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DESIGN ANALYSIS REPORT
ASARCO EAST HELENA
CORRECTIVE ACTION MANAGEMENT UNIT (CAMU)
PHASE 2 CELL

Prepared for:

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East Helena, MT 59635

Prepared by:

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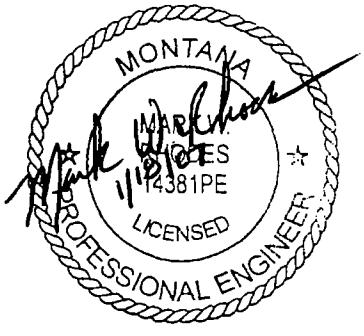

January 2007

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DESIGN ANALYSIS REPORT
ASARCO EAST HELENA
CORRECTIVE ACTION MANAGEMENT UNIT (CAMU) PHASE 2 CELL

1.0 INTRODUCTION

This document and its associated appendices constitute the design analysis submittal for the proposed Corrective Action Management Unit (CAMU) Phase 2 Cell near the Asarco East Helena Plant ("the plant"). The plant is described in detail in other documents, particularly the Comprehensive Remedial Investigation/Feasibility Study (RI/FS, Hydrometrics, 1990), the Current Conditions Release Assessment (CCRA, Hydrometrics, 1998), and the RCRA Facility Investigation (RFI, ACI, 2003). The CAMU Phase 2 Cell for the East Helena Plant will contain plant site soil and demolition debris generated through the implementation of the Montana Consent Decree (CDV-2004-212) and the RCRA Consent Decree (CV98-3-H-CCL).

Although not required by CAMU regulations, the proposed CAMU Phase 2 Cell is designed to comply with the Resource Conservation and Recovery Act (RCRA), Subtitle C regulations and guidelines and the Administrative Rules of Montana (ARM 17.50.506).

Tasks necessary to construct the CAMU Phase 2 Cell include:

1. Identification of Performance Standards
2. Site Selection
3. Geotechnical Investigation
4. Material Testing
5. Project Design
6. Project Construction
7. Waste Placement
8. Closure and Monitoring.

Each of these tasks is discussed in this Design Submittal.

2.0 PERFORMANCE STANDARDS

The following performance standards for hazardous waste landfills, defined in 40 CFR 264 and ARM 17.50.506 were used for design of this project.

2.1 BOTTOM LINER SYSTEM

(40 CFR § 264.301 (c)(1) and ARM 17.50.506)

a. The liner system shall include two or more liners with a leachate collection removal system above and between them.

b. The upper component of the bottom liner system shall consist of a flexible membrane with a minimum thickness of 35 mil, and will be designed and constructed to prevent migration of hazardous constituents into the bottom liner system.

c. The lower component of the bottom liner system shall consist of a composite liner which shall include a minimum of three (3) feet of compacted soil with a maximum hydraulic conductivity of 1×10^{-7} cm/sec overlain by a flexible membrane liner with a minimum thickness of 35 mil, designed and constructed to minimize the migration of hazardous constituents if a breach in the upper component were to occur.

d. The liner system shall be designed and constructed to comply with 40 CFR §§ 264.301 (a)(1)(i), (ii), and (iii) to ensure that it is engineered to withstand the chemical and physical stresses it will be subjected to while containing the source area soils and demolition debris. The liner system shall be located, designed, constructed, and operated to be completely above the seasonal high water table.

2.2 COVER SYSTEM

(40 CFR §§ 264.111, 264.310 AND 264.19)

The cover system shall:

a. Minimize the need for further maintenance;

b. Control, minimize or eliminate, to the extent necessary to protect human health and the environment, escape of source area soils and demolition debris, hazardous

constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere;

c. Provide long-term minimization of migration of liquids through the closed CAMU;
d. Function with minimum maintenance;
e. Promote drainage and minimize erosion or abrasion of the cover;
f. Accommodate settling and subsidence so that the cover's integrity is maintained; and
g. Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

2.3 LEACHATE COLLECTION AND REMOVAL SYSTEM

(40 CFR §§ 265.301 (c)(2) AND (c)(3))

a. The leachate collection and removal system immediately above the top liner must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill. It shall be designed and operated to ensure that leachate depth over the liner is minimized to the extent practicable, and does not exceed one (1) foot.
b. This system shall be designed and constructed to comply with 40 CFR §§ 264.301 (c)(3)(iii) and (iv) to ensure that it is engineered to withstand the chemical and physical stresses to which it will be subjected and to minimize clogging.
c. This system shall be constructed with a bottom slope of one percent or more.
d. This system shall be constructed of either a granular drainage material with a hydraulic conductivity of $1x10^{-2}$ cm/sec or more and with a minimum thickness of 12 inches, or of a synthetic geonet material with a transmissivity of $3x10^{-5}m^2$/sec or more.
e. The leachate collection and removal system shall have a sump to collect the leachate from the drainage layer and a removal system of sufficient size to prevent liquids from backing up into the drainage layer.

2.4 LEAK DETECTION, COLLECTION, AND REMOVAL SYSTEM

(40 CFR §§ 264.301 (c)(3) AND (c)(4), 264.302, AND 264.304)

a. The leak detection, collection and removal system between the liners shall be constructed with a bottom slope of one percent or more of granular drainage

materials with a hydraulic conductivity of 1 x 10^{-2} cm/sec and a thickness of 12 inches or more, or with synthetic or geonet drainage materials with a transmissivity of 3 x 10^{-5} m^2/sec or more and it shall be constructed with sumps and liquid removal methods that shall be operated to minimize the head on the bottom liner system in accordance with 40 CFR §§ 264.301 (c)(3)(v) and 264.301 (c)(4). An action leakage rate and response action plan will be established for the CAMU in accordance with 40 CFR §§ 264.302 and 264.304 to address design flow rates in the leak detection system which will result in a head greater than one foot on the bottom liner system.

b. The leak detection, collection and removal system between the liners shall be designed and constructed to comply with 40 CFR §§ 264.301 (c)(3)(iii) and (iv) to ensure that it is engineered to withstand the chemical and physical stresses to which it will be subjected and to minimize clogging.

2.5 SURFACE RUNON CONTROL SYSTEM

(40 CFR §§ 264.301 (g) AND (i))

The run-on control system shall be capable of preventing flow onto the active portion of the landfill during peak discharge from a 24-hour, 25-year storm. Collection and holding facilities that are associated with this system must be emptied, or otherwise managed expeditiously after storms, to maintain design capacity of the system.

2.6 SURFACE RUNOFF CONTROL SYSTEM

(40 CFR §§ 264.301 (h) AND (i))

The run-off management system shall collect and control at least the water volume resulting from a 24-hour, 25-year storm. Collection and holding facilities which are associated with this system must be emptied expeditiously, or otherwise managed after storms to maintain design capacity of the system.

2.7 CONTROL OF PARTICULATE MATTER

(40 CFR § 264.301 (j))

The CAMU shall be operated to control wind dispersal of waste soils, sediments, and demolition debris placed in it, consistent with the requirements of 40 CFR § 264.301(j).

2.8 MONITORING, INSPECTION & CONSTRUCTION QUALITY CONTROL

(40 CFR §§ 264.19 AND 264.303)

A Construction Quality Control (CQA) program shall be established for the CAMU to ensure that the constructed unit meets or exceeds all design criteria and specifications in accordance with 40 CFR §§ 264.19 and 264.303. The landfill systems must be inspected during operation and the leak detection system inspected after closure. Inspection of the landfill during operations will be in accordance with 40 CFR § 264.303.

2.9 CLOSURE CERTIFICATION AND POST CLOSURE CARE OF THE CAMU

(40 CFR §§ 264.310, 264.115 THROUGH .120)

The closure certification, monitoring, inspection, operation, maintenance, and record keeping requirements of 40 CFR §§ 264.310 and 264.115-120 must be adhered to after closure of the CAMU. The post-closure period of the CAMU shall be indefinite.

2.10 OTHER DESIGN CRITERIA

Other design criteria are listed by reference in Section 3.0 CAMU Design.

3.0 CAMU DESIGN

This design analysis addresses the CAMU Phase 2 Cell that will be constructed in 2007 to contain demolition debris and waste soils from current remedial cleanup activities. The location of the CAMU Phase 2 Cell is shown on Figure 3-1.

Most of the elements of CAMU Phase 2 Cell design were addressed in the CAMU Phase 1 Cell Design Report (Hydrometrics, 2000) approved by EPA in July 2000. Additional information addressed in this Design Analysis Report includes:

- Location of the CAMU Phase 2 Cell.
- Borehole and Test pit excavation and soil testing for CAMU Phase 2 Cell compacted clay liner construction (Section 3.2).
- Construction of three additional wells to better define site stratigraphy and groundwater flow conditions (Section 3.3).
- Changes to design of the Leachate Collection and Leak Detection Removal Designs.

3.1 SITE SELECTION

An examination of site soils adjacent to the CAMU Phase 1 Cell was completed in September 2006, and indicates that the area immediately south/southeast of the CAMU Phase 1 Cell is well suited as the site for the CAMU Phase 2 Cell. Further discussion of the CAMU Phase 2 Cell site location is found in the CAMU Phase 2 Cell Geotechnical Investigation (Hydrometrics, 2006). As required by Montana DEQ siting guidance, the proposed site, shown on Figure 3-1, has **no**:

- Wetlands
- Floodplains
- Faults
- Seismic impact zones
- Instability
- Underlying rock fractures or fissures

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ASARCO EAST HELENA
CORRECTIVE ACTION MANAGEMENT
UNIT (CAMU) PHASE 2 CELL

CAMU LOCATION MAP

FIGURE
3-1

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- Insufficient land area
- Insufficient public access
- Groundwater or surface water pollution potential
- Public water supplies
- Hydraulic connections to springs
- Airport that has jet aircraft within 10,000 feet or
- Other airports within 5,000 feet.

In addition, the site is:

- At least 200 feet from adjacent property lines.
- At least 500 feet from public drinking water sources, residences, schools, hospitals, and centers of community activity.
- At least 200 feet from an active fault.
- Without subsidence areas.
- Not in a sole-source aquifer recharge area.
- Without endangered species habitat.
- Not in designated state and federal wilderness, parks and preserves.
- Not zoned for activities other than industrial use or agriculture.
- Without historic or archaeological significance.
- Vertically separated from the underground aquifer and without springs.
- Distant from groundwater discharge to a water supply well or to surface water.
- In simple (homogeneous) hydrogeologic stratigraphy.
- In soils that are nearly impermeable or at least in a location which does not intercept or directly overlie an appreciable thickness of permeable soils.

When combined with proper landfill design and construction, this site will prevent the migration of wastes into the surrounding water and soil.

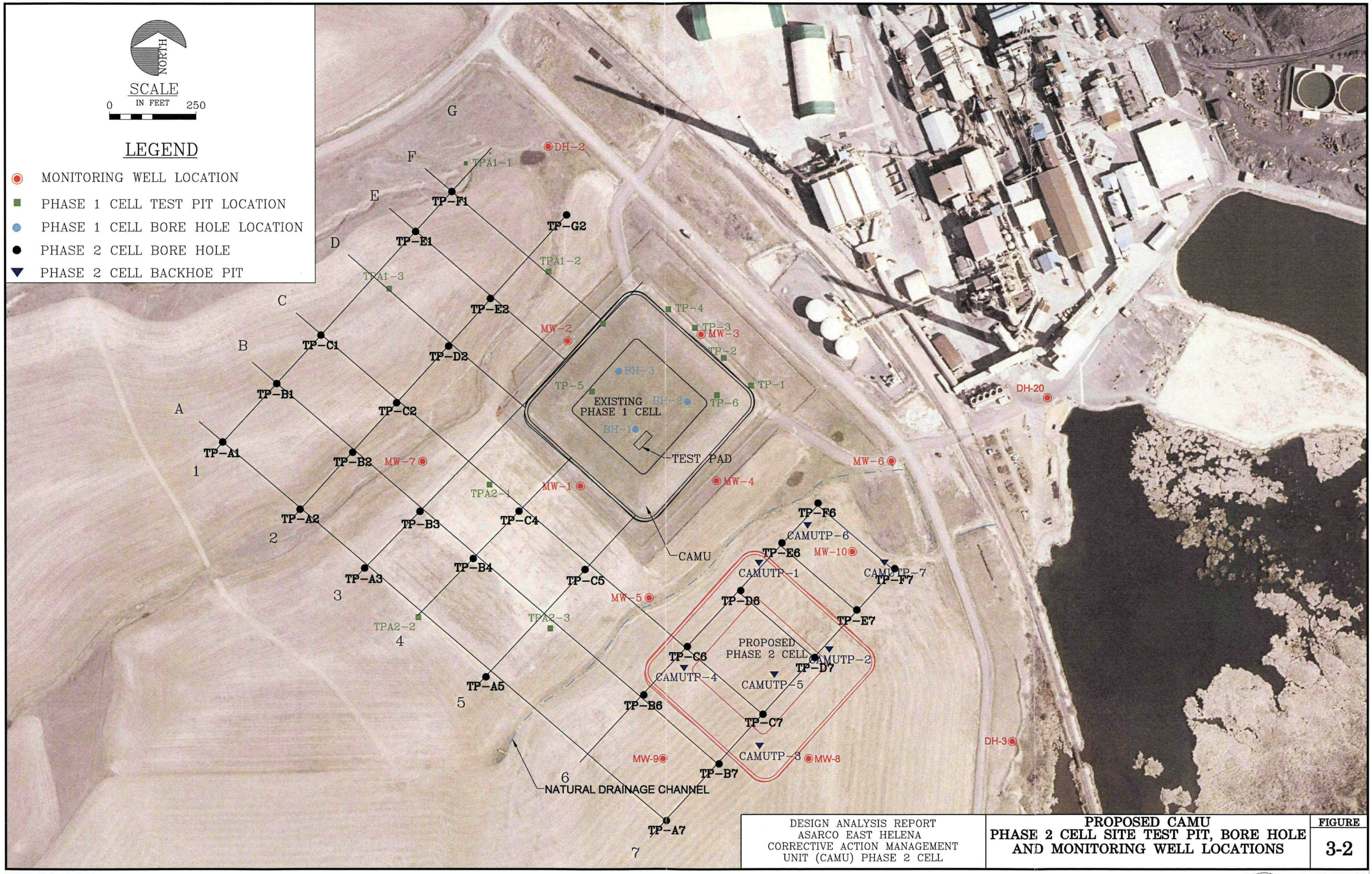
3.2 GEOTECHNICAL INVESTIGATION

Geotechnical evaluations were conducted during August and September 2006 to collect information for site evaluation and design. Twenty-eight (28) boreholes (TP-A1 through TP-G2) and seven (7) test pits (TP-1 through TP-7), shown on Figure 3-2, were drilled or excavated in the area of the CAMU Phase 2 Cell to collect geotechnical information. In addition, three groundwater monitoring wells (MW-8 through MW-10) were installed in the areas surrounding the CAMU Phase 2 Cell to provide additional stratigraphic information and to provide baseline and post construction groundwater quality and hydrology information. Details of the geotechnical investigation, including borehole and test pit logs, are documented in the CAMU Phase 2 Cell Geotechnical Investigation (Hydrometrics, 2006).

3.2.1 Review of Existing Data

Evaluation of the areal geology and hydrogeology has been addressed previously in the Remedial Investigation Report for the adjacent Asarco East Helena Lead Smelter (Hydrometrics, 1990) and the CAMU Phase 1 Cell Design Report (Hydrometrics, 2000). As described in this report, a test pad was constructed and a 6-foot sealed double-ring infiltrometer (SDRI) was installed in May 2000 in order to accurately measure the infiltration rate of a compacted clay liner (CCL) constructed from local borrow soil. The test pad was constructed using the field equipment and procedures that are similar to what will likely be used for CAMU Phase 2 Cell construction. As shown in Figure 3-3, the SDRI test results showed that an effective permeability less than 10^{-7} centimeters-per-second can be achieved using site borrow soils.

When combined with the list of desirable site characteristics, compiled in Section 3.1 of this report, these infiltrometer results confirm that site soils and geology will minimize the migration of any hazardous materials from the landfill and are conducive to construction of a reliable landfill.



