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Preliminary Engineering Specifications for a Test Demonstration Multilayer Protective Barrier Cover System

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1.0 INTRODUCTION

This report presents preliminary engineering specifications for a test protective barrier cover system and support radiohydrology facility to be constructed at the Hanford Protective Barrier Test Facility (PBTF). Construction of this test barrier and related radiohydrology facility is part of a continuing effort to provide construction experience and performance evaluation of alternative barrier designs used for long-term isolation of disposed radioactive waste materials.

Design specifications given in this report are tentative, based on interim engineering and computer simulation design efforts. Final definitive design specifications and engineering prints will be produced in FY 1986.

2.0 PROTECTIVE BARRIER TEST FACILITY SITE DESCRIPTION

The PBTF facility was established in 1983 for construction and evaluation of conceptual protective barrier cover system designs. The facility is located in the southwest quarter of Section 36, Township 13 North, Range 26 East. This area is denoted as the Facilities Area of the 218-W-5 Burial Ground Expansion Area, which is within the northwest quadrant of the 200 West Chemical Separation Area of the Hanford Site. The location of the PBTF is shown in figure 2-1. Currently, five surface barrier test plots have been constructed at the PBTF. Test plot barrier designs include: (1) mounded soil; (2) mounded rock; (3) impermeable off-flow; (4) multilayer infiltration/biotic intrusion; and (5) multilayer biotic intrusion. Design, construction, and monitoring evaluation activities related to these existing barriers are documented in a summary report (Phillips, et al., 1985).

The construction practices used in each PBTF test barrier and the performance of each barrier are varied. Construction practices and performance are continuously evaluated to provide information for definitive barrier design.

3.0 PHASE II TEST BARRIER DESIGN

An additional test barrier plot will be constructed at the PBTF in fiscal year 1985 or 1986. The design of the barrier will include information derived from continued engineering development, laboratory column testing, and numerical simulation and prediction computer modeling activities. In addition, a small radiohydrology test area will be constructed at the facility to quantitatively compare infiltration, storage, and drainage of precipitation, and intrusion of plants and animals into each barrier design. This facility will use inorganic and low concentration radiotracers in subsurface one-dimensional columns.

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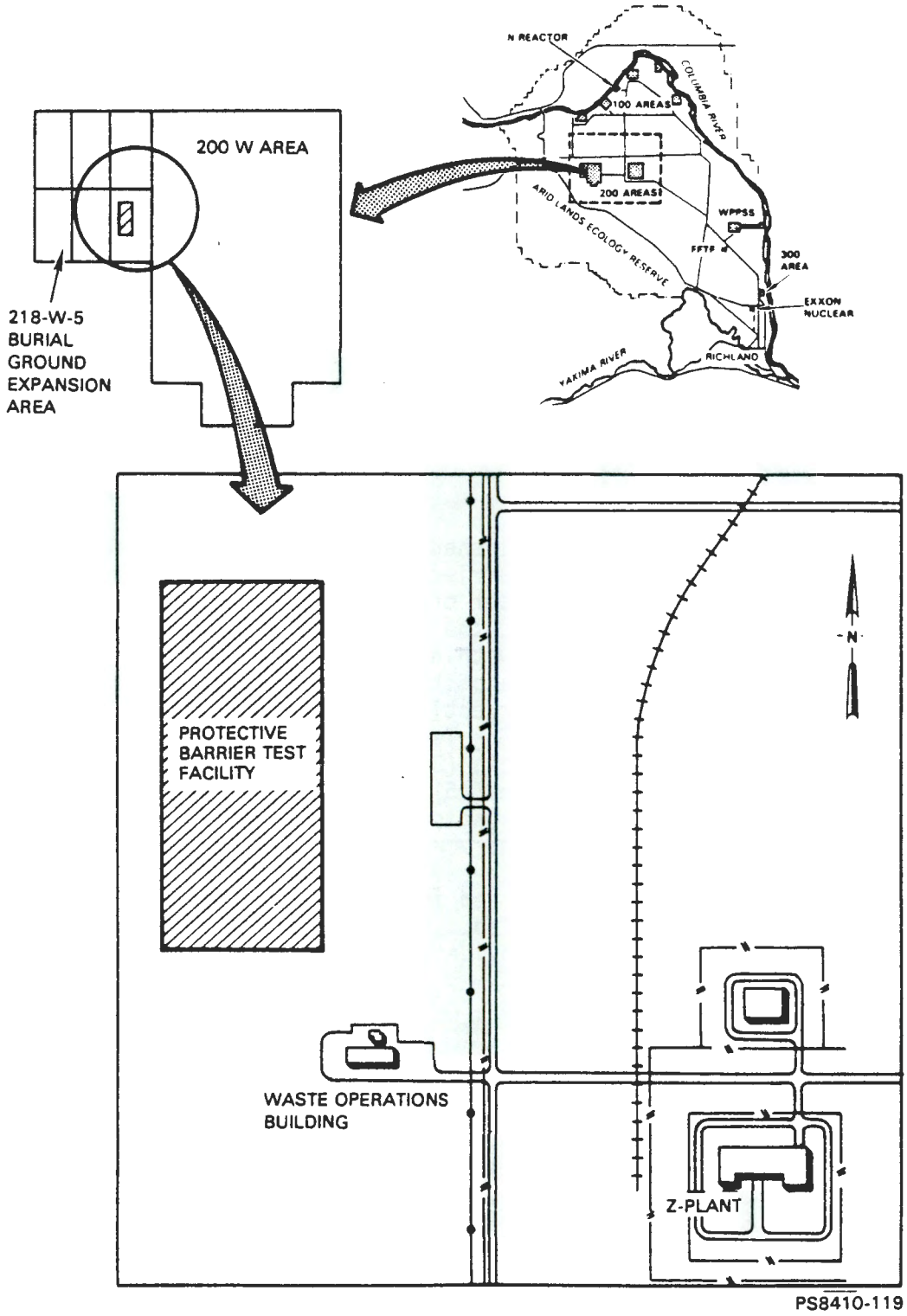

Figure 2-1. Location of the Protective Barrier Test Facility.

Construction of a Phase II multilayer test barrier and radiohydrology facility is the subject of this document. Phase II activities are those activities conducted subsequent to preliminary computer simulation modeling design studies. Phase I activities consist of previous laboratory and field work to construct preliminary comparative protective barriers.

3.1 PHASE II MULTILAYER INFILTRATION/BIOTIC INTRUSION TEST BARRIER

The performance of the existing multilayer infiltration/biotic intrusion test barrier currently is thought to be superior to other existing barriers regarding control of infiltration, and perhaps control of intrusion of flora and fauna. The barrier was designed and constructed in fiscal year 1983 using preliminary information from engineering studies, conceptual design, and materials specifications. As a result of recent construction experience; additional design evaluation; evaluation of materials availability, haulage, and handling; and computer modeling, optimization of this barrier design into a Phase II design is possible.

General layer configuration and materials specifications for construction of the Phase II multilayer barrier are listed below. The layers are described sequentially, from the bottom to the top layer:

(1) A 0.5-m layer of 2.5- to 25.0-cm dia. basalt riprap or rounded rock, with 1 to 1 side slopes

(2) A 0.3-m layer of 0.5- to 3.0-cm dia. crushed basalt or rounded rock, with 2 to 1 side slopes (items 1 and 2 can be optionally combined)

(3) A 0.3-m layer of 0.2- to 1.0-cm dia. crushed basalt or pea gravel, with 2 to 1 side slopes

(4) A single layer of woven glass filter material (geotextile) with an equivalent opening size of 0.04 cm, with from 7 to 15 percent of the total open area overlapped 100 percent

(5) A 0.3-m layer of 0.2- to 0.7-cm dia. washed sand, with 2 to 1 side slopes

(6) Two layers of woven glass filter material (geotextile) with an equivalent opening size of 0.04 cm, with from 7 to 15 percent of the total open area overlapped 50 percent

(7) A 0.6-m mixed covering of native soil (loamy sand to silt)

(8) A 0.3-m layer of 10.0- to 25.0-cm dia. basalt riprap or rounded rock (located from half to three-quarter depth of soil layer) containing interstitial native soil

(9) A 0.3-m layer of native soil containing 20 percent by weight nonerodable pebbles (0.3 to 0.5 cm in diameter).

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The outer slope of the test barrier will be armored with basalt riprap. General armoring configuration and material specifications for slope and perimeter trench construction includes a 5 to 4 mixture of 2.5- to 50.0-cm-dia. basalt riprap and native soil (loamy sand or silt), with 1 to 1 side slopes. Subsurface ceramic markers for preventing human intrusion will be installed near the base of the barrier and the armored side slope within the riprap layer. In addition, equivalent markers will be installed at approximately 30- and 60-cm depths within the native soil and sand layer of the test barrier. A cross sectional and plan view conceptual engineering sketch of the barrier, armored slope, and perimeter trench is shown in figures 3-1, 3-2, and 3-3. A brief description of each layer and its purpose follows.

