Draft

REPOSITORY SITE EVALUATION REPORT
NEW WORLD MINING DISTRICT
RESPONSE AND RESTORATION PROJECT

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NEW WORLD MINING DISTRICT
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1.0 INTRODUCTION

Maxim Technologies, Inc. (Maxim) prepared this report for the United States Department of Agriculture, Forest Service (USDA-FS), Region 1. The purpose of this report is to evaluate and summarize existing technical information on groundwater, surface water, geology, soil, and other resources at three potential mine waste repository areas located in the New World Mining District (District). The District is situated in Park County, Montana near the town of Cooke City. The locations of the candidate areas are shown on Figure 1. A central repository site is being considered to isolate approximately 60,000 cubic yards (46,000 cubic meters) of waste rock and tailings currently located at various abandoned mine and mill sites in the District and possibly an additional 370,000 cubic yards (283,000 cubic meters) of tailings from the McLaren tailings site near Cooke City. Based on preliminary estimates, each of the locations examined will be able to contain a minimum of 500,000 cubic yards (400,000 cubic meters) of waste material, or approximately 810,000 tons. Depending on design requirements, an area of approximately 15 to 25 acres will be required for the repository.

The three general areas examined in this report were selected during a meeting held on April 21, 1999 with USDA-FS, Montana Department of Environmental Quality (MDEQ), Maxim, and Maxim subcontractors. Based on data collected by Crown Butte Mines, Inc. (CBMI) during their evaluation of 27 potential tailings repository sites in the District, the three candidate areas selected for analysis in this report were deemed to be the best suited for a potential central mine waste repository. Based on data presented in this report and in consideration of certain other technical and administrative issues, the USDA-FS may identify a central repository site suitable for disposal of historic mining wastes located on District Properties. The three sites evaluated include two locations in the Fisher Creek drainage, a tributary to the Clark Fork of the Yellowstone River, (FC-4 and FC-6) and one location in the headwaters area of Soda Butte Creek, a tributary of the Lamar River (SB-4). Two individual subareas at the SB-4 location were identified and evaluated.

Objectives of this evaluation were to collect and review existing information on the three candidate repository areas and to summarize the advantages and disadvantages of each area based on that information. We have selected a preferred area based on the information reviewed and prepared recommendations for additional information needed to further evaluate the suitability of the preferred site for use as a central mine waste repository. Criteria which we used during our evaluation and selection process are listed in Table 1.

Technical information reviewed to support this analysis was obtained from the administrative record file located in the Gallatin Forest Supervisor Office in Bozeman, Montana. The data were collected during field investigations completed by various engineering and environmental consulting firms from 1990 to 1996 for Crown Butte Mines, Inc (CBMI). Additional information sources which were used in this evaluation included data collected by the Environmental Protection Agency (EPA) and Montana Department of Natural Resources and Conservation (DNRC) during prior investigations of the area, data collected by the Montana Bureau of Mines and Geology (MBMG), and published geologic and hydrogeologic information.

The following sections of this report summarize the general features of each of the three potential areas, along with geologic, hydrologic, and materials information available. Environmental conditions that would affect the suitability of each of the areas as a repository location are also summarized. Information for each area examined is presented in Table 2.

TABLE 1
Repository Site Evaluation Criteria
New World Mining District
Response and Restoration Project

GENERAL SITE FEATURES
- Size of Site (acres)
- Estimated Capacity
- Elevation of Site
- Slope
- Visual Compatibility
- Access to Site
- Operations and Maintenance

GEOLOGY
- Surficial Material
- Type of Bedrock
- Depth to Bedrock
- Repository Base Characteristics
- Proximity to Faults, Unstable Slopes
- Sulfide Mineralization/Acid Potential
- Non-sulfate Sulphur
- Acid/Base Potential

HYDROGEOLOGY
- Depth to Groundwater
- Hydraulic Conductivity
- Run-on/Run-off Characteristics
- Land Application Area

MATERIALS
- Embankment Materials Availability
- Permeable Backfill Availability
- Coversoil Availability and Quality
- Soil Properties
  - Shear Strength
  - Consolidation
  - Slope Stability
  - Chemical Properties

ENVIRONMENTAL
- Avalanche Potential
  - Disturbance Area/New Roads
- Wildlife
- Aspect
- Vegetation Type
- Wetlands Area/Occurrence

Figure 1

Figure 1 back page

TABLE 2
Summary of Repository Site Characteristics
Response and Restoration Project
New World Mining District

