START

0008801

RHO-WM-SR-3 P

Engineered Barrier Test Facility Status Report: 1984

Date Manuscript Completed: February 1985

S. J. Phillips
M. R. Adams
T. W. Gilbert
C. C. Meinhardt
R. M. Mitchell
W. J. Waugh
Waste Management Systems Engineering
Research and Engineering

Prepared for the U.S. Department of Energy
under Contract DE-AC06-77RL01030

Rockwell International
Rockwell Hanford Operations
P.O. Box 800
Richland, Washington 99352

9212500063

MAY 1990
RECEIVED
EDMC

THIS PAGE INTENTIONALLY
LEFT BLANK

9 2 1 2 5 0 0 0 6 6 4

ABSTRACT

This report provides a general summary of activities completed to date at the Hanford Engineered Barrier Test Facility. This facility is used to test and compare construction practices and performance of alternative designs of engineered barrier cover systems. These cover systems are being evaluated for potential use for isolation and confinement of buried waste dipsosal structures.

9 2 1 2 5 0 0 0 6 6 5

This page intentionally left blank.

9 2 1 2 5 0 0 0 6 6 6

EXECUTIVE SUMMARY

Engineered barrier cover systems are being evaluated at Hanford as cost-effective alternatives for isolation of burial grounds, cribs, caissons, tanks, etc. This report describes the status of development activities that compare and test the performance of several barrier cover system designs.

Comparative engineered barrier cover systems have been constructed at the Hanford Engineered Barrier Test Facility. This facility is located in the W-5-A burial ground expansion area within the 200 West Chemical Separation Area.

Constructed Test Barriers include the following designs:

- Mounded (monolithic) soil
- Mounded (monolithic) rock
- Impermeable surface layer with off-flow of precipitation
- Multilayer (earth material layers) infiltration/biotic intrusion
- Multilayer (earth material layers) biotic intrusion.

Fiscal year 1985 activities include construction of a refined multilayer with intrusion marker systems:

- Multilayer (earth material and woven glass layers) infiltration/biotic intrusion.

The design, specifications, materials requirements, and construction of existing barriers are summarized in the text of the document.

Numerous monitoring systems have been installed at the field test facility to evaluate the abiotic and biotic factors used to determine test barrier performance. Categories of monitoring systems include micrometeorologic, soil physics, soil mechanics, plant intrusion, and animal intrusion. Descriptions and placement of monitoring transducers, modules, and systems are discussed in the text of the document. Several examples of interim monitoring results are also provided.

A methodology to conceptually design engineered barrier cover systems and to evaluate materials requirements and costs for engineered barrier cover systems is outlined in the document. Cost estimates and examples of hypothetical designs are included.

9 2 1 2 5 0 0 0 6 6 7

Several directly related support activities are described in the document.

- Natural analog barrier evaluation.
- Large-scale, one-dimensional infiltration column tests.
- Wind erosion (wind tunnel) barrier surface stability tests.
- Barrier intrusion marker installation and performance tests.
- Computer simulation/prediction infiltration performance evaluation.

Successful completion of these tasks will result in the capability to prepare a definitive design for a scientifically defendable, long-term engineered barrier to be used for in-place stabilization and disposal of Hanford Defense Wastes.

Appendixes are attached to provide graphic and tabular information on engineered barrier cover system design, construction, and performance evaluation.

9 2 1 2 5 0 0 0 6 6 8

CONTENTS

1.0 Introduction 1
1.1 Need 2
1.2 Objectives 2
1.3 Scope 3

2.0 Preconceptual/Conceptual Barrier Design and Cost Assessment 3
2.1 Mounded Soil Design Concept 4
2.2 Mounded Rock Design Concept 4
2.3 Impermeable Off-Flow Design Concept 5
2.4 Multilayer Infiltration/Biotic Intrusion Design Concept 5
2.5 Multilayer Biotic Intrusion Design Concept 8
2.6 Additional Barrier Design Concepts 9

3.0 Engineered Barrier Test Facility Site Selection 9

4.0 Selection of Barrier Materials 10

5.0 Test Barrier Design 11

6.0 Test Barrier Monitoring Components 11
6.1 Abiotic Monitoring Components 11
6.1.1 Soil Physics Instrumentation 13
6.1.2 Micrometeorology Instrumentation 13
6.1.3 Particulate Filtering Instrumentation 14
6.2 Biotic Monitoring Components 14
6.2.1 Flora Intrusion Monitoring 15
6.2.2 Fauna Intrusion Monitoring 15

7.0 Test Barrier Materials and Cost Estimation 16

8.0 Test Barrier Construction and Monitoring Systems Deployment 17
8.1 Mounded Soil Barrier 18
8.2 Mounded Rock Barrier 19
8.3 Impermeable Off-Flow Barrier 19
8.4 Multilayer Infiltration/Biotic Intrusion Barrier 20
8.5 Multilayer Biotic Intrusion Barrier 20

9.0 Preliminary Test Barrier Performance Monitoring Results 21
9.1 Abiotic Monitoring 22
9.2 Biotic Monitoring 23

9 2 1 2 5 0 0 0 6 6 9

10.0 Related and Support Activities 25
10.1 Analog Tasks 25
10.2 Infiltration Column and Wind Tunnel Tasks 26
10.3 Wind Erosion Tasks 27
10.4 Intrusion Barrier Marker Tasks 27
10.5 Numerical Simulation/Prediction Modeling Tasks 28

Acknowledgements 29

References 30

APPENDIXES:
A. Sketches of Test Barriers Constructed at the Engineered Barrier Test Facility A-1
B. Location of the Engineered Barrier Test Facility at the Hanford Site B-1
C. Example Materials Requirements and Specifications for Construction at the Engineered Barrier Test Facility for Each Test Barrier C-1
D. As-Built Engineering Drawings of the Engineered Barrier Test Facility D-1
E. Example Soil Physics Laboratory Characterization of Several Existing and Initially Proposed Test Barrier Materials E-1
F. Example Characteristics of Monitoring Devices and Electronic Systems Deployed at the Engineered Barrier Test Facility F-1
G. Configuration and Placement of Flora and Fauna Intrusion Tracers within Test Barriers at the Engineered Barrier Test Facility G-1
H. Example of Computer Generated Information Used to Evaluate Design Alternatives for Engineered Barriers H-1
I. Example Sequence of Construction Methods Used at the Engineered Barrier Test Facility I-1
J. Example of Preliminary Comparative Soil Moisture Versus Depth Data for Test Barriers and a Control Area at the Engineered Barrier Test Facility J-1
K. Example of Micrometeorological Data Collected at Two Locations at the Engineered Barrier Test Facility K-1
L. Example of a Data Output Record from One Microprocessor-Based Field Data Logger at the Engineered Barrier Test Facility L-1
M. Sketch of a Hypothetical Multilayer Engineered Barrier Denoted as the "Hanford Standard Barrier" M-1

1.0 INTRODUCTION

An integral part of long-term waste management activities at the Hanford Site is the investigation of engineered barrier cover systems. These systems are being investigated on a preliminary basis as alternatives for in-place confinement of radioactive materials in solid- and liquid-waste disposal structures, i.e., burial grounds, cribs, and tanks. Engineered barrier cover systems are intended to provide radionuclide confinement by elimination or significant reduction of: (1) infiltration of meteoric water (precipitation) and the subsequent transport of the radionuclides in the geohydraulic system, (2) intrusion and subsequent uptake and dispersal of radionuclides by plants, (3) intrusion and dispersal of radionuclides by burrowing animals, and (4) erosion of overburden by wind.

To date, efforts investigating engineered barrier cover systems have included preconceptual design, engineering studies, conceptual design, test barrier construction, instrumentation placement, and preliminary performance monitoring. As of September 1984, five alternative barrier designs used for comparative analyses have been constructed at an Engineered Barrier Test Facility (EBTF). This facility is located in the W5A burial ground expansion area within the 200 West waste separations area of the Hanford Site. Numerous reports and engineering drawings have been issued that cover engineering activities associated with barrier preconceptual design, assessment, cost, and cover system construction, EBTF activities, and other activities (Murphy and Holter, 1980; McPherson et al., 1979).

Five generic barrier test plots have been constructed at the EBTF. These include: (a) mounded soil, (b) mounded rock, (c) impermeable surface layer, (d) multilayer infiltration/biotic intrusion, and (e) multilayer biotic intrusion. These test plot designs are divergent with respect to configuration and potential performance. Hence, comparative analysis of the performance of each barrier can be made prior to demonstrating an engineered barrier cover system at an actual waste disposal site. Demonstration of functional, long-term, technically defensible, and cost effective engineered barriers is a priority objective of waste management planning activities at the Hanford Site (DOE-RL, 1984a; DOE-RL, 1984b).

The primary intent of this report is to summarize past accomplishments and progress of engineering field activities relative to and construction of test engineered barriers during fiscal years 1983 and 1984. Additionally, a brief statement of ongoing and future activities is included to show the contribution of EBTF activities to laboratory, field, modeling, and engineering activities required to provide adequate confinement of radioactive materials that are disposed of at the Hanford Site.

9 2 1 2 5 0 0 0 6 7 1

1.1 NEED

Over the past four decades, radioactive waste disposal sites at Hanford have adequately confined waste materials within prescribed release limits. As a result, there has been no significant dose contribution to the public from the operation and maintenance of these sites. However, current regulations and guidance state that the objective of waste disposal is to *"isolate waste in a manner that protects the health and safety of the public and the environment for that period of time which it poses an unacceptable hazard because of its toxicity,"* and furthermore to *"isolate waste materials such that long-term confinement with minimal maintenance is required"* (EG&G, 1984; DOE, 1984). If engineered barrier cover systems or other alternative waste management options are not employed, long-term confinement of radioactive materials within prescribed release limits from high-level, transuranic, and low-level waste disposal sites cannot be assured (DOE-RL, 1984c).

1.2 OBJECTIVES

Nuclear waste management objectives for long-term waste confinement clearly delineate the need for isolation of waste materials. To this end, the objective of this report is to document the approach and progress of the development of engineered barrier cover systems to isolate waste materials. This interim report supports the objectives of waste management planning activities at Hanford, i.e., *"development of engineered barriers to control potential radionuclide transport, as well as radiation exposure to the inadvertent intruder, is an essential part of onsite stabilization and isolation of wastes near the surface, without the need for active monitoring, maintenance, or institutional controls"* (DOE-RL, 1984a; DOE-RL, 1984b).

The results of this activity are intended to be integrated with other relevant activities, planned or in progress, which will provide a technically defensible demonstration of engineered barrier cover systems. Related activities include: (a) conceptual and numerical simulation and prediction of hydrogeologic, biotic, and erosion interactions that tend to enhance or degrade barrier performance over extended time; (b) laboratory investigations of infiltration and erosion phenomena and establishment of semiquantitative design criteria; (c) field investigations of micrometeorological, hydrogeological, and biotic processes simultaneously interacting to affect barrier performance; (d) laboratory and field investigations concerning the placement of intrusion markers and their longevity within selected barrier designs; and (e) the effects of engineered barriers at specific or generic sites relative to overall performance assessment and public dose limitations.

9 2 1 2 5 0 0 0 6 7 2

1.3 SCOPE

The scope of information reported herein is limited to design and field activities conducted in support of engineered barrier cover systems testing at the EBTF. Progress to date includes utilization of background information derived from engineering studies, conceptual designs (Phillips, 1980), and support studies (Phillips and Jones, 1980; Jones, 1981) conducted over the past few years. These documents report research, development, and the engineering progress of barrier designs for radioactive waste disposal sites and their resulting performance.

Engineered barrier test facility activities have been in progress for approximately one and one-half years. Over that period, several tasks have been formulated, initiated, and completed. Completed tasks include scoping studies, preconceptual design, cost and materials analyses, design, construction, and monitoring instrument systems fabrication and placement. Other tasks that are in progress and that are intended to continue for in excess of 5 years include parametric monitoring of micrometeorological, geohydrological, and biotic factors required for modeling and performance assessment evaluations. Operational and monitoring activities are intended to continue at the EBTF until FY 1991. By this time, sufficient data should be compiled from the evaluation of individual barrier performance to provide performance standards for implementation of a definitive design for an operational barrier that will be constructed at selected Hanford waste disposal sites.

2.0 PRECONCEPTUAL/CONCEPTUAL BARRIER DESIGN AND COST ASSESSMENT

Numerous engineered barrier cover system designs have been evaluated for potential use at both radioactive and hazardous waste disposal sites (Fenimore, 1976; Larson et al., 1982; Mezga, 1984; DePoorter, 1981; Hakonson et al., 1981: Arora et al., 1981). Several designs have been tested by laboratory and/or field investigations conducted at sites throughout the United States. The performance of these barriers, depending on the intent to mitigate infiltration etc., has been successful for the most part. However, failure to systematically evaluate interrelated environmental factors and their synergistic effects on overall barrier performance has been sited as a primary reason for documented failures of several of the above barrier investigations (Jacobs et al., 1980). Therefore, the approach for design of EBTF barriers includes evaluation of reasonable interrelated processes, their rates and magnitudes, and their long-term consequences. For example, infiltration of meteoric water into a barrier and subsequent evaporation and transpiration therefrom cannot be evaluated unless factors such as plant/plant root density, species distribution, and erosive forces causing materials loss from the barrier surface over time are determined within reasonable bounds.

9 2 1 2 5 0 0 0 6 7 3

Preconceptual and conceptual engineering designs for EBTF barriers have been formulated from recent engineering studies, strategy studies and demonstration plans for isolation of high-level waste storage tanks, low-level and/or transuranic-contaminated waste storage caissons, low-level and/or transuranic-contaminated liquid disposal cribs, and high-level grout monolithic or caisson disposal structures. Development of engineered barrier cover systems for each category of disposal site may require specific design and construction considerations. However, fundamental performance requirements of barrier systems for these sites are not expected to be unique. Therefore, several test barrier systems were considered for evaluation at the EBTF. None of these barriers are presently thought to be optimum for long-term isolation of waste materials. The designs, however, serve to evaluate and compare the utility of each barrier concept. Sketches of test barriers are shown in Appendix A.

2.1 MOUNDED SOIL DESIGN CONCEPT

Greater confinement of waste materials has been identified as an effective waste management concept (NRC, 1982). Greater confinement of specific waste class categories by disposal at overburden depths of greater than 5 m has been identified as a potential methodology of achieving long-term waste isolation from the environment (NRC, 1981). Additional investigations of waste isolation requirements specific to Hanford waste disposal sites have suggested disposal of specific sites to overburden depths of from 2.5 to 15 m. As a result of these investigations and the proposed criteria and standards for waste isolation, a test barrier consisting of a single layer of homogeneous overburden above grade was selected as an alternative barrier concept for deployment at the EBTF. The above grade overburden layer barrier will henceforth be called the mounded soil test barrier (soils are a mixture of topsoil and sands). Conceptual design requirements for this barrier included: (a) an axisymmetric configuration; (b) above grade construction; (c) materials specifications to include only soil, i.e., natural soil and underlying glaciofluvial and aeolial sand; (d) side slope ratios of 3:1; (e) a truncated flat upper surface; and (f) a radial buffer area adjacent to the test barrier.

2.2 MOUNDED ROCK DESIGN CONCEPT

Isolation of waste disposed of below ground level is directly dependent on erosive forces that may tend to exhume overburden materials and in turn directly expose and disperse waste materials into the environment. Confinement of waste materials for long-term isolation, wherein erosion by wind and water mechanisms are eliminated or significantly reduced, has been identified as potentially acceptable by using mounded rock barriers. Conceptually, these barriers have been designed to include unimodal distributions of rock materials, either in single layers or in multiple layers of different sized materials to thicknesses of 1.5 to 2 m above grade. As a result of Hanford specific engineering studies and the criteria and standards for waste isolation, a test barrier consisting of a single layer of rock constructed above grade was selected as an alternative barrier concept for

9 2 1 2 5 0 0 0 6 7 4

deployment at the EBTF. This barrier will be henceforth denoted as the mounded rock barrier. Conceptual design requirements of this barrier included: (a) an axisymmetric configuration; (b) above grade construction; (c) material specifications to include rounded rock and angular basalt riprap configured in a bilaterally symmetrical mound; (d) side slope ratios of 1:1; (e) a truncated flat upper surface; and (f) a radial buffer area adjacent to the test barrier.

2.3 IMPERMEABLE OFF-FLOW DESIGN CONCEPT

Isolation of radioactive waste materials, through interdiction of geohydrologic and biotic pathways by construction of an impermeable layer of material over contaminated waste disposed of below grade, has often been identified as an effective concept (Fenimore, 1976; Pertusa, 1980; Arora, 1980; SCS, 1977). For short-term waste isolation, this concept is required for specific waste disposal sites containing significant quantities of hazardous waste materials (EPA, 1983; EPA, 1976). Impermeable layers, which were included as part of engineered barrier design concepts specific to Hanford, have been tentatively evaluated as being potentially effective. The effectiveness of this barrier concept is, however, dependent on interrelated factors that over time may cause significant accumulation of moisture under the barrier. Accumulation of moisture below the impermeable layer, if such occurs, may increase the mass transfer of radionuclides from below the barrier by solubilization and resultant advection and dispersion within the partially saturated hydrogeologic system. This phenomena has been theoretically evaluated in a recent report that addressed Hanford soils and meteorological conditions (Lu et al., 1982). As a result of the questionable performance of this barrier concept, field testing of an impermeable layered barrier with off flow of meteoric water was determined as desirable. A simple test barrier consisting of a sloped impermeable membrane over backfill material was selected as an alternative barrier concept for deployment at the EBTF. This sloped impermeable barrier concept is delineated as the impermeable off-flow barrier concept. Conceptual design requirements for this barrier included: (a) a 90 to 180 degree planer surface; (b) a sloped surface such that meteoric water could uniformly drain from the apex of the surface to the outer circumference of the surface; (c) above-grade construction; (d) material specifications below the impermeable barrier surface to include only soil; and (e) a radial buffer area adjacent to the test barrier.

2.4 MULTILAYER INFILTRATION/BIOTIC INTRUSION DESIGN CONCEPT

Confinement of radioactive materials disposed of in the ground requires that the rate and magnitude of mechanisms that tend to degrade isolation of these materials be minimized. These mechanisms or factors are interrelated and function to increase confinement or, if significantly perturbated, degrade confinement of waste materials. Infiltration of meteoric water into a barrier and ultimately into waste materials may result in inadequate confinement. Specific consequences of unacceptable infiltration may include: increased biomass over and within the barrier, increased root penetration

9 2 1 2 5 0 0 0 6 7 5

within the barrier and perhaps into the zone of waste confinement, increased intrusion of burrowing rodents within the barrier in relation to an increase of available edible vegetation inhabiting the barrier, and increased infiltration through the barrier as a result of an increase of rodent burrows. Conceptually, failure of a barrier to mitigate infiltration will cause failure of the barrier to control biointrusion, and similarly, biointrusion failure will enhance infiltration. Therefore, conceptual design of engineered barrier cover systems requires a thorough understanding of interrelated processes such that ensuing design efforts will take into account all reasonable hydrogeologic and biological failure mechanisms, and incorporate deterrents to these mechanisms in the design of demonstration barriers. To this end, preliminary design of a test barrier to simultaneously control infiltration and biointrusion was initiated which henceforth is delineated as the multilayer infiltration/biotic intrusion design concept. This design concept was selected for deployment at the EBTF with test design requirements that include: (a) an axisymmetric configuration; (b) above-grade construction; (c) materials selection to include natural earth materials specific to each barrier layer; (d) a geotextile material between soil or rock layers to evaluate its durability during construction; (e) side slopes of each layer to range from 1:1 for rock layers to 3:1 for soil layers; (f) bottom layers of the barrier to consist of rounded rock and gravel and angular rock and gravel in a bilateral symmetry; (g) a truncated flat upper surface; and (h) a radial buffer area adjacent to the test barrier.

The multilayer infiltration/biotic intrusion test barrier was conceptually designed in a vertically layered configuration for control of infiltration. Infiltration in this barrier design is controlled in part by providing a surface cover soil of specific water storage, water drainage, hydraulic conductivity, and pore size distribution characteristics. This surface layer consists of a medium that encourages plant growth and evaporation/evapotranspiration. Directly below the surface layer is provided a layer of coarse textured media of distinctly different pore-size distribution. This results in an abrupt interface of finer textured soil over coarse textured sand. This interface results in retention of soil moisture within the upper soil layer by a phenomena known as the Richards effect (Richards, 1950; Hillel and Talpaz, 1977; Miller, 1969). This phenomena explains mass transfer infiltration characteristics wherein soil moisture will accumulate at an interface of fine textured porous media overlying a coarse textured layer of porous media. Under this condition soil moisture will not breach the interface between vertical layers until a sufficient quantity of moisture accumulates above the interface to produce a hydraulic head that is in excess of the matrix potential conditions that hold moisture in the intersticies of particles within the soil layer. Hence, a discontinuity of materials with relatively small pore size distributions over an underlying layer of large pore size distribution materials will result in storage of water above the interface. This interface, if located sufficiently near the ground surface wherein evaporation and evapotranspiration processes predominate, will result in nominally all infiltration being returned to the atmosphere. As a result, infiltration of liquid phase water below a specifically designed multilayer barrier will be controlled. Thus, mass transfer of moisture,

9 2 1 2 5 0 0 0 6 7 6

solubilization of radionuclides from buried waste materials, and drainage of contaminated liquids from a given disposal site are eliminated or significantly reduced to acceptable levels.