3.1.1 Riprap/Round Rock Layer

A thick layer of large basalt riprap or rounded rock with a minimum of fine material will be installed above grade. This layer is intended to deter human intrusion resulting from excavation. This layer also functions to significantly deter intrusion and consequent uptake and dispersal of contaminants by indigenous flora and fauna.

3.1.2 Gravel Filter Layer

A layer of well-sorted gravel will be installed over the bottom riprap or rounded rock layer. This layer is intended to function as a filter material to prevent sand from the covering layer from filtering downward into the interstices of the riprap or rounded rock layer. This layer is intermediate in texture between the underlying coarse texture material and the finer textured overlying gravel layer. This layer also serves to deter intrusion by indigenous flora and fauna.

3.1.3 Fine Gravel Filter Layer

A layer of fine gravel or fine crushed rock will be installed above the gravel filter layer. The function of this layer is equivalent to that discussed above.

3.1.4 Woven Glass Layer

A single layer of woven glass fiber (geotextile) will be installed directly above the fine gravel filter layer. The purpose of this layer is to preserve physical stability of the overlying layer. Additionally, this fabric provides a redundant layer to prevent intrusion (see 3.1.6).

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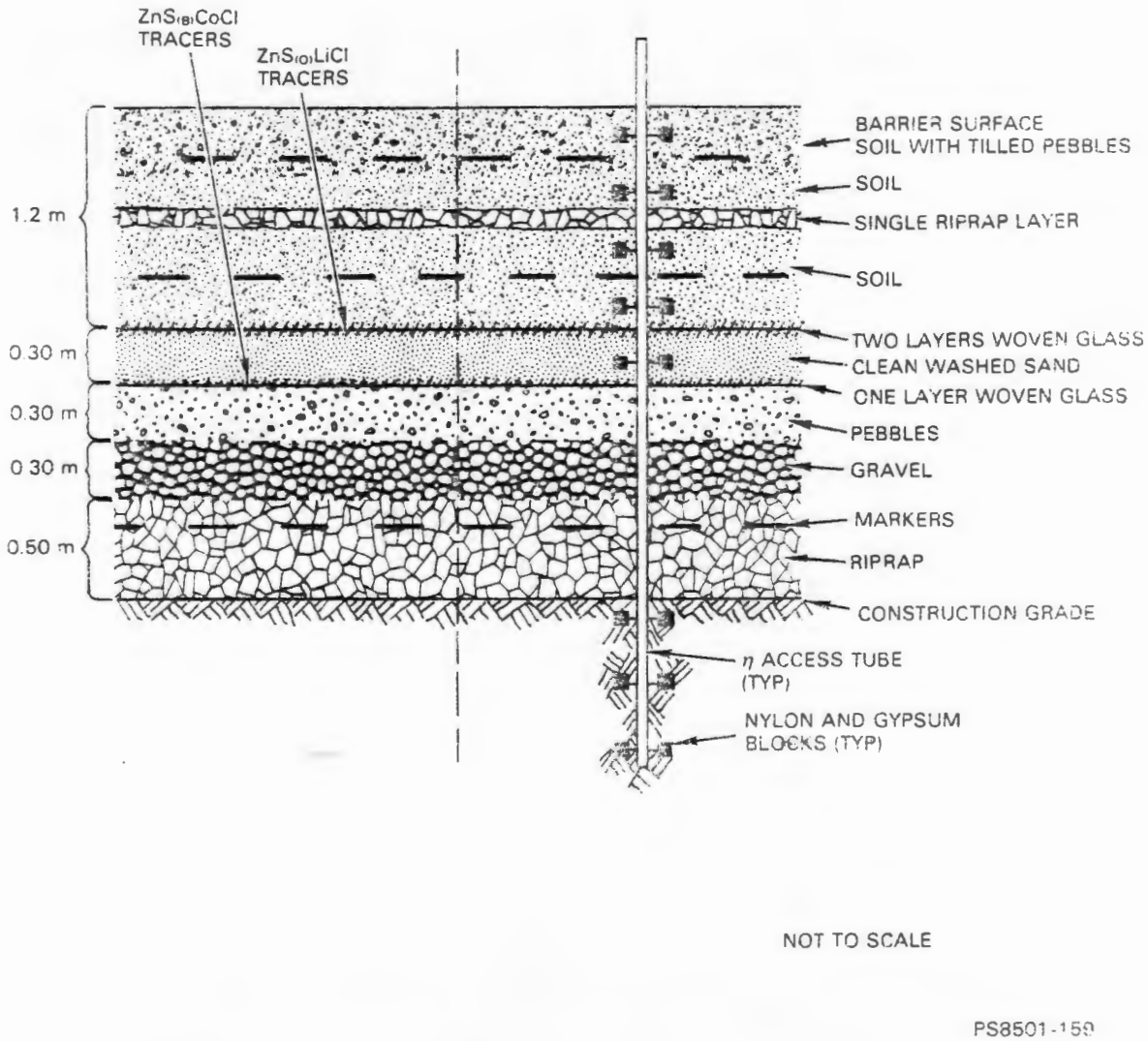

Figure 3-1. Cross Section Sketch of Phase II Multilayer Barrier Configuration (Layer Materials, Layer Dimensions, Geofabrics, and Monitoring Instruments).

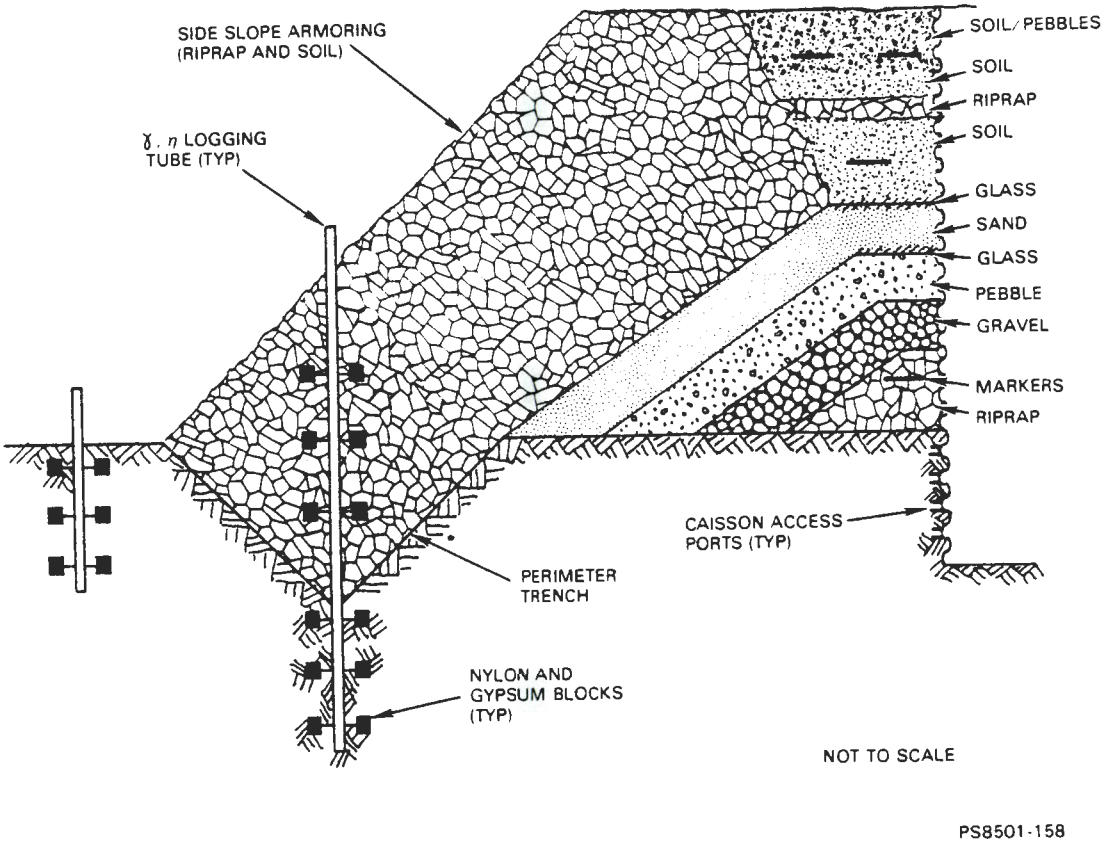

Figure 3-2. Cross Section Sketch of Phase II Multilayer Barrier Configuration (Barrier Slope, Perimeter Trench, Layers, Monitoring Caissons, and Monitoring Instruments).

