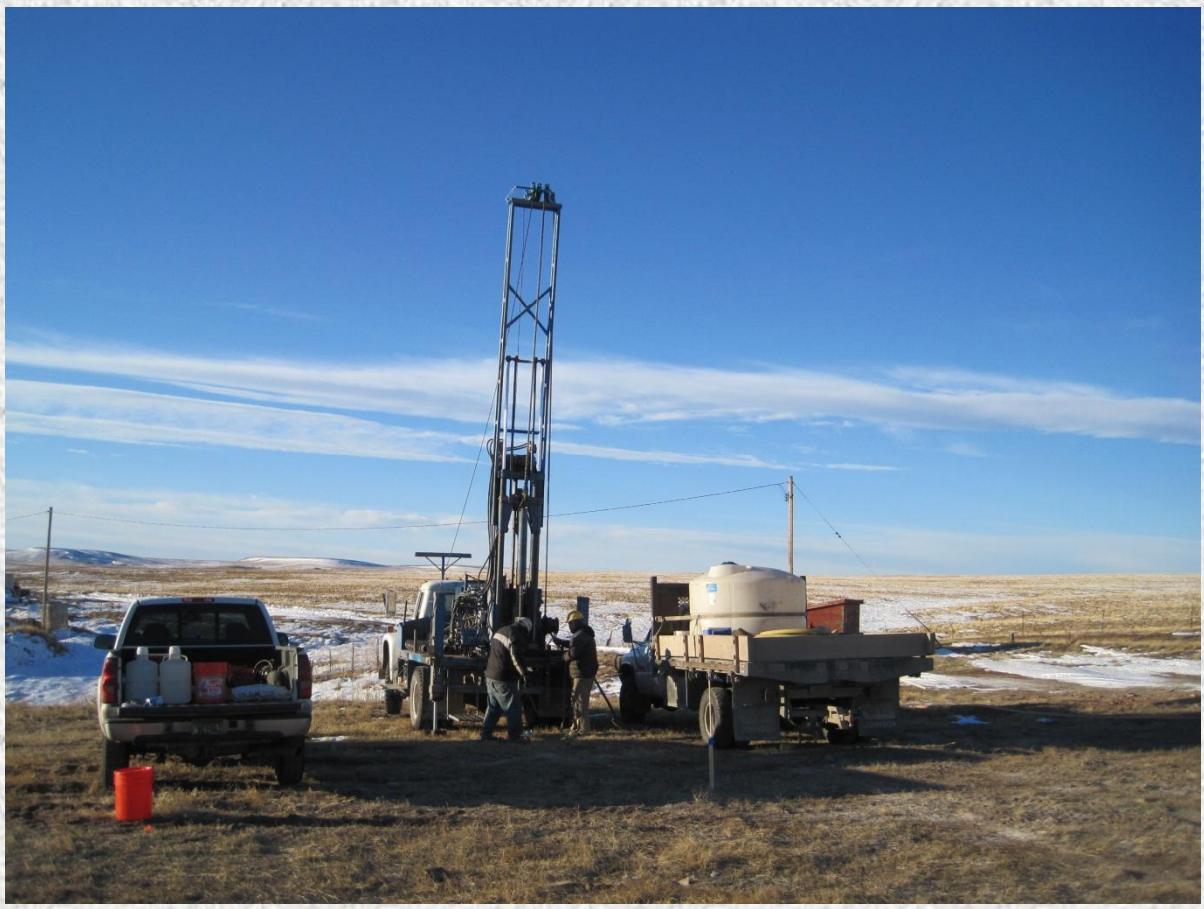
SAND COULEE
WATER TANK AND PIPELINE
GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION

Prepared For:

Montana Department of Environmental Quality
Helena, Montana



Hydrometrics, Inc.
Consulting Scientists and Engineers

FEBRUARY 2013

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Prepared for:

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SAND COULEE
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1.0 SITE CHARACTERIZATION

1.1 GENERAL DESCRIPTION

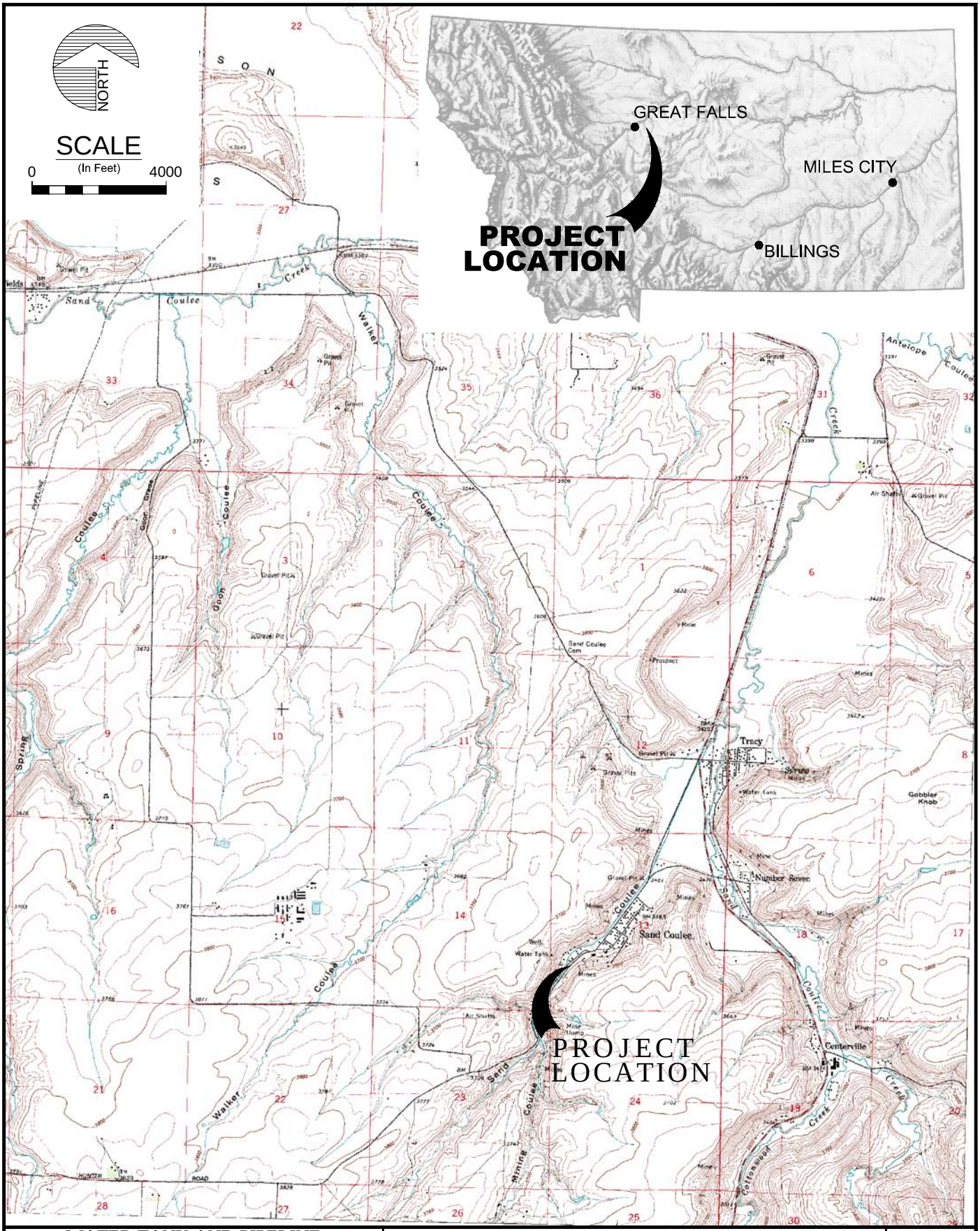
The project site is the town of Sand Coulee, Montana located in the SE 1/4 of Section 14 Range 4E Township 19N and the NW, SW, and NE of Section 13 Range 4E Township 19N (Figure 1-1). A geotechnical investigation was conducted on the dates of December 20, 2012 and January 3, 2013 to investigate subgrade conditions for a new water tank and new waterline, and to gather geotechnical and environmental samples. The subsurface investigation was carried out with a hollow stem auger drill rig and standard penetration resistance testing (SPT) for the tank and with direct-push methods for the waterline alignment. This report presents the results of the investigation and establishes soil parameters to support construction of the tank and waterline.