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UNIT (CAMU) PHASE 2 CELL

PROPOSED CAMU
PHASE 2 CELL SITE TEST PIT, BORE HOLE AND MONITORING WELL LOCATIONS

FIGURE
3-2

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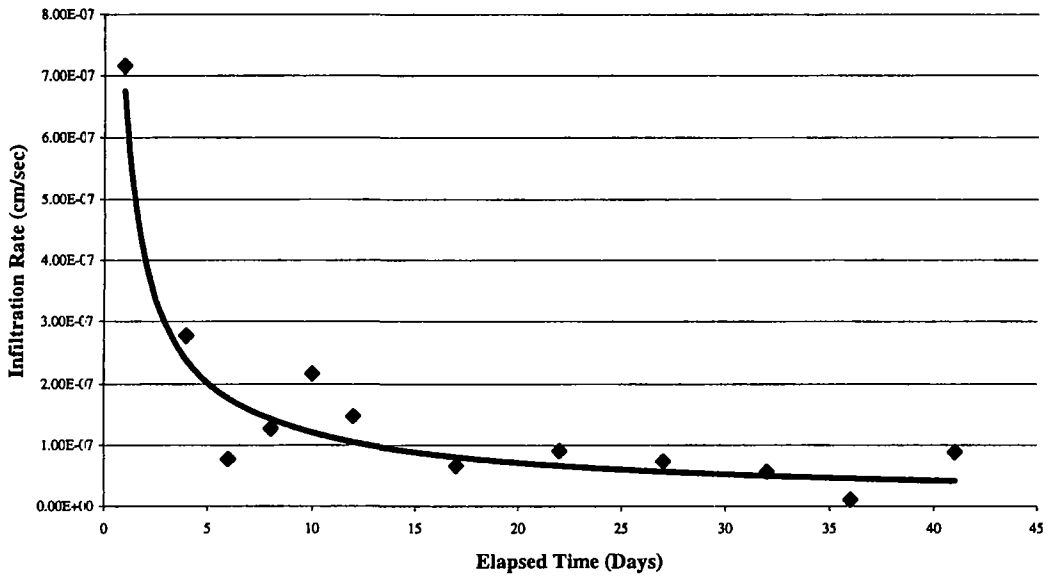
FIGURE 3-3. SEALED DOUBLE RING INFILTROMETER TEST RESULTS FROM MAY 2000



3.2.2 Results of Geotechnical Investigation

Results from the 2006 geotechnical investigation were documented in the CAMU Phase 2 Cell Geotechnical Investigation (Hydrometrics, 2006) and are summarized in the sections that follow. As explained in this report, the soil conditions encountered during this investigation resulted in a shift of the proposed CAMU Phase 2 Cell location to the area adjacent to and east of the existing CAMU Phase 1 Cell.

3.2.2.1 <u>Depth of Sandy Loam Soil Layer</u>

At the proposed site of the CAMU Phase 2 Cell, the depth of the clayey loam varied from 15 to 20 feet. At that depth, the loam soil transitions over a 2 to 5 foot interval to a poorly graded gravel, cobble, and boulder soil layer. Depths of loam are very similar to those encountered during the site investigation for the CAMU Phase 1 Cell.

The intent of siting the CAMU Phase 2 Cell in this particular soil unit is to use the loam soil as an impermeable foundation and as a construction material for the cell's compacted clay liner. The depth and quality of the clayey loam soil layer impacts the feasibility of

constructing the clay liner from site soil and controls the allowable depth of excavation for the CAMU cell.

3.2.2.2 Maximum Proctor Density

The insitu density of the site loams ranges from 85 to 96 pounds-per-cubic-foot (pcf). Maximum compacted densities were measured to be approximately 100 to 112 pcf. Therefore, compaction of site soil can be expected to increase the average insitu density of the soil by almost 20 percent. These densities are similar to those measured during the CAMU Phase 1 Cell investigation and suggest that compaction of the site soils will result in a significant increase in density and a corresponding decrease in permeability.

3.2.2.3 Soil Classification

Soil gradation and plasticity were measured from bulk test pit samples and were used to classify site soils and to determine their suitability for construction of the compacted clay liner. All samples from the CAMU Phase 2 Cell site were classified as fine-grained soils, and except for one test pit that classified as low plasticity silt (ML), samples from test pits were classified as low plasticity clay (CL). As discussed in the CAMU Phase 2 Cell Geotechnical Investigation (Hydrometrics, 2006), site soils were generally found to be finer and more plastic than those tested in the CAMU Phase 1 Cell investigation and are suitable for use in construction of the compacted clay liner.

The soil classification is used to verify the appropriateness of many of the soil properties used for design. A CL-ML soil is expected to have a unit weight in the range of 90 pcf when loose to 120 pcf when compacted. It is expected to have an angle of internal friction (ϕ) of 20° to 30° depending on the amount of sand and the density of the material. Saturated cohesion for this material is likely to range from 190 to 460 psf depending upon how much of the fine material is silt and how much is clay. This information is valuable for slope stability and settlement calculations, as well as many other design decisions.

3.2.2.4 Hydraulic Conductivity

To determine the effect of surcharge on permeability, falling head parameter tests were conducted on three test pit samples. Appendix A contains the laboratory results that are summarized in Table 3-1. With a 22 pounds-per-square-inch (psi) surcharge, hydraulic conductivity for the site clayey soils ranged from 3 to 9.7 x 10^7cm/sec. These results are consistent with those obtained for the CAMU Phase 1 Cell and indicate that hydraulic conductivity is reduced by one to two orders of magnitude under a surcharge pressure, and that an infiltration rate equal to or less than that obtained in the sealed double ring infiltrometer testing conducted for CAMU Phase 1 Cell should be obtained from the compacted clay liner constructed for the CAMU Phase 2 Cell.

TABLE 3-1. GEOTECHNICAL TEST PIT SAMPLE SUMMARY

CAMU Phase 2 Cell Sample No.	Soil Classification	% Fines	PI	Compaction Test Data (ASTM D 698)	Hydraulic[1] Conductivity (cm/sec)	Hydraulic[2] Conductivity (cm/sec)
TP-2	CL	57.9	8	Max. DD = 108 pcf OM = 17%	k= 1.8 x 10^{-6}	k= 9.3 x 10^{-7}
TP-3	CL	70.9	18	Max. DD = 100.5 pcf OM = 19.2%	k= 1.2 x 10^{-5}	k= 3.0 x 10^{-7}
TP-7	CL	61.9	8	Max. DD = 105 pcf OM = 18.5%	k= 2.0 x 10^{-6}	k= 9.7 x 10^{-7}

[1]Hydraulic conductivity measured after initial saturation with no effective stress (Hydrometrics, 2006).

[2]Hydraulic conductivity measured after increase of effective stress to 22 psi and resulting consolidation (2006).

3.3 SURFACE AND GROUNDWATER INVESTIGATIONS

The list of desirable site criteria compiled in Section 3.1 suggests that site surface water and groundwater should be isolated to the extent possible from the landfill. Monitoring wells 8, 9, and 10 indicate the water table is present between 29 and 57 feet bgs and will be separated from the bottom of the CAMU Phase 2 Cell by 20 feet of low permeability sandy loam soil as described in section 3.2.

3.3.1 Surface Water

Prickly Pear Creek flows along the east edge of Asarco's property boundary, but is over 2,000 feet from the landfill site. The floodplain boundary for Prickly Pear Creek coincides with the edge of Upper Lake, which is over 500 feet from the site. As shown in Figure 3-1, a small drainage gully to the northwest of the site collects runoff and empties into a storm water ditch that bounds the northeast side of the site. This ditch directs storm water to Upper Lake.

The CAMU Phase 2 Cell site lies within a drainage area of 23.7 acres with an average slope of about 4 percent and a longest flow path of 1437 feet. A 25-year, 24-hour precipitation event at the site is expected to produce 2.3 inches of rain and a peak flow of 4 cubic-feet-per-second (cfs) that needs to be diverted around the site.

The cap of the CAMU Phase 2 Cell occupies approximately 5.1 acres with an average slope of about 13 percent and a longest flow path of 425 feet. A 25-year, 24-hour precipitation of 2.3 inches is expected to produce a peak runoff flow of 4 cfs and a total runoff volume of 1.08 acre-feet that will need to be controlled by Best Management Practices (BMP) until the cap cover vegetation is established. Peak flows and runoff volumes were calculated using software (EFH 2) from the Natural Resource Conservation Service's Engineering Field Handbook. Appendix A contains documentation of the site surface water investigation and calculations of flows.

3.3.2 Groundwater

The groundwater regime and hydrogeology of the CAMU area have been interpreted from stratigraphic and water level data from groundwater monitoring wells and from hydrogeologic data collected during the plant site remedial investigation and subsequent long-term monitoring. In addition to the seven groundwater monitoring wells that were constructed adjacent to the CAMU Phase 1 Cell site, three additional groundwater monitoring wells were constructed outside the footprint of the CAMU Phase 2 Cell and centered approximately on the southeast (MW-8), southwest (MW-9), and northeast (MW-10) sides. Well depths were 70 feet. All CAMU monitoring wells were located horizontally

and vertically for subsequent interpretation of the groundwater potentiometric surface and groundwater flow direction. Table 3-2 shows well completion data for the CAMU Phase 2 Cell monitoring wells. Figure 3-2 shows the location of these wells with respect to the proposed CAMU Phase 2 Cell perimeter. Appendix B provides lithologic and construction logs for the wells.

In general, the stratigraphy encountered at the monitoring wells sites in the vicinity of the CAMU consists of silty clay (CL) interbedded with clayey silt (ML) from ground surface to 25 feet below ground surface (bgs). A 10 to 20 foot thick horizon of sandy gravel is present between 25 and 35 feet bgs. An ash/tuff unit underlies the sandy gravel unit in all CAMU monitoring wells. The ash/tuff unit in the CAMU monitoring wells was encountered to depths up to 72 feet bgs. None of the monitoring wells penetrate through the ash/tuff unit. Exhibit 1 in Appendix B contains geologic cross sections of the site created from the monitoring well logs.

Groundwater levels were measured in December 2006 to construct a groundwater potentiometric map for the CAMU area. A monitoring well network, consisting of over 40 monitoring wells at the Asarco plant site, was also evaluated to help define the groundwater potentiometric surface near the CAMU area.

Water levels ranged from approximately 36 feet bgs at well MW-10 to 55 feet bgs at MW-9. Previous investigations at the plant site (Hydrometrics, 1990) and in the Helena Valley (USGS, 1992) show that regional groundwater movement in the East Helena area is northward. Figure B-1 in Appendix B is a potentiometric map showing groundwater flow directions within the CAMU area.

3.4 SOIL MATERIALS

Earth fill, in sufficient quantities required for this project, exists within the East Helena area. Earth fill includes random fill, engineered fill, drainage gravel, and cover soil. All earth fill will be obtained from the project site except for drainage gravel, which is readily available from local sand and gravel suppliers. Test results for gradation and permeability of material

TABLE 3-2. SUMMARY OF CAMU MONITORING WELL CONSTRUCTION

Well Number	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8	MW-9	MW-10
Screened Interval Lithology	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff	ash/tuff
Ground Surface Elevation (ft)[1]	3947.78	3940.57	3935.84	3941.08	3949.62	3931.92	3957.69	3952.37	3958.92	3940.26
Measuring Point Elevation (ft)[1]	3949.43	3942.36	3937.38	3943.52	3952.52	3934.54	3959.99	3954.97	3961.72	3942.59
Total Depth Drilled (ft bgs)[2]	68	66	50	72	71	40	60	70	70	70
Screened Interval (ft bgs)[2]	58-68	56-66	38.5-48	54-64	55-65	30-40	44-57	45-65	50-70	42-62
Date Installed	06/26/1997	06/27/1997	06/30/1997	05/08/2000	05/11/2000	05/13/2000	05/16/2000	09/26/2006	09/26/2006	09/27/2006

[1] Mean Sea Level
[2] bgs - Below Ground Surface

from the local sources will be required as part of construction specification performance standards.

The compacted clay liners are key components of the CAMU liner and cover systems and require careful material control. Material for construction of the liners is available from excavated materials on-site. As explained in Section 3.2, results from the geotechnical investigation indicate that site soil is suitable for use in construction of the compacted clay liner for the CAMU Phase 2 Cell. During site preparation and excavation, the sandier (low clay content) site soil will be segregated from the more clayey soil, which will be tested to confirm suitable gradation and plasticity before being used for construction of the CCL.

Testing will be conducted during construction to verify that soils excavated for use in construction of the compacted clay liner are suitable. EPA guidance (EPA, 1989) explains that to produce a protective CCL, the soil used for construction of the soil liner should have certain characteristics. First, it should have at least 20 percent fines. Second, it should have a plasticity index greater than 10. Third, it should be composed of no more than 10 percent gravel-size particles, and fourth, it should contain no soil particles larger than 1 or 2 inches in diameter. As discussed in the CAMU Phase 2 Cell Geotechnical Investigation (Hydrometrics, 2006), it should be possible to meet these standards with site soil if used selectively. First, site soil has between 58 and 71 percent fines. The average fraction of fines for the four samples tested is 65 percent, which is well above the standard of 20 percent. Second, the Plasticity Index (PI) for site soil ranges between 8 and 18 percent, with an average of 12 percent, which is greater than the standard of 10 percent contained in EPA guidance. Third, site soils range from less than 1 to 8 percent gravel. The average gravel fraction is much less than the standard of 10 percent required to be indicative of soil suitable for construction of a compacted clay liner. Finally, material specifications for the compacted clay liner have been written to prevent soil particles greater than 1 or 2 inches from being used to construct the liner, as suggested by EPA design guidance.

3.5 WASTE MATERIAL

Waste material that is to be placed in the CAMU will consist of demolition debris and waste soils from within the plant area and generated from RCRA corrective action projects. The major demolition debris waste material source areas and quantities are listed in Table 3-3. Some demolition debris may contain asbestos that will be managed in accordance with all applicable National Emission Standards for Hazardous Air Pollutants (NESHAP), OSHA, MSHA, and DOT regulations. In order to ensure that the CAMU Phase 2 Cell design is compatible with the waste material that is to be placed in it, the chemical compatibility and gas generating potential of demolition debris was investigated and examined.

HDPE geomembranes have adequate chemical resistance to endure and retain their integrity well beyond other factors that will cause a liner to fail. Although not anticipated, if the leachates contain unusually high concentrations of oxidizing acids, chlorinated solvents, or detergents that remain constantly on the liner for considerable times, environmental stress cracking may occur. Waste materials at the East Helena Plant that could subject the cell liners to an extreme pH will be identified to the demolition contractor, who will be required to either neutralize these materials or to blend them with neutral material and place them in the upper portion of the cell.

The primary source of gas generation within most landfills is typically the decomposition of organic materials (primarily household waste such as paper and lawn waste) and the subsequent release of methane gas. Average municipal (sanitary) landfill refuse contains 55 percent woody materials (paper, grass, leaves, etc.) by weight and 28 percent organic carbon (EPA, 1979). In comparison, the smelter waste materials consist largely of smelter demolition debris and granular fill materials that contain only small quantities of organic materials. However, there is a small quantity of wood, such as treated timbers and railroad ties, that will be placed in the cell. Consequently, gas from these materials is expected to be generated and a gas extraction system was included in the design.