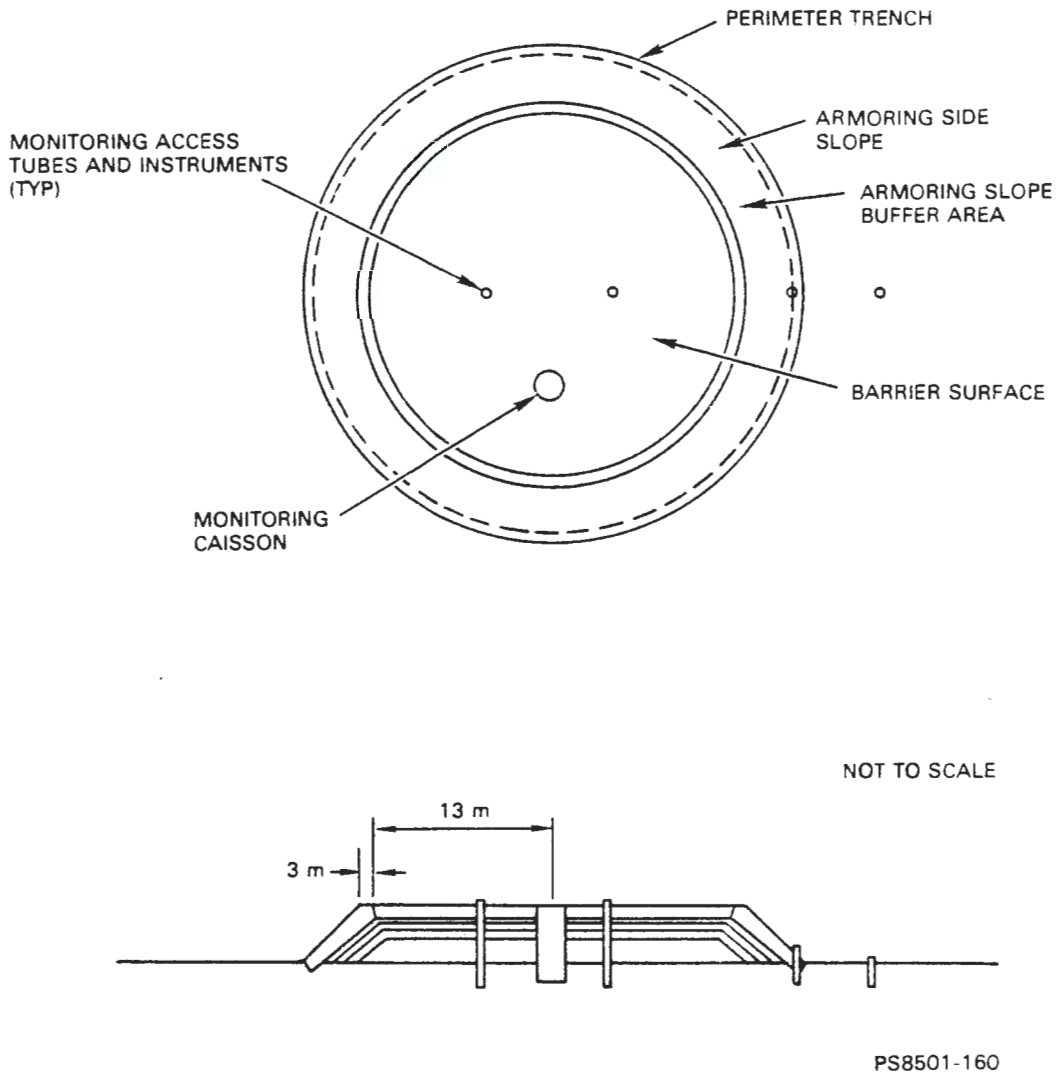

Figure 3-3. Generalized Sketch of Phase II Multilayer Barrier.

3.1.5 Sand Layer

A layer of screened, washed, coarse textured sand will be installed over the gravel filter layer. This layer fulfills two primary requirements: it filters native soil and sand from the cover layer downward into successive layers, and it ensures a distinct interface between the overlying native soil and sand and the clean, course textured sand within the subject layer. The interface is expected to function as a barrier to downward movement of soil water infiltrating through the cover layer. The interface results in retention and storage of water near the barrier surface, where it can be returned to the atmosphere by direct evaporation or by transpiration by flora inhabiting the overlying native soil layer. The interface phenomena is described as the "Richards Effect" (Richards, 1950).

3.1.6 Woven Glass Layer

Directly above the sand layer, double layers of fibrous woven glass will be installed. This layer preserves the distinct interface between the overlying native soil and sand cover and the underlying coarse textured sand layer, and reduces intrusion by indigenous flora and fauna. Construction experience has shown that operating the equipment to place the cover layer will perturbate the interface, which will result in loss of soil moisture retention capacity unless a geotextile or similar material is used.

3.1.7 Native Soil

A layer of native soil and sand excavated from a borrow area near the PBTF will be emplaced over the upper woven glass layers. This cover layer is intended to fulfill two major functions: (1) to retain soil moisture originating as precipitation near the barrier surface, where it can be effectively evapotranspired back to the atmosphere; and (2) to sustain a vegetative cover of short-rooted plant species to transpire infiltrating precipitation.

3.1.8 Rock/Interstitial Soil Layer

A layer of rock will be placed directly over the native soil layer. This layer will primarily serve to deter burrowing rodents and will contain interstitial native soil from its overlying layer. The thickness and materials composition of this layer will be insufficient to perturbate infiltration, evaporation, and evapotranspiration through the barrier.

3.1.9 Native Soil/Nonerodable Particle Cover Layer

A layer of native soil and particles sufficient in mass and diameter to sustain a stable barrier surface over an extended time will be placed over the barrier as a top cover layer. This layer will retain soil moisture and sustain a vegetative cover, as discussed in 3.1.7 (native soil).

3.1.10 Slope and Perimeter Trench

A cover of mixed basalt riprap, native soil, and sand will be emplaced on the slope of the test barrier and within the perimeter trench. This cover is intended to sustain the monolithic structure of the barrier against erosion, provide a distinct structure to the barrier to deter human intrusion (used in conjuction with the intrusion marker systems), and provide a deterrent to intrusion by indigenous flora and fauna.

3.2 RADIOHYDROLOGY TEST FACILITY

Infiltration of precipitation through protective barrier cover systems and subsequent transport of disposed contaminants is of primary concern. Evaluation of infiltration by typical monitoring techniques provides only indirect evidence of the direction, rate, and magnitude of infiltration. Therefore, a small facility is needed to determine the effectiveness of each PBTF barrier in significantly reducing or eliminating infiltration. An area will be constructed that consists of a subsurface caisson containing one-dimensional vertical segments of each PBTF barrier and specific layers of inorganic and low-concentration (near background) radiotracers. Requirements for the facility include a central access caisson (3.0 m deep by 3.5 m diameter), sample collection tubes, and connected outer caissons (3.0 m deep by 1.0 m diameter) containing layered or monolithic barrier materials and tracer materials.

Abiotic monitoring systems will be installed in one-dimensional barrier segments in columns installed below grade at the test facility. The systems will be used to compare the performance of each column with each respective test barrier located at the PBTF, under both ambient and increased infiltration conditions. Abiotic monitoring systems are discussed in 5.1.

Vertical barrier columns will include both static (non-weighing) and dynamic (weighing) lysimeters. The lysimeters permit controlled, quantitative measurement of radionuclide flux in addition to simultaneous mass balance of materials entering and leaving the soil surface, i.e., precipitation and evaporation/evapotranspiration of water vapor. No interconnection or drainage between columns will be permitted per design. Sampling and monitoring of each caisson will be conducted through a central access caisson. A preliminary sketch of representative columns and an access caisson is shown in figure 3-4. Design of the overall radiohydrology test facility will be modified from an existing installation (Phillips, et al., 1979).