Site Attribute		Repository Site Name			
		FC-4	FC-6	SB-4	
				A	B
GENERAL SITE FEATURES					
Size of Site (acres)		35	49	23	71
Elevation of Site (feet)		9500	9600	8400	8400
Slope (%)		12	7-10	7-10	13
Visual Compatibility		Fair	Fair	Fair-Good	Fair-Good
Access to Site		Fair/Poor	Fair-Poor	Good	Good
Operations and Maintenance		Fair	Fair	Good	Good
GEOLOGY					
Surficial Material		Qc	Qc	Qg	Qg
Type of Bedrock		Rhyodacite Porphyry	Gray granitic gneiss to schistose gneiss and granite	Gray granitic gneiss to schistose gneiss and granite	Gray granitic gneiss to schistose gneiss and granite
Depth to Bedrock (feet)		5	5	10-30 est.	20-50
Repository Base Quality		Bedrock - Fair	Qc/Bedrock – Fair	Qg – Good	Qg – Good
Proximity to Faults\ Unstable Slopes		Good	Good	Good	Good
Sulfide Mineralization (Acid Potential, meq/100g)		NA	NA	<1	<1
Non-Sulfate Sulphur (%)		NA	NA	<0.01	<0.01
Acid/Base Potential (Parts CaCO3/1000)		NA	NA	3-6	3-6
HYDROGEOLOGY					
Depth to Groundwater	Surficial Material	NA	NA	NA	NA
	Bedrock	NA	NA	4 to +2	4 to +2
Hydraulic Conductivity	Surficial Material	NA	NA	NA	NA
	Bedrock	NA	NA	$3x10^{-5}$ to $2x10^{-7}$	$3x10^{-5}$ to $2x10^{-7}$
Suitable Run-on/Run-off		Good	Fair	Fair	Good
Land Application Area		Fair-Poor	Fair	Good	Good

TABLE 2 (continued)
Summary of Repository Site Characteristics
Response and Restoration Project
New World Mining District

Site Attribute		Repository Site Name			
		FC-4	FC-6	SB-4	
				A	B
MATERIALS					
Embankment Materials Availability		Qc/Bedrock	Qc/Bedrock	Bedrock or glacial till. Rock could be crushed, glacial till may need mixing with other materials to be suitable.	Qg/Bedrock
Permeable Backfill Availability		Good	Good	?	?
Coversoil	Availability	Poor/Fair	Qc - Fair/Good	Qg - Good	Qg – Good
	Quality	Qal – Fair	Qc – Fair	Qg - Good	Qg – Good
Soil Properties	Shear Strength	Bedrock – Good	NA	NA	NA
	Consolidation	Bedrock	Qc/Bedrock	Qg	Qg
	Slope Stability	Good	Good	Good	Good
	Acid/Base Potential (Parts CaCO3/100)	NA	NA	11-33	11-33
	Acid Potential (meq/100g)	NA	NA	3-8	3-8
	Non-sulfate Sulfur (%)	NA	NA	0.04-0.13	0.04-0.13
ENVIRONMENTAL					
Avalanche Potential		yes	yes	no	No
Aspect		East	Southeast	Southeast	Southeast
Wetlands Area (acres)		6.7	2.0	2.4	9.2
Vegetation Type		Above timberline to some alpine coniferous forest	Open meadow	Alpine coniferous forest (burned)	Alpine coniferous forest (burned)

Note: NA indicates information not available

2.0 REPOSITORY SITE FC-4

The FC-4 site is located on the southeast flank of Henderson Mountain and is accessed from Fisher Creek Road and an unimproved gravel road which joins Fisher Creek Road from the west (Figure 1). The site is located near the center of Section 13, T9S R14E, Prime Meridian of Montana (PMM). Knight Piesold (1995) drilled two core boreholes (HM-1 and HM-2) to depths of 26.3 feet and 51.2 feet on and near this site in 1994 (Figure 1). Logs for these boreholes were examined for this evaluation and are contained in Appendix A.

2.1 GENERAL SITE FEATURES

The FC-4 site is situated on a relatively flat terrace on Henderson Mountain along on a ridge which extends southeasterly. The site encompasses an area of approximately 35 acres and slopes to the east at an average gradient of 12% (Figure 2). The elevation of the site is approximately 9,500 feet above sea level and is not forested (based on examination of a USGS topographic map of the area). The site is constrained by private land located to the northwest, southwest, and southeast. This limits the area available for the repository and also may limit expansion potential of the site.