The physical attributes of the layered barrier concept, which are to control infiltration, are used in barrier design in conjunction with biotic intrusion attributes. Plant roots and their biomass per unit volume of soil materials are dependent on several factors including the plant-available moisture at a given elevation within the soil, the temperature of the soil soil-moisture regime, and the homogeneity and isotropy of the soil materials. In addition, the activity and productivity of plant communities and their root systems, which may tend to exhume and translocate waste constituents from underlying waste disposal structures, are a direct function of the plant species that may inhabit a given site. In general, plant roots will tend to proliferate in a soil material where there is sufficient soil moisture and nutrients to satisfy the respiratory demands of the plant. In contrast, plant root productivities tend to decrease in dry soils or coarse textured soils containing negligible plant nutrients. The multilayered design for infiltration control by virtue of retaining soil moisture in the upper layer perpetuates growth of indigenous plants on the barrier. The increased biomass on the barrier then results in an increase of transpiration of moisture from the barrier. Additionally, increased biomass per unit area of the barrier may significantly reduce the effects of erosional processes that tend to degrade the surface layer of the barrier.

The layered barrier concept for control of infiltration and increased evaporation also can be designed to eliminate or significantly reduce exhumation of dispersal of buried contaminants by burrowing animals. Burrowing animals have been shown to be a significant biotic transport vector at disposal sites. Very coarse textured materials in a layered barrier configuration have been shown to significantly reduce biointrusion by animals (Cline et al., 1980). The effectiveness of these materials is dependent on several conditions. These include (a) sufficient thickness of coarse textured materials, (b) relative sustained dryness of the coarse material, and (c) minimal infiltration of moisture through the coarse material as a result of storage of annual meteoric water above the coarse layer and/or establishment of an effective plant community above the layer to evapotranspire annual meteoric water. Therefore, a coarse layer consisting of rock and riprap was incorporated at lower elevations of the multilayered engineered barrier cover system during conceptual design.

In summary, conceptual design of the multilayer barrier cover system for control of infiltration and biotic intrusion incorporated contemporary research and engineering thought to provide optimum waste confinement. Actual performance and continual optimization of this design will follow a determination of barrier performance at the EBTF and laboratory and simulation/production modeling.

9 2 1 2 5 0 0 0 6 7 7

2.5 MULTILAYER BIOTIC INTRUSION DESIGN CONCEPT

Isolation of materials buried or otherwise disposed of in the ground may be realized by alternative multilayer barrier cover systems concepts. These concepts retain the rationale of a multilayer design; however, specific layers within the design are modified to enhance control of specific factors or processes that may, at any time through the design life of the barrier, cause loss of waste confinement. Enhanced control of burrowing animal intrusion within the multilayer barrier concept was evaluated in a specific test barrier design constructed at the EBTF. This design concept primarily differs from the previously discussed barrier by using a mixed soil and riprap layer directly above the sand layer, forming a soil/riprap/sand interface. This barrier concept is delineated as the multilayer biotic intrusion test barrier. Conceptual design requirements of this test barrier, prior to deployment at the EBTF, included: (a) an axisymmetric configuration; (b) above-grade construction; (c) materials selection to include an admixture of soil and riprap for one layer underlying the surface soil layer; (d) a geotextile material at grade and below the sand layer; (e) side slopes of each layer to range from 1:1 to 3:1 for specific layers; (f) a truncated flat upper surface; and (g) a radial buffer area adjacent to the test barrier.

This concept is thought to increase the efficiency of the barrier to preclude or eliminate intrusion by animals. The previously discussed barrier design included layers of soil, sand, gravel, and rock or riprap in succession from the upper to lower elevations of the barrier. Burrowing animals will penetrate the soil layer and perhaps will exhume or otherwise degrade the sand and gravel layers below. As a result, the interface conditions required for moisture retention in the upper layer may be degraded, albeit an interface between the second (sand) and third (gravel) layers exists. Therefore, the biotic intrusion barrier design introduces large rock mixed with soil in a layer directly underlying the surface soil, or alternatively this layer can be thought of as an addition of large rock into the surface soil layer. This distinction is important in that an interface for moisture retention by this design now exists only below the sand, mixed soil, and rock material. There is a continuity of materials with approximately the same pore size distribution from the surface of the barrier through the upper two layers. Under partially saturated conditions, moisture advection through the mixed soil and rock layer will increase significantly per unit area in the intersticies of the rock where soil is placed. The total volume of moisture entering the soil-rock mix layer should be nominally equivalent to that of the multilayer infiltration/biotic intrusion test barrier, but the flux density of the moisture will increase because the flow path is reduced by approximately a factor of five. As a result, moisture will have the propensity to infiltrate the soil/sand/rock mixed layer at a higher rate and accumulate at the base of this layer at higher levels of saturation. Higher saturation over reduced time will increase the probability of failure of the barrier to retain soil moisture. In addition, the rock material in the soil/sand/rock mix layer is virtually impermeable to vapor phase flow of water, and a higher tortuosity of the layer will possibly result in a reduction of evaporation to the surface of the barrier.

In summary, this barrier design is intended to optimize the control of biointrusion by animals. The design, however, may significantly compromise the water retention capabilities of the multilayer barrier concept. Analysis of laboratory, field (EBTF), and computer simulation and prediction efforts will assist in evaluation of the effectiveness of this barrier concept.

2.6 ADDITIONAL BARRIER DESIGN CONCEPTS

Five design concepts have been briefly discussed above. These concepts are the results of a continuing effort at the Hanford Site to optimize the design of a generic engineered barrier cover system of geomechanically stable buried waste materials. These concepts account for control of important processes that may tend to degrade the performance of barriers over time. However, other processes such as erosion by wind and water and human intrusion have not been thoroughly considered in each design. Definitive materials specifications, materials longevity, depths, and placement (construction) techniques will be determined as development activities continue. Barrier performance, as discussed in this report, is limited to surface barriers. No consideration has been given to effects such as vapor and/or liquid phase moisture transport from the ground surface to and from waste materials. These and other design considerations will evolve as ongoing planned waste management activities continue; i.e., performance assessments, laboratory characterization studies, column and wind tunnel testing studies, subsidence corrective measures technology development, and numerical modeling simulations, etc., as discussed in Hanford waste management planning documentation (DOE-RL, 1984b). These activities will function to provide at least one additional EBTF engineered barrier cover system conceptual design and the subsequent deployment of an optimized test design at the EBTF.

3.0 ENGINEERED BARRIER TEST FACILITY SITE SELECTION

Subsequent to conceptual design of initial engineered barrier cover systems, selection of a field site for construction of each barrier was required. Primary considerations for site selection included: (a) an area representative of typical waste disposal operations; (b) an area where construction and monitoring activities would not adversely effect ongoing waste management operations; (c) an area where below grade excavation would not pose significant risk to occupational workers; (d) minimal topographic relief such that off-normal hydrogeological or micrometeorological effects would compromise the area as being typical of existing or proposed disposal sites; (e) an area of minimal past environmental disturbance such that the biotic conditions of the surrounding area would tend to promote succession of climax community condition within a relatively short time; (f) availability of electrical power adjacent to the site for proposed operation of monitoring and data collection/processing instrumentation; and (g) inclusion of the field site within a secure area for control of access of unauthorized personnel.

9 2 1 2 5 0 0 0 6 7 9

A site was selected within the 200 West separations area of the Hanford Site at the 218-W-5 burial ground expansion area. This location met site selection requirements and was approved for use by the cognizant responsible organizations. The relative location of this facility within the Hanford Site is shown in Appendix B. The facility was surveyed and perimeter markers placed. Access to the facility was limited by posting (signs) to preclude access to unauthorized personnel.

4.0 SELECTION OF BARRIER MATERIALS

Engineered barrier cover systems materials were primarily limited to natural earth materials. Natural earth materials consisting of silts, sand, gravel, rock, and mixtures of these materials are durable over extended time intervals (perhaps centuries to hundreds of centuries). Thus, these materials should be geochemically stable over the intended life expectancy of barriers. The availability of these materials, at reasonable unit and transportation costs, was also assumed in material selection during conceptual design. Quarry and borrow areas within a 20 km radius of the designated test facility were identified, and approval was obtained for aquisition and haulage of materials.

Synthetic materials were also specified in the conceptual design as adjuncts for construction of individual barriers. Geotextiles, i.e., synthetic polypropylene woven fabrics, were selected primarily for evaluation of their performance during construction of layered earth materials. As previously noted, construction of multiple layer barriers depends directly on establishment of a distinct interface between layers. Geotextile materials installed between layers during construction were necessary to sustain an interface condition because heavy equipment was required to place and configure successive layers of multiple layer barriers. The presence of these materials subsequent to construction is not required. Specifications for geotextile materials, i.e., strength characteristics, mesh (opening) size, etc., are given in Appendix C.

Specific requirements for natural earth materials were needed for each barrier configuration. Special emphasis was given to the specification of materials for multiple layer barrier conceptual designs due to interface conditions discussed previously. Each individual layer was mandated to be comprised of nominally a unimodal distribution of materials, for example, the sand layer underlying the soil layer of the multilayer infiltration/biotic intrusion barrier must sustain a distinct interface. This condition cannot be maintained over time if fine textured material from overlying soil layers filters downward into the underlying coarser textured sand layer. Similarly, sand from this layer will degrade the utility of the gravel layer underlying it if downward filtration of particulates occurs. Therefore, particulate filtering calculations and laboratory analyses were conducted to determine the propensity of particulate filtering under static

9 2 1 2 0 0 7 6 3 0

and dynamic conditions (construction conditions) (DOI, 1984). In addition, laboratory studies and tests of particulate filtering were conducted to determine optimum gradation of material layers. Specifications for each material are given in Appendix C.

5.0 TEST BARRIER DESIGN

Previously completed preconceptual and conceptual design analyses and materials selection information were compiled and reviewed for development of test barrier design. Site operations maps, burial ground layout drawings, facilities descriptions, equipment availability, site conditions, meteorology records, site topography, site access, materials availability and lead time, and general site conditions were reviewed. Subsequently construction drawings were prepared, reviewed, and approved for construction. Plan and cross section views of test barriers were included in the drawings, as were materials specifications and monitoring devices. Conceptual design requirements and criteria were factored into each barrier design drawing. The intent of construction drawings was to compile these drawings with field records subsequent to construction into as-built engineering drawings which reflect field design changes based on construction results. As-built drawings are included in this report for each test engineered barrier cover system test barrier in Appendix D.

6.0 TEST BARRIER MONITORING COMPONENTS

Each engineered barrier cover system is intended to control infiltration and/or biotic intrusion such that long-term confinement of subsurface waste materials is realized. The performance of each barrier over time requires quantitative assessment of parameters that control the flux of moisture within the barrier system, control the mass and heat transfer within and exterior to the barrier at the barrier/atmosphere interface, and control the physical stability of the barrier. Therefore, a monitoring effort was initiated to quantitatively measure several parameters and conditions thought fundamental to evaluating the basic performance of each test barrier. Monitoring components are divided into abiotic and biotic categories.

6.1 ABIOTIC MONITORING COMPONENTS

Monitoring of abiotic processes at the EBTF include measurement of hydrogeologic and micrometeorological factors. Measurement of these variables and gradients over a number of years will provide a sufficient data base such that empirical and numerical analyses of barrier performance can be extrapolated over long time intervals. Measurement of coupled hydrogeological and micrometeorological parameters will permit evaluation of water balance at each test barrier. This information will, within the constraints of the instrumentation systems and data limitations, result in an assessment of each barrier to preclude infiltration of meteoric water

9 2 1 2 5 0 0 0 6 8 1

into waste materials and isolation of waste materials within the geohydrologic system. Measurement of micrometeorological parameters will result in the assessment of the capability of each barrier to function as a stable entity that retains its design features over extended time. Synoptic and mesoscale meteorological data collected at the Hanford Meteorology Station will be used in conjunction with micrometeorological data for long-term prediction of barrier performance. Determination of the ability of each barrier layer to retain its physical configuration, i.e., density and distribution of particulate materials will also provide a measurement of the functionality of the barrier to eliminate or significantly reduce infiltration and biotic intrusion.

Abiotic process monitoring activities for each test barrier plot are intended to begin one year after construction and will continue until the cyclic dynamic equilibrium of each parameter is achieved. Cyclic dynamic equilibrium is that condition wherein the rate of change of a given hydrogeological condition is constant or nearly constant over annual, monthly, or seasonal time intervals. Due to disturbances and the construction practices used for deployment of barriers and instrumentation, the barriers are in disequilibrium with respect to ambient conditions in underlying soil materials, within and between each layer of a given barrier, within the surrounding buffer area, and in the surrounding environment. Hence, it is anticipated that at least one year will be required for hydrogeological conditions to attain near equilibrium such that valid monitoring data could be recorded. Cyclic dynamic equilibrium will not be rapidly achieved at each test barrier location due to the disturbances caused during monitoring activities and the extended time required to establish climax community plant species. However, if approximately five years of continuous field data are collected, conservative estimation of test barrier performance and extrapolation of performance over tens to thousands of years should be achievable.

Laboratory analyses of textural, structural, and moisture flux/retention characteristics of barrier materials have been conducted. This characterization activity was required to augment performance monitoring information for simulation and prediction of moisture infiltration into subject test barriers. Analyses of the following parameters were conducted for the soil, sand, and gravel used at the EBTF: (a) hydraulic conductivity as a function of moisture saturation; (b) retention of moisture at selected values of potential (i.e., negative pressure head); (c) bulk density; (d) particle density; and (e) particle size. The laboratory data from this activity is included in Appendix E.

Monitoring instruments and components designated for use at the EBTF were obtained from commercial sources. This equipment was also specified as having factory calibration and certification of performance. Where applicable, the range, accuracy, and limitations of each monitoring device were also evaluated under proposed field conditions. On receipt of instrumentation, laboratory calibration of several transducer-based instruments was completed. Laboratory calibration was conducted within the geologic media (i.e., soil, sand, gravel, or rock) in which each transducer was to be placed. Other instrumentation systems to be used at the EBTF have had extensive field calibration for use at similar sites at Hanford.

9 2 1 2 5 0 0 0 6 8 2

Monitoring instrumentation for hydrogeological and micrometeorological measurements is divided into three categories: soil physics, micrometeorology, and soil filtering. Data collected from instruments is electronically logged on microprocessor-based data loggers. Data collected from manually operated instruments not interfaced directly to data loggers is recorded and later entered into data files in a stand-alone computer system. Hard-copy records (i.e., paper tape and field-tabulated data logs) are retained as baseline documentation of actual field monitoring data.

6.1.1 Soil Physics Instrumentation

Soil physics data used to augment determination of mass and energy balance at each test barrier location are derived from several instruments. These include: (a) thermocouples used to determine temperature and temperature gradients within and below test barriers; (b) thermocouple psychrometers used to determine the moisture content and/or relative humidity of geologic media within and below test barriers; (c) resistance blocks also used to determine soil moisture within specific layers of soil within and below test barriers; (d) neutron soil moisture logging unit used to log the profile of soil moisture from the surface of each barrier to below original grade; and (e) gamma soil density logging unit used to determine potential changes in density of each layer of barrier materials. The function, range, accuracy and data compilation mode of each instrument under anticipated test barrier conditions is given in Appendix F.

6.1.2 Micrometeorology Instrumentation

Micrometeorological data are used in conjunction with soil physics data to determine the rate and magnitude of processes that control moisture flux within and from test barriers and erosion or deposition of materials from or onto test barriers. Several instruments or devices are used to collect data, including: (a) thermistors for determining temperature and thermal gradients in the atmosphere directly above each barrier and in a control area; (b) lithium chloride resistance gauges for determining relative humidity and humidity gradients at equivalent locations; (c) magnetic reed anomometers to determine wind velocity and velocity gradients at equivalent locations; (d) an air foil vane potentiometer for determining wind direction at several radial positions from a given test barrier and from a control area upwind from barrier locations in a control area; (e) dew/precipitation grids for determining the absence or presence of liquid phase water condensation at the soil interface; and (f) particulate samplers for determination of mass transfer of particulates near the ground surface at several radial locations within the buffer area of given test barriers, and within a control area upwind from the EBTF. The characteristics of these instruments are also given in Appendix F.

9 2 1 2 5 0 0 0 6 8 3

6.1.3 Particulate Filtering Instrumentation

The loss of physical integrity of a multilayer barrier containing clean gravel or rock layers will occur if significant filtering of particulates occurs. Particulate filtering will occur if pore sizes in the sand, gravel, or rock layers are large enough to permit finer textured material from an above layer to be displaced by gravity or by other forces so that the finer grained material will accumulate within a coarser underlying layer. Two instruments are used to determine if particulate filtering has or will occur. Additionally, a passive method of materials collection is used. A resistance grid used to determine if dew or precipitation for micrometeorological data analysis was modified by orienting the transducer vertically in a porous enclosure placed at the original grade within specific barriers. This transducer functions by noting decreased resistance if particulates accumulate directly upon the vertical sensor face. The gamma logging device used to determine changes in density of test barrier layers also determines the presence or accumulation of particulates translocated downward from upper layers of a barrier or the accumulation of particulates transported by wind into the rock barrier. This device determines the rate of accumulation of particulates by noting an increased density at the base of a given rock layer. An additional method of determining particulate filtering is provided by placing a coaxial tube below rock layers at grade within the mounded-rock and multilayer infiltration/biotic intrusion barriers. This coaxial arrangement consists of an external tube with a half-section cut from it over which grids are placed to prevent coarse rock from entering an internal tube. The internal tube consists of a half-section tube constructed with baffles such that particulates filtering only from directly above the cutout portions of the external tube will be collected. The inner tube is oriented with the cut face in a vertical arrangement. The internal tube can periodically be extracted from the external tube and the particulates, if found, can be gravimetrically and texturally examined.

6.2 BIOTIC MONITORING COMPONENTS

Biotic processes, primarily plant root and animal intrusion into waste materials, may result in loss of confinement of waste disposal structures. If loss of confinement above release limits results, introduction of radionuclides into biologic transport pathways may occur resulting in a dose to the public. Therefore, it is important to quantitatively determine and understand the mechanisms that control biotic intrusion so that an engineering solution can be developed to prevent intrusion. Engineered barrier cover systems are designed to preclude significant biotic intrusion. Direct monitoring of encroachment and intrusion of flora and fauna into engineered barrier test configurations located at the EBTF will permit evaluations of the quantities and rates of encroachment and intrusion so that extrapolation of barrier performance over extended time can be made. Limitations have been noted for establishing plant systems with specific species diversification that represent future environmental conditions (i.e., climax community plant populations). Additionally, engineered barriers at the EBTF will provide specific habitats for diverse species of animals. As with plant communities, it may take significant time for these

9 2 1 2 5 0 0 0 6 3 4

habitats to be occupied by indigenous animal communities. Therefore, monitoring of biotic processes at the EBTF will require continual evaluation of plant and animal species per unit area (and volume) of each barrier and control area for a number of annual cycles.

Encroachment of plants into buffer areas surrounding test barriers and encroachment directly onto these barriers is evaluated by determining the composition, distribution, and abundance of plants within control areas located in relatively undisturbed sectors of the EBTF. The plant communities from these areas are compared over time to the buffer and barrier test areas. Sampling transect methods are used.

Encroachment of animals onto buffer areas and actual test barriers is determined by using an approach similar to that used for plant encroachment. Animal species, distribution, and abundance in control areas are compared over time to those in buffer and test barrier areas.

Data from encroachment activities are tabulated in field logs and transferred to microprocessor-based computers to produce data bases and statistical analyses.

