Surface)	4.05	25	U-238	68
Thyroid	6.90	75	I-129	49

Infiltration = 0.05 in/yr

Organ	Dose Rate (millirem/year)	WAC Limit (millirem/year)	Dominant Radionuclide	Percent of Total Radiological Exposure
Whole Body	0.19	25	C-14	50
Critical Dose (Lower Intestine)	0.73	25	U-238	75
Thyroid	1.16	75	I-129	58

Notes:

* Calculated Cl-36 dose contributes about 0.05 mrem/yr to the whole body. This value would increase the whole body dose to 1.22 mrem/yr.

For maximum concentration (recharge = 0.2 in/yr) peak occurs at:
11,000 years for U-238 and C-14
5,000 years for I-129

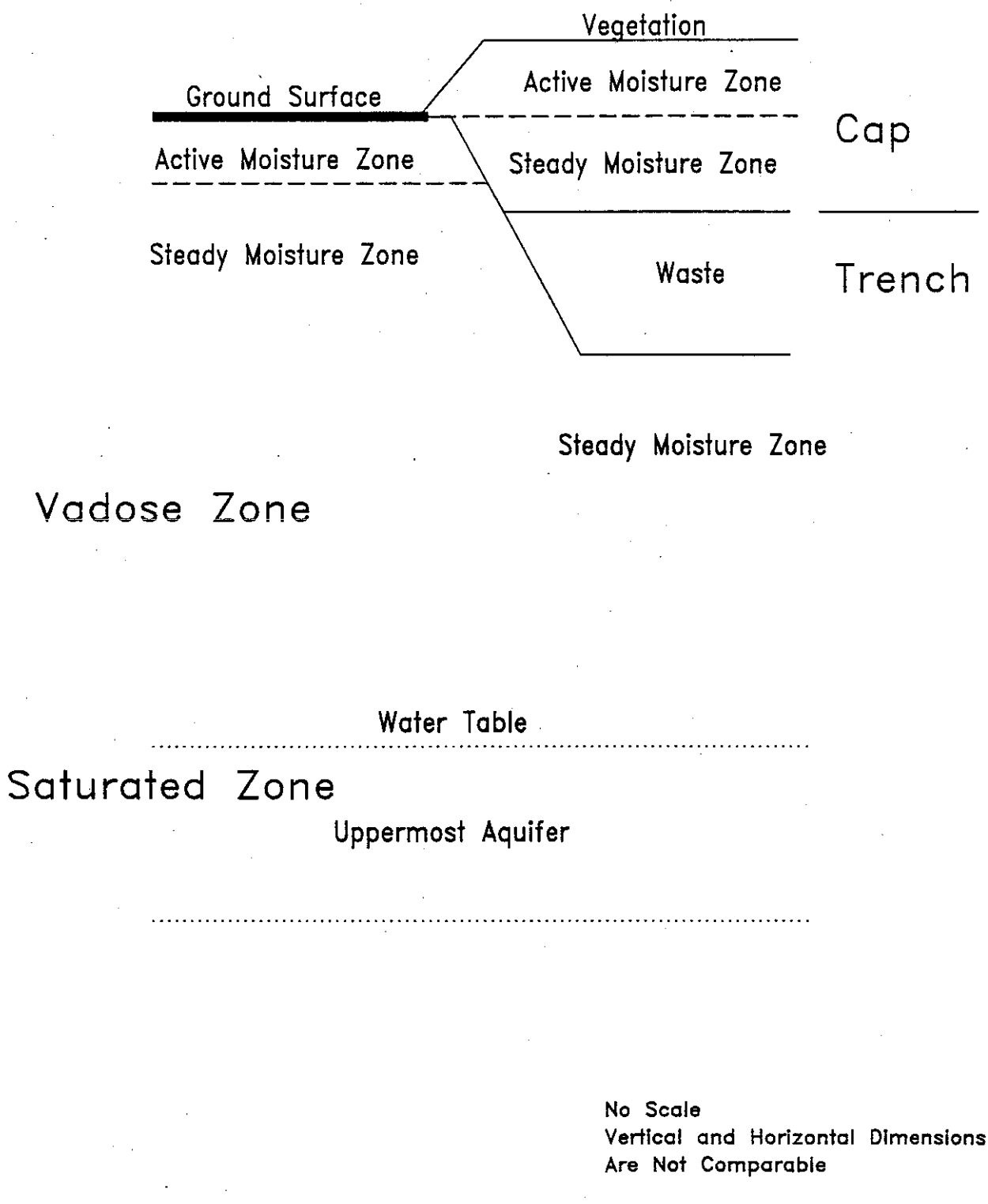
TABLE 5.3 (CONTINUED)
DOSE SUMMARY

Pathway	**Dose**
Direct Exposure	6.92×10^{-14} mrad/day
Gaseous Exposure	
C-14 and H-3 (combined)	5.2×10^{-02} mrem per year
Rn-222	6.3 pCi $m^{-2}s^{-1}$
Radon Exposure (Basement Scenario)	3.08 pCi $m^{-2}s^{-1}$

TABLE 5.4
DOSE RATE IN AIR ABOVE CLOSED TRENCHES

(mRad/hr)

Cap Thickness	Decay Time			
	0	4 hrs	1 yr	10 yrs
16.3 ft	1.46 E-16	1.46 E-16	1.28 E-16	3.92 E-17
16.0	3.10 E-16	3.10 E-16	2.72 E-16	8.32 E-17
14.0	4.71 E-14	4.71 E-14	4.13 E-14	1.26 E-14
12.0	7.10 E-12	7.10 E-12	6.22 E-12	1.91 E-12
10.0	1.07 E-9	1.07 E-9	9.33 E-10	2.86 E-10
8.0	1.59 E-7	1.59 E-7	1.39 E-7	4.25 E-8
6.0	2.37 E-5	2.37 E-5	2.08 E-5	6.35 E-6
4.0	3.63 E-3	3.63 E-3	3.17 E-3	9.70 E-4
2.0	6.01 E-1	6.05 E-1	5.26 E-1	1.61 E-1
0.0	1.62 E 2	1.68 E2	1.45 E 2	4.64 E 1



5018

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FIGURE 5-1

SCHEMATIC OF HYDROLOGIC MODEL

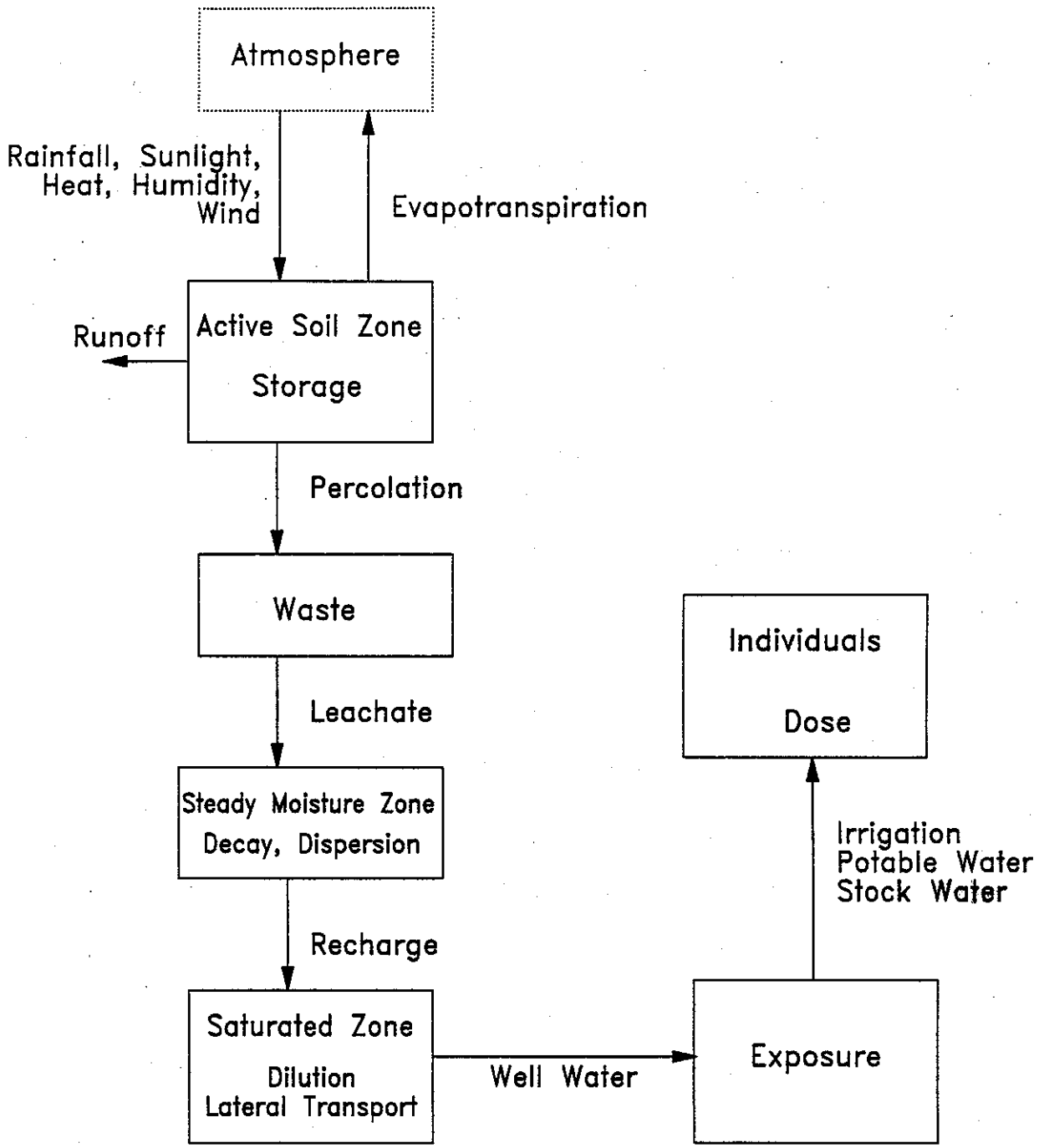

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FIGURE 5-2

FLOW DIAGRAM OF HYDROLOGIC MODEL

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6. FACILITY CLOSURE, STABILIZATION AND PERPETUAL CARE AND MAINTENANCE COSTS

6.1 GENERAL

Costs associated with facility closure, stabilization, and perpetual care and maintenance are compiled in this section. The costs include placement of the final cap over Trenches 1 through 6 (Trenches 1-6) and the Chemical Trench in the near future, and closure of the entire site at both scheduled or unscheduled time frames. The cost for placing the cap over Trenches 1-6 and the Chemical Trench (herein referred to as the partial cap) is projected to begin in 1996 if the State approves closure funds for expenditure. Final closure is anticipated to begin in 2056, with the closure and stabilization periods ending in 2063 when the primary lease expires between Department of Energy (DOE) and the State. Costs associated with an unscheduled site closure on December 31, 1996, are also included.

To determine the costs associated with closure, it is assumed that disposal volumes will average about 100,000 cubic feet per year from 1996 to the end of the remaining prime lease. This average is based upon US Ecology's estimate and includes projections from generators presently utilizing the site. The continuing decline in volume is due to the Facility only being allowed to receive LLRW waste originating in the Northwest and Rocky Mountain compacts, and a reduced amount of NORM waste allowed by the State. Based upon this reduced waste volume projection, Trench 20 should be the last trench required to be constructed prior to site closure in 2056. The costs for construction of future trenches are not included in the closure estimates as these costs are operating expenses. At scheduled closure, the licensed facility would still have space for up to eleven additional trenches (at varying sizes) available to fill the site to capacity closure. However, this condition (i.e. capacity closure) is not addressed in this Plan.

The total waste volume to be added to the site by scheduled closure is projected to be:

$$61 \text{ years} \times 100{,}000 \text{ ft}^3/\text{year} = 6{,}100{,}000 \text{ ft}^3$$

This waste volume projection should be handled by trenches through Trench 20. The site is presently operating in Trenches 16 and 18. Also, a small amount of space is still remaining in Trenches 11B and 14. Trenches 12 and 15 have yet to be constructed, along with Trenches 17, 19, and 20; each of these trenches should have a waste capacity of approximately 1.6M ft^3. This volume is based upon trench surface dimensions being 150 feet wide and 800 feet long; depth being 45 feet; and base excavation dimensions being 60 feet by 710 feet. Trench utilization was estimated by US Ecology at approximately 55% (below eight feet) for the more recent trenches.

For convenience of review, three scenarios for closure, stabilization, and perpetual care and maintenance (PC&M) are estimated for the Facility and are summarized in Section 6.2. The first scenario includes the estimated costs for installation of the partial cap along with the tunnel and monitoring equipment during 1996, followed by closure of the remaining trenches starting in 2056. The other two scenarios deal with unscheduled closure in 1996 and scheduled closure of the entire site (assuming the partial cap is not constructed) in 2056.

Sections 6.3 through 6.7 include detail cost estimates utilized to generate the closure, stabilization and PC&M scenarios summarized in Section 6.2 (the terms custodial, institutional control and perpetual care and maintenance periods are used interchangeably in this discussion). The last section (Section 6.8) addresses projected State of Washington administrative costs throughout the closure, stabilization, and PC&M Periods. These costs are also included in the cost summaries in Section 6.2. All costs estimated for closure through PC&M are to be covered by the State-administered Closure and Institutional Control Funds.

6.1.1 Schedule

It has been estimated that upon Facility closure, final cap construction plus all of the necessary site grading can be accomplished within two years (the Closure Period). Sections 6.4 and 6.5 detail the closure costs for this two-year period for both scheduled and unscheduled closure. During this Closure Period, all open trenches will be filled to grade with site soil and the final closure cap will be constructed. Environmental monitoring will be continued on the same schedule as when the Facility was operational.

For five years after closure, US Ecology personnel will be present at the Facility to conduct routine environmental and site monitoring (the Stabilization Period). During this period, US Ecology will compile relevant site records for transfer of the site license to the custodial agency (State of Washington/U.S. Department of Energy, hereinafter referred to as custodial agency) for institutional control. Section 6.6 includes detailed costs for this period.

Institutional control will follow stabilization. The duration of the institutional control period will be determined by the custodial agency and has been assumed for cost purposes to be 100 years from the time the site is transferred from the disposal operator, US Ecology, to the custodial agency. One hundred years is the maximum period allowed under Washington Administrative Code (WAC 246-250-360(2)) "Institutional Requirements." During the institutional control period, the custodial agency will monitor to assure continued satisfactory disposal site performance, restrict access to the site, and perform minor custodial activities.

Section 6.7 details the costs (PC&M Period) for the period of year 8 through year 107 following closure. During this period, all environmental monitoring is scheduled at annual sampling intervals except air monitoring which will be eliminated completely. It

is also assumed that twice annually a crew of three persons with a rented backhoe or grader will spend three days performing miscellaneous maintenance. At year 75 of the PC&M Period, it is assumed that the existing security fence surrounding the Facility will be replaced with a similar fence. Portions of the existing fencing at the US Ecology Facility have been in place for approximately 30 years with minimum deterioration, therefore it was assumed that new fencing placed at closure should last at least 75 years.

Section 6.8 details the State of Washington administrative costs. This section is subdivided into the three separate monitoring periods that have been detailed above. These costs include the projected expenses that will be incurred at the Facility and in Olympia, Washington.

The schedule listed below summarizes the time frames, tasks, and operator responsible for site care for the closure scenario for scheduled closure in 2056.

	Lease Closure	
Time Frame	Task	Operator
September 2056	Site Closure	US Ecology
October 2056 through September 2058	Closure Period	US Ecology
October 2058 through September 2063	Stabilization Period	US Ecology
October 2063 through end of 2163	PC&M Period	Custodial Agency

6.1.2 Funding Available

The balance in the Site Closure Account (Fund 125) as of December 31, 1995, was $22,818,1971 . Fund 125 is the specific State of Washington reference for the fund that holds the US Ecology Facility closure monies. This fund is controlled and administered by the State. Presently no additional monies other than interest are being added to the fund. The rate of interest being added to this closure fund is controlled by the State of Washington and is based upon how the fund is invested. The interest will vary based upon methods of investment. Presently, the interest rate realized is approximately 6%.

The balance in the Perpetual Surveillance/Maintenance Account (Fund 500) as of December 31, 1995, was $22,993,9952 . Fund 500 is the State controlled and administered fund which holds monies deposited for the maintenance of the site during the PC&M Period. A $1.75/cubic foot fee is collected by the US Ecology for Fund 500

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[1] Zeiler, G.M., 1996, Letter to Mr. Barry Bede, January 18, 1996, WDOE-Fiscal Officer

[2] Zeiler, G.M., 1996, op. cit.

as stipulated under Article VII of the Richland Site Sublease dated February 29, 1976. At the projected rate of waste receipts from January 1996 through the end of year 2056 and the current deposit rate of $1.75/cubic foot (i.e., $175,000 added to Fund per year for 61 years), the future worth of these monies (Fund 500) at scheduled closure at a 2% real interest rate will be approximately $97.5 million. Future worth is defined as the equivalence of any present amount, P, at t = 0, to any future amount, F, at time = n, and is calculated by: F = P(1 + i)n, where i is an interest rate (i.e., real rate of return). When the PC&M Period begins seven years later, the fund will have grown to approximately $112 million.

