# CONCEPTUAL REPOSITORY DESIGN TECHNICAL MEMORANDUM

## BLACK PINE MINE

Prepared for
Montana Department of Environmental Quality
Federal Superfund Section

Prepared by
Herrera Environmental Consultants, Inc.

In association with
Trihydro Corporation

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## BLACK PINE MINE

Prepared for
Montana Department of Environmental Quality
Federal Superfund Section
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# APPENDICES

# 1. INTRODUCTION

The Montana Department of Environmental Quality, Federal Superfund Section (DEQ) contracted Herrera Environmental Consultants (Herrera), in association with Trihydro Corporation (Trihydro), to prepare a Conceptual Repository Design for the Black Pine Mine (BPM). The onsite repository will serve as a long-term waste storage facility for solid media wastes and materials impacted by historic mining at the BPM.

A Repository Investigation was performed in 2012 to evaluate the preferred repository location and to confirm that the repository would comply with the DEQ's Applicable or Relevant and Appropriate Requirements (ARARs). A Repository Investigation Report was prepared in 2013 and presented the findings from test pitting, borings, and lab analyses. The Repository Investigation Report concluded that the preferred repository location is suitable for long-term waste storage (Herrera/Trihydro 2013). The results from the Repository Investigation provide the background information to prepare the Conceptual Repository Design. This Technical Memorandum (Tech Memo) outlines the design criteria used to develop the repository, conceptual layout, winter shutdown, and excavation and filling plans.

Additional supporting information is presented in the Reclamation Investigation (RI) Report (Herrera/Trihydro 2012) and the Repository Investigation Report (Herrera/Trihydro 2013).

# 2. DESIGN CRITERIA

## 2.1. Regulatory Requirements

DEQ ARARs provide the regulations for the repository design. Table 1-1 presents the repository ARARs. Investigations, material analyses, and geotechnical evaluations were performed during the Repository Investigation (Herrera/Trihydro 2013) to confirm that the siting and development of the repository will comply with the ARARs.

| Table 1-1. Repository ARARs, Black Pine Mine. | | |
|---|---|---|
| **Montana Solid Waste Management Act and Regulations** | **Description** | **Applicable/Relevant and Appropriate** |
| Montana Solid Waste Management Act and Regulations, Section 75-10-201, et seq., MCA, ARM 17.50.1001, et seq. | Provides that the management system of any solid waste facility must protect the public health and safety and conserve natural resources. | Relevant and Appropriate. These standards provide sound guidance for any solid waste facility for the treatment, storage, or disposal of mine wastes. |
| Floodplains, ARM 17.50.1004 | Provides that a solid waste facility located within the 100-year floodplain may not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste that poses a hazard to human health or the environment. | Applicable. If a new solid waste repository is constructed or existing solid waste facility is expanded in the 100-year floodplain, it will not restrict the flow of 100-year flood. In any event, disposal of mine wastes within a floodplain is to be avoided per other ARAR requirements. |
| Wetlands, ARM 17.50.1005 | Prohibits the location of a solid waste facility in a wetland, unless there is no practicable alternative. | Applicable. New solid waste facilities will not be located in a wetland. |
| Fault Areas, ARM 17.50.1006 | Prohibits the location of a solid waste facility within 200 feet (60 meters) of a fault that has had displacement in Holocene time unless an alternative setback will prevent damage to the solid waste facility and will protect human health and the environment. | Applicable. New solid waste facilities will not be located within 200 feet of a fault that has had displacement in Holocene time. |
| Seismic Areas, ARM 17.50.1007 | Prohibits the location of a solid waste facility in a seismic impact zone unless the solid waste structure is designed to resist the maximum horizontal acceleration in lithified earth material for the site. | Applicable. New solid waste facility will not be located in a seismic impact zone. |
| Unstable Areas, ARM 17.50.1008 | Prohibits the location of a solid waste facility in an unstable area (determined by local soil conditions, local geographic or geomorphologic features, and local artificial features or events) unless the solid waste facility is designed to protect its structural components. | Applicable. New solid waste facilities will not be located in an unstable geologic area or will be designed to protect the structural components of the facility. |
| Location Restrictions, ARM 17.50.1009 | Requires that a solid waste facility must have sufficient | Applicable. The listed requirements apply to |

| | | |
|---|---|---|
| | acreage and adequate separation of wastes from underlying groundwater or adjacent surface water, be located so as to prevent pollution of water systems, be accessible, and allow for reclamation of the land. | management and disposal of mine wastes at the site. |
| Section 75-10-212, MCA | Prohibits dumping or abandoning any debris or refuse upon or within 200 yards of any State road, other public property, or private property where hunting, fishing, or other recreation is permitted. | Applicable. The listed requirements apply to management and disposal of mine wastes at the site. |

## 2.2. Design Components

### 2.2.1. Excavation

The repository will be constructed partially below grade and partially above grade. An initial excavation, approximately 10 feet deep and totaling 159,200 cubic yards (cy), will be completed to provide clean materials for capping the repository and backfilling waste excavation areas (Appendix A, Sheet 5). This excavation will also reduce the height of the repository above the native ground surface, allowing the repository to better blend with the surrounding terrain. Approximately 159,200 cy of waste will be placed below the existing grade, with the remaining 233,000 cy placed above grade.

The excavation side slopes will be no steeper than 2 horizontal (H): 1 vertical (V) and are currently set at 3H:1V, as shown on Sheets 7 and 8 in Appendix A. The excavated bottom slope will mimic (parallel) the original ground slope, and will be designed with a minimum slope of 3 percent (33H:1V) and a maximum slope of not more than 20 percent (5H:1V) (Appendix A, Sheet 5). The bottom will also be developed with a cross-slope to route interim construction surface water to a sump along the northern perimeter of the repository (Appendix A, Sheet 5).

Materials excavated from the repository footprint will be segregated based on their properties and intended use (waste excavation backfill, soil cover, lower permeability clay materials, cover soil/topsoil, rock armor). These materials will be placed in stockpiles downslope of the repository.

### 2.2.2. Subgrade Preparation

Preparation of the subgrade in the bottom of the repository will include compacting and proof rolling the surface. Areas of unsuitable material (e.g., wet, yielding/pumping soils) will be excavated and replaced with compacted, suitable onsite material. The subgrade will be prepared such that it provides a firm base that allows for equipment to operate without rutting the subgrade.

Where competent bedrock is encountered, excavation grades will be adjusted. In areas where weathered bedrock or higher permeability materials (e.g., silty gravel with sand and cobbles) are encountered, the subgrade will be over-excavated 1 foot. Lower permeability material (e.g., clay, silt, and clayey gravel) borrowed during the excavation of the repository will be placed and compacted in these over-excavated areas.

The repository is configured as a closed depression; therefore, a sump will be excavated along the northern perimeter to provide interim water management prior to waste filling (Appendix A, Sheet 5). Saturated or yielding material or accumulated sediments and debris at the sump location will be excavated and replaced with compacted suitable material prior to waste placement.

### 2.2.3. Stockpile Areas

Material excavated from the repository footprint will be stockpiled for later use as backfill in waste excavation areas (Combination Mill) and as the cover system for the repository. Approximately 159,200 cy of material will be excavated from the repository footprint. Segregating and stockpiling this material will require a large area, measuring at least 200 feet by 400 feet. This stockpile area is planned to be located north of the repository, downslope from the existing power line road (Appendix A, Sheets 4 -6A).

Additional stockpile areas may be developed near waste excavation areas. Stockpiles will be contained within designated and controlled areas. Each area will be graded to provide positive drainage away from stockpile material.

### 2.2.4. General Requirements for USFS Roads

Relocation of USFS Road 678 around the repository will be designed to meet USFS road standards for a maintenance level 3 road (USFS 2014) (Appendix A, Sheet 11).

### 2.2.5. Waste Placement

The physical (e.g., grain size, natural moisture content, optimal moisture content) and chemical properties of the wastes to be placed in the repository vary depending on location. Wastes will be mixed as they are placed in the repository, or in some cases prior to hauling to the repository, to obtain optimal characteristics for compaction and stability. The mixed waste materials will be moisture conditioned as necessary, placed in 1 foot loose lifts, and compacted to 95% of standard Proctor maximum dry density.

Waste fill slopes in the repository will be limited to 3H:1V; although, temporary steeper slopes may be constructed during waste placement. The conceptual design for the repository calls for the majority of slopes to be flatter than 4H:1V. Slope stability will be verified as part of the final repository design.

The final repository surface will be graded to blend with the surrounding native topography, but will not exceed 3H:1V. The waste will be placed in a manner to provide drainage swales and minor ridges to breakup sheet flow, reduce erosion, and provide positive drainage to the north (Appendix A, Sheet 6).

### 2.2.6. Cover System Components

The repository cover system must provide adequate separation, protection, and barrier of waste from native materials. The cover system (Appendix A, Sheet 12) will be designed to reduce permeability to less than $1x10^{-5}$ centimeters per second (cm/sec), and will consist of the following components from top to bottom:

- An erosion protection layer consisting of a 0.5-foot layer of cover soil/topsoil with vegetation, or a 0.5-foot layer of native rock;
- A soil cover consisting of a 2.5-foot layer of native soil;
- A Composite Drainage Net (CDN) to collect and convey infiltrating water;
- A 60-mil thick, textured High Density Polyethylene (HDPE) geomembrane; and
- A protection layer comprised of compacted waste that is smooth and free of projections that can damage the overlying geomembrane.

Geomembrane and CDN will terminate in anchor trenches along the perimeter of the repository. The anchor trenches will be a minimum of 2 feet deep (Appendix A, Sheet 12). Along the northern perimeter/toe of the repository, the CDN will terminate in a gravel-filled collection trench or the bottom of a surface water collection ditch (Appendix A, Sheets 6, 6A, and 12). This trench or ditch will convey flow that infiltrates through the soil cover and is collected by the CDN away from the repository toward the culvert under the re-aligned USFS road.

With the exception of the CDN and HDPE geomembrane, cover system materials will be obtained from materials excavated from the repository footprint. The onsite soils will be segregated during the repository excavation and screened as necessary based on the soil properties and intended use.

As noted in the Repository Investigation Report, there is limited cover soil/topsoil available at the BPM. In an effort to limit new disturbance, the erosion layer will be a combination of vegetative cover and native rock armor. Based on investigations completed, sufficient cover soil exists within the footprint of the repository to cover approximately 6.4 acres of the repository. Areas covered with cover soil/topsoil will be hydroseeded. The remaining area (approximately 10.1 acres) will be protected with native rock, which will appear similar to existing rock-covered slopes in the area. The rock will be obtained by screening native material excavated from the repository subgrade.

The protection layer, which underlies the 60-mil HDPE geomembrane will be constructed of waste. Depending on the construction sequencing and timing, this layer may be covered with a temporary winter cover (Section 4). This winter cover will provide adequate protection, when combined with appropriate waste placement and compaction, to protect the overlying geomembrane. If construction timing is such that the last lift of waste material is not covered by a winter cover, and depending on the physical characteristics of the waste material, a non-woven geotextile will be considered for placement between the waste and the overlying geomembrane as a protection layer.

### 2.2.7. Stormwater Conveyance

Stormwater diversion (run-on) ditches will be constructed upslope of the repository to collect surface water runoff from upslope watersheds and convey the runoff away from the repository. Stormwater collection ditches will be constructed downslope of the repository to collect surface water runoff generated by precipitation falling directly on the repository and convey this runoff away from the repository. These ditches will be excavated into and constructed from native materials. Stormwater collection or diversion ditches will meet the following design criteria:

- Maximum drainage grades will be such that the need for rock armor or other energy dissipaters is minimized.
- Design velocity will be determined using a Manning's coefficient (n) equal to 0.035 for rock –lined ditches and 0.030 for vegetated ditches.
- The maximum allowable design velocity will be 5.0 feet per second (fps) for vegetated ditches (n = 0.030), unless also lined with turf reinforcement matting
- Ditches will be triangular in cross-section.
- Side slopes will be no steeper than 1H:1V. Side slopes will be flatter where allowed by the surrounding terrain, with 3H:1V side slopes preferred. However, localized 1H:1V side slopes will be allowed in areas to minimize excavation/disturbance.
- Ditches will be designed to convey the peak 25-year, 24-hour flow.

Run-on control berms may also be used to divert stormwater away from the repository. Run-on control berms will meet the following design criteria:

- Sizing and geometry criteria will be the same as identified for ditch design.
- Minimum berm top width shall be 3 feet.
- Berms shall be designed to convey the peak 25-year, 24-hour flow.

### 2.2.8. Temporary Erosion and Sedimentation Control (TESC)

Best Management Practices (BMPs) will be applied during construction to reduce the opportunity for sediments or waste to be transported offsite. BMPs will include straw wattles, berms, and silt fence for sedimentation control and stabilized construction entrances for truck traffic. A temporary sediment basin will also be constructed downslope from the repository. This sediment basin will be maintained for the duration of the repository construction (Appendix A, Sheets 4-6A).

# 3. EXCAVATION AND FILLING PLAN

The repository subgrade is planned to be excavated during one construction season, with waste placement and construction of the repository cover in subsequent construction seasons. Production rates for a variety of haul trucks, ranging from side dumps to 40-ton articulated trucks, were evaluated to estimate the required waste hauling time. A table summarizing this evaluation is provided as Appendix B. Based on this evaluation, placing waste in the repository could reasonably be completed over two, 4-month long construction seasons. This would require that approximately 200,000 cy of waste be excavated, hauled, and placed each field season. Completing the repository cover and project cleanup would require a fourth construction season.

## 3.1. Excavation

A run-on ditch will be cut along the up gradient extents (southern perimeter) of the repository to collect and divert surface water from entering the excavation. The repository will be excavated to the grades and slopes shown on the conceptual plans (Appendix A, Figure 5). A sump will be excavated in the northern center portion of the repository to collect water during the first winter season. A culvert will be installed across the existing power line road on the northern boundary of the repository to convey water from the excavation to a sediment basin down gradient of the repository (Appendix A, Figure 5). Prior to waste placement, the excavation bottom grades will be finish graded and saturated or yielding soils, or accumulated sediment and debris, associated with the sump will be removed.

## 3.2. Waste Placement

Waste will be hauled from both the Smart Creek drainage (Combination Mine) and the South Fork Lower Willow Creek drainage (Tim Smith waste rock dumps, Combination Mill, and South Fork Lower Willow Creek stream sediments) using existing USFS roads. Access into the repository will be from the north and the south to allow for haul trucks to access from two locations. Hauling from both areas simultaneously will reduce truck congestion. The existing USFS roads will not be widened to allow for two-way traffic; however, temporary turn-outs will be constructed and used to allow haul trucks to pass each other. Segments of the existing USFS roads, such as tight turns or corners, may also be upgraded/widened to allow for haul trucks.

Waste will be moisture conditioned and/or mixed, and placed in the repository in compacted 1 foot lifts. Waste will be placed in the repository such that a slope is maintained toward drainage points along the northern repository perimeter. Waste placement will begin along the northern edge of the repository and fill from north to south to allow for positive drainage and to reduce ponding. Placement will proceed up gradient to the south. Drainage will be

directed from the repository into the drainage ditch running along the northern edge of the repository and then to the sediment basin.

An interim, low-permeability winter cover (discussed in Section 4) will be placed over the waste following the completion of the first construction season of waste placement to limit infiltration into and erosion of the placed wastes.

The second construction season of waste placement will commence following spring snowmelt. At the completion of waste placement, the top of the waste will be graded and prepared for cover system installation. A winter cover will be placed over the top of the final grade. Construction of the cover system will commence during the subsequent construction season.

# 4. WINTER COVER EVALUATION

Placement of wastes in the repository is anticipated to require two construction seasons. Subsequently, a winter cover will be required to control waste from mobilizing during spring melt and to reduce infiltration of snowmelt and rainfall into the wastes. Two options for winter cover were evaluated for effectiveness, winter cover volume, and cost.

- The first option would make use of low permeability soils available on site. Native, clayey gravel excavated as part of the repository construction would be placed and compacted over the top of waste prior to winter shutdown. The native clayey material would be screened to remove large cobbles and debris and then placed and compacted to reduce surface water infiltration into the waste material. The required thickness of the clayey layer to effectively reduce infiltration is calculated to be 0.5-feet thick (Appendix C).
- The second option is to use an imported, spray-applied product such as Posi-Shell or similar. These products, which form a mineral mortar coating, are used for landfill intermediate cover. Posi-Shell is applied with a spray truck (similar to application of hydromulch). The applied materials form a layer approximately 0.2-feet thick.

A comparison of the two cover options is presented in Table 4-1.