1.2 PROPOSED CONSTRUCTION

A new 40-foot diameter water supply tank and new waterline is proposed to replace the existing water tank and pipeline. The new tank will be located approximately 350 feet uphill from the existing tank and it is assumed the tank will be placed on a ring foundation. The new waterline location will be located within the general proximity of the existing waterline alignment with some minor variances to improve the hydraulics of the system.

1.3 GEOLOGY

According to the Great Falls South 30' by 60' Quadrangle geologic map (MBMG, 2000), the geology at the water tank is mapped as the interface of 'Qgt Glacial Till' and 'Kks Sunburst Sandstone Member of Kootenai Formation' (Figure 1-2). Qgt is described as reddish brown



WATER TANK AND PIPELINE GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SAND COULEE, MONTANA	**SITE LOCATION MAP**	FIGURE **1-1**

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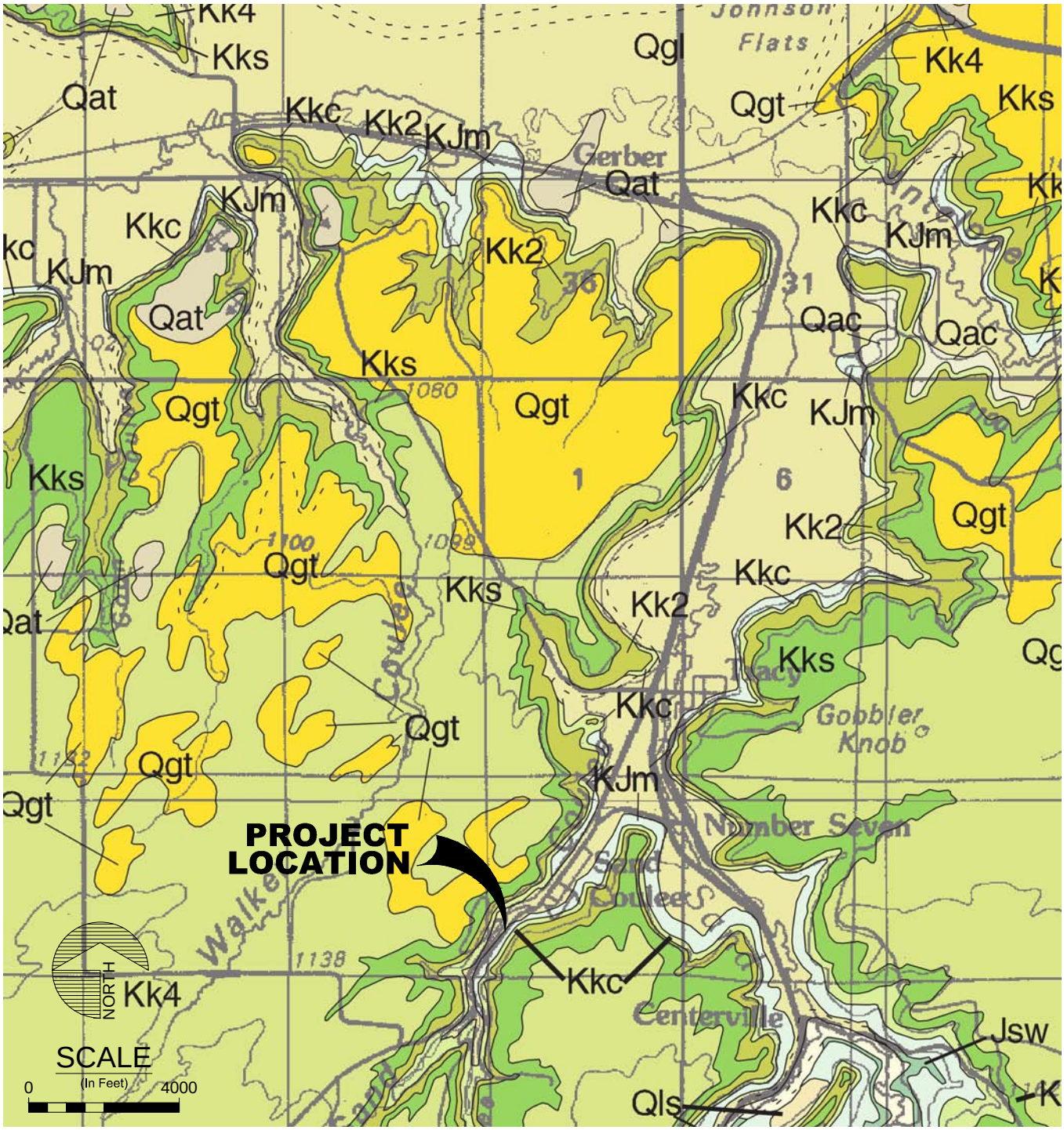

LEGEND

Qgt - Glacial Till

Qgl - Glacial Till and Reworked Glacial Lake Deposit

Kkc - Cutbank Sandstone Member of Kootenai Formation

Kks - Sunburst Sandstone Member of Kootenai Formation

KJm - Morrison Formation

Kk2 - Kootenai Formation, Member 2

Kk4 - Kootenai Formation, Member 4

Map from MBMG, Geologic Map of the Great Falls South 30' x 60' Quad, OFR MBMG 407, 2000

WATER TANK AND PIPELINE GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SAND COULEE, MONTANA	**GEOLOGIC MAP**	FIGURE **1-2**

clay, silt, and sand with scattered pebbles, cobbles, and boulders, and Kks is described as red-weathered mudstone that contains lenses of sandstone and limestone.

The geology along the waterline alignment is mapped as Cretaceous aged 'Kk2 Second Member of Kootenai Formation,' 'Kkc Cutbank Member Kootenai Formation,' 'KJm Morrison Formation' and Pleistocene aged 'Qgl Glacial Lake and Reworked Glacial Lake Deposit.'

1.4 NRCS SOILS DATA

Internet-based soils maps from the Natural Resource and Conservation Services (NRCS) show the soils at the water tank site to be dominated by the Bitton and Roy soils complex, and also near the mapped interface with the Gerber silty clay loam. Physical and chemical characteristics of the soils are described in Appendix A; in general the soils are fine-grained at the surface down to the weathered bedrock at depth. The Soil Survey indicates that the tank location is limited in its potential for building development because of grade, depth to bedrock (shallow), and shrink-swell potential of the soils.

The NRCS maps indicate that the soils along the waterline alignment are comprised of the Britton and Roy soils complex, and the Fergus silty clay loam. The Soil Survey indicates that the Fergus soils are somewhat limited for shallow excavations due to unstable excavation walls.

2.0 EXPLORATION AND TESTING

2.1 FIELD INVESTIGATION

Three boreholes at the proposed water tank location were drilled to depths ranging from 2.5 to 6.5 feet before encountering refusal, using a truck mounted CME 55 drill rig and 6-inch hollow stem auger (Appendix B). Standard Penetration Testing (SPT) was conducted using a manual 140-pound hammer and 2-inch by 1.5-inch split spoon sampler, and the borings were logged by a Montana registered Professional Engineer.

Borings were located approximately 20 feet from the center of the proposed water tank to the southwest, southeast, and northeast. This arrangement was used in order to document soil type and variability across the footprint of the water tank. Borehole locations are shown on Figure 2-1.