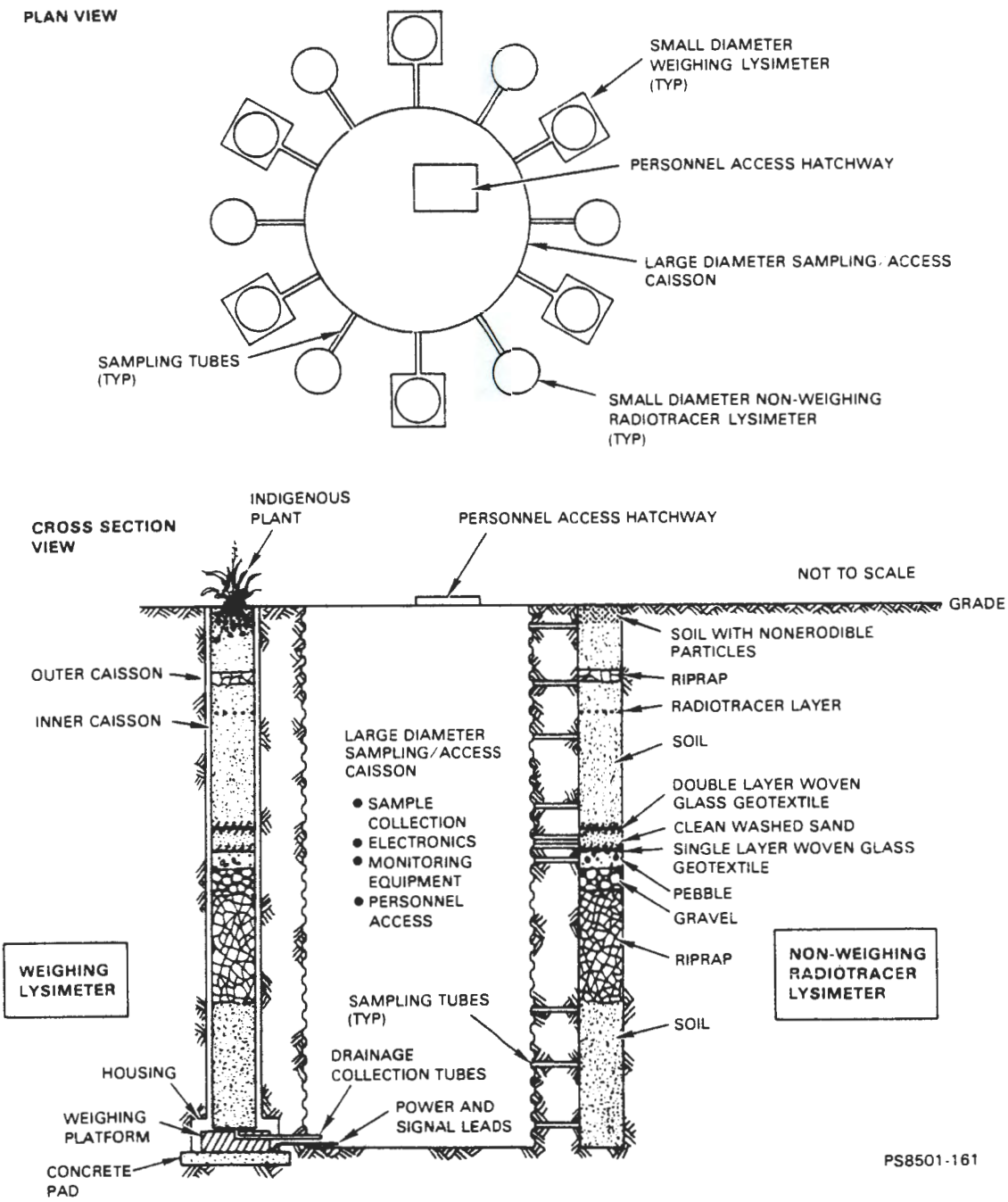

Figure 3-4. Generalized Sketch of Radiohydrology Lysimeter Facility Located at the Protective Barrier Test Facility.

4.0 CONSTRUCTION

4.1 MATERIALS

Material specifications for barrier layers, slopes, and perimeter trenches are given in table 4-1. Material specifications for the radiohydrology facility are given in table 4-2.

4.2 LOCATION

Existing barriers at the PBTF are constructed in a row oriented in a north-south direction. The Phase II multilayer infiltration/biotic intrusion barrier will be added to the north end of the present configuration. The radiohydrology module will be constructed at the south end of the PBTF, east of the materials staging area. The layout is shown in figure 4-1.

5.0 BARRIER PLOT PERFORMANCE MONITORING

Performance monitoring will be conducted on the Phase II multilayer barrier plot in the same manner as the existing PBTF test barrier plots. Monitoring is designed to evaluate natural processes that tend to encroach upon, degrade, and penetrate barriers. Evaluation of these processes will augment efforts to simulate and predict barrier performance over an extended time.

Performance monitoring is divided into two categories, abiotic and biotic process monitoring.

5.1 ABIOTIC PROCESSES

Abiotic monitoring activities are to include evaluation of micrometeorological, hydrogeologic, and materials transport processes. The designs of the monitoring systems for the Phase II multilayer barrier test plot are patterned after those systems currently used at the PBTF.

The instrument systems emplaced at PBTF and within the barrier plots consist of the following:

- Thermocouple psychrometers
- Resistance blocks
- Neutron/gamma probe access wells
- Micrometeorological stations
- Particulate (airborne) samplers.

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Table 4-1. Phase II Multilayer Infiltration/Biotic Intrusion Test Barrier.

Material	Units required	Material specifications
Basalt riprap	1,450 m^3	2.5- to 25.0-cm diameter
Crushed rock	45 m^3	0.5- to 3.0-cm diameter
Fine crushed rock	68 m^3	0.2- to 1.0-cm diameter
Clean washed/sieved sand	82 m^3	0.2- to 0.3-cm diameter U.S. Standard Sieve Mesh / % Passing (by weight): 0.95 — 62-100 4 — 30-95 16 — 6-30 50 — 0-4 100 — 0
Geofabric	300 m^2	~0.1-cm thickness Woven cleaned silicon-dioxide glass (filaments only)
Soil/sand	40 m^3	20.0 to 30.0 percent passing a 230 sieve
Aluminum tubing	10 m	~0.1-cm wall thickness ~2.5-cm diameter (inside)
Sheet steel	10 m^2	~0.6-cm thickness
Steel sheet metal	4 m^2	~0.3-cm thickness
Steel H-Beam	7 m	~0.8-cm thickness ~10.0- x 10.0-cm overall height width
Corrugated steel culvert	3.2 m	~0.6-cm wall thickness ~3.0-cm diameter Galvanized

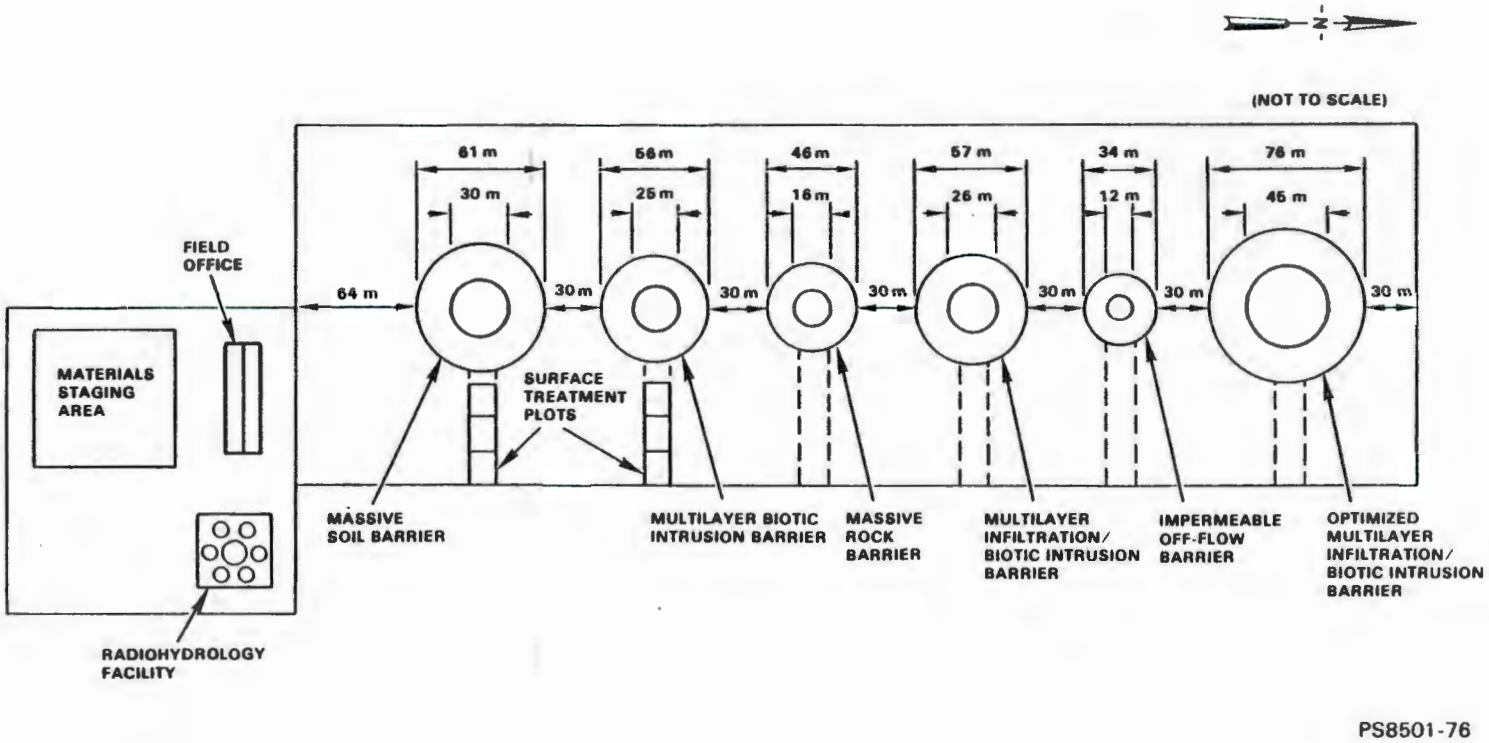

Figure 4-1. Generalized Layout of Protective Barrier Test Facility and Radiohydrology Facility.

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Thermocouple psychrometers allow measurement or derivation of several parameters, which include relative humidity, temperature, vapor pressure, and moisture content/potential, with respect to depth. Resistance blocks are used to determine moisture content/potential with depth. Logging wells are designed to accommodate neutron and gamma downhole logging probes, and neutron probe measurements allow determination of moisture content. Gamma probes allow measurement of soil density. Micrometeorological stations are equipped with a variety of devices to measure temperature, relative humidity, wind direction and velocity, and dew duration. Other parameters are determined at the Hanford Meteorological Station located approximately 2.0 km northeast of the PBTF. Particulate samplers allow wind erosion monitoring by collection of airborne particulates at various intervals above grade. The abiotic monitoring system layout for the Phase II multilayer barrier test plot is shown in figures 3-1 through 3-3. The components of this system are described below.