9 2 1 2 5 0 0 0 6 3 5

6.2.1 Flora Intrusion Monitoring

During and immediately proceeding barrier construction, chemical tracers were introduced into subsurface soils and into specific layers of selected test barriers. Lithium chloride and cobalt chloride are mixed into layer materials or into soils at grade at concentrations of approximately 7.5×10^{-3} g/kg. Ions from these compounds in soils are typically found at very low concentrations in Hanford soils. As plant roots penetrate barrier layers or breach the layer wherein these tracers are placed, uptake of elemental lithium or cobalt should occur with translocation to surface vegetation of these elements within the vascular system of a subject plant (i.e., stems, leaves, etc.). Sampling, field characterization, and spectrophotometric analysis of these materials are used to determine species of plants intruding into specific barrier layers and the number of plants within each species where uptake has occurred. The results of this activity are used to determine if plant root intrusion occurs, to what depth intrusion occurs, at what location on the barrier (i.e., top or side slopes) does intrusion occur, and the rate of intrusion over time. The results of plant root uptake and vegetative chemical analyses for plants in control areas are compared to plants grown under controlled conditions where uptake of lithium and cobalt by different plant species is artificially induced. Detailed procedures for field, laboratory, and control area plant uptake, characterization, statistical analysis, and chemical analysis are used (Cline, 1980).

6.2.2 Fauna Intrusion Monitoring

Phosphorescent and fluorescent powders, zinc sulfide and pigmentaceous respirable materials respectively, were applied at grade below each barrier and within specific layers of several tests barriers. These materials are

used to determine intrusion by fauna inhabiting test barrier areas. These materials were sprayed directly on the ground surface or on the upper surface of selected barrier layers at a known concentration. These materials are detectable by ultraviolet excitation at the surface of a given barrier in the field at concentrations of approximately 50 x 10^{-3} g/kg in soil. Laboratory analysis by ultraviolet spectrometry of these materials mixed into soils can determine concentrations less than 2.5 x 10^{-3} g/kg. Zinc sulfide, with differing spectral signatures (ultraviolet spectrometry), is used for different test barriers so that intrusion into a specific barrier can be traced to its origin. As animals (i.e., insects, mammals, etc.) penetrate barrier layers or breach the barrier to grade, phosphorescent or flourescent tracers will be translocated to the barrier surface as a function of burrowing activities. Tracer materials will contaminate both soil materials exhumed from barrier layers and the animal itself. As these materials and animal species are sampled, characterized, and analytically evaluated, a semiquantitative determination of the effects of animal intrusion can be made. Results from this activity will determine if animal intrusion has occurred, from which layers and to what depths intrusion has occurred, what species are predominately responsible for intrusion, and the rate of intrusion. Results will also determine favorable and unfavorable habitats for specific animal species and will compare these to control areas located near the EBTF. Procedures for evaluating species specific habitats, distributions, etc., and data analysis for such are used in this activity (Daubenmire, 1959).

Deployment of tracer materials within specific test barriers and layers within these barriers has been specifically determined. Illustrations of tracer placement for each test barrier are given in Appendix G.

7.0 TEST BARRIER MATERIALS AND COST ESTIMATION

Prior to construction of test barriers, a determination of the approximate material requirements and the materials handling, transportation, and deployment costs was required. Material and cost estimations of specific designs were needed to determine or optimize costs versus materials availability, haulage and handling requirements, and operational requirements such as direct haulage or stock-piling of materials for later direct placement at a given test barrier site. To this end, a cost/materials estimating model specific to engineered barrier cover systems was developed. The model uses existing commercially available software which uses spreadsheet format keystroke programming. Several attributes of the model include: (a) variable depth, plan dimension, and slope of each barrier and/or barrier layer; (b) graphical representation of single- or multiple-layered barriers as cross sectional profiles; (c) specific or hypothetical site application; (d) access and display of preconstruction site characterization data; (e) tabulation and listing of optional procurement and materials handling factors; (f) scaling factors for differing magnitudes of construction

9 2 1 2 5 0 0 0 6 8 6

activities; (g) cost trade-offs as a function of material sources and haul distances; (h) identification of and cost relationships of crew sizes and equipment requirements; and (i) unit costs for materials and labor.

This model is used as a preliminary tool for determining the magnitude of construction requirements and costs for barriers. Example tabulations and graphic representations of hypothetical engineered barrier test cases are given in Appendix H. Verification of this model in future applications will provide an essential element of demonstration barrier cost optimization.

8.0 TEST BARRIER CONSTRUCTION AND MONITORING SYSTEMS DEPLOYMENT

Construction of test barriers was preceded by approval of construction permits, excavation permits, delegation of work authority, etc. Initial construction/preconstruction included a civil survey of the site as delineated in construction engineering drawings. This survey was conducted by staking and flagging the perimeter of the facility, access roads, buffer areas, and test plots. Standard survey instruments (i.e., theodolites and survey rods and chains) were used. Site preparation included designation of a spoils area approximately 1 km from the EBTF where spoils and grubbed vegetation could be disposed. Access roads, buffer areas, and barrier test plots were grubbed using a paddlewheel scraper. The scraper effectively removed all vegetation and topsoil to a depth of approximately 20 cm from the preconstruction grade. Subsequently, buffer areas and test barrier plots were resurveyed, flagged, and temporary fencing was installed around each plot.

Subplots were established within each plot to place and mix biotic intrusion chemicals tracers. Lithium chloride and cobalt chloride tracers in aqueous solution were applied at grade within each subplot using a mechanical sprayer. Directly after cessation of spraying activities, chemical tracers were mixed into subsoils to a depth of approximately 20 cm using a mechanical mixing device. Immediately after completion of this activity, an appropriate cover layer of soil or rock was emplaced over the tracer layer so that tracers would not be dispersed by environmental conditions (e.g., resuspension by wind over buffer or undisturbed areas of the EBTF).

Either before or subsequent to chemical tracer placement, specific soil physics instruments were deployed below and at grade at test barrier plots. Neutron/gamma soil moisture-density access tubing was installed by: (a) excavation of subsoils to depths of approximately 3 m below grade using a dragline, placement of tubing, and backfilling using a front end loader; or (b) augering a hole approximately 0.6 m deep, placement of tubing, and backfilling by hand. Lithium chloride, due to its thermal neutron capture cross section, may interfere with neutron moisture logging activities. Effects of concentration and configuration of this tracer layer are being evaluated. The mounded soil, mounded rock, and multilayer infiltration/biotic intrusion test barriers were instrumented to depth below each barrier

at a maximum of 0.6 m, whereas the impermeable off-flow and multilayer biotic intrusion test barriers were instrumented to a maximum depth below grade of 3 m. Emplacement of electronic soil physics transducers below grade used similar excavation and installation procedures. Separation of access tubing and transducers/transducer lead wires was maintained at a minimum distance of 0.75 m so that electronic and thermalization interferences would be reduced or eliminated.

Coaxial tubes used for determination of filtering (described previously) were also installed at grade before emplacement of barrier materials. Two each approximately 12-m-long, 0.1-m-diameter tubes were installed below the mounded rock and multilayer infiltration/biotic intrusion test barriers. Rock (rounded large diameter rock or large angular basalt riprap) was placed by hand over these tubes to a depth of approximately 0.5 m in such a manner that heavy equipment would not directly traverse and subsequently destroy the gratings constructed within the upper surface of these tubes. Appendix I contains an example of barrier construction sequence.

8.1 MOUNDED SOIL BARRIER

Construction of the mounded soil barrier primarily involved use of large earth moving scrapers. These units were used to collect soil from a borrowing area located adjacent to the EBTF, transport this material, and place it within flagged boundaries within the subject plot. The borrowed material had been previously wetted to control dust and provide greater efficiency of scraper operations. This is a standard operational procedure used at the Hanford Site. After placement of the required volume of material, a bulldozer was used to configure the barrier to approximate design dimensions. A blade was used to complete the shaping of the barrier and the leveling of the buffer area directly adjacent to the test barrier. Straw was distributed over the surfaces of the barrier and buffer areas using a mechanical chopper/blower device. The straw was then incorporated into the ground surface by repeatedly traversing the barrier and buffer areas with the bulldozer. This activity, in principle, is also a standard operational procedure used for equivalent construction activities at the Hanford Site. Monitoring transducers were emplaced in the soil at specified design elevations as lifts of soil were deposited progressively from grade to the test barrier's design height. Transducers and transducer leads were protected during construction by backfilling by hand around transducer strings. Moisture density access tubing emplaced from below grade to design height (from approximately 1 m to 5 m in length with an inside diameter of 5 cm) was also protected during construction by backfilling by hand around each tube.

8.2 MOUNDED ROCK BARRIER

The mounded rock test barrier was primarily constructed using a bulldozer. Materials were transported to the test barrier plot by dump trucks. Materials were obtained from two locations; large rounded rock was received from a gravel quarry located approximately 7 km from the EBTF and basalt riprap was received from the rock quarry located approximately 23 km from the site. For the most part, trucks dumped the barrier materials directly within flagged perimeter areas of the barrier or directly adjacent to the barrier perimeter. The bulldozer then configured the materials to conform with design specifications. One half of the barrier (bilateral symmetry) consisted of rounded rock and the other riprap. Hence, a vertical interface between these materials was required. This was accomplished by pushing feed materials laterally toward the interface from above using the bulldozer. As with the previously discussed test barrier, a blade was used to level the buffer area adjacent to the test barrier. The same procedure was used to distribute and incorporate straw into the buffer area. The same methods were also used to deploy the electronic monitoring transducers and downhole logging tubes, except that the transducer leads were encased in protective sleeves that were left in place after construction. Similar sleeves were used around logging access tubing; however, these sleeves were removed subsequent to construction. These sleeves were found necessary to prevent damage to monitoring transducers, their leads, and access tubing because of the mass and instability of large rock placement.

8.3 IMPERMEABLE OFF-FLOW BARRIER

Placement of instrumentation below grade within the impermeable off-flow test barrier has been discussed previously. Construction of the above-grade section of the barrier was completed using a front-end loader. As with the previous barriers, test barrier plot configurations and progressive lift emplacement of materials at these plots was controlled by continuous surveying using a theodolite and associated equipment. Final configuration of the surface of this barrier was completed by hand due to the requirement for precise slope control of the barrier surface. Plastic sheeting, in a double-layer overlap configuration, was placed by hand directly over the sloping surface of sand base material. Plastic sheeting was assembled by applying an adhesive between the overlapping seams of each sheet so that a nearly continuous membrane resulted. Gravel was placed by hand directly on the plastic membrane. This placement method was required to minimize tearing and puncturing of the membrane. A blade was also used in the buffer area around this test barrier. The configuration of this barrier, in plan dimensions, is a circular sector; hence, the buffer area does not conform to a radial geometry as do the other test barriers. No electronic transducers were installed above grade within this test barrier. Moisture/density access tubing, however, extends upward vertically through the barrier surface in several locations.

9 2 1 2 5 0 0 0 6 8 9

8.4 MULTILAYER INFILTRATION/BIOTIC INTRUSION BARRIER

Construction of the multilayer infiltration/biotic intrusion test barrier, by virtue of multiple layering design, required a greater degree of control of construction practices. The rounded rock and angular basalt riprap base layer of this barrier was constructed using the same construction practices and equipment that were used for the mounded rock test barrier. The gravel layer, consisting of rounded gravel and crushed angular gravel overlying rounded rock and riprap respectively, was placed by offloading materials from dump trucks directly on the slope of the underlying rock and pushing this material into place with a bulldozer.

A polypropylene geotextile was placed directly over the gravel layer after shaping operations were completed. The geotextile fabric was installed by hand in a manner similar to that for the plastic sheeting discussed above. The geotextile materials were overlapped by approximately one fifth so that if deformation of the underlying gravel layer were to occur as a result of heavy equipment operations, the overlying sand would not breach (i.e., filter) downward into the gravel layer through seams in the geotextile. Clean washed sand (concrete sand) was placed directly over the geotextile using the same operations as described for the underlying gravel layer. During construction of this layer, it was determined that approximately 30 cm of sand was required to overlay the geotextile. Bulldozer tracks caused tears on the geotextile if sufficient sand depth was not maintained, especially on sideslopes of the barrier layer. The surface of the sand layer was leveled and shaped by hand after successive traverses of the bulldozer were used to compact the sand layer. A flat surface was maintained to assure a distinct interface condition between the clean-washed sand layer and the upper soil layer of the barrier.

Electronic transducers used to monitor moisture, temperature, and particulate filtering were installed by hand within the sand layer and in the overlying soil/sand layer. Transducer leads extending from grade, below which were placed additional transducers, were protected by casings equivalent to those described for the mounded rock barrier and installed within the rock and gravel layers. Moisture density logging access tubes were also encased within the rock and gravel layers to preclude damage to the access tubing during construction. Coaxial filtering tubes were also installed at grade, below the rock layer of this test barrier, in a manner equivalent to that described for the mounded rock test barrier. The final layer of the multilayer infiltration/biotic intrusion barrier, which consisted of soil, was constructed in a manner equivalent to that of the mounded soil test barrier. Final shaping, grading, and mulching with straw was also conducted at this barrier using the methods previously described for the mounded soil barrier.

8.5 MULTILAYER BIOTIC INTRUSION BARRIER

The multilayer biotic intrusion test barrier was constructed using methods, procedures, and equipment equivalent to that of the multilayer infiltration/biotic intrusion test barrier discussed above. Construction proceeded by placing a geotextile layer at grade. This material was

9 2 1 2 5 0 0 6 9 0

intended to preclude displacement of above-gravel materials into the soil materials existing at grade. A gravel layer was placed directly over the geotextile at grade. Another geotextile layer was then placed completely over the gravel layer, including its slopes. This geotextile and the geotextile underlying the gravel layer completely enclosed the gravel layer. The geotextile directly overlying the gravel layer was also used to provide a distinct interface condition at the gravel layer so that moisture retention in the overlying sand layer would occur. During construction, the geotextile at this elevation also functions to prevent particulate filtering from the sand layer into the gravel layer.

A sand layer (clean washed sand) was placed atop the upper geotextile material. Placement and shaping methods were commensurate with that described for the infiltration/biotic intrusion test barrier. Large angular basalt riprap was then placed directly over the sand layer. As before, the placement of this material was completed using the same techniques and equipment as described for the previous barrier. Subsequent to placement of the rock materials, soil was placed directly above the rock so that it would filter down into the existing rock layer. This method of mixing soil with rock materials was only partially successful. After construction of this layer, soil was placed over the rock soil admixture layer to design depth. This barrier configuration provides a barrier to burrowing mammals nearer the surface of the barrier then does the design of the multilayer infiltration/biotic intrusion barrier. However, intrusion by insect colonies, plant root systems, etc., may not be significantly reduced by this design. Furthermore, infiltration or the rate of infiltration within the rock/soil layer may significantly increase. Monitoring systems above grade in this test barrier were installed using methods equivalent to those in the previous barrier description.

9 2 1 2 5 0 0 0 6 9 1

9.0 PRELIMINARY TEST BARRIER PERFORMANCE MONITORING RESULTS

Engineered barrier cover systems test barriers have been constructed over a period of approximately one and one half years. Construction of test barrier plots at the EBTF have significantly disrupted the hydrogeologic and biotic environment. A rigorous monitoring effort immediately before barrier construction would primarily monitor only the effects of construction, whereas the objective of monitoring is to determine intermediate and long-term test barrier performance. Therefore, only a limited effort has been initiated to date to collect barrier performance data. A one-year minimum interval between construction and initiation of detailed monitoring activities is thought necessary to permit the establishment of hydrogeologic and some biotic equilibrium conditions (ambient or near-ambient field conditions). As such, commencement of detailed monitoring activities was initiated in October of 1984. Thus, detailed descriptions and results of barrier performance monitoring will not be reported in this document. Preliminary hydrogeological and biotic monitoring activities conducted to date are presented to serve as examples of the scope and general detail of ongoing monitoring efforts.

9.1 ABIOTIC MONITORING (EXAMPLE PRELIMINARY RESULTS)

Moisture content determinations within each barrier, within respective barrier layers, and in subgrade soils will be ultimately used as verification data to numeric computer models for simulation of mass and energy balance through and from engineered barrier systems. Moisture content versus depth is determined by three techniques discussed previously. Data from the use of one of these techniques will be used to illustrate the format and utility of the information collected.

Collection of data from subsurface transducers (i.e., gypsum blocks) is accomplished by connecting specific transducer leads from these blocks directly to a data logger, and collecting sufficient signal current over sufficient time to result in estimation of the maximum, minimum, mean, and standard deviation of moisture content. Moisture content data from gypsum blocks installed in the field is accurately determined by comparison of field data logger paper tape information with laboratory calibration curves produced for each type of geologic media within or below each test barrier. On a preliminary basis, an increase in soil moisture below a given barrier could be interpreted as: (a) a failure of the barrier to preclude infiltration of meteoric water through the barrier; or (b) drainage from the barrier as a result of application of water to barrier materials used during construction. At least one annual climatic cycle will be required to differentiate between these conditions. Conversely, a static moisture condition below a given barrier may be interpreted as assurance that the barrier is functioning to design specifications with respect to infiltration if it can be shown that negligible flux occurs.

Soil moisture content data at a depth of 0.6 m from a location adjacent to a test barrier within the buffer area (i.e., a control location) and soil moisture content data from the same depth below grade beneath the center of the mounded soil, mounded rock, and multilayer infiltration/biotic intrusion barriers are shown for example comparison in Appendix J.

Measurement of micrometeorological parameters both in control (undisturbed) and test barrier test plot areas is also conducted as part of determination of abiotic barrier performance. Numerous parameters are measured as previously discussed. Data from micrometeorological stations located at the EBTF are supplemented by data from a large meteorological station located approximately 2 km from the EBTF. Micrometeorological data collected at the site will be primarily used for determining boundary layer conditions occurring near or at the ground/atmosphere interface at the slope and surface of each barrier. Quantification of these conditions is needed in order to evaluate mechanisms and the relative importance of these mechanisms which may tend to enhance or degrade test barrier performance. For example, wind velocity over the surface of the ground directly influences the temperature of the ground surface, the relative humidity of the geologic media directly below grade, the soil moisture content at and below grade, and the deposition or loss of particulates onto or from the surface of the ground.

Data from measurements of wind velocity gradients at two locations upwind and in the lee of the mounded soil test barrier are used for an illustrative example of micrometeorological data. This example, illustrated in Appendix K, shows relative effects of wind velocity above a climax community vegetative cover (control area) upwind from a given barrier and the wind velocity in the lee of the mounded soil barrier at two elevations. The influence of the barrier on the wind velocity regime in proximity of the barrier is clearly shown. Interpretation of this data as to the long-term performance of the barrier, however, awaits development of empirical methods to quantify the interrelated effects of wind, and in addition, numerical methods to simulate and predict long-term consequences of test barriers subjected to differing wind regimes.

The preponderance of field abiotic monitoring data is collected by electronic devices and is processed and output by data loggers. Preliminary statistical treatment of the data and determinations of the range of variation in data can therefore be made in the field. This serves to optimize monitoring activities by determining effective sampling frequencies, transducer placement, etc. An example of data logger output for soil physics and micrometeorological data from one location, one station, at one test barrier site is given in Appendix L to illustrate data format.

Qualitative observations concerning the physical stability of barriers can also be made as part of performance monitoring activities for abiotic processes. For example, wind erosion has caused a change of surface configuration of test barriers. Wind erosion has caused significant erosion (upwind) and deposition (downwind) of the mounded soil barrier. The shape of this barrier, in a one-year period since construction, has changed from a truncated cone to a more ovate form which tends to aerodynamic stability for the barrier. This observation thus serves to guide continuing efforts for barrier design (e.g., (a) design barriers for aerodynamic stability, and (b) armor or otherwise protect the upwind side of the barrier to negate wind erosion). This obviates the process of iteration and optimization of barrier designs based on laboratory, field, and modeling efforts.

9.2 BIOTIC MONITORING (EXAMPLE PRELIMINARY RESULTS)

As with abiotic preliminary monitoring results, results of plant and animal encroachment and intrusion during the past year are significantly influenced by the gross disturbance of the test barrier plots by construction activities. Therefore, only preliminary data has been collected, and only limited interpretation of this data is possible at this time. Data herein are given as examples and are not definitive.

Encroachment of plant species onto test barriers and barrier buffer areas will increase over time; however, an evaluation of flora encroachment by accelerating this process was thought prudent in that encroachment is evaluated only on specific subplots of specific test barriers. As such,

9 2 1 2 5 0 0 0 6 9 3

natural encroachment over time can be compared with accelerated encroachment. Furthermore, evaluation of climax community vegetation and its effects on barrier performance is of major importance, and accelerated encroachment will permit evaluation of this community within a reasonable time.