TABLE 3-3. MAJOR DEMOLITION DEBRIS WASTE MATERIAL QUANTITIES

		Cubic Yds
2006		
On Site Stored Demolition Material		14,000
	2006 Total	**14,000**
2007		
Blast baghouse area (exc. Stack)		4,120
Acid plant contact section (exc Stack)		2,100
Monier Flue		1,650
Blast furnace flue		6,250
Stacks (Oak Park Chimney)		6,890
Garage, Gas meter house & North end of Highline trestle		100
Dross plant baghouse		130
Sample mill & old crushing mill		2,100
Ore yard & Thawhouse		980
Spray dryer building		250
Main Office		545
New & old breaking floors, Sinter stocking building & Charge floor		1,370
Carpenter shop and Pump house & Blast heat exchanger		130
Blast furnace building		140
Blast office, lunchroom & loco crane shed		160
Direct Smelt building		400
Machine shop & Blacksmith shop		180
Cement & Dust silos		50
Power house		100
South end of High line trestle		25
Paint shop & Motor storage shed		250
High lead shop, Refractory, and Meeting room		423
Powerhouse		100
	2007 Total	**28,443**

TABLE 3-3. MAJOR DEMOLITION DEBRIS WASTE MATERIAL QUANTITIES (continued)

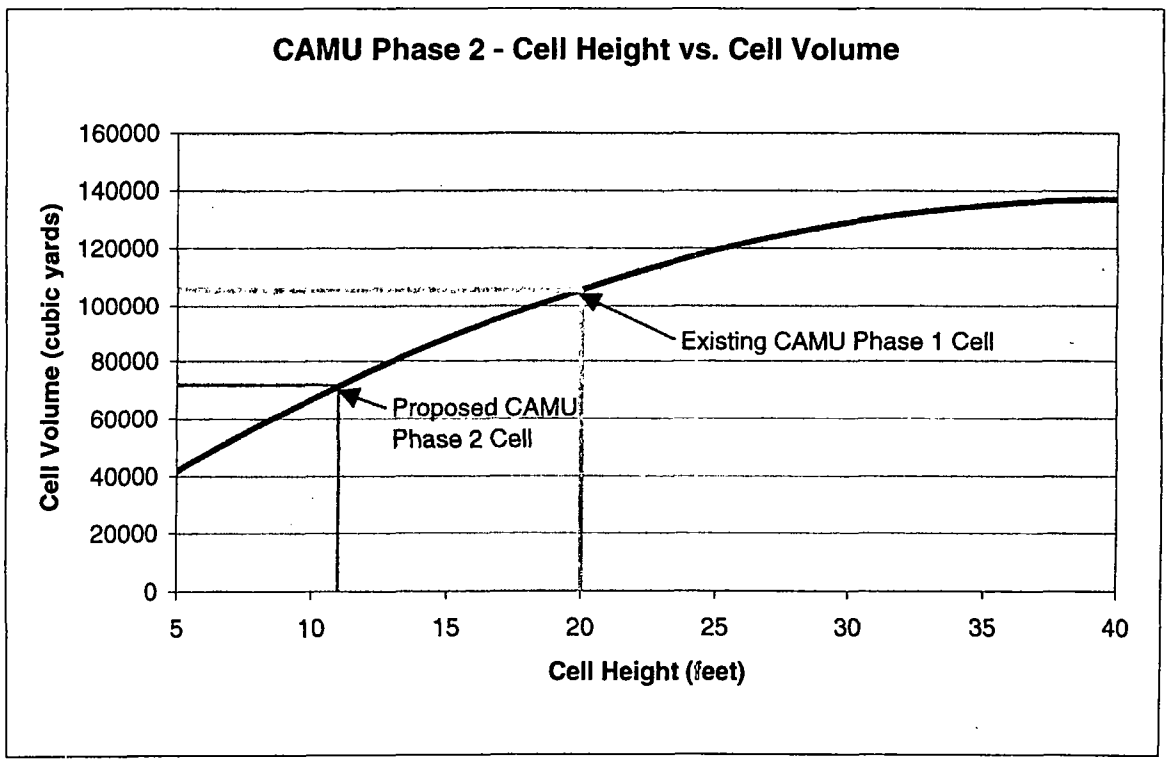
	Cubic Yds
2008	
Shop lunchroom, Zinc Plant pumphouse & Truck scale	75
Storage Trailer, Contractor change & lunchroom	545
Records Storage, Warehouse annex, & belly yard rail	540
Slag handling pad, Warehouse oil & Oxygene/acetyl storage	635
Ore Storage Building (grade level)	12,000
Warehouse, Environmental office	500
Acid tanks, Coverall Bldgs, Truck scale & High grade	500
Rail road ties & timbers (slag dump & belly yard)	1,000
Slag dump cleanup	2,000
Excavation for Plant Cap	2,000
Remediation of property for Chemet	5,000
Lake Shore Shed	10
Sanitary Treatment	10
Zinc Plant Loco Shop	10
2008 Total	**24,825**
2009	
Bathhouse, Medical office, & Thornock tank	1,000
HDS water treatment, Car wash. Neutralization building & acid sump	1,000
Northwestern Energy substation	50
Rodeo tank & storm water sumps	50
2009 Total	**2,100**
TOTAL	**69,368**

3.4 SIZE AND CONFIGURATION

Preliminary estimates for the construction indicate that approximately 70,000 cubic yards of demolition debris and waste material will be removed from the plant site and disposed in the CAMU Phase 2 Cell. The sources and estimated quantities of waste material for the CAMU Phase 2 Cell are shown in Table 3-3.

The preliminary configuration of the CAMU Phase 2 Cell area includes 3:1 side slopes on the inside of the cell and 5:1 side slopes on the cap. A stability analysis of these slopes is contained in Appendix C. This configuration provides a potential storage volume in the cell of approximately 70,000 cubic yards, which is adequate capacity required to dispose of the wastes listed in Table 3-3, however, additional capacity can be obtained by raising the height of the cell while maintaining the identical footprint. Figure 3-4 shows the effect on cell volume of varying the cell height.

FIGURE 3-4. CAMU PHASE 2 CELL HEIGHT VS. VOLUME



The footprint for the CAMU Phase 2 Cell covers approximately five acres. Table 3-4 lists the configuration parameters. The site plan is shown on Figure 3-1.

The cross sections for the cell are shown on Figure 3-5. The proposed bottom of the cell excavation is approximately 8 feet below ground surface and the CAMU cap is approximately 10 feet above the ground surface.

3.5 COMPONENT DESIGN

The CAMU cell is designed and constructed to meet the Performance Standards stated in 40 CFR 264 subpart N - Landfills. General specifications are described below. In accordance with EPA and Montana DEQ guidance, the landfill has been designed and constructed with multiple barriers encapsulating the waste.

3.5.1 Liner Systems

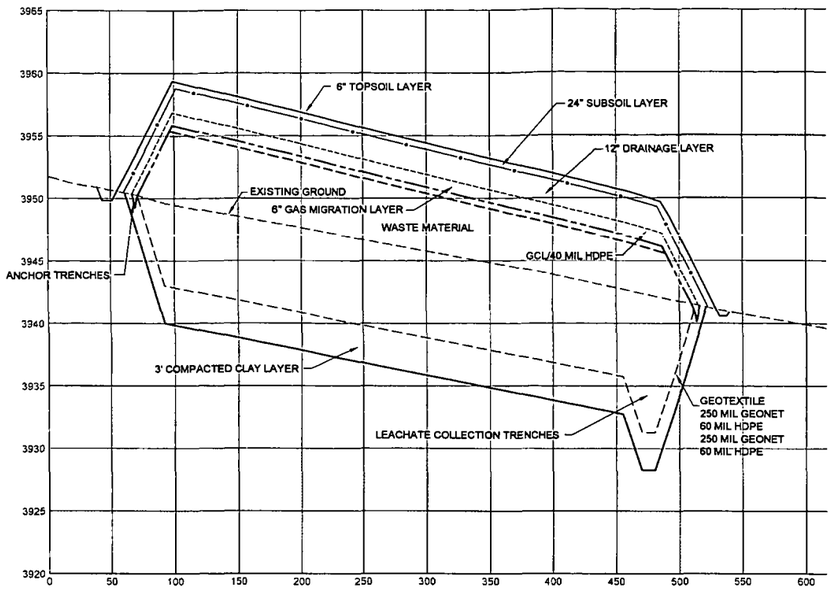
The typical landfill section, including the primary, secondary and cap liner systems; is shown on Figure 3-6. The primary liner underlies the waste material, but is separated from the waste by a geonet. The secondary liner system underlies the primary liner and is separated from it by another geonet layer. Unlike the primary liner, the secondary liner system is a composite consisting of a 3-foot thick layer of compacted clayey soil overlain by a flexible membrane. The cap liner system overlies the waste material and contains a composite liner consisting of a geosynthetic clay overlain by a flexible membrane. The cell liner systems utilize a 60-mil HDPE geomembrane for their flexible membrane component, while the cap liner uses a 40-mil HDPE geomembrane.

3.5.1.1 <u>Primary Flexible Membrane Liner (FML)</u>

The primary FML consists of a high density polyethylene (HDPE) geomembrane that is designed to contain any leachate that is produced from the waste material and to withstand the stresses applied to it from the weight of the waste material and cap, from construction of the cell, and from the settlement of underlying soils.

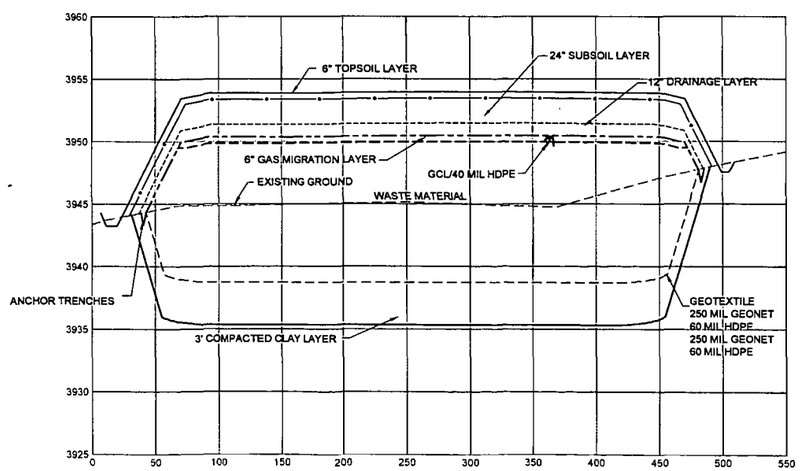
TABLE 3-4. CAMU PHYSICAL CONFIGURATION PARAMETERS

COMPONENT	QUANTITY
Landfill Footprint Width	455 Feet
Landfill Footprint Length	455 Feet
Area of Landfill Footprint	202,500 Square-Feet
Net Landfill Waste Capacity	70,000 Cubic-Yards
CELL COMPONENT	
Depth of Landfill Excavation	8 Feet
Slope of Landfill Bottom Sides	3:1
Area of Landfill Excavation Bottom	160,801 Square-Feet
Area of Landfill Excavation Slopes	48,383 Square-Feet
Total Area of Landfill Excavated Surface	209,184 Square-Feet
Volume of Excavation	61,304 Cubic-Yards
Volume of 3' Clay Liner	23,243 Cubic-Yards
Volume of Geogrids	325 Cubic-Yards
Volume of FML Liners	52 Cubic-Yards
Net Excavated Waste Capacity	37,685 Cubic-Yards
COVER COMPONENT	
Slope of Landfill Cap Sides	5:1
Height of Landfill Fill	11 Feet
Area of Top of Landfill Cap	119,025 Square-Feet
Areas of Landfill Cap Sides	89,743 Square-Feet
Total Area of Landfill Cap	208,768 Square-Feet
Volume of Landfill Cap	66,418 Cubic-Yards
Volume of GCL Liner	39 Cubic-Yards
Volume of FML Liner	39 Cubic-Yards
Volume of 1' Gravel Drain	7,732 Cubic-Yards
Volume of 2.5' Cover Soil	19,330 Cubic-Yards
Net Cap Waste Capacity	39,278 Cubic-Yards



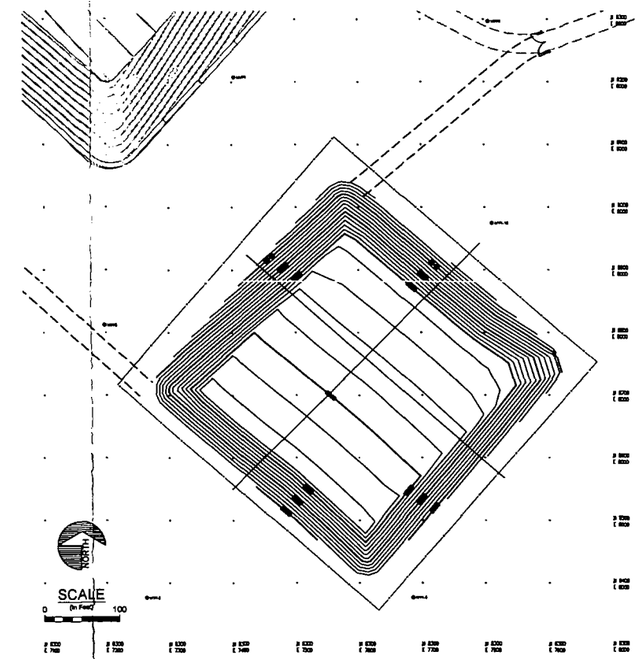
CROSS SECTION 8600(N),7300(E) - 9050(N),7750(E)

SCALE: (H) 1"=60' (V) 1"=6'



CROSS SECTION 9000(N),7500(E) - 8650(N),7900(E)

SCALE: 1"=60' SCALE: (H) 1"=60' (V) 1"=6'



CAMU PLAN VIEW

SCALE: 1"=100'

DESIGN ANALYSIS REPORT ASARCO EAST HELENA CORRECTIVE ACTIONS MANAGEMENT UNIT (CAMU)	TYPICAL CAMU PHASE 2 CELL CROSS-SECTIONS	FIGURE 3-5

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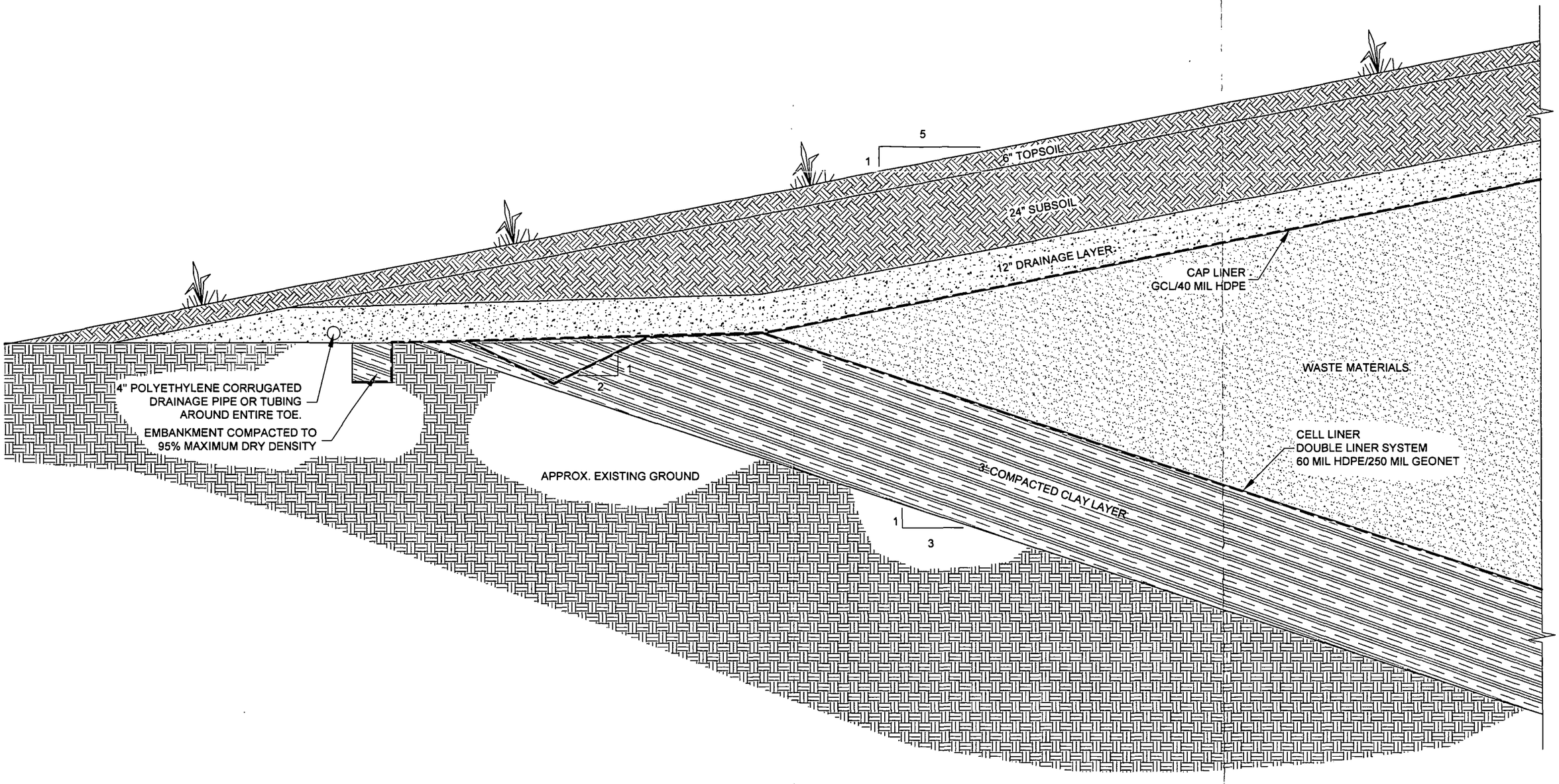
Hydrometrics, Inc.
Consulting Scientists and Engineers



LANDFILL SECTION

NOT TO SCALE

DESIGN ANALYSIS REPORT ASARCO EAST HELENA PHASE 2 CORRECTIVE ACTION MANAGEMENT UNIT (CAMU)	TYPICAL LANDFILL SECTION	FIGURE 3-6

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Hydrometrics, Inc.
Consulting Scientists and Engineers

The stress analysis completed for the design of this liner is included in Appendix C. This analysis includes determination of the stress placed on the membrane by its own weight prior to filling, during filling due to lifts of waste being placed against the cell side slopes, and following filling due to settlement of the cell foundation from the weight of the cell overburden. Other considerations in the design of the liner include the chemical compatibility of the liner and the waste material, the survivability required for the liner, and construction considerations.

As discussed in Section 3.4.2, wastes to be placed in the CAMU Phase 2 Cell are primarily demolition debris and waste soils containing elevated arsenic and metals concentrations. These wastes are compatible with the selected liner materials.