Resistance blocks of two types will be installed vertically near the central axis of the circular plot within soil and sand materials. Resistance blocks will also be placed below construction grade to a depth of 1.0 m.

Neutron/gamma probe access wells will be installed vertically through the test plot. These wells will be placed at locations within the barrier plot, near the central axis, at the midpoint of the side slope, through the perimeter trench, and one approximately 1.5 m radially outward from the edge of the barrier.

5.2 BIOTIC PROCESS MONITORING

The potential for radionuclide transport through a protective barrier is related to the dynamic nature of plant and animal communities. Therefore, understanding the processes that control these communities is important to barrier design and assessment.

Biotic monitoring systems for the PBTF are designed to measure encroachment of plant and animal species on as well as through the barriers. These monitoring systems are described in the following sections.

5.2.1 Biotic Encroachment Monitoring

Biotic encroachment will be assessed in two ways. First, the composition, distribution, and abundance of plant species on four permanent transects will be compared with that in the barrier plots. Burrow densities and the relative abundance of important animal populations on permanent plot transects and in barrier plots will be compared as an index of the attractiveness of the barrier plots to various species. Encroachment will be assessed by measuring changes in species abundance and animal activity on the barrier plots over time.

These activities are currently underway at the PBTF for the existing barrier plots, and will be expanded to include the Phase II multilayer infiltration/biotic intrusion barrier test plot.

5.2.2 Biotic Intrusion Monitoring

Chemical tracers will be emplaced during the construction of the improved mounded multilayer barrier. These tracers will allow plant and animal intrusion to be detected nondestructively.

Lithium chloride and cobalt chloride have been selected for detecting plant root penetration (plant uptake followed by tissue sample analysis). Zinc sulfide will be used for detecting animal intrusion through visual inspection of burrowing animal excavation material.

Due to the thermal neutron capture cross section of lithium chloride, interference with neutron logging of soil moisture may occur; therefore, lithium chloride will not be placed within a 3.0-m radius of neutron logging access tubes.

The configuration of tracer materials within the barrier plot is shown in figure 5-1.

5.3 HUMAN INTRUSION SYSTEMS MONITORING

A potential exists for intrusion of protective barrier cover systems by humans. To eliminate or significantly deter human intrusion, two systems are used. First, the intrinsic structure of the barrier slope and base layer consists of large rock materials. Secondly, large markers will be installed in barrier perimeter excavations and small porcelain markers will be installed within specific barrier layers. These redundant marker systems will result in significant warnings to potential intruders. Testing of components of surface and subsurface markers will be conducted at the PBTF.

5.3.1 Subsurface Ceramic Markers

Small ceramic embossed disks (markers) will be placed in barrier layers. Markers will be placed on 2.0-m centers in the riprap/rounded rock layer, and at two elevations in the native soil layer (one set of markers below and one above the native soil rock layer). General specifications and placement of subsurface markers are given in drawing SK-2-23649 (DOE, 1985(a)) (figure 5-2). Subsurface markers will be placed in a 90° segment of the Phase II barrier.

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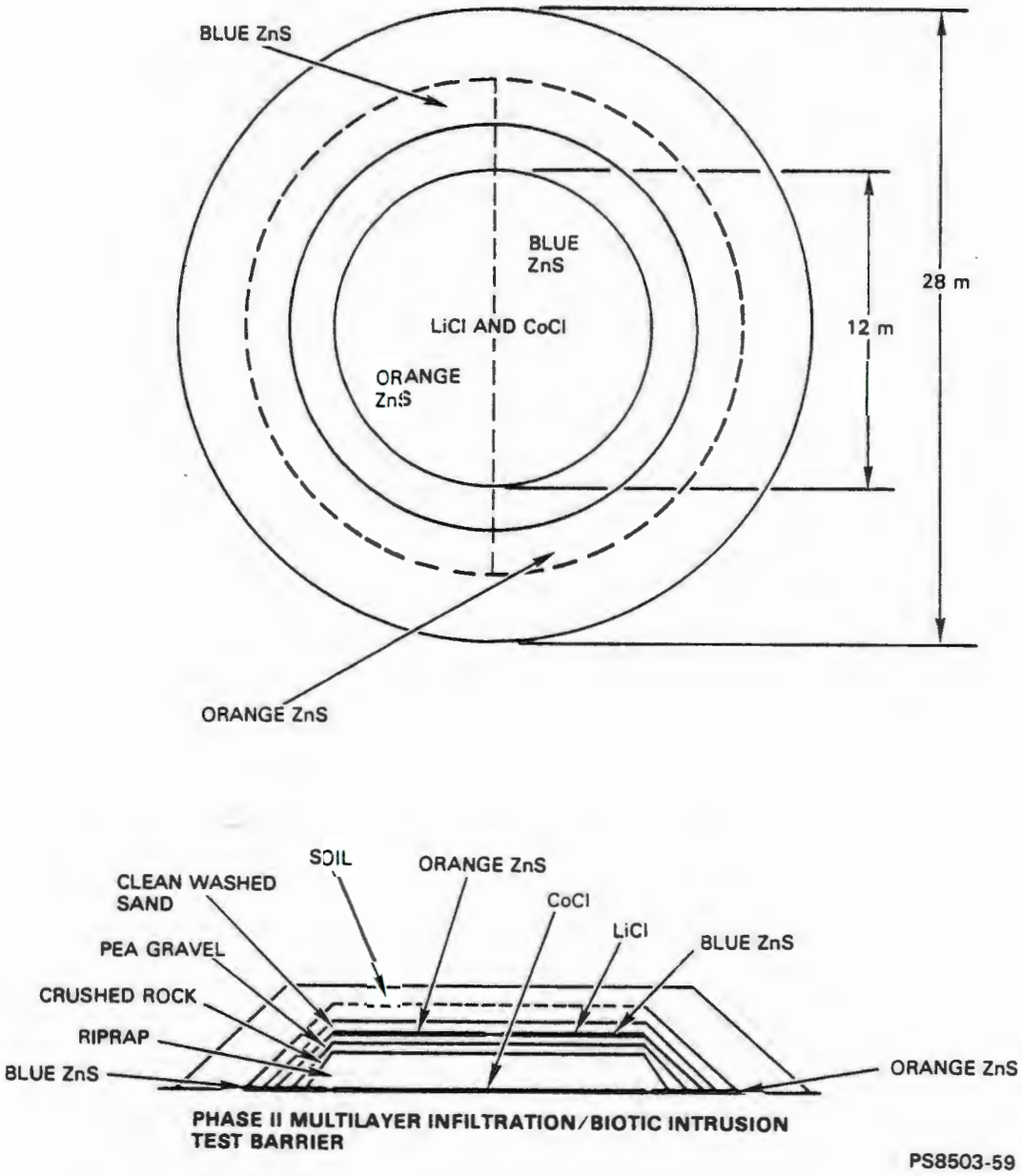

Figure 5-1. Configuration of Tracer Materials Within the Barrier Plot.

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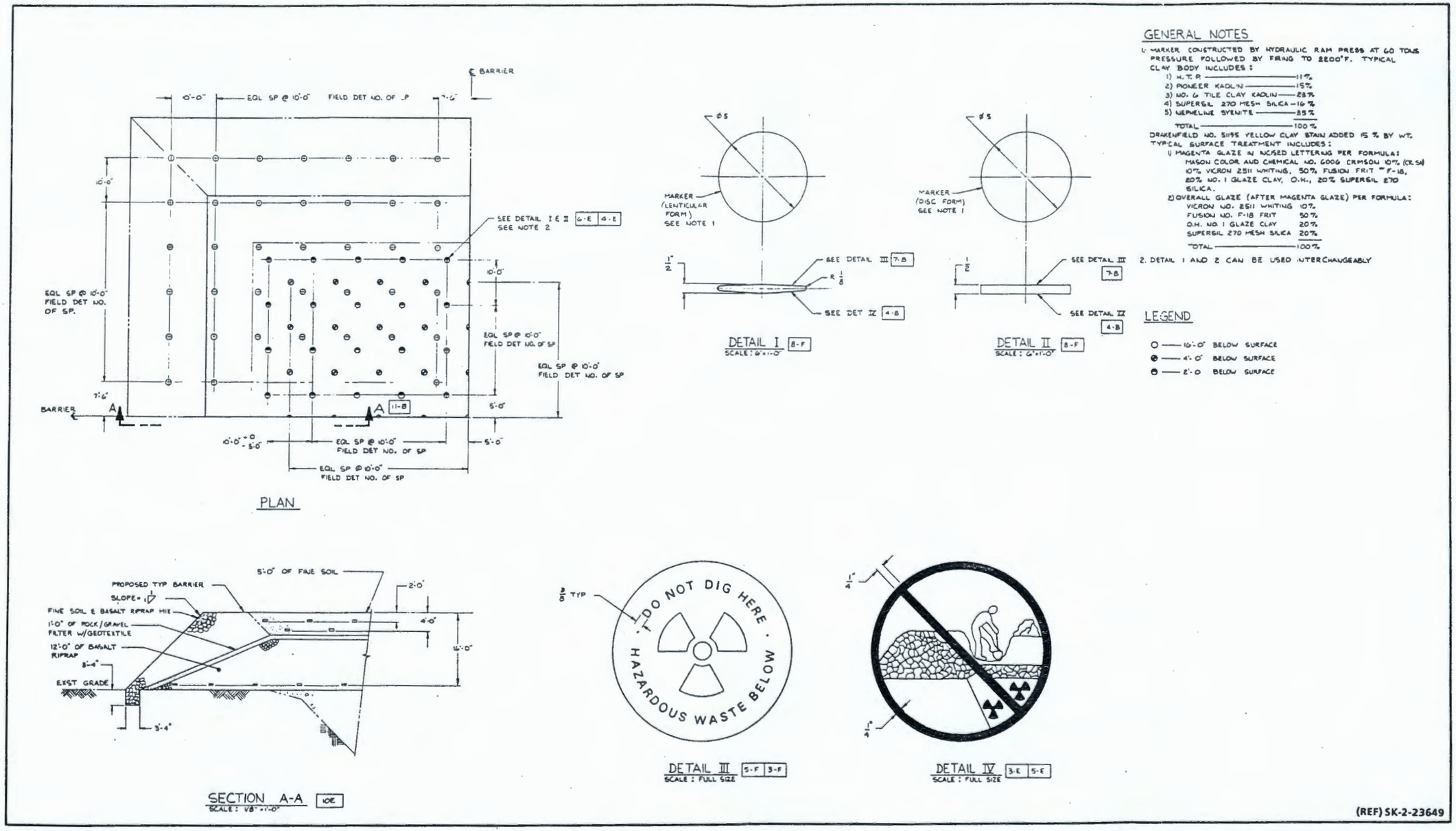