Adjusted blow counts range from 63 to 100+ blows per foot (bpf), indicating very dense material. Appendix C contains blow count data.

Fourteen direct-push borings were planned to investigate the waterline alignment. However, access to three of these locations (MB-3, MB-4, and MB-6) was problematic and these holes were excluded from the investigation. Eleven direct-push borings were installed in total: MB-2, MB-5, MB-7, MB-8, MB-9, MB-10, MB-11, MB-12, MB-13, MB-14, and MB-15. Two of the borings encountered refusal prior to reaching the target depth of 8.0 feet; MB-2 and MB-14, and MB-8 was stopped a few inches prior to target depth based on the drillers' recommendation that the core felt full due to increased driving resistance. Additionally, a visual survey of the excluded borehole locations indicated a high likelihood of shallow bedrock.

LEGEND

- BH1 AUGER BORING
- MB5 DIRECT PUSH MACRO BORING
- MB3 EXCLUDED BORING

SCALE
0 (In Feet) 250

NORTH

WATER TANK AND PIPELINE
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INVESTIGATION
SAND COULEE, MONTANA

BOREHOLE LOCATION MAP

FIGURE
2-1

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2.2 SOILS

Soils encountered in the borings for the new water tank generally consisted of a thin veneer of clayey topsoil, then silty sand, then glacial till and weathered bedrock. The weathered bedrock appears to be mudstone/claystone from the Fifth Member of the Kootenai Formation.

Soils encountered in the borings for the waterline alignment varied based upon location. Boring MB-2 which is located between the new and existing tank locations is virtually identical to water tank borehole BH-1. Borings in the bottom of the valley generally encountered fill, including coal debris, and then in place silts/clays and sands. The in-place materials appear to be glacial lake or reworked glacial lake deposits, as mapped on the Great Falls South geologic map. Essentially, this material is alluvial fill. Boring MB-15 was slightly coarser than the other borings, likely from outwash from the drainage to the east, and MB-14 encountered refusal at 4.2 feet, presumably on weathered bedrock trending from the ridge to the east. These conditions indicate that the portion of the waterline on the northeast side of town may encounter more difficult digging conditions.

The soils encountered during the investigation agree with the mapped geology, however, most of the glacial material appears to be transported/reworked rather than in-place.

Appendix B contains logs for the tank and waterline borings.

2.3 GROUNDWATER

Groundwater was not encountered in the borings for the water tank and is not expected to be an issue during construction or during the life of the tank. The highest potential for moisture related issues at the tank would be from leaks in the tank or appurtenances.

Groundwater was encountered along the waterline alignment in the borings MB-5 and MB-8. A piezometer was installed in boring MB-5 to allow for monitoring of groundwater. Piezometers were also installed in borings MB-7, MB-9, and MB-10 in case groundwater

elevations increase to within 8-feet of the ground surface. One-inch PVC casing was used with a 5-foot screen section in the bottom and solid pipe to above the ground surface.

2.4 LABORATORY TESTING - GEOTECHNICAL

Laboratory testing which included gradation, liquid and plastic limits (plasticity), moisture-density, and resistivity was performed on a bulk sample from borehole BH-1 (drilling cuttings from 0.0 to 4.0 foot) for the water tank and from several samples at pipe burial depth along the waterline alignment. Laboratory results are summarized in Table 2-1 and included in Appendix D.

According to the testing, the sample from BH-1 has a plasticity index of 15 and classifies as a CL, Lean CLAY with Sand in the Unified Soil Classification System. The maximum standard Proctor dry density is 111.7 pounds per cubic foot (pcf) with an optimum moisture content of 15.2 percent (ASTM D 698 Method C).

Selected samples from borings MB-5, MB-7, and MB-12 have plasticity indices ranging from 6 to 11 and classified as CL, Lean CLAY and Sandy Lean CLAY, and CL-ML, Sandy Silty CLAY.

Material from boring BH-1 was also tested for resistivity to assist with corrosion resistance planning for the tank. The resistivity of the sample BH-1, 0.0 to 4.0 feet, is 2010 ohm-cm.

TABLE 2-1. GEOTECHNICAL LAB TESTING SUMMARY

Location	Sample Depth (ft)	USCS Classification	Fines (%)	Plasticity Index	Max Density[1] (pcf)	Optimum Moisture[1] (%)	Minimum Resistivity (Ohm-cm)
BH-1	0.0-4.0	CL	73	15	111.7	15.2	2010
MB-5	5.5-8.0	CL	51	11	-	-	-
MB-7	6.3-8.0	CL-ML	55	6	-	-	-
MB-12	5.2-8.0	CL	89	10	-	-	-

1. ASTM D698 Method C

3.0 ANALYSIS – WATER TANK

3.1 BEARING CAPACITY BASED ON SPT

Bearing capacity calculations based on the two points of SPT data from borehole BH-1 that were less than 100 blows per foot (BPF) were performed with equations correlating SPT data to allowable bearing pressure. According to the calculations, bearing capacity is not likely to be an issue for the tank. Assuming a 40-foot diameter tank with up to 20 feet of water and a perimeter strip footing 4 feet in width, contact pressure would be approximately 3,000 psf, which is multiple times less than the calculated allowable bearing capacity.

3.2 SETTLEMENT AND SWELL

Drilling suggests that the subgrade soils are very dense (stiff) and that bedrock is very shallow. The NRCS soils report suggests that the soils at the tank site could be problematic for swell and settlement, however, the presence of shallow bedrock, moderate plasticity (15), stiffness, and limited total thickness of the clay lenses does not support that this is an overwhelming problem. We do not expect significant settlement or swell from the subgrade soils at the site as long as construction related disturbance is dealt with, however, differential settlement is a risk due to the inclined bedrock surface. In general differential settlements are more of a concern than total settlement since total settlement does not induce stress on the tank structure, as long as tank appurtenances have been designed accordingly.

Refusal was encountered presumably on weathered bedrock at depths of 2.5 in borings BH-2 and BH-3 and at 6.3 feet in BH-1. If, for example, the foundation depth is 4 feet, this would leave approximately 2 feet of soil under a portion of the tank when the rest is founded on bedrock. The material encountered in BH-1 and a depth of 4.8 to 6.0 feet was logged as silty clay, which is not ideal bearing material. Although the material is unlikely to settle significantly, any settlement would directly be differential settlement since the portion founded on bedrock would not settle. In general, differential settlement is a greater concern than overall settlement.

According to guidelines in the literature (Bowles, 1996) allowable differential settlement for a 40-foot diameter tank would be approximately 0.8 inches (center to edge). Settlement on this order of magnitude is possible given that a portion of the tank would be on several feet of soil based on the soils encountered in boring BH-1.

3.3 LATERAL EARTH PRESSURE

Lateral earth pressure values have been calculated, which may be used to support tank design, if necessary. Lateral earth pressure coefficients and equivalent fluid pressures were calculated assuming the following parameters; friction angle of 32 degrees and unit weight of 120 pcf, representative of the soils at the site. Calculations are attached in Appendix C.

Rankine earth pressure calculations estimate the following coefficients and equivalent fluid pressures: 37 pcf for the active case (K_a = 0.31), 56 pcf for the at-rest case (K_o = 0.47), and 391 pcf for the passive case (K_p = 3.3).

3.4 SEISMIC SITE CLASSIFICATION

Based on Table 1613.5.2 of the International Building Code (IBC, 2006), the tank foundation subgrade fits the criteria for Site Class B, 'Rock' due to the presence of shallow bedrock.