Accelerated plant encroachment activities were initiated by seeding the mounded soil, and multilayer infiltration/biotic invasion test activities were initiated by seeding the mounded soil barriers with wheatgrasses (*Agropyron desertorum* and *Agropyron dasystachynm*), at an application of approximately 3×10^{-3} kg/m^2. Russian thistle (*Salsola kali*) was seeded into the slope and top of the mounded soil test barrier in 36 subplots approximately 0.5 m apart at an application of approximately 1.1×10^2 seeds/m^2. *Salsola kali* seeds were also seeded into 17 subplots of equivalent size at the same rate on the top surface of the multilayer infiltration/biotic intrusion test barrier. All seed application was completed by January 1984, and seedling emergence was recorded in March of 1984. At that time, seedling development on the southern aspect of both test barriers was greater than that for northern aspects. By May of 1984, nearly all vegetation introduced onto each barrier had suffered high mortality. Exceptions included one mature *Salsola kali* and a few immature plants of the same species on the south of the mounded soil test barrier. The above surface vegetative growth of these plants was collected and archived for future analytical determination of concentrations of tracer materials indicative of root intrusion within each test barrier.

Encroachment of animals was evaluated by visual inspection of the type and number of animals burrowing into buffer areas surrounding each test barrier and directly into test barriers. To date, preliminary results indicate excavations or burrows of the Great Basin pocket mouse (*Perognathus parvus*) within 5 locations of the buffer area to the east of the mounded soil test barrier and two excavations within the multilayer infiltration/biotic intrusion barrier (one each in the eastern slope and top of the test barrier). Excavated materials (i.e., soil/sand) have not been found to contain detectable concentrations of tracer materials. One additional burrow within the eastern slope of the mounded rock test barrier has been noted. The species inhabiting or excavating this burrow are unknown at this time.

Quantitative assessment and trend analyses of plant and animal encroachment and intrusion can only be completed upon collection of and analysis of data from a diversity of plant and animal species over time. Five years or more of continual seasonal data may be required to substantiate encroachment and intrusion.

9 2 1 2 5 0 0 0 6 9 4

10.0 RELATED AND SUPPORT ACTIVITIES

The EBTF was established primarily to quantitatively and qualitatively demonstrate the attributes and detriments of several engineered barrier cover systems so that after assessing the performance of these barriers, a definitive design of a generic barrier could be produced that could perform over extended time to design objectives. However, development of this generic barrier, so that it is technically defensible and acceptable to scientific, engineering, and lay review, will require several support studies in concert with EBTF investigations. These studies, for the most part, have been initiated. They include, for example: (a) field evaluation of natural analogs of barrier layering sequences and flora and fauna intrusion; (b) laboratory wind tunnel experimentation of bounding conditions of wind erosion; (c) laboratory large column experimentation of bounding conditions of infiltration of meteoric water through individual and layered sequences of geologic media; (d) laboratory and field evaluation of longevity and placement of ceramic and/or porcelain intrusion markers; and (e) conceptual, empirical, and numerical modeling of interrelated processes that influence the performance of barriers over extended time. These related activities have been identified in technology plans and specific test plans issued within the past year. A brief discussion of aspects of several of these studies is given to provide insight to the interrelation of scope and intended results.

10.1 ANALOG TASKS

Engineered barrier cover systems designs have analogous features that exist in nature (i.e., layering of surface sediments and soil profiles). These analogs are known to have existed for hundreds to perhaps thousands of years in south central Washington state, both in proximity to and within the Hanford Site. Analogs to the mounded soil, mounded rock, multilayer infiltrating/biotic intrusion, and multilayer biotic intrusion test barriers have been identified at or near Hanford. Initial observations from preliminary evaluation of each analog have concluded: (a) in several cases the infiltration of soil moisture has been interrupted (i.e., significant drainage reduced) when a relatively fine-grained soil/sand layer is underlain by a layer of coarser textured material, wherein an abrupt textural interface exists between these layers; (b) in several cases where the same layering sequence exists, plant roots tend to proliferate in the sand/soil layer and do not intrude significantly into the coarser underlying layer(s); (c) burrowing mammals do not tend to penetrate gravel or rock layers underlying soil/sand layers; (d) an increase in biomass (i.e., vegetation per unit area) can be expected over surface materials primarily consisting of large rock; (e) plant roots and animals penetrate or otherwise intrude vertically downward to significant depths, into soil/sand layers that do not have underlying coarse textured layers; and (f) vegetative growth and surface layers of gravels or other large particles significantly reduce wind erosion of fine grained soil/sand materials at grade. To evaluate these observations, a task to quantify natural analog barriers in the field was supported and is presently continuing. Final results from this task should be available in 1986.

9 2 1 2 5 0 0 0 6 9 5

10.2 INFILTRATION COLUMN AND WIND TUNNEL TASKS

The performance of monolithic and layered engineered barrier cover systems to preclude or significantly reduce infiltration under elevated conditions or precipitation requires quantitative investigation. There exists a need to evaluate infiltration under increasing precipitation conditions so that bounding limitations or confidence intervals can be established for barrier infiltration performance. In addition, as a result of bounding limitations, optimization of layer thicknesses and materials specifications can be made, and significant construction cost savings can be realized. Hence, a task to construct, test, and determine bounding case limitations of barrier systems has been initiated. This task involves design, construction, and operation of large one-dimensional soil/gravel/rock, etc., columns wherein artificial precipitation is added at mean, one standard deviation, and two standard deviation rates, frequencies, and durations. All other conditions are nominally held as constant (i.e., temperature, relative humidity, air flow), indicative of mean annual environmental conditions. This task will bound infiltration limits for specific barriers under controlled conditions. In turn, this task will be followed by small scale field caisson/lysimeter studies to quantify and further provide bounding conditions for infiltration under dynamic and cyclic field conditions. Initial phases of this task should conclude in 1986. Later phases, given sufficient support, should be completed in 1989. The data provided by this task will directly interface with EBTF activities to provide design specifications for a demonstration engineered barrier cover system.

An important element of barrier performance is the ability of a given barrier to sustain a stable geometric configuration over a period of time. The configuration, if not designed properly, could be significantly compromised by effects of wind erosion. Typical methods to control wind erosion are concerned with near-term conditions. Application of these control methods may perturbate other factors controlling infiltration and biotic intrusion into barriers; for example: (a) control by tillage practices used in agriculture; (b) control by establishing nonindigenous vegetation (a temporary effect due to plant succession and range fires); (c) control by establishment of artificial or vegetative windbreaks (temporary solutions due to plant succession and longevity of materials); and (d) control by surface application of organic or inorganic spray mulches (limited by decomposition or leaching of materials). Long-term approaches include distributing coarse-textured geologic media at grade directly on soil/sand materials. The validity of this approach is questionable due to interrelated barrier performance factors; for example: (a) a layer of gravel over a soil profile will enhance rather than retard infiltration; (b) specific distributions of gravel or equivalent material at grade may reduce wind erosion at low wind velocities, yet significantly increase erosion at high wind velocities (Sehmel, 1976); (c) a surface gravel layer may enhance establishment of deep-rooted plant species; and (d) gravel mulch layers may cause significant edge effects wherein erosion may result in undercutting the upper layer of a barrier. Conversely, a gravel or similar layer may enhance deposition onto the gravel surface of the barrier and thereby enhance infiltration. A laboratory and field investigation has been planned to evaluate, quantify,

9 2 1 2 5 0 0 0 6 9 6

and provide solutions to wind erosion effects tending to degrade barrier performance. This investigation initially includes wind tunnel testing of various barrier surface conditions under controlled wind velocity conditions. Later studies include field experimentation and development of empirical and perhaps numerical models required to simulate and predict wind erosion conditions, and the effectivity of barrier surface treatments to provide wind erosion abatement.

10.3 WIND EROSION TASKS

Short-term control of erosion by establishment of plant species directly on barrier surfaces directly subsequent to barrier construction is being evaluated. The relationship of establishment of these species with application of gravel mulches directly on barrier surfaces for long-term erosion control is also being evaluated. Field plots of vegetative surface treatments and gravel mulch coverings have been established at the EBTF and elsewhere within the 200 West area of the Hanford Site. Specific aspects of this task include development of a method and of required equipment to successfully introduce plant seed into gravel mulched surface layers. Alternative considerations include distribution of seed directly onto the barrier surface before application of gravel mulch material. This task will emphasize optimization of thicknesses of gravel layers used in conjunction with climax community plant species to preclude erosion of surface soil materials. Additionally, the task will emphasize establishment of and invasion of shrubs [i.e., sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) ubiquitous to Hanford into gravel surface layers. This task is scheduled for completion in 1989.

10.4 INTRUSION BARRIER MARKER TASKS

Engineered barrier cover systems deployed at the EBTF to date are used to investigate infiltration of meteoric water and intrusion of natural vegetation and of burrowing animals. Another aspect of the development of engineered barrier cover systems is that of human intrusion. A task has been recently initiated to introduce markers within given barrier layers so that if a human intruder were to breach the barrier, a warning would be provided to the intruder to cease excavation. Intrusion markers to be tested include ceramic and porcelain disks that will be placed in several layers within a given barrier design. The placement, survivability, and durability of these markers depend on such things as the construction practices used to configure barriers. Intrusion marker placement, survivability, durability, etc., will be investigated at a designated area at the EBTF. Placement and survivability experimentation will, for the most part, be completed in 1986, while durability observations made by periodical excavation and visual inspection of several markers will perhaps continue through 1990.

9 2 1 2 5 0 0 0 6 9 7

10.5 NUMERICAL SIMULATION/PREDICTION MODELING TASKS

Abiotic and biotic processes influencing performance of layered or monolithic geologic media systems have been evaluated on a preliminary basis concerning infiltration and the mass flux of meteoric water through barrier systems into underlying contaminated materials (DOE-RL, 1984c). Computer simulation modeling of coupled micrometeorologic, biotic-induced evapotranspiration, evaporation, and soil physics processes provided the following preliminary conclusions: (a) coarse soil barriers, with or without plants, will not prevent drainage of infiltrating soil moisture when subject to precipitation of 30 cm/yr; (b) fine-textured soil overlying coarse layers will effectively store and retain infiltrating soil moisture such that evapotranspiration processes will prevent drainage of soil moisture to underlying materials; (c) the texture and thickness of soil layers must be considered for effective engineered barrier cover systems design; (d) the temporal distribution of rainfall (meteoric water) and evaporation/evapotranspiration are important factors directly influencing performance of engineered barriers; and (e) based on model assumptions, it is possible to design and construct a multilayer engineered barrier cover system using onsite materials that will perform to eliminate infiltration of water into and from waste zones (Gupta et al., 1978). An illustration of the multilayer barrier modeled on the above considerations is given in Appendix M. Continued simulation and prediction modeling activities are in progress. These efforts, coupled with laboratory and field investigations will provide a rapid and reliable basis for definitive design of a full-scale demonstration engineered barrier cover system for deployment at Hanford.

Nearly all investigations concerning the mechanisms and processes involved in earth sciences conducted at the Hanford Site provide synergistic information that supports development of engineered barrier cover systems. These are too numerous to discuss here; however, the successful completion of these and other associated investigations significantly improves the quantitative assessment of barrier performance.

9 2 1 2 5 0 0 0 6 9 8

ACKNOWLEDGEMENTS

The efforts of T. L. Silcox for draft report preparation and Publications Services Department for word processing, technical editing, and graphics coordination are sincerely acknowledged. Guidance and support of division/program offices of the Richland Operations Office of the U.S. Department of Energy and Rockwell Hanford Operations are also greatly appreciated.

9 2 1 2 5 0 0 0 6 9 9

REFERENCES

Arora, H. S. (1980), Infiltration Control for Low-Level Radioactive Solid Waste Disposal Areas: An Assessment, ORNL/TM-6473, Oak Ridge National Laboratory, Oak Ridge, TN.

Arora, H. S., D. D. Huff, D. S. Ward, and O. M. Sealand (1981), An Assessment of the Effect of a Bentonite Seal on Groundwater Storage in Underlying Waste Disposal Trenches at Oak Ridge National Laboratory, ORNL/TM-7416, Oak Ridge National Laboratory, Oak Ridge, TN.

Cline, J. F., K. A. Gano, and L. E. Rogers (1980), "Loose Rock Biobarriers in Shallow Land Burials," Health Physics, 39:497-504.

Daubenmire, R. (1959), "A Canopy Coverage Method of Vegetational Analysis," Northwest Sci., 33:43-69.

DePoorter, G. L. (1981), "Arid Site SLB Technology Development at the Los Alamos National Laboratory," ORNL/NFW-81/34, in Proc. of the Third Annual DOE Low-Level Waste Management Program Meeting, New Orleans, LA.

DOE (1984), Radioactive Waste Management, DOE Order 5820.2, U.S. Department of Energy, Washington, D.C.

DOE-RL (1984a), Hanford Waste Management Plan, U.S. Department of Energy - Richland Operations Office, Richland, WA.

DOE-RL (1984b), Hanford Waste Management Technology Plan, U.S. Department of Energy - Richland Operations Office, Richland, WA.

DOE-RL (1984c), "Preliminary Analysis of the Performance of the Hanford Reference Engineered Barrier and Marker System," Appendix D, in Draft Hanford Defense Waste Environmental Impact Statement, U.S. Department of Energy - Richland Operations Office, Richland, WA

DOI (1984), "Earth Manual," Water Resources Technical Publication, U.S. Department of Interior, Washington, D.C.

EG&G (1984), Guidance Document for DOE Order 5820 Chapter III, Management of Low-Level Waste, EG&G Idaho Inc., Idaho Falls, ID.

EPA (1976), Resource Conservation and Recovery Act (as Ammended), 42USCA6901, U.S. Environmental Protection Agency, Washington, D.C.

EPA (1983), Protection of the Environment, Title 10 Code of Federal Regulations Part 260, U.S. Environmental Protection Agency, Washington, D.C.

Fenimore, J. W. (1976), Evaluation of Burial Ground Soil Covers, DPST-76-427, Savannah River Laboratory, Aiken, SC.

Gupta, S. K., K. K. Tanji, D. R. Nielson, J. W. Bigger, C. S. Simmons, and J. McIntyre (1978), "Field Simulation of Soil Water Movement with Crop Water Extraction," Paper No. 9013, in Water Sci. and Eng., University of California, Davis, CA.

Hakonson, T. E., G. C. White, E. S. Gladney, and M. Muller (1981), "Preliminary Assessment of Geologic Materials to Minimize Biological Intrusion of Low-Level Waste Trench Covers and Plans for the Future," ORNL/NFW-81/34, in Proc. of the Third Annual DOE Low-Level Waste Management Program Information Meeting, New Orleans, LA.

Hillel, D. and H. Talpaz (1977), "Simulation of Soil Water Dynamics in Layered Soil," Soil Sci., 123:54-62.

Jacobs, D. G., J. S. Epler, and R. R. Rose (1980), Identification of Technical Problems Encountered in the Shallow Land Burial of Low-Level Radioactive Waste, ORNL/SUB-80/13619/1, Oak Ridge National Laboratory, Oak Ridge, TN.

Jones, T. L. (1981), "Monitoring and Physical Characterization of Unsaturated Zone Transport: Radionuclide Migration Studies," ORNL/NFW-81/34, in Proc. of the Third Annual DOE Low-Level Waste Management Program Information Meeting, New Orleans, LA.

Larson, T. H., T. M. Johnson, B. L. Herzog, K. Cartwright, and C. J. Stone (1982), "Trench Cap Studies," ORNL/NFW-82/18, in Proc. of the Fourth Annual DOE Low-Level Waste Management Program Information Meeting, New Orleans, LA.

Lu, A. H., S. J. Phillips, and M. R. Adams (1982), "Finite Element Model Evaluation of Barrier Configurations to Reduce Infiltration into Waste Disposal Structures: Preliminary Results and Design Considerations," in Proc. of the Waste Management 82 Symposium, Tuson, AZ.

Mezga, J. J. (1984), The Role of Trench Caps in the Shallow Land Burial of Low-Level Wastes, ORNL/TM-9156, Oak Ridge National Laboratory, Oak Ridge, TN.

McKenzie, D. H., L. L. Cadwell, C. E. Cushing, R. Harty, W. E. Kennedy, M. A. Simmons, J. K. Soldat, and B. Swartzman (1982), Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Disposal: A Report on Tasks 1 and 2 of Phase 1, NUREG/CR-2675 (Vol. 1), Nuclear Regulatory Commission, Washington, D.C.

McPherson, R. B., E. C. Watson, and S. J. Phillips (1979), "Disposition Criteria Acceptable for Public Use of Decommissioned Low-Level Waste Burial Grounds," in Proc. of the Health Physics Soc. Annual Meeting, Philadelphia, PA.

9 2 1 2 5 0 0 0 7 0 1

Miller, D. C. (1969), Flow and Retention of Water in Layered Soils, Conservation Research Report No. 13, U.S. Department of Agriculture, Washington, D.C.

Murphy, E. S. and G. M. Holter (1980), Technology, Safety, and Costs of Decommissioning a Reference Low-Level Waste Burial Ground, NUREG, CR-0570, Nuclear Regulatory Commission, Washington, D.C.

NRC (1981), Environmental Impact Statement on 10CFR Part 61 (Licensing Requirements for Land Disposal of Radioactive Waste), NUREG-0782, Nuclear Regulatory Commission, Washington, D.C.

NRC (1982), 10CFR Part 61 (Licensing Requirements for Land Disposal of Radioactive Waste), Nuclear Regulatory Commission, Washington, D.C.

Pertusa, M. (1980), "Materials to Line or Cap Disposal Pits for Low-Level Wastes," GE 80-1, Geotechnical Engineering Report, University of Texas, Austin, TX.

Phillips, S. J. (1980), "Geohydrologic Technology Developments for Retired Radioactive Waste Burial Site Decommissioning," in Proc. of the NEA Special Meeting for Decommissioning Requirements in Design of Nuclear Facilities, Paris, France.

Phillips, S. J. and T. L. Jones (1980), "Verification of Partially Saturated Zone Moisture Migration: Model and Field Facilities," in Proc. of the Interagency Low-Level Waste Management Symposium, Denver, CO.

Richards, L. A. (1950), "Laws of Soil Moisture," Trans. Amer. Geophys. Union, 31:750-756.

SCS (1977), Study of Engineering and Water Management That Will Minimize the Infiltration of Precipitation into Trenches Containing Radioactive Waste: Final Report, NTIS-PB-283/365, SCS Engineers, Long Beach, CA.

Sehmel, G. A. (1976), "Initial Observation of Airborne Concentrations of Small Particle Size Ranges During Two Dust Storms," BNWL-2000, in PNL Annual Report for 1975 to USEDA Division of Biomedical and Environmental Research Part 3, Atmospheric Sciences, Pacific Northwest Laboratory, Richland, WA.

Unger, P. W. (1971), "Soil Profile Gravel Layers, I. Effects on Water Storage Distribution and Evaporation," Soil Sci Soc Amer Proc., 35:631-634.

