DOE/RL-94-76
Draft A

Constructability Report for the 200-BP-1 Prototype Surface Barrier

United States
Department of Energy
Richland, Washington

Approved for Public Release

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1.0 INTRODUCTION

1.1 BACKGROUND

The development of permanent isolation surface barriers is critical to supporting the Hanford Site environmental restoration mission. In-place management of certain waste management units may be the most desirable closure for many waste sites at Hanford. Remedial action objectives outlined in the "Phase I Remedial Investigation Report for the 200-BP-1 Operable Unit" (DOE/RL 1993b) suggest that a likely remedial action could involve the use of a surface barrier. To further evaluate this technology, a "Treatability Study Plan for the 200-BP-1 Prototype Surface Barrier" (DOE/RL 1993a) was completed to gain performance and constructability data. Data collected from this treatability test will be used for design and construction of the final remedial action for the remaining waste management unit within the 200-BP-1 Operable Unit.

The preliminary performance objectives for long-term surface barriers are listed below:

- Isolate wastes from the accessible environment for at least 1000 yr
  - reduce the likelihood of plant, animal, and inadvertent human intrusion
  - control the exhalation of noxious gases
  - minimize erosion-related problems
- Meet or exceed all requirements of Resource Conservation and Recovery Act (RCRA) Subtitle C hazardous waste regulations and WAC-173-303, "Dangerous Waste Regulations," for closure of any hazardous/dangerous waste site
- Limit the recharge of water through the waste to the water table to near-zero (0.05 cm of water per year [1.6×10^{-9} cm/sec])
- Function in a semiarid to subhumid climate
- Be maintenance free.

1.2 BARRIER PROGRAM OBJECTIVES

To date, barrier performance has been evaluated only through laboratory and small-scale field experiments. A large-scale field experimentation was needed to enable engineers and scientists to obtain field experience in constructing protective barriers and evaluating their performance. Construction issues that were not readily apparent on the engineering drawing and specifications may be more easily discovered in the field. Construction of a large-scale prototype barrier will also provide data that can be transferred to larger construction activities for surface barriers on the Hanford Site.

The following are programmatic objectives for the prototype surface barrier.

- Integrate the various components of a permanent isolation barrier into a functional system
- Verify the constructability of multilayered earthen barriers
- Document the design, construction, and testing process for the purposes of peer evaluation and critique, regulator review, and technology transfer
- Provide large-scale testing of phenomena that are not adequately tested on small field plots, in laboratories, or with lysimeters
- Provide a performance baseline by demonstrating barrier system functionality under stressed and ambient conditions
- Obtain concurrence from regulators, end users, and the expert technical peer review panel on barrier design and performance
- Provide a cost-estimating basis for the construction of permanent isolation barriers

Figure 1 shows a cross section of surface isolation barrier layers.

Barrier components and their functions are described in the engineering report "Prototype Surface Barrier at 200-BP-1 Operable Unit" (WHC 1993).

1.3 CONSTRUCTABILITY REPORT

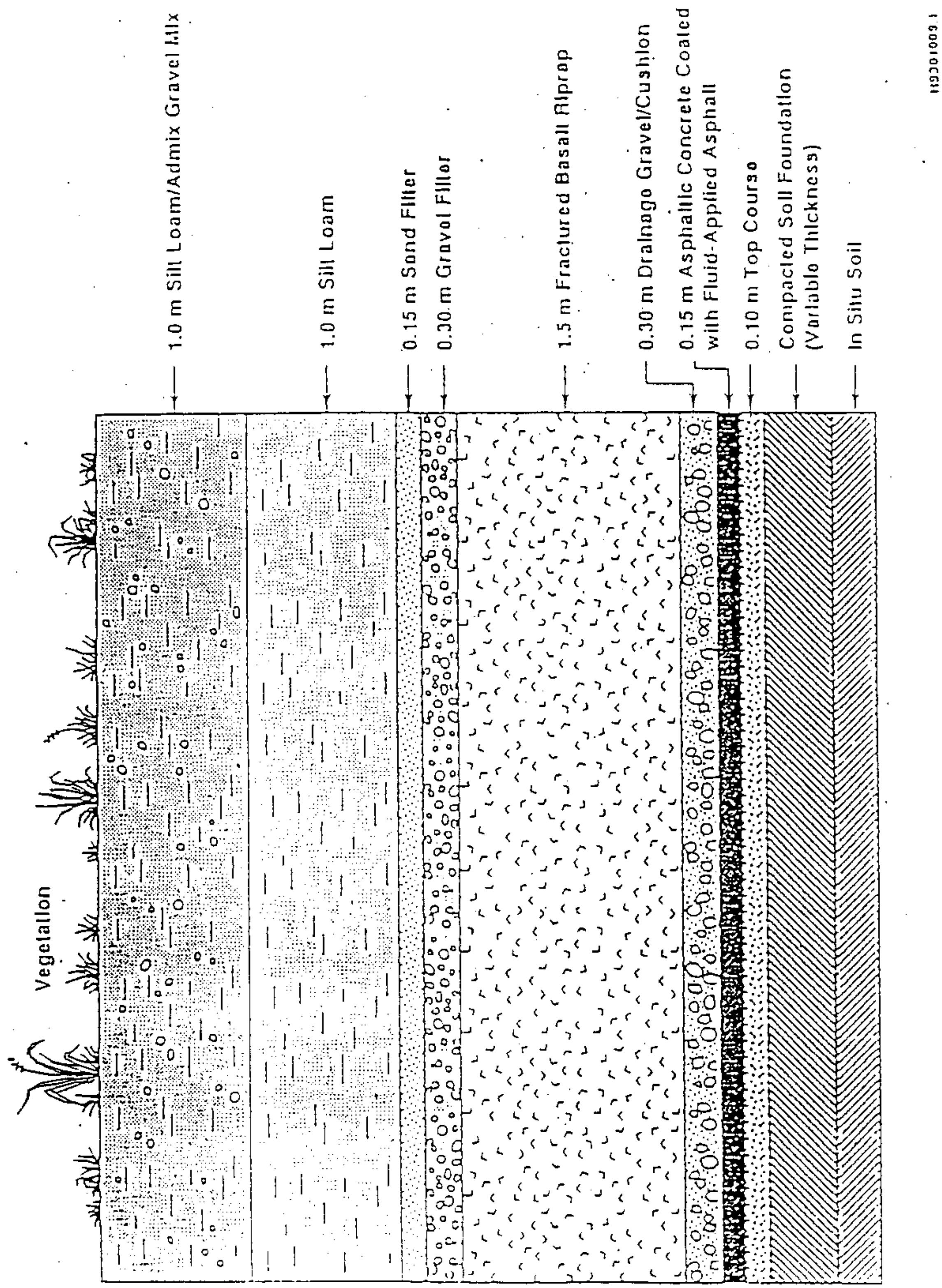
This constructability document is an interim report detailing the constructability of the Prototype Surface Barrier and includes efforts expended before July 1, 1994. This report has been prepared in support of TPA Milestone M-15-02E.