Fisher Creek is located approximately 2500 feet from the northeast edge of the site (Figure 1). Topography in the vicinity of the site consists of relatively steep slopes to the southwest and a gentler slope to the northwest (Figure 2). The topography drops off relatively quickly to the northeast towards Fisher Creek and is a gentle downhill slope to the east and southeast.

The site is accessed by an unimproved road which starts at Fisher Creek Road, approximately 1.8 miles from its junction with Montana Highway 212. This road is relatively steep with numerous switchbacks as it climbs approximately 700 feet to the site. This road would need to be improved to accommodate trucks hauling waste to the site.

2.2 GEOLOGY

Geology in the vicinity of the FC-4 site consists of a rhyodacite porphyry of the Henderson Mountain stock mapped by Elliott (1979) (Figure 3). This Tertiary intrusive unit and associated dikes are approximately 44 million years old and are light to medium greenish gray, weak to moderately altered, and are usually propylitic (Elliott, 1979). The units have a high mafic mineral content and approximately 25 to 40% phenocrysts, which are typically orange weathering plagioclase, hornblende, and biotite in an aphanitic potassium feldspar-rich groundmass. Cambrian Flathead Sandstone outcrops along the southwest side of the site and several exposures of Precambrian granitic gneiss are mapped in the center of the area (Elliott, 1979). Geologic mapping of the area indicates that bedrock is near the surface over most of the site, with thin glacial or colluvial deposits present. Glacial deposits are mapped below the site to the southeast and south of the access road.

Borehole logs for the two geotechnical wells (HM-1 and HM-2, Appendix A) indicate approximately five feet of silty sand with gravel and cobbles overlie bedrock at the site (Figure 3). Core recovery in the bedrock was relatively good and the Rock Quality Designation (RQD) of the bedrock improved with depth. Fracture spacing ranged from greater than 10 fractures per foot in the upper 10 feet of bedrock to typically one or less fracture per foot for bedrock below 15 feet.

The geotechnical stability of the site would likely be good, based on the fact that the facility would be placed on bedrock. The presence of steep slopes to the southwest above the site may impact the suitability of the repository area due to landslide and/or avalanche potential. Knight Piesold (1994) in a letter to Crown Butte Mines also considered the site to be geotechnically stable.

Mineralization of the rhyodacite bedrock reported on the log for borehole HM-2 indicated minor traces of sulfides in the rock. The bedrock was reported to be highly altered with most of the feldspars being chloritized into epidote and selenite. Information of the sulphur content and acid/base potential of the rhyodacite was not available. No faults or other adverse geologic features are mapped in the vicinity of the site. The base material for a repository in this location would be rhyodacite bedrock.

2.3 HYDROGEOLOGY

Information on the depth to groundwater or static water level in the boreholes is not reported on the borehole logs. The logs did contain results of packer tests which were conducted on bedrock in the boreholes. The tests were performed at depths of nine to 17 feet below ground surface (BGS) and 15 to 26.3 feet BGS in borehole HM-1 and at depths of eight to 17 feet, 17 to 27 feet, 28 to 37 feet, and 37 to 51.2 feet BGS in borehole HM-2. Reported hydraulic conductivities of the bedrock were relatively low, and ranged from 4.1×10^{-4} centimeters per second (cm/sec) to 5.7×10^{-5} cm/sec.

Groundwater at the site likely moves in a bedrock-controlled system, with rock joints and fractures controlling infiltration and near subsurface water movement beneath the site. Recharge to the bedrock system is derived from colluvium and bedrock exposed to the west and southwest. Groundwater flow is likely toward the east and northeast. Run-on to the site would be derived from higher slopes to the west and southwest.

2.4 MATERIALS CHARACTERISTICS

Material needed for embankment fill, permeable backfill, and coversoil could be obtained from the thin sand and gravel colluvium which covers the site, excavated from bedrock, or imported from other areas. The quantity of colluvial material which may be available from the repository area was estimated by assuming an average thickness of five feet over the 35 acre site. This would result in a volume of approximately 280,000 cubic yards (214,000 cubic meters) of material. The suitability of this material for embankment construction or coversoil would depend on the gradation and chemical characteristics of the material.

Additional construction materials may be available by excavation of bedrock in the repository area or Flathead Sandstone which outcrops to the southwest (Figure 3). These materials would likely need to be crushed and screened to make suitable materials. No information on the chemical characteristics of the bedrock materials was found.