4.0 CONCLUSIONS AND RECOMMENDATIONS – WATER TANK

4.1 FOUNDATION

Foundation details are not known at this time, so it is assumed that the tank will feature a perimeter/ring footing approximately 3 to 4 feet below grade. Except for the clay lens logged in BH-1 the subgrade soils are generally good bearing materials, however, the bedrock is much better. Given the variability to depth of bedrock across the tank footprint and the clay in boring BH-1 we recommend removing material down to competent/fresh bedrock below the footing and replacing with engineered fill. This will eliminate the clay lens and allow for performance verification of the foundation material during placement of engineered fill. Section 4.2 Earthwork discusses subgrade preparation methods.

4.2 EARTHWORK

4.2.1 Subgrade and Foundation base Preparation

The site should be excavated down to foundation grade, which should be in competent weathered bedrock under most of the tank. Under the southwestern portion of the tank the excavation may be in soil, in which case the soil should be excavated down to bedrock and then replaced with engineered fill back up to foundation grade. This will also remove the clay lens documented in borehole BH-1. The bedrock nature of this site may warrant excavating several inches below foundation grade to allow for placement of a leveling coarse. Leveling coarse material should be clean, well-draining gravel.

Prior to placement of structural fill or leveling coarse material the exposed subgrade should proof rolled with a smooth drum roller in vibratory mode. The structural fill should be compacted in maximum 6-inch thick lifts and compacted to at least 95% of maximum Proctor density. Structural fill should be free-draining gravel.

Inclusion of a drain at the base of the structural fill or footer is conservative at this site, however, it may be warranted to protect the subgrade from moisture in the event of leaks from the tank and to allow for indication of such leaks. If a drain is installed, it may consist

of 4-inch perforation pipe ring drain below the tank connected to a lateral solid pipe that discharges downslope. The outlet of the drain should be protected with a flap gate or screen.

4.2.2 Exterior Backfill

The site soils may be used as exterior backfill. Placement should occur in maximum 6-inch thick lifts and compacted to at least 95% of Maximum Proctor density. The drill cuttings sample from 0.0 to 4.0 feet in boring BH-1 had a maximum Proctor density of 111.7 pcf at moisture content of 15.2 percent.

4.2.3 Site Grading and Drainage

The tank backfill should be graded to slope at a minimum of 5% for the first 10 feet surrounding the structure. General site grading ensure that runoff routes away from the tank.

5.0 ANALYSIS - WATERLINE

5.1 WATERLINE DESIGN

5.1.1 General

It is our understanding that the replacement waterline will be constructed with an invert depth of approximately 6 feet. We anticipate that the waterline will be installed with open cut techniques.

5.1.2 Geotechnical Parameters

General geotechnical design considerations are given below in Table 5-1. In general the soils encountered at anticipated pipe depth are clays or clayey sands. Several of the borings encountered refusal prior to the 8-foot target depth (MB-2, MB-14) and are expected to encounter difficult digging in weathered bedrock conditions. Additionally, a visual survey of the excluded borehole locations indicated a high likelihood of shallow bedrock and difficult digging conditions are likely in the area of MB-3, MB-4 and MB-6.

TABLE 5-1. GEOTECHNICAL PARAMETERS

Location	Street	Soil Description at Invert Depth	USCS Soil Type	Origin
MB-2	-	Clay, Bedrock	CL	Native
MB-5	Gulch Lane	Sandy Clay with Gravel	CL	Native
MB-7	-	Sandy Silty Clay	CL-ML	Native
MB-8	Gulch Lane	Clayey Sand with Gravel	SC	Fill
MB-9	East Hunter	Clayey Sand with Gravel	SC	Fill
MB-10	Rosie's Lane	Silty Gravelly Sand	SM	Native
MB-11	Miner's Lane	Gravelly Sand	SW	Native
MB-12	Dahns Lane	Silty Clay	CL	Native
MB-13	-	Gravelly Sand	SW	Native
MB-14	Fortune Lane	Bedrock	-	Native
MB-15	Dahns Lane	Sandy Clay	CL	Native

6.0 CONCLUSIONS AND RECOMMENDATIONS – WATERLINE

6.1 EXCAVATION CONSIDERATIONS

For the purpose of excavation for the waterline, the soils along the alignment would be conservatively grouped as Type C soils according to OSHA regulations (29CFR1926 Subpart P). Bedrock would classify as Type B material. For excavations deeper than five feet, cut slopes in soil should be no steeper than 1.5H:1V and 1H:1V for cut slopes in bedrock. For portions of the excavation that transition to bedrock the excavation slope may transition from 1.5H:1V to 1H:1V. Excavations less than five feet in depth may waive benching requirements, as long as the excavation is inspected be a competent person. The contractor shall ultimately be responsible for adherence to OSHA and other safety regulations.

6.2 GROUNDWATER

Groundwater was encountered in two borings, MB-5 and MB-8. Boring MB-5 is located at the base of the slope below the existing water tank, adjacent to Rusty Ditch that runs through town and MB-8 is located near the east end of Gulch Lane. Depth to water was approximately 2.5 feet at MB-5 and 7.3 feet at MB-8 at the time of the investigation. Piezometers were installed at MB-5, MB-7, MB-9, and MB-10 to allow for monitoring of groundwater levels in support of construction. Based on the layout of the waterline it appears that the portion that runs through Gulch Lane will most certainly encounter groundwater.

7.0 ENVIRONMENTAL SAMPLING AND TESTING

Selected samples from the borings along the waterline alignment were submitted to Energy Labs, in Helena, Montana for testing to assist with treatment and/or disposal options for soils from the waterline excavation. Analytical tests included Toxicity Characteristic Leaching Procedure (TCLP), Acid-Base Acounting (ABA), pH, conductivity, and lime requirement (SMP buffer method). The following sections summarize the methodology and results of the testing program. Original laboratory data is attached in Appendix E.

7.1 SAMPLE SELECTION

The macro borings provide the unique benefit of collection of material for the entire depth of the boring in a clear acrylic sleeve (core tube). Following field work the sample cores were split open, logged, and sampled. During this time a representative from MT DEQ met with Hydrometrics' sample team to determine which material in the core tubes to sample. Six samples were identified as follows based on the suspected level of contamination related to coal waste: MB-5 from 0.2-1.8 feet, MB-8 from 1.5-3.2 feet, MB-9 from 0.0-2.2 feet, MB-12 from 0.0-2.9 feet, MB-14 from 2.1-3.3 feet, and MB-10 from 0.0-1.9 feet. Table 7-1 summarizes sample identification. Appendix F contains a photo log of the macro core tubes during sample processing.

TABLE 7-1. SAMPLE IDENTIFICATION

Sample Code and Number	Boring	Sample Depth (ft)	Material Description
SCR-1301-100	MB-5	0.2-1.8	Sandy CLAY, with coal fragments (Fill)
SCR-1301-101	MB-8	1.5-3.2	Silty SAND with Gravel, abundant coal (Fill/Coal Slack)
SCR-1301-102	MB-9	0.0-2.2	SAND with Gravel, with coal fragments possibly burned trash (Coal Slack/Fill)
SCR-1301-103	MB-12	0.0-2.9	Clayey SAND with Gravel (Coal Slack/Fill)
SCR-1301-104	MB-14	2.1-3.3	COAL DEBRIS (Coal Slack/Fill)
SCR-1301-105	MB-10	0.0-1.9	Sand SILT with trace Gravel, abundant coal debris (Fill)

7.2 SAMPLING

Collection of core tubes in the field and subsequent grab sampling was carried out according to Hydrometrics HS-SOP-34, Procedure for Collection Direct-Push Soil Samples. After core tubes were split in Hydrometrics' lab and the material was logged, sample material was removed directly from the core tubes and placed in double Ziploc bags. Samples were then transferred to Energy Labs' Helena office for analysis.