Key issues discussed in this constructability report include the following:

- Design errors/problems discovered during construction of the prototype barrier
- Construction problems encountered in the field
- Specified materials and products;
  - are they available locally or readily fabricated?
  - do specifications relate to established performance objectives?
  - are the specifications appropriate and achievable?
- Effect of local conditions on materials (such as locally available gravels and basalt not within specification, effect of seasonal heat on fluid asphalt, etc.)
- Project costs

The report is provided to aid in the design and construction of future barriers, in general, and as a tool in making decisions regarding applicability of surface barriers for the 200-BP-1 Operable Unit. While this report deals with the constructability of the Prototype Surface Barrier, an effort is made in the "Conclusions" and "Recommendations" sections to extrapolate the pertinent constructability information to multilayered surface barriers in general.

Figure 1. Cross Section of Surface Isolation Barrier.



1.4 PRECONSTRUCTION ACTIVITIES

1.4.1 Contracting

A fixed-price contract was prepared for construction of the Prototype Barrier based on a well-defined scope, lack of radiation zone work, and an expectation of lower costs as compared to plant forces construction. A market poll was conducted prior to publishing the bid package. A determination was made that there would be enough competition among small businesses that a small business waiver would not be required. ICF Kaiser Hanford (ICF KH) developed the bid package and procured a contractor for the construction of the prototype barrier.

1.4.2 Procurement Effort

A request for proposals was published in the Commerce Business Daily (CBD) on September 11, 1993. The original CBD announcement specified that the contract for construction of the Prototype Surface Barrier would be set aside for small businesses only.

Only one small business responded, with a proposal approximately 38% greater than the fair cost estimate prepared by ICF KH. According to federal government procurement regulations, the contract could not be awarded to the sole bidder because of a price quote of more than 10% above the fair cost estimate and inadequate competition. To do so would require a government audit of the bid and negotiations on a final price, a process estimated to take much longer than rebidding the work.

ICF KH, in concert with Westinghouse Hanford Company (WHC), requested a waiver of the small business set-aside. The U.S. Department of Energy, Richland Operations Office (DOE-RL) granted the waiver, and a second CBD announcement was issued on October 5, 1993.

Requests for proposals (RFPs) were issued, resulting in 2 bids, both of which were slightly lower than the fair cost estimate. Proposals from the second bid cycle were opened November 11, 1993.

The lack of competition from the original RFP and rebidding process resulted in a 2 month delay, setting the project back into the winter months.

1.4.3 Award to Contractors

George Grant Construction, of the Tri-Cities, Washington, was awarded the contract for construction of the Prototype Surface Barrier. Subcontractors to George Grant Construction included the following:

- Earthwork Subcontractor - Contractor's Equipment Maintenance, Inc. (C.E.M.I.).
- Asphaltic Concrete - Acme Construction and Materials, Inc.
- Fluid-Applied Asphalt - S.A.M.S. Systems (of Colorado).

1.5 SITE PREPARATION

Preliminary site work began in September 1993, in parallel with the second bid cycle for contracts. This work was done with ICF KH construction forces and WHC Plant Forces personnel. The following activities were completed: 1) installation of a raw water line, 2) topographic survey and placement of survey control monuments, 3) grouting underground crib piping and vents, 4) abandonment of one groundwater monitoring well and several in-situ probe casings, 5) placement of a water disposal basin for infiltration testing and monitoring, and 6) clearing and grubbing the site of vegetation.

1.6 MOBILIZATION

A pre-construction meeting was held with the contractor on December 15, 1993. The Notice to Proceed was issued on December 17, 1993. The contractor subsequently mobilized to the project site on December 27, 1993.

Equipment was set up at the grout waste site, near the 200 East Area, on December 27, 1993. A haul route was established by opening up part of the fence and using an old gate (811) through another fence. This allowed a shorter haul route, reducing the hauling cycle time. Cycle time for loading the trucks, travel to the prototype barrier, and unloading was approximately 15 minutes.