Another possible borrow source for construction material for this site is glacial till which is mapped below the site to the southeast. Information regarding the volume of material which may be available from this location are not available. Typically, glacial till contains mixtures of silt, sand, gravel, and cobbles which could be crushed and graded by size as necessary to provide construction materials with suitable properties. Chemical analytical data on this material are not available; however, the material would likely

Figure 2

Figure 2 back page

Figure 3

Figure 3 back page

have similar physical and chemical characteristics to glacial till encountered at site SB-4 (Figure 1). Data for glacial till at site SB-4 indicate the material is a silty, sandy, gravel with cobbles and boulders. The SB-4 site glacial till has a high buffering capacity with an acid/base potential which ranges from 11 to 33 parts $CaCO_3$ per 100 parts. The acid generation potential of 3 to 8 milliequivalents per 100 grams (meq/100g) is moderate and the non-sulfate sulphur percentage of 0.04 to 0.13 is low to moderate, indicating a low to moderate potential to generate acid.

2.5 ENVIRONMENT

Environmental considerations, which were examined, indicate site FC-4 is generally above timberline and is covered with grass and forb dominated vegetation (Figure 4). Wetlands mapped in the area of the potential repository site encompass an area of approximately 6.7 acres (Figure 4). No information on the abundance or diversity of wildlife in the area was available. Some avalanche hazard potential exists from an avalanche path which may affect the northwest corner of the site (email from Wendi Urie, Interagency Spatial Analysis Center, Bozeman MT, regarding personal communication with Karl Birkeland, Southwest Montana Avalanche Forecasting Center). The site aspect is to the east. The disturbance area would likely include the actual repository area, potential borrow source areas, and area disturbed by reconstruction of the access road. Revegetation of the site would be difficult due to the elevation and aspect.

2.6 SUMMARY

The FC-4 site would likely be acceptable as a central repository site for District mine wastes. No fatal flaws which would eliminate this site from consideration were found in the existing data reviewed during our evaluation. Several advantages and disadvantages for the site are listed below.

Advantages

- Site is situated well with respect to run-on control
- Existing access road to site
- Geotechnical information indicates location acceptable

Disadvantages

- Access road will require improvements
- 700 feet elevation gain from Fisher Creek Road
- Coversoil availability may be limited, depending on suitability of local colluvium
- Additional disturbance may be required for borrow material source
- High alpine site would be more difficult to revegetate
- Unknown suitability of Quaternary colluvium for embankment construction
- Adjacent to private land which limits footprint and expansion potential
- Avalanche potential from Henderson Mountain
- Potential for landslide impacts from Henderson Mountain needs to be examined

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Figure 4

Figure 4 back

3.0 REPOSITORY SITE FC-6

The FC-6 site is located on the southeast flank of Sheep Mountain, 4,000 feet northeast of Fisher Creek. Site access is from the Fisher Creek Road, approximately 2.5 miles from its junction with Montana Highway 212, just beyond the Fisher Creek crossing. The site is located in the northwest 1/4, Section 7, T9S R15E, PMM.

Site FC-6

Site FC-6

3.1 GENERAL SITE FEATURES

The FC-6 site encompass an area of approximately 49 acres. The site is located at an average elevation of 9,600 feet above sea level on a relatively broad, gently sloping hillside which extends southeast of Sheep Mountain (Figure 1). The FC-6 site generally slopes to the south and southeast at a gradient which ranges from 7% to 10% (Figure 2). Slopes steepen rapidly to the west toward Sheep Mountain, are relatively flat towards the east, and fall gently to the south.

Access to this potential repository site is via an unimproved dirt road which extends from Fisher Creek Road to Goose Lake and a new site access road. The Goose Lake Road climbs the relatively steep valley side of Fisher Creek for approximately 0.7 miles, and then climbs less steeply another 0.4 miles. This 1.1 miles of unimproved road would need to be improved to handle trucks hauling waste to the repository. Another 0.6 miles of new road construction would be required to access the site. Elevation gain of the access roads from the Fisher Creek road junction to the site is approximately 800 feet.

3.2 GEOLOGY

Geology at the site consists of undifferentiated Quaternary surficial deposits overlying Precambrian granitic gneiss with minor schist, amphibolite, and quartzite (Figure 3). The gneiss is weakly to strongly foliated and the potential repository area contains several quartz dolerite and metadolerite dikes which were mapped by Elliott (1979). Elliott (1979) describes the undifferentiated Quaternary colluvium on the site as consisting of talus, colluvium, and neoglacial deposits. Sandstone of the Cambrian Flathead Formation outcrops south of the site.