6.1.3 Present Worth Calculations

To explain present worth calculations, the following example is presented. At scheduled closure in 2056, the $13,176,968 (see Table 6-4) is the present worth of $45,426,045 (in 1996 dollars) at a 2% escalation factor, where 2% is the "real rate of return" for money invested in the closure fund. Present worth is defined as the equivalence of any future amount, F, at t = n, to any present amount, P, and is calculated by: P = F(1 + i)-n, where i is an interest rate. This $13,176,968 at 2% interest will escalate to $45,426,045 in 61 years, where $45,426,045 is the estimated cost (in 1996 dollars) for site closure at year 2056. The estimated costs are based upon construction, monitoring, labor and materials increasing only at the rate of inflation. If inflation is 3% and the assumed value for the "real rate of return" is 2%, then the State would have to realize greater than a 5% return for the invested closure fund to have the estimated monies to fund closure in 2056. It should be realized that at closure in 2056, the $22.8M presently in the closure fund (Fund 125), if escalated at the 5% rate for the 61 years, would result in the future value for the closure monies of approximately $450M.

US Ecology has utilized two multipliers in arriving at the estimates for future site closure which need justification. These two multipliers are the 25% contingency and the 2% "real rate of return."

The 25% contingency is a "catch all" multiplier to include unforeseen events, excess rates of inflation, realized real rates of returns less than 2%, or future problems in acquiring competitive contract pricing. The 25% contingency has been used by the NRC on several occasions and is discussed in NUREG/CR-570 and NUREG/CR-1754 as an acceptable multiplier for covering future unforeseen events.

The 2% "real rate of return" has been used by the NRC in NUREG/CR-1266, Appendix D, where 2% represents the difference between escalation and interest on invested funds. Present worth and discount rates are also utilized by the EPA in reference to superfund cost comparisons. For example, the Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 in June 1993 recommended that for Superfund the discount rate be reduced from 10 to 7%. This rate includes inflation.

However, with inflation at approximately 2.3% in 1994, the resulting real rate of return would be 4.7%, which is substantially above the 2% used herein.

There are several additional bases for justification of the 2% "real rate of return". One basis is a study completed by Paine Webber Managed Accounts Services on certificates of deposits (6-month annualized average monthly rate) and inflation for years 1969 through 1994. The study indicated an average Certificates of Deposit (CD) rate of 8.03% and average inflation rate of 5.7%. The difference of 2.3% is above the 2% used in this estimate. CD accounts historically are the most conservative investment mechanism available.

Another justification for the 2% real rate of return are 30-year Treasury bill yields against the implicit price deflator for Gross National Product (GNP), published by the US Department of Commerce, Bureau of Economic Analysis. For example, between 1984 and 1994, T-bills average yield was 8.4% and the GNP deflator increased an average of 3.3% per year for the period. The difference between the T-bill yield and the GNP deflator can be construed to indicate a "real rate of return" of 4.9%.

Another basis for the 2% rate of return utilization can be found in a document provided by Wheat, First Securities, Inc. of Richmond, Virginia which compares the Standard and Poor 500 total return from 1925 through 1995 with inflation for the same period. The "real rate of return" for this period using this comparison was shown to be 9.2% per year, above the 2% used in this estimate. Based upon the several comparisons presented above, it should not be difficult for the State to achieve the required 2% "real rate of return" utilized in this Plan to generate the monies needed to fund future site closure.

6.2 SUMMARY OF COSTS

Costs are included to provide estimates for three closure scenarios. The first scenario includes costs for construction of the partial cap over Trenches 1-6 and the Chemical Trench beginning in 1996 and for completing the cap over the remainder of the site at scheduled closure. The second scenario includes costs for unscheduled closure in December 1996. The final scenario includes costs for scheduled closure at the end of 2056 (assuming partial cap is not constructed). The detailed calculations of the closure, stabilization and PC&M cost items, summarized in this section, are presented in detail in Sections 6.3 through 6.8.

The closure cost summaries include the estimated costs prepared using 1996 dollars, including a 25% contingency. Also, the cost estimates are shown as present worth based upon 2% real rate of return at the beginning of 1996. The cost projections assume that costs associated with construction, monitoring, labor, etc. increase only at the rate of inflation. Presenting the costs in 1996 dollars means that if an item costs the described amount in 1996, it will cost the same in the year spent escalated only at the inflation rate.

For the Scheduled Closure (Table 6-4) and Partial Cap Construction/Final Closure (Table 6-1) estimates, a 7% interest charge was added. This cost would be incurred by the State of Washington if US Ecology is required to fund all closure and stabilization costs and not be reimbursed until the conclusion of the specified period in which the monies were expensed. Reimbursement by the State is assumed to be made in a timely manner once a US Ecology invoice has been submitted for work completed. A site oversight fee of 29% was also added to these costs for the closure and stabilization periods. This fee was determined by the Washington Utility and Transportation Commission (WUTC) as an acceptable operating oversight margin for the Facility. Additionally, Scheduled Closure (Table 6-5) and Partial Cap Construction/Final Closure (Table 6-2) estimates are presented without the additional interest and oversight fees for comparison. For Unscheduled Closure (Table 6-3) the 7% interest and 29% oversight charges were not added. Unscheduled closure would only take place because of unforeseen circumstances preventing US Ecology from performing its duties as site operator. In the unlikely event this scenario would occur, it is presumed US Ecology would not be able to provide oversight during closure.

The costs presented are based upon current site operating costs, vendor quotations, or were taken from "Means Site Work Cost Data," 1996, published by R.S. Means Company, Inc. The cost estimates provide for the total costs that would be incurred if an independent contractor was hired to perform the closure and stabilization items. Means includes a "Geographic Factor" to be applied to the national average costs. The geographic factor of 0.935 for Richland was not included in the estimates in order to present conservative estimates.

Estimates of soils available on site were used to determine projected cost for acquiring the quantities of cap materials required for construction. The amount of material presently on site was estimated at 560,000 CY. The current topographic map (included as Drawing No. 853770.04-01-002 in Appendix E) was used to estimate the amount of soil located on site which could be available for cap construction. The soil volumes were estimated utilizing the average end area method. The procedure for this method involves approximating the area enclosed by a higher-elevation (high) contour and a lower-elevation (low) contour, finding the average of the two areas, and multiplying the average area by the difference in elevation between the two contours. Areas considered for borrow include: the area north of existing disposal cells; material placed on Trenches 1-6; materials placed on Trenches 8-9; and material placed on Trench 19. It was assumed that material would be removed to elevation 725 Mean Sea Level (MSL) from Trenches 8-9, Trench 19 and the borrow area located north of the site. This elevation is the natural grade elevation for the facility. Borrow areas north of the facility would be graded to provide adequate surface drainage. Material would be removed from Trenches 1-6 to elevation 730 MSL to allow for adequate cover over the waste disposed in these trenches. To utilize soil from the northern area, it was assumed the existing structures will be demolished and the receiving and state trailers would be used for construction and administrative offices.

At unscheduled closure in 1996, an additional quantity of approximately 12,500 CY will need to be acquired from off-site sources. It is assumed a borrow source would be located within five miles of the Facility.

At scheduled closure in 2056, an additional quantity of approximately 178,300 CY will need to be acquired. During the remaining operating life of the Facility, it is estimated 226,000 CY of soil will be generated from waste placement and be available for cap construction. This volume of soil is equivalent to the estimated total waste volume to be disposed during the scheduled closure period (100,000 CF per year). This excavated soil volume will be in addition to the 560,000 CY presently located on site.

6.2.1 Index of Cost Summaries

Below is the list of tables containing the summary of costs for the different closure scenarios presented in this section. Each summary includes the estimated cost for site closure, stabilization, PC&M and State of Washington Administration. The following cost summary tables are presented in this section:

- 6-1 Summary of Costs -- Partial Cap Construction/Final Closure (Includes 7% Interest and 29% Oversight);
- 6-2 Summary of Cost -- Partial Cap Construction/Final Closure (Less Interest and Oversight Charges);
- 6-3 Summary of Cost -- Unscheduled Closure December 31, 1996;
- 6-4 Summary of Costs -- Scheduled Closure In 2056 (Includes 7% Interest and 29% Oversight); and
- 6-5 Summary of Costs--Scheduled Closure In 2056 (Less Interest and Oversight Charges).

TABLE 6-1 SUMMARY OF COSTS--PARTIAL CAP CONSTRUCTION/FINAL CLOSURE

(INCLUDES 7% INTEREST AND 29% OVERSIGHT):

Partial Cap Construction	Present Worth Estimated Costs	Estimated Costs Presented in 1996 Dollars
• Partial Trench Cap (1 Year; 1997) (Refer to Section 6.3)	$ 6,846,976	$ 6,846,976
• Tunnel Construction and Other Monitoring (1 Year; 1997) (Refer to Section 6.3.1)	$ 1,783,672	$ 1,783,672
Subtotal	**$ 8,630,648**	**$ 8,630,648**
Completion of Cap		
• Scheduled Site Closure (2 years; 2056 - 2058) (Refer to Section 6.5.2)	$ 11,679,255	$ 40,262,857
Stabilization Period (5 years; 2058 - 2063) (Refer to Section 6.6)	$ 1,267,740	$ 4,682,427
• PC & M Period (100 years; 2063 - 2163) (Refer to Section 6.7)	$ 994,047	$ 8,866,619
• Total State of Washington Administration Costs--(Refer to Section 6.8)		
Site Closure	$ 83,324	$ 287,250
Stabilization	$ 51,887	$ 191,646
PC&M	$ 240,592	$ 2,146,010
Subtotal	**$ 14,058,345**	**$ 56,436,809**
TOTAL	**$ 22,947,493**	**$ 65,067,457**

TABLE 6-2 SUMMARY OF COSTS--PARTIAL CAP CONSTRUCTION/FINAL CLOSURE

(LESS INTEREST AND OVERSIGHT CHARGES)

Partial Cap Construction	Present Worth Estimated Costs	Estimated Costs Presented in 1996 Dollars
• Partial Trench Cap (1 Year; 1997) (Refer to Section 6.3)	$ 4,960,499	$ 4,960,499
• Tunnel Construction and Other Monitoring (1 Year; 1997) (Refer to Section 6.3.1)	$ 1,119,304	$ 1,119,304
Subtotal	**$ 6,079,803**	**$ 6,079,803**
Completion of Cap		
• Scheduled Site Closure (2 years; 2056 - 2058) (Refer to Section 6.5.2)	$ 7,907,840	$ 27,261,348
• Stabilization Period (5 years; 2058 - 2063) (Refer to Section 6.6)	$ 527,653	$ 1,948,900
• PC & M Period (100 years; 2063 - 2163) (Refer to Section 6.7)	$ 994,047	$ 8,866,619
• Total State of Washington Administration Costs (Refer to Section 6.8)		
Site Closure	$ 83,324	$ 287,250
Stabilization	$ 51,887	$ 191,646
PC&M	$ 240,592	$ 2,146,010
Subtotal	**$ 9,805,343**	**$ 40,701,773**
TOTAL	**$ 15,885,146**	**$ 46,781,576**

TABLE 6-3 SUMMARY OF COSTS-UNSCHEDULED CLOSURE DECEMBER 31, 1996

	Present Worth Estimated Costs	Estimated Costs Presented in 1996 Dollars
• Unscheduled Site Closure (2 years; 1997 - 1998) (Refer to Section 6.4)	$ 17,609,992	$ 17,609,992
• Stabilization Period (5 years; 1999 - 2003) (Refer to Section 6.6)	$ 1,765,862	$ 1,948,900
• PC & M Period (100 years; 2004 - 2103) (Refer to Section 6.7)	$ 3,461,130	$ 8,866,619
• Total State of Washington Administration Costs (Refer to Section 6.8)		
Site Closure	$ 278,858	$ 287,250
Stabilization	$ 173,649	$ 191,646
PC&M	$ 805,177	$ 2,146,010
TOTAL	**$ 24,094,668**	**$ 31,050,417**

TABLE 6-4 SUMMARY OF COSTS--SCHEDULED CLOSURE IN 2056

(INCLUDES 7% INTEREST AND 29% OVERSIGHT)

	Present Worth Estimated Costs	Estimated Costs Presented in 1996 Dollars
• Scheduled Site Closure (2 years; 2056 - 2058) (Refer to Section 6.5.1)	$13,176,968	$ 45,426,045
• Stabilization Period (5 years; 2058 - 2063) (Refer to Section 6.5)	$ 1,267,740	$ 4,682,427
• PC & M Period (100 years; 2064 - 2163) (Refer to Section 6.6)	$ 994,047	$ 8,866,619
• Total State of Washington Administration Costs	(Refer to Section 6.8)	
Site Closure	$ 83,324	$ 287,250
Stabilization	$ 51,887	$ 191,646
PC&M	$ 240,592	$ 2,146,010
TOTAL	**$ 15,814,558**	**$ 61,599,997**

TABLE 6-5 SUMMARY OF COSTS--SCHEDULED CLOSURE IN 2056

(LESS INTEREST AND OVERSIGHT CHARGES)

	Present Worth Estimated Costs	Estimated Costs Presented in 1996 Dollars
• Scheduled Site Closure (2 years; 2056 - 2058) (Refer to Section 6.5.1)	$ 8,921,918	$ 30,757,261
• Stabilization Period (5 years; 2058 - 2063) (Refer to Section 6.5)	$ 527,653	$ 1,948,900
• PC & M Period (100 years; 2064 - 2163) (Refer to Section 6.6)	$ 994,047	$ 8,866,619
• Total State of Washington Administration Costs (Refer to Section 6.8)		
Site Closure	$ 83,324	$ 287,250
Stabilization	$ 51,887	$ 191,646
PC&M	$ 240,592	$ 2,146,010
TOTAL	**$ 10,819,421**	**$ 44,197,686**

6.2.2 Cost Comparisons

As noted in Section 6.1.2, the State administered Site Closure and Perpetual Surveillance/Maintenance Accounts are $22.8M and $22.9M, respectively, as of December 31, 1995. At 6% interest (projected return of State funds), these two accounts should grow to $24.2M and $24.4M, respectively, by December 31, 1996.

For unscheduled closure in 1996 (see Table 6-3), the estimated costs for the closure and stabilization periods is $19.8M; this cost is below the monies projected to be available in the Closure Accounts by the end of 1996. The estimated PC&M cost for this scenario, adjusted for present worth, is $4.3M, substantially below the monies available in the Perpetual Surveillance/Maintenance Account.

For scheduled closure in 2056 (see Tables 6-4 and 6-5), the estimated costs for the closure and stabilization periods, after present worth adjustments, are $14.6M (with oversight monies included) or $9.6M (without oversight monies included); these costs are both below the monies available in the closure fund. Additionally, the estimated PC&M cost of $1.2M is substantially below the monies available in the Perpetual Surveillance/Maintenance Account.

Should the decision be made to install the partial cap over Trenches 1-6 and the Chemical Trench (see Tables 6-1 and Table 6-2), it is estimated that either $8.6M (with oversight monies included) or $6.1M (without oversight monies) would be expended from the closure fund. The present worth cost to complete the remaining final closure in 2056 and site stabilization through 2063 is $13.1M (with oversight monies) or $8.6M (without oversight monies included). Thus the total estimated monies required for final site closure and stabilization is $21.7 or $14.7M, with either scenario being below the monies available in the closure fund.

6.2.3 Index for Cost Detail Sections

Below is the list of sections containing the detailed cost calculations for the closure, post-closure and perpetual maintenance periods. These detailed costs were used to develop the summary tables presented in Section 6.2. The detailed costs are contained in the following sections:

- 6.3 Partial Trench Cap Construction: Trenches 1-6 & Chemical Trench (1 year);
- 6.3.1 Tunnel Construction and Other Monitoring Components; (1 year for construction, 10 years for monitoring)
- 6.4 Unscheduled Closure Period (2 years);
- 6.5.1 Scheduled Closure of Entire Site Utilized (2 years);

- 6.5.2 Scheduled Closure; Less Partial Cap Areas (2 years)
- 6.6 Stabilization Period (5 years);
- 6.7 PC&M Period (100 years); and
- 6.8 State of Washington Administration Costs.

As discussed, these cost sections were utilized to generate the summary for the three closure scenarios. Estimates in the following sections represent 1996 costs.

6.3 Partial Trench Cap Construction: Trenches 1-6 and Chemical Trench (One Year)

The costs associated with this section and the other sections are based upon current site operating costs or were taken from "Means Site Work Cost Data", 1996, published by R.S. Means Company, Inc. The cost estimates provide for the total costs that would be incurred if an independent contractor were hired to perform the closure and stabilization activities.

a. Grade Surface of Trenches 1-6 and Chemical Trench

Excess overburden will be removed. Five feet of overburden soil will remain over this area to form a uniform base for cap construction. The amount of material to be removed was estimated using the most current site topographic map included in this plan.