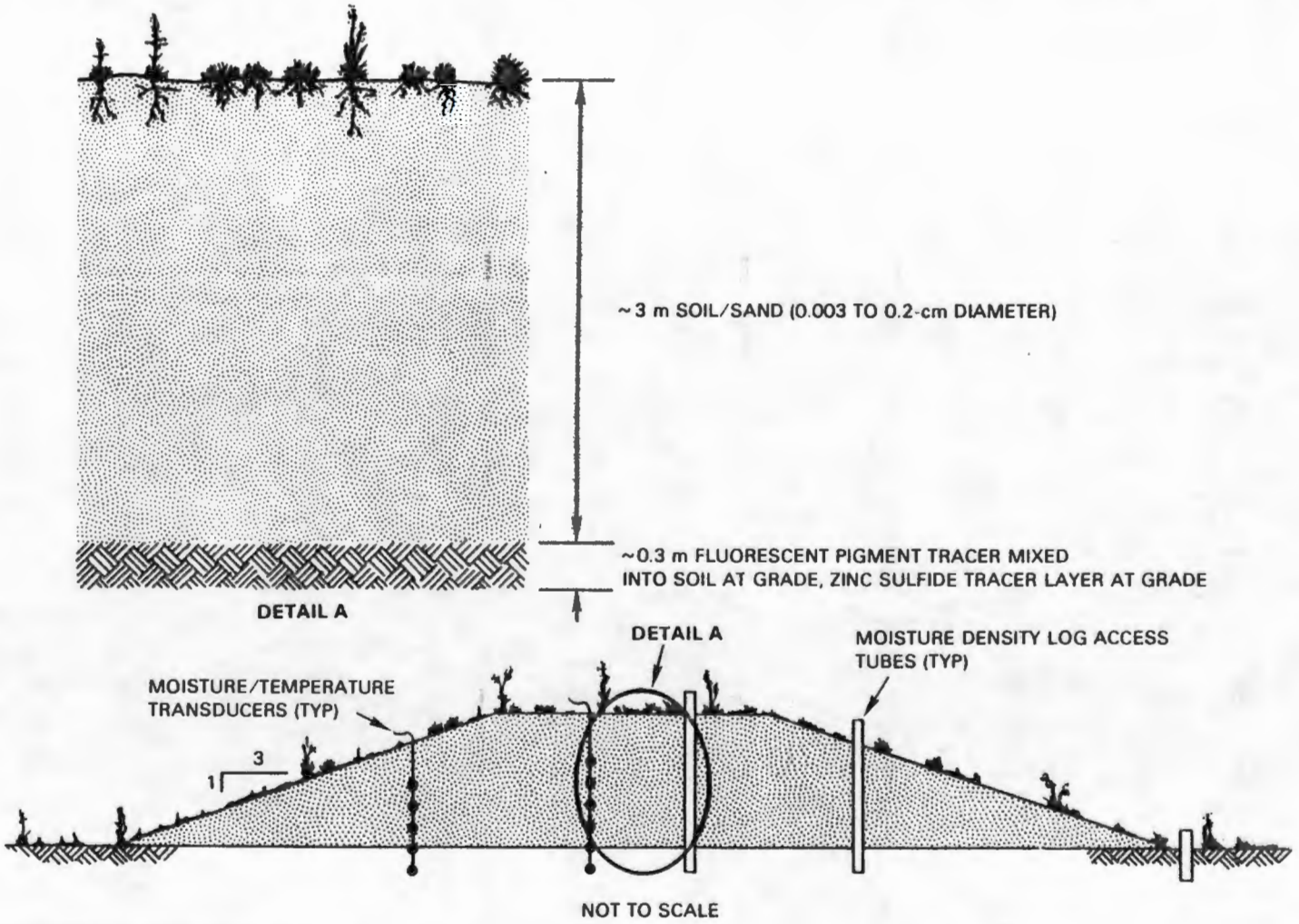
9 2 1 2 5 0 0 0 7 0 2

APPENDIX A

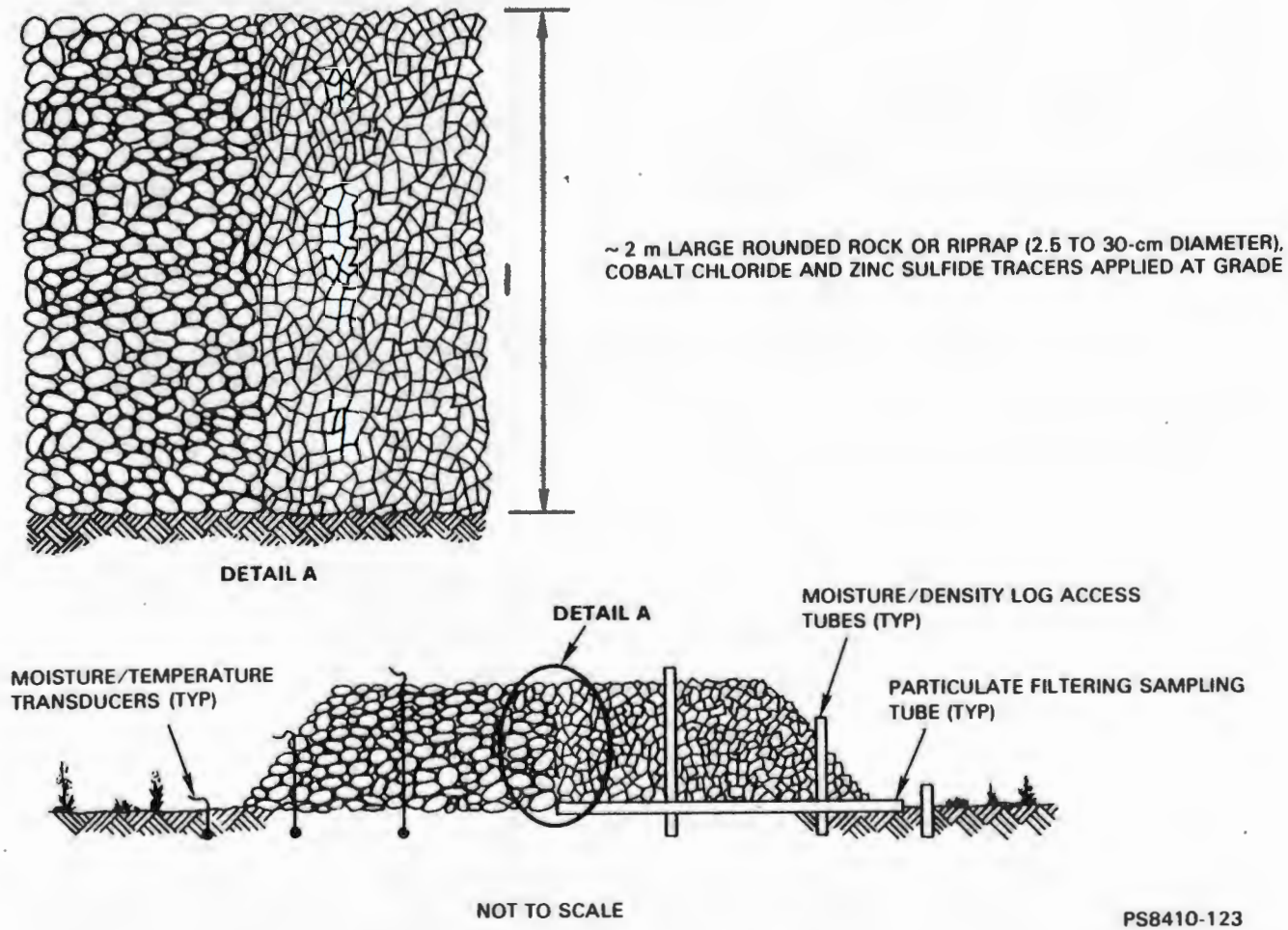
SKETCHES OF TEST BARRIERS CONSTRUCTED AT THE ENGINEERED BARRIER TEST FACILITY

Mounded soil, mounded rock, impermeable off-flow, multilayer infiltration/biotic intrusion, and multilayer biotic intrusion test barrier sketches are shown. Simplified monitoring systems installed within each test barrier are also shown.

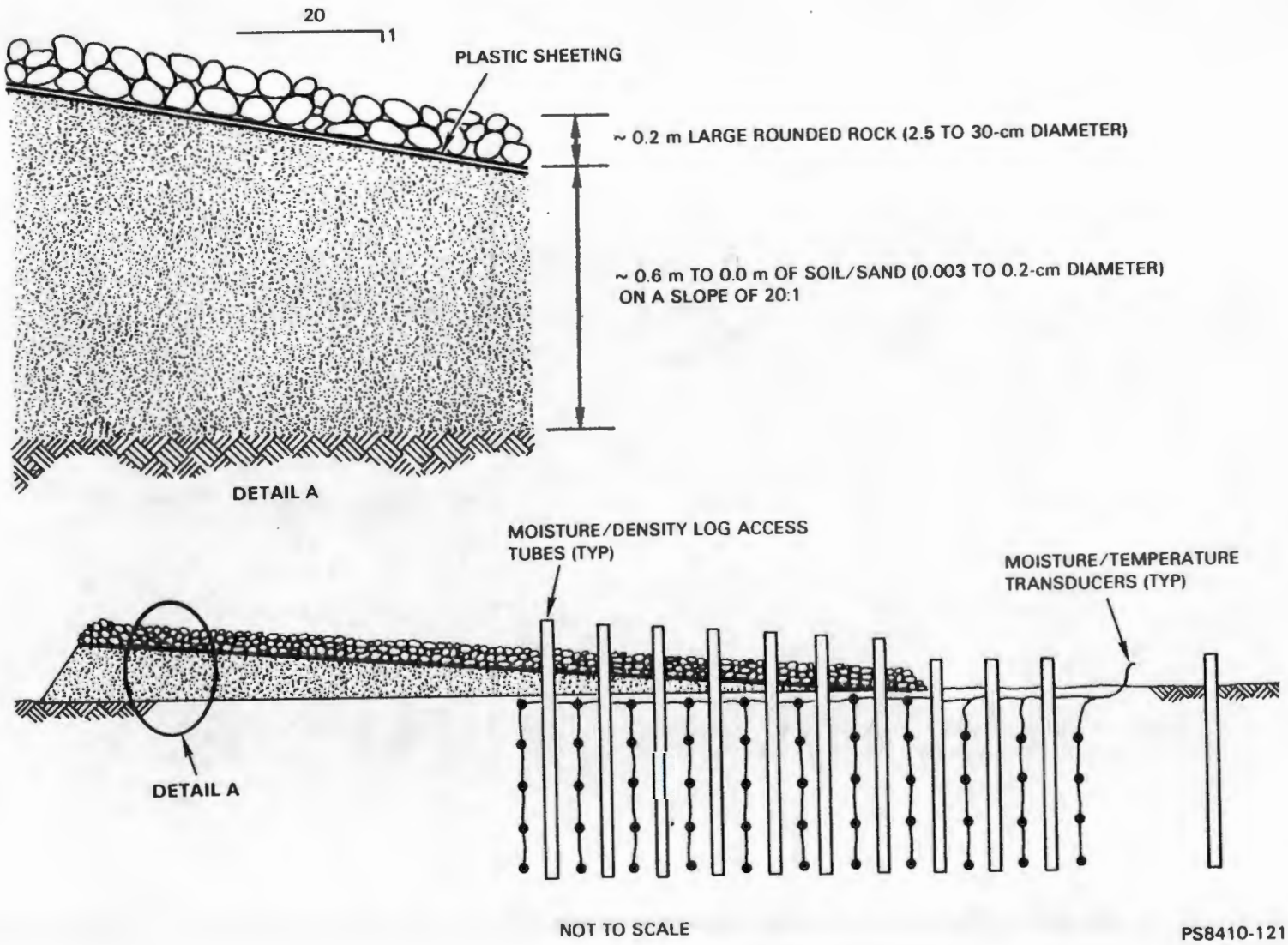
9 2 1 2 5 0 0 0 7 0 3



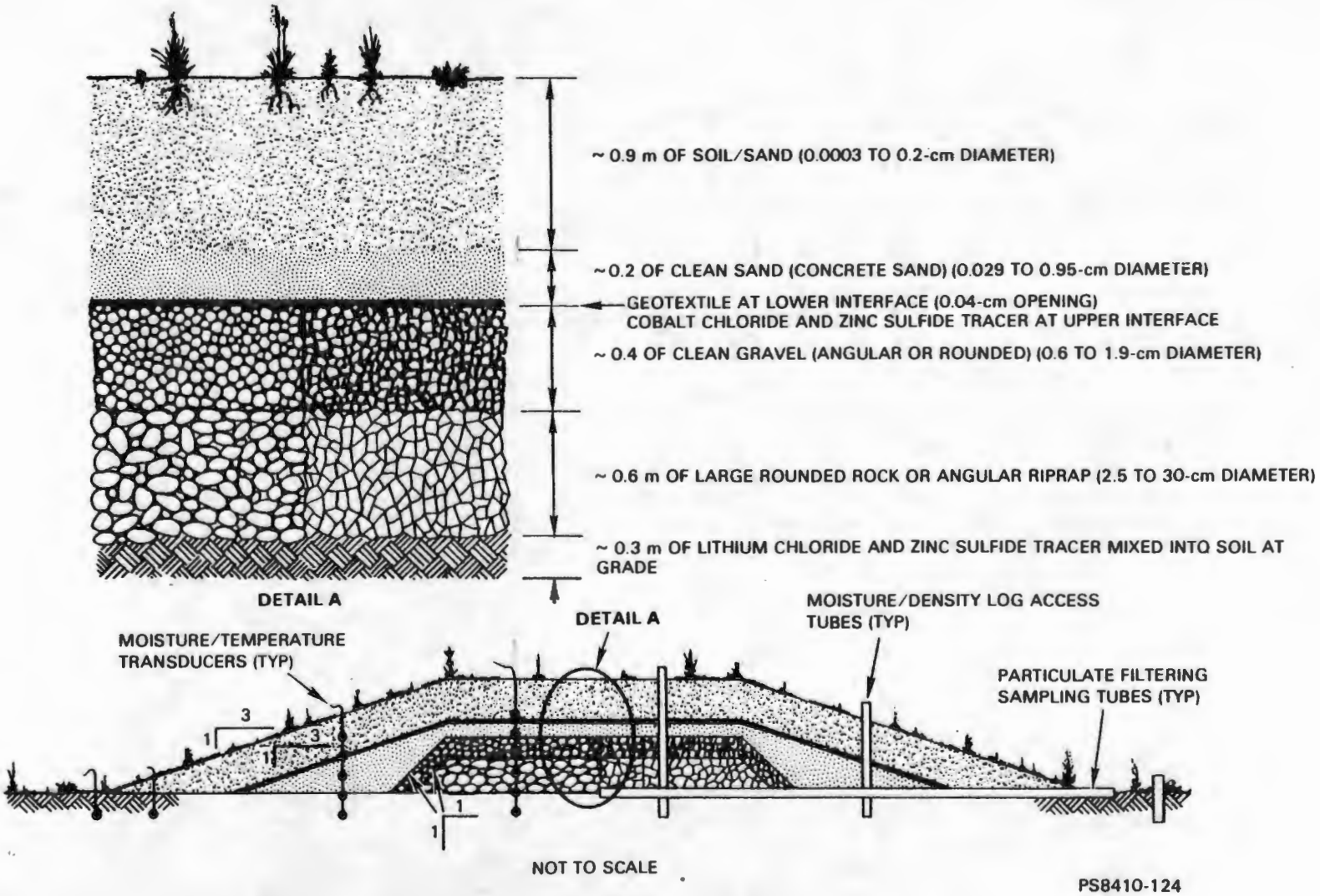
Mounded Soil Test Barrier.



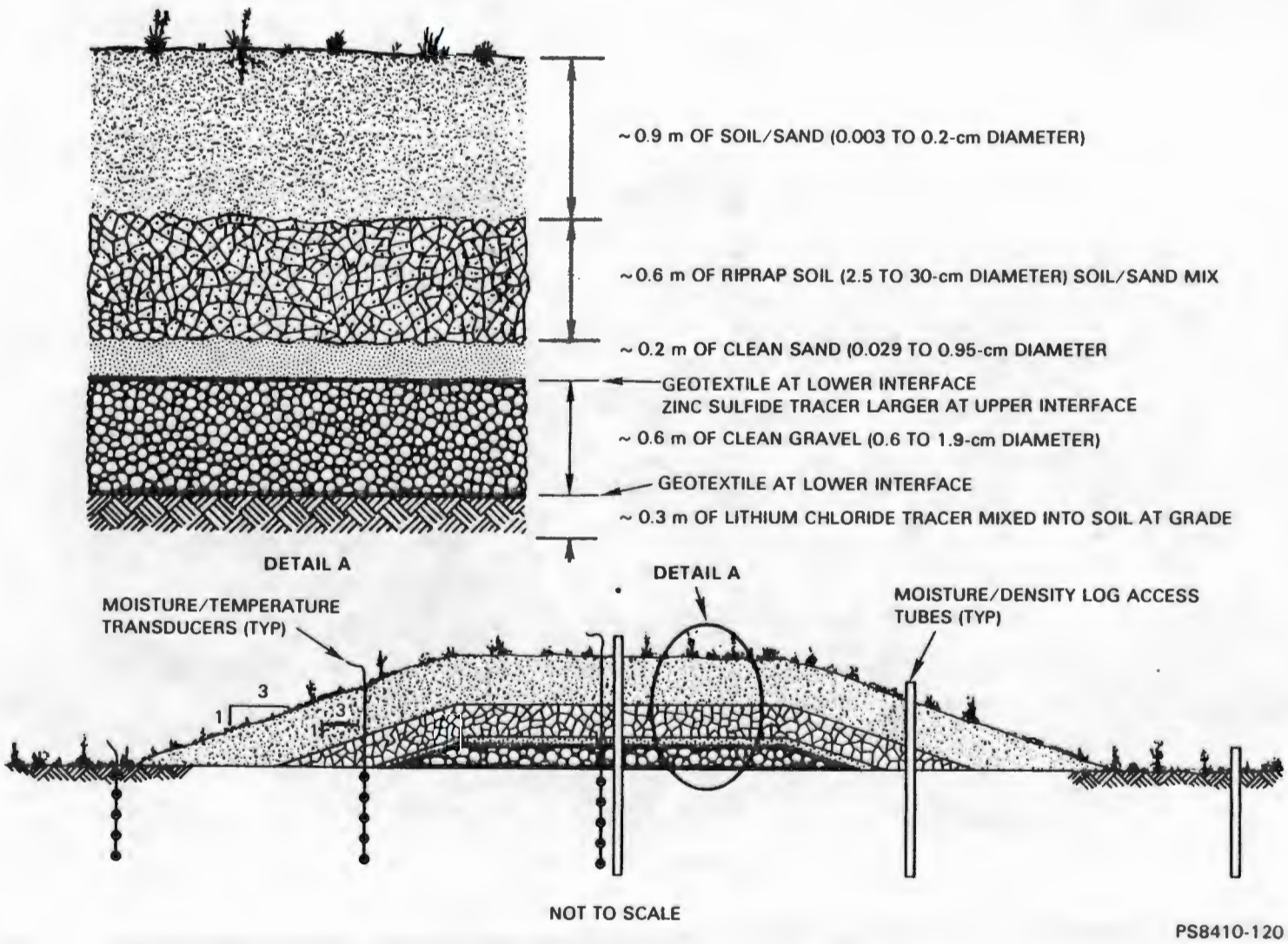
Mounded Rock Test Barrier.



Impermeable Off-Flow Test Barrier.



Multilayer Infiltration/Biotic Intrusion Test Barrier.



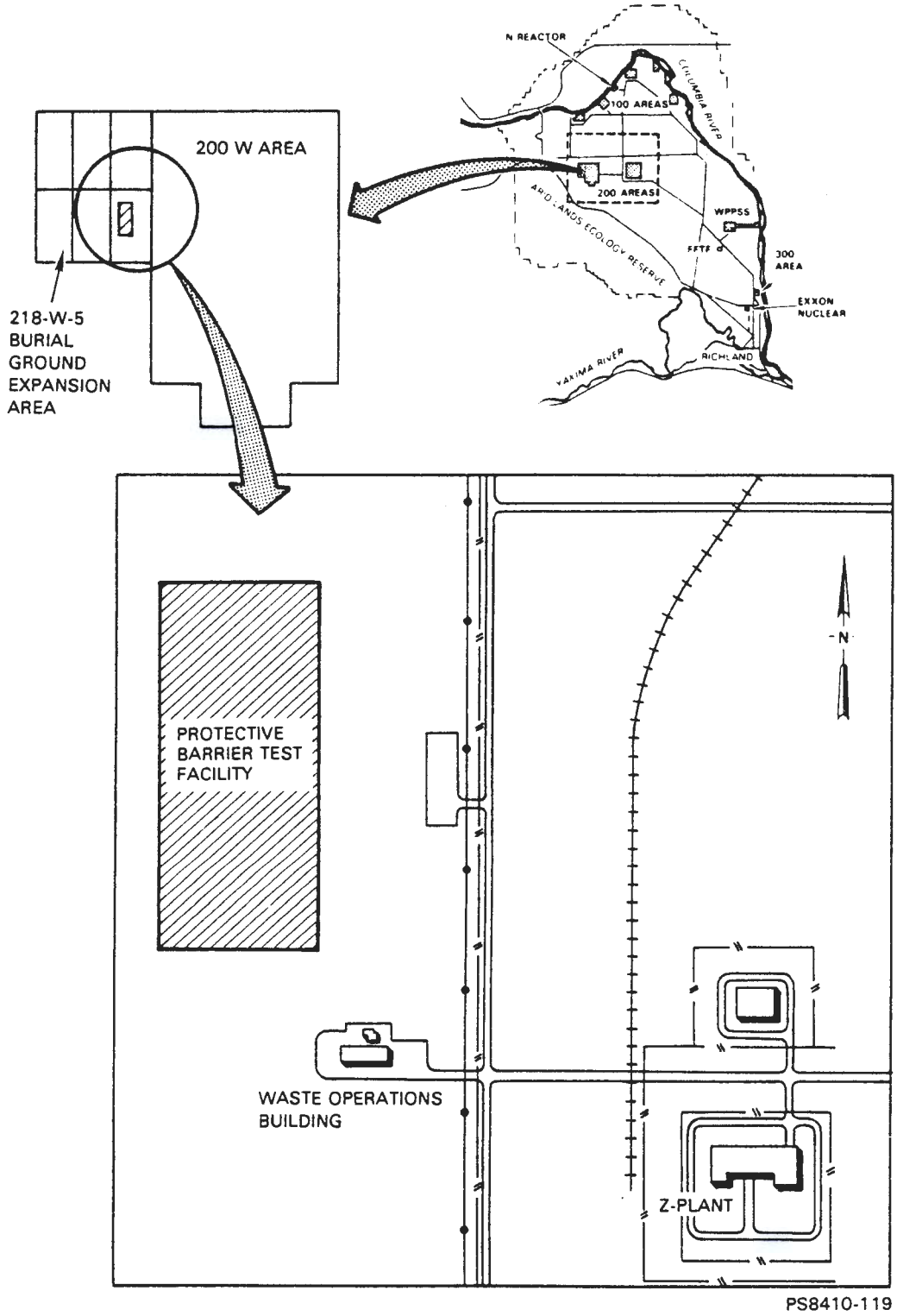
Multilayer Biotic Intrusion Test Barrier.