Figure 5-2. Specifications and Placement of Subsurface Markers.

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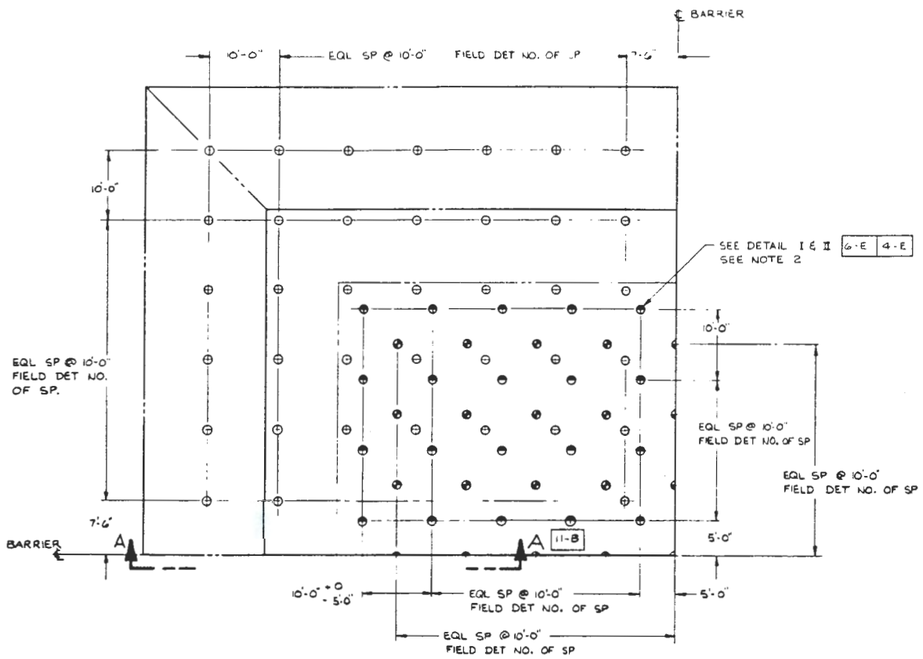

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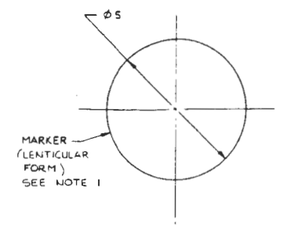

DETAIL I 8-F
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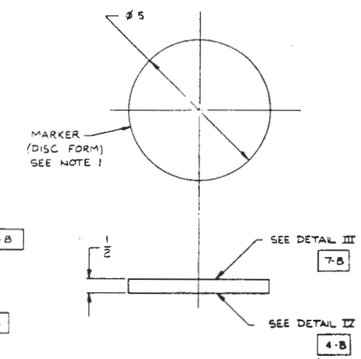


DETAIL II 8-F
SCALE: 6"=1'-0"

GENERAL NOTES

1. MARKER CONSTRUCTED BY HYDRAULIC RAM PRESS AT 60 TONS PRESSURE FOLLOWED BY FIRING TO 2200°F. TYPICAL CLAY BODY INCLUDES:
   1) H.T.P. ——— 11%
   2) PIONEER [illegible] ——— 15%
   3) NO. 6 TILE CLAY KAOLIN ——— 23%
   4) SUPERSIL 270 MESH SILICA — 16%
   5) NEPHELINE SYENITE ——— 35%

   TOTAL ——— 100%

   DRAKENFIELD NO. 5195 YELLOW CLAY STAIN ADDED 15% BY WT.

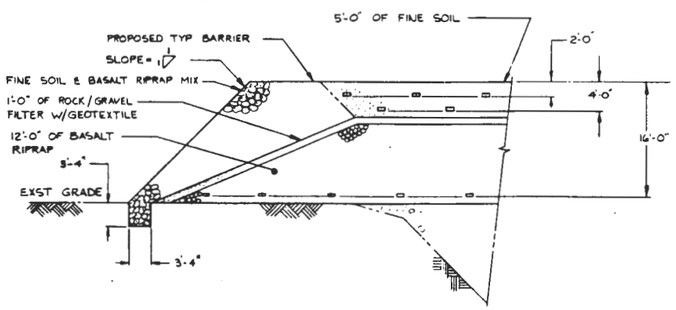
   TYPICAL SURFACE TREATMENT INCLUDES:
   1) MAGENTA GLAZE IN INCISED LETTERING PER FORMULA: MASON COLOR AND CHEMICAL NO. 6006 CRIMSON 10% (CR SN) 10% VICRON 2511 WHITING, 50% FUSION FRIT # F-18, 20% NO. 1 GLAZE CLAY, O.H., 20% SUPERSIL 270 SILICA.
   2) OVERALL GLAZE (AFTER MAGENTA GLAZE) PER FORMULA:

VICRON NO. 2511 WHITING	10%
FUSION NO. F-18 FRIT	50%
O.H. NO. 1 GLAZE CLAY	20%
SUPERSIL 270 MESH SILICA	20%
TOTAL	100%

2. DETAIL 1 AND 2 CAN BE USED INTERCHANGEABLY

LEGEND

- ○ —— 16'-0" BELOW SURFACE
- ◉ —— 4'-0" BELOW SURFACE
- ◓ —— 2'-0 BELOW SURFACE



SECTION A-A 10E
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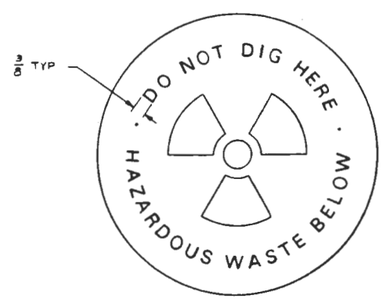

DETAIL III 5-F 3-F
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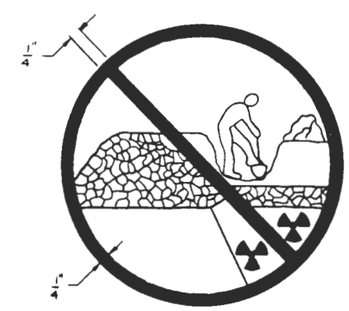

DETAIL IV 3-E 5-E
SCALE: FULL SIZE

(REF) SK-2-23649

Figure 5-2. Specifications and Placement of Subsurface Markers.

5.3.2 Surface Granite Markers

Protective barriers or groups of protective barriers will be marked in peripheral configuration with surface granite monolithic markers. Specifications for these are given in drawing SK-2-23650, sheet 2 (DOE, 1985(b)) (figure 5-3). Placement of one surface marker is anticipated at this time. This marker will be emplaced in an excavation and backfilled per specifications. General specifications for these markers are given in drawing SK-2-23650, sheet 1 (DOE, 1985(c)) (figure 5-4).

6.0 SUPPORT TASKS

As a precursor to construction of the Phase II multilayer infiltration/biotic intrusion protective barrier, information and engineering data will be required. Data from well drilling logs, soil excavations, sieve analysis, soil water retention and drainage, and hydraulic conductivity field and laboratory studies are currently being collected and analyzed. From this data, one- and two-dimensional infiltration, evaporation/evapotranspiration partially saturated flow numerical models will be used. These models will simulate and predict ambient and long-term barrier performance. Model tasks conducted by Pacific Northwest Laboratory are not scheduled for completion until October 1985. Therefore, definitive design specifications given in this report are tentative, based on interim results. Detailed levels of design specifications will be included on engineering drawings as final modeling results are produced. However, general specifications are not anticipated to change appreciably.