· Stockpile excess material.	$	2.24	/cy	110,000	cy	$	246,400
· Haul, place & compact material to achieve 1% design slope	$	1.87	/cy	54,000	cy	$	100,980
· Rough grade existing surface to contours shown on design drawing.	$	0.13	/cy	55,560	sy	$	7,223
				Subtotal of Grading Surface Costs		$	354,603

b. Barrier Layer:

Mixture of 12 % bentonite and 88% site sand.
500,000 sf, layer thickness is one foot plus 10%

· Bentonite, purchased in 2,000 lb. super sacks, trucked to site. ($73/ton)(ton/2000lb)(100lb/cf)=$98.55/cy (500,000 sf x 1.1 x 12%)/27 = 2,450 cy	$	118.80	/cy	2,450	cy	$	291,060
· Haul and spread materials to mix area: $1.10/cy x (1/27) x 500,000 sf (500,000 sf x 1.1 / 27) = 20,370 cy	$	2.24	/cy	20,370	cy	$	45,630
· Mix sand and bentonite with rototiller: (500,000 sf x 1.1 / 27) = 20,370 cy	$	0.43	/cy	20,370	cy	$	8,759
· Haul, place and compact on cap: (500,000 sf x 1.1 / 27) = 20,370 cy	$	3.00	/cy	20,370	cy	$	61,111
				Subtotal of Barrier Layer Costs		$	406,560

c. Capillary Break Layer:

500,000 sf, layer thickness is one foot plus 10%

· Gravel material delivered to site: (500,000 sf x1.1)/27 = 20,370 cy	$	15.80	cy	20,370	cy	$	321,852
· Place on cap: (500,000 sf x 1.1)/27 = 20,370 cy	$	2.00	/sy	55,560	sy	$	111,120
· Geotextile (materials and installation): (2 x 500,000 sf / 9) = 11,120 sy	$	0.71	/sy	111,120	sy	$	78,895
				Subtotal of Capillary Break Layer Costs		$	511,867

d. Site Sand Layer:

500,000 sf,layer thickness is three feet plus 10%

· Haul from stockpile, place and compact on cap: (500,000 sf x 3.3 / 27) = 61,120 cy	$	1.87	/cy	61,120	cy	$ 114,294
				Subtotal of Site Sand Costs		$ 114,294

e. Capillary Barrier Layer:

Layer contains 70% sandy silt and 30% pea gravel. Sandy silt portion is comprised of 60% silt, 40% sand.
Assume on-site stockpiles will be screened to obtain silt.
500,000 sf, layer thickness is three feet plus 10%

· Silt (8 cy of native soil yields about 1 cy of silt) (500,000 sf x 3.3 x 0.7 x0.6)/27 = 25,700 cy	$	4.50	/cy	205,600	cy	$ 925,200
· Transport additonal site soils and silt to pug mill	$	3.50	/cy	61,120	cy	$ 213,920
· Pea gravel, purchased and delivered to site: ($9.00/ton (ton/2000 lb)120 pcf=$14.60 cy (500,000 sf x 3.3 x 0.30)/27 = 18,350 cy	$	20.66	/cy	18,350	cy	$ 379,111
· Run mixture through pug mill: (500,000 sf x 3.3 / 27) = 61,120 cy	$	3.65	/cy	61,120	cy	$ 223,088
· Transport from pug mill and place on cap: (500,000 sf x 3.3 / 27) = 61,120 cy	$	3.00	/cy	61,120	cy	$ 183,360
				Subtotal of Capillary Barrier Layer Costs		$ 1,924,679

f. Gravel Mulch:

On-site stockpiles of soil will be screened to obtain silt for gravel mulch. Assume gravel mulch mixture is 50% gravel and 50% silt.
500,000 sf, layer thickness is four inches

· Silt layer is comprised of 60% silt, 40% sand						
· Silt (8 cy of native soil yields about 1 cy of silt) (500,000 sf x 0.33 x 0.5 x 0.6)/27 = 1,850 cy	$	4.50	/cy	14,800	cy	$ 66,600
· Pea gravel, purchased and delivered to site: ($9.00/ton (ton/2000lb)120 pcf=$14.60/cy (500,000 sf x 0.33 x 0.50)/27 = 3,050 cy	$	20.66	/cy	3,050	cy	$ 63,013
· Transport additional site soils and silt to pug mill: (500,000 sf x 0.4 /27) =7,400 cy	$	3.50	/cy	7,400	cy	$ 25,900
· Run mixture through pug mill: (500,000 sf x 0.4 /27) =7,400 cy	$	3.65	/cy	7,400	cy	$ 27,010
· Transport from pug mill and place on cap: (500,000 sf x 0.4 /27) =7,400 cy	$	3.00	/cy	7,400	cy	$ 22,200
				Subtotal of Gravel Mulch Costs		$ 204,723

g. Total Estimated Costs for Section 6.3, *(Partial Trench Cap Construction)* in 1996 Dollars

Subtotal of Construction Costs	$	3,516,726
Design/Construction QA/QC (10%)	$	351,673
Surveying	$	100,000
Total Partial Trench Cap Costs	**$**	**3,968,399**
Plus 25% Contigency	**$**	**4,960,499**
Plus Interest @ 7% (1 year)	**$**	**5,307,733**
Plus US Ecology oversight @ 29%	**$**	**6,846,976**

6.3.1 Tunnel Construction and Other Monitoring Components (One year for construction, ten years for monitoring)

a. Facility Cost

. Mobilization	$	10,000	/ea		$	10,000
. Excavation and Backfill	$	47.11	/lf	200 lf	$	9,422
. Tunnel Liner	$	475.00	/lf	200 lf	$	95,000
. Electricity and Ventilation	$	80.00	/lf	200 lf	$	16,000
. Electric Service	$	30.00	/lf	500 lf	$	15,000
. Instrumentation Borings (6 locations, 10 borings at each location, 5 borings 125 ft, 5 boring 75 ft = 6,000 lf)	$	20	/lf	6,000 lf	$	120,000
. Sensors	$	1,000	/ea	60 ea	$	60,000
. Base Station and Wiring	$	50,000	/ea	1 ls	$	50,000
. Miscellaneous	$	25,000	/ea	1 ls	$	25,000
					$	400,422
. Engineering @ 5% of total above					$	20,021
				Total Facility Cost	$	420,443

b. Operating Costs

. Labor (1/4 man - year)	$	50	/hr	520 hrs	$	26,000
. Maintenance (@ 5% of electric, instruments, and miscellaneous cost)	$	11,500	/ea	1 ea	$	11,500
. Data Analysis and Reporting	$	10,000	/ea	1 ea	$	10,000
				Annual Operating Cost	$	47,500
				Ten Years of Operation	$	475,000

c. Total Estimated Costs for Section 6.3.1, *(Tunnel Construction and Monitoring)* in 1996 Dollars

Total Costs for Tunnel Construction and Operation	**$**	**895,443**
Plus 25% Contigency	**$**	**1,119,304**
Plus Interest @ 7%	**$**	**1,382,691**
Plus US Ecology oversight @ 29%	**$**	**1,783,672**

6.4 Unscheduled Closure Period (2 Years)--From beginning of year 1 through end of year 2 (1997 and 1998)

6.4.1 Personnel Costs:

a. Salaries

. 1 Facility Manager	$ 48,300	/yr	2	yr	$	96,600
. 1 RSO	$ 40,250	/yr	2	yr	$	80,500
. Rad Tech	$ 36,750	/yr	2	yr	$	73,500
. 1 Secretary/Clerk	$ 23,000	/yr	2	yr	$	46,000
. 1 Foreman	$ 38,180	/yr	2	yr	$	76,360
. 3 Laborers/Operators	$ 35,880	/yr	2	yr	$	215,280
					$	588,240
			Benefits @ 40%		$	235,296
			Total Salaries		$	823,536

b. Office Expenses:

. Utilities	$ 280	/mo	24	mo	$	6,720
. Telephone	$ 450	/mo	24	mo	$	10,800
. Miscellaneous Office Supplies	$ 225	/mo	24	mo	$	5,400
. Travel	$ 225	/mo	24	mo	$	5,400
. Vehicle Expenses	$ 500	/mo	24	mo	$	12,000
. Miscellaneous Expenses	$ 1,125	/mo	24	mo	$	27,000
			Total Office Expenses		$	67,320

c. Total Section 6.4.1 (a & b) **Total Personnel Costs** $ 890,856

6.4.2 Building Removal

. Shop 40x100x20 metal bldg.	$ 0.21	/cf	80,000	cf	$	16,800
. Shop 40x100x20 metal bldg.	$ 10.85	/sy	4,000	sy	$	43,400
. Warehouse 24x36x20 metal bldg	$ 0.21	/cf	17,280	cf	$	3,629
. Warehouse concrete foundation	$ 10.85	/sy	864	sy	$	9,374
. Office 41x41x20 wood bldg	$ 0.23	/cf	1,681	cf	$	387
. Office concrete foundation	$ 10.85	/sy	33,620	sy	$	364,777
			Total Building Removal		$	438,367

6.4.3 Landfill Closure (Interim Closure of Remaining Active Trenches)

Backfill to Grade (assume backfill volumes based on Jan. 1996 trench volume capacities)

. Trench 18	$ 2.41	/cy	131,499	cy	$	333,075
. Trench 16	$ 2.41	/cy	65,340	cy	$	165,500
. Trench 11B	$ 2.41	/cy	15,414	cy	$	39,042
. Trench 14	$ 2.41	/cy	21,518	cy	$	54,503
. Surcharge with 10' site soil (assume the above listed trenches require covering)	$ 2.41	/cy	64,000	cy	$	162,106
			Total Landfill Closure		$	754,227

6.4.4 Final Cap Construction

a. Grade Cap Surface

Excess overburden will be removed to form a uniform base for cap construction. Five feet of overburden soil will remain over Trenches 1-6. The amount of material will be removed was estimated using the most current site topographic map.

. Stockpile excess material	$	2.24 /cy	250,000	cy	$	560,000
. Haul, place & compact material to achieve 1% design slope	$	1.87 /cy	161,000	cy	$	301,070
. Rough grade existing surface to contours shown on design drawings.	$	0.13 /sy	166,670	sy	$	21,667
			Subtotal of Grading Surface Costs		$	882,737
b. Haul additional material from offsite sources 10 mile round trip	$	13.00 /cy	12,500	cy	$	162,500
			Subtotal for hauling off-site material		$	162,500

c. Barrier Layer

Mixture of 12 % bentonite and 88% site sand. 1,500 MSF[1]; layer thickness is one foot plus 10%.

. Bentonite, purchased in 2,000 lb. super sacks, trucked to site. ($88/ton)(ton/2000 lb)(100 lb/cf)=$118.80/cy (1.1 ft x 1,500 MSF x 0.12)/27 = 7,333 cy	$	118.80 /cy	7,333	cy	$	871,160
. Haul and spread materials to mix area: (1.1 ft x 1,500 MSF)/27 = 61,111 cy	$	2.24 /cy	61,111	cy	$	136,889
. Mix sand and bentonite with rototiller: (1.1 ft x 1,500 MSF)/27 = 61,111 cy	$	0.43 /cy	61,111	cy	$	26,278
. Haul, place and compact on cap (1.1 ft x 1,500 MSF)/27 = 61,111 cy	$	3.00 /cy	61,111	cy	$	183,333
			Subtotal of Barrier Layer Costs		$	1,217,660

d. Capillary Break Layer

1,500 MSF, layer thickness is one foot plus 10%.

. Material delivered to site: (1.1 ft x 1,500 MSF)/27 = 61,111 cy	$	15.80 /cy	61,111	cy	$	965,554
. Place on cap: (1,500 MSF/9) = 166,670 sy	$	2.00 /cy	166,670	cy	$	333,340
. Geotextile (materials and installation): (1,500 MSF/9)x2 = 166,670 sy	$	0.71 /sy	333,340	sy	$	236,671
			Subtotal of Capillary Break Layer Costs		$	1,535,565

e. Site Sand Layer

1,500 MSF, layer thickness is three feet plus 10%

. Haul from stockpile, place and compact on cap: (1,500 MSF x 3.3)/27 =183,333 cy	$	1.87 /cy	183,330	cy	$	342,827
			Subtotal of Site Sand Costs		$	342,827

[1] **MSF is an abbreviation for thousand square feet.**

f. Capillary Barrier Layer

1,500 MSF, layer thickness is three feet plus 10%
Layer contains 70% sandy silt and 30% pea gravel.
Sandy silt portion is comprised of 60% silt, 40% sand.
Assume on-site stockpiles will be screened to obtain silt.

. Silt (8 cy of native soil yields about 1 cy of silt)						
(1,500 MSF x 3.3 x 0.7 x 0.6)/27 = 77,000 cy	$	4.50 /cy	616,000	cy	$	2,772,000
. Transport additonal site soils and silt to pug mill	$	3.50 /cy	183,330	cy	$	641,655
. Pea gravel, purchased and delivered to site:						
(3.3 ft x 0.3 x 1,500 MSF)/27 =55,000 cy	$	20.66 /cy	55,000	cy	$	1,136,300
. Run mixture through pug mill:	$	3.65 /cy	183,330	cy	$	669,155
(1,500 MSF x 3.3)/27 =183,333 cy						
. Transport from pug mill and place on cap:	$	3.00 /cy	183,330	cy	$	549,990
(1,500 MSF x 3.3)/27 =183,333 cy						
Subtotal of Capillary Barrier Layer Costs					$	5,769,100

g. Gravel Mulch

On-site stockpiles of soil will be screened to obtain silt for gravel mulch. Assume gravel mulch mixture is 50% gravel and 50% silt.

1,500 MSF, layer thickness is four inches

. Silt, ***(8 cy of native soil yields about 1 cy of silt)***						
(1,500 MSF x 0.33 x 0.5x0.6)/27 = 5,500 cy	$	4.50 /cy	44,000	cy	$	198,000
. Pea gravel, purchased and delivered to site:						
($12.75/ton(ton/2000 lb)120 pcf =$20.66/cy	$	20.66 /cy	9,170	cy	$	189,452
(1,500 MSF x.33x.5)/27 =9,170 cy						
. Transport additional site soils and silt to pug mill:						
(1,500 MSF x.4)/27 =22,220cy	$	3.50 /cy	22,200	cy	$	77,700
. Run mixture through pug mill:						
(1,500 MSF x .4)/27 =22,220cy	$	3.65 /cy	22,200	cy	$	81,030
. Transport from pug mill and place on cap:	$	3.00 /cy	22,200	cy	$	66,600
(1,500 MSF x.4)/27 =22,220cy						
Subtotal of Gravel Mulch Costs					$	612,782

h. Total Estimated Cost for Section 6.4.4 in 1996 dollars	Subtotal of Construction Costs	$	10,523,171
	Design/Construction QA/QC (10%)	$	1,052,317
	Surveying	$	200,000
	Total Closure Costs at 1998	$	11,775,488

6.4.5 Environmental Monitoring

. Groundwater Monitoring						
7 samples per quarter for 8 quarters	$	1,660	/smp	56	smp	$ 92,960
. Vegetation Sampling						
6 samples annually for 2 years	$	451.00	/smp	12	smp	$ 5,412
. Soil Sampling						
6 samples per quarter for 8 quarters	$	451.00	/smp	48	smp	$ 21,648
. Air Monitoring						
4 samples per quarter for 4 quarters	$	100.00	/smp	16	smp	$ 1,600
. Vadose Zone Monitoring						
11 samples for 8 quarters	$	460.00	/smp	88	smp	$ 40,480
				Total Environmental Monitoring		$ 162,100

6.4.6 Miscellaneous Closure Items

. Aerial photo and topographic map	$	12,900	/each	1	each	$ 12,900
. Site surveying	$	6,000	/each	1	each	$ 6,000
. Miscellaneous engineering	$	3,000	/each	1	each	$ 3,000
. License Transfer						
Legal Fees	$	27,500	/each	1	each	$ 27,500
Records Review	$	6,500	/each	1	each	$ 6,500
. Closure of facility office and transfer of records to corporate office	$	11,000	/each	1	each	$ 11,000
				Total Miscellaneous Closure Items		$ 66,900

6.4.7 Subtotal Estimated Costs for Section 6.4, *(Unscheduled Closure)* in 1996 Dollars

Personnel and office expenses (6.4.1)	**$**	**890,856**
Building removal (6.4.2)	**$**	**438,367**
Landfill closure (6.4.3)	**$**	**754,227**
Final cap construction(6.4.4)	**$**	**11,775,488**
Environmental Monitoring (6.4.5)	**$**	**162,100**
Miscellaneous (6.4.6)	**$**	**66,900**
Total Unscheduled Closure Costs	**$**	**14,087,938**
plus 25% Contingency	**$**	**17,609,922**

6.5 Scheduled Closure Period (2 Years)--From beginning of year 1 through end of year 2;

6.5.1 Scheduled Closure of Entire Site (2056 and 2057):

6.5.1.1 Personnel Costs:

a. Salaries

. 1 Facility Manager	$ 48,300	/yr	2	yr	$	96,600
. 1 RSO	$ 40,250	/yr	2	yr	$	80,500
. Rad Tech	$ 36,750	/yr	2	yr	$	73,500
. 1 Secretary/Clerk	$ 23,000	/yr	2	yr	$	46,000
. 1 Foreman	$ 38,180	/yr	2	yr	$	76,360
. 3 Laborers/Operators	$ 35,880	/yr/ea.	2	yr	$	215,280
					$	588,240
			Benefits @ 40%		$	235,296
			Total Salaries Costs		$	823,536

b. Office Expenses:

. Utilities	$ 280	/mo	24	mo	$	6,720
. Telephone	$ 450	/mo	24	mo	$	10,800
. Miscellaneous Office Supplies	$ 225	/mo	24	mo	$	5,400
. Travel	$ 225	/mo	24	mo	$	5,400
. Vehicle Expenses	$ 500	/mo	24	mo	$	12,000
. Miscellaneous Expenses	$ 1,125	/mo	24	mo	$	27,000
			Total Office Expenses		$	67,320

c. Cost Section 6.5.1.1 (a & b) **Total Personnel Cost** $ 890,856

6.5.1.2 Building Removal:

. Shop 40x100x20 metal bldg.	$ 0.21	/cf	80,000	cf	$	16,800
. Shop concrete foundation	$ 10.85	/sy	4,000	sy	$	43,400
. Warehouse 24x36x20 metal bldg.	$ 0.21	/cf	17,280	cf	$	3,629
. Warehouse concrete foundation	$ 10.85	/sy	864	sy	$	9,374
. Office 41x41x20 wood bldg	$ 0.23	/cf	1,681	cf	$	387
. Office concrete foundation	$ 10.85	/sy	33,620	sy	$	364,777
			Total Building Removal		$	438,367

6.5.1.3 Landfill Closure (Interim Closure of Remaining Active Trenches)

Backfill to Grade (assume a standard trench is full and requires backfill to grade only)

. Trench Dimensions: 150' x 850' x 8'	$ 2.41	/cy	38,000	cy	$	96,251
. Surcharge with 10' site soil (assume 1-1/2 standard trenches require covering): 1.5 x 150' x 850' x 10'	$ 2.41	/cy	70,850	cy	$	179,457
			Total Interim Landfill Closure		$	275,707

6.5.1.4 Final Cap Construction

a. Grade Cap Surface

Excess overburden will be removed to form a uniform base for cap construction. Five feet of overburden soil will remain over Trenches 1-6. The amount of material will be removed was estimated using the most current site topographic map.