**Table 4-1. Winter Cover Evaluation, Black Pine Mine.**

| | Native Clayey Gravel | Posi-Shell (or similar product) |
|---|---|---|
| Winter Shutdown Cover Volume by Year (cy) | 13,300 | 5,300 |
| Total Winter Shutdown Cover Volume (cy)[1] | 26,600 | 10,600 |
| Cost per Winter Cover Lift | $66,550[2] | $35,943[3] |
| Total Cost | $133,100 | $71,886 |

[1] Total volume based on two winter shutdowns.

[2] Cost for native clayey gravel material includes excavation, selective processing, placement, and compaction. Unit cost is $5.00/cy.

[3] Costs for Posi-Shell include application through a sprayer. Unit cost is $0.05/square foot (sf).

Posi-shell and the native clayey gravel material have similar permeability characteristics, but the Posi-Shell takes up less than half of the volume that the native clayey gravel would require. Posi-Shell will also cost nearly half the estimated cost to process, place, and compact the native clayey gravel material. Posi-shell, or similar products, offer the additional benefit of shorter application timeframes, which will allow the contractor to extend waste excavation and hauling activities.

Based on the evaluation of the winter cover options, the preferred winter cover would be application of Posi-Shell, or similar product. The benefits or limitations of these types of products will be further evaluated with suppliers during development of the repository design. Final selection of a winter cover alternative will be made at that time.

# 5. MATERIAL QUANTITIES

Material quantities for the repository include waste material, winter cover, geomembrane, CDN, soil cover, cover soil, and native rock armor. Borrow material from the repository excavation is also required for backfill in the Combination Mill waste excavation areas. The material quantities are presented in Table 5-1.

**Table 5-1. Material Quantities, Black Pine Mine.**

| Waste Volumes | | | | |
|---|---|---|---|---|
| **Area** | **Excavation (cy)** | **Backfill[2] (yes / no)** | **Backfill (cy)** | |
| Combination Mine Waste Rock | 203,200[1] | no | - | |
| Combination Mine Soils Removal Area | 5,000 | no | - | |

| | | | | |
|---|---|---|---|---|
| Tim Smith Waste Rock Dumps (includes No. 1 and No. 2) | 22,650 | no | - | |
| Combination Mill Sediments, Soils, and Tailings Impoundments | 128,300 | yes | 40,000 | |
| South Fork Lower Willow Creek Stream Sediments | 19,700 | no | - | |
| Historic Mine Waste Rock Area | 13,350 | no | - | |
| **Total** | **392,200** | | **40,000** | |
| Volume of Material Available from Repository Excavation for use as Backfill | | | 79,300 | |

**Repository Excavation**

| Description | Excavation (cy) | Area (ac) | | |
|---|---|---|---|---|
| Repository Excavation | 159,200[3] | 13 | | |
| **Total** | **159,200** | | | |

**Repository Cover System**

| Description | | Area (ac) | Area (sf) | Cap Material (cy) |
|---|---|---|---|---|
| Winter Cover (Posi-Shell or similar) Application 1 | | 16.5 | 718,860 | 5,300 |
| Winter Cover (Posi-Shell or similar) Application 2 | | 16.5 | 718,860 | 5,300 |
| 60-mil, Textured HDPE Geomembrane | | 16.7 | 729,400 | - |
| Composite Drainage Net | | 16.7 | 729,400 | - |
| Repository Final Soil Cover (2.5 feet thick) | | 16.5 | | 66,550 |
| Repository Cover Soil (0.5 feet thick) | | 6.4 | | 5,200 |
| Repository Native Rock Armor (0.5 feet thick) | | 10.1 | | 8,150 |
| **Total Material Required for Interim and Final Repository Cap** | | | | **90,500** |

**Required Repository Volume**

| Description | Excavation (cy) | | | |
|---|---|---|---|---|
| Waste Volume | 392,200 | | | |
| Cap Volume | 90,500 | | | |
| **Total Required Repository Volume** | **482,700** | | | |

| Available Repository Volume | | | | |
|---|---|---|---|---|
| **Description** | **Available Volume (cy)** | | **Difference (cy)** | **Difference (%)** |
| Excavation Area Volume below Existing Grade | 159,200 | | | |
| Proposed Repository Final Grading Volume above Existing Grade | 308,000 | | | |
| **Total** | **467,200** | | **15,500** | **3.2** |
| **USFS Road Re-alignment Volume Quantities** | | | | |
| **Description** | **Total Excavation (cy)** | **Area (ac)** | **Length (ft)** | |
| Cut | 2,411 | | | |
| Fill | 2,275 | | | |
| Disturbance | | 1.29 | | |
| Length | | | 2,076 | |

[1]The Combination Mine waste rock pile contains approximately 232,000 cy of material, including 29,000 cy of cover material. The clean cover material will be salvaged and replaced following removal of contaminated materials. The volume of contaminated materials to be removed is 203,200 cy.

[2] Backfill is not assumed to be required for the Combination Mine waste rock pile or Tim Smith waste rock dumps. These excavation areas will be excavated back to native material and the approximate pre-mining surface. Backfill is not assumed to be required for the Combination Mine soils removal areas or the South Fork Lower Willow Creek stream sediments excavation areas. These excavation areas will be backfilled and blended with the surrounding topography through local grading.

[3] Initial repository excavation volume includes ~45,000 cy of clayey gravel based on interpolation of test pit and borehole logs from the RI and Repository Investigation (Herrera/Trihydro 2012, Herrera/Trihydro 2013).

# 6. REFERENCES


Herrera/Trihydro. 2012. Reclamation Investigation Report for the Black Pine Mine, Granite County, Montana. Prepared for Montana Department of Environmental Quality, Helena, Montana, by Herrera Environmental Consultants, Inc., Missoula, Montana, and Trihydro Corporation, Helena, Montana. May 2012.

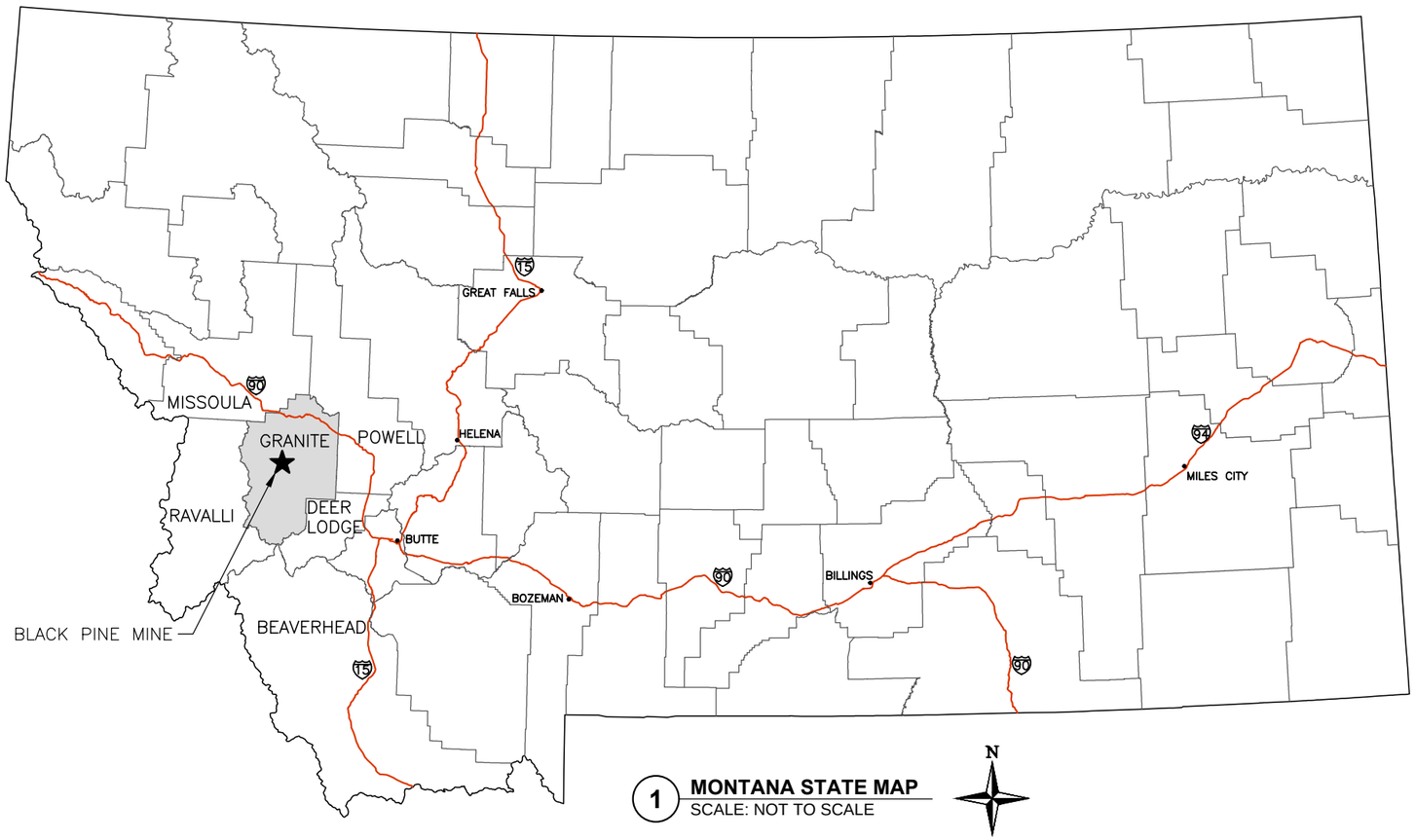
Herrera/Trihydro. 2013. Repository Investigation Report for the Black Pine Mine, Granite County, Montana. Prepared for Montana Department of Environmental Quality, Helena, Montana, by Herrera Environmental Consultants, Inc., Missoula, Montana, and Trihydro Corporation, Helena, Montana. December 2013.

United States Forest Service. 2014. Email communication from Sonny Thornborrow to Devin Clary regarding FSR #678 Maintenance Level. April 24, 2014.

# APPENDIX A

# Conceptual Repository Plans

# DEPARTMENT OF ENVIRONMENTAL QUALITY
# FEDERAL SUPERFUND SECTION
## DRAFT BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN PLAN SET
## GRANITE COUNTY




1 **MONTANA STATE MAP**
SCALE: NOT TO SCALE

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| SHEET NO. | TITLE | REV. |
|---|---|---|
| TITLE | PROJECT LOCATION MAP AND INDEX OF SHEETS | B |
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| 2 | SITE VICINITY MAP | B |
| 3 | SITE ACCESS MAP | B |
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| 6A | PROPOSED ALTERNATE GRADING PLAN (1 OF 2) | A |
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NOT FOR CONSTRUCTION

**NOTE:**

SITE LEGAL DESCRIPTION:
BLACK PINE MINE REPOSITORY, SECTION 16 & 17, TOWNSHIP 8 NORTH, RANGE 14 WEST

Montana Department of Environmental Quality

| REV. | DATE | DESCRIPTION | BY | CHK |
|---|---|---|---|---|
| B | 7/31/2014 | ISSUE FOR CONCEPTUAL DESIGN | REP | TH |
| A | 6/27/2014 | ISSUE FOR CLIENT REVIEW | REP | TH |

REVISIONS

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PROJECT LOCATION MAP AND INDEX OF SHEETS

BLACK PINE MINE REPOSITORY
CONCEPTUAL DESIGN
FEDERAL SUPERFUND SECTION

SHEET TITLE

REV: B

## EXPLANATION

- BLACK PINE MINE PROPERTY BOUNDARY
- RIVERS AND STREAMS
- INTERSTATES
- ROADS
- ACCESS ROUTE
- TOWNSHIP/RANGE BOUNDARIES
- SECTION LINE
- COUNTY LINE
- OHP — OVERHEAD POWER
- EDGE OF ROAD
- EXISTING STRUCTURE
- 6260 — EXISTING GROUND SURFACE CONTOURS (5' INTERVAL)
- PROPOSED STRAW WATTLES OR SILT FENCE
- PROPOSED INITIAL EXCAVATION BOUNDARY
- PROPOSED USFS ROAD CENTERLINE RE-ALIGNMENT
- PROPOSED REPOSITORY BOUNDARY
- INTERCEPTOR TRENCH/STORMWATER DIVERSION DITCH
- 6260 — PROPOSED GROUND SURFACE CONTOURS (5' INTERVAL)
- PROPOSED DISTURBANCE BOUNDARY
- PROPOSED CULVERT
- WASTE ROCK AREAS
- TAILINGS AREAS
- ADIT
- SHAFT
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- PROPOSED REPOSITORY LOCATION
- PROPOSED SEDIMENT BASIN
- INITIAL REPOSITORY EXCAVATION AREA
- AMENDED COVER SOIL OR NATIVE ROCK COVER
- SOIL COVER
- PROTECTION LAYER
- WASTE MATERIAL
- EXISTING GROUND

## GENERAL:

1. CONTRACTOR SHALL LIMIT MACHINERY MOVEMENT TO CONSTRUCTION LIMITS DEFINED ON REPOSITORY SITE LAYOUT OR IDENTIFIED AS ACCEPTABLE BY ENGINEER AND OWNER.
2. CLEARING LIMITS FOR TEMPORARY ACCESS ROAD AND PROPOSED STRUCTURES SHALL BE LIMITED TO THE AREA REQUIRED FOR SAFE EQUIPMENT OPERATION.
3. CLEARING LIMITS SHALL BE STAKED BY CONTRACTOR AND APPROVED BY ENGINEER AND OWNER AT LEAST 3 DAYS PRIOR TO CLEARING ACTIVITIES. CLEARING LIMITS SHALL BE STAKED TO MINIMIZE THE AREA OF DISTURBANCE. EQUIPMENT USED FOR THIS PROJECT SHALL BE FREE OF EXTERNAL PETROLEUM-BASED PRODUCTS WHILE WORKING AROUND STREAMS. ACCUMULATION OF SOILS OR DEBRIS SHALL BE REMOVED FROM THE DRIVE MECHANISMS (WHEELS, TRACKS, TIRES, ETC.) AND UNDERCARRIAGE OF EQUIPMENT PRIOR TO ITS WORKING WITHIN ANY STREAM CHANNEL.
4. EQUIPMENT SHALL BE CHECKED DAILY FOR LEAKS, AND ANY NECESSARY REPAIRS SHALL BE COMPLETED PRIOR TO COMMENCING WORK ACTIVITIES.
5. THE CONTRACTOR IS RESPONSIBLE TO ENSURE THAT NO PETROLEUM PRODUCTS, HYDRAULIC FLUID, SEDIMENTS, SEDIMENT-LADEN WATER, CHEMICALS, OR ANY OTHER TOXIC OR DELETERIOUS MATERIALS ARE ALLOWED TO ENTER OR LEACH INTO STREAM CHANNELS.
6. ALL TEMPORARY EROSION AND SEDIMENT CONTROL BMPS SHALL BE INSTALLED, MONITORED, AND MAINTAINED IN ACCORDANCE WITH A PROJECT SPECIFIC STORM WATER EROSION CONTROL PLAN APPROVED BY OWNER, PRIOR TO THE START OF WORK.
7. TOPSOIL, IF ENCOUNTERED FROM GRADING AREAS SHALL BE STRIPPED TO A DEPTH APPROVED BY THE ENGINEER AND OWNER AND STOCKPILED.