7.3 LABORATORY RESULTS

7.3.1 Toxicity Characteristic Leaching Procedure (TCLP)

Samples were tested for leaching characteristics for RCRA 8 metals: Arsenic, Barium, Cadmium, Chromium, Lead, Selenium, Silver, Mercury. All of the samples were below the reporting limit for each analyte. These results indicate that none of the samples indicate the need for special disposal methods in regards to the RCRA 8 metals.

7.3.2 Acid-Base Accounting

Acid-Base Accounting using the Sobek method was carried out on each sample. The Sobek method includes Neutralization Potential, Acid Potential, Acid-Base Potential, Total Sulfur, Hot Water Soluble Sulfur, Cold HCL Soluble Sulfur, Hot HNO_3 Soluble Sulfur, Residual Sulfur. Results from all the samples are summarized in Table 7-2, Acid-Base Accounting.

7.3.3 pH

The pH (saturated paste) of the samples ranged from 3.6 to 6.8 standard units (s.u.), with five of the six samples below 6.5 s.u. The lowest pH (3.6) is from sample SCR-1301-104 (MB-14 from 2.1-3.3 feet).

7.3.4 Specific Conductance/Conductivity

The conductivity (saturated paste) of the samples ranged from 1.2 to 5.0 mmhos/cm. The highest conductivity is from sample SCR-1301-100 (MB-5 from 0.2-1.8 feet).

7.3.5 Lime Reduction SMP Buffer Analysis

The lime requirement for each sample was evaluated via the Shoemaker-McLean-Pratt (SMP) buffer method. The lime requirement, in tons/1000 tons of material, ranged from less than one (non-detect-ND) to 11. The sample with the highest lime requirement is sample SCR-1301-104 (MB-14 from 2.1-3.3 feet).

TABLE 7-2. ACID-BASE ACCOUNTING

Sample Code and Number	Neutralization Potential	Acid Potential	Acid-Base Potential	Total Sulfur	Hot Water Soluble Sulfur	Cold HCL Soluble Sulfur	Hot HNO3 Soluble Sulfur	Residual Sulfur
Units	t/kt	t/kt	t/kt	%	%	%	%	%
SCR-1301-100	11	3.3	7	0.82	0.43	0.09	0.10	0.20
SCR-1301-101	9	4.5	5	0.69	0.17	0.03	0.14	0.35
SCR-1301-102	5	1.6	3	0.55	0.08	0.04	0.05	0.38
SCR-1301-103	41	3.6	37	0.45	0.05	<0.01	0.12	0.28
SCR-1301-104	-0	4.3	-5	1.1	0.04	0.05	0.14	0.90
SCR-1301-105	21	0.8	20	0.10	<0.01	<0.01	0.02	0.07

8.0 LIMITATIONS

This report has been prepared based on a limited amount of data and is intended to assist in design and construction of the proposed water tank and pipeline. Actual site conditions may vary at locations other than the borings. Recommendations in this report are made assuming conditions outlined in this report (i.e., foundation type and depth) and are contingent upon Hydrometrics' involvement in review and construction. Changes in the scope or configuration of this project from that presented herein will require review. These services have been performed in a manner consistent with the level of care and skill ordinarily exercised by members of the profession currently practicing in this area under similar conditions.

9.0 REFERENCES

Bowles, Joseph E., 1996. Foundation Analysis and Design, Fifth Edition.

Occupational Safety & Health Administration, 1989. Safety and Health Regulations for Construction, Soil Classification, 1926 Subpart P, App A.

International Building Code (IBC), 2006.

Montana Bureau of Mines and Geology, 2000. Geologic Map of the Great Falls South 30' x 60' Quadrangle, Open File MBMG 407.

Natural Resource and Conservation Services, Web Soil Survey, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx, 02/06/13

APPENDIX A

NRCS SOILS REPORT

United States Department of Agriculture

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Cascade County Area, Montana

February 6, 2013

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:6,010 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cascade County Area, Montana
Survey Area Data: Version 9, Jan 4, 2012

Date(s) aerial images were photographed: 7/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Cascade County Area, Montana (MT613)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
28	Bitton and Roy soils, 10 to 65 percent slopes	23.4	44.6%
80	Fergus silty clay loam, 0 to 2 percent slopes	28.9	55.2%
85	Gerber silty clay loam, 0 to 4 percent slopes	0.1	0.2%
Totals for Area of Interest		**52.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments

on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Cascade County Area, Montana

28—Bitton and Roy soils, 10 to 65 percent slopes

Map Unit Setting

Elevation: 3,400 to 5,300 feet
Mean annual precipitation: 15 to 19 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 105 to 130 days

Map Unit Composition

Roy and similar soils: 45 percent
Bitton and similar soils: 45 percent
Minor components: 10 percent

Description of Bitton

Setting

Landform: Hills
Down-slope shape: Linear
Across-slope shape: Linear

Properties and qualities

Slope: 10 to 65 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: Moderate (about 6.9 inches)

Interpretive groups

Farmland classification: Not prime farmland
Land capability (nonirrigated): 7e
Hydrologic Soil Group: B
Ecological site: Draft Silty (Si) RRU 46-C 13-19" p.z. (R046XC508MT)

Typical profile

0 to 7 inches: Stony loam
7 to 40 inches: Very stony loam
40 to 60 inches: Very stony clay loam

Description of Roy

Setting

Landform: Hills
Down-slope shape: Linear
Across-slope shape: Linear

Properties and qualities

Slope: 10 to 65 percent
Depth to restrictive feature: More than 80 inches

Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 3.9 mmhos/cm)
Available water capacity: Low (about 4.9 inches)

Interpretive groups

Farmland classification: Not prime farmland
Land capability (nonirrigated): 7e
Hydrologic Soil Group: C
Ecological site: Draft Silty (Si) RRU 46-C 13-19" p.z. (R046XC508MT)

Typical profile

0 to 6 inches: Stony loam
6 to 32 inches: Very stony clay loam
32 to 60 inches: Very stony sandy clay loam

Minor Components

Castner

Percent of map unit: 5 percent
Landform: Hills
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Draft Shallow (Sw) RRU 46-C 13-19" p.z. (R046XC506MT)

Sinnigam

Percent of map unit: 5 percent
Landform: Hills
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Draft Shallow (Sw) RRU 46-C 13-19" p.z. (R046XC506MT)

80—Fergus silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 3,300 to 4,200 feet
Mean annual precipitation: 15 to 19 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 105 to 130 days

Map Unit Composition

Fergus and similar soils: 90 percent
Minor components: 10 percent

Description of Fergus

Setting

Landform: Alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 3.9 mmhos/cm)
Available water capacity: High (about 9.3 inches)

Interpretive groups

Farmland classification: All areas are prime farmland
Land capability classification (irrigated): 3e
Land capability (nonirrigated): 3e
Hydrologic Soil Group: C
Ecological site: Draft Clayey (Cy) RRU 46-N 13-19" p.z. (R046XN247MT)

Typical profile

0 to 6 inches: Silty clay loam
6 to 25 inches: Silty clay loam
25 to 42 inches: Silty clay loam
42 to 60 inches: Silty clay loam

Minor Components

Twin creek

Percent of map unit: 10 percent
Landform: Alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Draft Silty (Si) RRU 46-N 13-19" p.z. (R046XN252MT)

85—Gerber silty clay loam, 0 to 4 percent slopes

Map Unit Setting

Elevation: 3,000 to 4,000 feet
Mean annual precipitation: 11 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 105 to 135 days

Map Unit Composition

Gerber and similar soils: 90 percent
Minor components: 10 percent

Description of Gerber

Setting

Landform: Till plains
Down-slope shape: Linear
Across-slope shape: Linear

Properties and qualities

Slope: 0 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 4.0 mmhos/cm)
Available water capacity: High (about 9.7 inches)

Interpretive groups

Farmland classification: Farmland of statewide importance
Land capability classification (irrigated): 3e
Land capability (nonirrigated): 3e
Hydrologic Soil Group: C
Ecological site: Draft Clayey (Cy) RRU 46-N 13-19" p.z. (R046XN247MT)

Typical profile

0 to 7 inches: Silty clay loam
7 to 14 inches: Silty clay
14 to 32 inches: Silty clay loam
32 to 60 inches: Clay loam

Minor Components

Acel

Percent of map unit: 4 percent
Landform: Outwash terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Draft Clayey (Cy) RRU 46-N 13-19" p.z. (R046XN247MT)

Abor

Percent of map unit: 3 percent
Landform: Plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Draft Clayey (Cy) RRU 46-N 13-19" p.z. (R046XN247MT)

Lawther

Percent of map unit: 3 percent
Landform: Alluvial fans
Down-slope shape: Linear

Across-slope shape: Linear
Ecological site: Draft Clayey (Cy) RRU 46-N 13-19" p.z. (R046XN247MT)

Soil Information for All Uses

Suitabilities and Limitations for Use

The Suitabilities and Limitations for Use section includes various soil interpretations displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each interpretation.