. Stockpile excess material.	$	2.24 /cy	250,000	cy	$	560,000
. Haul, place & compact material to achieve 1% design slope	$	1.87 /cy	290,000	cy	$	542,300
. Rough grade existing surface to contours shown on design drawings.	$	0.13 /sy	300,000	sy	$	39,000
			Subtotal of Grading Surface Costs		$	1,141,300
b. Haul additional material from offsite sources 10 mile round trip	$	13.00 /cy	178,300	cy	$	2,317,900
			Subtotal For Hauling Material		$	2,317,900

c. Barrier Layer

Mixture of 12 % bentonite and 88% site sand.
2,700 MSF, layer thickness is one foot plus 10%
Bentonite, purchased in 2,000 lb. Super

. Sacks, trucked to site. ($88/ton)(ton/2000 lb)(100 lb/cf)=$118.80/cy (1.1 ft x 2,700 MSF x 0.12)/27 = 13,200 cy	$	118.80 /cy	13,200	cy	$	1,568,160
. Haul and spread materials to mix area: (1.1 ft x 2,700 MSF)/27 = 110,000 cy	$	2.24 /cy	110,000	cy	$	246,400
. Mix sand and bentonite with rototiller: (1.1 ft x 2,700 MSF)/27 = 110,000 cy	$	0.43 /cy	110,000	cy	$	47,300
. Haul, place and compact on cap (1.1 ft x 2,700 MSF)/27 = 110,000 cy	$	3.00 /cy	110,000	cy	$	330,000
			Subtotal of Barrier Layer Costs		$	2,191,860

d. Capillary Break Layer

2,700 MSF,layer thickness is one foot plus 10%

. Gravel material delivered to site: (1.1 ft x 2,700 MSF)/27 = 110,000 cy	$	15.80 /cy	110,000	cy	$	1,738,000
. Place on cap: (2,700 MSF/9) = 300,000 sy	$	2.00 /cy	300,000	cy	$	600,000
. Geotextile (materials and installation): (2,700 MSF/9)x2= 600,000 sy	$	0.71 /sy	600,000	sy	$	426,000
			Subtotal of Capillary Break Layer Costs		$	2,764,000

e. Site Sand Layer

2,700 MSF,layer thickness is three feet plus 10%

. Haul from stockpile, place and compact on cap: (2,700 MSF x 3.3)/27 = 330,000 cy	$	1.87 /cy	330,000	cy	$	617,100
			Subtotal of Site Sand Costs		$	617,100

f. Capillary Barrier Layer

Layer contains 70% sandy silt and 30% pea gravel. Sandy silt portion is comprised of 60% silt, 40% sand. Assume on-site stockpiles will be screened to obtain silt.

2,700 MSF,layer thickness is three feet plus 10%

. Silt (8 cy of native soil yields about 1 cy of silt)							
(2,700 MSF x 3.3 x 0.7 x 0.6)/27 = 138,600 cy	$	4.50	/cy	1,108,800	cy	$	4,989,600
. Transport additonal site soils and silt to pug mill	$	3.50	/cy	330,000	cy	$	1,155,000
. Pea gravel, purchased and delivered to site:							
(3.3 ft x 0.3 x 2,700 MSF)/27 =99,000 cy	$	20.66	/cy	99,000	cy	$	2,045,340
. Run mixture through pug mill:	$	3.65	/cy	330,000	cy	$	1,204,500
(3.3 x 2,700 MSF)/27 = 330,000 cy							
. Transport from pug mill and place on cap:	$	3.00	/cy	330,000	cy	$	990,000
(3.3 x 2,700 MSF)/27 = 330,000 cy							
Subtotal of Capillary Barrier Layer Costs						$	10,384,440

g. Gravel Mulch

On-site stockpiles of soil will be screened to obtain silt for gravel mulch. Assume gravel mulch mixture is 50% gravel and 50% silt.

2,700 MSF, thickness is four inches

. Silt, ***(8 cy of native soil yields about 1 cy of silt)***							
(2,700 MSF x 0.33 x 0.5x0.6)/27 = 9,900 cy	$	4.50	/cy	79,200	cy	$	356,400
. Pea gravel, purchased and delivered to site:							
($12.75/ton(ton/2000 lb)120 pcf =$20.66/cy	$	20.66	/cy	16,500	cy	$	340,890
(2,700 MSF x.33x.5)/27 =16,500 cy							
. Transport additional site soils and silt to pug mill:							
(2,700 MSF x.4)/27 =40,000 cy	$	3.50	/cy	40,000	cy	$	140,000
. Run mixture through pug mill:							
(2,700 MSF x.4)/27 =40,000 cy	$	3.65	/cy	40,000	cy	$	146,000
. Transport from pug mill and place on cap:	$	3.00	/cy	40,000	cy	$	120,000
(2,700 MSF x.4)/27 =40,000 cy							
Subtotal of Gravel Mulch Costs						$	1,103,290

h. Subtotal Estimated Cost for Section 6.5.1.4. in 1996 Dollars	$	20,519,890
Design/Construction QA/QC (10%)	$	2,051,989
Surveying	$	200,000
Total Cap Closure Costs at 2056	**$**	**22,771,879**

6.5.1.5 Environmental Monitoring

. Groundwater Monitoring						
7 samples per quarter for 8 quarters	$	1,660 /smp	56	smp	$	92,960
. Vegetation Sampling						
6 samples annually for 2 years	$	451.00 /smp	12	smp	$	5,412
. Soil Sampling						
6 samples per quarter for 8 quarters	$	451.00 /smp	48	smp	$	21,648
. Air Monitoring						
4 samples per quarter for 4 quarters	$	100.00 /smp	16	smp	$	1,600
. Vadose Zone Monitoring						
11 samples for 8 quarters	$	460.00 /smp	88	smp	$	40,480
			Total Environmental Monitoring		$	162,100

6.5.1.6 Miscellaneous Closure Items

. Aerial photo and topographic map	$	12,900 /each	1	each	$	12,900
. Site surveying	$	6,000 /each	1	each	$	6,000
. Miscellaneous engineering	$	3,000 /each	1	each	$	3,000
. License Transfer						
Legal Fees	$	27,500 /each	1	each	$	27,500
Records Review	$	6,500 /each	1	each	$	6,500
. Closure of facility office and transfer of records to corporate office	$	11,000 /each	1	each	$	11,000
			Total Miscellaneous Closure Items		$	66,900

6.5.1.7 Subtotal Estimated Costs for Section 6.5.1, *(Scheduled Closure Entire Site)* in 1996 Dollars

Personnel and office expenses (6.5.1.1)	**$**	**890,856**
Building removal (6.5.1.2)	**$**	**438,367**
Interim landfill closure (6.5.1.3)	**$**	**275,707**
Final cap construction (6.5.1.4)	**$**	**22,771,879**
Environmental Monitoring (6.5.1.5)	**$**	**162,100**
Miscellaneous (6.5.1.6)	**$**	**66,900**
Total Closure Costs at 2056	**$**	**24,605,809**
Plus 25% Contingency	**$**	**30,757,261**
Plus Interest @ 7% (2 years)	**$**	**35,213,989**
Plus US Ecology oversight @ 29%	**$**	**45,426,045**

6.5.2 Scheduled Closure of Entire Site--less partial cap areas (2056 and 2057):

6.5.2.1 Personnel Costs:

a. Personnel Salaries

. 1 Facility Manager	$ 48,300	/yr	2	yr	$	96,600
. 1 RSO	$ 40,250	/yr	2	yr	$	80,500
. Rad Tech	$ 36,750	/yr	2	yr	$	73,500
. 1 Secretary/Clerk	$ 23,000	/yr	2	yr	$	46,000
. 1 Foreman	$ 38,180	/yr	2	yr	$	76,360
. 3 Laborers/Operators	$ 35,880	/yr/ea.	2	yr	$	215,280
					$	588,240
			Benefits 40%		$	235,296
			Total Salaries Costs		$	823,536

b. Office Expenses

. Utilities	$ 280	/mo	24	mo	$	6,720
. Telephone	$ 450	/mo	24	mo	$	10,800
. Miscellaneous Office Supplies	$ 225	/mo	24	mo	$	5,400
. Travel	$ 225	/mo	24	mo	$	5,400
. Vehicle Expenses	$ 500	/mo	24	mo	$	12,000
. Miscellaneous Expenses	$ 1,125	/mo	24	mo	$	27,000
			Total Office Expenses		$	67,320

c. Cost Section 6.5.2.1 (a &b) **Total Personnel Costs** $ 890,856

6.5.2.2 Building Removal

. Shop 40x100x20 metal bldg.	$ 0.21	/cf	80,000	cf	$	16,800
. Shop concrete foundation	$ 10.85	/sy	4,000	sy	$	43,400
. Warehouse 24x36x20 metal bldge	$ 0.21	/cf	17,280	cf	$	3,629
. Warehouse concrete foundation	$ 10.85	/sy	864	sy	$	9,374
. Office 41x41x20 wood bldg	$ 0.23	/cf	1,681	cf	$	387
. Office concrete foundation	$ 10.85	/sy	33,620	sy	$	364,777
			Total Building Removal		$	438,367

6.5.2.3 Landfill Closure (Interim Closure of Remaining Active Trenches)

Backfill to Grade (assume a standard trench is full a requires backfill to grade only)

. Trench Dimensions: 150' x 850' x 8'	$ 2.41	/cy	38,000	cy	$	96,251
. Surcharge with 10' site soil (assume 1-1/2 standard trenches require covering): 1.5 x 150' x 850' x 10'	$ 2.41	/cy	70,850	cy	$	179,457
			Total Interim Landfill Closure		$	275,707

6.5.2.4 Final Cap Construction

a. Grade Cap Surface

Excess overburden will be removed to form a uniform base for cap construction. Five feet of overburden soil will remain over Trenches 1-6. The amount of material will be removed was estimated using the most current site topographic map.

Stockpile excess material.	$	2.24 /cy	150,000	cy	$	336,000
. Haul, place & compact material to achieve 1% design slope	$	1.87 /cy	236,000	cy	$	441,320
. Rough grade existing surface to contours shown on design drawings.	$	0.13 /sy	255,560	sy	$	33,223
			Subtotal of Grading Surface Costs		$	810,543
b. Haul additional material from offsite sources 10 mile round trip	$	13.00 /cy	203,326	cy	$	2,643,238
			Subtotal for Handling Material		**$**	**2,643,238**

c. Barrier Layer

Mixture of 12 % bentonite and 88% site sand.
2,300 MSF, layer thickness is one foot plus 10%
Bentonite, purchased in 2,000 lb. Super

. Sacks trucked to site. ($88/ton)(ton/2000 lb)(100 lb/cf)=$118.80/cy (1.1 ft x 2,300 MSF x 0.12)/27 =11,250 cy	$	118.80 /cy	11,250	cy	$	1,336,500
. Haul and spread materials to mix area: (1.1 ft x 2,300 MSF)/27 = 93,710 cy	$	2.24 /cy	93,710	cy	$	209,910
. Mix sand and bentonite with rototiller: (1.1 ft x 2,300 MSF)/27 = 93,710 cy	$	0.43 /cy	93,710	cy	$	40,295
. Haul, place and compact on cap (1.1 ft x 2,300 MSF)/27 = 93,710 cy	$	3.00 /cy	93,710	cy	$	281,130
			Subtotal of Barrier Layer Costs		$	1,867,836

d. Capillary Break Layer

2,300 MSF, layer thickness is one foot plus 10%

. Gravel material delivered to site: (1.1 ft x 2,300 MSF)/27 = 93,710 cy	$	15.80 /cy	93,710	cy	$	1,480,618
. Place on cap: (2,300 MSF/9) = 255,560 sy	$	2.00 /cy	255,560	cy	$	511,120
. Geotextile (materials and installation): (2,300 MSF/9) = 255,560 sy	$	0.71 /sy	255,560	sy	$	181,448
			Subtotal of Capillary Break Layer Costs		$	2,173,186

c. Site Sand Layer

2,300 MSF, layer thickness is three feet plus 10%

. Haul from stockpile, place and compact on cap: (2,300 MSF x 3.3)/27 = 281,110 cy	$	1.87 /cy	281,110	cy	$	525,676
			Subtotal of Site Sand Costs		$	525,676

e. Capillary Barrier Layer:

Layer contains 70% sandy silt and 30% pea gravel. Sandy silt portion is comprised of 60% silt, 40% sand.
Assume on-site stockpiles will be screened to obtain silt.
2,300 MSF, layer thickness is three feet plus 10%

. Silt (8 cy of native soil yields about 1 cy of silt)						
(2,300 MSF x 3.3 x 0.7 x 0.6)/27 = 118,070 cy	$	4.50 /cy	944,560	cy	$	4,250,520
. Transport additonal site oils and silt to pug mill	$	3.50 /cy	330,000	cy	$	1,155,000
. Pea gravel, purchased and delivered to site:						
(3.3 ft x 0.3 x 2,300 MSF)/27 =84,330 cy	$	20.66 /cy	84,330	cy	$	1,742,258
. Run mixture through pug mill:	$	3.65 /cy	281,110	cy	$	1,026,052
(3.3 x 2,300 MSF)/27 = 281,110 cy						
. Transport from pug mill and place on cap:	$	3.00 /cy	281,110	cy	$	843,330
(3.3 x 2,300 MSF)/27 = 281,110 cy						
			Subtotal of Capillary Barrier Layer Costs		$	9,017,159

g. Gravel Mulch

On-site stockpiles of soil will be screened to obtain silt for gravel mulch. Assume gravel mulch mixture is 50% gravel and 50% silt.
2,300 MSF, layer thickness is 4 inches

. Silt, ***(8 cy of native soil yields about 1 cy of silt)***						
(2,300 MSF x 0.33 x 0.5x0.6)/27 = 8,430 cy	$	4.50 /cy	67,440	cy	$	303,480
. Pea gravel, purchased and delivered to site:						
($12.75/ton(ton/2000 lb)120 pcf =$20.66/cy	$	20.66 /cy	14,060	cy	$	290,480
(2,300 MSF x.33x.5)/27 =14,060 cy						
. Transport additional site soils and silt to pug mill:						
(2,300 MSF x.4)/27 =34,070 cy	$	3.50 /cy	34,070	cy	$	119,245
. Run mixture through pug mill:						
(2,300 MSF x.4)/27 =34,070 cy	$	3.65 /cy	34,070	cy	$	124,356
. Transport from pug mill and place on cap:	$	3.00 /cy	34,070	cy	$	102,210
(2,300 MSF x.4)/27 =34,070 cy						
			Subtotal of Gravel Mulch Costs		$	939,770

h. Subtotal Estimated Cost For Section 6.5.2.4 in 1996 Dollars	**$**	**17,977,407**
Design/Construction QA/QC (10%)	$	1,797,741
plus Surveying	$	200,000
Total Closure Costs at 2056	**$**	**19,975,148**

6.5.2.5 Environmental Monitoring

. Groundwater Monitoring						
7 samples per quarter for 8 quarters	$	1,660 /smp	56	smp	$	92,960
. Vegetation Sampling						
6 samples annually for 2 years	$	451.00 /smp	12	smp	$	5,412
. Soil Sampling						
6 samples per quarter for 8 quarters	$	451.00 /smp	48	smp	$	21,648
. Air Monitoring						
4 samples per quarter for 4 quarters	$	100.00 /smp	16	smp	$	1,600
. Vadose Zone Monitoring						
11 samples for 8 quarters	$	460.00 /smp	88	smp	$	40,480
		Total Environmental Monitoring			$	162,100

6.5.2.6 Miscellaneous Closure Items

. Aerial photo and topographic map	$	12,900 /ea	1	ea	$	12,900
. Site surveying	$	6,000 /ea	1	ea	$	6,000
. Miscellaneous engineering	$	3,000 /ea	1	ea	$	3,000
. License Transfer						
Legal Fees	$	27,500 /ea	1	ea	$	27,500
Records Review	$	6,500 /ea	1	ea	$	6,500
. Closure of facility office and transfer of records to corporate office	$	11,000 /ea	1	ea	$	11,000
		Total Miscellaneous Closure Items			$	66,900

6.5.2.7 Subtotal Estimated Costs for Section 6.5.2,
***(Scheduled Closure of Entire Site--- less partial cap areas)* in 1996 Dollars**

Personnel and office expenses (6.5.2.1)	**$**	**890,856**
Building removal (6.5.2.2)	**$**	**438,367**
Interim landfill closure (6.5.2.3)	**$**	**275,707**
Final cap construction (6.5.2.4)	**$**	**19,975,148**
Environmental Monitoring (6.5.2.5)	**$**	**162,100**
Miscellaneous (6.5.2.6)	**$**	**66,900**
Total Closure Costs at 2056	**$**	**21,809,078**
Plus 25% Contingency	**$**	**27,261,348**
Plus Interest @ 7% (2 years)	**$**	**31,211,517**
Plus US Ecology oversight @ 29%	**$**	**40,262,857**