## ABBREVIATIONS

| | |
|---|---|
| CY | CUBIC YARD |
| FT AMSL | FEET ABOVE MEAN SEA LEVEL |
| TYP. | TYPICAL |
| MAX. | MAXIMUM |
| MIN. | MINIMUM |
| NO. | NUMBER |
| MW | MONITORING WELL |
| RY | REPOSITORY |
| HDPE | HIGH DENSITY POLYETHYLENE |

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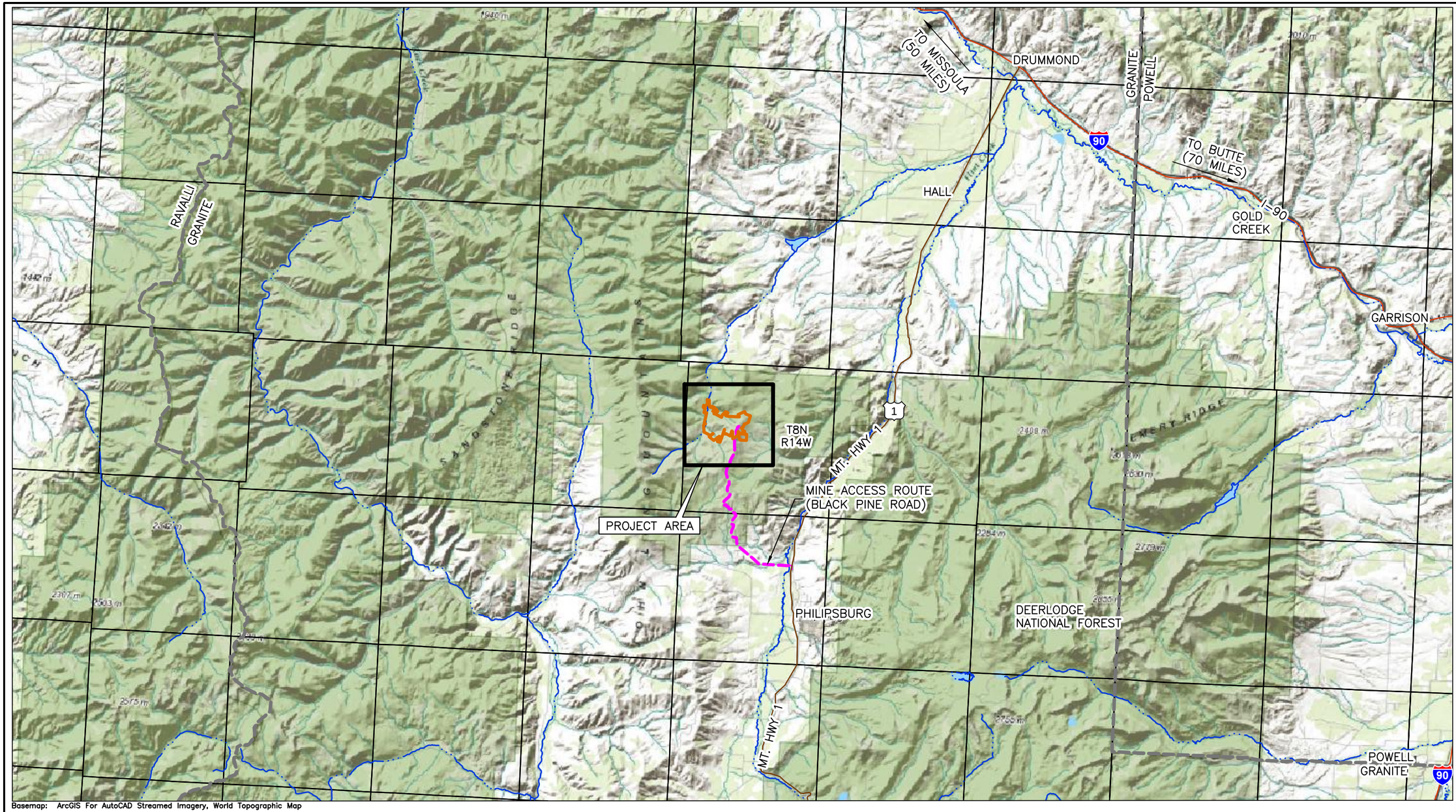
# EXPLANATION AND NOTES

# BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 1 OF 15

REV: B




Basemap: ArcGIS For AutoCAD Streamed Imagery, World Topographic Map


**NOTE:**

THE BLACK PINE MINE REPOSITORY SITE IS ACCESSED BY TRAVELING NORTH FROM PHILIPSBURG ON HIGHWAY 1, 2.25 MILES TO BLACK PINE ROAD. THE ACCESS ROUTE FOLLOWS BLACK PINE ROAD TO THE WEST AND THEN TURNING NORTH FOR APPROXIMATELY 7.0 MILES TO A JUNCTION WITH FOREST SERVICE ROAD 448. BEAR RIGHT ONTO FOREST SERVICE ROAD 448 AND TRAVEL AN ADDITIONAL 1.4 MILES ON FOREST SERVICE ROAD 448 TO A JUNCTION WITH FOREST SERVICE ROAD 678; TURN WEST. THE REPOSITORY SITE LIES DIRECTLY ADJACENT TO FOREST SERVICE ROAD 678.

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N

0 4 MILES

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SCALE: 1" = 4 MILES
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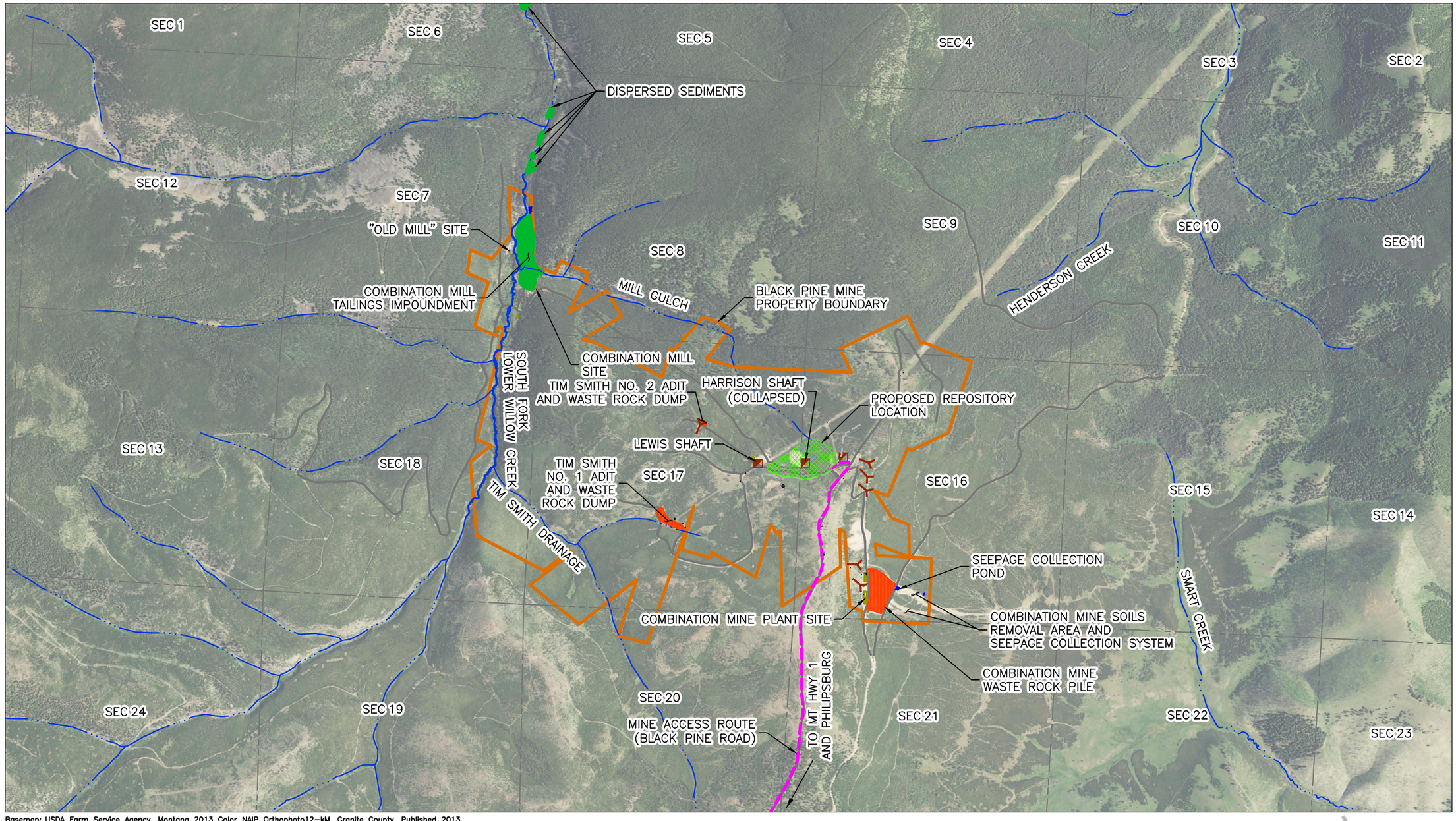
# SITE VICINITY MAP

## BLACK PINE MINE REPOSITORY
## CONCEPTUAL DESIGN
## FEDERAL SUPERFUND SECTION




Basemap: USDA Farm Service Agency, Montana 2013 Color NAIP Orthophoto12-kM, Granite County. Published 2013.

**NOTES:**

1. IMAGERY WAS MOVED NORTHEAST TO MATCH FEATURES
2. TRAFFIC CONTROL TO BE PROVIDED AND MAINTAINED FOR DURATION OF REPOSITORY CONSTRUCTION, LOADING, AND CLOSURE.
3. TREE TRIMMING MAY BE NECESSARY ON THE SITE ACCESS ROAD TO PROVIDE ACCESS FOR CONSTRUCTION EQUIPMENT.
4. SALVAGE AND STOCKPILE TREES FOR PLACEMENT ON FINISH GRADING.

NOT FOR CONSTRUCTION

N

0 2,000'

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SCALE: 1" = 2,000'
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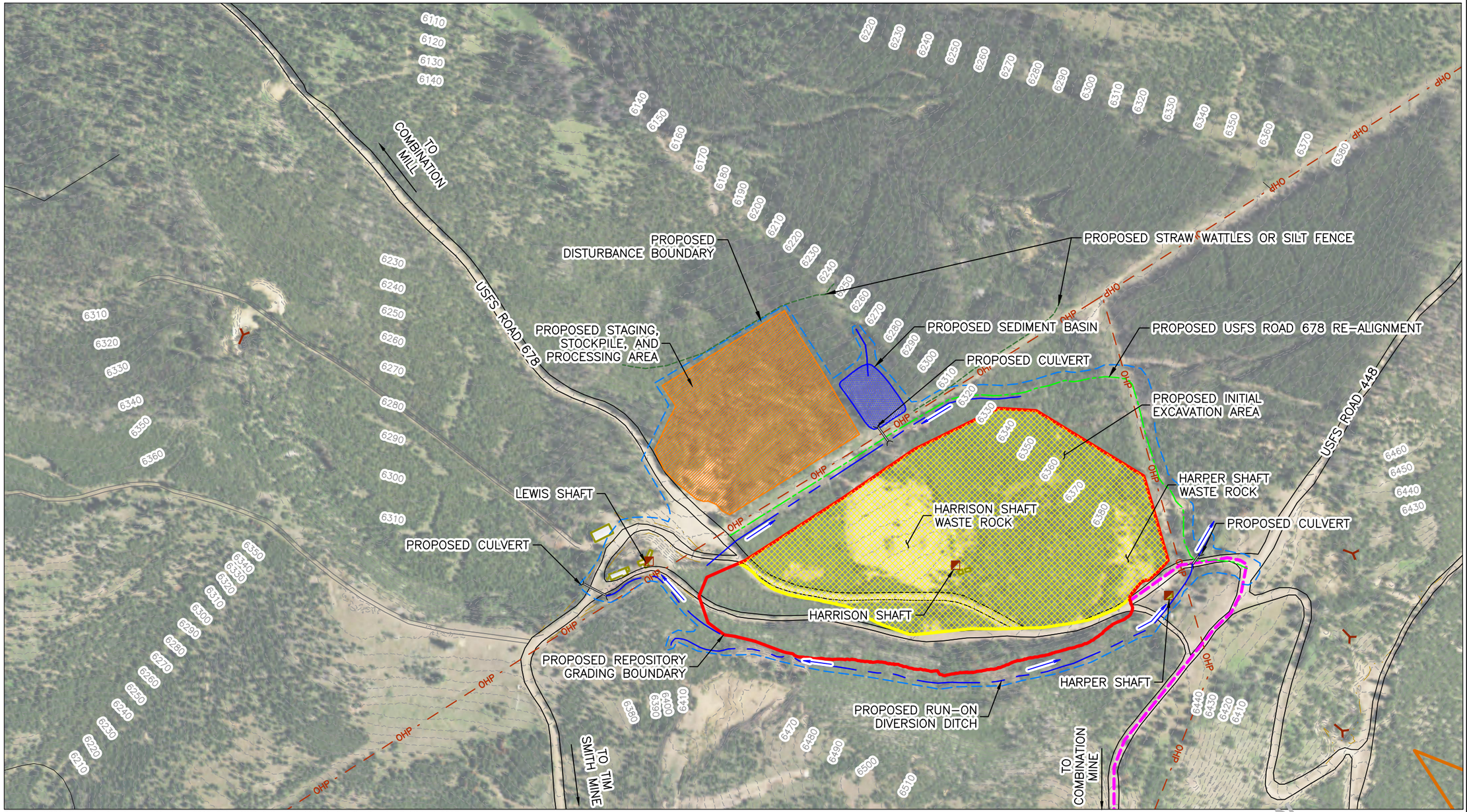
# SITE ACCESS MAP

## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 3 OF 15

REV: B




Basemap: USDA Farm Service Agency, Montana 2013 Color NAIP Orthophoto12-kM, Granite County. Published 2013.

**NOTES:**

1. THE PROPOSED STAGING, PROCESSING, AND STOCKPILE AREA LIES ADJACENT TO AN EPHEMERAL DRAINAGE. STRAW WATTLES OR SILT FENCE TO BE INSTALLED BETWEEN DISTURBANCE AND THE EPHEMERAL DRAINAGES, PERPENDICULAR TO FLOW, DOWN STREAM OF THE PROPOSED STAGING, PROCESSING AND BORROW AREA. FINAL LOCATIONS WILL BE APPROVED IN THE FIELD BY THE ENGINEER AND OWNER.
2. NO WORK SHALL BE CONDUCTED OUTSIDE OF THE DISTURBANCE LIMITS SHOWN ON SHEET 4 UNLESS PREVIOUSLY AUTHORIZED BY THE ENGINEER AND OWNER.

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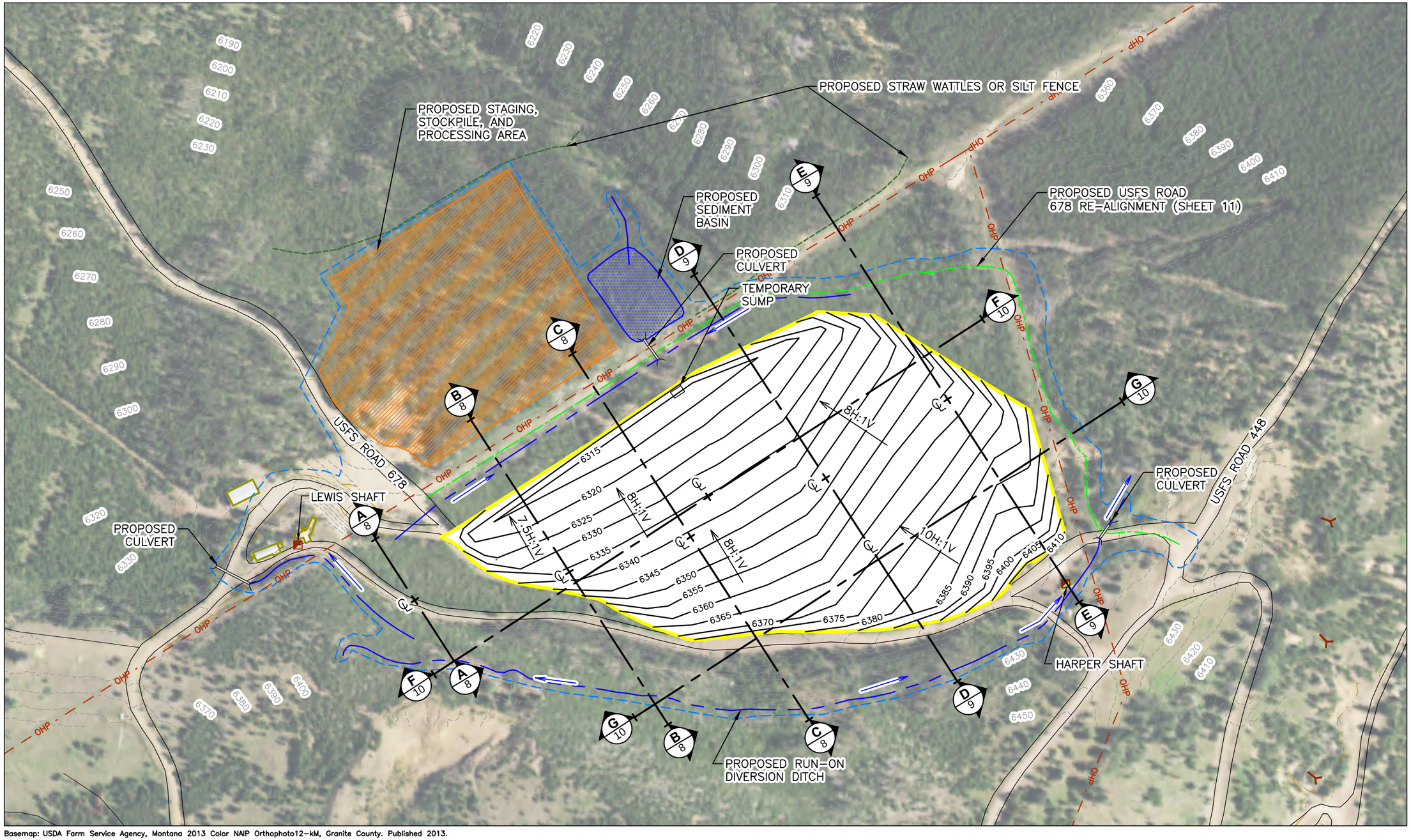
# REPOSITORY SITE LAYOUT

# BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION




Basemap: USDA Farm Service Agency, Montana 2013 Color NAIP Orthophoto12-kM, Granite County. Published 2013.