Activity began at Pit 30 on April 14, 1994 for processing of native, course granular materials. The Pit 30 materials were hauled to the 200 East Area through Gate 811. Cycle time for loading the trucks, travel to the prototype barrier, and unloading was approximately 15 minutes.

Activity began at the Vernita Quarry on February 17, 1994 for mining of natural basalt formation materials. Processing of materials began on June 10, 1994. Basalt from Vernita Quarry was hauled along State Route 240 to the Yakima Barricade and into the 200 East Area through Gate 811. Cycle time for loading the trucks, travel to the prototype barrier, and unloading was approximately 50 minutes.

Activity began at the McGee Ranch borrow area on April 6, 1994 for excavation of native silt materials. The silts from McGee Ranch were hauled along State Route 240, through the Yakima Barricade, and into the 200 East Area through Gate 811. Cycle time for loading the trucks, travel to the prototype barrier and unloading was approximately 45 minutes. Silt was stockpile west of the construction site for subsequent pugmilling.

2.0 BARRIER CONSTRUCTION

2.1 CONSTRUCTION METHOD

The following activities describe construction processes and sequence. Each section describes activities applicable to that section only.

2.2 SUBGRADE FILL

As originally designed, the subgrade of the barrier was to be constructed of sandy soil (containing cobbles less than 75 mm in their greatest dimension with a constitution not more than 20% of the volume of the fill), which was to be obtained from the grout waste borrow area, placed and compacted to 95% of maximum density (WSDOT M41-10, Section 2-03.3(14)C, Method C).

The grout waste materials were previously excavated and stockpiled from construction of the Grout Waste Project. An Engineering Change Notice (ECN) was written (ECN W-263-5) to properly specify the sandy grout waste material, which was determined to be structurally sound, ensuring adequate support for the overlying barrier [WSDOT M41-10, Section 2-03.3(14)C].

The subgrade fill was screened with a grizzly at the grout site and hauled by a fleet of 3 dump trucks approximate 3 miles from the grout waste site to the barrier. The total duration of placing the subgrade fill (approximately 38,000 yd^3) was approximately 30 working days.

The subgrade fill was required to make a level surface for subsequent testing and monitoring activities. Depth of the subgrade fill varied from 0 to 5 m as required by the original gradient of the soil surface in the crib area. The subgrade fill was placed level in the north-south direction and sloped down at 2% in the east-west direction to provide drainage for testing and monitoring activities.

Placement and compaction of the subgrade fill was completed as specified in the contract documents. Because the subgrade was placed during cold weather, there were a few days when the surface was required to be reworked to ensure that frozen materials were not embedded. The contractor was required to remove frozen materials and rework the surface daily during freezing temperatures. Onsite inspections verified that this effort was being conducted.

2.3 LOWER NEUTRON PROBE ACCESS TUBES

The neutron probe access tubes were installed in accordance with the design plans and specifications. During excavation on the southwest corner of the bottom probe, insitu soils above the crib were encountered, raising concern that contaminated material may have been excavated. The contractor stopped excavation and WHC Health Physics verified that soils being excavated were not radiologically contaminated. Health Physics verification consumed very little time, and excavation continued with only minor delays.

2.4 TOP COURSE

The top course material consisted of crushed material (small enough to pass through a 5/8-in. mesh) hauled by dump truck from Pit 30 on the 200 Area Plateau and dumped on the barrier site. The material was blade-flattened by a 10 G motor grader. Compaction was completed to 95% of maximum density to a minimum of 4 in. deep by a steel drum vibratory roller (WSDOT M41-10, 4-04, 3(5)).

2.5 PAN LYSIMETERS

A basin was excavated in the top course and sub grade to construct the pan lysimeters. These lysimeters were built to determine performance of the asphalt layer. The lysimeter was lined with geomembrane, geotextile, and geosynthetic clay liner material.

The pan lysimeter was originally filled to a depth of 0.2 m with drainage gravel, covered with 0.1 m of top course. When the asphaltic concrete was placed over the top course and application of the asphaltic concrete attempted, the drainage gravel moved, allowing the geotextile and top course gravel to shift under the force of the roller. Geotextile, top course gravel and asphaltic concrete were pushed in undulations in front of the roller, rendering the asphaltic concrete impossible to compact.

The movement of materials within the lysimeters was stopped by modification of the lysimeter fill. The lysimeters were modified by removing the asphalt, removing the drainage gravel and geotextile, removing 0.1 m of the drainage gravel (leaving 0.1 m), replacing the geotextile, and increasing the depth of the top course to 0.2 m to completely cover the geotextile. The geotextile was then overlaid by the asphalt. Lysimeter function was not modified by these construction changes.

Modifications made to lysimeter design and construction on the Test Pad provided an improved construction method for the lysimeter in the Prototype Barrier, which was constructed without incident.

2.6 ASPHALTIC CONCRETE

The asphaltic concrete was placed as planned. It was prepared in Richland, Washington, and hauled to the barrier site with conventional dump trucks. A conventional paving machine, laying varying widths of asphaltic concrete per pass, was used to lay a total of 35,013 tons of asphaltic concrete (est. approximately 34,000 tons on the prototype barrier).

Paving was done in two lifts of approximately 7.5 cm each. General overlap of the terraces was approximately 1.5 to 1.8 m, which exceeded the specification of a minimum of 1.5 m. A nuclear gauge was used to verify compaction. The total duration of this work was 4 days, including paving the Test Pad.