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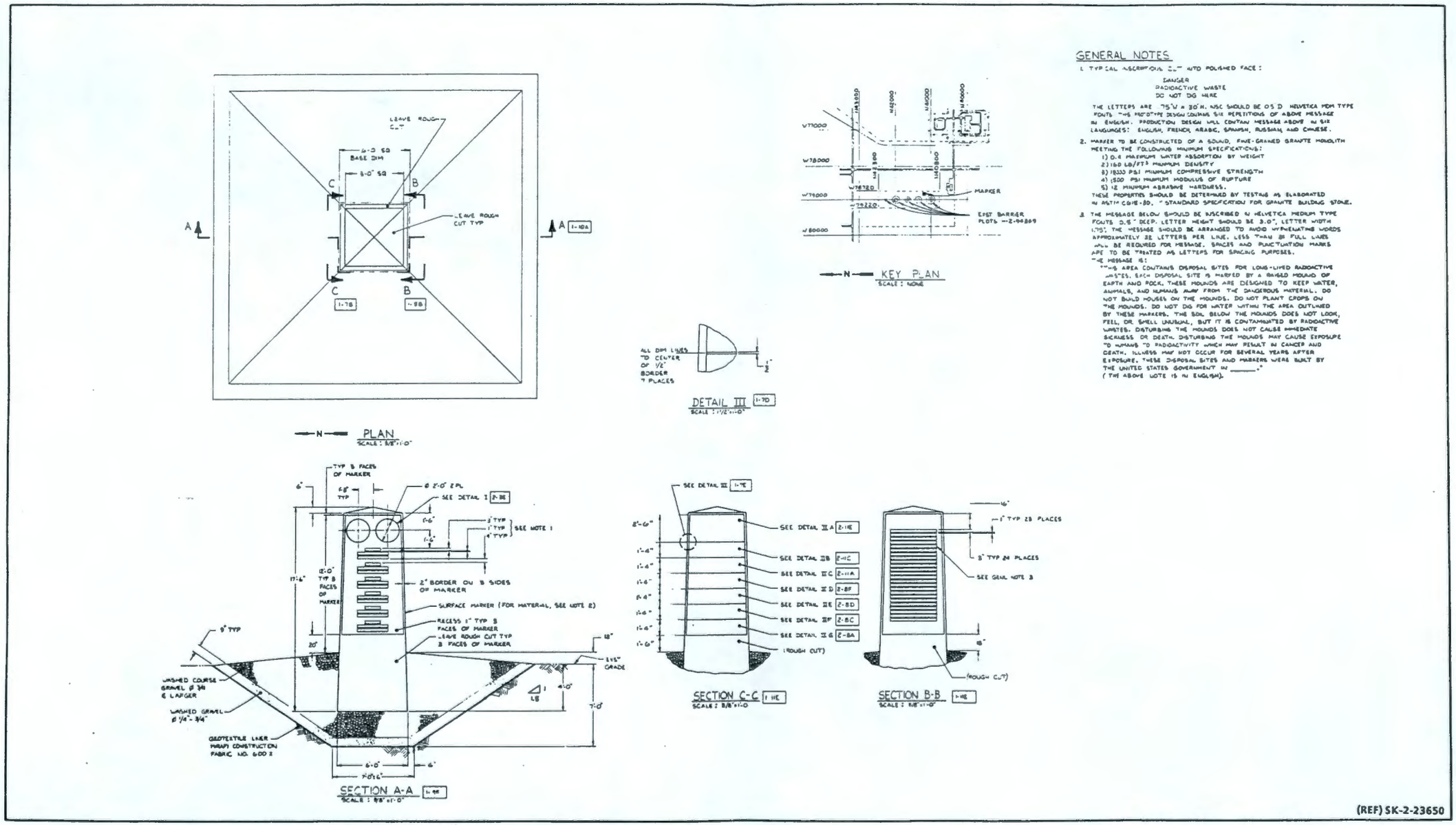
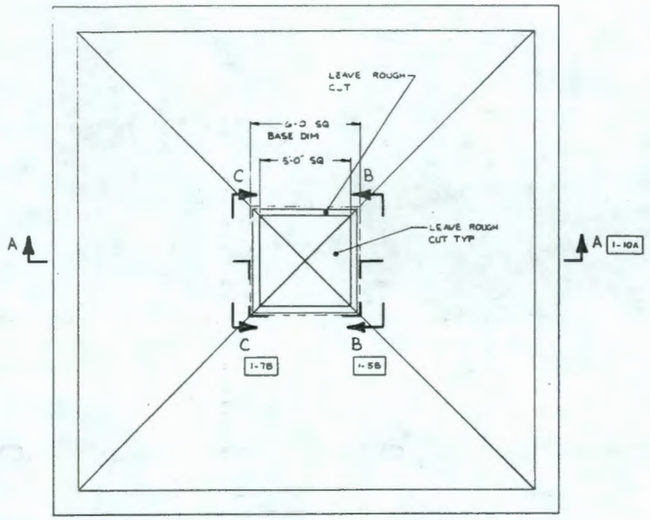
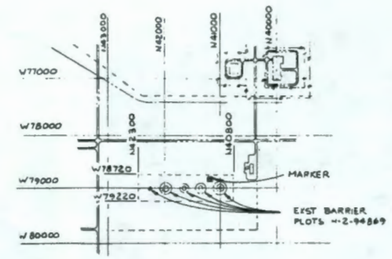


Figure 5-3. Specifications for Protective Barrier Markers.

9 2 1 2 5 0 1 0 4 9 3



N PLAN
SCALE : 3/8"=1'-0"



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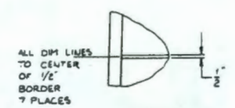


DETAIL III 1-7D
SCALE : 1 1/2"=1'-0"

GENERAL NOTES

1. TYPICAL INSCRIPTIONS CUT INTO POLISHED FACE:

   DANGER
   RADIOACTIVE WASTE
   DO NOT DIG HERE

   THE LETTERS ARE .75"W x 3.0"H. INSC SHOULD BE 0.5"D HELVETICA MDM TYPE FONTS. THIS PROTOTYPE DESIGN CONTAINS SIX REPETITIONS OF ABOVE MESSAGE IN ENGLISH. PRODUCTION DESIGN WILL CONTAIN MESSAGE ABOVE IN SIX LANGUAGES: ENGLISH, FRENCH, ARABIC, SPANISH, RUSSIAN, AND CHINESE.

2. MARKER TO BE CONSTRUCTED OF A SOUND, FINE-GRAINED GRANITE MONOLITH MEETING THE FOLLOWING MINIMUM SPECIFICATIONS:
   1) 0.4 MAXIMUM WATER ABSORPTION BY WEIGHT
   2) 160 LB/FT³ MINIMUM DENSITY
   3) 18000 PSI MINIMUM COMPRESSIVE STRENGTH
   4) 1500 PSI MINIMUM MODULUS OF RUPTURE
   5) 12 MINIMUM ABRASIVE HARDNESS.

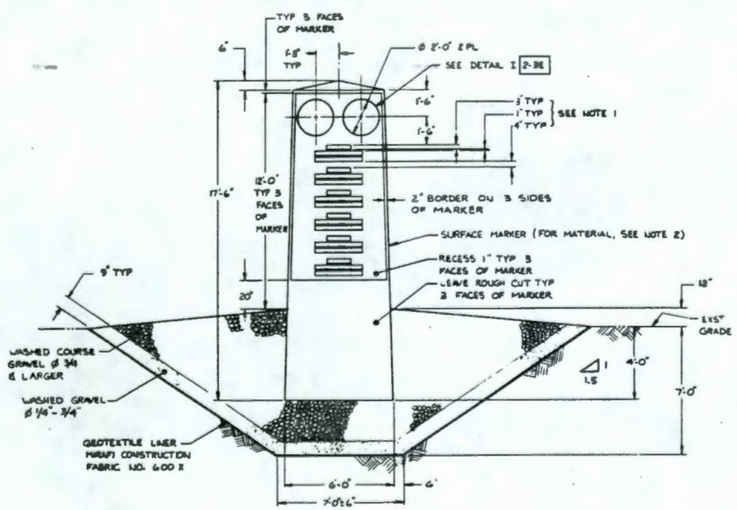
   THESE PROPERTIES SHOULD BE DETERMINED BY TESTING AS ELABORATED IN ASTM C615-80, "STANDARD SPECIFICATION FOR GRANITE BUILDING STONE.

3. THE MESSAGE BELOW SHOULD BE INSCRIBED IN HELVETICA MEDIUM TYPE FONTS 0.5" DEEP. LETTER HEIGHT SHOULD BE 3.0", LETTER WIDTH 1.75". THE MESSAGE SHOULD BE ARRANGED TO AVOID HYPHENATING WORDS APPROXIMATELY 32 LETTERS PER LINE. LESS THAN 24 FULL LINES WILL BE REQUIRED FOR MESSAGE. SPACES AND PUNCTUATION MARKS ARE TO BE TREATED AS LETTERS FOR SPACING PURPOSES.