**NOTES:**

1. IMAGERY WAS MOVED NORTHEAST TO MATCH FEATURES.
2. EXCAVATION SIDE SLOPES SHALL BE CUT AT 3H:1V.
3. AREAS OF WET, YIELDING, OR HIGHLY PERMEABLE SOILS, AS NOTED IN THE FIELD BY THE ENGINEER OR OWNER, WILL BE OVER-EXCAVATED 1 FOOT AND REPLACED WITH COMPACTED ON-SITE CLAY MATERIAL.

NOT FOR CONSTRUCTION

N

0 200'

| REV. | DATE | DESCRIPTION | BY | CHK |
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SCALE: 1" = 200'
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# INITIAL EXCAVATION GRADING PLAN

## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 5 5 OF 15

REV: B

PROPOSED STRAW WATTLES OR SILT FENCE

PROPOSED SEDIMENT BASIN

PROPOSED CULVERT

COLLECTION TRENCH (DETAIL B, SHEET 12)

PROPOSED USFS ROAD 678 RE-ALIGNMENT (SHEET 11)

USFS ROAD 678

LEWIS SHAFT

PROPOSED CULVERT

PROPOSED RUN-ON DIVERSION DITCH (DETAIL A, SHEET 12)

PROPOSED CULVERT

HARPER SHAFT

TIE INTO EXISTING USFS ROAD

USFS ROAD 448

OHP

4.5H:1V

5.3H:1V

9H:1V

5H:1V

7.5H:1V

4.3H:1V

3.25H:1V

3.5H:1V

6H:1V

Basemap: USDA Farm Service Agency, Montana 2013 Color NAIP Orthophoto12-kM, Granite County. Published 2013.

**NOTES:**

1. IMAGERY WAS MOVED NORTHEAST TO MATCH FEATURES.
2. FINAL GRADING WILL BE AS APPROVED IN THE FIELD BY THE ENGINEER AND OWNER.

NOT FOR CONSTRUCTION

0 200'

| REV. | DATE | DESCRIPTION | BY | CHK |
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DATE: 6/2014

SCALE: 1" = 200'

FILE: 776-GRADEPROP

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# PROPOSED FINAL GRADING PLAN (1 OF 2)

## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 6 OF 15

REV: B

Basemap: USDA Farm Service Agency, Montana 2013 Color NAIP Orthophoto12-kM, Granite County. Published 2013.

**NOTES:**

1. IMAGERY WAS MOVED NORTHEAST TO MATCH FEATURES.
2. FINAL GRADING WILL BE AS APPROVED IN THE FIELD BY THE ENGINEER AND OWNER.

NOT FOR CONSTRUCTION

0 200'

| REV. | DATE | DESCRIPTION | BY | CHK |
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| A | 7/31/2014 | ISSUE FOR CONCEPTUAL DESIGN | REP | TH |

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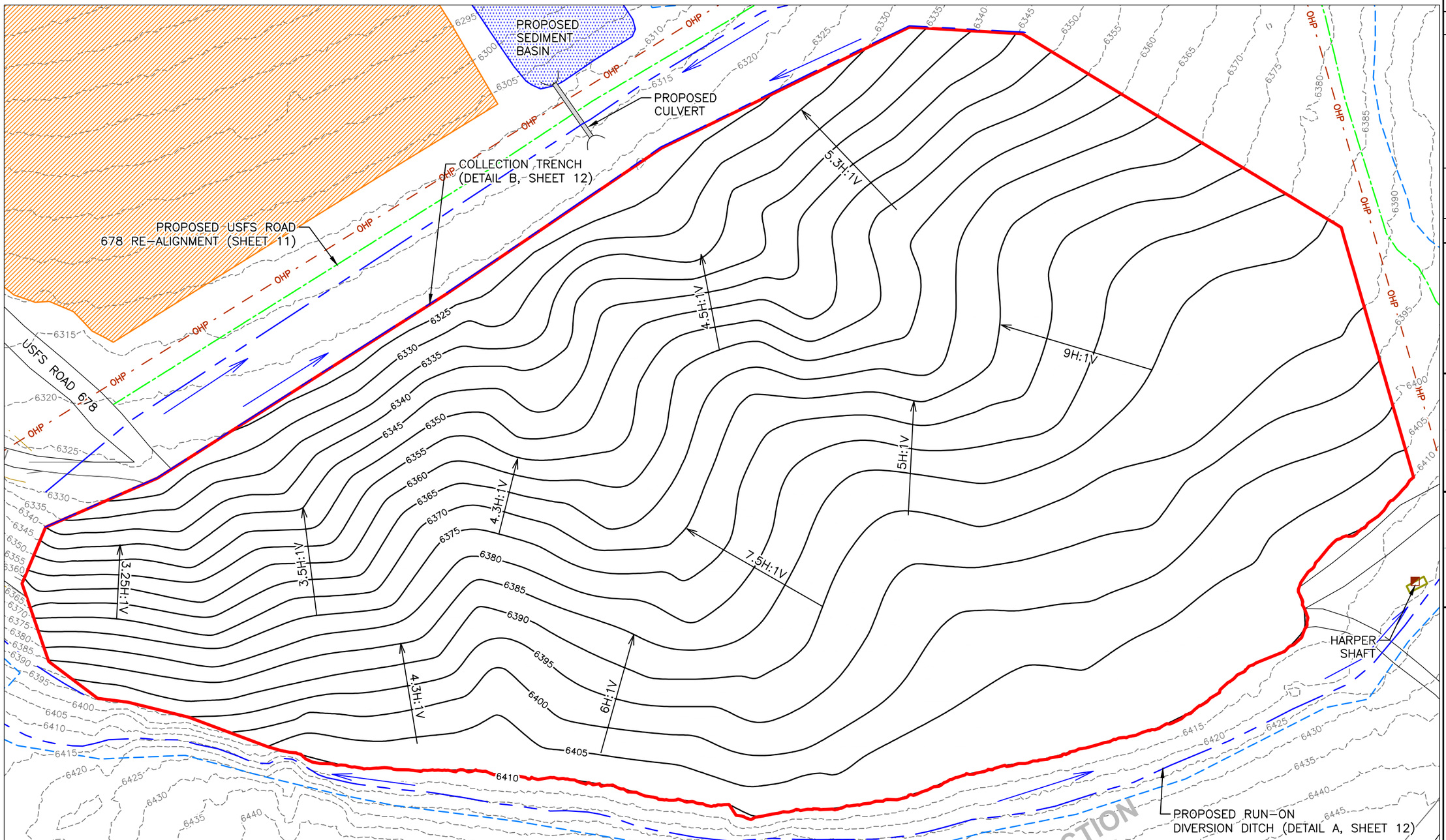
# PROPOSED ALTERNATE GRADING PLAN (1 OF 2)

## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 6A 7 OF 15
REV: A




Basemap: Topographic Contours Developed From LIDAR Surveys Conducted In June/July/August, 2010 By DJ&A, P.C. And MT LIDAR

**NOTE:**

1. FINAL GRADING WILL BE AS APPROVED IN THE FIELD BY THE ENGINEER AND OWNER.

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| REV. | DATE | DESCRIPTION | BY | CHK |
|---|---|---|---|---|
| A | 7/31/2014 | ISSUE FOR CONCEPTUAL DESIGN | REP | TH |

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SCALE: 1" = 100'
FILE: 776-GRADEPROP2

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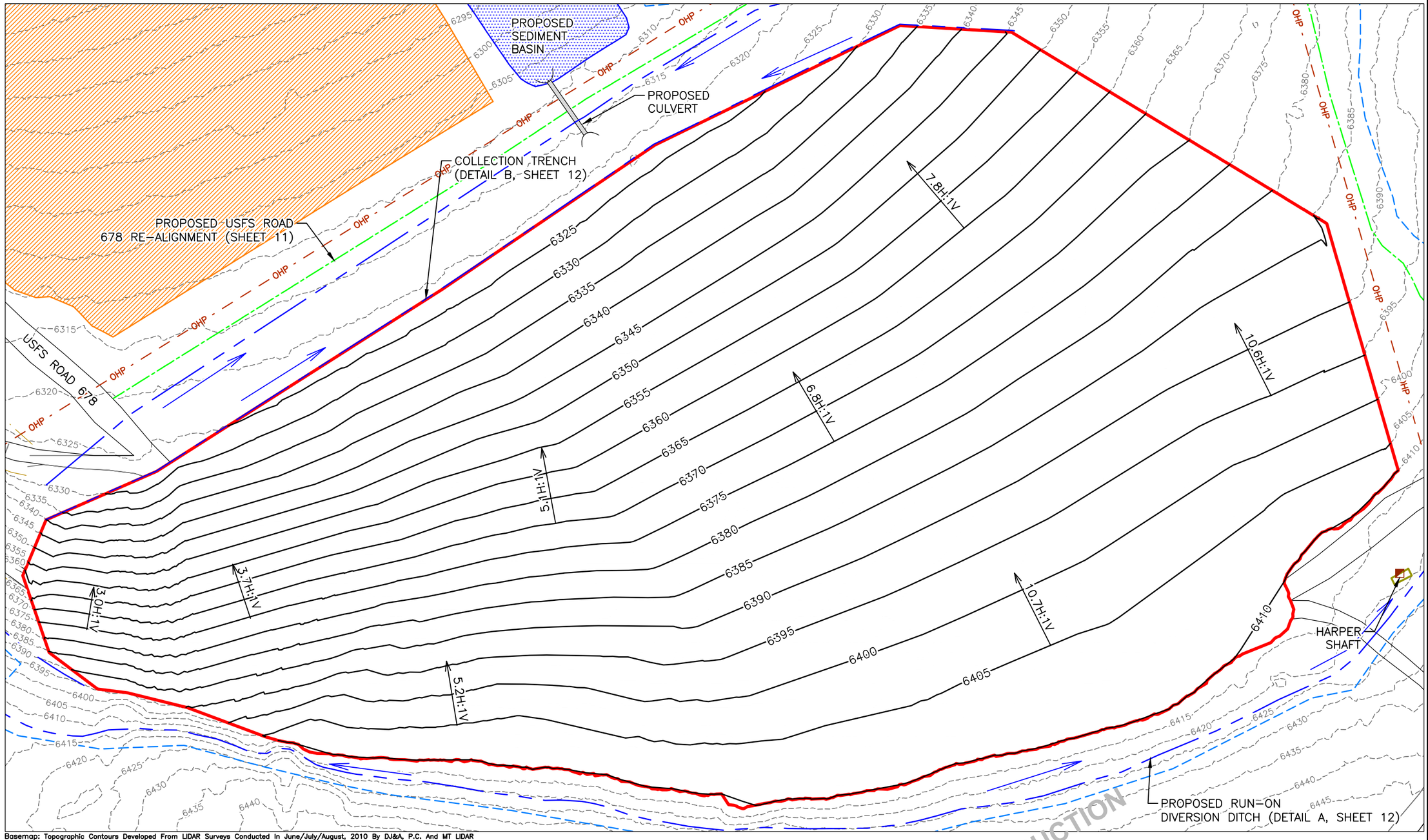
# PROPOSED FINAL GRADING PLAN (2 OF 2)

## BLACK PINE MINE REPOSITORY
## CONCEPTUAL DESIGN
## FEDERAL SUPERFUND SECTION

SHEET 7
8 OF 15
REV: A




Basemap: Topographic Contours Developed From LIDAR Surveys Conducted In June/July/August, 2010 By DJ&A, P.C. And MT LIDAR

**NOTE:**

1. FINAL GRADING WILL BE AS APPROVED IN THE FIELD BY THE ENGINEER AND OWNER.

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DATE: 6/2014
SCALE: 1" = 100'
FILE: 776-ALTGRADEPROP2

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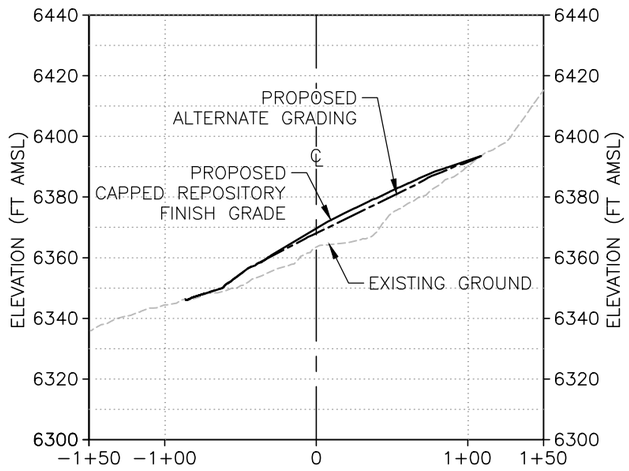
# PROPOSED ALTERNATE GRADING PLAN (2 OF 2)

## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 7A 9 OF 15

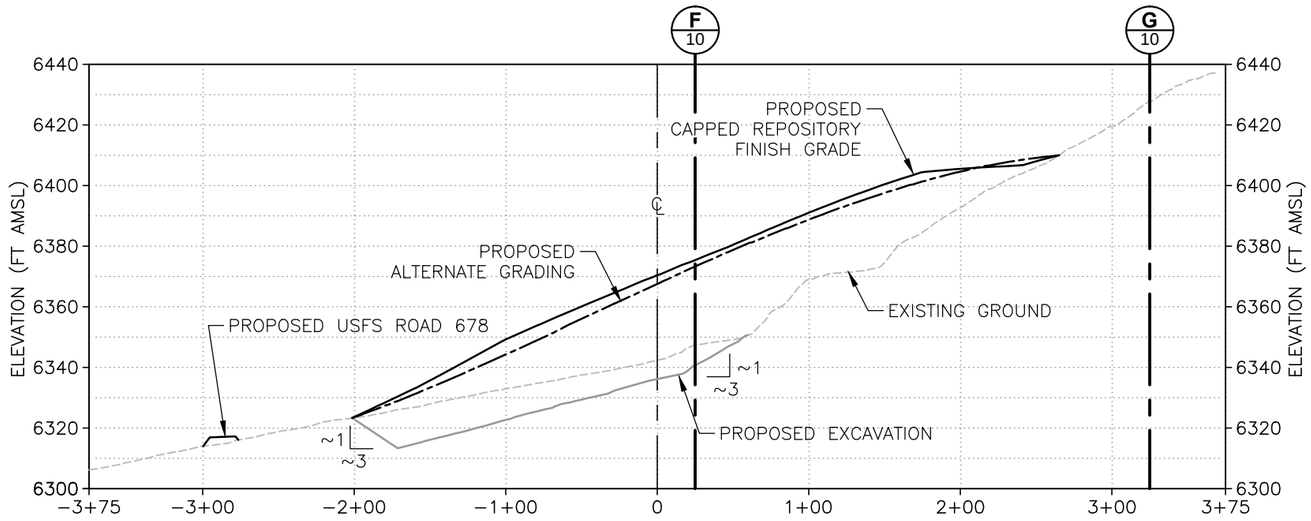
REV: A




**A** **CROSS-SECTION A-A'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL

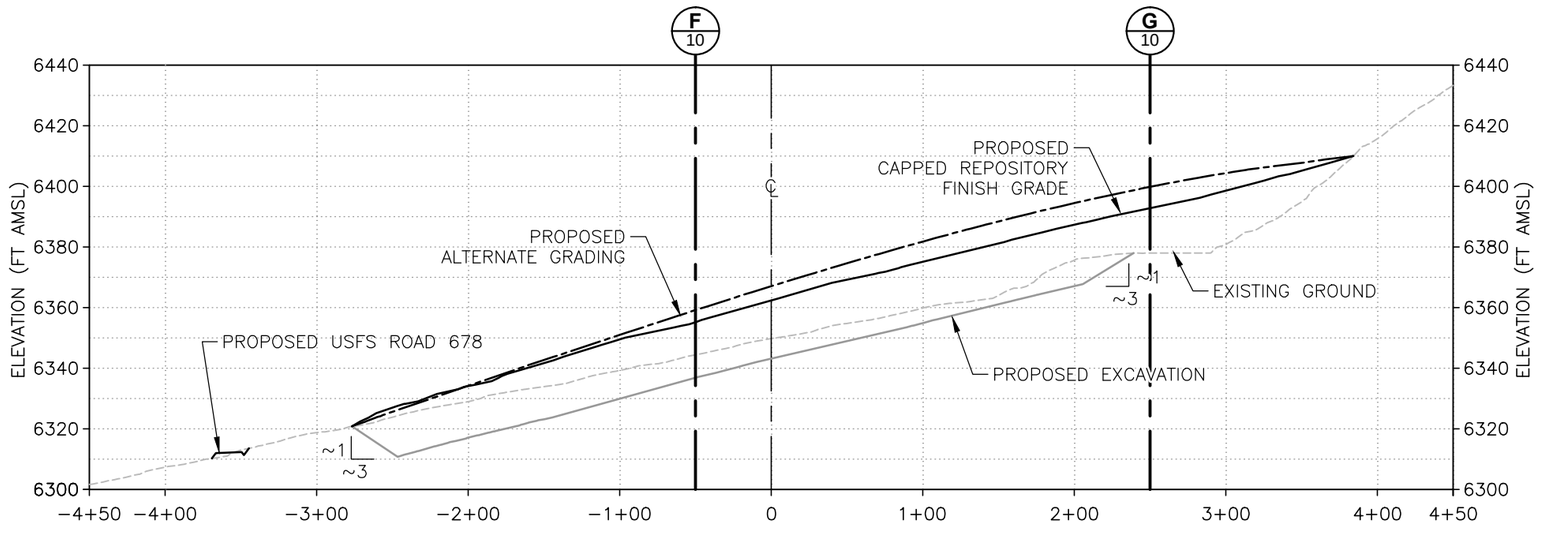
VERTICAL EXAGGERATION = 2X




**B** **CROSS-SECTION B-B'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL

VERTICAL EXAGGERATION = 2X




**C** **CROSS-SECTION C-C'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL

VERTICAL EXAGGERATION = 2X

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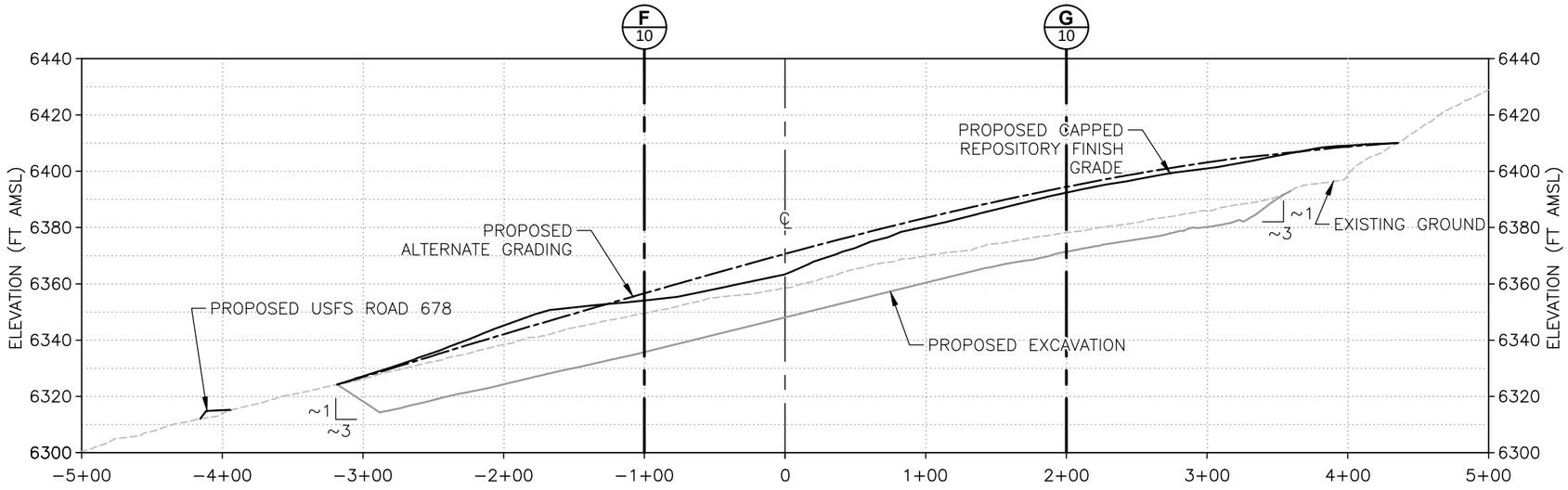
REPOSITORY CROSS-SECTIONS
(SHEET 1 OF 3)

BLACK PINE MINE REPOSITORY
CONCEPTUAL DESIGN
FEDERAL SUPERFUND SECTION

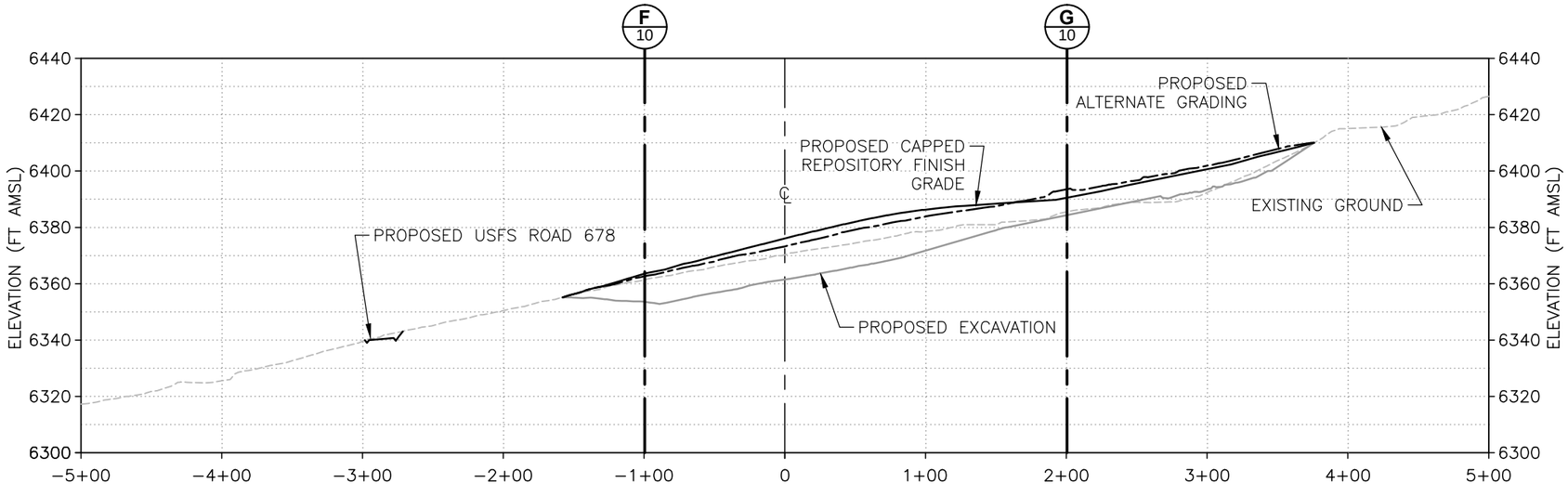
SHEET 8
10 OF 15

REV.: B




**D** **CROSS-SECTION D-D'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL
VERTICAL EXAGGERATION = 2X




**E** **CROSS-SECTION E-E'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL
VERTICAL EXAGGERATION = 2X

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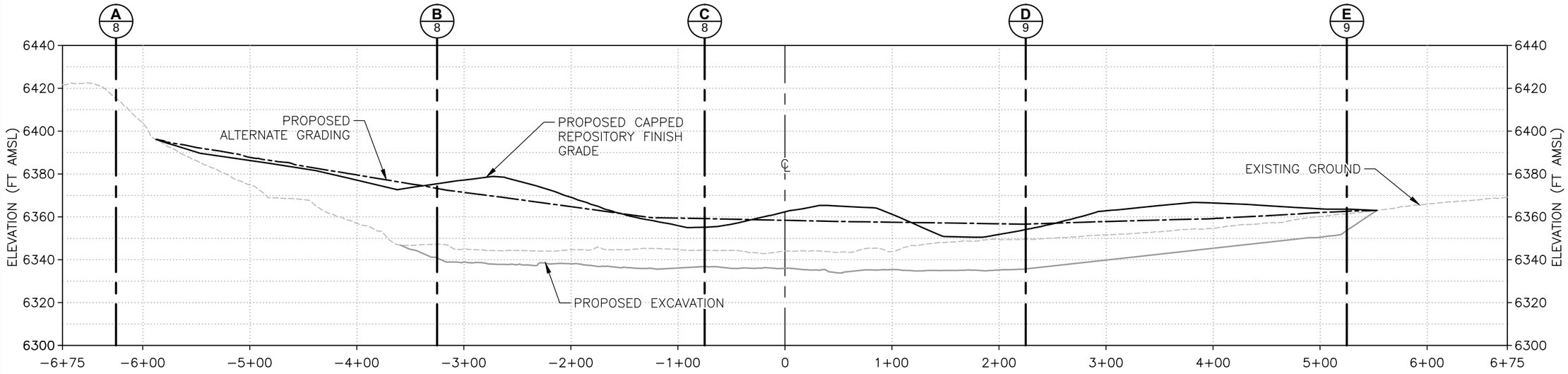
# REPOSITORY CROSS-SECTIONS (SHEET 2 OF 3)

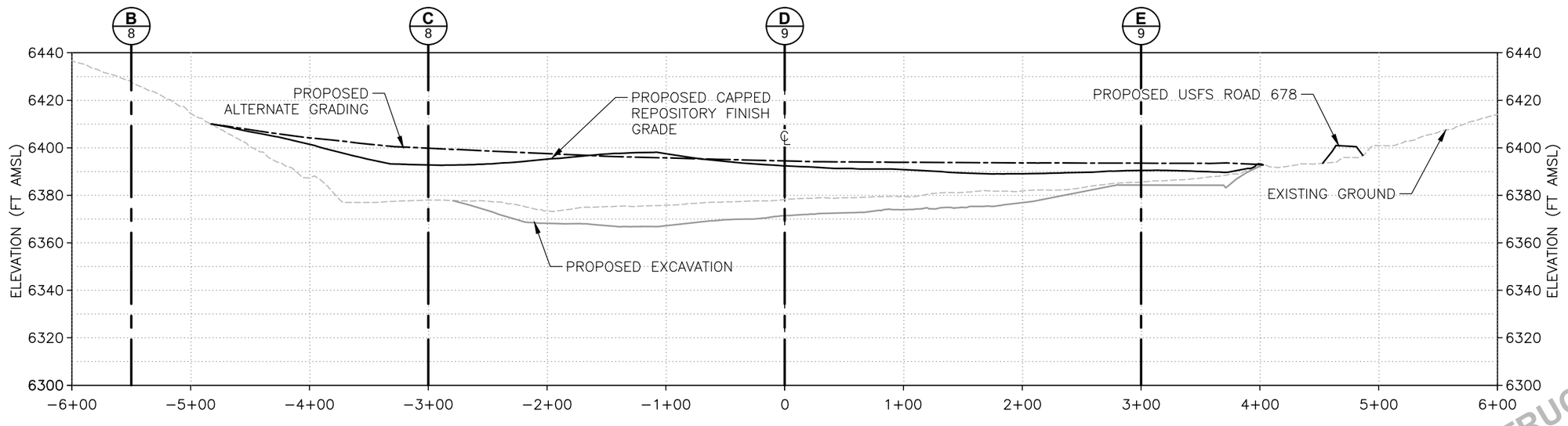
## BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION

SHEET 9
11 OF 15
REV: B




**F** **CROSS-SECTION F-F'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL
VERTICAL EXAGGERATION = 2X




**G** **CROSS-SECTION G-G'**
SCALE: H: 1" = 100' V: 1" = 50'

0 100' 0 50'
HORIZONTAL VERTICAL
VERTICAL EXAGGERATION = 2X

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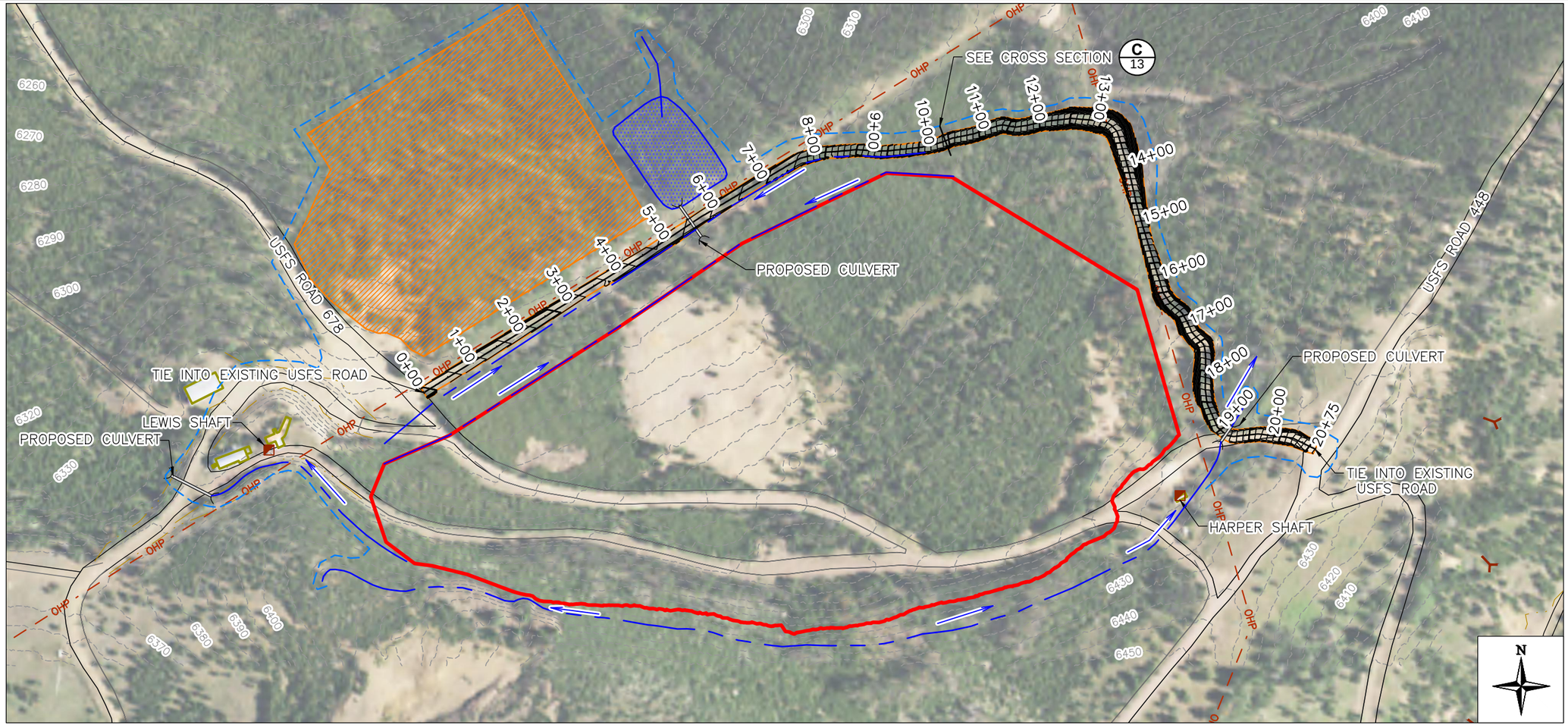
# REPOSITORY CROSS-SECTIONS (SHEET 3 OF 3)

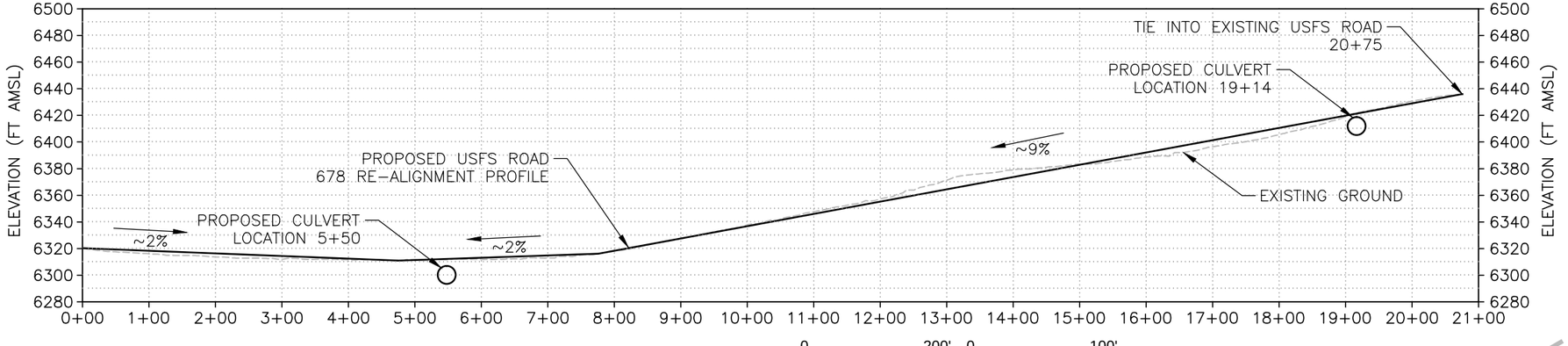
BLACK PINE MINE REPOSITORY
CONCEPTUAL DESIGN
FEDERAL SUPERFUND SECTION

SHEET 10
12 OF 15
REV.: B




1 **USFS ROAD PLAN VIEW**
SCALE: 1" = 200'