Two geotechnical boreholes (SM-1 and SM-2, Appendix A) were drilled south of this potential repository location in 1994 (Knight Piesold, 1994) during an investigation of potential tailings disposal sites (Figure 3). Boreholes SM-1 and SM-2 were drilled to depths of 58.5 feet and 26.3 feet respectively and are located in material mapped as granitic gneiss by Elliott (1979). Borehole SM-1 encountered seven feet of silty sand with gravel overlying bedrock (logged as rhyolite) and the log for borehole SM-2 reported four feet of silty sand with gravel overlying bedrock (also logged as rhyolite). Bedrock was highly fractured and oxidized to approximately 15 feet bgs. Minor to significant chloritization was also noted in the bedrock.

Core recovery of bedrock from the two boreholes was excellent. RQD in borehole SM-1 was typically low to a depth of 45 feet, where it improved to a range of 68% to 100%. RQD in borehole SM-2 ranged from 0% in the upper bedrock to 96% for the core run from 16.3 to 21.6 feet. Fracture spacing generally corresponded to the RQD for the boreholes, with more than 10 fractures per foot in the upper 10 feet of bedrock and between one and three fractures per foot for the deeper bedrock.

Slope stability of the repository site is considered good due to the relatively gentle slopes present at the site and the shallow depth to bedrock (Knight Piesold, 1994). The stability of steeper rock slopes above the site to the west is not known and should be evaluated prior to considering this site further. No faults are mapped in the vicinity of the site. Base material for a repository constructed at this location would be either Quaternary colluvium or granitic gneiss, depending on the thickness and composition of the colluvium.

3.3 HYDROGEOLOGY

As indicated above, this site is located on undifferentiated Quaternary colluvium of unknown thickness and composition. The northern portion of the site encompasses a small drainage basin and the southern portion of the site slopes gently to the south. A small lake is located immediately east of the site. Recharge to the site is likely from bedrock and colluvium to the west. Data on the depth to groundwater in the colluvium or bedrock near the site were not recorded on the two borehole logs located south of the potential site. Surface run-on to the site would be from the west.

Packer tests were performed on the bedrock in both of the boreholes located south of the site. One test conducted in borehole SM-1 at a depth of 16.3 to 26.3 feet resulted in a hydraulic conductivity of 1.1×10^{-4} cm/sec. Two tests performed in borehole SM-2 at depths of 8 to 16.3 feet and 16.3 to 26.3 feet yielded hydraulic conductivities of 1.1×10^{-4} cm/sec and 1.5×10^{-4} cm/sec. These hydraulic conductivity values are relatively low and are typical of granitic bedrock.

3.4 MATERIALS CHARACTERISTICS

Geotechnical borehole data from the two boreholes indicate that the bedrock in the area south of the site is mantled by four to seven feet of silty sand with gravel and occasional cobbles and boulders. The colluvial material in these boreholes was non-plastic, loose, and slightly moist. Potential material sources for repository construction include the undifferentiated Quaternary colluvium and granitic gneiss bedrock. Data on the thickness, gradation, engineering, or chemical characteristics of the Quaternary colluvium is not available. Quantities of colluvial material which may be available were estimated assuming an average thickness of five feet over the 49 acre potential repository site. This would result in a volume of material of approximately 395,000 cubic yards (300,000 cubic meters).

Physical properties of the granitic gneiss bedrock encountered in the boreholes indicate that this material would likely be suitable for repository construction. The material would need to be crushed and sorted to obtain suitable material. Chemical properties of the granitic gneiss bedrock would be expected to be similar to properties of the same geologic map unit which was investigated at site SB-4 (Figure 1). Data for granitic gneiss at site SB-4 indicates a low buffering capacity with an acid/base potential which ranges from 3 to 6 parts CaCO3 per 100. The material also has low acid generation potential with an acid generation potential of less than 1 meq/100g and a non-sulfate sulphur percentage of less than 0.01. The quantities of granitic gneiss available would depend on the final repository design and the depth excavated.

3.5 ENVIRONMENT

Vegetation at the FC-6 site is reportedly open meadow covered with grass and forbs, with some whitebark pine on the eastern side (Figure 4). Scattered wetlands are mapped in the area, and comprise an area of approximately two acres of the 49 acre site (Figure 4). No site specific information on wildlife is available. Some avalanche hazard potential exists from the steep slopes of Sheep Mountain to the west; however, runout zones would likely only affect a small sliver on the western border of the site (email from Wendi Urie, Interagency Spatial Analysis Center, Bozeman, MT regarding personal communication with Karl Birkeland, Southwest Montana Avalanche Forecasting Center). The steep slopes to the west should be evaluated for stability and avalanche potential prior to selection of this site as a repository. The aspect of the site is to the southeast. The disturbance area associated with this site would include the repository area, reconstruction of the existing road, and construction of approximately 0.6 miles of new road.