Landfill liners are required to have characteristics that help ensure a high degree of survivability for the liner. However, due to the nature of the construction debris being placed in the CAMU Phase 2 Cell the geomembranes were design to meet very high survivability specifications. The following minimum characteristics for very high survivability geomembranes (Koerner, 1998) were included in the material specifications for the geomembrane:

Thickness	40 mils
Tensile Strength (ASTM D882)	74 lb/in.
Tear Strength (ASTM D1004 Die C)	20 lb.
Puncture Strength (ASTM D4833)	45 lb.
Impact Strength (ASTM D3998 modified)	15 ft-lb.

Finally, construction considerations were taken into account in the liner design. Although a 40-mil HDPE will satisfy the strength and survivability requirements for design, the 60-mil HDPE geomembrane used in the cell design provides an additional factor of safety during the critical period of increased stress that may occur when the CAMU is being filled.

3.5.1.2 Secondary Composite Liner

The secondary composite liner ensures that any leakage through the primary FML is collected by the leak detection, collection, and removal (LDCR) system and prevents migration of groundwater into the landfill. It consists of a 60-mil HDPE FML, identical to the primary FML in design, underlain by a 3 foot thick layer of compacted clay.

As discussed in Section 3.4.1, compaction of native site soil has been shown to produce a compacted clay liner with a permeability of 10^{-7} centimeters-per-second as required by 40 CFR 264 subpart N.

60 mil - phase 1
& compacted clay layer

3.5.1.3 Cap Composite Liner

This component of the landfill cap closes the landfill and prevents infiltration of precipitation. It consists of a 40-mil HDPE FML, underlain by a geosynthetic clay liner (GCL). On cap slopes, the GCL will be reinforced. An HDPE geomembrane was chosen for this FML to ensure that the permeability of the cap liner is no less than the cell liner system, as required by 40 CFR 264 subpart N. In addition to acting as a component of the composite liner, the GCL covering the waste material provides a smooth surface for installation of the cap FML and provides an additional factor of safety in preventing percolation through the cap.

3.5.2 Leachate Systems

The primary leachate collection and removal (PLCR) system and the leak detection, collection and removal (LDCR) system will be constructed of geonet materials with a minimum transmissivity of $3 \times 10^{-5} m^2/sec$. The leachate collected in the leachate system will be removed through individual standpipes placed in each leachate system layer. Unlike in the CAMU Phase 1 Cell, these pipes will consist of individual vertical 24-inch HDPE access pipes, which allow collection, pumping, and withdrawal of leachate without penetrating the cell liners. This revised design should allow the two leachate systems to be emptied more easily.

In the design analysis of the CAMU Phase 2 Cell, Hydrologic Evaluation of Landfill Performance Modeling (HELP 3) was performed to evaluate the leachate generation potential

of the landfill. Output from this model was used to check sizing of leachate system piping and flow capacities of drainage composite materials.

The HELP 3 model indicated that no leachate was expected to be generated following the filling of the cell. Tables 3-5 and 3-6 summarize the results of this modeling. However, if leachate is produced or if storm water enters the cell during construction, it will be collected and transported to the adjacent Asarco Lead Smelter for treatment in the existing High Density Sludge (HDS™) water treatment system in accordance with the existing MPDES Permit or transported to a licensed Treatment, Storage, and Disposal Facility (TSDF) should the HDS™ water treatment system be removed.

HELP 3 was also performed to evaluate leachate generation and runoff during the filling of the cell. Output from this model indicates the designed leachate collection system capacity will be exceeded during a 25-year, 24-hour storm when the fill in the cell is less than 60 inches. Therefore, during construction, the construction contractor will be required to have pumps ready in case of a significant rainfall event.

3.5.2.1 Primary Leachate Collection and Removal (PLCR) System

This landfill component is designed to collect any leachate associated with the waste material. Waste material deposited in the CAMU cell will be underlain by a layer of needle punched geotextile which will act as a filter barrier between the waste and a geonet drain layer. This geonet drain layer will have a minimum transmissivity of 0.145 gallons/ minute/foot ($3x10^{-5}$ m^2/sec) at 4,000 pounds per square foot of confining pressure, as required by the performance standards discussed in Section 2.3. The performance of the PLCR was checked using HELP 3 modeling, and found to prevent more than 12 inches of leachate from collecting above the primary liner, as shown in Table 3-6.

A geonet was selected as a drainage component primarily due to its economy when compared to a gravel layer. Perforated drainpipe embedded in a gravel drain layer has the advantage of common usage and design, but requires a minimum of 1 foot of cell depth. Geonets promote

TABLE 3-5. AVERAGE ANNUAL PRECIPITATION AND LEACHATE VOLUMES FOR 80 YEARS

	Inches	Cubic Feet	Percent
Precipitation	11.36	210226.7	100.00
Runoff	0.097	1,796	0.855
Evapotranspiration	11.237	208033	98.957
Lateral Drainage Collected From SWCR	0.00203	37.6	0.01790
Percolation/Leakage Through Cap Composite Liner	0.00000	0.00000	0.00000
Lateral Drainage Collected From PLCR	0.00000	0.00000	0.00000
Percolation/Leakage Through Primary FML	0.00000	0.00000	0.00000
Lateral Drainage Collected From LDCR	0.00000	0.00000	0.00000
Percolation/Leakage Through Secondary Composite Liner	0.00000	0.00000	0.00000

SWCR - Surface Water Collection and Removal
PLCR - Primary Leachate Collection and Removal
LDCR - Leak Detection Collection and Removal

TABLE 3-6. PEAK DAILY PRECIPITATION AND LEACHATE VOLUMES FOR 80 YEARS

	Inches	Cubic Feet
Precipitation	1.62	29991
Runoff	0.400	7399
Drainage Collected From Layer SWCR	0.013	246
Percolation/Leakage Through Cap Composite Liner	0.00000	0.00000
Drainage Collected From PLCR	0.00000	0.00000
Percolation/Leakage Through Primary FML	0.00000	0.00000
Drainage Collected From LDCR	0.00000	0.00000
Percolation/Leakage Through Secondary Composite Liner	0.000000	0.00000

rapid transmission of liquids while requiring only 1/4 inch of cell depth. While the square-foot cost of geonet is comparable to drain gravel, the reduction in cell depth from use of the geonet in design resulted in major cost savings on the project.

4 inch Standpipe or 24 inch

The geonet drainage layer is laid on a 3 percent slope and drains to a collection trench along one edge of the landfill. The collection trench contains a perforated drain pipe enveloped in drain gravel, collects leachate from the geonet layer and directs it to the 24-inch diameter pipe sump for removal. Leachate removal is accomplished through the vertical standpipe that exits above the cell cap. The 24-inch standpipe is big enough to accommodate even a submersible pump, should one be needed, and provides a useful volume of pump storage capacity.

3.5.2.2 Leak Detection, Collection, and Removal (LDCR) System

This system is designed to detect and collect any leakage through the Primary FML within 24 hours. Another geonet layer was used for the LDCR for the same reasons discussed for the PLCR. In fact, the system is identical to the PLCR in design except the geonet is placed between two geomembranes and, therefore, requires no geotextile filter. As for the PLCR, the geonet layer is sloped approximately 3 percent to a collection trench where leachate is directed to a sump for removal. Maximum travel time to the sump for this design is approximately three hours, which is less than the 24 hours required by performance standards. Appendix C contains this analysis.

3.5.3 Surface Water Collection and Removal (SWCR) System

This system allows surface precipitation to drain away from the surface of the Cap Composite Liner, and consists of a 1-foot thick layer of drain gravel on a 3 percent slope. This layer drains to a corrugated drain pipe embedded in a gravel-filled trench at the toe of the landfill cap slope. The drain pipe outlets to a shallow infiltration and evaporation pond adjacent to the landfill which prevents run-off from mixing with diverted run-on flows.

Repo 8 + 16

3.5.4 Cover System

This component provides frost protection to the cap composite liner and, after seeding, protects the surface of the landfill from erosion. It consists of 6-inches of seeded topsoil overlying 24-inches of subsoil. The project specifications require the organic rich topsoil to be salvaged and stockpiled separate from the underlying subsoil to ensure a proper medium for seeding with grasses. The combination of cover system and SWCR provides a total of 3.5-feet of frost protection to the cap composite liner. The CAMU cover has been designed with a top slope of 3 percent and fairly flat side slopes of 5:1 to resist erosion and minimize maintenance.

3.5.5 Groundwater Monitoring System

Finally, the landfill has been designed and will be constructed with monitoring systems that can detect a failure of the CAMU Phase 2 Cell. As described in section 3.6.2.2, the first line of detection takes place in the LDCR. A secondary line of monitoring, consisting of ten groundwater monitoring wells, has been constructed around the landfill site and will be monitored on a semi-annual basis. A statistical analysis of the data from this monitoring will detect any impacts to the groundwater quality associated with the landfill. A sampling and monitoring plan is currently being developed for monitoring the CAMU and will be added as Appendix D to this document when it is complete.

4.0 PLACEMENT OF WASTE SOILS, SEDIMENTS AND DEMOLITION DEBRIS IN CELL

Materials will be placed and compacted in the cell to minimize voids, settlement, and damage to the liners. Smelter demolition debris and waste soils will be placed and compacted in the cell in lifts not to exceed 2 feet thick across the bottom of the cell.

All materials delivered to the cell for placement will require some segregation. This will allow consolidation of the materials during compaction and will result in a homogeneous mass with a minimal amount of voids. Specifically, bulk concrete and metal debris will be broken or otherwise reduced in size not to exceed 2 feet in diameter. Large organic material (e.g. timbers) and manufactured metal will be placed horizontally in the cell as flat as possible to minimize voids. Special care will be taken near the sides and bottom of the cell to place crushed concrete or brick as a cushion layer to protect the liner systems against puncture. The project specifications require the contractor to use 3/8" minus crushed concrete or brick as a protective layer (12-inches thick) adjacent to the bottom and sides of the cell. This material shall be free of oversized material and sharp objects.

A dust control program will be required to minimize the creation and spread of dust during the excavation, loading, hauling, placement and compaction activities.

5.0 TEMPORARY CLOSURE AND MONITORING

The construction of the CAMU Phase 2 Cell will begin in 2007. Once the cell is excavated and the liner, leak detection, and leachate collection systems are constructed the cell will be filled with waste materials from both 2006 and 2007 demolition work. Placement of waste materials generated from 2006 demolition work will free up containment building storage space that may be used to store waste materials generated from demolition work after temporary closer of the CAMU cell before the end of the 2007 construction season. By the end of the 2007 construction season, a temporary cap consisting of 20 mil Reinforced Polyethylene (RPE 25) will be placed over the waste, using sandbags to hold it in place. Prior to placement of the liner, the surface of the waste will be graded to drain, rolled smooth, and covered with a cushion fabric. The cell has been designed to contain 40,000 cubic yards of material in the excavated portion of the cell. This will allow the contractor to grade the waste material level with the existing ground surrounding the CAMU Phase 2 Cell which will help to promote runoff from the temporary cover. The temporary RPE 25 cap will also be used at the conclusion of subsequent construction seasons. This temporary component of the landfill cap will help to reduce infiltration of precipitation into the waste material until final capping of the CAMU Phase 2 Cell is completed. An Operation and Maintenance Plan (O&M Plan) will be prepared to address temporary closure activities of the CAMU. The plan will be added as an addendum to this document in Appendix E.

6.0 FINAL CLOSURE AND MONITORING

Upon completion of placement of demolition debris and waste soils in the CAMU Phase 2 Cell, the CAMU cap will be constructed. This component of the landfill cap closes the landfill and prevents infiltration of precipitation. An Operation and Maintenance Plan (O&M Plan) will be prepared to address post closure activities of the CAMU.

7.0 STANDARD PLANS AND SPECIFICATIONS

Final design drawings for CAMU construction will be submitted pending EPA review of this Design Analysis Report. Designated Divisions and Sections of the 1996 Standard Specifications for Road, Bridge, and Municipal Construction as adopted by the Montana State Department of Transportation (MDOT, 1996) will be utilized for the construction specifications. Construction specifications will be submitted with design drawings, and a preliminary construction schedule is found in Appendix F.

8.0 REFERENCES

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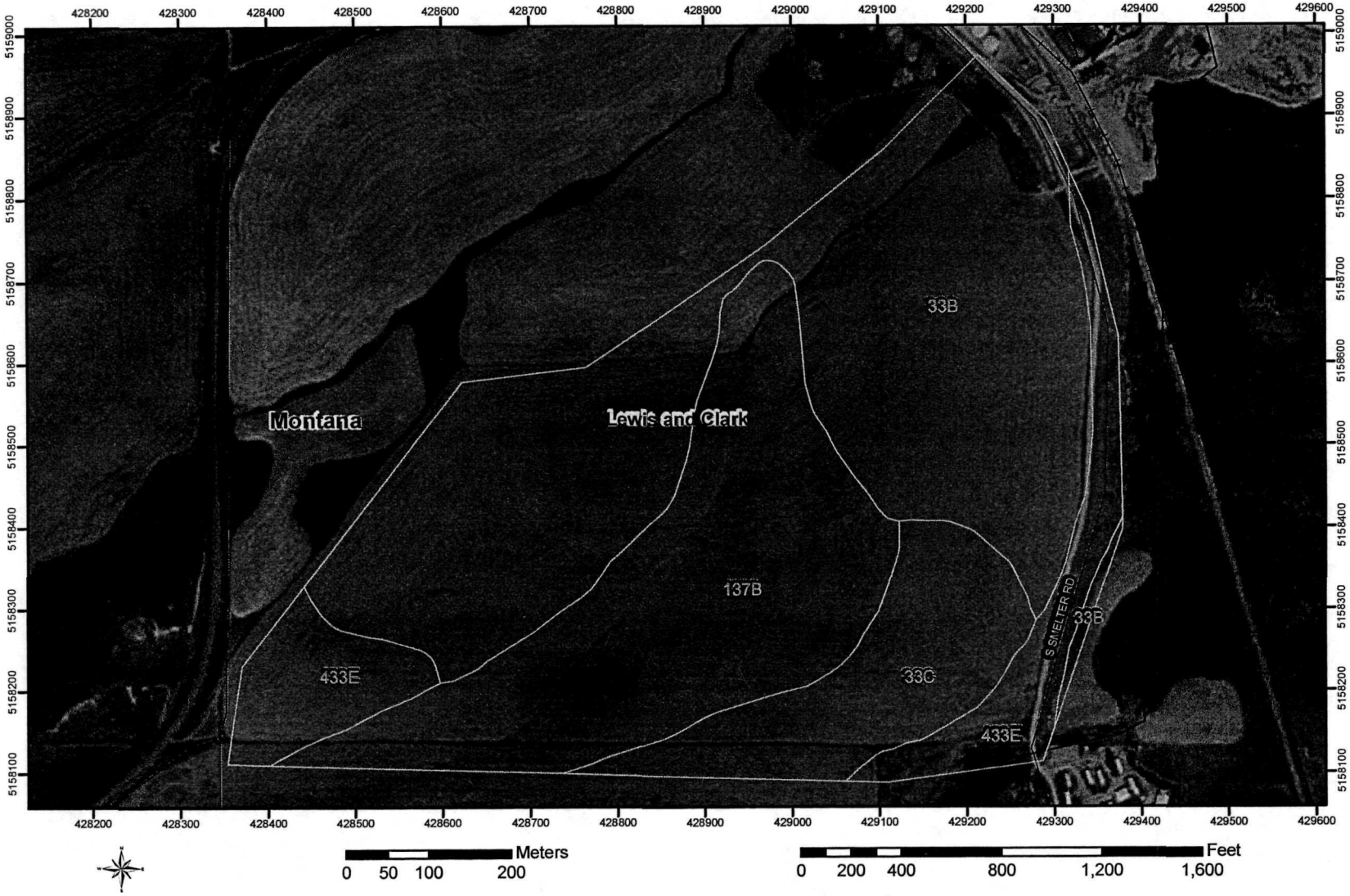
APPENDIX A

SURFACE WATER HYDROLOGY

CAMU Phase 2 Cell Soils Information



Map Unit Legend Summary

Lewis and Clark County Area, Montana

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
33B	Sappington-Amesha loams, 1 to 4 percent slopes	71.8	49.2
33C	Sappington-Amesha loams, 4 to 8 percent slopes	16.8	11.5
137B	Musselshell-Crago complex, 2 to 8 percent slopes	40.4	27.7
433E	Crago-Musselshell gravelly loams, 4 to 35 percent slopes	17.0	11.7