0 200'




A **USFS ROAD PROFILE**
SCALE: H: 1" = 200' V: 1" = 100'

0 200' 0 100'
HORIZONTAL VERTICAL
VERTICAL EXAGGERATION = 2X

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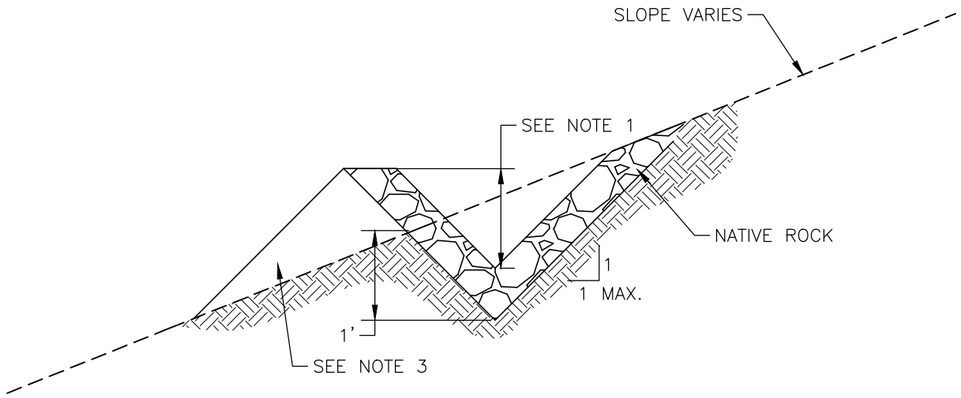
# FOREST SERVICE ROAD RE-ALIGNMENT PLAN AND PROFILE

BLACK PINE MINE REPOSITORY
CONCEPTUAL DESIGN
FEDERAL SUPERFUND SECTION

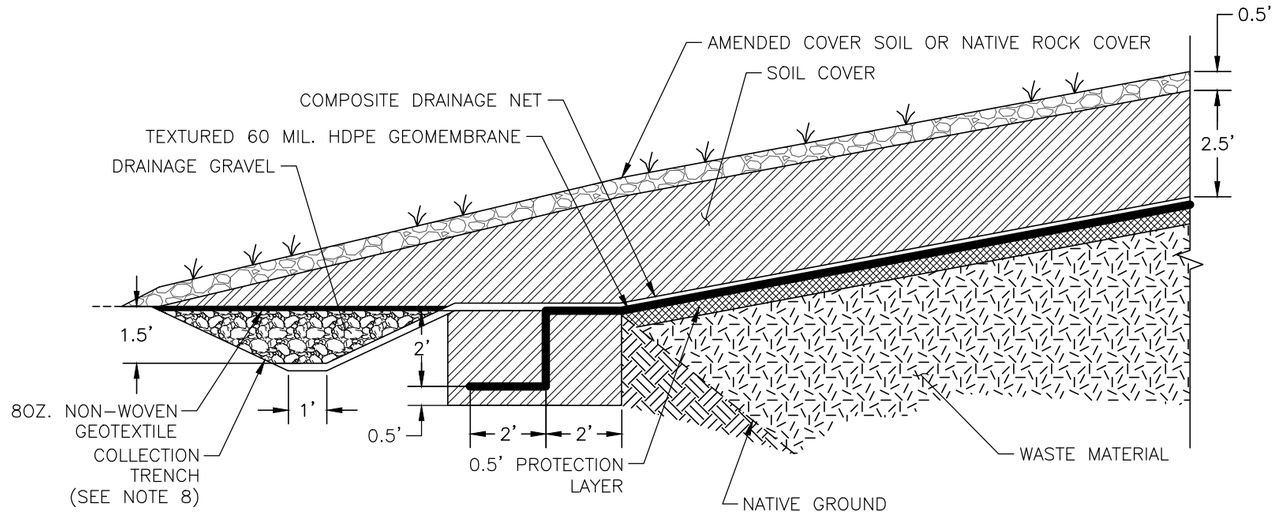
SHEET 11
13 OF 15
REV: B



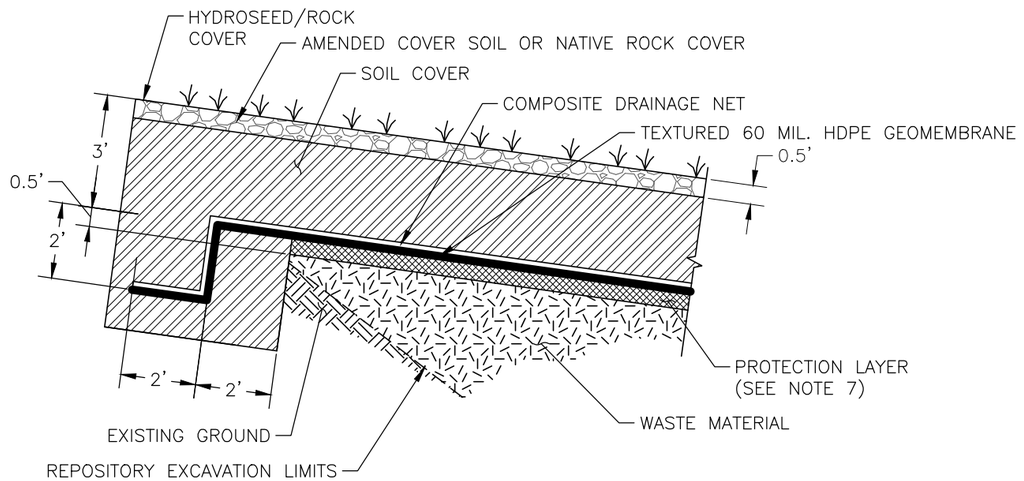

**A** **SECTION - RUN-ON DIVERSION DITCH**
SCALE: NONE

## NOTES:

1. MINIMUM DITCH DEPTH 1.5 FEET.
2. CUT DITCH MINIMUM 1 FOOT DEEP INTO EXISTING SLOPES WITH MAXIMUM 1H:1V SIDE SLOPES.
3. CONSTRUCT BERM WITH SPOILS FROM DITCH EXCAVATION.
4. LOCATE DITCH CENTERLINE AS SHOWN ON SHEETS 5 THROUGH 7, AND A MINIMUM OF 5 FEET FROM EDGE OF REPOSITORY COVER EXTENTS.
5. MINIMUM DITCH SLOPE SHALL BE 2%.
6. DITCH SHALL BE CUT IN AND LINED WITH NATIVE ROCK.
7. PROTECTION LAYER TO BE CONSTRUCTED OF COMPACTED WASTE MATERIAL.
8. MINIMUM COLLECTION TRENCH SLOPE SHALL BE 2%.




**B** **REPOSITORY COVER AND COLLECTION TRENCH**
SCALE: NONE




**C** **REPOSITORY COVER AND ANCHOR TRENCH**
SCALE: NONE

NOT FOR CONSTRUCTION

| REV. | DATE | DESCRIPTION | BY | CHK |
|---|---|---|---|---|
| B | 7/31/2014 | ISSUE FOR CONCEPTUAL DESIGN | REP | TH |
| A | 6/27/2014 | ISSUE FOR CLIENT REVIEW | REP | TH |

REVISIONS

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DATE: 6/2014
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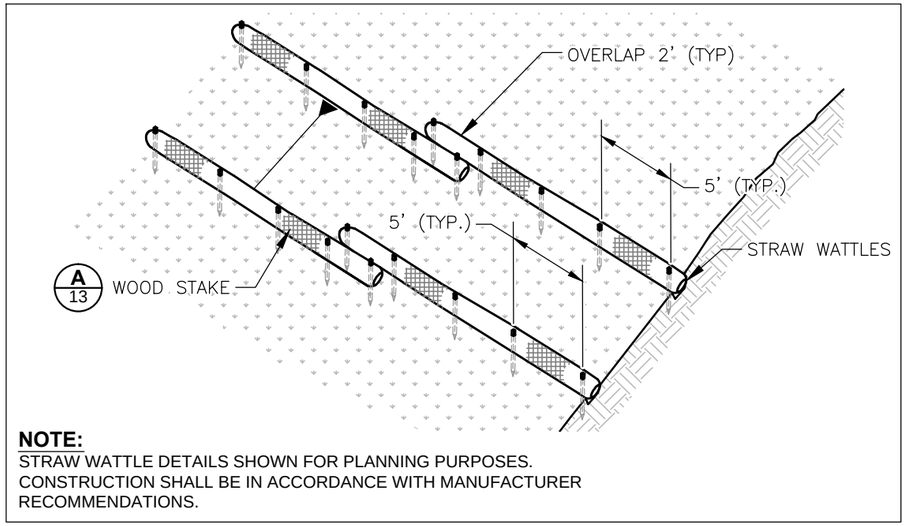
**CONSTRUCTION DETAILS (SHEET 1 OF 2)**

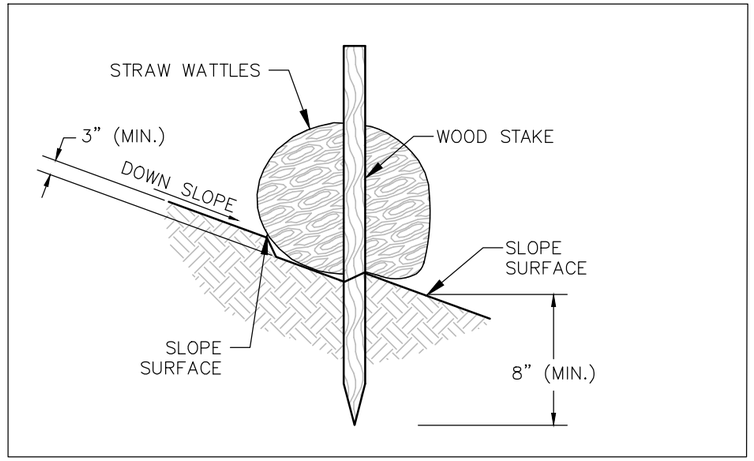
**BLACK PINE MINE REPOSITORY CONCEPTUAL DESIGN FEDERAL SUPERFUND SECTION**

SHEET 12
14 OF 15
REV: B



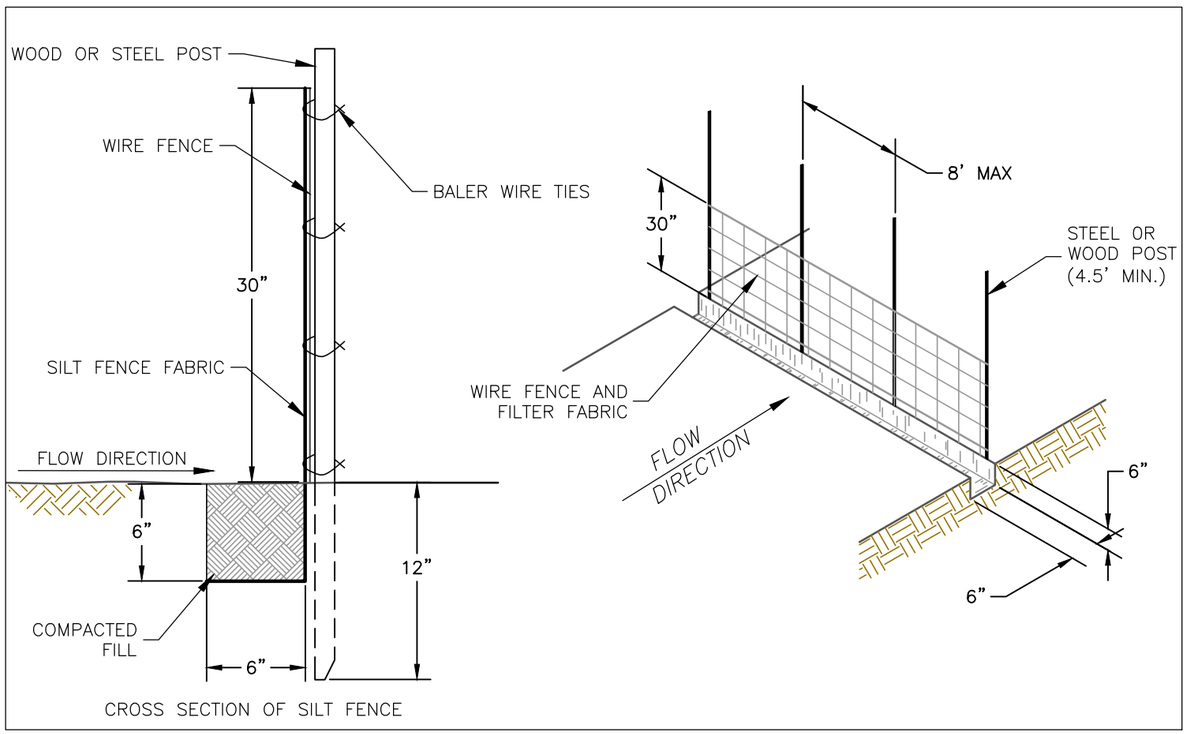

**NOTE:**
STRAW WATTLE DETAILS SHOWN FOR PLANNING PURPOSES. CONSTRUCTION SHALL BE IN ACCORDANCE WITH MANUFACTURER RECOMMENDATIONS.

**1 STRAW WATTLE DETAILS**
SCALE: NONE



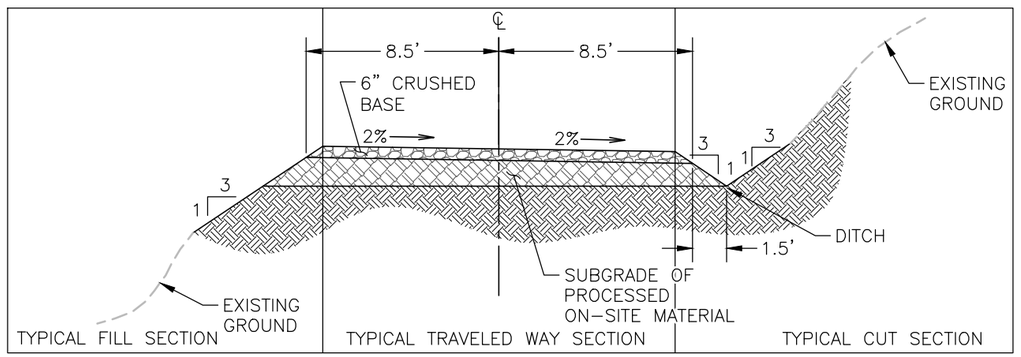

Source: North American Green, Evansville, IN, 2006

**A STAKE DETAILS**
SCALE: NONE




**NOTE:**
SET POSTS AND EXCAVATE A 6" X 6" TRENCH UPSLOPE ALONG THE LINE OF POSTS.

**B SILT FENCE**
SCALE: NONE




**C USFS ROAD TYPICAL CROSS SECTION**
SCALE: NONE

**NOTES:**

1. WIDTH VARIES, MINIMUM WIDTH 16 FEET OR AS APPROVED BY ENGINEER OR OWNER.
2. ROAD IMPROVEMENTS/CONSTRUCTION WILL COMPLY WITH THE USFS SPECIFICATIONS.