6.6 Stabilization Period (5 Years), from beginning of year 3 through end of year 7:

6.6.1 Personnel Costs:

. 1 Facility Manager	$ 48,300 /yr	5 yr	$	241,500
. 1 RSO	$ 40,250 /yr	5 yr	$	201,250
. 1 Foreman	$ 38,180 /yr	5 yr	$	190,900
. 1 Laborer/Operator	$ 35,880 /yr	5 yr	$	179,400
			$	813,050
		Benefits @ 40%	$	325,220
		Total Personnel Costs	$	1,138,270

6.6.2 Office Expenses:

. Utilities	$ 170.00 /mo	60 mo	$	10,200
. Telephone	$ 125.00 /mo	60 mo	$	7,500
. Travel	$ 125.00 /mo	60 mo	$	7,500
. Vehicle Expenses	$ 500.00 /mo	60 mo	$	30,000
. Miscellaneous Expenses	$ 185.00 /mo	60 mo	$	11,100
		Total Office Expenses	$	66,300

6.6.3 Construction Equipment

Rental of a small backhoe				
4 times per year, 2 days each rental period	$ 450.00 /day	40 days	$	18,000
		Total Construction Equipment	$	18,000

6.6.4 Environmental Monitoring

. Groundwater Monitoring				
7 samples per quarter for 5 years	$ 1,660 /smp	140 smp	$	232,400
. Vegetation Sampling				
6 samples annually for 5 years	$ 451.00 /smp	30 smp	$	13,530
. Soil Sampling				
6 samples per quarter for 5 years	$ 451.00 /smp	120 smp	$	54,120
. Air Monitoring				
4 samples per quarter for 1 year	$ 100.00 /smp	16 smp	$	1,600
. Vadose Zone Monitoring				
11 samples per quarter for 5 years	$ 460.00 /smp	220 smp	$	101,200
		Total Environmental Monitoring	$	402,850

6.6.5 Subtotal Estimated Costs for Section 6.6, (Stabilization Period)		**$**	**1,559,120**
in 1996 Dollars	**Plus 25% Contingency**	**$**	**1,948,900**
	Plus Interest @ 7% (5 years)	**$**	**2,733,527**
	Plus US Ecology oversight @ 29%	**$**	**4,682,427**

6.7 *Perpetual Care and Maintenance* Period (100 Yrs), from beginning of year 8 through end of year 107

In years 8-107, groundwater monitoring, vegetation sampling, soil sampling, and vadose monitoring will be conducted on an annual basis. Air monitoring will not be conducted.

6.7.1 Environmental Monitoring

. Groundwater Monitoring						
7 samples annually	$	1,660 /smp	700	smp	$	1,162,000
. Vegetation Sampling						
6 samples annually	$	451.00 /smp	600	smp	$	270,600
. Soil Sampling						
6 samples annually	$	451.00 /smp	600	smp	$	270,600
. Vadose Zone Monitoring						
11 samples annually	$	100.00 /smp	1,100	smp	$	110,000
. Pump replacements/repair						
Assume replacement of both purge and sample pumps in all wells every 10 years (replace a total of 70 pumps)	$	310.00 /pump	70	pumps	$	21,700
		Total Environmental Monitoring			$	1,813,200

6.7.2 Contractor Costs

. Assume following rates:
Technicians at $57.50/hr
Maintenance Laborers at $31.60/hr
Maintenance Foreman at $44.70/hr

Each item below is costed for 100 years unless otherwise specified

. HP technicians:						
Groundwater and Vadose Zone Sampling						
2 Techs, $57.50/hr, 8hr/dy, 10 dy/qtr	$	57.50 /hr	64,000	hrs	$	3,680,000
. Vegetation and Soil Sampling						
2 Techs, $57.50/hr, 8hr/dy, 1dy/yr	$	57.50 /hr	1,600	hrs	$	92,000
. Maintenance Personnel						
2 laborers, 8hr/dy, 3dy/visit, 2 visits/yr	$	31.60 /hr	9,600	hrs	$	303,360
1 foreman, 8hr/dy, 3dy/visit, 2 visits/yr	$	44.70 /hr	4,800	hrs	$	214,560

NOTE: Routine trench surveys and environmental monitorings to be conducted by on-site RSO.

Equipment						
$450/day, 3 dy/visit, 2 visit/yr	$	450.00	/yr	600	yr	$ 270,000
Contingency Costs						
3 men plus equipment for 3 days each year						
2 laborers, 8hr/dy, 3dy/visit, 1 visits/yr	$	31.60	/hr	4,800	hrs	$ 151,680
1 foreman, 8hr/dy, 3dy/visit, 1 visits/yr	$	44.70	/hr	2,400	hrs	$ 107,280
$450/day, 3 dy/visit, 1 visit/yr	$	450.00	/yr	300	yr	$ 135,000
Trench Surveys						
2 techs, $57.50/hr, 8hr/dy, 2dy/sur, 1 srvy/yr	$	57.50	/yr	3,200	yr	$ 184,000
Fence Replacement						
Assume entire fence will be replaced						
once during closure period						
8850 lf x $15.90/lf	$	15.90	/lf	8,850	lf	$ 140,715
1 gate	$	1,500	/gate	1	ea	$ 1,500
				Total Contractor Costs		$ 5,280,095

6.7.3 Subtotal Estimated Costs for Section 6.7, *(PC & M)* in 1996 Dollars

Total PC & M Period	**$**	**7,093,295**
Plus 25% Contingency	**$**	**8,866,619**

6.8 State of Washington Administration Costs

The following assumed rates are used through this section in calculating estimated State costs

HP Tech at Richland at $34,500/yr ($16.50/hr)
HP at Olympia at $40,250/yr ($19/hr)
Secretarial support at Olympia at $20,700/yr ($10.00/hr)

6.8.1 Site Closure (2 Years)

a. Personnel Salaries

. Richland HP Tech						
1 Full time for 2 years	$ 34,500	/yr	2	yr	$	69,000
. Olympia HP						
1 Part time for 2 years	$ 40,250	/yr	1	yr	$	40,250
. Olympia Secretarial Support						
1 Part time for 2 years	$ 20,700	/yr	1	yr	$	20,700
					$	129,950
			60% OH & Benefits		$	77,970
			Total Salaries Cost		$	207,920

b. Expenses

. Miscellaneous Office Supplies						
Copying, postage, etc. at $1,700 yr	$ 1,700	/yr	2	yr	$	3,400
. Travel (1 visit per month, 3 days each visit)						
Airfare (12 round trips per year for 2 years)	$ 350	/visit	24	visits	$	8,400
Car rental (3 days, 1 per month for 2 years)	$ 65	/dy	72	dy	$	4,680
Per diem (3 days, 1 per month for 2 years)	$ 75	/dy	72	dy	$	5,400
			Subtotal, Travel		$	18,480

c. Total Costs Section 6.8.1 (a & b)

Total State Administration Costs for Site Closure	$	229,800
Plus 25% Contingency	$	287,250

6.8.2 Stabilization Period (5 Years)

a. Personnel Salaries

. Assume no on-site state supervision

. Personnel:

Olympia HP						
3 months/year for 5 years	$ 40,250	/yr	1.25	yrs	$	50,313
Olympia HP						
1 site visit/qtr, 3 days per visit	$ 19.00	/hr	480	hrs	$	9,120
Olympia Secretarial Support						
2 weeks per year	$ 10.00	/hr	400	hrs	$	4,000
					$	63,433
			60% OH & Benefits		$	38,060
			Total Salaries Cost		$	101,492

b. Expenses

. Miscellaneous Office Supplies						
Copying, postage, etc. at $1,125 yr	$	1,125	/yr	5	yr	$ 5,625
. Travel (1 visit per month, 3 days each visit)						
Airfare (12 round trips per year)	$	350	/rt	60	rt	$ 21,000
Car rental (3 days, 1 per month for 5 years)	$	65	/dy	180	dy	$ 11,700
Per diem (3 days, 1 per month for 5 years)	$	75	/dy	180	dy	$ 13,500
				Subtotal Expenses		$ 51,825

c. Total Cost Section 6.8.2 (a & b)

Total State Costs for Stabilization Period	$ 153,317
Plus 25% Contingency	$ 191,646

6.8.3 Post Closure and Maintenance Period (100 Years)

a. Personnel Salaries

. Assume no on-site state supervision

. Personnel:

Olympia HP						
3 months/year for 10 years	$	40,250	/yr	2.50	yrs	$ 100,625
Olympia HP						
1 month/year for 90 years	$	40,250	/yr	7.50	yrs	$ 301,875
Olympia HP						
1 site visit/month, 3 days each for 10 years	$	19.00	/hr	2,880	hrs	$ 54,720
Olympia HP						
1 site visit/quarter, 3 days each for 90 years	$	19.00	/hr	8,640	hrs	$ 164,160
Olympia Secretarial Support						
2 weeks per year for 100 years	$	10.00	/hr	8,000	hrs	$ 80,000
						$ 701,380
				60% OH & Benefits		$ 420,828
				Total Salaries Cost		$ 1,122,208

b. Expenses

. Miscellaneous Office Supplies						
Copying, postage, etc. at $1,125 yr	$	1,125	/yr	100	yr	$ 112,500
. Travel (1 visit per month, 3 days each visit for 10 years)						
Airfare (12 round trips per year for 10 years)	$	350	/rt	120	rt	$ 42,000
Car rental (3 days, 1 per month for 10 years)	$	65	/dy	360	dy	$ 23,400
Per diem (3 days, 1 per month for 10 years)	$	75	/dy	360	dy	$ 27,000
. Travel (1 visit per quarter, 3 days each visit for 90 years)						
Airfare (4 round trips per year for 90 years)	$	350	/rt	360	rt	$ 126,000
Car rental (3 days, 1 per quarter for 90 years)	$	65	/dy	1,080	dy	$ 70,200
Per diem (3 days, 1 per quarter for 90 years)	$	75	/dy	1,080	dy	$ 81,000
				Subtotal, Expensesl		$ 482,100

c. Total Cost Section 6.8.3 (a & b)

Post Closure and Maintenance Period	**$ 1,716,808**
Plus 25% Contingency	**$ 2,146,010**

6.8.4 Subtotal Estimated Cost for Section 6.8, (State of Washington Administrative Costs) in 1996 Dollars — **Total $ 2,624,906**

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Section 6

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SET 1 DRAWINGS

CLOSURE CAP

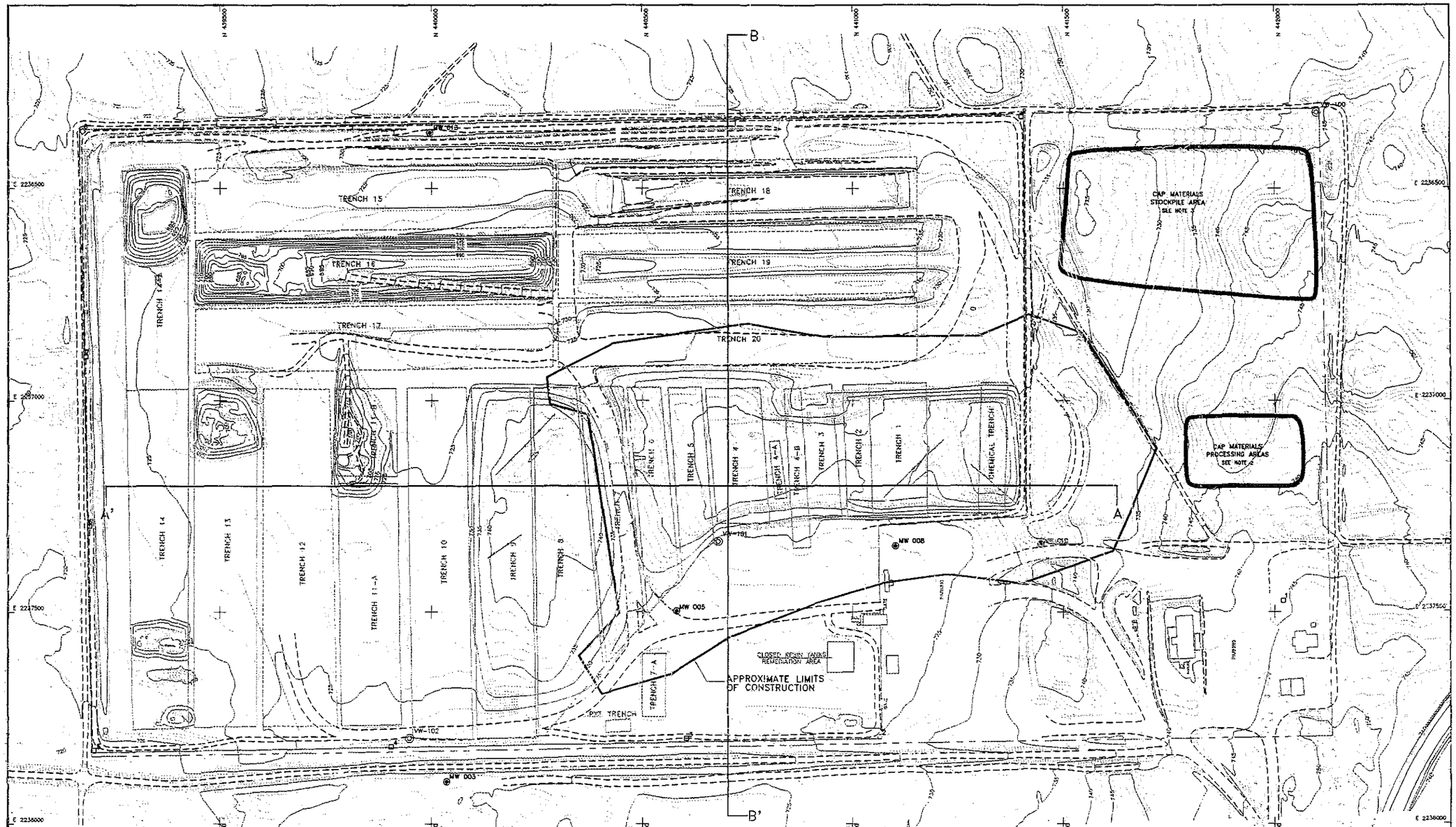
TRENCHES 1 - 6 AND CHEMICAL TRENCH

TITLE	SHEET NO.
COVER SHEET	1
SITE PLAN SHOWING AREA OF CONSTRUCTION	2
SITE GRADING PLAN	3
BOTTOM OF SAND LOW PERMEABILITY BARRIER LAYER	4
TOP OF CAPILLARY BARRIER LAYER	5
CROSS-SECTION N440700 AND E2237200	6

SET 2 DRAWINGS

SITE CLOSURE CAP

TITLE	SHEET NO.
COVER SHEET	1
SITE PLAN SHOWING AREA OF CONSTRUCTION	2
SITE GRADING PLAN	3
BOTTOM OF SAND LOW PERMEABILITY BARRIER LAYER	4
TOP OF CAPILLARY BARRIER LAYER	5
CROSS-SECTION E22373200 AND E2236700	6
CROSS-SECTION N440700 AND N439700	7



NOTES:

1) OVERBURDEN SOIL PLACED OVER CLOSED TRENCHES SHALL BE REMOVED. THE SURFACE SHALL BE REGRADED TO ELEVATIONS SHOWN.
2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.