RUSLE2 Related Attributes

Lewis and Clark County Area, Montana

Map symbol and soil name	Pct. of map unit	Hydrologic group	Kf	T factor	Representative value		
					% Sand	% Silt	% Clay
33B:							
Sappington	60	B	.37	2	41.6	37.4	21.0
Amesha	35	B	.37	5	42.1	37.9	20.0
33C:							
Sappington	50	B	.37	2	41.6	37.4	21.0
Amesha	40	B	.37	5	42.1	37.9	20.0
137B:							
Musselshell	70	B	.37	2	39.2	37.3	23.5
Crago	25	B	.37	2	41.6	37.4	21.0
433E:							
Crago	50	B	.37	2	41.6	37.4	21.0
Musselshell	40	B	.37	2	39.2	37.3	23.5

Input Parameters for EFH 2 Software[1]

Upgradient Drainage Area

Drainage Area	23.7	acres
Curve Number	75	Small Grain Straight Row + Crop Residue Cover-Poor Condition, Soil Type B
Slope	0.039	ft/ft
Longest Flow Path	1437	ft
25 yr, 24 hr Precip	2.3	in
25 yr, 6 hr Precip	1.4	in
P_6/P_{24}	0.6087	since 0.518 < 0.6087 < 0.639 use Type I Distribution

CAMU Phase 2 Drainage Area - No Vegetation

Drainage Area	5.15	acres
Curve Number	86	Fallow - Bare, Soil Type B
Slope	0.04	ft/ft
Longest Flow Path	425	ft
25 yr, 24 hr Precip	2.3	in
25 yr, 6 hr Precip	1.4	in
P_6/P_{24}	0.6087	since 0.518 < 0.6087 < 0.639 use Type I Distribution

CAMU Phase 2 Drainage Area - with Vegetation

Drainage Area	5.15	acres
Curve Number	69	Pasture, Grassland-Fair Condtion, Soil Type B
Slope	0.04	ft/ft
Longest Flow Path	425	ft
25 yr, 24 hr Precip	2.3	in
25 yr, 6 hr Precip	1.4	in
P_6/P_{24}	0.6087	since 0.518 < 0.6087 < 0.639 use Type I Distribution

[1]Natural Resource and Conservation Services (NRCS), March 2003 Version 1.1.0

Runoff Factor (continued)

Table 7-9 Cultivated Agricultural Land[1]

Cover Description			Curve Numbers for Hydrologic Soil Group			
Cover Type	Treatment[2]	Hydrologic Condition[3]	A	B	C	D
Fallow	Bare soil	–	77	86	91	94
	Crop residue	Poor	76	85	90	93
	cover (CR)	Good	74	83	88	90
Row	Straight row (SR)	Poor	72	81	88	91
Crops		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured &	Poor	66	74	80	82
	terraced (C & T)	Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small	grain SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded	SR	Poor	66	77	85	89
or broadcast		Good	58	72	81	85
Legumes or	C	Poor	64	75	83	85
Rotation		Good	55	69	78	83
Meadow	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition, and $I_a = 0.2S$.

[2] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Runoff Factor (continued)

[3] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or closed-seeded legumes in rotations, (d) percent of residue cover on the land surface (good >20%), and (e) degree of roughness.

Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Row crops are typically sugar beets and corn, whereas wheat, oats and barley would be classified as small grain.

Table 7-10 Other Agricultural Lands[1]

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow--continuous grass, protected from grazing and generally mowed for hay	—	30	58	71	78
Brush--brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods--grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads--buildings, lanes, driveways, and surrounding lots	—	59	74	82	86

[1] Average runoff condition, and $I_a = 0.2S$

[2] Poor: <50% ground cover or heavily grazed with no mulch
Fair: 50 to 75% ground cover and not heavily grazed
Good: >75% ground cover and lightly or only occasionally grazed

Client: Asarco, LLC
County: Lewis and Clark State: MT
Practice: CAMU Phase 2 Cell 25-yr, 24-hr Storm Runoff-Upgradient of site
Calculated By: M. Rhodes Date: 11/7/2006
Checked By: _____ Date: _____

Drainage Area:	23.7	Acres (user entered value)
Curve Number:	75	(user entered value)
Watershed Length:	1437	Feet
Watershed Slope:	3.9	Percent
Time of Concentration:	0.42	Hours (calculated value)
Rainfall Type:	I	

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	25						
24-Hr rainfall (in)	2.3						
Ia/P Ratio	0.29	0.00	0.00	0.00	0.00	0.00	0.00
Used	0.29	0.00	0.00	0.00	0.00	0.00	0.00
Runoff (in)	0.54						
(ac-ft)	1.07	0.00	0.00	0.00	0.00	0.00	0.00
Unit Peak Discharge (cfs/acre/in)	0.307	0.000	0.000	0.000	0.000	0.000	0.000
Peak Discharge (cfs)	4						

Client: Asarco, LLC
County: Lewis and Clark State: MT
Practice: CAMU Phase 2 Cell 25-yr, 24-hr Storm Runoff-Cap no Vegetation
Calculated By: M. Rhodes Date: 11/7/2006
Checked By: _____ Date: _____

Drainage Area:	5.15	Acres (user entered value)
Curve Number:	86	(user entered value)
Watershed Length:	425	Feet
Watershed Slope:	4	Percent
Time of Concentration:	0.11	Hours (calculated value)
Rainfall Type:	I	

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	25						
24-Hr rainfall (in)	2.3						
Ia/P Ratio	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Used	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Runoff (in)	1.08						
(ac-ft)	0.46	0.00	0.00	0.00	0.00	0.00	0.00
Unit Peak Discharge (cfs/acre/in)	0.730	0.000	0.000	0.000	0.000	0.000	0.000
Peak Discharge (cfs)	4						

Client: Asarco, LLC
County: Lewis and Clark State: MT
Practice: CAMU Phase 2 Cell 25-yr, 24-hr Storm Runoff-Cap with Vegetation
Calculated By: M. Rhodes Date: 11/7/2006
Checked By: _____ Date: _____

Drainage Area:	5.15	Acres (user entered value)
Curve Number:	69	(user entered value)
Watershed Length:	425	Feet
Watershed Slope:	4	Percent
Time of Concentration:	0.18	Hours (calculated value)
Rainfall Type:	I	

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	25						
24-Hr rainfall (in)	2.3						
Ia/P Ratio	0.39	0.00	0.00	0.00	0.00	0.00	0.00
Used	0.39	0.00	0.00	0.00	0.00	0.00	0.00
Runoff (in)	0.33						
(ac-ft)	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Unit Peak Discharge (cfs/acre/in)	0.238	0.000	0.000	0.000	0.000	0.000	0.000
Peak Discharge (cfs)							

APPENDIX B

MONITORING WELL LOGS AND GROUNDWATER DATA

HYDROMETRICS INC.
Consulting Scientists and Engineers
Helena, Montana

Monitoring well

Hole Name: MW-8

Date Hole Started: 9/25/06 Date Hole Finished: 9/26/06

Client: ASARCO, INC.

Project: Interim Measures East Helena Facility

County: Lewis and Clark State: Montana

Property Owner: Asarco Inc.

Legal Description: Sec 36 T10N, R3W

Descriptive Location: South of CAMU; East of CAMU Phase II

Recorded By: John Bergin

Drilling Company: Boland Drilling

Driller: Rick & Chuck

Drilling Method: Air Rotary

Drilling Fluids Used: Air

Purpose of Hole: CAMU Monitoring Well

Target Aquifer:

Hole Diameter (in): 4.5"

Total Depth Drilled (ft): 70

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	
Surface Casing Used?	Y	4" Steel	
Screen/Perforations?	Y	0.020-inch slot, Sch 40 PVC	45-65
Sand Pack?	Y	1020 Silica Sand	43-70
Annular Seal?	Y	Bentonite Chips	0 - 43
Surface Seal?	Y	Cement	0-0.5
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Bailer/pump	
Water Samples Taken?	N		
Boring Samples Taken?	N		

Static Water Level Below MP: 50.91

Date: 11/2/06

MP Description: Top of Casing

MP Height Above or Below Ground (ft):

Surface Casing Height (ft):

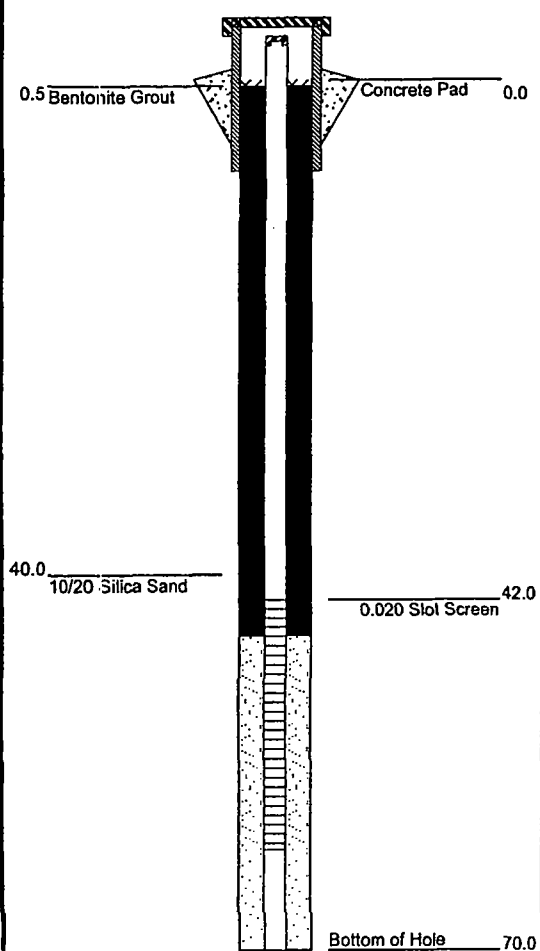
Riser Height (ft):

Ground Surface Elevation (ft):

MP Elevation (ft):

Remarks:

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 1.5' Silty Sand
Top Soil, light brown, dry, loamy silt with sand and gravel (1/2"). Ash (white) layer approximately 0.5' thick at 15' bgs. Veins of ash @ 1.5'

1.5 - 21.0' Silty Clayey Sand
Light brown, moist (@5') clayey silt with sand to coarse sand. Some gravels (1/2")

21.0 - 23.0' Sand
Brown, moist silty sand - coarse sand (5%). Well graded / clean fine sand at approximately 21.5' bgs.

23.0 - 33.0' Silty Gravel
Gravel (1"), light brown moist silty sand (10%) (auger cuttings)
refusal @ 25' but ODEX through

33.0 - 70.0' Silty Sand
Volcanic Ash - Some gravel. Light Yellow, moist silty sand. Increasing sand with depth, moderate cohesion.

STANDARD REV1 K:\GINT\PROJECTS\1054.GPJ HYDHLN2.GDT 12/1/06

HYDROMETRICS INC.
Consulting Scientists and Engineers
Helena, Montana

Monitoring well

Hole Name: MW-9

Date Hole Started: 9/26/06 Date Hole Finished:

Client: ASARCO, INC.
Project: Interim Measures East Helena Facility
County: Lewis and Clark State: Montana
Property Owner: Asarco Inc.
Legal Description: Sec 36 T10N, R3W
Descriptive Location: Southwest of CAMU; South end of CAMU Phase II

Recorded By: John Bergin
Drilling Company: Boland Drilling
Driller: Rick & Chuck
Drilling Method: Air Rotary
Drilling Fluids Used: Air
Purpose of Hole: CAMU Monitoring Well
Target Aquifer:
Hole Diameter (in): 4.5"
Total Depth Drilled (ft): 70

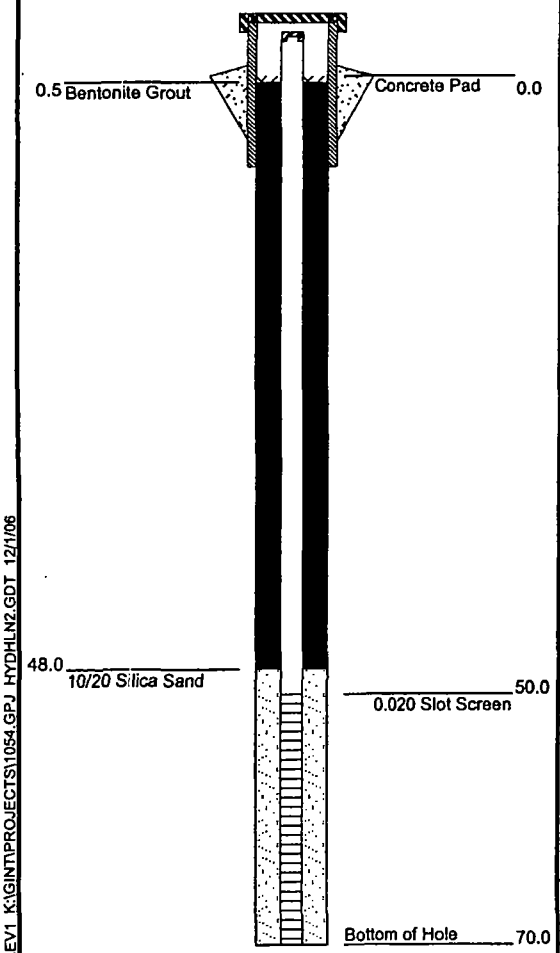
WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	
Surface Casing Used?	Y	4" Steel	
Screen/Perforations?	Y	0.020-inch slot, Sch 40 PVC	50-70
Sand Pack?	Y	1020 Silica Sand	48-70
Annular Seal?	Y	Bentonite Chips	0.5-48
Surface Seal?	Y	Cement	0-0.5
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Bailer/pump	
Water Samples Taken?	N		
Boring Samples Taken?	N		

Static Water Level Below MP: 56.90
Date: 11/2/06
MP Description: Top of Casing
MP Height Above or Below Ground (ft):

Surface Casing Height (ft):
Riser Height (ft):
Ground Surface Elevation (ft):
MP Elevation (ft):

Remarks:

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 5.0' **Topsoil**
Brown with slight plasticity and slightly moist. Silty Sand (SM-SC)

5.0 - 10.0' **Silty Clay**
Light brown, very slightly moist, little plasticity, silty

10.0 - 23.0' **Silty Clay**
Light Brownish Red, Dry, Little plasticity, silty

23.0 - 25.0' **Silty Gravel**
Dark Brown, dry with slight plasticity

25.0 - 30.0' **Silty Gravel**
Gravel with some silt. Little plasticity.

30.0 - 34.0' **Silty Gravel**
Gravel with silt, Dry.

34.0 - 50.0' **Sandy Clay**
Light Yellow, moderate plasticity, slightly moist. Clay with sand; increasing sand and moisture with depth.

50.0 - 65.0' Water Injected. White slurry with occasional rock fragments.

65.0 - 70.0' Some reddish brown slurry in white slurry with occasional rock fragments.

STANDARD REV1 K:\GINT\PROJECTS\11054.GPJ HYDHLN2.GDT 12/1/06

HYDROMETRICS INC.
Consulting Scientists and Engineers
Helena, Montana

Monitoring well

Hole Name: MW-10

Date Hole Started: 9/27/06 Date Hole Finished:

Client: ASARCO, INC.
Project: Interim Measures East Helena Facility
County: Lewis and Clark State: Montana
Property Owner: Asarco Inc.
Legal Description: Sec 36 T10N, R3W
Descriptive Location: Southwest of CAMU; Northeast edge of CAMU Phase II

Recorded By: John Bergin
Drilling Company: Boland Drilling
Driller: Rick & Chuck
Drilling Method: Air Rotary
Drilling Fluids Used: Air
Purpose of Hole: CAMU Monitoring Well
Target Aquifer:
Hole Diameter (in): 4.5"
Total Depth Drilled (ft): 70

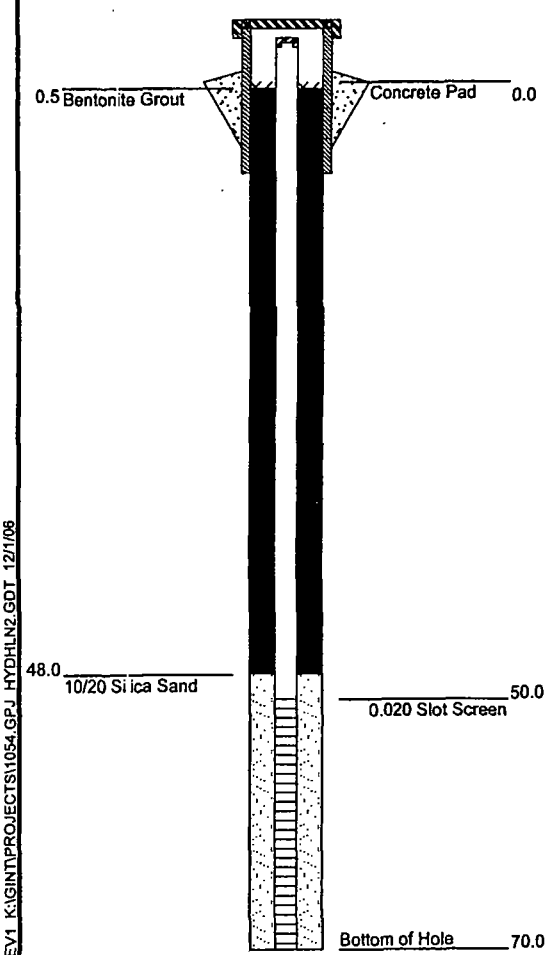
WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	
Surface Casing Used?	Y	4" Steel	
Screen/Perforations?	Y	0.020-inch slot, Sch 40 PVC	42-62
Sand Pack?	Y	1020 Silica Sand	40-62
Annular Seal?	Y	Bentonite Chips	0.5-40
Surface Seal?	Y	Cement	0-0.5
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Bailer/pump	
Water Samples Taken?	N		
Boring Samples Taken?	N		

Static Water Level Below MP: 38.24
Date: 11/3/06
MP Description: Top of Casing
MP Height Above or Below Ground (ft):

Surface Casing Height (ft):
Riser Height (ft):
Ground Surface Elevation (ft):
MP Elevation (ft):

Remarks:

WELL CONSTRUCTION



GRAPHICS

GEOLOGICAL DESCRIPTION

0.0 - 5.0' Topsoil
Topsoil. Light brown silt with some rocks, dry, little plasticity.