The specification for the asphaltic concrete was written to specify that 6% of the material, or greater, would be <0.074 mm, but this specification was not always met. This deviation from the specification was documented on a non-conformance report and reviewed by the engineers and the Barrier Development Team. The deviation was not perceived to be a major concern.

To verify acceptability of the asphaltic concrete, laboratory and field permeability tests were conducted. Cores were obtained from the north end of the barrier for laboratory permeability testing. Field tests were completed using a modified falling head permeameter which increases the head space. This method provided good results in a matter of days instead of weeks, as previously assumed.

In-situ and laboratory permeability testing of the asphaltic concrete required 2 weeks, which was not originally scheduled. Application of fluid-applied asphalt was delayed to permit resolution of the Non-Conformance Report.

2.7 FLUID-APPLIED ASPHALT

A polymer-modified asphalt was designed to be applied over the asphaltic concrete to form a very low permeability layer. The polymer-modified asphalt (or fluid-applied asphalt) is applied by spraying the liquid directly onto the asphaltic concrete surface. Spraying was done with an asphalt distributor truck. Application of the fluid-applied asphalt was completed in 20 days.

Originally, when fluid-applied asphalt was applied in 100 mm thicknesses, as specified, it developed bubbles (approximately 1 cm maximum diameter) which propagated from the asphaltic concrete surface up to the surface of the fluid-applied asphalt. Field personnel walked over the fluid-applied asphalt with tools to "pop" the bubbles while they were hot, allowing the fluid-applied asphalt layer to flow into the bubbles and seal the holes.

Some bubbles were found after the fluid-applied asphalt cooled. Those bubbles were repaired by heating the material with a propane torch, which allowed the softened fluid-applied asphalt to flow into the hole left by the previous bubble.

Bubbles in the fluid-applied asphalt applied during elevated ambient temperatures were found to be prevented by reducing nozzle size, and, at selected locations, by application of the fluid-applied asphalt over a geotextile fabric.

A contractor-recommended application of a white latex paint to the surface of the fluid-applied asphalt layer, to reflect the sun, helped to control the temperature of the fluid-applied asphalt and keep it in a workable condition.

Additionally, it was found that thinner layers of fluid-applied asphalt application tended not to bubble as much. Several layers were applied so that the total depth of fluid-applied asphalt was in excess of 300 mm, making certain that the surface was consistent and smooth at >200 mm. Five to seven thin layers of fluid-applied asphalt were applied to get acceptable results.

2.8 WATER COLLECTION SYSTEM

A water collection system was designed to determine water balance from various areas on the barrier. Twelve water collection systems were installed using concrete curbing and galvanized steel gutters to divide the asphalt surface. During testing, water will be applied to the surface of the barrier to simulate three times normal precipitation.

All surfaces of the test zone and dividing structures were reinforced with fluid-applied asphalt to help provide leak-proof surfaces. Crickets, which developed thermal expansion cracks during construction, were repaired with application of fluid-applied asphalt. Curbs and gutters were reinforced with geotextile and covered with fluid-applied asphalt. After the fluid-applied asphalt was applied, collection piping was placed in gutters to channel water to measuring devices.

Collection piping was installed as illustrated on the construction drawings. The pipes were pneumatically pressure-tested before the trenches were backfilled. Siphon vaults were installed and coated with bitumastic. Dosing siphons and vault piping were installed to quantify water applied during the testing.

Collection areas were tested by flooding the zone with water prior to placement of the drainage gravel.

During one of the flooding tests, two holes were discovered in the galvanized steel gutters which had not been plug-welded during manufacture of the gutters. The holes were welded, and testing and construction continued. Additionally, during the testing, corner joints between the curbs were found to be leaky. Application of fluid-applied asphalt in those joints will prevent them from leaking.

2.9 GRAVEL DRAINAGE LAYER

Drainage gravel consisted of screened, cleaned, round river rock, 3/8 in. to 1.5 in. (WSDOT M 41-9-03.1(3)C, Grade 5)), from Pit 30. The gravel was placed and consolidated by 2 passes of a vibratory roller.

Placement of the drainage gravel was completed in less than a week.

2.10 BASALT LAYER

Drilling and blasting of the basalt at the Vernita Quarry was done by an experienced explosives expert employed by the contractor. The shot design and quantity of explosives required prior approval by ICF KH, WHC, and DOE. There was initial concern by US West/AT&T about seismic shock to a nearby fiber optic phone line. US West and AT&T representatives observed and monitored the test shot, and no problems were experienced.

The test shot was made early to ensure that no programmatic delays due to blasting were encountered which would delay production of the basalt.

With information from the test shot, the loading pattern was opened and stemming was shortened to create less waste before production shots were made.

The site was cleared and grubbed of overburden prior to blasting. Uncleaned, well-blasted (overshot) basalt, was passed through 10-in.-spaced grizzly bars to scalp off any oversize material.

Initially the basalt product contained an excess of fine particles, rendering it slightly out of specification. The cause was determined to be that the basalt contained normal cracks which had occurred during initial placement of the basalt and throughout the ensuing time. The cracks filled from the natural weathering processes with wind and waterborne silt, which, when combined with the small fraction of the blasted basalt, biased the range of particle sizes. The intent of the specification was met by the produced basalt, and the specification was modified to allow the use of the native materials as was originally intended.

2.11 SHOULDER BALLAST

Railroad ballast (rock from 2 in. down to 3/8 in.) was designed to act as a transition between the large basalt particle sizes and the small gravel to prevent the gravel filter from falling between large basalt pieces. The shoulder ballast has been placed up to the height of the bottom of the gravel filter layer.