LEGEND

- VW-100 VADOSE MONITORING WELL
- MW 008 GROUNDWATER MONITORING WELL
- POWER POLE
- 1237T
- 000 ENVIRONMENTAL MONITORING STATIONS
- PROPERTY LINE
- FENCE LINE
- EXISTING TRENCH
- FUTURE TRENCH
- FACILITY ACCESS ROADS
- PRESENT TOPOGRAPHIC CONTOUR LINE
- APPROXIMATE LIMITS OF CONSTRUCTION

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
0 2 4 6 8 10 20
MILES IN EACH DIRECTION (%)

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PAC" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
RICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endris Eng.	Chase Env.			Issued for facility use

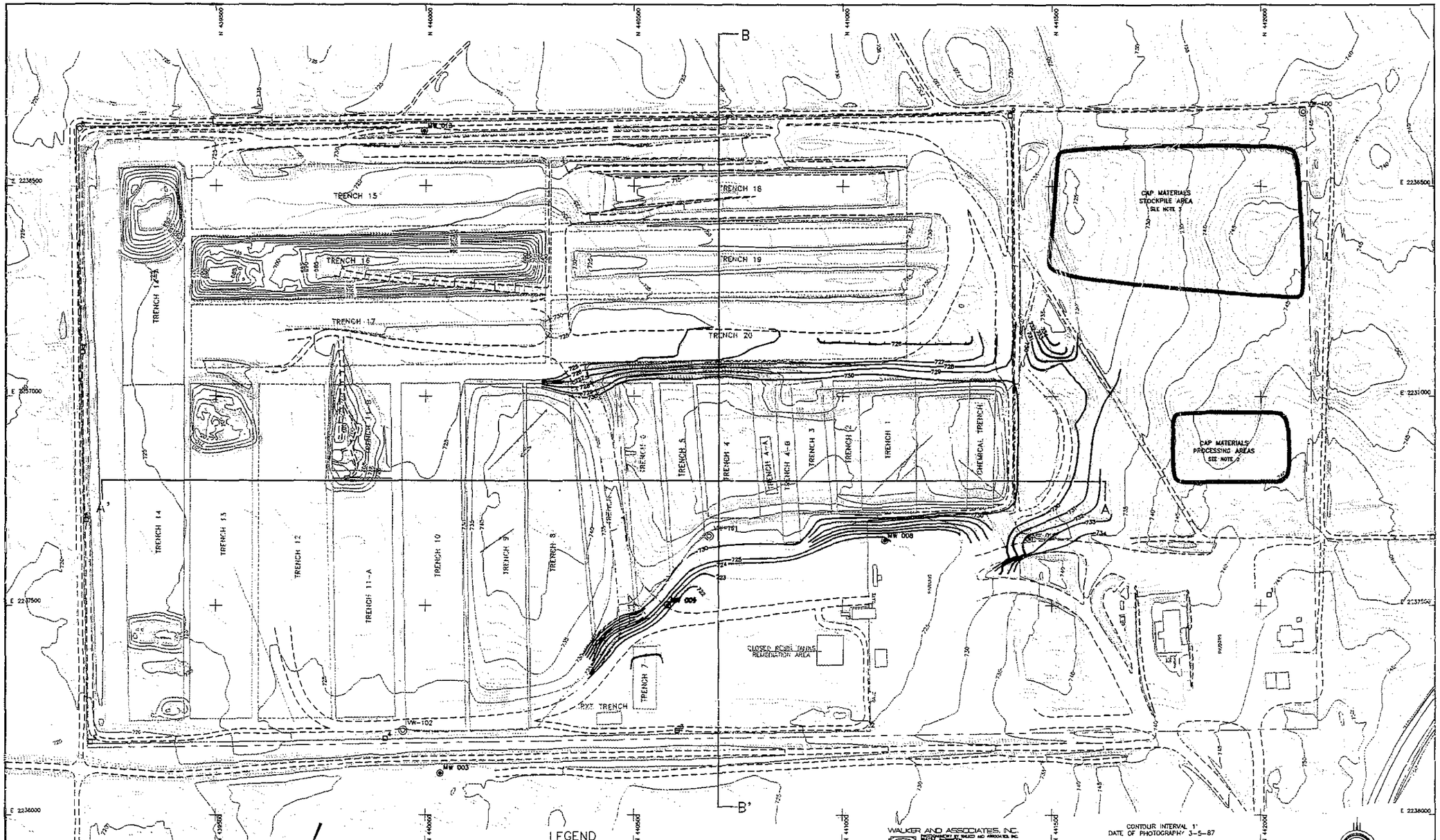
REVISIONS

US ECOLOGY, INC.
Prepared By: GRANT and CEG
Reference Drawings
WN-TOP-205-000 REV 0

Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108

CLOSURE CAP
FACILITY TOPOGRAPHY MAP
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-01-002 rev 0
Sheet No. 2



NOTES:

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2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/ADDING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.

LEGEND

- VW-100 VADOSE MONITORING WELL
- MW 008 GROUNDWATER MONITORING WELL
- POWER POLE
- LIGHT
- 000 ENVIRONMENTAL MONITORING STATIONS
- PROPERTY LINE
- FENCE LINE
- EXISTING TRENCH
- FUTURE TRENCH
- FACILITY ACCESS ROADS
- PRESENT TOPOGRAPHIC CONTOUR LINE
- REGRADED SUBGRADE ELEVATION

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
6 0.3 PERCENT OF CALM(%)
0 2 4 6 8 10 20
MILES IN EACH DIRECTION (%)

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PUG" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
ENVIRONMENT BY WALKER AND ASSOCIATES, INC.
RICHLAND, WASHINGTON
TWO BASE TIES CREATED BY PROGRAMMETRIC ESTIMATES FOR 1"=100'
MAPPING FROM PHOTO DATE: AUGUST 20, 1985
GROUND CONTROL BY
ROGERS SURVEYING INC. P.S.
RICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endrie Eng.	Chase Eng.			Issued for facility use

REVISIONS

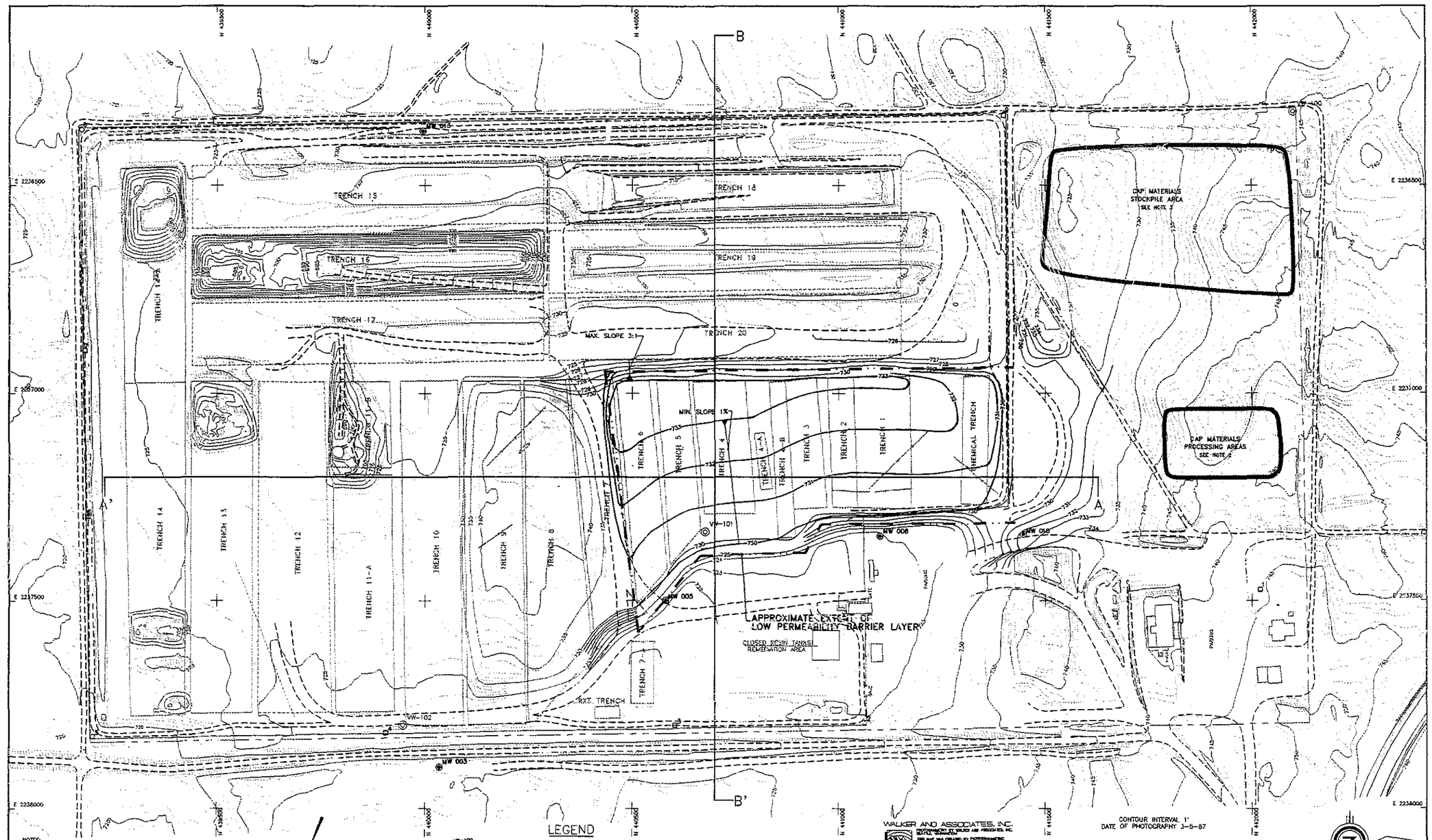
US ECOLOGY, INC.
Prepared By: GRANT
and CGS

Reference Drawings
WN-TOP-205-000 REV 0

Drawn By: Endrie Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108

CLOSURE CAP
SITE SUBGRADE PLAN
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-01-003 rev 0
Sheet No. 3



NOTES:

1) OVERBURDEN SOIL PLACED OVER CLOSED TRENCHES SHALL BE REMOVED. THE SURFACE SHALL BE REGRADED TO ELEVATIONS SHOWN.
2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.

LEGEND

- VW-100 VADOSE MONITORING WELL
- MW 008 GROUNDWATER MONITORING WELL
- POWER POLE
- LIGHT
- 000 ENVIRONMENTAL MONITORING STATIONS
- PROPERTY LINE
- FENCE LINE
- EXISTING TRENCH
- FUTURE TRENCH
- FACILITY ACCESS ROADS
- PRESENT TOPOGRAPHIC CONTOUR LINE
- REGRADED CONTOUR LINE
- PROPOSED ELEVATION OF BOTTOM OF LOW PERMEABILITY BARRIER LAYER

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
0 2 4 6 8 10 30
WIND IN EACH DIRECTION (%)

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PUG" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
KICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY J-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV.	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endris Eng.	Chase Env.			Issued for facility use

REVISIONS

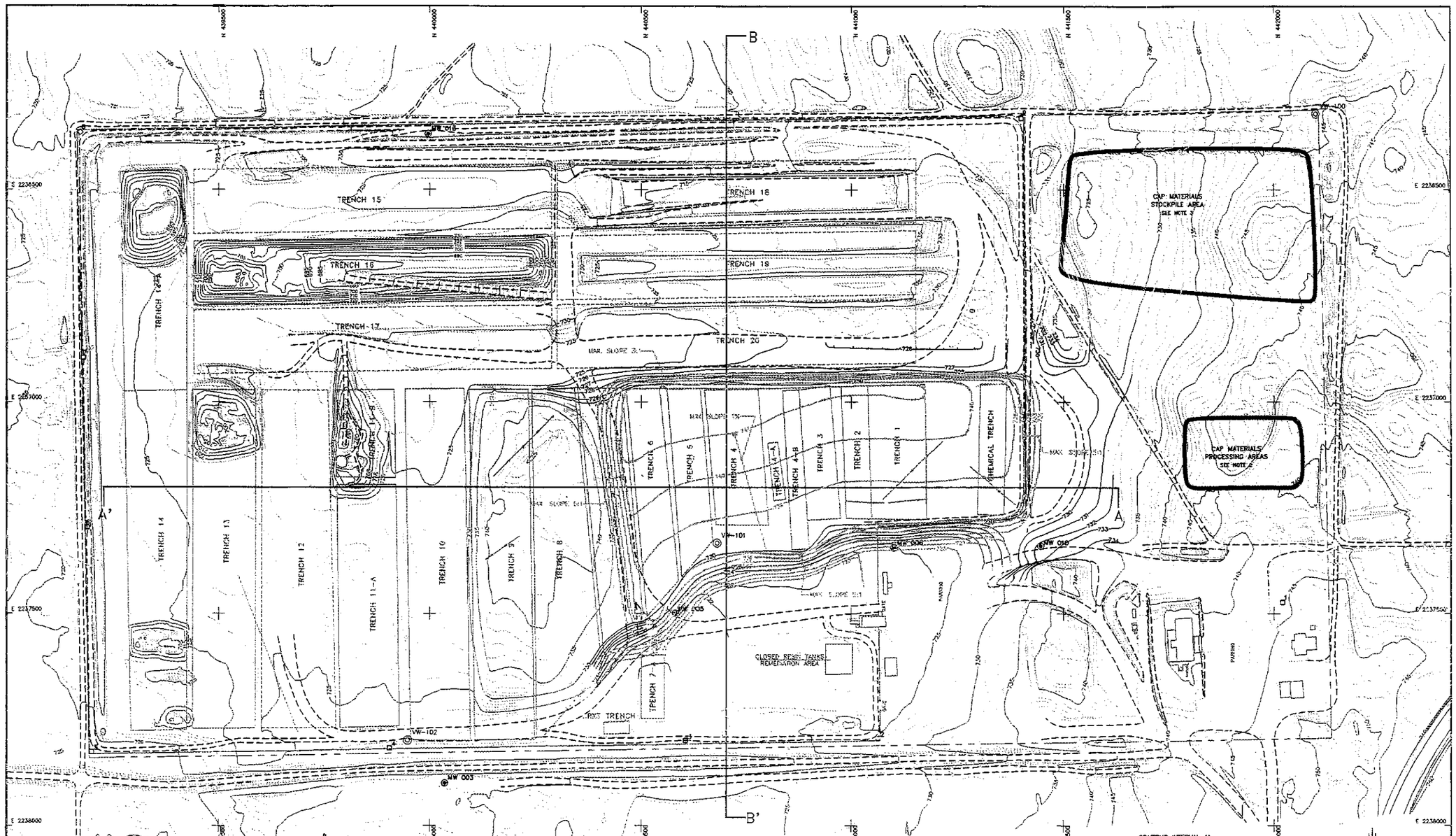
US ECOLOGY, INC.
Prepared By: GRANT and CGG CHASE ENVIRONMENTAL GROUP, INC.