3.6 SUMMARY

The FC-6 site would likely be acceptable as a central repository site for District mine wastes. No fatal flaws which would eliminate this site from consideration were found in the existing data reviewed during our evaluation. Several advantages and disadvantages for the site listed below.

Advantages

- Potential for good subsurface and cover materials (Quaternary colluvium)
- Gentle slope

Disadvantages

- 800 feet elevation gain from Fisher Creek Road
- High alpine site would be more difficult to revegetate
- Unknown quality of Quaternary colluvium for embankment construction and coversoil
- Relatively long access road would need improving, which would change its recreational character
- New road construction required
- Avalanche potential
- Because of high open location, may be visible from Goose Lake Road
- Potential for landslide impacts from Sheep Mountain needs to be examined

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4.0 REPOSITORY SITE SB-4

The SB-4 site is located north and east of the Fisher Creek road, approximately one-half mile north of the point where the road begins at Montana Highway 212 (Figure 1). Two potential sites in this general vicinity were identified during our evaluation of existing data. The sites are located in the NE1/4, Section 19 and SE1/4, Section 18, T9S R15E, PMM. A preliminary geotechnical investigation of this area was performed by Bechtel Corporation in the summer of 1991 (Bechtel, 1992). This investigation consisted of preliminary geologic mapping, drilling three boreholes, installation of observation wells, and performing laboratory testing of soils for engineering properties and acid generation potential. Two of the boreholes are located along the road south of the potential sites and one is located within the lower site. The geotechnical data presented in this section were obtained from this report. Several additional piezometers were reportedly installed in this general area during tailings repository evaluations performed by Crown Butte Mines, Inc. Data from these additional piezometers were not found prior to this evaluation.

In our discussion of the evaluation criteria which follows, we describe site features which are common to both sites due to the proximity of the two locations and, where appropriate, describe features which are unique to the individual sites. The more northerly, higher site is referred to as SB-4A and the more southerly, lower site is referred to as SB-4B (Figure 1).

Private land adiacent to site SB-4A

Site SB-4B

4.1 GENERAL SITE FEATURES

The SB-4 sites are situated at an elevation of approximately 8,400 feet above sea level on a forested valley area (Figure 1). Slopes in the area average approximately 10% and range from 7 to 13% to the south (Figure 2).

Site SB-4A encompasses an area of approximately 23 acres. The site is located near the drainage divide between Soda Butte Creek and the Clark Fork of the Yellowstone River. It is located approximately 1000 feet south of the Clark Fork of the Yellowstone River and approximately one mile north of Soda Butte Creek. The area can be accessed by traveling north on the Fisher Creek Road approximately 3/4 mile from Highway 212 and then northwest on approximately 3000 feet of new road which would need to be constructed.

Site SB-4B is located in the southern portion of the SB-4 area and covers approximately 71 acres. The site is accessed via the Fisher Creek road and is located approximately 3/4 mile from the Highway 212 junction. The site is bound to the south and west by the Fisher Creek Road.

4.2 GEOLOGY

The geology of the two sites consists of glacial till overlying Precambrian granitic gneiss (Figure 3). Both potential repository locations in this area were selected based on the location of glacial till, which would be a base material for the repositories. Geotechnical boreholes SB-22 and SB-24 (Appendix A) are located south of the southern site (SB-4B) near the Fisher Creek road. Borehole SB-23 (Appendix A) is located 600 to 800 feet north of boreholes SB-22 and SB-24 within the SB-4B site (Figure 3). All three of the geotechnical boreholes drilled near this site encountered colluvium and glacial till overlying gray granitic gneiss, schistose gneiss, and white to pink gneissic granite. The colluvium ranged in thickness from 5.5 feet in SB-23 to approximately 8 feet in SB-22 and SB-24. The thickness of glacial till was 14.5 feet in SB-22, 41 feet in SB-23, and 16 feet in SB-24. Borehole SB-23 encountered 12.6 feet of quartz diorite below the till and then banded gneissic granite. Gneiss was encountered beneath the till in boreholes SB-22 and SB-24. Appendix A contains borehole logs for these geotechnical borings.