NOT FOR CONSTRUCTION

| REV. | DATE | DESCRIPTION | BY | CHK |
|---|---|---|---|---|
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| A | 6/27/2014 | ISSUE FOR CLIENT REVIEW | REP | TH |

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CONSTRUCTION DETAILS (SHEET 2 OF 2)

BLACK PINE MINE REPOSITORY
CONCEPTUAL DESIGN
FEDERAL SUPERFUND SECTION

SHEET 13
15 OF 15
REV: B

# APPENDIX B

# Waste Hauling Production Rate Evaluation

**APPENDIX B. EVALUATION OF TRUCK PRODUCTION RATES**
**REPOSITORY LOADING**
**BLACK PINE MINE**

| | haul distance (miles) | haul distance (feet) |
|---|---|---|
| Combination Mill | 1.6 | 8,448 |
| Combination Mine | 1.5 | 7,920 |
| Average Round Trip Distance | 3.1 | 16,368 |

| | yardage (cubic yards) |
|---|---|
| Combination Mill | 148,000 |
| Combination Mine | 203,200 |
| Total Yardage[1] | 351,200 |

[1] - Does not include waste material from Tim Smith Mine or Historic Mine Areas.

| Work Days per Week | Weeks per Month | Work Days per Month | Total Months | Total Work Days | Hours per Day | Total Work Time (hours) |
|---|---|---|---|---|---|---|
| 6 | 4.28 | 25.68 | 4 | 102.72 | 9 | 924.48 |

| Type of Truck | Top Speed - Loaded (mph) | Top Speed - Empty (mph) | Max. Capacity (Ton) | Capacity - struck (cubic yards) | Capacity - heaped (cubic yards) | *Travel Time - loaded (min) | *Travel Time - empty (min) | **Time to Load/Unload (min) | Total Haul Time (min) | Total Haul Time per load (hour) |
|---|---|---|---|---|---|---|---|---|---|---|
| Articulated Haul D25D | 15 | 20 | 25 | 13 | 18 | 12.4 | 9.3 | 10 | 31.7 | 0.53 |
| Articulated Haul D30D | 15 | 20 | 30 | 16.4 | 21.6 | 12.4 | 9.3 | 10 | 31.7 | 0.53 |
| Articulated Haul D400E | 15 | 20 | 40 | 21.6 | 28.8 | 12.4 | 9.3 | 11 | 32.7 | 0.55 |
| Belly Dump (40,000) | 15 | 20 | 23 | 17 | 19 | 12.4 | 9.3 | 7 | 28.7 | 0.48 |
| Side Dump (60,000lb) | 15 | 20 | 30 | 21 | 29 | 12.4 | 9.3 | 6 | 27.7 | 0.46 |
| Side Dump (40,000lb) | 15 | 20 | 20 | 17.3 | 24 | 12.4 | 9.3 | 6 | 27.7 | 0.46 |

* estimate per ~8500 feet at 6% grade plus rolling
**estimate

**APPENDIX B. EVALUATION OF TRUCK PRODUCTION RATES**
**REPOSITORY LOADING**
**BLACK PINE MINE**

**Scenarios**

| Type of Truck | # of Trucks | ***Total Haul Time per Load (min) | Total Haul Time per Load (hours) | Total # of Loads | Est. Capacity per Truck (cubic yards) | Yardage per Total Work Time per Truck (cubic yards) | Total Yardage | |
|---|---|---|---|---|---|---|---|---|
| Articulated Haul D25D | 4 | 31.7 | 0.53 | 1,750 | 15.5 | 27,122 | 108,488 | *** Assuming an additional 10 minutes haul |
| | 8 | 41.7 | 0.70 | 1,330 | 15.5 | 20,618 | 164,943 | time per every 4 trucks |
| | 12 | 51.7 | 0.86 | 1,073 | 15.5 | 16,630 | 199,559 | |
| | 16 | 61.7 | 1.03 | 899 | 15.5 | 13,935 | 222,954 | |
| | 20 | 71.7 | 1.20 | 774 | 15.5 | 11,991 | 239,823 | |
| Articulated Haul D30D | 4 | 31.7 | 0.53 | 1,750 | 19.0 | 33,246 | 132,985 | *** Assuming an additional 10 minutes haul |
| | 8 | 41.7 | 0.70 | 1,330 | 19.0 | 25,274 | 202,188 | time per every 4 trucks |
| | 12 | 51.7 | 0.86 | 1,073 | 19.0 | 20,385 | 244,621 | |
| | 16 | 61.7 | 1.03 | 899 | 19.0 | 17,081 | 273,298 | |
| | 20 | 71.7 | 1.20 | 774 | 19.0 | 14,699 | 293,977 | |
| Articulated Haul D400E | 4 | 32.7 | 0.55 | 1,696 | 25.2 | 42,747 | 170,986 | *** Assuming an additional 10 minutes haul |
| | 8 | 42.7 | 0.71 | 1,299 | 25.2 | 32,736 | 261,885 | time per every 4 trucks |
| | 12 | 52.7 | 0.88 | 1,053 | 25.2 | 26,524 | 318,288 | |
| | 16 | 62.7 | 1.05 | 885 | 25.2 | 22,294 | 356,699 | |
| | 20 | 72.7 | 1.21 | 763 | 25.2 | 19,227 | 384,543 | |
| Belly Dump | 4 | 28.7 | 0.48 | 1,933 | 18.0 | 34,789 | 139,155 | ***Assuming an additional 12 minute haul |
| | 8 | 40.7 | 0.68 | 1,363 | 18.0 | 24,532 | 196,253 | time per every 4 trucks |
| | 12 | 52.7 | 0.88 | 1,053 | 18.0 | 18,946 | 227,348 | |
| | 16 | 64.7 | 1.08 | 857 | 18.0 | 15,432 | 246,909 | |
| | 20 | 76.7 | 1.28 | 723 | 18.0 | 13,017 | 260,349 | |
| Side Dump (60,000) | 4 | 27.7 | 0.46 | 2,002 | 25.0 | 50,062 | 200,248 | ***Assuming an additional 12 minute haul |
| | 8 | 39.7 | 0.66 | 1,397 | 25.0 | 34,930 | 279,440 | time per every 4 trucks |
| | 12 | 51.7 | 0.86 | 1,073 | 25.0 | 26,822 | 321,869 | |
| | 16 | 63.7 | 1.06 | 871 | 25.0 | 21,770 | 348,313 | |
| | 20 | 75.7 | 1.26 | 733 | 25.0 | 18,319 | 366,373 | |
| Side Dump (40,000) | 4 | 27.7 | 0.46 | 2,002 | 20.7 | 41,351 | 165,405 | ***Assuming an additional 12 minute haul |
| | 8 | 39.7 | 0.66 | 1,397 | 20.7 | 28,852 | 230,817 | time per every 4 trucks |
| | 12 | 51.7 | 0.86 | 1,073 | 20.7 | 22,155 | 265,864 | |
| | 16 | 63.7 | 1.06 | 871 | 20.7 | 17,982 | 287,706 | |
| | 20 | 75.7 | 1.26 | 733 | 20.7 | 15,131 | 302,624 | |

# APPENDIX C

# Clay Winter Cover Calculations

**PERRONE CONSULTING, INC.**
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Bainbridge Island, WA 98110
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www.perroneconsulting.com

Project BLACK PINE MINE Sheet 1 of 9
Job No. 12104
Subject Interim Cover Thickness Date 6/26/14
Calc. By: V.J. Perrone Chk'd By:

## I. TASK

Evaluate interim repository cover thickness requirements.

## II GIVEN

A. Interim cover required from November to May.

B. Repository Area ≈ 15 acres.

C. Cover sloped to drain at 3% grade.

D Laboratory permeability test on cover material.

E. Average monthly snowpack

## III ANALYSIS

A. Laboratory data - Saturated permeability, $k_{sat}$

| Sample | Depth (ft) | LL | PL | USCS | Void Ratio, e | k (cm/sec) |
|---|---|---|---|---|---|---|
| RY-SS-10 | 14-16 | 35 | 15 | CL Sandy clay. | 0.421<br>0.368 | $2.5\times10^{-6}$<br>$2.0\times10^{-8}$ |
| RY-SS-11 | 6-8 | 28 | 17 | SC clayey Sand | 0.470<br>0.480<br>0.470 | $4.6\times10^{-7}$<br>$1.0\times10^{-6}$<br>$1.0\times10^{-7}$ |

See Figure 1, e vs log k

Samples were remolded & compacted to 95% Standard proctor & saturated prior to permeability testing.

RY-SS-10: $k_{avg} = 1.3\times10^{-6}$ cm/sec

RY-SS-11: $k_{avg} = 5.2\times10^{-7}$ cm/sec

$k_{avg} = 9.1\times10^{-7} \approx 10^{-6}$ cm/sec.

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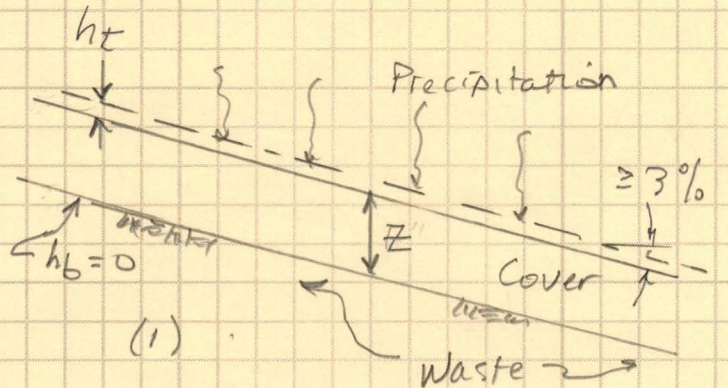
Project BLACK PINE MINE Sheet 2 of 9
Job No. 12104
Subject Interim Cover Date 6/26/14
Calc. By: VJP Chk'd By:

B. Estimate infiltration volumes for saturated cover.




1. Seepage $q = kiA$ (1)

$k = 10^{-6}$ cm/sec $= 1.2 \times 10^{-4}$ ft/hr

$A = 15$ acres $= 6.5 \times 10^5$ ft$^2$

$$i = \frac{h_t - h_b}{Z}$$

where: $h_t$ = water head at top of cover
$h_b$ = water head at bottom of cover = 0
$Z$ = cover thickness

2. Estimate $h_t$

Maximum monthly snowpack water equivalent ≈ 12 inches

Assume melt-out 12 inches in ½ month

$$m = \frac{12 \text{ inches}}{7 \text{ days} \times 24 \text{ hrs/day} \times} = 0.07 \text{ inches/hr}$$

Say: $m = 0.1$ inches/hr ≠ $h_t = 0.1$ inch

Melt duration, $t = \frac{12 \text{ in}}{0.1 \text{ in/hr}} = 120$ hrs

Let $Z = 6$ inches

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Project BLACK PINE MINE Sheet 3 of 9
Job No. 12104
Subject Interim Cover Date 6/26/14
Calc. By: VJP Chk'd By:

3. Estimate Flow volume $Q = qt$

$$q = 1.2 \times 10^{-4}\ ft/hr \times \frac{0.1\ inch - 0}{6\ inches} \times 6.5 \times 10^{5}\ ft^2$$

$$q = 1.30\ ft^3/hr$$

$$Q = qt = 1.30\ ft^3/hr \times 120\ hrs$$

$$Q = 156\ ft^3 \cong 1{,}200\ gallons$$

C. Estimate infiltration volume for unsaturated cover

1. Unsaturated permeability, $k_u$

$k_u = f(\psi)$ where $\psi$ = matric suction

Soil water characteristic curve relationship:

$$\frac{\theta - \theta_r}{\theta_s - \theta_r} = \left(\frac{\psi_a}{\psi}\right)^{\lambda} \qquad (2)$$

where:

- $\theta$ = Volumetric water content = 26.6%
- $\theta_r$ = Vol. residual water content = 0%
- $\theta_s$ = Vol. saturated water content = 29.9%
- $\psi_a$ = Air entry suction = 21.7 kPa
- $\lambda$ = curve fitting constant = 0.037

Ref. 1, Table 4 attached.

Type C soil, CL, LL=27, PL=15, 24% sand, 76% fines, Standard Proctor, optimum moisture content.

Calculate $\psi$ at optimum moisture content. Substituting in eq'n 2:

$$\frac{26.6 - 0}{29.9 - 0} = \left(\frac{21.7\ kPa}{\psi}\right)^{0.037}$$

$$(0.89)^{1/0.037} = \frac{21.7}{\psi}$$

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Project BLACK PINE MINE — Sheet 4 of 9
Job No. 12104
Subject Interim Cover — Date 6/26/14
Calc. By: VJP — Chk'd By:

$\psi \approx 500$ kPa – Type C soil

Also use Type M soil (Ref 1, Table 4)

LL = 32, PL = 14, 14% sand, 1% gravel, 85% fines.

$\theta = 26.2\%$, $\theta_s = 33.7\%$, $\theta_r = 0\%$

$\psi_a = 4.0$ kPa, $\lambda = 0.052$

Substituting into eq'n 2:

$$\frac{26.2 - 0}{33.7 - 0} = \left(\frac{4.0\ \text{kPa}}{\psi}\right)^{0.052}$$

$$(0.78)^{1/0.052} = \frac{4.0\ \text{kPa}}{\psi}$$

$\psi \approx 90$ kPa

Say $\psi = 100$ to 500 kPa

Relative permeability, $k_r = \frac{k_a}{k_{sat}}$

$$k_r = \frac{1}{\left\{\ln\left[e + \left(\frac{\psi}{A}\right)^B\right]\right\}^C} \qquad (3)$$

where:

Ref. 2, Fig 3f, Yolo light clay.

- A = curve fit parameter = 3.39
- B = " " " = 1.024
- C = " " " = 6.06
- e = void ratio = 0.3

Substituting into eq'n 3 with $\psi = 100$ kPa

$$k_r = \frac{1}{\left\{\ln\left[0.3 + \left(\frac{100}{3.39}\right)^{1.024}\right]\right\}^{6.06}}$$

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Project BLACK PINE MINE Sheet 5 of 9
Job No. 12104
Subject Interim Cover Date 6/26/14
Calc. By: VJP Chk'd By:

$k_r = 5.3 \times 10^{-4}$

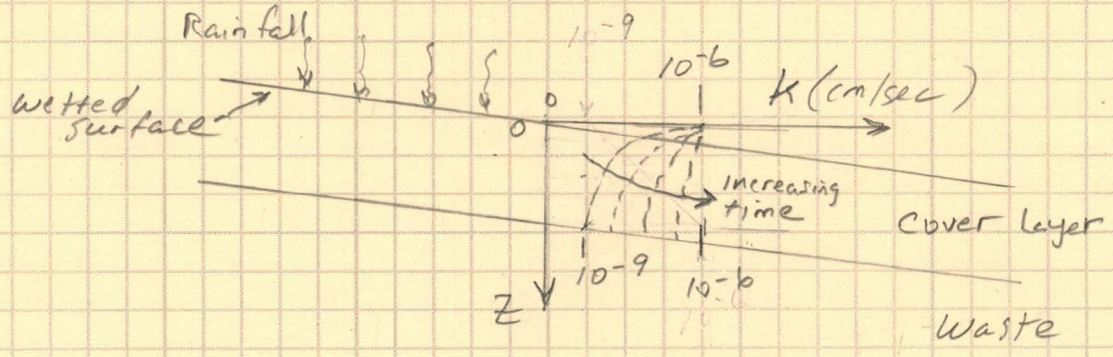
Say $k_r = 10^{-3}$

Then,

$k_u = k_{sat} \times 10^{-3}$

$k_u = 10^{-6} \times 10^{-3}$

$k_u = 10^{-9}$ cm/sec




Since k varies from $k_u = 10^{-9}$ cm/sec initially & then increases as cover layer moisture increases (suction decreases) to $k_{sat} = 10^{-6}$ cm/sec after prolonged wetting, actual Q < 1200 gallons

Assume $k_{effective} = 10^{-7}$ cm/sec.

then $Q = 1200 \text{ gals} \times \frac{10^{-7}}{10^{-6}} = \underline{120 \text{ gals}}$

## IV CONCLUSIONS

A. Six inch thick interim clay cover is adequate

B. Estimated infiltration < 120 gallons.

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Project BLACK PINE MINE Sheet 6 of 9
Job No. 12104
Subject Interim Cover Date 6/26/14
Calc. By: KJP Chk'd By:

## V REFERENCES

1. Tinjum, Benson, Blotz, 1997. "Soil water Characteristic Curves for Compacted clay," JGGED, NOV 1997, PP 1060 - 1069.

2. Leong and Rahardjo, 1997. "Permeability Functions for Unsaturated Soils," JGGED, Dec 1997, PP 1118 - 1126.

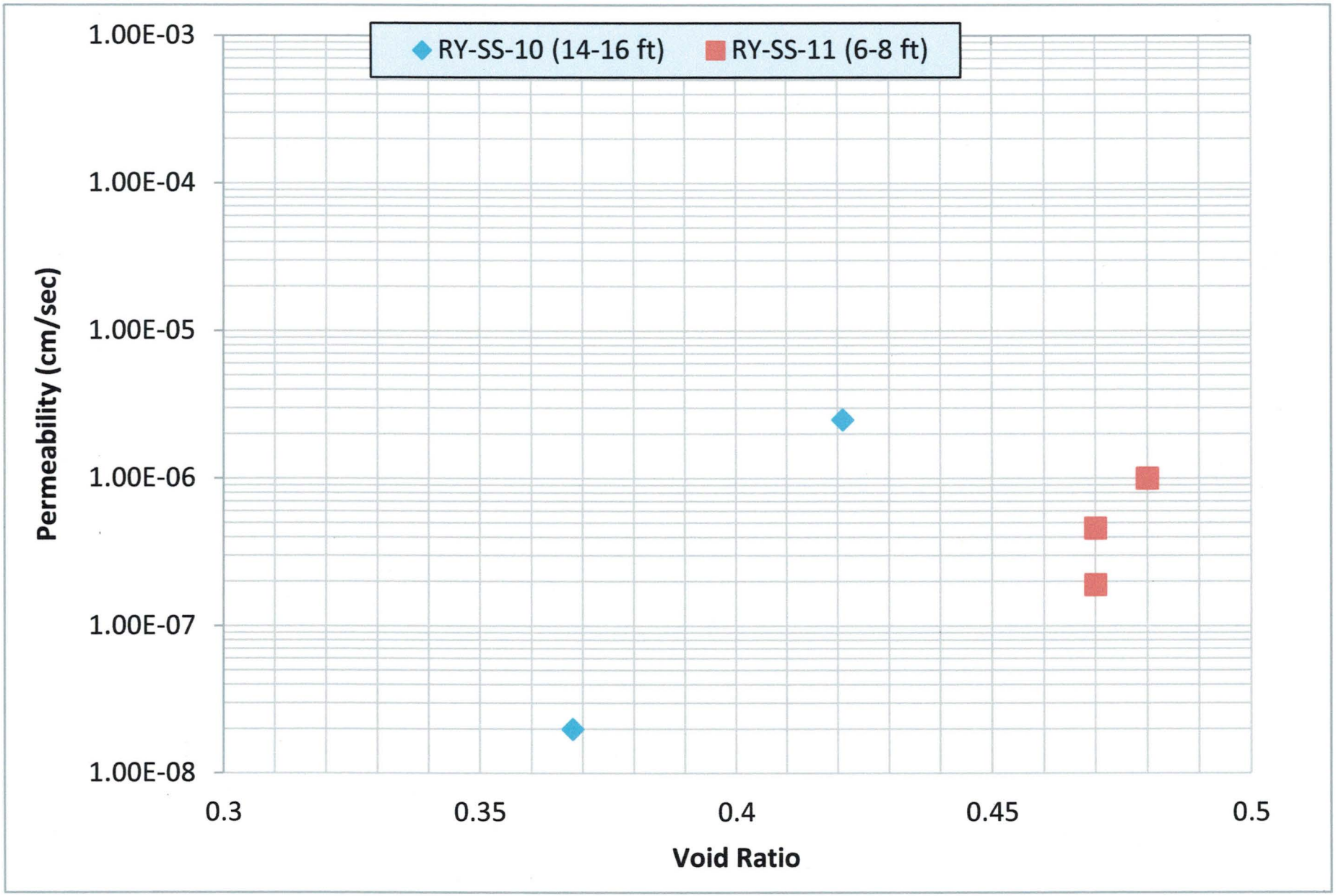


FIGURE 1
Void Ratio vs. Log K

Sheet 7 of 9
6/24/14

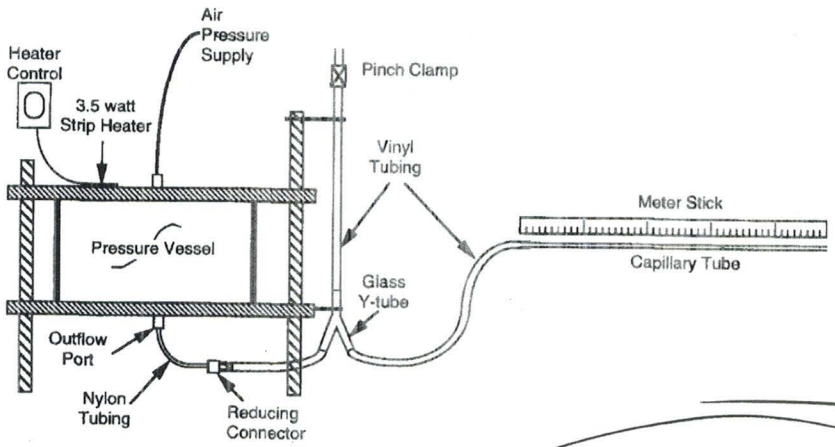


FIG. 4. Schematic of Outflow Collection and Measurement System

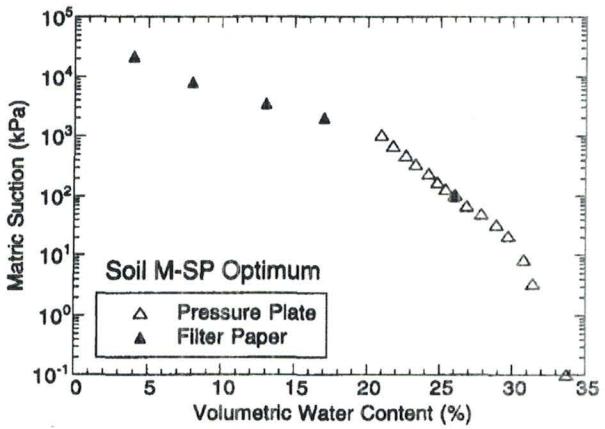


FIG. 5. SWCC Defined Using Pressure Plate Extractor and Filter Paper Method

The parameters in (1) and (2) describe the shape of the SWCC, as illustrated in Fig. 2. Soils with a steeper SWCC are characterized by smaller $\lambda$ [Fig. 2(a)] or $n$ [Fig. 2(b)]. Higher air-entry suction is characterized by greater $\psi_a$ in (1) [Fig. 2(a)] or smaller $\alpha$ in (2) [Fig. 2(b)]. That is, $\lambda$ and $n$ are directly related, whereas $\psi_a$ and $\alpha$ are inversely related. Soils with smaller pore size typically have greater $\psi_a$ or smaller $\alpha$, and soils with a broader range of pore sizes have smaller $\lambda$ or $n$ (Corey 1994).

TABLE 4. Brooks-Corey Parameters for SWCCs

| Soil (1) | Compaction water content (%)[a] (2) | Dry unit weight (kN/m³) (3) | $\theta_s$ (%) (4) | $\theta_r$ (%) (5) | $\lambda$ (%) (6) | $\psi_a$ (kPa) (7) | Standard error (8) |
|---|---|---|---|---|---|---|---|
| B | 21.8 (dry)[b] | 16.1 (SP)[c] | 39.2 | 0.0 | 0.091 | 2.5 | 0.441 |
| | 29.6 (opt) | 17.2 (SP) | 35.4 | 0.0 | 0.068 | 17.0 | 0.065 |
| | 35.8 (wet) | 16.4 (SP) | 38.1 | 0.0 | 0.078 | 26.0 | 1.03 |
| | 19.3 (dry) | 18.7 (MP) | 29.4 | 0.0 | 0.093 | 7.5 | 0.756 |
| | 26.0 (opt) | 19.2 (MP) | 27.5 | 0.0 | 0.128 | 18.4 | 0.223 |
| | 30.3 (wet) | 18.1 (MP) | 31.7 | 0.0 | 0.037 | 9.2 | 0.035 |
| C | 16.9 (dry) | 17.4 (SP) | 35.5 | 0.0 | 0.100 | 10.7 | 0.909 |
| | 26.6 (opt) | 18.9 (SP) | 29.9 | 0.0 | 0.037 | 21.7 | 0.016 |
| | 33.5 (wet) | 17.4 (SP) | 35.5 | 0.0 | 0.059 | 25.1 | 0.193 |
| | 9.6 (dry) | 19.6 (MP) | 27.75 | 0.0 | 0.074 | 6.2 | 0.132 |
| | 20.6 (opt) | 20.6 (MP) | 23.64 | 0.0 | 0.103 | 10.2 | 0.145 |
| | 25.3 (wet) | 19.7 (MP) | 27.0 | 0.0 | 0.030 | 24.9 | 0.010 |
| F | 23.2 (dry) | 15.4 (SP) | 43.9 | 0.0 | 0.131 | 17.4 | 0.586 |
| | 34.7 (opt) | 16.3 (SP) | 40.7 | 0.0 | 0.054 | 11.7 | 0.208 |
| | 39.0 (wet) | 15.8 (SP) | 42.5 | 0.0 | 0.025 | 18.2 | 0.114 |
| | 19.6 (dry) | 18.0 (MP) | 34.5 | 0.0 | 0.162 | 14.7 | 0.195 |
| | 28.6 (opt) | 18.8 (MP) | 31.6 | 0.0 | 0.149 | 45.6 | 0.126 |
| | 33.8 (wet) | 18.0 (MP) | 34.5 | 0.0 | 0.118 | 130.5 | 0.822 |
| M | 19.7 (dry) | 17.1 (SP) | 37.8 | 0.0 | 0.065 | 2.5 | 0.241 |
| | 26.2 (opt) | 18.2 (SP) | 33.7 | 0.0 | 0.082 | 4.0 | 0.166 |
| | 35.0 (wet) | 17.1 (SP) | 37.8 | 0.0 | 0.047 | 5.1 | 0.069 |
| | 20.0 (dry) | 19.8 (MP) | 27.9 | 0.0 | 0.126 | 7.6 | 0.026 |
| | 23.6 (opt) | 20.1 (MP) | 26.8 | 0.0 | 0.081 | 18.9 | 0.101 |
| | 27.6 (wet) | 19.5 (MP) | 29.0 | 0.0 | 0.053 | 22.8 | 0.058 |

[a]Volumetric water content.
[b]Dry, opt, and wet = dry of optimum water content, near optimum water content, and wet of optimum water content.
[c]SP and MP = standard Proctor compaction effort and modified Proctor compaction effort.

## MATERIALS AND METHODS

### Soils

Four clays from the University of Wisconsin soil bank (Trast 1993) were selected for testing. They are referred to here as B, C, F, and M, following the nomenclature in Benson and Trast (1995). These soils range in depositional origin, mineralogical composition, plasticity, particle-size distribution, and compaction characteristics. A summary of the mineralogy of the soils is contained in Table 1. Atterberg limits and particle-size characteristics are in Table 2. Compaction characteristics of the soils are in Table 3. Compaction curves for each soil corresponding to standard and modified compactive efforts (ASTM D 698, D 1557) are contained in Trast (1993) and Tinjum (1995).

### Pressure Plate Extractors

Volumetric pressure plate extractors were used to measure the SWCCs. Pressure plate extractors work on the principle of axis translation. Axis translation employs the fundamental definition of matric suction; i.e., matric suction is the pressure difference across the air-water interface, namely, $\psi = u_a - u_w$, where $u_a$ is the pore air pressure and $u_w$ is the pore water pressure. In a pressure plate extractor, $u_w$ is maintained constant (usually $u_w = 0$) and $u_a$ is increased to obtain the desired matric suction (Hilf 1956; Olson and Langfelder 1965; Fredlund and Rahardjo 1993).

A schematic of the extractor used in this study is shown in Fig. 3. A detailed description of the extractor can be found in Tinjum (1995). Pressure was applied using regulated compressed air. A saturated porous ceramic disk with an air-entry pressure of 1,500 kPa was placed below the soil. A thin porous stainless steel disk was placed beneath the ceramic disk to direct outflow from the ceramic disk to the outflow port (Fig. 3). The volume of expelled water was measured continuously without removing the soil specimen from the extractor via a



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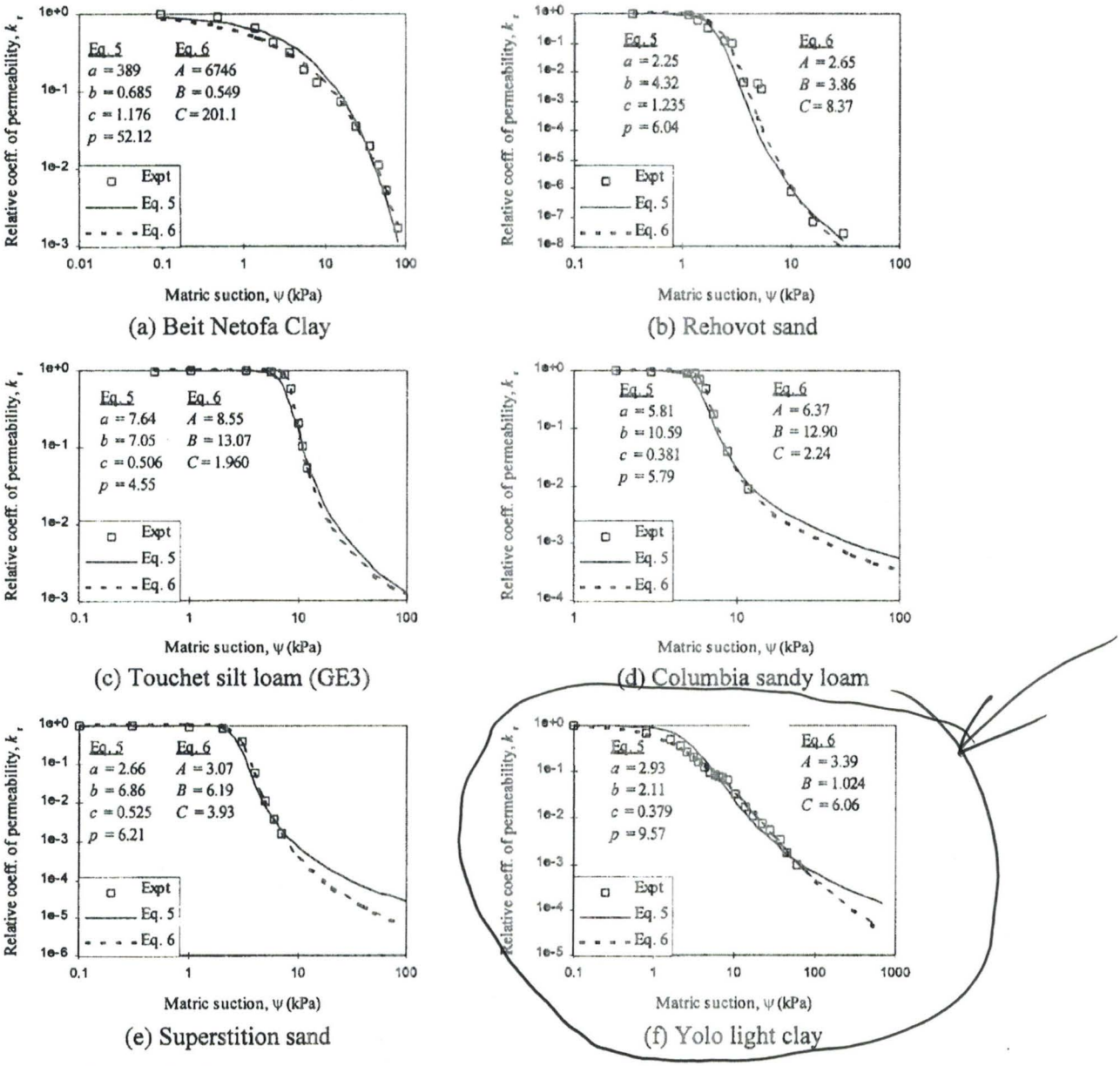


**FIG. 3. Best Fitted Permeability Function $k(\psi)$ Using (5) and (6) for Several Soil Types [Data from Moore (1939), Richards (1952), Brooks and Corey (1964), Rubin et al. (1964), and Rawitz (1965)]**

$$k_r = \frac{1}{\left\{\ln\left[e + \left(\frac{\psi}{A}\right)^B\right]\right\}^C} \tag{6}$$

The curves given by (6) are shown in Figs. 3 and 4 as dotted lines. The values of the constants $A$, $B$, and $C$ are also shown in the figures. It can be observed that the fit in all cases is better than that given by (5).

The empirical permeability functions given by (3) and (6) are very useful for soils with enough permeability data where representative values of $p$ or $A$, $B$, and $C$ can be obtained.

## MACROSCOPIC MODELS

The objective of the macroscopic models is to derive an analytical expression for the permeability function (Mualem 1986). Common to these models is the first assumption of similarity between laminar flow (microscopic level) to flow in porous media (macroscopic level). The flow is then solved for a simple laminar flow system to interrelate the macroscopic variables of average flow velocity, hydraulic gradient, permeability, and hydraulic radius. A direct analogy of these variables to the corresponding variables for a soil-water-air system is then made. Because of the simplifying assumptions made, all the microscopic models have the following general form:

$$k_r = S_e^{\delta} \tag{7}$$

where $S_e$ = effective degree of saturation defined as $S_e = (S - S_r)/(1 - S_r)$; $S$ and $S_r$ = degree of saturation and residual degree of saturation, respectively; and the exponent $\delta$ is a constant. The value of $\delta$ varies depending on the assumptions made: Averjanov (1950) suggested $\delta = 3.5$, Yuster (1951) suggested $\delta = 2$, Irmay (1954) suggested $\delta = 3$, and Corey (1954) suggested $\delta = 4$. The main criticism of the macroscopic models



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