Building Site Development

Building site development interpretations are designed to be used as tools for evaluating soil suitability and identifying soil limitations for various construction purposes. As part of the interpretation process, the rating applies to each soil in its described condition and does not consider present land use. Example interpretations can include corrosion of concrete and steel, shallow excavations, dwellings with and without basements, small commercial buildings, local roads and streets, and lawns and landscaping.

Dwellings With Basements

Dwellings are single-family houses of three stories or less. For dwellings with basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of about 7 feet.

The ratings for dwellings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility. Compressibility is inferred from the Unified classification of the soil. The properties that affect the ease and amount of excavation include depth to a water table, ponding, flooding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified

use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Dwellings With Basements

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:6,010 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cascade County Area, Montana
Survey Area Data: Version 9, Jan 4, 2012

Date(s) aerial images were photographed: 7/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Dwellings With Basements

Dwellings With Basements— Summary by Map Unit — Cascade County Area, Montana (MT613)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
28	Bitton and Roy soils, 10 to 65 percent slopes	Very limited	Bitton (45%)	Too steep (1.00)	23.4	44.6%
				Large stones (0.99)		
			Roy (45%)	Too steep (1.00)		
				Large stones (0.86)		
			Castner (5%)	Too steep (1.00)		
				Depth to hard bedrock (1.00)		
			Sinnigam (5%)	Depth to hard bedrock (1.00)		
				Slope (0.04)		
				Large stones (0.29)		
80	Fergus silty clay loam, 0 to 2 percent slopes	Somewhat limited	Fergus (90%)	Shrink-swell (0.50)	28.9	55.2%
			Twin Creek (10%)	Shrink-swell (0.50)		
85	Gerber silty clay loam, 0 to 4 percent slopes	Very limited	Gerber (90%)	Shrink-swell (1.00)	0.1	0.2%
			Acel (4%)	Shrink-swell (1.00)		
			Lawther (3%)	Shrink-swell (1.00)		
Totals for Area of Interest					**52.4**	**100.0%**

Dwellings With Basements— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	28.9	55.2%
Very limited	23.5	44.8%
Totals for Area of Interest	**52.4**	**100.0%**

Rating Options—Dwellings With Basements

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Corrosion of Steel

"Risk of corrosion" pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel in

installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel in installations that are entirely within one kind of soil or within one soil layer.

The risk of corrosion is expressed as "low," "moderate," or "high."

Custom Soil Resource Report
Map—Corrosion of Steel

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- High
- Moderate
- Low
- Not rated or not available

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:6,010 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cascade County Area, Montana
Survey Area Data: Version 9, Jan 4, 2012

Date(s) aerial images were photographed: 7/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Corrosion of Steel

Corrosion of Steel— Summary by Map Unit — Cascade County Area, Montana (MT613)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
28	Bitton and Roy soils, 10 to 65 percent slopes	High	23.4	44.6%
80	Fergus silty clay loam, 0 to 2 percent slopes	High	28.9	55.2%
85	Gerber silty clay loam, 0 to 4 percent slopes	High	0.1	0.2%
Totals for Area of Interest			**52.4**	**100.0%**

Rating Options—Corrosion of Steel

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Shallow Excavations

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Custom Soil Resource Report
Map—Shallow Excavations

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:6,010 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cascade County Area, Montana
Survey Area Data: Version 9, Jan 4, 2012

Date(s) aerial images were photographed: 7/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Tables—Shallow Excavations

Shallow Excavations— Summary by Map Unit — Cascade County Area, Montana (MT613)						
Map unit symbol	**Map unit name**	**Rating**	**Component name (percent)**	**Rating reasons (numeric values)**	**Acres in AOI**	**Percent of AOI**
28	Bitton and Roy soils, 10 to 65 percent slopes	Very limited	Bitton (45%)	Too steep (1.00)	23.4	44.6%
				Large stones (0.99)		
				Unstable excavation walls (0.10)		
			Roy (45%)	Too steep (1.00)		
				Large stones (0.86)		
				Unstable excavation walls (0.10)		
			Castner (5%)	Depth to hard bedrock (1.00)		
				Too steep (1.00)		
			Sinnigam (5%)	Depth to hard bedrock (1.00)		
				Slope (0.04)		
				Large stones (0.29)		
80	Fergus silty clay loam, 0 to 2 percent slopes	Somewhat limited	Fergus (90%)	Unstable excavation walls (0.10)	28.9	55.2%
			Twin Creek (10%)	Unstable excavation walls (0.10)		
85	Gerber silty clay loam, 0 to 4 percent slopes	Somewhat limited	Gerber (90%)	Unstable excavation walls (0.10)	0.1	0.2%
			Acel (4%)	Too clayey (0.28)		
				Unstable excavation walls (0.10)		
			Lawther (3%)	Too clayey (0.28)		
				Unstable excavation walls (0.10)		
Totals for Area of Interest					**52.4**	**100.0%**

Shallow Excavations— Summary by Rating Value		
Rating	**Acres in AOI**	**Percent of AOI**
Somewhat limited	29.0	55.4%
Very limited	23.4	44.6%
Totals for Area of Interest	**52.4**	**100.0%**

Rating Options—Shallow Excavations

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Soil Reports

The Soil Reports section includes various formatted tabular and narrative reports (tables) containing data for each selected soil map unit and each component of each unit. No aggregation of data has occurred as is done in reports in the Soil Properties and Qualities and Suitabilities and Limitations sections.

The reports contain soil interpretive information as well as basic soil properties and qualities. A description of each report (table) is included.

Building Site Development

This folder contains a collection of tabular reports that present soil interpretations related to building site development. The reports (tables) include all selected map units and components for each map unit, limiting features and interpretive ratings. Building site development interpretations are designed to be used as tools for evaluating soil suitability and identifying soil limitations for various construction purposes. As part of the interpretation process, the rating applies to each soil in its described condition and does not consider present land use. Example interpretations can include corrosion of concrete and steel, shallow excavations, dwellings with and without basements, small commercial buildings, local roads and streets, and lawns and landscaping.

Dwellings and Small Commercial Buildings

Soil properties influence the development of building sites, including the selection of the site, the design of the structure, construction, performance after construction, and maintenance. This table shows the degree and kind of soil limitations that affect dwellings and small commercial buildings.

The ratings in the table are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect building site development. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Dwellings are single-family houses of three stories or less. For dwellings without basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. For dwellings with basements, the foundation is

assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of about 7 feet. The ratings for dwellings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility. Compressibility is inferred from the Unified classification. The properties that affect the ease and amount of excavation include depth to a water table, ponding, flooding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Small commercial buildings are structures that are less than three stories high and do not have basements. The foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. The ratings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility (which is inferred from the Unified classification). The properties that affect the ease and amount of excavation include flooding, depth to a water table, ponding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Information in this table is intended for land use planning, for evaluating land use alternatives, and for planning site investigations prior to design and construction. The information, however, has limitations. For example, estimates and other data generally apply only to that part of the soil between the surface and a depth of 5 to 7 feet. Because of the map scale, small areas of different soils may be included within the mapped areas of a specific soil.