5.0 - 10.0' Silt and Gravel
Dark brown, silt and gravel / broken rock. Very slight moisture, very little plasticity.

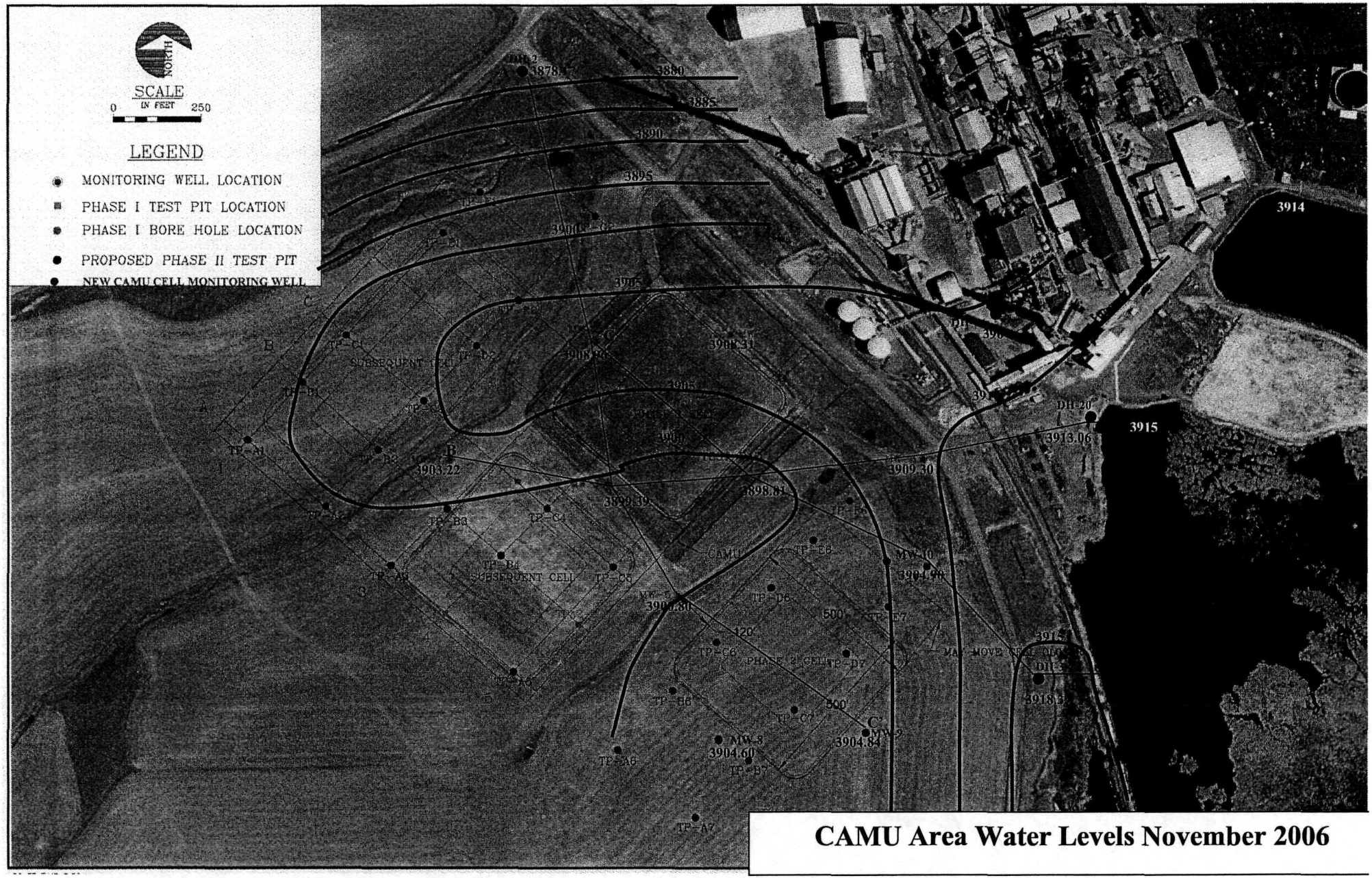
10.0 - 24.0' Rock
Rock with some silt, little plasticity.

24.0 - 30.0' Silt with Gravel
White silt with gravel mixed in. Volcanic Ash.

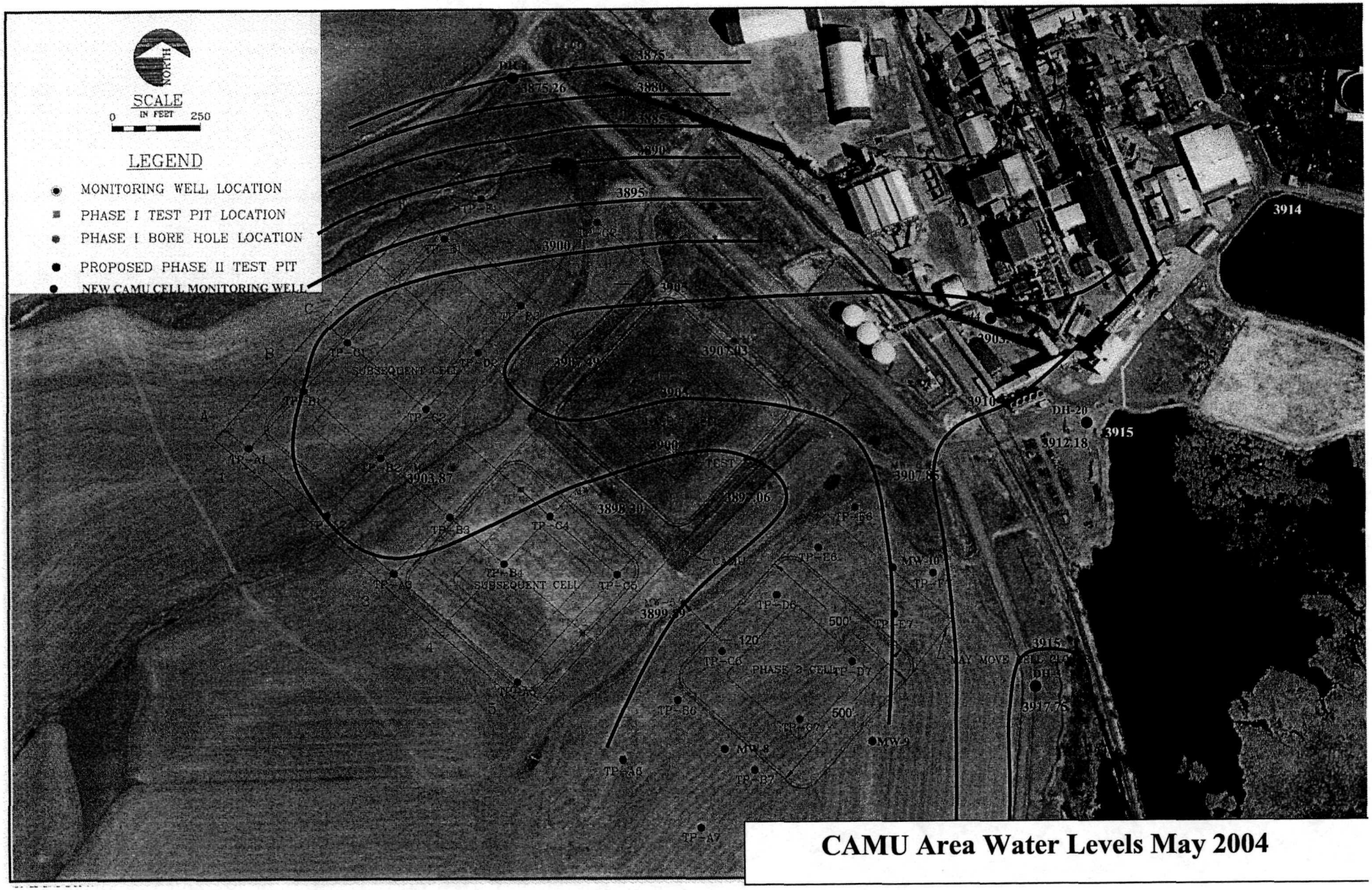
30.0 - 35.0' Silt with gravel
Light brown silt with some rocks, moderate plasticity, slightly moist. Volcanic Ash.

35.0 - 70.0' Silt with gravel
Light Yellow as above. Volcanic Ash.

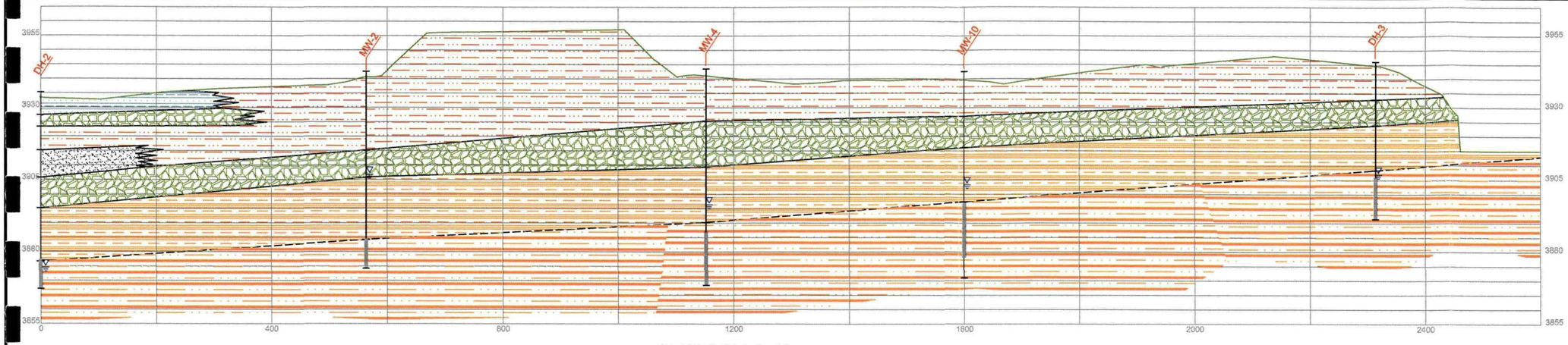
STANDARD REV1 K:\GINT\PROJECTS\1054.GPJ HYDHLN2.GDT 12/1/06



CAMU Area Water Levels November 2006

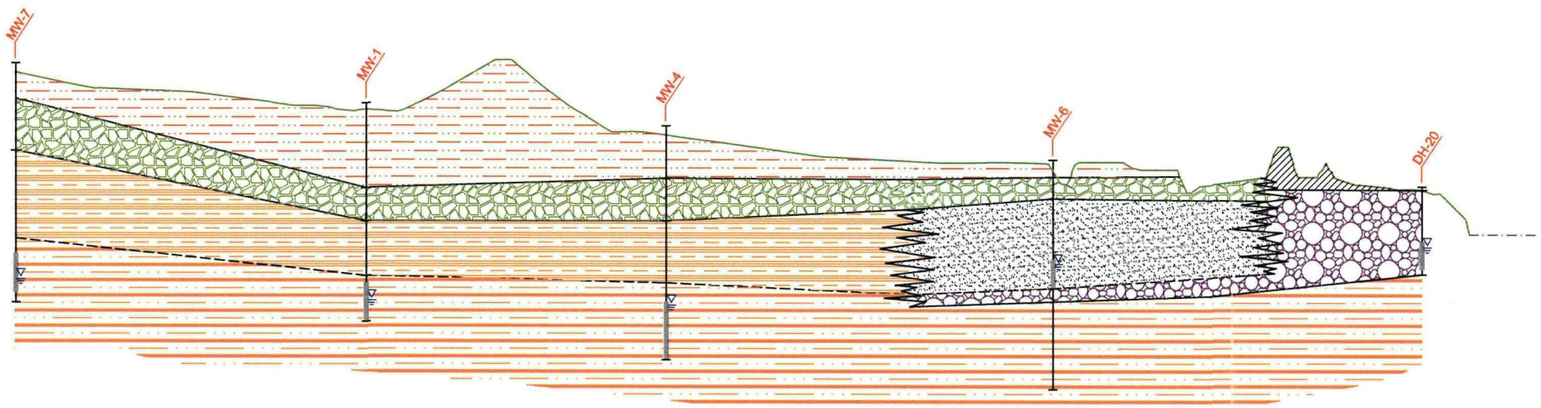


CAMU Area Water Levels May 2004



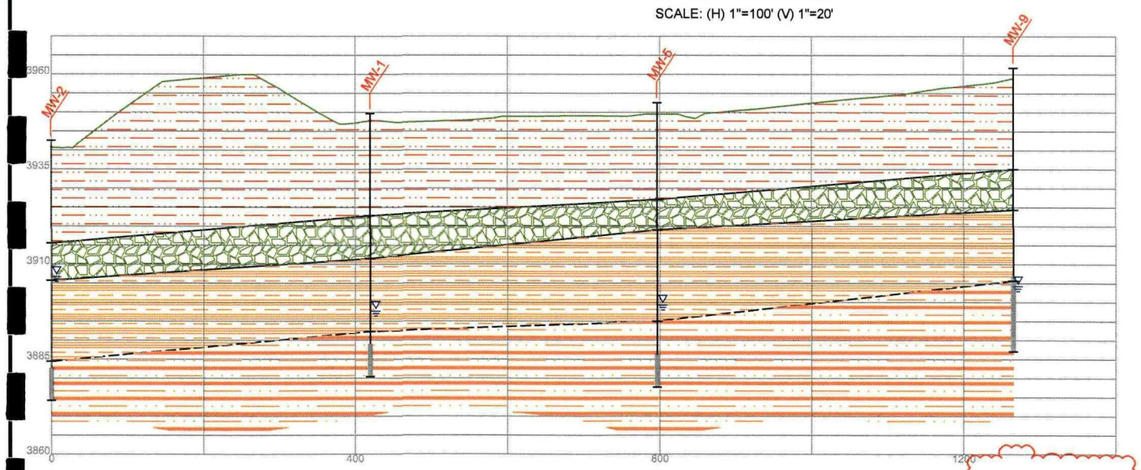
SECTION A-A'

SCALE: (H) 1"=100' (V) 1"=20'



SECTION B-B'

SCALE: (H) 1"=100' (V) 1"=20'



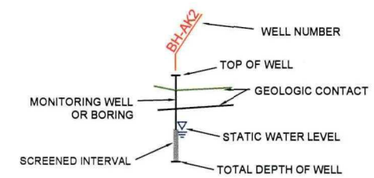
SECTION C-C'

SCALE: (H) 1"=100' (V) 1"=20'

PLEASE NOTE
PRINTED 1/2 SIZE

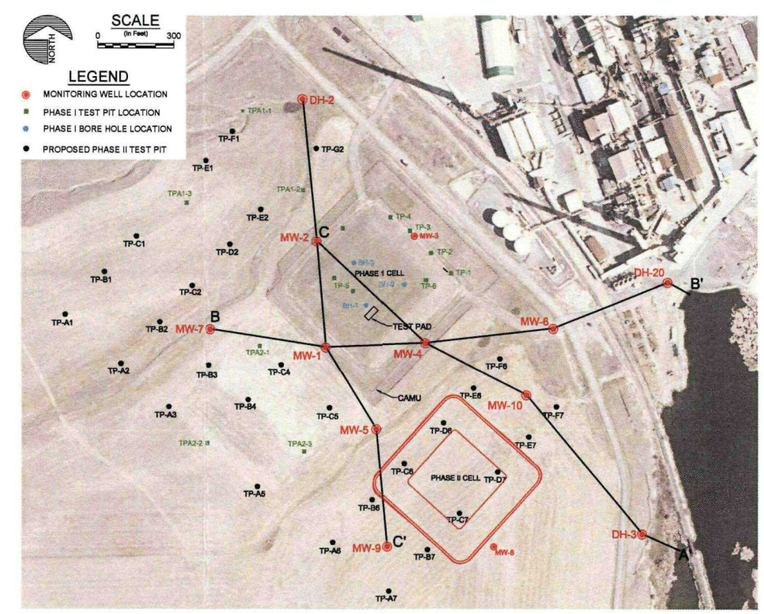
SCALE VERIFICATION BAR IS ONE INCH ON ORIGINAL DRAWING
0 1
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

LEGEND



EXPLANATION

- FILL COMMONLY CONSISTS OF INTERMIXED SAND, SILT, CLAY AND GRAVEL. OFTEN INCLUDES WASTE CONSTITUENTS INCLUDING BRICKS, WOOD, COBBLES, SLAG, OTHER DEBRIS AND CONCRETE.
- FINE-GRAINED DEPOSITS CONSISTING OF INORGANIC SILTS
- ALLUVIAL GRAVEL AND COBBLES; HETEROGENEOUS, SAND, SILT OR CLAY MATRIX, VARIABLE WITH DEPTH AND LOCATION.
- FINE-GRAINED DEPOSITS CONSISTING OF INORGANIC SILTS AND CLAYS
- FINE-GRAINED DEPOSITS CONSISTING OF INORGANIC SILTS AND SAND
- ALLUVIAL SAND AND GRAVEL; HETEROGENEOUS, SAND, AND SILT MATRIX, VARIABLE WITH DEPTH AND LOCATION.
- FINE GRAINED SEDIMENTS CONSISTING OF VOLCANIC ASH-TUFF AS WELL AS CLAYS DERIVED FROM THESE VOLCANIC DEPOSITS. UNALTERED VOLCANIC ASH-TUFF DEPOSITS ARE GENERALLY GREENISH-YELLOW-WHITE IN COLOR. ASH DEPOSITS ARE GENERALLY AT LEAST PARTIALLY DECOMPOSED TO SMECTITE OR BENTONITE CLAY 2 - 5 FEET FROM TOP BECOMING LESS CLAYEY AND MORE INDURATED WITH DEPTH
- VOLCANIC ASH-TUFF AS DESCRIBED ABOVE, SANDIER WITH DEPTH.



Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana 59601
3020 Bozeman Avenue
(406) 443-4150

GEOLOGIC
CROSS SECTIONS

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EXHIBIT
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APPENDIX C

DESIGN ANALYSIS

FLEXIBLE MEMBRANE LINER DESIGN												
TABLE OF DESIGN PARAMETERS												
FML Specific Gravity			$= G_s =$	0.94	to	0.95	use:	0.94		Appendix D[1]		
FML Friction Angles												
	CL/FML		$= \delta_1 =$	15	° to	26	° use:	15	°	Table 5-6[1]		
	FML/GCL		$= \delta_2 =$	6	° to	11	° use:	6	°	Table 5-5[1]		
FML Thickness			= t =	30	mil to	120	mil use:	60	mil			
FML Yield Sress			$= \sigma =$	2300	psi to	3200	psi use:	150	lb/in	Table 5-3[1]		
			150	lb/in /	0.06	in x	0.95	=	2375	psi		
				50000	psf to	400000	psf	=	342000	psf		
Modulus			= E =	25000	psi					Table 5-3[1]		
Cell Slope Angle			$= \beta =$	18.43	°							
Depth of Cell			= D =	8	ft							
Design Lift Thickness			$= D_L =$	2.5	ft							
Density Waste			$= \gamma =$	80	pcf to	150	pcf use:	130	pcf			
Cell Side Slope			= S =	3	: 1							
Height of Cap			= H =	11	ft							
Waste Internal Friction			$= \phi =$	0	° to	40	° use:	30	°			
1. Calculate the required liner thickness for settlement.							Section 5.3.4 & 5.6.6[1]					
	$t_{REQUIRED} = p / \cos(\beta) \times X / \sigma_{ALLOWABLE} \times (\tan(\delta)_1 + \tan(\delta)_2)$											
		p =	$\gamma \times (D + H)$									
		=	130	pcf x (	8	ft +	11	ft)				
		=	2470	psf								
		=	17.1528	psi								
		X =	Deformation Distance									
		=	2	inches	(see Figure 5.9, Koerner, 1990)							
	t =	17.1528	psi	x	2	in.	x [tan(	15	°)+tan(	6	°)]	
		cos (	18.43	°)	2375	psi						
	=	0.00568	inches									
	$t_{REQUIRED}$ =		6	mils	<=	60	mils	**OK**				
	FS = $\sigma_{ALLOWABLE} / \sigma$											
		$\sigma =$	$p / \cos(\beta) \times X / t \times (\tan(\delta)_1 + \tan(\delta)_2)$									
		=	17.1528	psi	x	2	in.	x [tan(	15	°)+tan(	6	°)]
			cos (	18.43	°)	0.06	in.					
		=	224.828	psi								
	FS =	2375	psi /	224.828	psi							
	=	10.5636	>=	1	**OK**	Table 5.17[1]						
2. Check FML Stress, σ, Before Waste Placement From FML Weight On Slopes.										Figure 3-6[2]		
		Steepest side slopes are in the bottom cell.										
$\sigma =$	T / A											
	T =	$W \times \sin(\beta) - F$										
		W =	Liner weight									
		=	$[G_s \times \delta_w \times t][1 \times D / \sin(\beta)]$									
		= [	0.94	x	62.4	pcf x	60	/1000/12]x[1ftx	8	ft / sin(	18.43	°)
		=	7.42	lb/ft								
		F =	Friction Force between liner and slope									
			Least amount of friction is found between liner1 and GCL									

		=	W x cos(β) x tan(δ_2)									
		=	7.42	lbxcos(	18.43	°)xtan(	6	°)				
		=	0.74	lb/ft								
	T =	7.42	lbxsin(	18.43	°) -	0.74	lb					
	=	2.35	-	0.74								
	=	1.60623	lb/ft									
	A =	1'xt										
	=	1ft x	60	/1000/12								
	=	0.005	sf									
σ =	1.6062	lb/ft /	0.005	sf								
=	321.25	psf/ft										
	FS =	342000	psf /	321.246	psf							
	=	1064.61	>=	10	**OK**	Table 5.17[1]						
3. Check Tension Stress, σ, Carried By Primary Geomembrane During Filling										Section 5.6.8[1]		
σ =	(F_{Above} - F_{Below}) / t											
	F_{Above} =	W x cos(β) x tan(δ_1)										
		W=	W_W - T_W =		Weight of waste - Internal Friction Force on Edge of Waste							
			W_W =	0.5 x D_L^2 x S x γ								
			=	0.5 x (	2.5	ft)^2 x	3	x	130	pcf		
			=	1218.75	lb/ft							
			T_W =	σ_H x tan(ϕ) x D_L								
				σ_H =	K_O x σ_V							
					K_O =	1 - sin ϕ						
					=	1 - sin(	30	°)				
					=	0.5						
					σ_V =	γ xD_L/ 2						
					=	130	pcf x	2.5	ft / 2			
					=	162.5	psf					
				σ_H =	0.5	x	162.5	psf				
				=	81.25	psf						
			T_W =	81.25	psf x	tan(	30	°) x	2.5	ft		
			=	469.097	lb / ft							
		W=	1218.75	lb/ft -	469.097	lb/ft						
		=	749.653	lb/ft								
		W x cos(β) =		749.653	lbxcos(	18.43	°)					
			=	711.204	lb/ft							
	=	711.204	lb/ft x	tan(	15	°)						
	=	190.566	lb/ft									
	F_{Below} =	W x cos(β) x tan(δ_2)										
	=	711.204	lbxtan(	6	°)							
	=	74.7505	lb/ft									
σ = (	190.57	lb/ft -	74.7505	lb/ft) / (	60	/1000"	/12"/')					
=	115.82	lb/ft /	0.005	ft								
=	23163	psf										
	FS=	σ / σ_{actual}										
	=	342000	psf /	23163.2	psf							
	=	14.7648	>=	0.5	**OK**	Table 5.17[1]						
4. Check Minimum Thickness for General Membrane Installation Survivability										Table 5.11[3]		

t_{MIN} =	40	mil for High Survivability, typical of landfill liners and covers.											
	60	mil	>=	40	mil	**OK**							
5. Check Tension Stress, σ, After Filling Due to Subsidence													
Settlement of bottom of Landfill Due to 19 foot Height of Fill =							ρ						
	ρ =	2	inches (see settlement calculation)										
Installed Area of Liner =			208,656	sf									
Installed Area of Liner After Settlement =					208,731	sf							
Strain, ε = (	208,731	-	208,656	) sf /		208,656	sf						
	ε =	75	sf /	208,656	sf								
	ε =	0.00036	in/in										
σ =	ε x E												
σ =	0.0004	x	25000	psi									
σ =	8.9889	psi <	150	psi									
FS=	σ / σ_{actual}												
=	150	psf /	8.98894	psf									
=	16.687	>=	10	**OK**		Table 5.17[1]							
[1] Koerner, Robert M., *Designing With Geosynthetics, Second Edition*, Prentice Hall, 1990.													
[2] U.S. Environmental Protection Agency, "Requirements for Hazardous Waste Landfill Design,													
	Construction, and Closure" (EPA/625/4-89/022), August 1989												
[3] Koerner, Robert M., *Designing With Geosynthetics, Fourth Edition*, Prentice Hall, 1998.													

GEONET DESIGN									
Normal Stess,	$\sigma_{N\text{-}ALLOWABLE}$ =		118	psi to	250	psi	use:	134	psi
Geonet thickness, t =		160	mils to	910 mils			use:	250	mils
	t =							0.25	inches
$\tau_{ALLOWABLE}$ =	1500	psi							
Cell Side Slope		= S =	3	: 1					
Cell Slope Angle		= β =	18.43	°					
Transmisivity,	$T_{@3900PSF}$ =		3.0	gal/min/ft					
1. Calculate the normal stress on the geonet						Section 5.6.8[1]			
$\sigma_{N\text{-}ACTUAL}$ = γ x (H + D)									
γ =	130	pcf							
H =	10	ft							
D =	8	ft							
$\sigma_{N\text{-}ACTUAL}$ =	130	pcf x (	10	ft +	8	ft)			
=	2340	psf							
=	16.25	psi							
FS =	134	psf /	16.25	psi					
=	8.24615	>=	1	**OK**					
2. Calculate the shear stress on the geonet						Section 5.6.8[1]			
τ =	F_{BELOW} / t								
	F_{BELOW} =	74.7505	lb/ft						
τ =	74.75052	lb/ft / 12 /	0.25	in					
=	24.91684	psi							
FS =	1500	psi /	24.916839	psi					
=	60.2003	>=	1	**OK**					
3. Calculate required slope			try:	3%		Figure 4-15[2]			
t=	maximum travel time to sump.								
=	Distance to sump / Seepage Velocity								
=	D_{slope} / V_{slope} + D_{bottom} / V_{bottom}								
D_{slope} =	25.2982	feet							
D_{bottom} =	sqrt(2) x cell bottom length								
=	sqrt(2)x	407	feet						
=	575.585	ft							
V_{slope} =	T / t								
	T =	f(i, σ)							
		i =	1 / sqrt(1 + S^2)						
		=	1 / sqrt(1+	3	^{2})				
		=	0.3162278						
		σ =	H / 2 * γ * acos(β)						
		=	10	ft / 2 x	130	pcf x cos(	18.43	°)	
		=	616.6619	psf					
	T =	3.0	gal/min/ft =		0.4011	sf/min			

	V_{slope} =	0.4	sf/min/(	0.25	/12 ft)					
	=	19.3	ft/min							
	V_{bottom} =	T / t								
		T =	f(i, σ)							
			i =	0.03						
			σ =	$\sigma_{N\text{-}ACTUAL}$						
			=	2340	psf					
		T =	0.5	gal/min/ft	=	0.0668	sf/min			
	V_{bottom} =	0.1	sf/min/(	0.25	/12 ft)					
	=	3.2	ft/min							
t=	25.29822	ft /	19.3	ft/min +	575.58	ft /	3.2	ft/min		
=	180.7047	minutes								
=	3.011746	hours	<=	24	hours	**OK**				
	3%	**OK**								
[1] Koerner, Robert M., *Designing With Geosynthetics, Second Edition*, Prentice Hall, 1990.										
[2] U.S. Environmental Protection Agency, "Requirements for Hazardous Waste Landfill Design,										
	Construction, and Closure" (EPA/625/4-89/022), August 1989									

ANCHORAGE

Calculate anchor capacity for FML placed in various anchorage configurations

Friction Angle	$= \delta_L =$	15	° to	26	°	use:	15	°
Soil ϕ Angle	$= \phi =$	25	° to	38	°	use:	30	°
Slope Angle	$= \beta =$	18.43	°					
Soil Unit Wt	$= \gamma =$	100	pcf to	130	pcf	use:	130	pcf
Embedment	$= L_H =$	3	ft					
"V"Embedment	$= L_V =$	2	ft					
"V"Depth	$= d_V =$	1	ft					
Cover Depth	$= d_c =$	2	ft					
Anchor Burial	$= d_{AT} =$	1	ft					

1. Horizontal Embedment Anchor — Figure 3-8[2]

$T_H =$ Anchor Capacity

$T_H = (q \times L_H \times \tan(\delta_L)) / (1.5 \times \cos(\beta) - \sin(\beta)\tan(\delta_L))$

$q = \gamma \times d_c$

= 130 pcf x 2 ft

= 260 psf

= (260 psf x 3 ft x tan(15 °)) / (1.5x cos (18.43 °) - sin(18.43 °)x tan(15 °))

= **156.1621** lb/ft >= 115.8159 lb/ft **OK**

2. "V" Trench — Figure 3-8[2]

$T_V =$ Anchor Capacity

$T_V = \tan(\delta_L) [q (L_H - L_V + L_V / \cos(i)) + (d_V \times L_V \times \gamma c / (2 \times \cos(i)))]$

$1.5 \times \cos(\beta) - \sin(\beta) \times \tan(\delta_L)$

i = 45 °

$T_V =$ tan (15 °) [260 psf (3 ft - 2 ft + 2 ft/ cos(45 °)) + (1 ft x 2 ft x 130 pcf / (2 x cos (45 °))]

1.5cos(18.43 °) - sin(18.43 ° x tan(15 °)

= **238.0929** lb/ft >= 115.8159 lb/ft **OK**

3. Anchor Trench — Figure 3-8[2]

$T_A = q \times L_H \times \tan(\delta_L) + (K' + K_A) \tan(\delta_L)(0.5 \times \gamma \times d_{AT}^2 + q \times d_{AT})$

$1.5 \times \cos(\beta) - \sin(\beta) \times \tan(\delta)$

$T_{Ap} =$ 260 psf x 3 ft x tan(15 °) + 3.33x tan(15 °)(0.5 x 130 pcf x 1 ft² + 260 psf x 1 ft)

1.5cos(18.43 °) - sin(18.43 ° x tan(15 °)

$T_{Ap} =$ **372.8371** lb/ft >= 115.8159 lb/ft **OK**

$T_{Ao} =$ 260 psf x 3 ft x tan(15 °) + 0.833x tan(15 °)(0.5 x 130 pcf x 1 ft² + 260 psf x 1 ft)

1.5cos(18.43 °) - sin(18.43 ° x tan(15 °)

$T_{Ao} =$ **210.3634** lb/ft >= 115.8159 lb/ft **OK**

[2] U.S. Environmental Protection Agency, "Requirements for Hazardous Waste Landfill Design, Construction, and Closure" (EPA/625/4-89/022), August 1989

SLIDING									
Verify that soil cover will not slide on FML.									
Friction Angle		$= \delta_L =$	10	° to	45	°	use:	17	°
Yield Stess		=	2300	psi to	3200	psi	use:	2300	psi
Weight of Soil		=	130	pcf					
Slope Angle		$= \beta_2 =$	11.30993	°					
Cap Slope		$= S_2 =$	5	:1					
1. Calculate the load from the waste material in the bottom cell, only.									
$V_C =$	Volume of Soil on Side Slope Liner								
=	2	feet x	D / sin(β)						
=	2	feet x	2.5	ft / sin(	18.43	°)			
=	15.81549	cf/ft							
W =	Total Weight on Side FML								
=	15.81549	cf/ft x	130	pcf					
=	2056.013	lb / ft							
W' =	Effective Weight on Side FML								
=	15.81549	cf/ft x (	130	pcf -	62.4	pcf)			
=	1069.127	lb/ft							