2.12 GRAVEL FILTER

The purpose of the gravel filter is to support the overlying sand filter, which supports the silt layer. The gravel filter material is crushed material (small enough to pass through a 5/8-in. mesh; comparable with the "Top Course") hauled by dump truck from Pit 30 or supplied by sand-and-gravel contractors. The gravel filter was placed over the drainage gravel and shoulder ballast according to the drawings. The material is graded to blade flat or to the required slope by a 10 G motor grader. Compaction on the flat areas is completed to 95% of maximum density to a minimum of 4-in. depth by a steel drum vibratory roller (WSDOT M41-10, 4-04, 3(5)).

2.13 CLEAN FILL SIDE SLOPE

The clean fill side slope was placed, as designed, to be a rocky, freely draining gravely material. It is produced by mining and screening the Pit 30 material. It is transported to the prototype barrier site, placed in 1-ft lifts and compacted as common fill by two passes with large rubber-tired vehicles.

The clean fill was originally not within the range of the specification because there were too many fines in the gravel, caused by not removing the overburden above the gravel. The specification was modified by ECN W-263-5, to clarify that the material was to be largely cobbles and sands - a "gravely material." The product is used as-is, with production after topsoil stripping.

2.14 TEST PAD

2.14.1 "Virginia Breakover Compaction Test Pad"

Two separate "test pads" were constructed. One pad was constructed to demonstrate maximum compactability of the asphaltic concrete (Virginia Breakover Test). The Test Pad for the Virginia Breakover is typically used on construction projects to define appropriate compaction of asphaltic concrete to match the specifications.

2.14.2 Asphaltic Concrete Test Pad

The second Asphaltic Concrete Test Pad was constructed with materials and construction methods identical to the asphaltic concrete layer. Test Pad construction was completed in parallel to the barrier in order to simulate the asphaltic concrete layer within the barrier.

A strip of fluid-applied asphalt was added to the west end of the Test Pad for additional testing purposes.

Included in the Test Pad is a pan lysimeter, identical to the lysimeter within the Prototype Barrier. Permeability data generated from Test Pad testing are presented in Section 3.2.

2.15 JULY 1 - END OF TERM FOR THIS REPORT

The scope of this draft report includes activities conducted before July 1, 1994. The remainder of the barrier construction will be described in a subsequent addition to this report, which will include the following sections.

- 2.16 GEOTEXTILE SEPARATOR/CUSHION PLACEMENT
- 2.17 SILT
  - 2.17.1 Place Lower Silt Layer
  - 2.17.2 Install Neutron Probe Access Tubes
  - 2.17.3 Loosen Silt Layer
  - 2.17.4 Compaction Data
- 2.18 SILT/PEA GRAVEL ADMIX
  - 2.18.1 Process, Install Pea Gravel Admix
  - 2.18.2 Compaction Data
- 2.19 PLACE PERIMETER CRUSHED BASALT
- 2.20 COMPLETE BARRIER FACILITY
  - 2.20.1 Loosen Admix Area
  - 2.20.2 Construct Access Road, Parking Area
  - 2.20.3 Place Signs and Chain Barricade
  - 2.20.4 Decommission Basalt Mining Operation
  - 2.20.5 Decommission Silt Borrow Area
  - 2.20.6 Stabilize and Seed Impacted Areas
- 2.21 DEMOBILIZE

3.0 TESTING/INSPECTION DURING CONSTRUCTION

3.1. PERTINENT COMPACTION DATA

All testing and inspection results will be included in a Construction Quality Assurance Report which will be completed after construction. The

Quality Assurance Report will be attached to the final version of this document as an appendix.

3.2 PERMEABILITY DATA OF ASPHALTIC CONCRETE LAYER

3.2.1 Barrier Permeability Data

Laboratory permeameter tests were completed on asphalt cores from the barrier. Initial results indicated a hydraulic conductivity of 10^{-9} cm/s. The cores were obtained from the "non-functional" area of the Prototype Barrier, at the north end. Table 1 presents laboratory data from barrier testing.

Table 1. Laboratory Asphaltic Concrete Permeability Data for the 200-BP-1 Prototype Barrier.

SAMPLE	PERMEABILITY, cm/s
1A	2.12×10^{-09}
2A	1.17×10^{-09}
3A	7.09×10^{-10}
4A	8.34×10^{-10}
5A	1.60×10^{-09}

3.2.2 Test Pad Permeability Data

A modified falling head permeameter test was completed on the Test Pad and barrier surface. Table 2 presents data from these tests.

Table 2. Field Asphaltic Concrete Permeability Data for the 200-BP-1 Prototype Barrier.

SAMPLE	PERMEABILITY, cm/s
1 NW Corner	1.91×10^{-09}
2 NW Corner, Seam	1.08×10^{-07}
3 N Center	1.47×10^{-08}
4 NE Center	4.33×10^{-08}
5 NE Corner	1.51×10^{-08}

4.0 LESSONS LEARNED

Because this construction project dealt with a prototype, it should be assumed from the outset that specifications and plans should change. The design was remarkably complete, and the project had few planning problems. As is common in all projects, however, when problems were encountered inadequate or insufficient planning could be causative. This section describes some of the lessons learned in design and construction of the Prototype Barrier.

While it is difficult to clearly separate the lessons learned into causative sections, an attempt is made to do that here to facilitate organization of thought for potential solutions for the future.