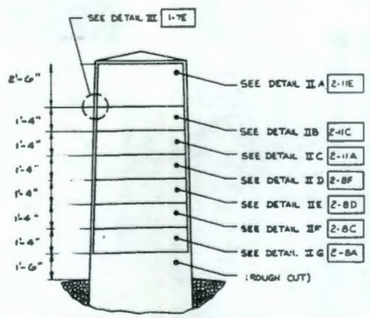
   THE MESSAGE IS:

   "THIS AREA CONTAINS DISPOSAL SITES FOR LONG-LIVED RADIOACTIVE WASTES. EACH DISPOSAL SITE IS MARKED BY A RAISED MOUND OF EARTH AND ROCK. THESE MOUNDS ARE DESIGNED TO KEEP WATER, ANIMALS, AND HUMANS AWAY FROM THE DANGEROUS MATERIAL. DO NOT BUILD HOUSES ON THE MOUNDS. DO NOT PLANT CROPS ON THE MOUNDS. DO NOT DIG FOR WATER WITHIN THE AREA OUTLINED BY THESE MARKERS. THE SOIL BELOW THE MOUNDS DOES NOT LOOK, FEEL, OR SMELL UNUSUAL, BUT IT IS CONTAMINATED BY RADIOACTIVE WASTES. DISTURBING THE MOUNDS DOES NOT CAUSE IMMEDIATE SICKNESS OR DEATH. DISTURBING THE MOUNDS MAY CAUSE EXPOSURE TO HUMANS TO RADIOACTIVITY WHICH MAY RESULT IN CANCER AND DEATH. ILLNESS MAY NOT OCCUR FOR SEVERAL YEARS AFTER EXPOSURE. THESE DISPOSAL SITES AND MARKERS WERE BUILT BY THE UNITED STATES GOVERNMENT IN _____."

   (THE ABOVE NOTE IS IN ENGLISH).



SECTION A-A 1-9B
SCALE : 3/8"=1'-0"



SECTION C-C 1-11E
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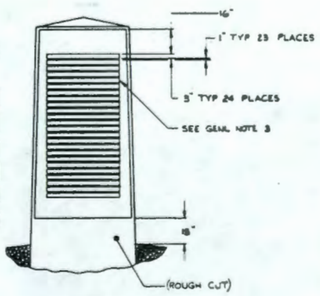

SECTION B-B 1-11E
SCALE : 3/8"=1'-0"

(REF) SK-2-23650

Figure 5-3. Specifications for Protective Barrier Markers.

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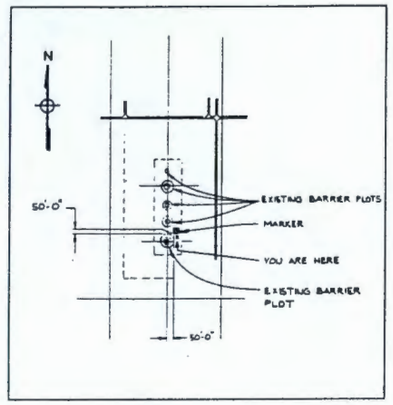

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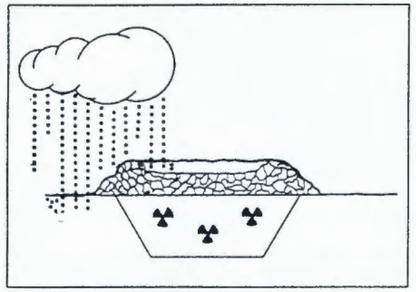

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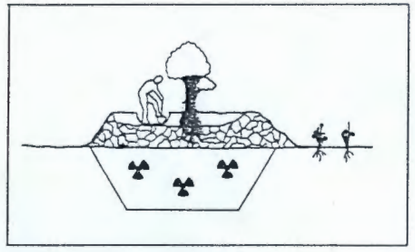

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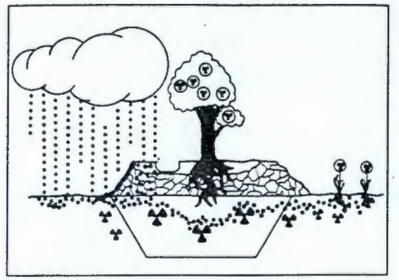

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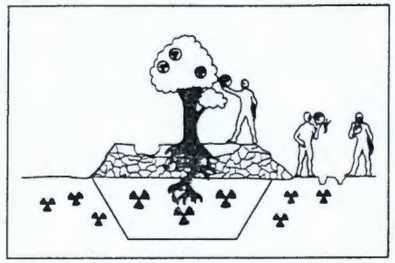

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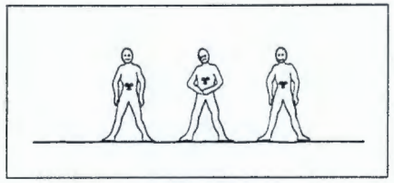

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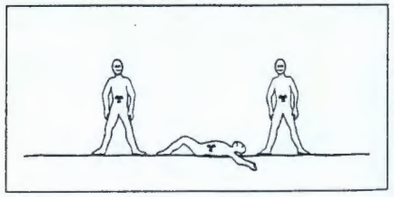
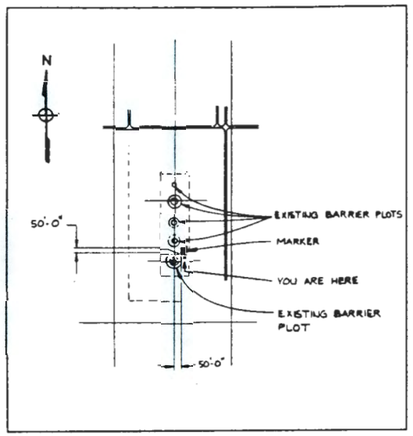


DETAIL IIG 1-6C

DETAIL I 1-0D
SCALE : 3"=1'-0"

(REF) SK-2-23650

Figure 5-4. General Specifications for Markers.



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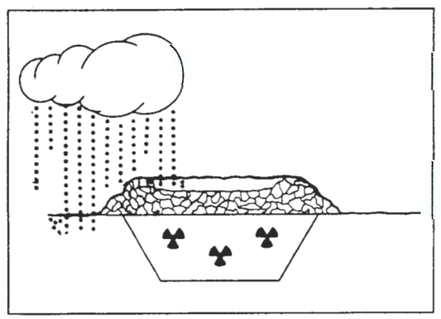

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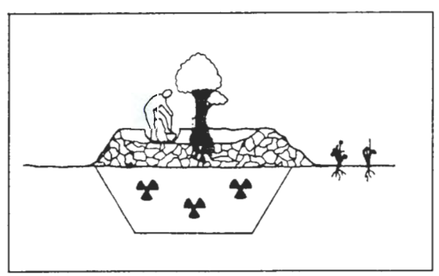

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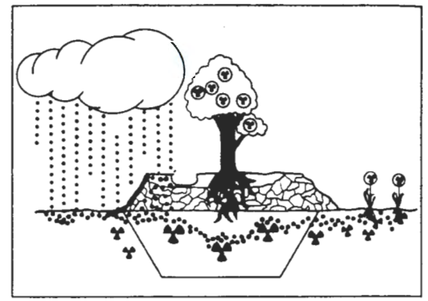

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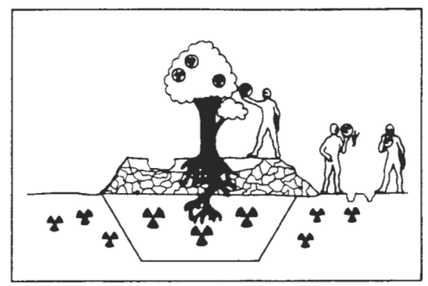

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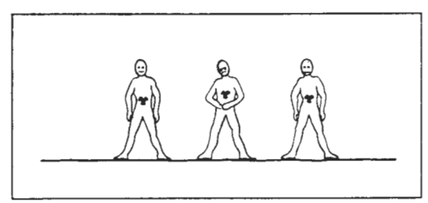

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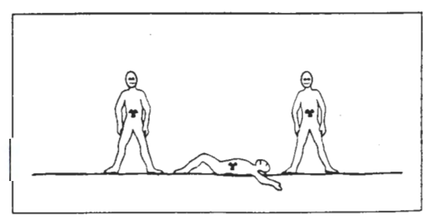

DETAIL IIG 1-6C

DETAIL I 1-10D
SCALE : 3"=1'-0"

(REF) SK-2-23650

Figure 5-4. General Specifications for Markers.

7.0 REFERENCES

1. Phillips, S. J., T. W. Gilbert, W. J. Waugh, M. R. Adams, C. C. Meinhardt, and R. M. Mitchell, 1985, Engineering Barrier Test Facility Status Report: 1984, RHO-MA-SR-3-P, Rockwell Hanford Operations, Richland, Washington.

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6. Phillips, S. J., A. C. Campbell, G. W. Gee, H. H. Hoober, and K. O. Schwarzmiller, 1979, A Field Test Facility for Monitoring Water-Radionuclide Transport Through Partially Saturated Geologic Media: Design, Construction, and Preliminary Descriptions, PNL-3266, Pacific Northwest Laboratory, Richland, Washington.

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