Settlement

Settlement of Landfill								
Based on standard penetration testing								
B = 455 feet > 4 feet								
ρ =	Δq_s x 12 / (N x ((B+1)/B)^2							
	Δq_s =	20	ft x	105	pcf -	10	ft x	103.0629
	=	2100	psf -	1030.629	psf			
	=	1069.371	psf					
	Δq_s =	0.534685	tsf					
ρ =	0.534685	tsf x 12 / (	3.21	x ((	455	ft + 1) /	455	ft)^2)
ρ =	2	inches						
Based on Consolidation Testing								
$\Delta\sigma$ =	20	ft x	124.5	pcf -	10	ft x	103.0629	
=	2490	psf -	1030.629	psf				
=	1459.371	psf						
Borehole	γ_d (pcf)	e	ε_1	ε_2	σ_1 (psf)	σ_2 (psf)	Δe	C_c
BH-2-1	86	0.489554	0.03	0.057	950	2300	0.027	0.070312
BH-2-2	89	0.471747	0.11	0.146	950	2300	0.036	0.093749
BH-1-3	85	0.495489	0.052	0.07	950	2300	0.018	0.046874
BH-1-1	71	0.578585	0.138	0.187	950	2300	0.049	0.127603
BH-3-3	90	0.465812	0.04	0.057	950	2300	0.017	0.04427
BH-3-4	86	0.489554	0.028	0.042	950	2300	0.014	0.036458
Average		0.498457						0.069878
St Dev		0.040907						0.035225
90%								0.11502
p =	H x C_c	x log	$\sigma_o + \Delta\sigma$					
	(1 + e_o)		σ_o					
=	7	ft x	0.11502	x log	1030.629	psf +	1459.371	psf
	(1 +	0.498457	)			1030.629	psf	
=	0.537314	x log (	2.415999	)				
p =	0.205843	ft						
p =	2	inches						
Range of p								
=	7	ft x	0.127603	x log	1030.629	psf +	1459.371	psf
	(1 +	0.578585	)			1030.629	psf	
=	0.565835	x log (	2.415999	)				
p =	0.21677	ft						
=	7	ft x	0.036458	x log	1030.629	psf +	1459.371	psf
	(1 +	0.465812	)			1030.629	psf	
=	0.174105	x log (	2.415999	)				
p =	0.066699	ft						
p =	1	to	3	inches				

```
******************************************************************************
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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     U:\HELP\MARK1.D4
TEMPERATURE DATA FILE:       U:\HELP\MARK2.D7
SOLAR RADIATION DATA FILE:   U:\HELP\MARK3.D13
EVAPOTRANSPIRATION DATA:     U:\HELP\MARK4.D11
SOIL AND DESIGN DATA FILE:   U:\HELP\CAMU2.D10
OUTPUT DATA FILE:            U:\HELP\CAMU2OUT.OUT


TIME:   9:38     DATE:  12/12/2006


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

     TITLE:  East Helena Plant Phase 2 CAMU

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


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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   9
          THICKNESS                    =     30.00   INCHES
          POROSITY                     =      0.5010 VOL/VOL
          FIELD CAPACITY               =      0.2840 VOL/VOL
          WILTING POINT                =      0.1350 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1350 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.190000006000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0300	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000012000	CM/SEC
SLOPE	=	12.90	PERCENT
DRAINAGE LENGTH	=	398.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.06	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	144.00	INCHES
POROSITY	=	0.5010	VOL/VOL
FIELD CAPACITY	=	0.2840	VOL/VOL
WILTING POINT	=	0.1350	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1590	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.189999994000E-01	CM/SEC

LAYER 6

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

THICKNESS	=	0.25	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	33.0000000000	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	370.0	FEET

LAYER 7

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	5 - BAD	

LAYER 8

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

THICKNESS	=	0.25	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	33.0000000000	CM/SEC
SLOPE	=	3.00	PERCENT
DRAINAGE LENGTH	=	370.0	FEET

LAYER 9

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 10

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	36.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	69.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	5.100	ACRES
EVAPORATIVE ZONE DEPTH	=	24.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.240	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.024	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.240	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	42.728	INCHES
TOTAL INITIAL WATER	=	42.728	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HELENA MONTANA

MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	138	
END OF GROWING SEASON (JULIAN DATE)	=	266	
AVERAGE ANNUAL WIND SPEED	=	7.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	63.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	54.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	49.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	63.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HELENA MONTANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.66	0.44	0.69	1.01	1.72	2.01
1.04	1.18	0.83	0.65	0.54	0.60

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HELENA MONTANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
18.10	26.00	31.60	42.30	52.20	60.10
67.90	65.90	55.60	45.10	31.40	23.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HELENA MONTANA

STATION LATITUDE = 46.36 DEGREES

****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.77	199385.062	100.00
RUNOFF	0.047	871.132	0.44
EVAPOTRANSPIRATION	10.730	198652.109	99.63
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
DRAINAGE COLLECTED FROM LAYER 6	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 7	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 7	0.0000		
DRAINAGE COLLECTED FROM LAYER 8	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 10	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0000		
CHANGE IN WATER STORAGE	-0.007	-138.277	-0.07
SOIL WATER AT START OF YEAR	42.730	791069.312	
SOIL WATER AT END OF YEAR	42.723	790931.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.108	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.60	270289.844	100.00
RUNOFF	0.001	25.160	0.01
EVAPOTRANSPIRATION	14.202	262916.594	97.27
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0000		
DRAINAGE COLLECTED FROM LAYER 6	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 7	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 7	0.0000		
DRAINAGE COLLECTED FROM LAYER 8	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 10	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0000		
CHANGE IN WATER STORAGE	0.397	7347.981	2.72
SOIL WATER AT START OF YEAR	42.723	790931.000	
SOIL WATER AT END OF YEAR	42.786	792088.687	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.334	6190.283	2.29
ANNUAL WATER BUDGET BALANCE	0.0000	0.130	0.00

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ANNUAL TOTALS FOR YEAR 3-79 NOT INCLUDED

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ANNUAL TOTALS FOR YEAR 80

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.38	192165.047	100.00
RUNOFF	0.011	210.413	0.11
EVAPOTRANSPIRATION	10.239	189559.516	98.64
DRAINAGE COLLECTED FROM LAYER 2	0.0449	830.826	0.43
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.003	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0002		
DRAINAGE COLLECTED FROM LAYER 6	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 7	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 7	0.0000		
DRAINAGE COLLECTED FROM LAYER 8	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 10	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0000		
CHANGE IN WATER STORAGE	0.084	1564.125	0.81
SOIL WATER AT START OF YEAR	44.196	818205.437	
SOIL WATER AT END OF YEAR	44.281	819769.562	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.009	161.202	0.08
ANNUAL WATER BUDGET BALANCE	0.0000	0.163	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 80

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.68	0.38	0.75	1.01	1.70	2.05
	1.06	1.10	0.89	0.66	0.53	0.54
STD. DEVIATIONS	0.38	0.26	0.42	0.54	0.73	0.90
	0.61	0.60	0.61	0.40	0.29	0.31
RUNOFF						
TOTALS	0.018	0.017	0.024	0.026	0.004	0.000
	0.000	0.000	0.000	0.000	0.001	0.007
STD. DEVIATIONS	0.061	0.052	0.056	0.056	0.033	0.000
	0.000	0.000	0.000	0.000	0.006	0.045
EVAPOTRANSPIRATION						
TOTALS	0.433	0.398	0.725	1.218	1.830	2.143
	1.470	1.004	0.890	0.462	0.313	0.352
STD. DEVIATIONS	0.153	0.148	0.164	0.294	0.569	0.623
	0.846	0.419	0.502	0.245	0.155	0.141
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0006	0.0013
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0001	0.0035	0.0083
	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 7						

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 4

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0002	0.0005
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 7

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ACROSS LAYER 10

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 80

	INCHES		CU. FEET	PERCENT
PRECIPITATION	11.36	(1.782)	210226.7	100.00
RUNOFF	0.097	(0.1300)	1796.95	0.855
EVAPOTRANSPIRATION	11.237	(1.6427)	208033.34	98.957
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00203	(0.00933)	37.622	0.01790
PERCOLATION/LEAKAGE THROUGH FROM LAYER 4	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 4	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH FROM LAYER 7	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 7	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH FROM LAYER 10	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 10	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.019	(0.6793)	347.18	0.165

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 80

	(INCHES)	(CU. FT.)
PRECIPITATION	1.62	29991.059
RUNOFF	0.400	7399.6572
DRAINAGE COLLECTED FROM LAYER 2	0.01331	246.45171
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00026
AVERAGE HEAD ACROSS LAYER 4	0.025	
DRAINAGE COLLECTED FROM LAYER 6	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00000
AVERAGE HEAD ACROSS LAYER 7	0.000	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00000
AVERAGE HEAD ACROSS LAYER 10	0.000	
SNOW WATER	1.28	23704.6992

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2636

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1276

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FINAL WATER STORAGE AT END OF YEAR 80

LAYER	(INCHES)	(VOL/VOL)
1	5.5763	0.1859
2	0.3840	0.0320
3	0.0000	0.0000
4	0.0450	0.7500
5	22.8960	0.1590
6	0.0025	0.0100
7	0.0000	0.0000
8	0.0025	0.0100
9	0.0000	0.0000
10	15.3720	0.4270
SNOW WATER	0.000	

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APPENDIX D

SAMPLING AND MONITORING PLAN
(PENDING)

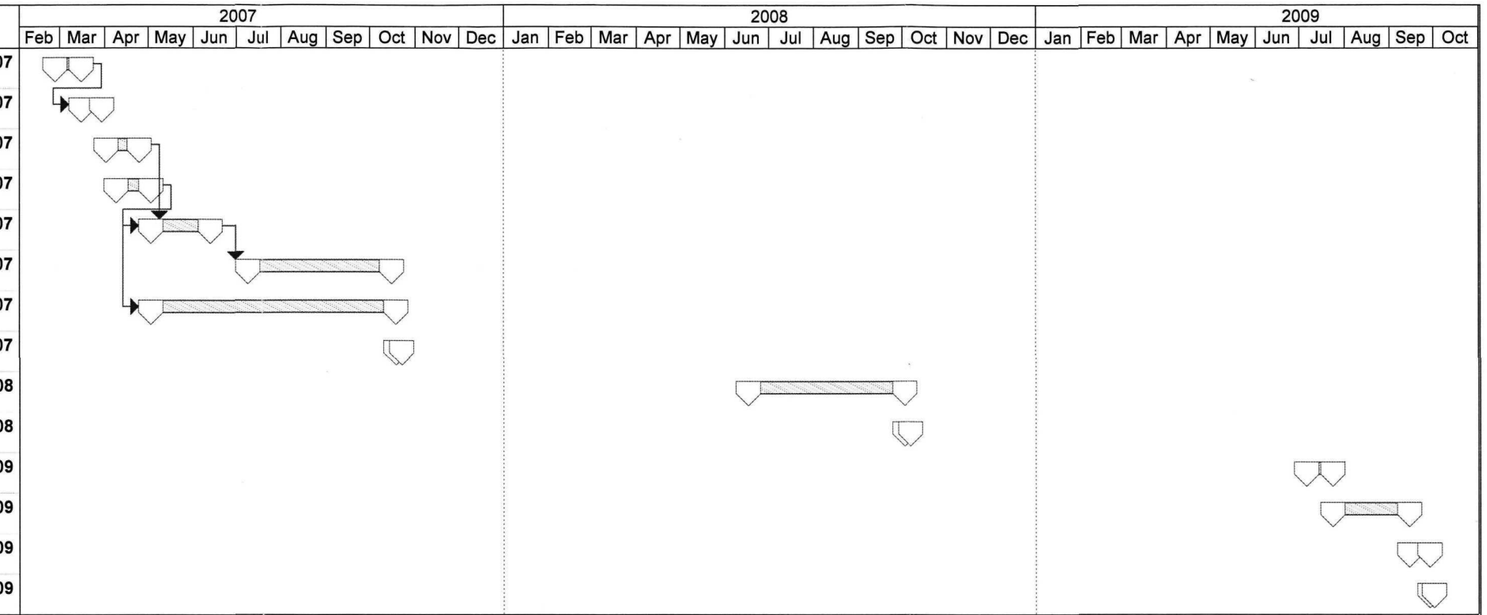
APPENDIX E

OPERATION AND MAINTENANCE PLAN
(PENDING)

APPENDIX F

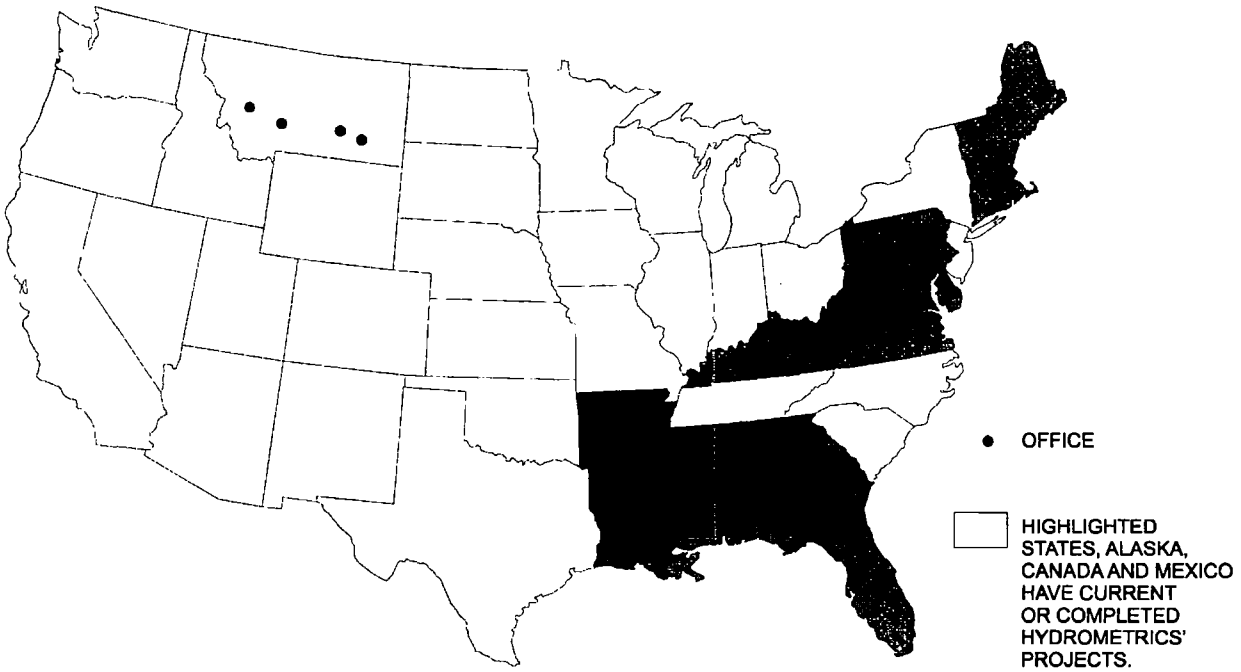
CONSTRUCTION SCHEDULE

ID		Task Name	Duration	Start	Finish
1		**Contract Award**	**14 days**	**Mon 2/26/07**	**Thu 3/15/07**
6		**Prepare Initial Work Plans and Permits**	**10 days**	**Fri 3/16/07**	**Thu 3/29/07**
15		**Mobilization**	**17 days**	**Mon 4/2/07**	**Tue 4/24/07**
24		**CAMU Excavation and Stockpile**	**18 days**	**Mon 4/9/07**	**Wed 5/2/07**
31		**CAMU Cell Liner System**	**29 days**	**Thu 5/3/07**	**Tue 6/12/07**
37		**Load, Haul, Place, Compact Waste for 2007**	**71 days**	**Mon 7/9/07**	**Mon 10/15/07**
45		**Other Construction Activities**	**121 days**	**Thu 5/3/07**	**Thu 10/18/07**
52		**Demobilization**	**2 days**	**Fri 10/19/07**	**Mon 10/22/07**
55		**Load, Haul, Place, Compact Waste for 2008**	**78 days**	**Tue 6/17/08**	**Thu 10/2/08**
62		**Demobilization**	**2 days**	**Fri 10/3/08**	**Mon 10/6/08**
65		**Load, Haul, Place, Compact Waste for 2009**	**14 days**	**Mon 7/6/09**	**Thu 7/23/09**
71		**CAMU Cap System**	**37 days**	**Fri 7/24/09**	**Mon 9/14/09**
79		**Other Construction Activities**	**10 days**	**Tue 9/15/09**	**Mon 9/28/09**
84		**Demobilization**	**3 days**	**Tue 9/29/09**	**Thu 10/1/09**



Project: CAMU PHASE 2 CONS SCH
Date: Thu 1/18/07

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary



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TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1065506

SITE NAME: EAST HELENA RCRA CORRECTIVE ACTION

DOCUMENT DATE: 01/01/2007

DOCUMENT NOT SCANNED

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- ☐ PHOTOGRAPHS
- ☐ 3-DIMENSIONAL
- ☐ OVERSIZED
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