The information is not site specific and does not eliminate the need for onsite investigation of the soils or for testing and analysis by personnel experienced in the design and construction of engineering works.

Government ordinances and regulations that restrict certain land uses or impose specific design criteria were not considered in preparing the information in this table. Local ordinances and regulations should be considered in planning, in site selection, and in design.

Report—Dwellings and Small Commercial Buildings

[Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the potential limitation. The table shows only the top five limitations for any given soil. The soil may have additional limitations]

Dwellings and Small Commercial Buildings– Cascade County Area, Montana							
Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
28—Bitton and Roy soils, 10 to 65 percent slopes							
Bitton	45	Very limited		Very limited		Very limited	
		Too steep	1.00	Too steep	1.00	Slope	1.00
		Large stones	0.99	Large stones	0.99	Large stones	0.99
Roy	45	Very limited		Very limited		Very limited	
		Too steep	1.00	Too steep	1.00	Slope	1.00
		Large stones	0.86	Large stones	0.86	Large stones	0.86
		Shrink-swell	0.50			Shrink-swell	0.50
80—Fergus silty clay loam, 0 to 2 percent slopes							
Fergus	90	Very limited		Somewhat limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	0.50	Shrink-swell	1.00
85—Gerber silty clay loam, 0 to 4 percent slopes							
Gerber	90	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00

Roads and Streets, Shallow Excavations, and Lawns and Landscaping

Soil properties influence the development of building sites, including the selection of the site, the design of the structure, construction, performance after construction, and maintenance. This table shows the degree and kind of soil limitations that affect local roads and streets, shallow excavations, and lawns and landscaping.

The ratings in the table are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect building site development. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations

between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Local roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a subgrade of cut or fill soil material; a base of gravel, crushed rock, or soil material stabilized by lime or cement; and a surface of flexible material (asphalt), rigid material (concrete), or gravel with a binder. The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. The properties that affect the ease of excavation and grading are depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, depth to a water table, ponding, flooding, the amount of large stones, and slope. The properties that affect the traffic-supporting capacity are soil strength (as inferred from the AASHTO group index number), subsidence, linear extensibility (shrink-swell potential), the potential for frost action, depth to a water table, and ponding.

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

Lawns and landscaping require soils on which turf and ornamental trees and shrubs can be established and maintained. Irrigation is not considered in the ratings. The ratings are based on the soil properties that affect plant growth and trafficability after vegetation is established. The properties that affect plant growth are reaction; depth to a water table; ponding; depth to bedrock or a cemented pan; the available water capacity in the upper 40 inches; the content of salts, sodium, or calcium carbonate; and sulfidic materials. The properties that affect trafficability are flooding, depth to a water table, ponding, slope, stoniness, and the amount of sand, clay, or organic matter in the surface layer.

Information in this table is intended for land use planning, for evaluating land use alternatives, and for planning site investigations prior to design and construction. The information, however, has limitations. For example, estimates and other data generally apply only to that part of the soil between the surface and a depth of 5 to 7 feet. Because of the map scale, small areas of different soils may be included within the mapped areas of a specific soil.

The information is not site specific and does not eliminate the need for onsite investigation of the soils or for testing and analysis by personnel experienced in the design and construction of engineering works.

Government ordinances and regulations that restrict certain land uses or impose specific design criteria were not considered in preparing the information in this table. Local ordinances and regulations should be considered in planning, in site selection, and in design.

Report—Roads and Streets, Shallow Excavations, and Lawns and Landscaping

[Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range

from 0.01 to 1.00. The larger the value, the greater the potential limitation. The table shows only the top five limitations for any given soil. The soil may have additional limitations]

Roads and Streets, Shallow Excavations, and Lawns and Landscaping– Cascade County Area, Montana							
Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
28—Bitton and Roy soils, 10 to 65 percent slopes							
Bitton	45	Very limited		Very limited		Very limited	
		Too steep	1.00	Too steep	1.00	Too steep	1.00
		Large stones	0.99	Large stones	0.99	Large stones	0.99
		Frost action	0.50	Unstable excavation walls	0.10		
Roy	45	Very limited		Very limited		Very limited	
		Too steep	1.00	Too steep	1.00	Too steep	1.00
		Large stones	0.86	Large stones	0.86	Large stones	0.54
		Shrink-swell	0.50	Unstable excavation walls	0.10	Droughty	0.15
		Frost action	0.50				
80—Fergus silty clay loam, 0 to 2 percent slopes							
Fergus	90	Very limited		Somewhat limited		Not limited	
		Shrink-swell	1.00	Unstable excavation walls	0.10		
		Low strength	1.00				
85—Gerber silty clay loam, 0 to 4 percent slopes							
Gerber	90	Very limited		Somewhat limited		Not limited	
		Shrink-swell	1.00	Unstable excavation walls	0.10		
		Low strength	1.00				

Soil Chemical Properties

This folder contains a collection of tabular reports that present soil chemical properties. The reports (tables) include all selected map units and components for each map unit. Soil chemical properties are measured or inferred from direct observations in the field or laboratory. Examples of soil chemical properties include pH, cation exchange capacity, calcium carbonate, gypsum, and electrical conductivity.

Chemical Soil Properties

This table shows estimates of some chemical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the survey area. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Cation-exchange capacity is the total amount of extractable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. Soils having a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer than soils having a high cation-exchange capacity. The ability to retain cations reduces the hazard of ground-water pollution.

Effective cation-exchange capacity refers to the sum of extractable cations plus aluminum expressed in terms of milliequivalents per 100 grams of soil. It is determined for soils that have pH of less than 5.5.

Soil reaction is a measure of acidity or alkalinity. It is important in selecting crops and other plants, in evaluating soil amendments for fertility and stabilization, and in determining the risk of corrosion.

Calcium carbonate equivalent is the percent of carbonates, by weight, in the fraction of the soil less than 2 millimeters in size. The availability of plant nutrients is influenced by the amount of carbonates in the soil.

Gypsum is expressed as a percent, by weight, of hydrated calcium sulfates in the fraction of the soil less than 20 millimeters in size. Gypsum is partially soluble in water. Soils that have a high content of gypsum may collapse if the gypsum is removed by percolating water.

Salinity is a measure of soluble salts in the soil at saturation. It is expressed as the electrical conductivity of the saturation extract, in deciseimens per meter at 25 degrees C. Estimates are based on field and laboratory measurements at representative sites of nonirrigated soils. The salinity of irrigated soils is affected by the quality of the irrigation water and by the frequency of water application. Hence, the salinity of soils in individual fields can differ greatly from the value given in the table. Salinity affects the suitability of a soil for crop production, the stability of soil if used as construction material, and the potential of the soil to corrode metal and concrete.

Sodium adsorption ratio (SAR) is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity and aeration, and a general degradation of soil structure.