Additionally, some attempt is made to separate out problems which would not impact non-prototypical barriers, since certainly this Prototype Barrier was less constructable and cost more than would a barrier which did not have testing and monitoring features incorporated into the design.

4.1 PROJECT PLANNING

4.1.1 Work Stoppage - 4/18/94 through 5/21/94

DOE-RL suspended construction activities on April 18, 1994 to allow the Yakima Indian Nation time to review and comment on decision making documents regarding the construction of the prototype barrier. After consultation, construction activities were resumed on May 21, 1994. Work-around activities were completed during the construction suspension, which reduced both schedule and cost impacts. It is critical to involve all stakeholders in the decision making process prior to initiating construction activities.

4.1.2 Seasonal Cycles

Seasonal cycles have a significant impact on the integrity of barrier components. Freezing temperatures make it extremely difficult to meet compaction requirements. Due to the mild winter during construction of the prototype, only minor delays were encountered due to frozen materials. Scheduled downtime in the winter months will need to be a requirement.

4.1.3 Permeability Testing of Asphaltic Concrete

No time was scheduled for permeability testing of the asphaltic concrete on the main barrier. However, because this barrier is a prototype for potential future barriers on the 200 Area Plateau, extensive testing and analysis was required. This included actual coring of the asphalt layer of the barrier for laboratory examination.

Once large-scale barrier performance is better proven for the Hanford environment, the extensive testing and analysis will not be required. When barriers are standardized, routine construction testing, designed into the barrier as a Quality Assurance function, will suffice to prove that construction follows design.

4.1.4 Surface Contamination

At the beginning of the project, a surface radiological survey was performed at the construction site. The survey identified radiological contamination in the southwest portion of the construction area. The contamination was removed by on-site construction forces.

There will always be the potential for surface contamination above cribs over which barriers will be placed. Careful planning must ensue for future barriers to ensure that contaminated materials are not encountered. New topographic surveys should be done to ensure that a current datum is referenced, and that the topography over the waste area has not been modified by placement of clean fill or by excavation or other removal of surrounding soils.

4.2 DESIGN PROBLEMS

The majority of the design problems were associated with the testing and monitoring aspects of the barrier. The following sections discuss these problems along with material specification problems.

4.2.1 Materials Specification

Barrier design must be based on a well-defined philosophy, and specifications must be written to support that philosophy (i.e., if the design philosophy is to use available materials, then barrier construction specifications should describe those available materials). Time must be provided during project planning for evaluation of barrier materials. This section describes problems associated with material specifications.

4.2.1.1 Asphaltic Concrete. The asphaltic concrete mix was developed to minimize permeability while maintaining structural integrity for the overlaying materials. During the placement of the asphaltic concrete, some material was slightly out of specification. When the asphalt being emplaced on the barrier fell outside the specification, a Non-Conformance Report was issued by the project Construction Quality Assurance inspector. The specification was reviewed, permeability testing was accomplished, and an ECN was written to better define the specification. The contractor was allowed to continue to emplace the asphaltic concrete

Although the asphaltic concrete contains less than the specified amount of fine materials (those soil materials passing a 200-mesh [0.075 mm] screen), permeability of the asphaltic concrete at 10^{-9} cm/sec exceeded the specification of 10^{-7} cm/sec.

Asphaltic concrete specification problems could be remedied in the future by requiring the contractor to demonstrate compliance with the specification prior to placement. Continued periodic sampling should verify that the specification continues to be met.

4.2.1.2 **Basalt.** Gradation tests on the processed basalt were sometimes slightly out of specification. Although the average particle size was within the text specification, the listed range of particle sizes was not always within specification. The blasted basalt yielded more fines than originally anticipated (Section 2.10).

On this project, the specification was modified by an ECN to allow use of the desired materials. In the future, the specification must be carefully written to ensure that the proper materials have been identified.

4.2.2 Requirements Definition

As the project proceeded, the Barrier Design Team identified additional modifications to existing monitoring components of the barrier. Since this was a fixed-price contract, it was difficult to include research and development aspects without cost and schedule impacts. A great deal of coordination was required to satisfy all of the program's needs. Since this is a prototype, these problems will go away when the prototype has been constructed and tested.

4.2.3 Survey

A survey error caused potential placement problems with the lower neutron probe access tubes. The subgrade fill was placed then re-excavated as planned down to below original grade (which was cover for surface contamination) for placement of the lower neutron probe access tube. There was a potential for exposure of an off-site contractor to radiologically contaminated material.

To reduce the likelihood that a contractor might inadvertently excavate contaminated soil, an up-to-date topographic map must be made prior to barrier design.

The geographic survey was based on the old Merrick system, which was replaced with another system by DOE in 1991. The change in mapping systems caused a coordinate change, causing incorrect placement of the monuments. Because of this, the barrier was not centered over the crib. In this case the barrier is only 8 to 9 in. off, and will not cause a problem, but the potential for such a problem must be avoided in the future.

4.2.4 Pan Lysimeters

The pan lysimeters were originally filled with 0.2 m of rounded rock then covered with geomembrane and 0.1 m of drainage gravel. When the asphalt was rolled over the drainage gravel, the round rocks moved, allowing the drainage gravel to shift, causing the roller to "push" the asphalt in front of it.

The problem was resolved by removing the asphalt, removing the drainage gravel and geotextile, removing 0.1 m of the cobbles (leaving 0.1 m of cobbles), replacing the geotextile, and substituting 0.2 m of drainage gravel, over which was laid the asphalt. This was probably a one-time error. Now that it is recognized that the original depth of round in the prototype was not functional, lysimeters with that depth of rock will not be designed. This was the type of error that "prototypes" are designed to prevent in "working" systems.