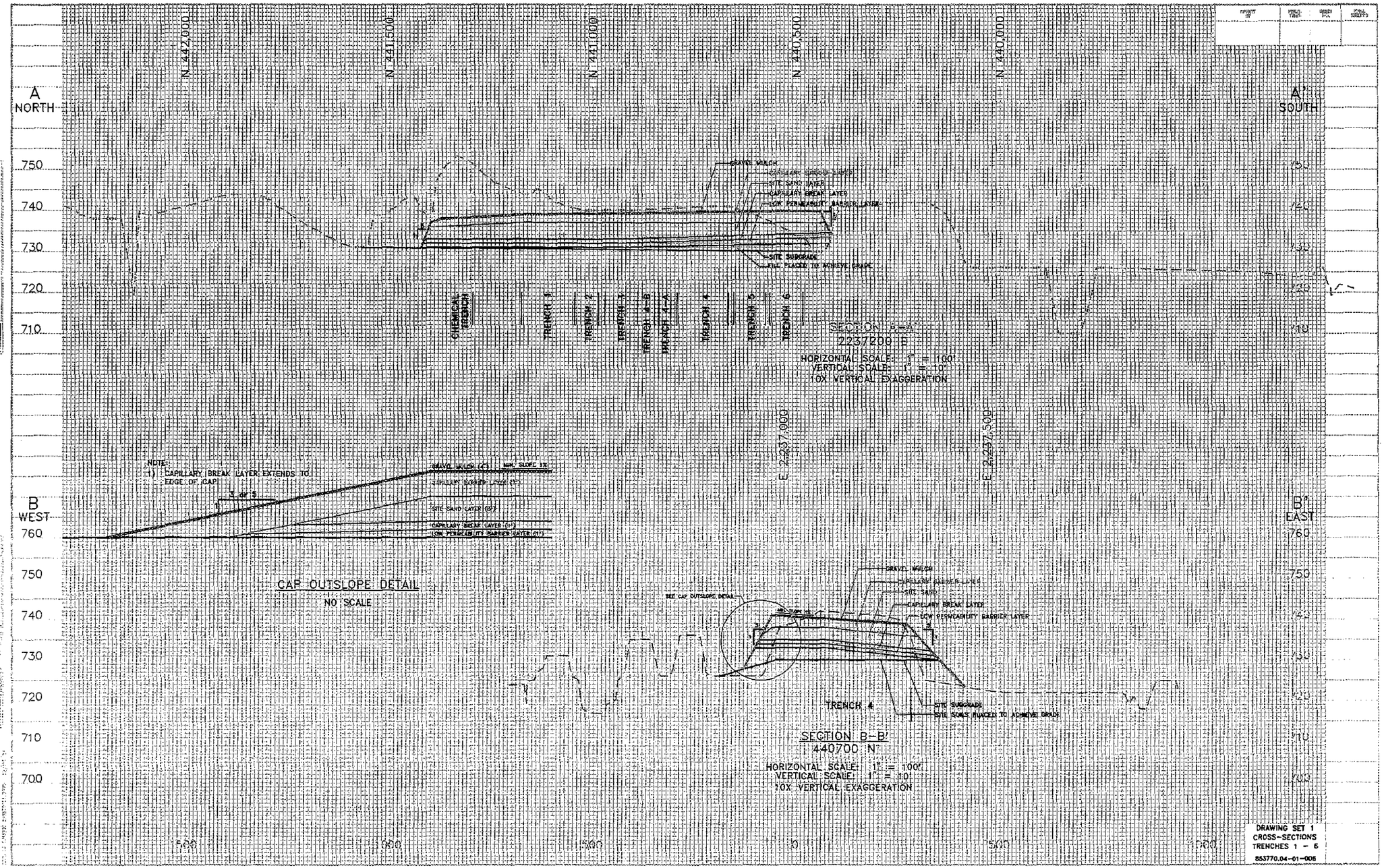
Reference Drawings
WN-TOP-205-000 REV 0

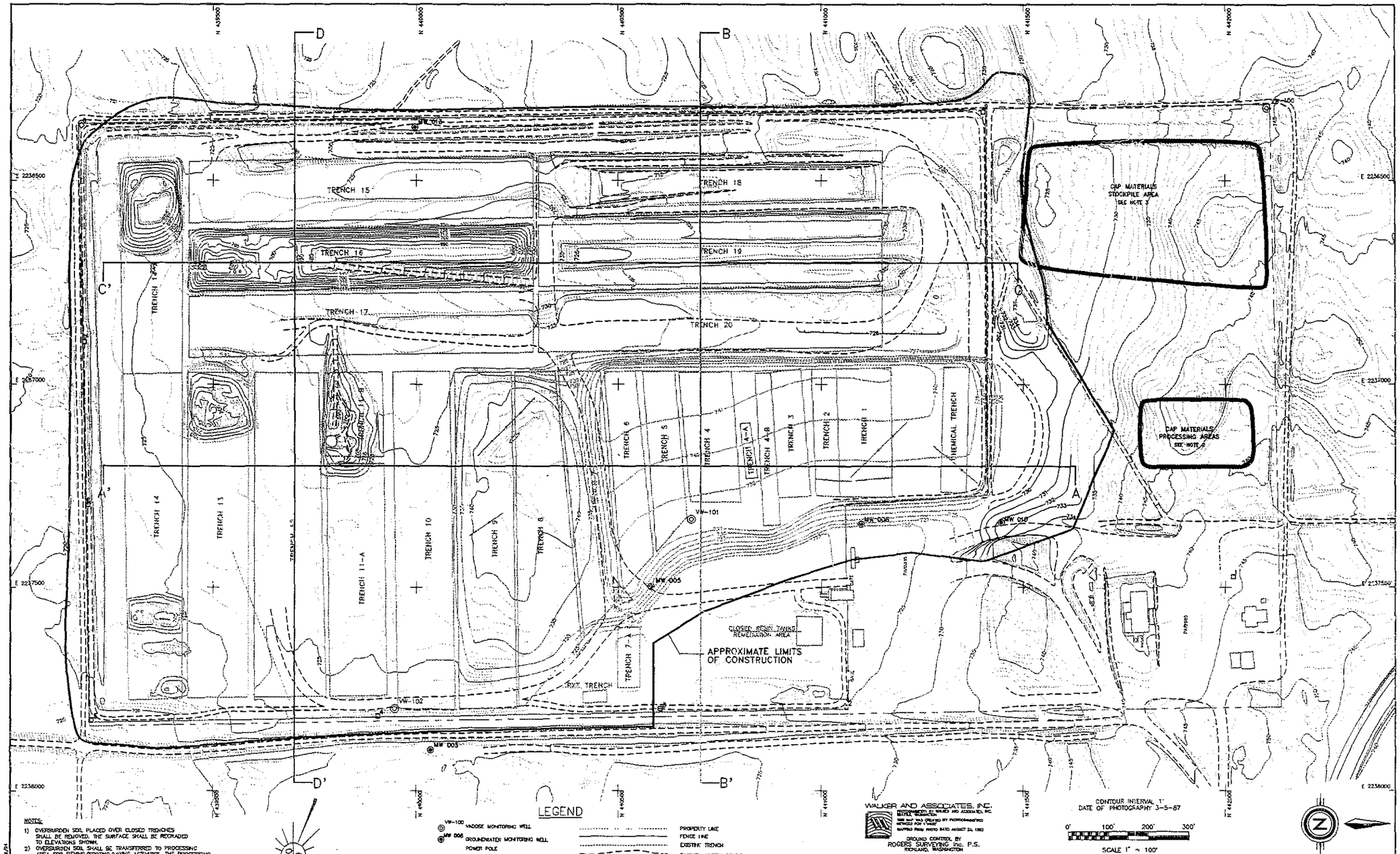
Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108

CLOSURE CAP
BOTTOM OF LOW PERMEABILITY BARRIER LAYER
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-01-004 rev 0
Sheet No. 4


TRENCH 15
TRENCH 16
TRENCH 17
TRENCH 18
TRENCH 19
TRENCH 20
TRENCH 14
TRENCH 13
TRENCH 12
TRENCH 11-A
TRENCH 10
TRENCH 9
TRENCH 8
TRENCH 7
TRENCH 6
TRENCH 5
TRENCH 4
TRENCH 4-A
TRENCH 4-B
TRENCH 3
TRENCH 2
TRENCH 1
CHEMICAL TRENCH
RYE TRENCH
CAP MATERIALS STOCKPILE AREA SEE NOTE 3
CAP MATERIALS PROCESSING AREAS SEE NOTE 2
CLOSED RESIN TANKS REMEDIATION AREA
MAX. SLOPE 3:1
MAX. SLOPE 5:1
MAX. SLOPE 10:1
MAX. SLOPE 15:1
MAX. SLOPE 20:1
MAX. SLOPE 25:1
MAX. SLOPE 30:1
MAX. SLOPE 35:1
MAX. SLOPE 40:1
MAX. SLOPE 45:1
MAX. SLOPE 50:1
MAX. SLOPE 55:1
MAX. SLOPE 60:1
MAX. SLOPE 65:1
MAX. SLOPE


A
NORTH
A'
SOUTH
N 442,000
N 441,500
N 441,000
N 440,500
N 440,000
750
740
730
720
710
GRAVEL MULCH
CAPILLARY BARRIER LAYER
SITE SAND LAYER
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
SITE SUBGRADE
FILL PLACED TO ACHIEVE GRADE
CHEMICAL TRENCH
TRENCH 1
TRENCH 2
TRENCH 3
TRENCH 4-B
TRENCH 4-A
TRENCH 4
TRENCH 5
TRENCH 6
SECTION A-A'
2237200 E
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
E 2,237,000
E 2,237,500
NOTE:
1) CAPILLARY BREAK LAYER EXTENDS TO EDGE OF CAP
2 OF 3
1
GRAVEL MULCH (0")
MIN. SLOPE 3%
CAPILLARY BARRIER LAYER (6")
SITE SAND LAYER (12")
CAPILLARY BREAK LAYER (1")
LOW PERMEABILITY BARRIER LAYER (6")
B
WEST
B'
EAST
CAP OUTSLOPE DETAIL
NO SCALE
SEE CAP OUTSLOPE DETAIL
GRAVEL MULCH
CAPILLARY BARRIER LAYER
SITE SAND
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
TRENCH 4
SITE SUBGRADE
SITE SOILS PLACED TO ACHIEVE GRADE
SECTION B-B'
440700 N
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
1500
1000
500
0
500
1000
DRAWING SET 1
CROSS-SECTIONS
TRENCHES 1 - 6
853770.04-01-006


TRENCH 15
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TRENCH 14
TRENCH 13
TRENCH 12
TRENCH 11-A
TRENCH 10
TRENCH 9
TRENCH 8
TRENCH 7
TRENCH 6
TRENCH 5
TRENCH 4
TRENCH 4-A
TRENCH 4-B
TRENCH 3
TRENCH 2
TRENCH 1
CHEMICAL TRENCH
PIT TRENCH
CAP MATERIALS STOCKPILE AREA SEE NOTE 3
CAP MATERIALS PROCESSING AREAS SEE NOTE 4
CLOSED RCRA TANKS REMEDIATION AREA
APPROXIMATE LIMITS OF CONSTRUCTION
VW-101
VW-102
MW 005
MW 006
MW 008
MW 010
A
A'
B
B'
C
C'
D
D'
N 439500
N 440000
N 440500
N 441000
N 441500
N 442000
E 2236500
E 2237000
E 2237500
E 2238000
CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87
0' 100' 200' 300'
SCALE 1" = 100'
WALKER AND ASSOCIATES, INC.
GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
RICHLAND, WASHINGTON
LEGEND
VADOSE MONITORING WELL
GROUNDWATER MONITORING WELL
POWER POLE
LIGHT
ENVIRONMENTAL MONITORING STATIONS
PROPERTY LINE
FENCE LINE
EXISTING TRENCH
FACILITY ACCESS ROADS
PRESENT TOPOGRAPHIC CONTOUR LINE
REGRADED CONTOUR LINE
FINAL CAP OVER TRENCHES 1 - 6 AND CHEMICAL TRENCH
PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"
The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PUG" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).
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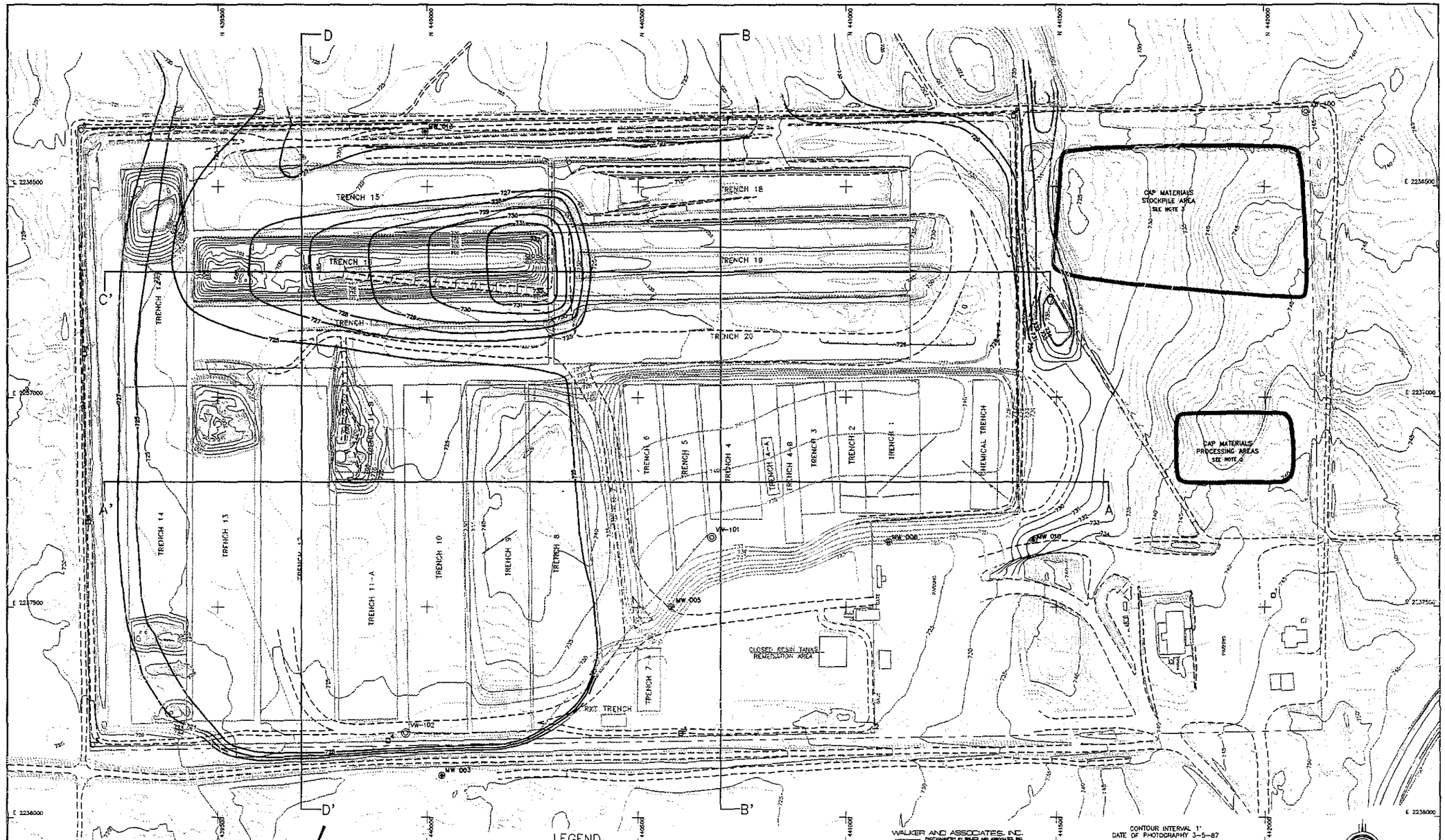
2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIZING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.
4) AS-BUILT ELEVATIONS AND LOCATIONS OF TRENCH 16 WERE OBTAINED FROM ROGERS AND ASSOCIATES, APRIL 30, 1993.
US ECOLOGY, INC.
Prepared By: GRANT
and CEG
Issued for facility use
REVISIONS
Reference Drawings
WN-TOP-205-000 REV 0
Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108
SITE CLOSURE PLAN
FACILITY TOPOGRAPHY MAP
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON
Drawing No. 853770.04-02-002 rev 0
Sheet No. 2



NOTES:

1) OVERBURDEN SOIL PLACED OVER CLOSED TRENCHES SHALL BE REMOVED. THE SURFACE SHALL BE REGRADED TO ELEVATIONS SHOWN.
2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.
4) AS-BUILT ELEVATIONS AND LOCATIONS OF TRENCH 16 WERE OBTAINED FROM ROGERS AND ASSOCIATES, APRIL 30, 1993.

LEGEND

- VW-100 VADOSE MONITORING WELL
- WW 006 GROUNDWATER MONITORING WELL
- POWER POLE
- LIGHT
- 000 ENVIRONMENTAL MONITORING STATIONS
- PROPERTY LINE
- FENCE LINE
- EXISTING TRENCH
- FACILITY ACCESS ROADS
- PRESENT TOPOGRAPHIC CONTOUR LINE
- REGRADED CONTOUR LINE
- PROPOSED GRADING ELEVATION
- FINAL CAP OVER TRENCHES 1 – 5 AND CHEMICAL TRENCH

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
0 2 4 6 8 10 20
MPH IN EACH DIRECTION (%)

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PMC" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
RICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endris Eng.	Chase Env.			Issued for facility use

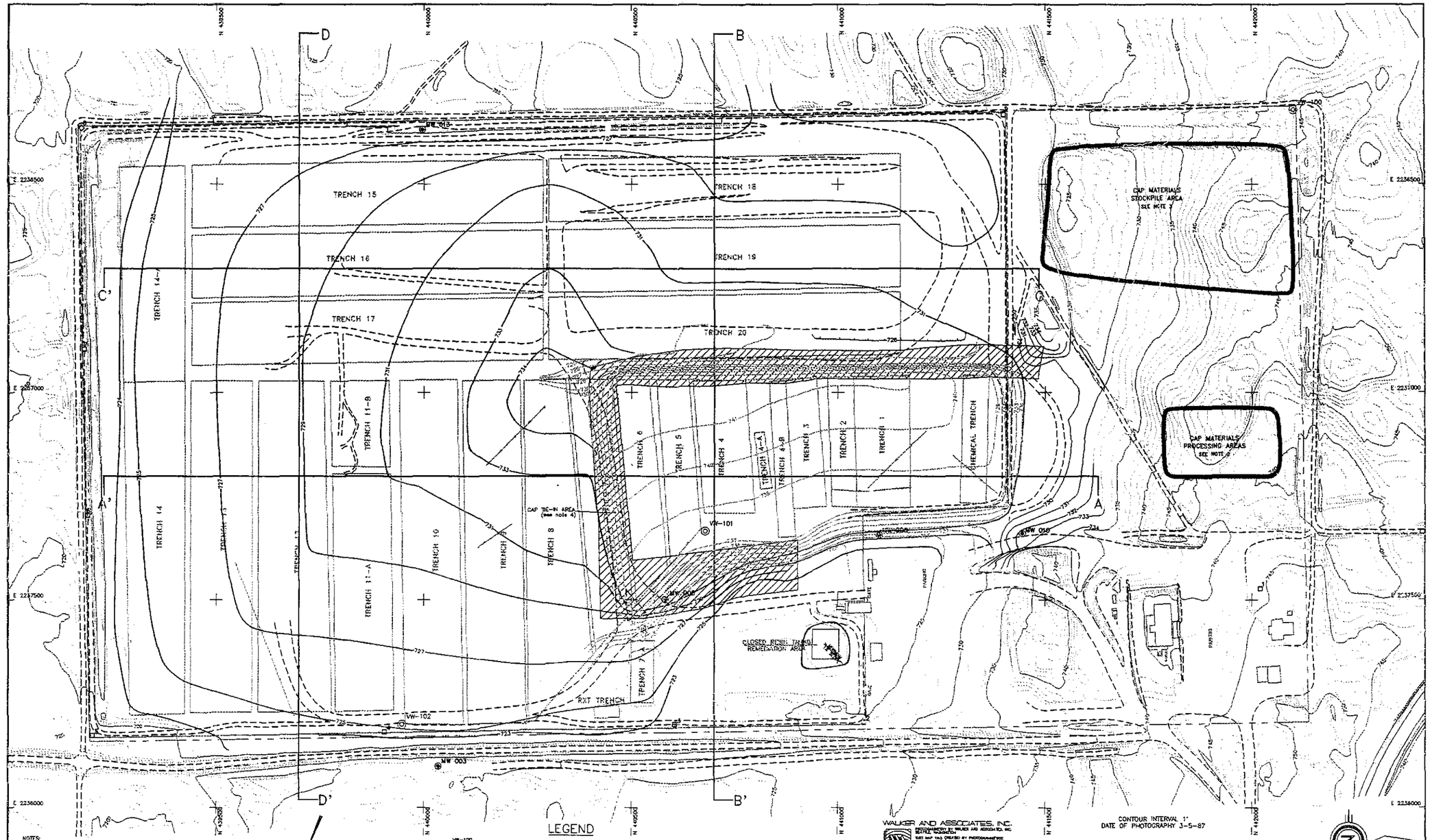
REVISIONS

US ECOLOGY, INC.
Prepared By: GRANT and CGY
Reference Drawings
WN-TOP-205-000 REV 0

Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108

SITE CLOSURE PLAN
SITE GRADING PLAN
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-02-003 rev 0
Sheet No. 3



NOTES:

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2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.
4) A PORTION OF THE FINAL CAP PLACED OVER TRENCHES 1 – 6/ CHEMICAL TRENCH WILL BE REWORKED IN ORDER TO CONSTRUCT THE REMAINING PORTIONS OF THE CAP AT FACILITY CLOSURE.
5) MONITORING WELLS SHALL BE EXTENDED PRIOR TO CAP CONSTRUCTION.