APPENDIX B

LOCATION OF THE ENGINEERED BARRIER TEST FACILITY AT THE HANFORD SITE

The Engineered Barrier Test Facility is an experimental area located within the 218-W-5 burial ground expansion area. This burial ground is scheduled to begin waste disposal operations in 1986.

9212500070 9



218-W-5 Burial Ground Expansion Area.

9 2 1 2 5 0 0 7 1 0

APPENDIX C

EXAMPLE MATERIALS REQUIREMENTS AND SPECIFICATIONS FOR CONSTRUCTION AT THE ENGINEERED BARRIER TEST FACILITY FOR EACH TEST BARRIER

The material description, volume or quantity, and the engineering specifications for materials used for the mounded soil, mounded rock, impermeable off-flow, multilayer infiltration/biotic intrusion, and multilayer biotic intrusion test barriers are listed in the following tables.

9 2 1 2 5 0 0 0 7 1 1

Multilayer Biotic Intrusion Barrier

Material	Units required	Material specifications
Gravel	100 m^3	Angular basalt, washed, 0.6 to 2.0-cm diameter
Geotextile	420 m^3	Polypropylene filter cloth
Sand	55 m^3	Concrete sand washed Characteristics -- U.S. Standard Sieve Mesh / % Passing (by weight): 3/8 in. 100; 4 30 - 95; 16 6 - 30; 50 0 - 4; 100 0
Rock	140 m^3	Crushed basalt, 2 to 30-cm diameter
Native soil/sand	540 m^3	Hanford topsoil and underlying sand

PS84-3316-7

9 2 1 2 5 0 0 0 7 1 2

Multilayered Infiltration/Biotic Intrusion Barrier

Material	Units required	Material specifications
Rock	40 m^3	Crushed basalt, 2 to 30-cm diameter
Rock	40 m^3	Round, 2 to 30-cm diameter
Gravel	35 m^3	Angular basalt, washed, 0.6 to 2.0-cm diameter
Gravel	35 m^3	Screened round, 0.6 to 2.0-cm diameter
Geotextile	270 m^2	Polypropiyene filter cloth
Sand	60 m^3	Concrete sand washed
		Characteristics --
Soil/sand	500 m^3	Hanford topsoil and underlying sand

U.S. Standard Sieve Mesh	% Passing (by weight)
3/8 in.	62 - 100
4	30 - 95
16	6 - 30
50	0 - 4
100	0

PS84-3316-8

9 2 1 2 5 0 0 0 7 1 3

Impermeable Off-Flow Barrier

Material	Unit required	Material specifications
Soil/sand	40 m^3	Hanford topsoil and underlying sand
Plastic sheet	200 m^2	0.05-cm thick, PVC sheeting
Gravel	11 m^3	Clean, 5-cm rounded gravel

PS84-3316-2

9 2 1 2 5 0 0 0 7 1 4

Mounded Soil

Material	Unit required	Material specifications
Soil/sand	1,160 m^3	Hanford topsoil and underlying sand

PS84-3316-3

Mounded Rock

Material	Unit required	Material specifications
Rock	160 m^3	Crushed basalt 2.5 to 30-cm diameter
Rock	160 m^3	Round rock 2.5 to 30-cm diameter

PS84-3316-4

9 2 1 2 5 0 0 0 7 1 5

This page intentionally left blank.

9 2 1 2 5 0 0 0 7 1 6

APPENDIX D

AS-BUILT ENGINEERING DRAWINGS OF THE ENGINEERED BARRIER TEST FACILITY

Drawing H-2-93048 denotes plan and cross-sectional views of mounded soil, mounded rock, and multilayer infiltration/biotic intrusion test barriers.

Drawing H-2-94869 denotes plan and cross-sectional views of impermeable off-flow and multilayer biotic intrusion test barriers.

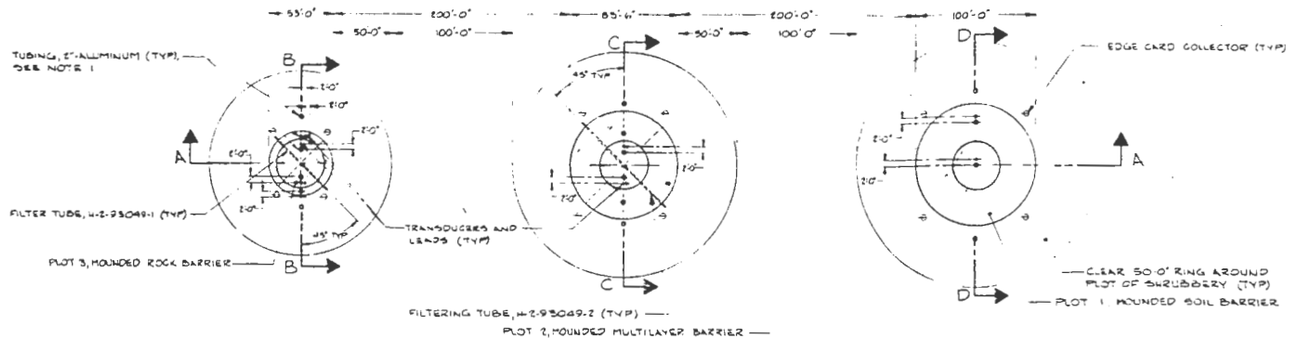
Materials specifications and construction notes are also shown on each drawing.

9 2 1 2 5 0 0 7 1 7

This page intentionally left blank.

9 2 1 2 5 0 0 0 7 1 8

9 2 1 2 5 0 0 0 7 1 9



PLAN
SCALE: 1" = 40'-0"

GENERAL NOTES:

1. 2" ALUMINUM TUBES SHALL BE REINFORCED INTERNALLY BY 1½" PIPE DURING CONSTRUCTION OF CLOSURE PLOTS. 1½" PIPE TO BE REMOVED AFTER CONSTRUCTION. 1½" PIPE SHALL BE SCHEDULE 40 ASTM-A53 TYPE E GR B, CS. 1½" PIPE TO EXTEND 2'-0" ABOVE BARRIER SURFACE.
2. CLOSURE PLOT ANIMAL AND PLANT TRACERS:
   PLOT 1: A LAYER OF LITHIUM CHLORIDE, ⅓ AREA OF GREEN FLORESCENT PIGMENT, ⅓ LAYER OF ZINC SULFIDE, AND ⅓ LAYER OF RED FLORESCENT PIGMENT TO BE PLACED AT EXISTING GRADE.
   PLOT 2: LAYERS OF COBALT CHLORIDE AND ZINC SULFIDE TRACERS TO BE PLACED AT SOIL-SAND INTERFACE. LAYERS OF OF LITHIUM CHLORIDE AND ZINC SULFIDE TRACERS TO BE PLACED AT EXISTING GRADE.
   PLOT 3: COLBANT CHLORIDE LITHIUM CHLORIDE, AND ZINC SULFIDE TRACERS TO BE PLACED AT EXISTING GRADE.

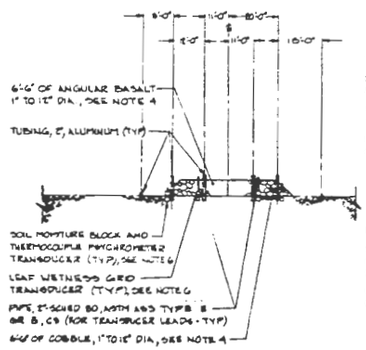
COBALT CHLORIDE — RED FLORESCENT PIGMENT
LITHIUM CHLORIDE — GREEN FLORESCENT PIGMENT
ZINC SULFIDE

TRACER DIAGRAM
SCALE: NONE

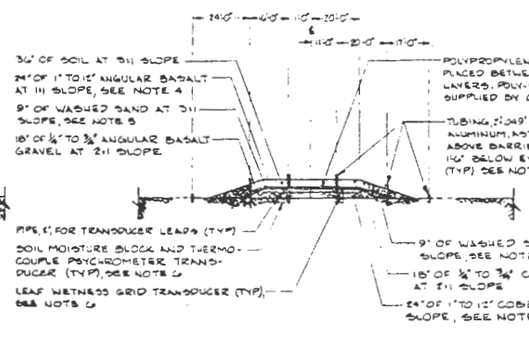
3. SURFACE REVEGETATION:
   PLOT 1 AND 2: DRILL SEED INTO PREPARED SURFACE. BROADCAST STRAW MULCH OVER SEEDED SURFACE AND CRIMP.
   PLOT 3: NONE
   REMAINING DISTURBED SURFACES SAME AS FOR PLOTS 1 AND 2.
4. ROCKS LARGER THAN 6" SHALL BE KEPT TO A MINIMUM.
5. SIEVE ANALYSIS DATA:

MESH #	SPECIFICATION % PASSING (BY WT)	ACTUAL % PASSING (BY WT)
⅜	65 - 100	100
4	50 - 95	93
16	0 - 30	0
50	0 - 4	1
100	0	0

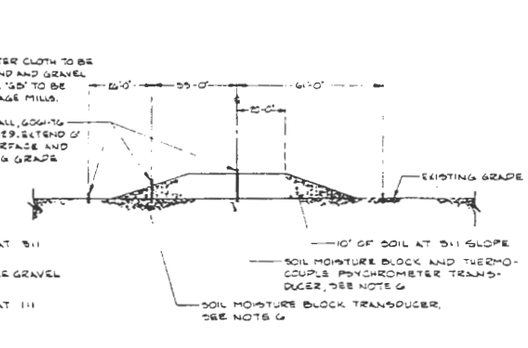
6. ALL LEAF WETNESS GRID TRANSDUCERS SHALL BE PLACED AT EXISTING GRADE. ALL SOIL MOISTURE BLOCK AND THERMOCOUPLE PSYCHROMETER TRANSDUCERS SHALL BE PLACED 2'-0" BELOW EXISTING GRADE.



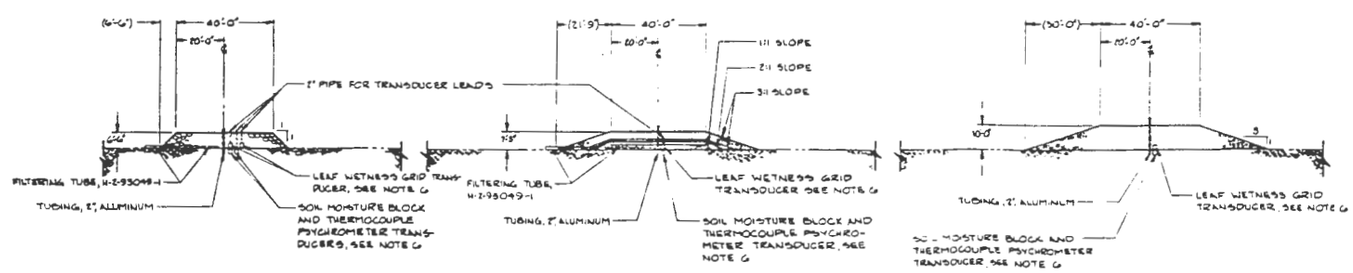
SECTION B-B
SCALE: 1" = 20'-0"



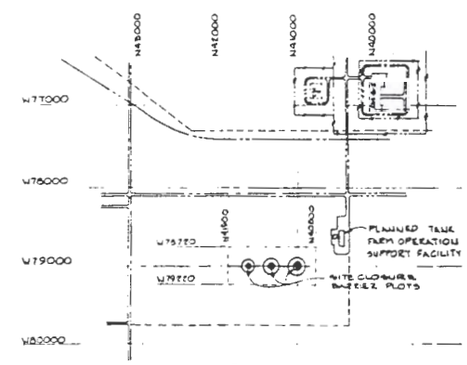
SECTION C-C
SCALE: 1" = 20'-0"



SECTION D-D
SCALE: 1" = 20'-0"

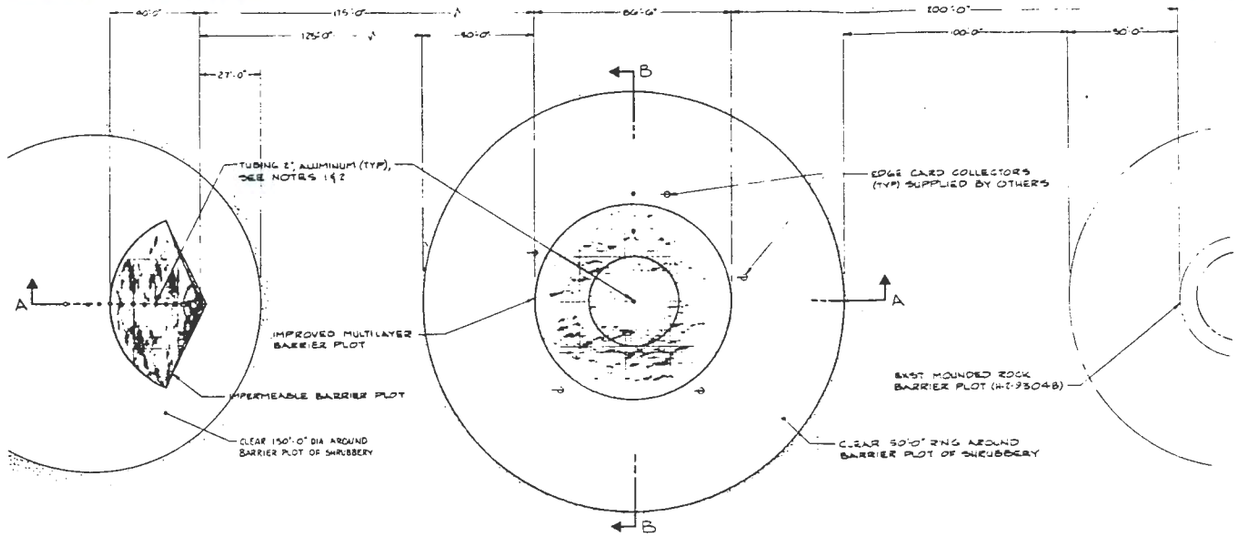


SECTION A-A
SCALE: 1" = 20'-0"

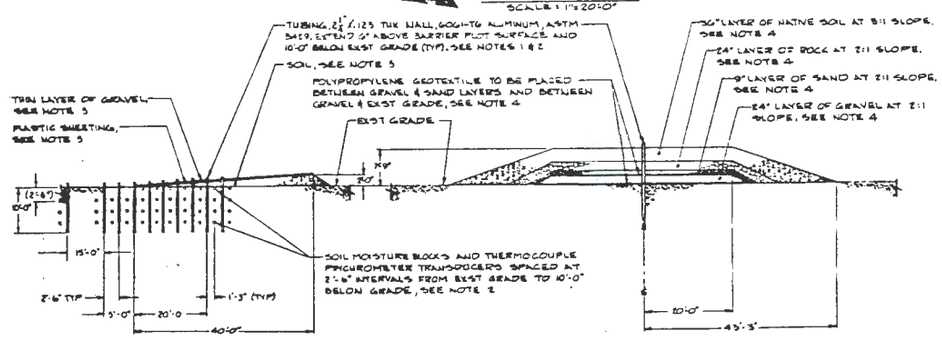


KEY PLAN
SCALE: NONE

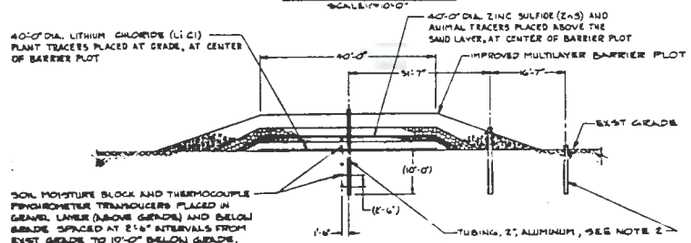
9 2 1 2 5 0 0 0 7 2 0



PLAN △
SCALE: 1"=20'-0"



SECTION A-A △
SCALE: 1"=10'-0"



SECTION B-B △
SCALE: 1"=10'-0"

GENERAL NOTES:

△1. 2" ALUMINUM TUBES SHALL BE REINFORCED INTERNALLY BY 1½" PIPE DURING CONSTRUCTION OF BARRIERS. 1½" PIPE TO BE REMOVED AFTER CONSTRUCTION. 1½" PIPE SHALL BE SCHEDULE 40, ASTM-A53 TYPE S, GR B, CS. 1½" PIPE TO EXTEND 2'-0" ABOVE BARRIER SURFACE.

△2. MONITORING EQUIPMENT FOR THE IMPROVED MULTILAYER BARRIER PLOT SHALL CONSIST OF: 7 THERMOCOUPLE PSYCHROMETERS, 7 SOIL MOISTURE BLOCKS, AND 3 ALUMINUM ACCESS TUBES. MONITORING EQUIPMENT FOR THE IMPERMEABLE BARRIER PLOT SHALL CONSIST OF: 51 THERMOCOUPLE PSYCHROMETERS, 51 SOIL MOISTURE BLOCKS, AND 10 ALUMINUM ACCESS TUBES.

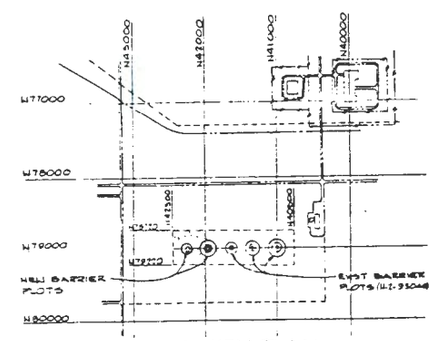
△3

△4. MATERIAL REQUIREMENTS FOR THE IMPROVED MULTILAYER BARRIER PLOT SHALL BE AS FOLLOWS:

MATERIAL	UNITS REQUIRED	MATERIAL SPECIFICATIONS
POLYPROPYLENE FILTER CLOTH	292 YD²	MARAFI CONSTRUCTION FABRIC #600 X
GRAVEL	120 YD³	ANGULAR BASALT, UNWASHED ¾"-⅜" DIAMETER
SAND	70 YD³	WASHED, DESIRABLE CHARACTERISTICS: U.S. STANDARD SIEVE MESH — % PASSING (BY WEIGHT): 10 — 100; 20 — 95; 4 — 30; 6 — 30; 30 — 0; 100 — 0
ROCK, RIP RAP	225 YD³	RELATIVELY FREE OF FINES, 1½" DIAMETER
NATIVE SOIL	700 YD³	HANFORD "TOPSOIL"

△5. MATERIAL REQT FOR IMPERMEABLE BARRIER PLOT SHALL BE AS FOLLOWS:

MATERIAL	UNITS REQD	MATERIAL SPECIFICATIONS
SOIL	60 YD³	— —
PLASTIC SHEET	250 YD²	2 LAYERS 28 MIL (0.0008") THK POLYETHALENE SHEETING, LOWER EDGE OF OVERLAP SEALED WITH SILICON RUBBER BEAD 50% OVERLAY
GRAVEL	20 YD³	REASONABLY CLEAN, 2" ROUNDED GRAVEL



KEY PLAN
SCALE: NONE

Appendix E

EXAMPLE SOIL PHYSICS LABORATORY CHARACTERIZATION OF SEVERAL EXISTING AND INITIALLY PROPOSED TEST BARRIER MATERIALS

Tables of physical properties, moisture release data, partially saturated hydraulic conductivity equation variables, and particle size analysis data are presented.

Material identified in these tables as washed sand, black soil, and top soil are equivalent to clean washed sand used below the geotextile layer in the multilayer barriers, underlying soil below grade at each test barrier location, and soil collected at grade from the engineered barrier test facility prior to construction, respectively. Ash, attapulgite, and halloysite are test mixtures of flyash slag collected from an onsite location and of natural clay minerals.

Additional data has been collected by Pacific Northwest Laboratory and Washington State University.

9 2 1 2 5 0 0 0 7 2 1

Physical Properties of Soil Samples.