4.2.5 Water Supply Line - Water Hammer

The raw water pipeline developed several leaks after it was installed. Initially, a water hammer occurred causing the pipe to burst. The system was redesigned to include pop off valves to eliminate the water hammer.

Additional leaks were found in the pipe joints. The joints were excavated and replaced.

Future barriers will not require accelerated precipitation testing. Thus, the problem will disappear with the construction and testing of the Prototype Barrier.

4.2.6 Curbs and Gutters

Heat from the sun caused the curbs to expanded and buckle. Upon cooling and contraction, cracks in the curbs appeared at the joints with dikes. The cracks were repaired by applying fluid-applied asphalt over a geotextile. Once the overlaying materials were placed, the temperature will remain stable and the expansion problem will be eliminated.

Future barriers will not have the requirement for infiltration collection systems. However, possible solutions where water collection systems will be required may be to: 1) construct the concrete curbs with expansion joints and steel reinforcing, 2) construct asphaltic concrete curbs which would have a coefficient of expansion similar to underlying structures, or 3) immediately paint the structures with white latex paint to reflect the sun, thereby precluding sorption of heat by the structures.

4.2.7 White Paint Coating Over Fluid-Applied Asphalt

A coating of flat, white, latex paint was requested by the contractor to be applied over the fluid-applied asphalt. The paint reflects heat from the sun, allowing the fluid-applied asphalt to remain cooler. The white paint coating made no difference in barrier function, but only in constructability.

In the event that fluid-applied asphalt is used in future barriers, some concern must be manifest in the design to prevent heating of the fluid-applied asphalt surface.

4.2.8 Compaction Of Terrace Transitions

The terrace transitions on the prototype barrier were left rough, and the fluid-applied asphalt did not flow into the rough surfaces. Hand application of the fluid-applied asphalt was required to ensure an even coat over all surfaces.

If fluid-applied asphalt is required on future barriers, a smooth, compacted transition between terraces will be needed. Terrace transitions will not be required on future barriers.

4.3 CONSTRUCTION PROBLEMS

The specification for the polymer-modified asphalt (fluid-applied asphalt) defined two applications of 100 mm, each. The fluid-applied asphalt, as it was applied over the asphaltic concrete, developed small air bubbles which communicated with the micro cracks in the surface of the asphaltic concrete. Another potential bubble causative factor appeared to be application by larger nozzles on the asphalt distributor. Personnel with trowels went over the still warm surface of the fluid-applied asphalt opening the bubbles, which then filled as the fluid-applied asphalt flowed into itself.

The fluid-applied asphalt also developed bubbles due to heating in the hot sun. It is possible that if the fluid-applied asphalt were applied in the cool of the very early morning and coated before the surface became warm, the bubbles would not form.

Field modifications demonstrated that thinner layers of fluid-applied asphalt did not bubble so much, that applications by smaller nozzles and at slower speeds did not bubble so much, and that fluid-applied asphalt, when kept cooler (e.g., with a coating of heat reflective white latex paint), did not bubble. The fluid-applied asphalt also did not bubble when it overlaid a geotextile.

4.4 DEVIATIONS

As of July 1, 1994, a total of 14 ECNs were required during barrier construction, which is not considered excessive for a project of this size. Copies of all ECNs will be attached to the final constructability report.

5.0 PROJECT COSTS

5.1 PROTOTYPE BARRIER COSTS

Table 3 shows the original estimate for the Prototype Barrier, and the forecast actual cost of July 1, 1994. This table will be updated for the final report. Although the base bid for construction was almost $400,000 below the engineers' estimate, delays and changes in scope increased costs by approximately $200,000.

Table 3. Prototype Barrier Estimate Project Costs (through 7/1/94).

	Original Estimate	Actual Cost
ENGINEERING DESIGN	$271,000	$268,400
ENGINEERING INSPECTION	197,400	211,000
LINE	372,400	262,000
FIXED-PRICE CONSTRUCTION	2,638,700	2,143,000
CONSTRUCTION MANAGEMENT	175,500	32,000
PROJECT INTEGRATION (WHC)	216,800	94,000
SUBTOTAL	$3,871,800	3,010,400
CONTINGENCY	369,900	N/A
PROJECT TOTAL	$4,241,700	3,010,400

5.2 APPLICATION OF UNIT COSTS TO FUTURE BARRIERS

The following unit costs (Table 4) are based on the actual bid for the Prototype Barrier (5 acre footprint). Extrapolation of these unit costs for estimates of larger barriers should take into account some economy-of-scale factors.

Additionally, cost factors will be changed by mobilization of off-site contractors to the site (e.g., If the fluid-applied asphalt batch plant could have been set up on site, total time for application of the fluid-applied asphalt would have been 4 days, providing a great savings for the contractor, and therefore for the contract.)

Table 5 shows the breakdown of fixed-price construction costs.

Table 4. Unit Costs.