Colluvium encountered in the boreholes was described on the borehole logs as sandy silt and silty sand with gravel. Glacial till in the boreholes consisted of very dense silty sandy gravel, with cobbles and boulders. The glacial till was drilled by coring. Granitic gneiss underlying the till was reported on the drill logs as relatively massive to slightly jointed with occasional mineralized seams containing 1 to 3% sulfide minerals. Joint surfaces and minor veinlets typically contained limonite, hematite, carbonate, or green chloritic clay coatings. Core recovery in the bedrock was typically excellent, and RQD ranged from 80 to 100% for the core. Slope stability of the area is considered good due to the relatively low overall slope of the topography. No faults are mapped in the vicinity of these repository locations.

4.3 HYDROGEOLOGY

Groundwater was encountered in the three boreholes drilled at the site. Artesian conditions were present in boreholes SB-22, SB-23, and SB-24, which were completed in granitic gneiss underlying colluvial and glacial till deposits. Borehole SB-22 is sandpacked in gneiss at a depth of 56 to 70 feet below ground surface and a hydrostatic head greater than 3.3 feet above ground surface was reported. Borehole SB-24 is sandpacked from 47.5 to 70 feet below ground surface and had a hydrostatic head greater than 2.3 feet above ground surface. The static water level in borehole SB-23, which was completed in bedrock at a depth of 46.5 feet to 70.5 feet below ground surface, was reported at a depth of 4.4 feet below ground surface. It appears glacial till overlying the bedrock is serving as a confining layer for the bedrock hydrologic system encountered in these wells.

Hydraulic conductivities of the bedrock materials were obtained by performing packer tests on each of the boreholes. Hydraulic conductivity values for gneiss bedrock in boreholes SB-22, SB-23, and SB-24 were relatively low and ranged from $3x10^{-5}$ to $2x10^{-7}$ cm/sec. Groundwater conditions in the colluvium and glacial till were not recorded on the well logs and no groundwater occurrence information was found. It is anticipated that groundwater flow in the glacial till would be limited by the fine grained and heterogeneous nature of the till.

4.4 MATERIALS CHARACTERISTICS

Colluvial material encountered in the boreholes consists of a relatively thin surficial deposit up to 10 feet thick. The colluvium consists of medium dense silty sand and sandy silt with some gravel and minor clay. The fines are of very low plasticity with plasticity indices of 3.6 and 3.0 on two samples from boreholes SB-22 and SB-24. Glacial till encountered in the boreholes is very dense and recovery of the material by coring ranged from 70 to 90%. Glacial till consists of rounded gravel, cobbles, and boulders bound in a silty sand matrix.

A colluvium/till sample obtained from a depth of 7.5 to 9.0 feet BGS in borehole SB-22 consisted of gravelly silty sand (SM). A colluvium sample obtained from a depth of 7.0 - 8.0 feet BGS in borehole SB-24 consisted of gravelly silty sand to gravelly clayey sand (SM/SC). Both samples had low plastic indices and moisture contents ranged from 9.3 to 12%.

Availability of materials for repository construction is likely good for both sites. If it is assumed that the upper 10 feet of colluvial material is used for construction, approximately 400,000 yards (305,000 cubic meters) of material would be available at the SB-4A site and 887,000 cubic yards (677,000 cubic meters) at the SB-4B site. Glacial till material would also likely be available at both sites by excavating deeper. Granitic gneiss bedrock material could also be obtained for repository construction, if necessary. Granitic gneiss is mapped surrounding the SB-4A site and to the north and east of the SB-4B site. Chemical analytical data on glacial till from boreholes at site SB-4 indicates that the material has a good buffering capacity with an acid/base potential which ranges from 11 to 100 parts CaCO3 per 100. The acid generation potential of 3 to 8 milliequivalents per 100 grams (meq/100g) is low to moderate and non-sulfate sulphur percentage of 0.04 to 0.13 is relatively low. The suitability of the material for coversoil appears to be good, but may need to be amended.

Chemical analytical data for quartz diorite and granitic gneiss at site SB-4 indicates that the bedrock has low buffering capacity with an acid/base potential which ranges from 3 to 6 parts CaCO3 per 100. The acid generation potential is low with less than 1 meq/100g reported as is the non-sulfate sulphur percentage of less than 0.01.

4.5 ENVIRONMENTAL

Environmental conditions at the site appear to be good for most parameters. No avalanche potential is present because no steep, open slopes are located above the sites. Vegetation of the area is shown as lodgepole pine forest; however, most of the area has been recently burned (Figure 4). Approximately 2.4 acres of wetlands are present on the SB-4A site and approximately 9.2 acres in the central portion of the SB-4B site are mapped as wetlands (Figure 4). No information on wildlife in the area was found. The aspect of the sites is to the southeast. The disturbance area required for the lower site would be limited to the size of the repository. Disturbance in the upper site would include the repository area and the area of new road construction.