Material	Bulk density (mg/m^3)	Particle density (mg/m^3)	Saturation water content (m^3/m^3)	Saturated hydraulic conductivity (cm/s)
Washed Sand	1.77	2.88	0.39	5.4×10^{-3}
Gravel	1.49	2.97	0.50	0.33
Black Soil	1.50	2.79	0.46	1.9×10^{-3}
Top Soil	1.60	2.77	0.42	1.1×10^{-3}
Ash + Attapulgite	0.70	2.71	0.74	2.0×10^{-3}
Ash + Halloysite	1.00	2.51	0.60	8.4×10^{-4}

Moisture Release Data.

Material	0.1 -Bar	0.33 -Bar	Water content (g/g)			10 -Bar	15 -Bar
			0.67 -Bar	1 -Bar	5 -Bar		
Washed Sand	0.033	0.033	0.031	0.028	0.026	0.023	0.021
Black Soil	0.079	0.058	0.054	0.043	0.037	0.033	0.030
Top Soil	0.080	0.062	0.050	0.046	0.039	0.034	0.033
Ash + Attapulgite	0.650	0.606	0.544	0.500	0.402	0.364	0.359
Ash + Halloysite	0.314	0.252	0.242	0.203	0.156	0.142	0.130

9 2 1 2 5 0 0 0 7 2 2

Constants for the Moisture Release Equation $\psi = aw^{-b}$.

Material	a -(Bars)	ψ_e (Bars)	$\theta_s (m^3/m^3)$	k_s(cm/s)	b	m	n
Washed Sand	1.8×10^{-15}	3.1×10^{-9}	0.39	5.4×10^{-3}	9.5	22	2.32
Black Soil	1.31×10^{-7}	6.5×10^{-5}	0.46	1.9×10^{-3}	5.25	13.5	2.57
Top Soil	3.95×10^{-8}	8.2×10^{-5}	0.42	1.1×10^{-3}	5.71	14.4	2.53
Ash + Attapulgite	5.5×10^{-3}	3.6×10^{-3}	0.74	2.0×10^{-3}	7.58	18.2	2.40
Ash + Halloysite	1.64×10^{-4}	2.9×10^{-3}	0.60	8.4×10^{-4}	5.60	14.2	2.54

NOTE: (ψ in Bars, w in g/g), the water content based unsaturated conductivity function

$k = k_s (\theta/\theta_s)^m$ and the water potential based conductivity function

$k = k_s (\psi_e/\psi)^n$, θ is water content in m^3/m^3, ψ_e is air entry potential (Bars)

$m = 2b + 3$

$n = 2 + 3/b$

Particle Size Analysis - All Entries are in Mass Percent (g/g x 100).

Material	Gravel >2mm	Sand 1mm-2mm	Sand 20µm-1mm	Silt 2-20µm	Clay <2µm
Washed Sand	21.2	16.7	59.5	2.0	1.0
Black Soil	0.5	91.2		5.6	1.8
Top Soil	0.4	84.2		8.8	5.4
Ash	--	80.1		18.4	0.7
Ash + Attapulgite*	--	40.1		9.2	50.3
Ash + Halloysite*	--	40.1		9.2	50.3

*The particle size analysis was run only on the ash sample. The clay minerals were assumed to be composed only of particles <2µm. These two values were therefore calculated from the ash measurement.

9 2 1 2 5 0 0 0 7 2 3

This page intentionally left blank.

9 2 1 2 5 0 0 0 7 2 4

APPENDIX F

EXAMPLE CHARACTERISTICS OF MONITORING DEVICES AND ELECTRONIC SYSTEMS DEPLOYED AT THE ENGINEERED BARRIER TEST FACILITY

Monitoring systems are divided into three categories: (1) atmospheric, (2) soil, and (3) filtering. The first category includes micrometeorological instruments installed above grade at several locations at the Engineered Barrier Test Facility. The second category includes soil physics instruments installed primarily to measure infiltration parameters. The final category includes devices intended to measure geotechnical engineering properties of soils.

In each category one or more device or system is used that is also in another category. This permits efficient data collection by minimizing the number of data logging systems used to collect and preprocess field data.

9 2 1 2 5 0 0 0 7 2 5

Atmospheric Monitoring Instrument Characteristics for Above Barrier Conditions.

Transducer	Temperature range (°C)	Relative humidity range	Accuracy (ambient)	Misc.	Data mode
Temperature Thermister	-10 to +100	Saturated/ unsaturated vapor conditions	±0.8°C	--	Electronic
Relative Humidity Lithium chloride resistance gauge	<80	10% - 97%	±1.0%	~1 year expected operational life	Electronic
Wind Velocity Magnet-read anamometer	-30 to +80	Saturated/ unsaturated vapor conditions	±0.2 m/s	Threshold velocity 0.5 m/s	Electronic
Wind Direction Air foil vane potentiometer	-50 to +70	Saturated/ unsaturated vapor conditions	±5°C	Threshold velocity 0.4 m/s	Electronic
Dew/Precipitation Resistance grid	0 - dew point	≤ dew point	Determined on calibration	--	Electronic
Erosion Particulate samplers	All	Saturated/ unsaturated vapor conditions	±6%	Functional accuracy determined under actual conditions and proposed wind tunnel tests	Manual

NOTE: Auxiliary atmospheric data is collected at a central meteorological station.

Soil Monitoring Instrument Characteristics Under Barrier Conditions.

Transducer	Temperature range (°C)	Relative humidity range	Pore-water content range	Accuracy (ambient)	Data mode
Temperature Thermocouple	0.0 to +200	Saturated/ unsaturated vapor conditions	Saturated/ unsaturated liquid conditions	±0.3°C	Electronic
Relative Humidity Thermocouple psychrometer	2.0 to +80	95% - 99.9%	Unsaturated conditions	±0.5%	Electronic
Moisture Content/ Potential Thermocouple psychrometer	-80	95% - 99.9%	0.8 to >20 bars	±0.2 bar	Manual
Resistance block	0.0 to 80	Unsaturated/ saturated vapor conditions	0.3 to >15 bars	±0.5 bar	Electronic
Neutron	0.0 to +70	Unsaturated/ saturated vapor conditions	Unsaturated/ saturated liquid conditions	±2.0% (vol)	Manual
Density Gamma logging device	70	Unsaturated/ saturated vapor conditions	Unsaturated/ saturated liquid conditions	±0.3 g/cm^3	Manual

Filtering Monitoring Instrument Characteristics Under Barrier Conditions.

Transducer	Temperature range (°C)	Relative humidity range	Accuracy (ambient)	Misc.	Data mode
Filtering Resistance grid	0 to >25	Unsaturated/ saturated vapor conditions	To be determined	Modified dew monitoring transducer	Electronic
Gamma logging device	0 to 70	Unsaturated/ saturated vapor conditions	±0.3 g/cm^3	Used to determine Δ density	Manual
Coaxial	All	Unsaturated/ saturated vapor conditions	±2% (wt)	Direct sampling of particulate below rock layers	Manual

APPENDIX G

CONFIGURATION AND PLACEMENT OF FAUNA AND FLORA INTRUSION TRACERS WITHIN TEST BARRIERS AT THE ENGINEERED BARRIER TEST FACILITY

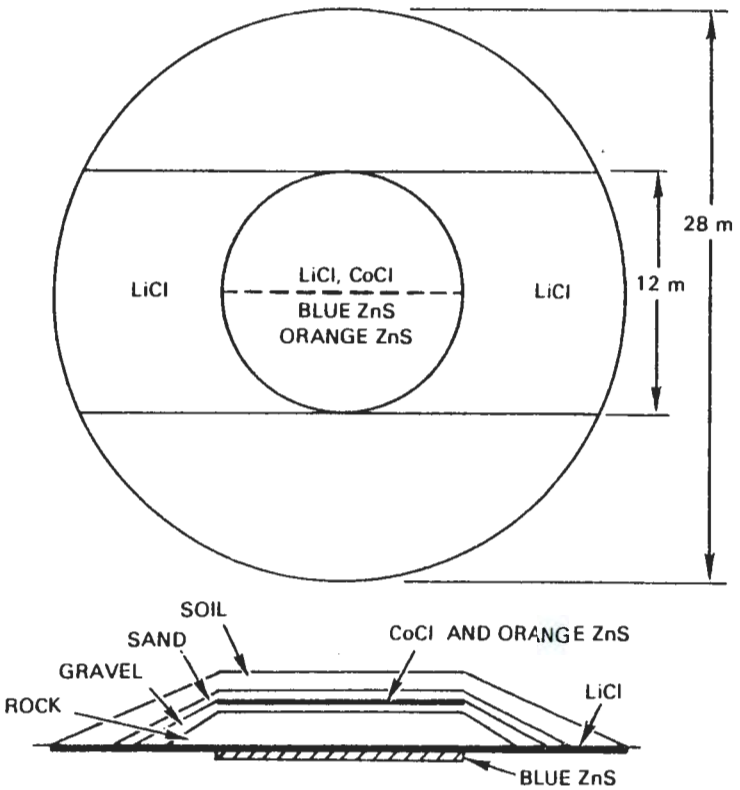
Lithium and cobalt chloride is used to evaluate barrier intrusion and uptake by plant root systems. Lithium and cobalt quantities are determined in the laboratory by spectrophotometric analysis.

Zinc sulfide and colored pigments are used to evaluate intrusion and materials dispersal by burrowing animals. The orange and blue zinc sulfide and the red and green pigments used each have a specific sprectral signature when subjected to ultraviolet light. Qualitive measurements are made in the field with a portable ultraviolet light. Quantitative measurements are made in the laboratory using spectrophotometric methods.

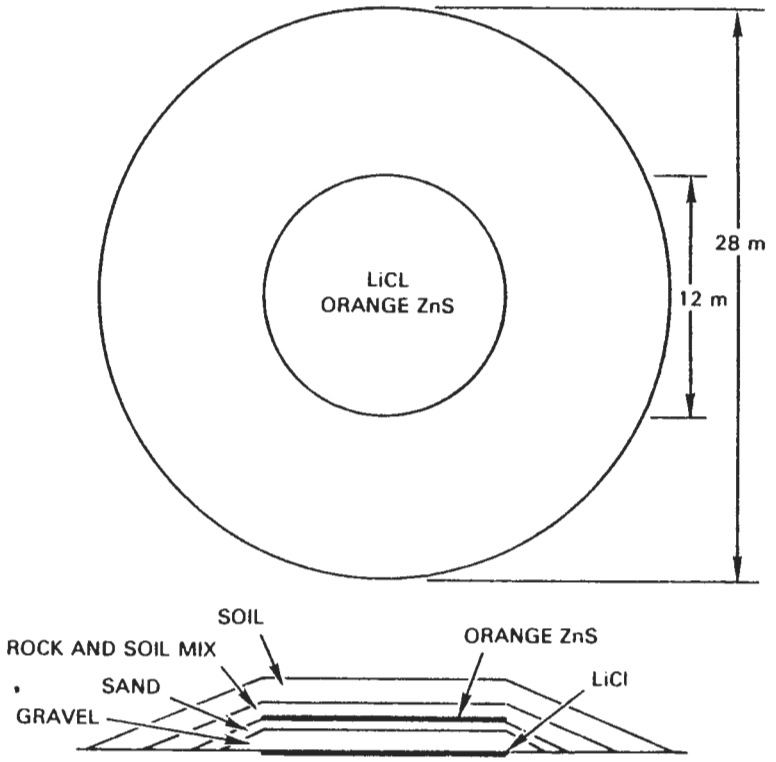
Tracer materials were placed at construction grade or within specific barrier layers.

No tracer material was used in the impermeable off-flow test barrier.

9 2 1 2 5 0 0 0 7 2 9

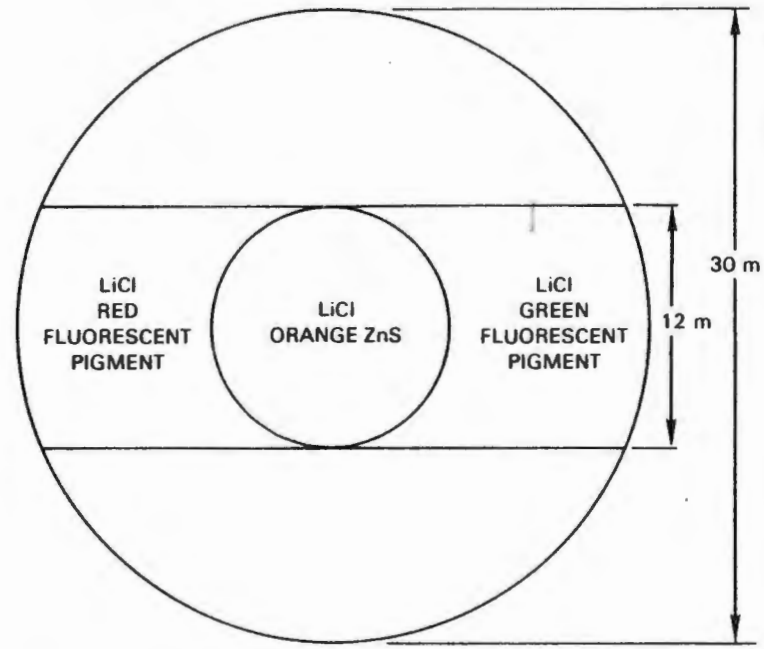


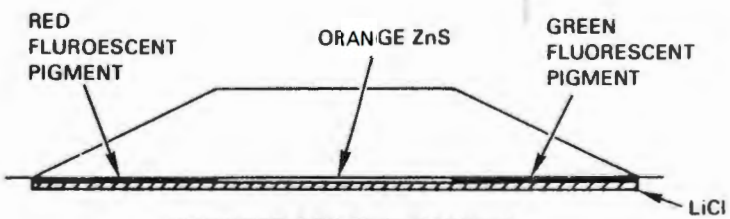
MULTILAYER INFILTRATION/BIOTIC INTRUSION TEST BARRIER



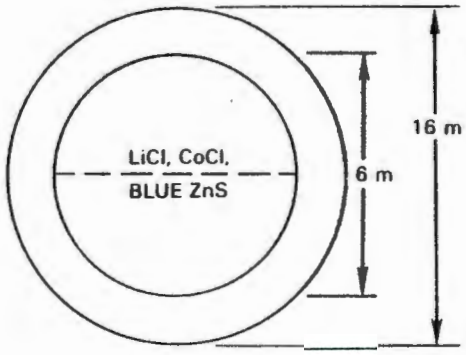
MULTILAYER BIOTIC INTRUSION TEST BARRIER

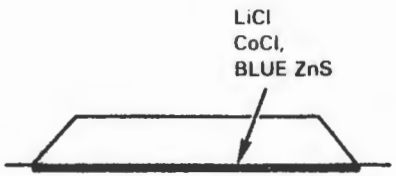
PS8410-131





MOUNDED SOIL TEST BARRIER





MOUNDED ROCK TEST BARRIER

PS8410-130

This page intentionally left blank.

9 2 1 2 5 0 0 0 7 3 2

APPENDIX H

EXAMPLE OF COMPUTER GENERATED INFORMATION USED TO EVALUATE DESIGN ALTERNATIVES FOR ENGINEERED BARRIERS

A spreadsheet program is used to evaluate design options, materials handling and transportation options, volumetric materials requirements, construction and administrative costs, and barrier specifications.

Included are tables and figures of example information for actual Hanford disposal sites and hypothetical barrier designs. Tables and figures are directly output on computer output devices. Example information provided herein have been enhanced from tabular or graphic computer output.

9 2 1 2 5 0 0 0 7 3 3

Alternatives for Acquisition of Materials Used for Engineered Barrier Cover Systems

Alternative	Major operations	Notes
I	1 Purchase materials 2 Delivery stockpile 3 Build stockpile 4 Load from stockpile 5 Delivery to site 6 Barrier construction	All materials are purchased from vendors offsite and delivered to a centrally located stockpile. From there the materials are delivered to the site(s) as needed.
II	1 Purchase materials 2 Deliver directly to site 3 Barrier construction	All materials are purchased from vendors offsite and delivered directly to the site(s). Materials are assumed to be placed on the site and utilized as delivered.
III	1 Screening plant operations 2 Loading at screening plant 3 Delivery to site 4 Barrier construction	All materials are produced using a screening plant located at a central location. Rounded rock, gravel, and washed sand are produced, stockpiled, and delivered to the site(s) as needed.
IV	1 Basalt quarry blasting 2 Screening/crushing plant operations 3 Loading at screening plant 4 Delivery to site 5 Barrier construction	All materials are produced from basalt rock quarried onsite. Required gravel and sand is produced by use of a screening/crushing plant. The materials are stockpiled and delivered to the site(s) as needed.
V	1 Purchase available materials onsite 2 Loading at stockpile 3 Delivery to site 4 Barrier construction	Required rock and gravel is purchased from onsite stockpiles and delivered to the site(s). Sand is purchased and delivered by an offsite vendor.

PS84-3316-5

Example Materials Requirements

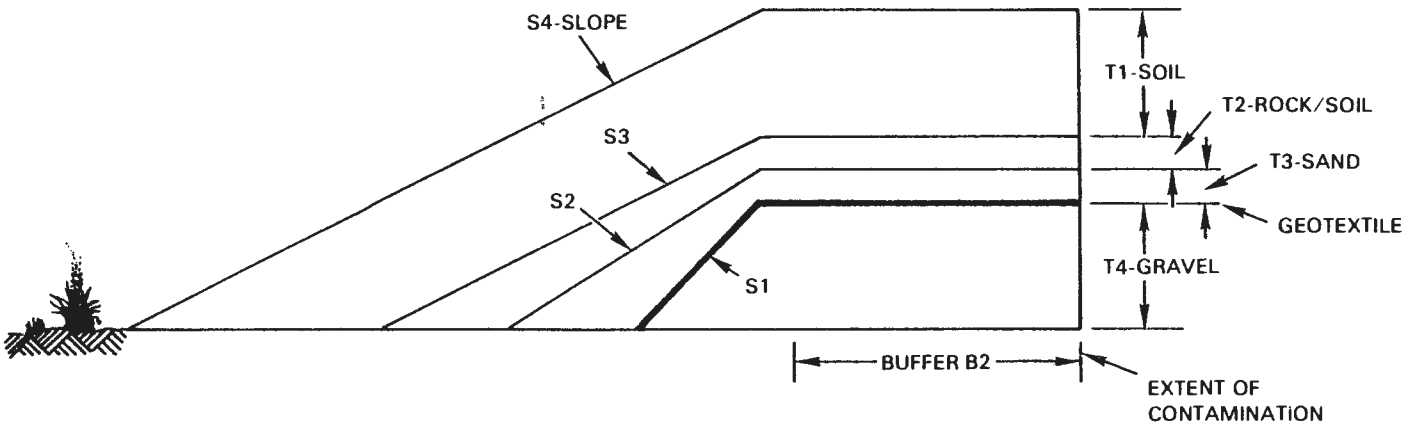
Example sites	Soil (m^3)	Sand (m^3)	Gravel (m^3)	Rock (m^3)	Geotextile(m^2)
216-A-24	11,109	1,768	4,407	4,675	7,331
216-B-45	1,298	150	293	397	659
216-B-43/50	323,503	63,996	188,149	171,235	256,958

PS84-3316-1

Example Disposal Cost Comparison for Alternative Sites Utilizing a Multilayer Biotic Intrusion Barrier (Thousands of Dollars)

Example sites	Material alternative	Barrier subtotal	Contract administration	Engineer and inspection	Contin-gency	Scaling power rule	Total ($1,000)
		--	12%	10%	20%	1	
216-A-24	II	$630	$80	$60	$150	$0	$920
216-B-45	V	$60	$7	$6	$14	$0	$87
216-B-43/50	IV	$25,000	$3,000	$2,500	$6,200	$0	$36,700

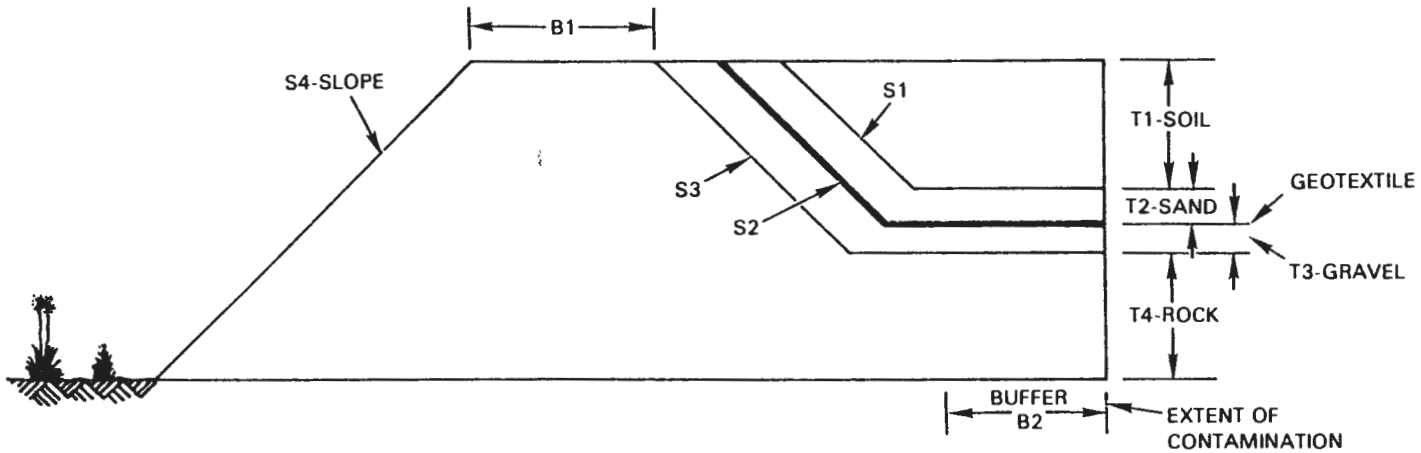
PS84-3316-6



BARRIER SPECIFICATIONS METERS (m)				SLOPES	
T1 =	1.00	B1 =	N/A	S1 =	1.00
T2 =	0.67	B2 =	5.0	S2 =	0.50
T3 =	0.25	TOTAL THICKNESS = 2.7 m		S3 =	0.50
T4 =	0.75			S4 =	0.33

PS8410-133

Computer Model Generated Example of a Multilayer Biotic Intrusion Barrier Cross Section (Graphically Enhanced).