BARRIER LAYER	TOTAL UNITS BID	COSTS PER UNIT	FACTORS
SANDY SOIL FILL	34,000 CY	$4.32/CY	haul approximately 2 mi. and place
3/4-in. CRUSHED GRAVEL FILTER	13,500 T	$16.90/T	haul approximately 21 mi. and place
ASPHALTIC CONCRETE	3,400 T	$84.03/T	haul approximately 21 mi. and place
FLUID-APPLIED ASPHALT	8,050 SY	$36.02/SY	haul approximately 21 mi. and place
DRAINAGE GRAVEL	6,300 T	$18.10/T	haul approximately 2 mi. and place
FRACTURED BASALT	14,000 CY	$20.93/CY	haul approximately 16 mi. and place
PIT RUN GRAVEL	40,000 CY	$6.88/CY	haul approximately 2 mi. and place
MCGEE SILT	3,300 CY	$19.09/CY	haul approximately 14 mi. and place
GRAVEL ADMIX SILT	46,000 CY	$32.82/CY	haul, approximately 14 mi., mix and place

Table 5. Breakdown of Fixed-Price Construction Costs.

DESCRIPTION	BASE BID
Bond Insurance	27,000
Mobilization	51,000
Sandy Soil Fill	160,000
Neutron Probe - Access Tubes	21,000
Pan Lysimeters	47,000
Collection Piping	35,000
Vaults for Siphons	21,000
Coat Inside Vaults w/Bitumastic	1,000
Dosing siphons and Vault Piping	22,000

Table 5. Breakdown of Fixed-Price Construction Costs (cont.).

DESCRIPTION	BASE BID
Top Course Surfacing	47,000
Asphaltic Concrete at Terraces & Test Pad	285,700
Fluid-applied Asphalt	290,000
Gutters and Upper Collected System Piping	90,000
Concrete Curbing/Gutter Crickets	13,000
Drainage Gravel	114,000
Basalt	293,000
Gravel Filter	67,000
Sideslope Fill	275,000
Sand Filter	40,000
Silt - Lower Layer	63,000
Neutron Probe - Access Tubes in Silt	25,000
Blend Silt & Pea Gravel	128,000
Grade and Compact Access Road	6,000
Post Barricade & Gravel Stabilization	15,000
Punchlist/Cleanup	3,500
Demobilize	2,800
Change Orders	32,000
TOTAL - SUBCONTRACT	2,175,000

6.0 SUMMARY AND RECOMMENDATIONS

Completion of this prototype surface barrier over the 216-B-57 crib demonstrates that large-scale barriers can be constructed as designed. Only minor changes in construction specifications were needed to meet Quality Control requirements. As indicated in the "Treatability Study Plan for the 200-BP-1 Prototype Surface Barrier" (DOE/RL 1993a) improved designs and construction methods will be incorporated into future barrier projects.

This section summarizes the construction activities for the 200-BP-1 prototype surface barrier. In addition, recommendations are presented for further development of surface barriers.

6.1 RECOMMENDATIONS

Completion of Phase I of the treatability test plan identified issues which will improve subsequent barrier designs. This section identifies recommendations for further investigation.

6.1.1 Alternative Pricing Mechanisms

Fixed-price contracts are cost effective for well-defined projects. Due to the nature of this barrier, many research and development issues were identified which made it difficult to accommodate this contract method. Future barrier fixed-price contracts will not have these difficulties.

Alternative pricing mechanisms may also be evaluated for obtaining competitive prices. Use of unit prices and contract quantity estimates for fixed-price basis for overages or potential add-ons in the field may reduce costs. With such a contracting mechanism, the line items could include "Topsoil Stripping Volume," "Rock Crushing," "Provide Material xx," "Excavate x Amount of Material," etc. A base bid (fixed price) could be used for approximate quantities with optional unit prices for overage/underage.

Cost incentives could be included in the contract for beating the required schedule, and penalties could be included for late completion, if the schedule was within the contractor's control.

6.1.2 Fluid-Applied Asphalt

Due to the relatively high line item cost and construction difficulties of the fluid-applied asphalt layer, alternative products should be evaluated. Results of the initial permeability testing on the asphaltic concrete exceeded the design requirements, which may eliminate the need for the fluid-applied asphalt.

6.1.3 Barrier Materials

A reliable source of barrier materials will be required to proceed with large-scale remediation of the 200 Areas. Material such as basalt may be located in culturally sensitive areas which may make it difficult to obtain the desired quantities. Early planning is needed to secure these materials prior to initiating additional barrier construction activities.

6.2 SUMMARY

Initial procurement of the construction contract was delayed approximately 2 months due to the lack of competition amongst bidders. A second bid package was issued and a contract was awarded to George Grant Construction of Richland, Washington. The bid price was approximately 15% below the fair price estimate.

Initial mobilization to the site began on December 27, 1993. Construction activities proceeded on schedule except for a one month construction suspension (Section 4.1.1). Freezing temperatures during placement of the basefill resulted in only minor cost impacts due to the relatively mild winter.

Barrier components were installed as designed with only minor modifications. Standard construction equipment was adequate to meet the Quality Control requirements. Modifications to material specification were required to use existing materials as originally planned. Performance requirements were met using these materials.

Since this was a prototypical barrier, the design included many special requirements for subsequent performance testing. The majority of the construction issues were associated with these aspects. All issues were resolved to satisfy the requirements for the Phase II testing.

7.0 REFERENCES

DOE/RL, 1993a, *Treatability Study Plan for the 200-BP-1 Prototype Surface Barrier*, DOE/RL-93-27, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL, 1993b, *Phase I Remedial Investigation Report for the 200-BP-1 Operable Unit*, DOE/RL-93-70, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

WHC, 1993, *Prototype Surface Barrier at 200-BP-1 Operable Unit*, WHC-SD-EN-TI-142, Rev. 0, Westinghouse Hanford Company, Richland, Washington.