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
0 2 4 6 8 10 20
*MEAN AT EACH DIRECTION (%)

LEGEND

- VW-100 VADOSE MONITORING WELL
- NW 000 GROUNDWATER MONITORING WELL
- POWER POLE
- LIGHT
- 000 ENVIRONMENTAL MONITORING STATIONS
- PROPERTY LINE
- FENCE LINE
- EXISTING TRENCH
- FACILITY ACCESS ROADS
- PRESENT TOPOGRAPHIC CONTOUR LINE
- REGRADED CONTOUR LINE
- BOTTOM OF SAND/ BENTONITE LAYER
- FINAL CAP OVER TRENCHES 1 – 6 AND CHEMICAL TRENCH

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on N.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PUC" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
ENGINEERS AND SURVEYORS
SURVEY MAPPING
SURVEY MAP WAS CREATED BY PHOTOGRAMMETRIC METHODS FOR 1987
MAPPING FROM PHOTO DATED AUGUST 23, 1987

GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
RICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endris Eng.	Chase Env.			Issued for facility use

REVISIONS

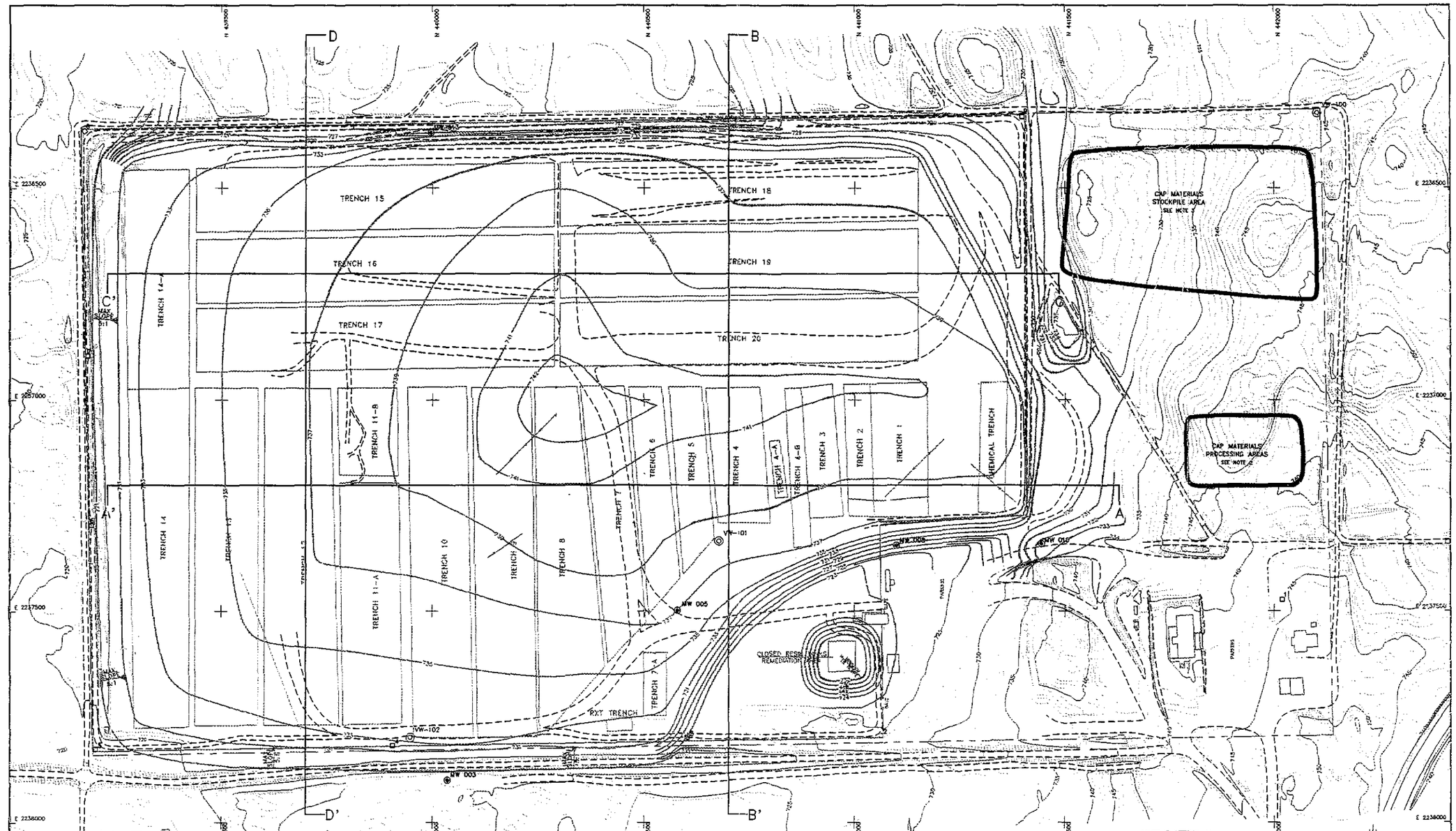
US ECOLOGY, INC.
Prepared By: GRANT and CGG

Reference Drawings
WN-TOP-205-000 REV 0

Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No.: WA-108

SITE CLOSURE PLAN
BOTTOM OF LOW PERMEABILITY BARRIER LAYER
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY, INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-02-004 rev 0
Sheet No. 4



NOTES:

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2) OVERBURDEN SOIL SHALL BE TRANSFERRED TO PROCESSING AREA FOR SIEVING/SORTING/MIXING ACTIVITIES. THE PROCESSING AREA SHALL BE GRADED AS NECESSARY FOR EQUIPMENT PLACEMENT.
3) THE SOILS TO BE USED IN CAP CONSTRUCTION SHALL BE PLACED IN SEGREGATED STOCKPILES BASED UPON CLASSIFICATION.

PERCENT OF TIME (%)
HANFORD METEOROLOGICAL STATION NUMBER
PERCENT OF CALM(%)
0 2 4 6 8 10 20
MEAN IN EACH DIRECTION (%)

LEGEND

VW-100 VADOSE MONITORING WELL
NW 008 GROUNDWATER MONITORING WELL
POWER POLE
LIGHT
ENVIRONMENTAL MONITORING STATIONS
PROPERTY LINE
FENCE LINE
EXISTING TRENCH
FACILITY ACCESS ROADS
PRESENT TOPOGRAPHIC CONTOUR LEVEL
TOP OF CAPILLARY BARRIER LAYER

LATITUDE N 46° 32' 17"
LONGITUDE W 119° 33' 29"

The horizontal control is based on H.G.S. North American datum of 1927, adjusted 1947, Lambert Grid system, Washington South Zone. The reference points used were station "PUK" (Quad 481194, Station No. 1047) and "CABLE" (Quad 481191, Station No. 1011).

The vertical control is based on U.S.C. & G.S. datum, 1947 adjustment of second-order leveling from B.M. No. J-317.

WALKER AND ASSOCIATES, INC.
GROUND CONTROL BY
ROGERS SURVEYING Inc. P.S.
RICHLAND, WASHINGTON

CONTOUR INTERVAL 1'
DATE OF PHOTOGRAPHY 3-5-87

0' 100' 200' 300'
SCALE 1" = 100'

REV	DRAWN	CHECK	APPR	DATE	DESCRIPTION
0	Endris Eng.	Chase Env.			Issued for facility use

REVISIONS

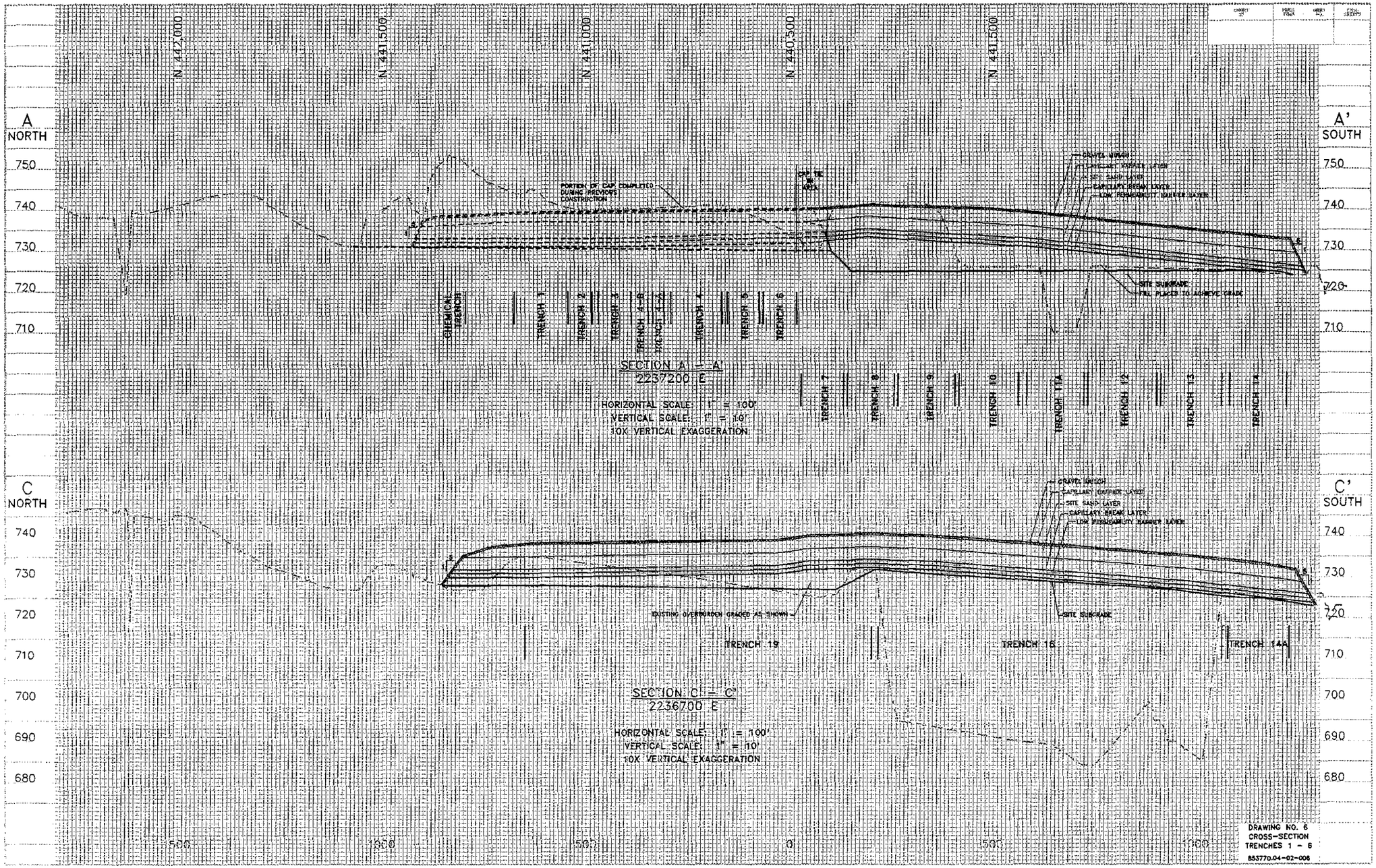
US ECOLOGY, INC.
Prepared By: GRANT
and CGG

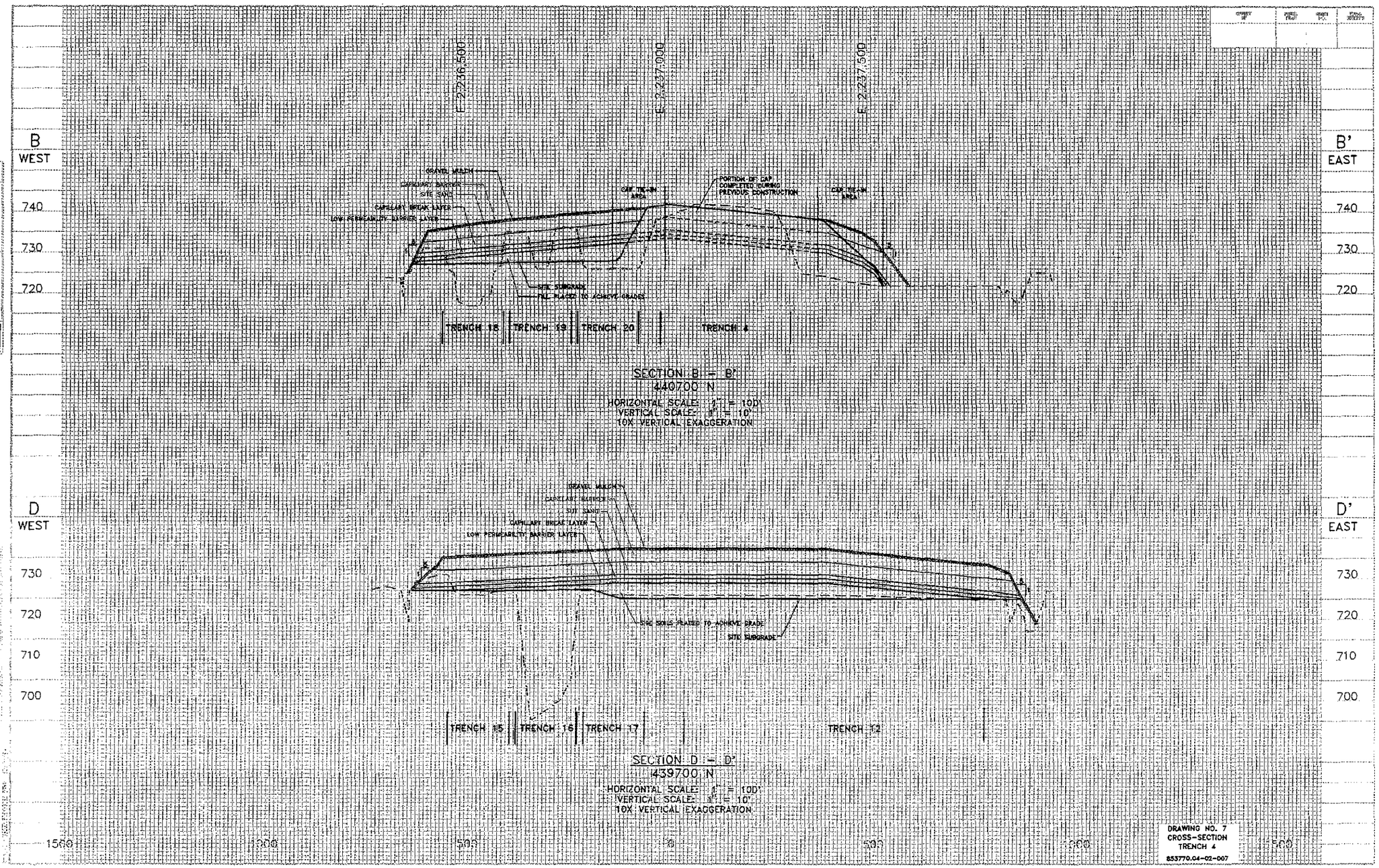
Drawn By: Endris Eng.
Checked By: Chase
Appr. By:
Date:
Scale: 1" = 100'
Project No. WA-108

Reference Drawings
WN-TOP-205-000 REV 0

SITE CLOSURE PLAN
TOP OF CAPILLARY BARRIER LAYER
LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT FACILITY
US ECOLOGY,INC.
RICHLAND, WASHINGTON

Drawing No. 853770.04-02-005 rev 0
Sheet No. 5


N 442,000
N 441,500
N 441,000
N 440,500
N 441,500
A
NORTH
A'
SOUTH
750
740
730
720
710
PORTION OF CAP COMPLETED DURING PREVIOUS CONSTRUCTION
CAP TIE AREA
GRAVEL BERM
CAPILLARY BREAK LAYER
SITE SAND LAYER
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
SITE SUBGRADE
FILL PLACED TO ACHIEVE GRADE
CHEMICAL TRENCH
TRENCH 1
TRENCH 2
TRENCH 3
TRENCH 4-B
TRENCH 4-A
TRENCH 4
TRENCH 5
TRENCH 6
SECTION A - A'
2237200 E
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
TRENCH 7
TRENCH 8
TRENCH 9
TRENCH 10
TRENCH 11A
TRENCH 12
TRENCH 13
TRENCH 14
C
NORTH
C'
SOUTH
740
730
720
710
700
690
680
GRAVEL BERM
CAPILLARY BREAK LAYER
SITE SAND LAYER
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
EXISTING OVERBURDEN GRADED AS SHOWN
SITE SUBGRADE
TRENCH 19
TRENCH 16
TRENCH 14A
SECTION C - C'
2236700 E
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
500
0
500
1000
DRAWING NO. 6
CROSS-SECTION
TRENCHES 1 - 6
853770.04-02-006


E 2236,500
E 2237,000
E 2237,500
B
WEST
B'
EAST
740
730
720
GRAVEL MULCH
CAPILLARY BARRIER
SITE SAND
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
CAP TIE-IN AREA
PORTION OF CAP COMPLETED DURING PREVIOUS CONSTRUCTION
CAP TIE-IN AREA
SITE SUBGRADE
FILL PLACED TO ACHIEVE GRADES
TRENCH 18
TRENCH 19
TRENCH 20
TRENCH 4
SECTION B - B'
440700 N
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
D
WEST
D'
EAST
730
720
710
700
GRAVEL MULCH
CAPILLARY BARRIER
SITE SAND
CAPILLARY BREAK LAYER
LOW PERMEABILITY BARRIER LAYER
SITE SOILS PLACED TO ACHIEVE GRADE
SITE SUBGRADE
TRENCH 15
TRENCH 16
TRENCH 17
TRENCH 12
SECTION D - D'
439700 N
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'
10X VERTICAL EXAGGERATION
1500
1000
500
0
500
1000
1500
DRAWING NO. 7
CROSS-SECTION
TRENCH 4
853770.04-02-007