BARRIER SPECIFICATIONS METERS (m)				SLOPES	
T1 =	1.50	B1 =	5.00	S1 =	0.50
T2 =	0.15	B2 =	0.00	S2 =	1.00
T3 =	0.15	TOTAL THICKNESS = 5.40 m		S3 =	1.00
T4 =	3.60			S4 =	1.00

PS8410-132

Computer Model Generated Example of a Multilayer Infiltration/Biotic Intrusion Barrier Cross Section (Graphically Enhanced).

APPENDIX I

EXAMPLE SEQUENCE OF CONSTRUCTION METHODS USED AT THE ENGINEERED BARRIER TEST FACILITY

Construction is shown in three figures. The first figure shows offloading of gravel onto a geotextile at grade. A tracer material was installed below the geotextile. Another geotextile was installed over the gravel layer. Sand was then placed over the second (upper) geotextile layer. Another tracer material was placed within this sand layer. The second figure shows placement of basalt riprap over the sand layer. The third figure shows placement of soil material within and over the riprap layer. Final shaping and surface stabilization follows placement of the soil layer.

Construction practices used for other test barriers use similar equipment and construction practices.

9 2 1 2 5 0 0 0 7 3 9

9 2 1 2 5 0 0 0 7 4 1

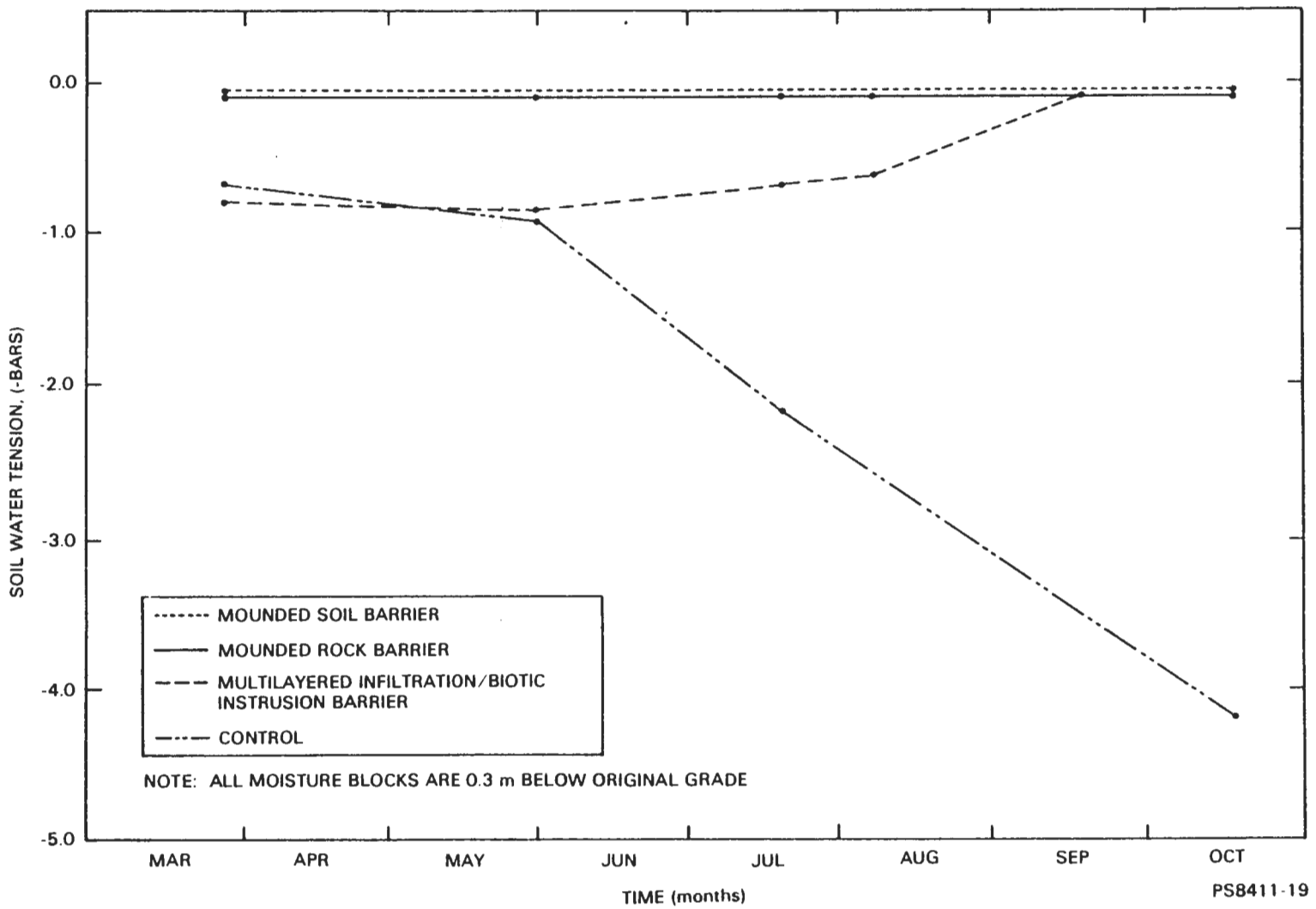
APPENDIX J

EXAMPLE OF PRELIMINARY COMPARATIVE SOIL MOISTURE VERSUS DEPTH DATA FOR TEST BARRIERS AND A CONTROL AREA AT THE ENGINEERED BARRIER TEST FACILITY

At the time of each barrier's construction, water was added to soil materials as a typical engineering practice, hence soil moisture is not at equilibrium conditions. Redistribution of soil moisture by liquid and vapor phase mass transfer mechanisms will establish dynamic (seasonal/annual) equilibrium at each barrier over the next few years.

Data from soil moisture blocks is shown. Additional data from other soil moisture monitoring devices, (e.g., neutron probe) will be used to determine equilibrium conditions, infiltration, evaporation, etc.

9 2 1 2 5 0 0 0 7 4 3

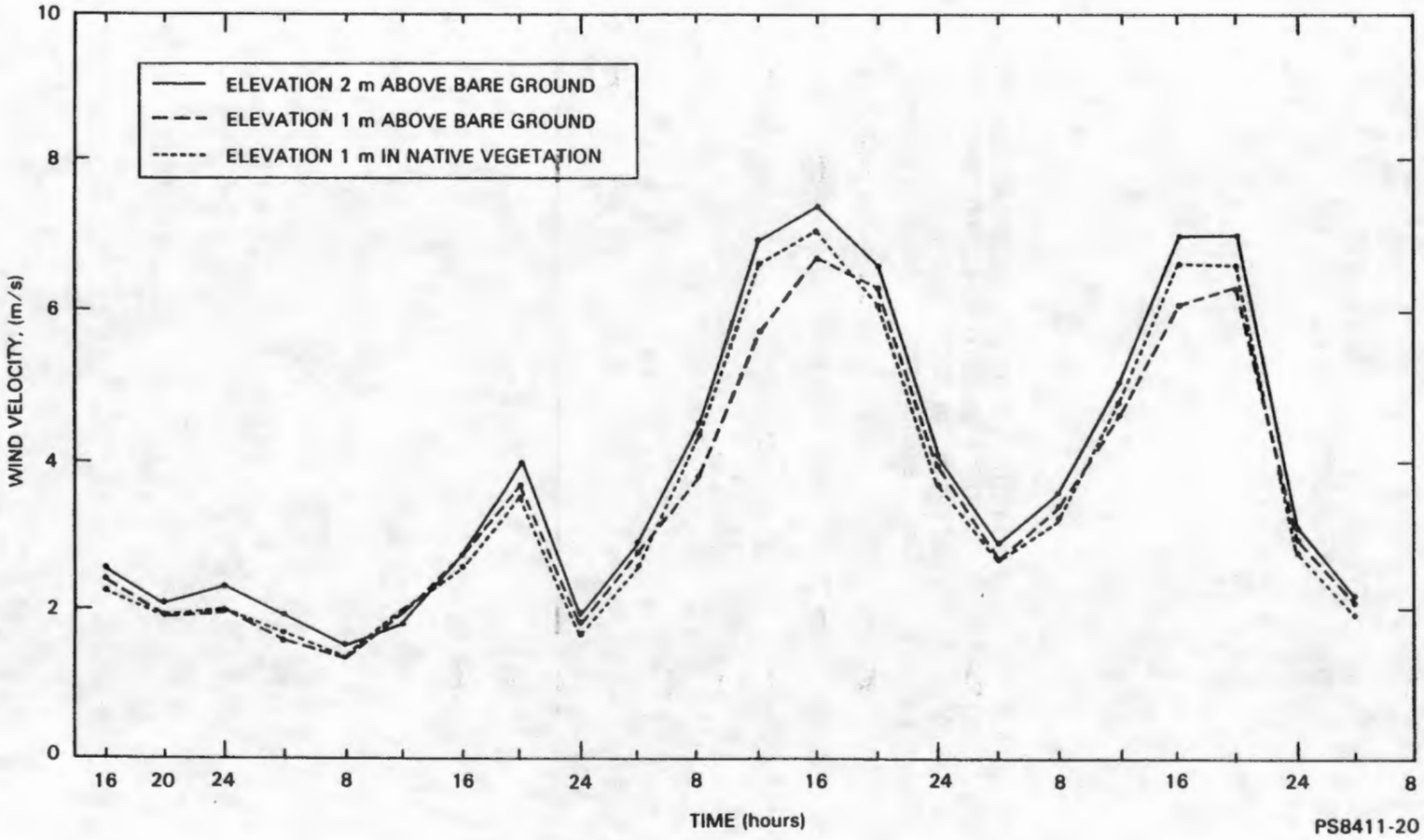

0.0
-1.0
-2.0
-3.0
-4.0
-5.0
SOIL WATER TENSION, (-BARS)
MOUNDED SOIL BARRIER
MOUNDED ROCK BARRIER
MULTILAYERED INFILTRATION/BIOTIC INSTRUSION BARRIER
CONTROL
NOTE: ALL MOISTURE BLOCKS ARE 0.3 m BELOW ORIGINAL GRADE
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
TIME (months)
PS8411-19

APPENDIX K

EXAMPLE OF MICROMETEOROLOGICAL DATA COLLECTED AT TWO LOCATIONS AT THE ENGINEERED BARRIER TEST FACILITY

Wind velocity versus elevation above grade at two stations [(1) bare ground and (2) native vegetation] is shown for comparison of effects of ground surface roughness. This type of data is used to determine, for example, wind erosion magnitude, evaporation, and particulate flux.

9 2 1 2 5 0 0 0 7 4 5

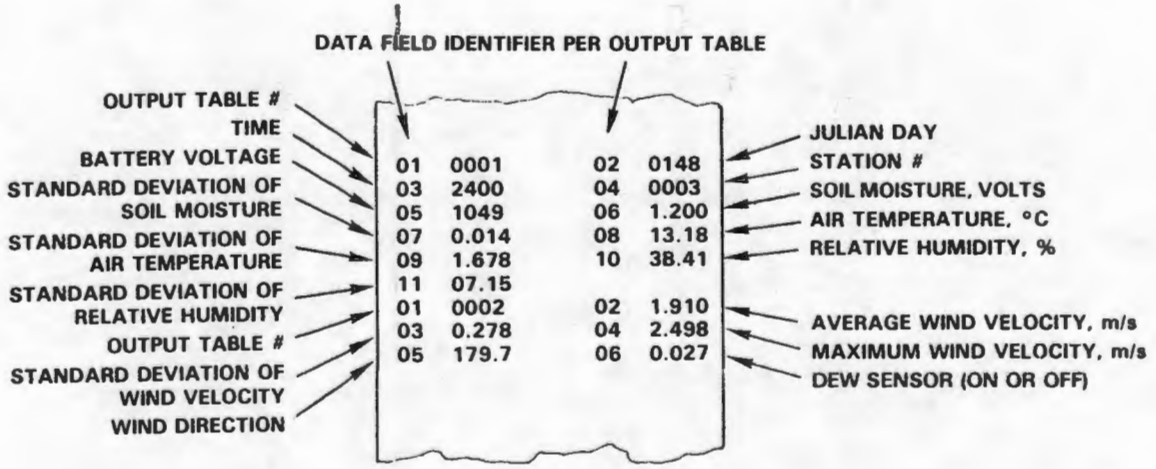

ELEVATION 2 m ABOVE BARE GROUND
ELEVATION 1 m ABOVE BARE GROUND
ELEVATION 1 m IN NATIVE VEGETATION
WIND VELOCITY, (m/s)
0
2
4
6
8
10
16
20
24
8
16
24
8
16
24
8
16
24
8
TIME (hours)
PS8411-20

APPENDIX L

EXAMPLE OF A DATA OUTPUT RECORD FROM ONE MICROPROCESSOR-BASED FIELD DATA LOGGER AT THE ENGINEERED BARRIER TEST FACILITY

Data collection input programs and display output programs are entered at each monitoring station location. Mean values of each parameter and statistically determined ranges are typically displayed on paper tape for laboratory data file entry and subsequent analysis.

9 2 1 2 5 0 0 0 7 4 7


DATA FIELD IDENTIFIER PER OUTPUT TABLE
OUTPUT TABLE #
TIME
BATTERY VOLTAGE
STANDARD DEVIATION OF SOIL MOISTURE
STANDARD DEVIATION OF AIR TEMPERATURE
STANDARD DEVIATION OF RELATIVE HUMIDITY
OUTPUT TABLE #
STANDARD DEVIATION OF WIND VELOCITY
WIND DIRECTION
01 0001 02 0148
03 2400 04 0003
05 1049 06 1.200
07 0.014 08 13.18
09 1.678 10 38.41
11 07.15
01 0002 02 1.910
03 0.278 04 2.498
05 179.7 06 0.027
JULIAN DAY
STATION #
SOIL MOISTURE, VOLTS
AIR TEMPERATURE, °C
RELATIVE HUMIDITY, %
AVERAGE WIND VELOCITY, m/s
MAXIMUM WIND VELOCITY, m/s
DEW SENSOR (ON OR OFF)

PS8409-15

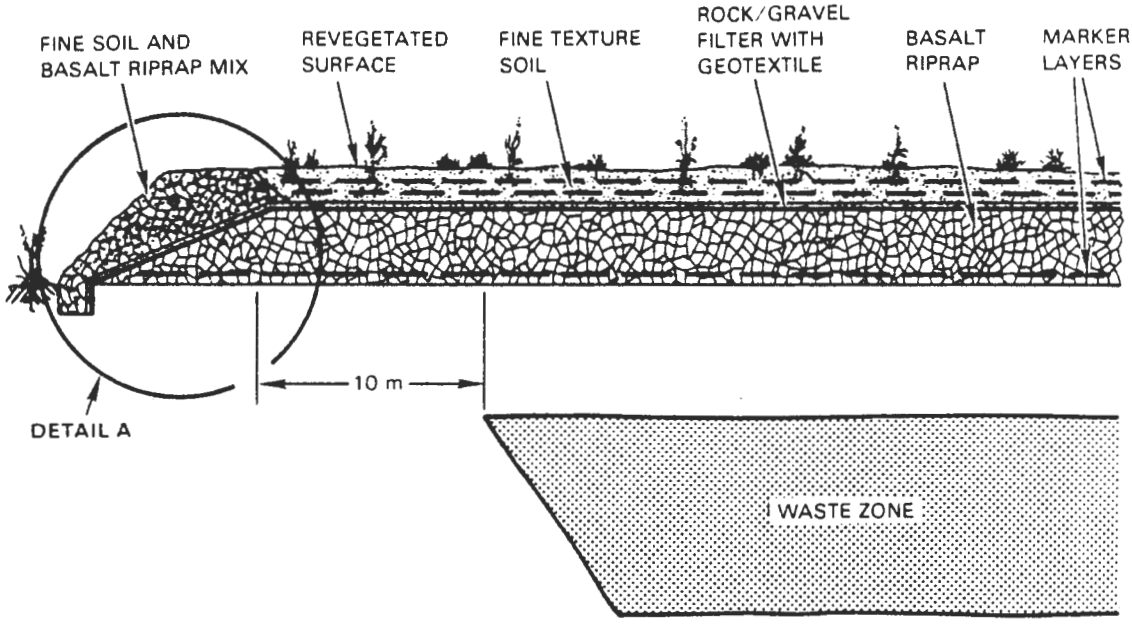
APPENDIX M

SKETCH OF A HYPOTHETICAL MULTILAYER ENGINEERED BARRIER DENOTED AS THE "HANFORD STANDARD BARRIER"

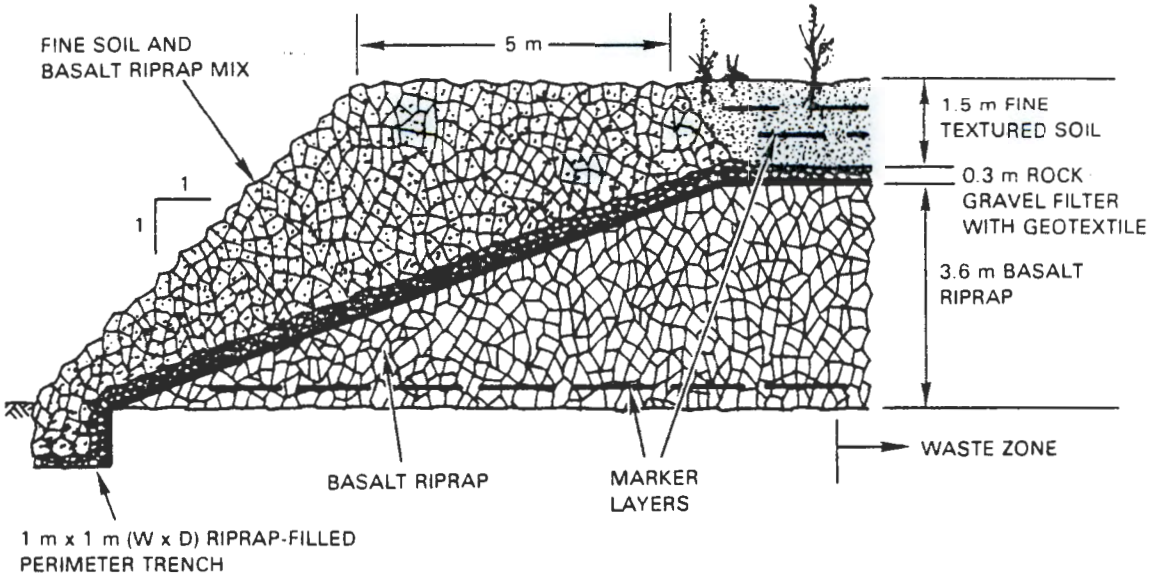
This hypothetical barrier is used for evaluating, for example, relative costs and construction impacts.

Optimization of this barrier and other designs will be made by computer simulation, performance analysis, and other techniques.

9212500074 9



CROSS-SECTION OF BARRIER SYSTEM OVERLYING WASTE TANKS



DETAIL A

(NOT TO SCALE)

PS8501-77

DISTRIBUTION

Number of Copies	
ONSITE	
55	Rockwell Hanford Operations S. J. Phillips (50) Document Control (2) Publications Services Department (3)

9212500751

THIS PAGE INTENTIONALLY
LEFT BLANK

9 2 1 2 5 0 0 0 7 5 2