4.6 SUMMARY

Both the SB-4A and SB-4B sites would likely be acceptable as a central repository site for District mine wastes. No fatal flaws which would eliminate either of these sites from further consideration were found in the data reviewed during our evaluation. Several advantages and disadvantages for the sites listed below.

Advantages

- Underlain by relatively thick glacial till
- Access would be good for both sites
- Lower elevation would aid in revegetation efforts
- Good construction materials availability
- Upward hydraulic gradient would limit downward leachate migration
- Location would be relatively close to McLaren tailings, improves economics of response action

Disadvantages

- Sites may be visible from residences
- New road construction required for SB-4A
- Additional disturbance may be necessary for bedrock borrow material

5.0 RECOMMENDATIONS

Based on our review of the available geologic, hydrologic, engineering, and other data, we recommend that the SB-4 area, including both the SB-4A and SB-4B locations, be further evaluated as potential repository sites. The locations will need to be examined in more detail following spring thaw to verify groundwater conditions and site specific material characteristics. Although the evaluation presented in this report focused on individual sites which had been previously evaluated by CBMI, there may be other locations on District Properties which may be suitable for mine waste repository siting. Upon gaining access to the site in the spring of 1999, other locations in the SB-4 area may be identified as potentially suitable for a repository. If other areas are identified during the field investigation, these areas should be considered for further evaluation.

The SB-4 area is recommended for several reasons, including:

1. ***Access*** – Locations in the SB-4 area will require only minimal road construction for access. The locations are near the Fisher Creek road, and hauls from the majority of waste rock sources in the district will be downhill, with no steep climbs or new road construction will be necessary. If the area is used for McLaren tailings disposal, significant economic advantage is gained over sites FC-4 and FC-6 due to lower haul costs.

2. ***Materials*** - Materials availability in the area is apparently good, with both glacial till and granitic gneiss bedrock available for repository construction. Glacial till extends to a depth of 20 to 50 feet in the area and granite bedrock could be quarried nearby to the north or east.

3. ***Hydrogeology*** - Repository base material at both Site SB-4A and Site SB-4B and other locations in the SB-4 area would be glacial till. Glacial till typically has a relatively low permeability and does not have joints and fractures which would facilitate groundwater movement. An upward hydrologic gradient which is apparently present in the area, would limit migration of potential leachate from the repository to the bedrock hydrogeologic system.

4. ***Elevation*** - This area is the lowest of the potential sites evaluated and would be the easiest to revegetate.

5. ***Location*** - The area is similar in distance from District properties waste sources and would be closer to the McLaren Tailings if this material is transported to the central repository.

6. ***Environment*** - Disturbance area will be limited to the actual repository area and possibly a bedrock borrow source area. Vegetation type in the area is lodgepole pine and the area has been burned. Wetlands in the area are relatively contiguous and impacts may be limited, depending on the results of a siting investigation.

7. ***Slope Stability/Avalanche Potential*** – The area would be very stable and not be affected by avalanches.

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6.0 ADDITIONAL INVESTIGATION

We recommend completing certain additional investigative activities at sites in the SB-4 area to verify suitability as a central repository:

1. ***Geophysical Exploration*** - Completion of seismic refraction investigations are recommended at the sites to allow preliminary determinations of unconsolidated material thicknesses, stratigraphy, and bedrock topography. This information would be used to delineate a specific repository location and determine geotechnical borehole and monitoring well locations.

2. ***Geotechnical Borehole Drilling*** - Additional geotechnical drilling is needed to establish the thickness of colluvial and glacial till overburden, characterize engineering and chemical properties of glacial till and bedrock, and identify potential sources of borrow materials.

3. ***Groundwater Monitoring Wells*** - Groundwater monitoring wells should be installed on the perimeter of the area to verify groundwater elevation and flow characteristics. Groundwater samples should be analyzed for standard chemical parameters to establish background conditions for the site. Of particular importance is the investigation of the groundwater interaction between the colluvium/glacial till overburden and the bedrock groundwater system. Identification of an upward gradient in the bedrock system, if present, by completion of multi-depth wells will be necessary to characterize three-dimensional groundwater movement and support repository design.

4. ***Test Pits*** - Backhoe test pits should be excavated at the site to collect material samples for engineering tests and materials suitability determination.

5. ***Contour Map*** - A one-meter contour map of the site should be prepared to support engineering design.

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7.0 REFERENCES

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APPENDIX A
BOREHOLE LOGS