Chemical Soil Properties– Cascade County Area, Montana								
Map symbol and soil name	**Depth**	**Cation-exchange capacity**	**Effective cation-exchange capacity**	**Soil reaction**	**Calcium carbonate**	**Gypsum**	**Salinity**	**Sodium adsorption ratio**
	In	*meq/100g*	*meq/100g*	*pH*	*Pct*	*Pct*	*dS/m*	
28—Bitton and Roy soils, 10 to 65 percent slopes								
Bitton	0-7	10-20	—	6.6-7.8	0-5	0	0	0
	7-40	10-15	—	7.4-8.4	5-10	0	0	0
	40-60	15-20	—	7.4-8.4	5-15	0	0.0-2.0	0
Roy	0-6	15-20	—	6.1-7.8	0	0	0	0
	6-32	25-30	—	6.6-7.8	0	0	0	0
	32-60	20-25	—	7.4-8.4	2-15	0	0.0-3.9	0
80—Fergus silty clay loam, 0 to 2 percent slopes								
Fergus	0-6	20-25	—	6.6-7.8	0	0	0	0
	6-25	20-30	—	6.6-7.8	0	0	0	0
	25-42	20-25	—	7.4-8.4	5-15	0	0	0
	42-60	15-20	—	7.4-9.0	5-15	0	0.0-3.9	0
85—Gerber silty clay loam, 0 to 4 percent slopes								
Gerber	0-7	20-25	—	6.6-7.8	0	0	0	0
	7-14	25-30	—	7.4-8.4	0	0	0	0
	14-32	20-25	—	7.4-8.4	5-15	0	0	0
	32-60	20-25	—	7.4-9.0	5-10	0	0.0-4.0	0

Soil Physical Properties

This folder contains a collection of tabular reports that present soil physical properties. The reports (tables) include all selected map units and components for each map unit. Soil physical properties are measured or inferred from direct observations in the field or laboratory. Examples of soil physical properties include percent clay, organic matter, saturated hydraulic conductivity, available water capacity, and bulk density.

Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage.

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field.

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination.

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Absence of an entry indicates that the data were not estimated. The asterisk '*' denotes the representative texture; other possible textures follow the dash.

Engineering Properties– Cascade County Area, Montana												
Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
28—Bitton and Roy soils, 10 to 65 percent slopes												
Bitton	0-7	*Stony loam	CL-ML, ML, SC-SM, SM	A-4	0	20-35	80-95	75-90	55-75	40-70	25-35	5-10
	7-40	*Very stony loam	CL-ML, GC-GM, ML, SC-SM	A-2, A-4	0	40-65	50-85	45-80	35-70	25-60	25-35	5-10
	40-60	*Very stony clay loam	GC	A-2, A-6	0	30-40	45-70	40-65	35-55	30-50	30-40	10-15
Roy	0-6	*Stony loam	CL-ML, SC-SM	A-4	0	10-25	80-100	70-95	60-85	45-70	20-30	5-10
	6-32	*Very stony clay loam, Extremely stony clay, very cobbly clay loam	CL, GC, SC	A-2, A-6, A-7	0	30-65	40-80	30-70	20-65	20-55	30-50	15-30
	32-60	*Very stony sandy clay loam, Extremely stony clay loam, very cobbly clay loam	CL-ML, GC, GC-GM, SC-SM	A-2, A-4, A-6	0	30-65	40-80	30-70	20-65	20-55	25-40	5-15

Engineering Properties– Cascade County Area, Montana												
Map unit symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
80—Fergus silty clay loam, 0 to 2 percent slopes												
Fergus	0-6	*Silty clay loam	CL, CL-ML	A-4, A-6	0	0	80-100	75-100	70-95	65-90	25-40	5-15
	6-25	*Silty clay loam, Clay loam, clay	CH, CL	A-6, A-7	0	0	80-100	75-100	65-95	60-90	35-55	15-30
	25-42	*Silty clay loam, Clay loam, clay	CH, CL	A-6, A-7	0	0	80-100	75-100	65-95	60-90	35-55	15-30
	42-60	*Silty clay loam, Clay loam, clay	CL	A-6, A-7	0	0	80-100	75-100	60-95	55-90	30-50	10-25
85—Gerber silty clay loam, 0 to 4 percent slopes												
Gerber	0-7	*Silty clay loam	CL	A-6, A-7	0	0	100	95-100	90-100	80-95	30-45	10-20
	7-14	*Silty clay, Clay	CH, CL	A-7	0	0	100	95-100	85-100	75-95	40-65	20-45
	14-32	*Silty clay loam, Silty clay, clay loam	CH, CL	A-6, A-7	0	0	95-100	90-100	85-100	75-95	35-55	15-35
	32-60	*Clay loam, Silty clay, silty clay loam	CH, CL	A-6, A-7	0	0	95-100	90-100	80-100	65-95	35-55	15-35

Soil Qualities and Features

This folder contains tabular reports that present various soil qualities and features. The reports (tables) include all selected map units and components for each map unit. Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Soil Features

This table gives estimates of various soil features. The estimates are used in land use planning that involves engineering considerations.

A *restrictive layer* is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restrict roots or otherwise provide an unfavorable root environment. Examples are bedrock, cemented layers, dense layers, and frozen layers. The table indicates the hardness and thickness of the restrictive layer, both of which significantly affect the ease of excavation. *Depth to top* is the vertical distance from the soil surface to the upper boundary of the restrictive layer.

Subsidence is the settlement of organic soils or of saturated mineral soils of very low density. Subsidence generally results from either desiccation and shrinkage, or oxidation of organic material, or both, following drainage. Subsidence takes place gradually, usually over a period of several years. The table shows the expected initial subsidence, which usually is a result of drainage, and total subsidence, which results from a combination of factors.

Potential for frost action is the likelihood of upward or lateral expansion of the soil caused by the formation of segregated ice lenses (frost heave) and the subsequent collapse of the soil and loss of strength on thawing. Frost action occurs when moisture moves into the freezing zone of the soil. Temperature, texture, density, saturated hydraulic conductivity (Ksat), content of organic matter, and depth to the water table are the most important factors considered in evaluating the potential for frost action. It is assumed that the soil is not insulated by vegetation or snow and is not artificially drained. Silty and highly structured, clayey soils that have a high water table in winter are the most susceptible to frost action. Well drained, very gravelly, or very sandy soils are the least susceptible. Frost heave and low soil strength during thawing cause damage to pavements and other rigid structures.

Risk of corrosion pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel or concrete. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel or concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel

or concrete in installations that are entirely within one kind of soil or within one soil layer.

For uncoated steel, the risk of corrosion, expressed as *low*, *moderate*, or *high*, is based on soil drainage class, total acidity, electrical resistivity near field capacity, and electrical conductivity of the saturation extract.

For concrete, the risk of corrosion also is expressed as *low*, *moderate*, or *high.* It is based on soil texture, acidity, and amount of sulfates in the saturation extract.

Soil Features– Cascade County Area, Montana									
Map symbol and soil name	**Restrictive Layer**				**Subsidence**		**Potential for frost action**	**Risk of corrosion**	
	Kind	**Depth to top**	**Thickness**	**Hardness**	**Initial**	**Total**		**Uncoated steel**	**Concrete**
		In	*In*		*In*	*In*			
28—Bitton and Roy soils, 10 to 65 percent slopes									
Bitton		—	—		—	—	Moderate	Moderate	Low
Roy		—	—		—	—	Moderate	High	Moderate
80—Fergus silty clay loam, 0 to 2 percent slopes									
Fergus		—	—		—	—	Low	High	Moderate
85—Gerber silty clay loam, 0 to 4 percent slopes									
Gerber		—	—		—	—	Low	High	Moderate

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APPENDIX B

BOREHOLE LOGS

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Soil Boring Log

Hole Name: BH-1

Date Hole Started: 12/20/2012 Date Hole Finished: 12/20/2012

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151971.0986

Easting: 1553424.2367

Ground Elevation:

County: Cascade State: Montana

Property Owner:

Legal Description: T19N R4E S14 SE1/4

Location Description: Approx. 20 ft SW of Tank Center

Recorded By: JRG

Drilling Company: Boland

Driller: Jason

Drilling Method: Hollow Stem Auger

Drilling Machine: CME 55

Drilling Fluid: None

Sample Hammer Drop System: 140 lb Cathead

Inner Rod Size (ID/OD, in):

Hole Diameter (in): 6"

Total Depth Drilled (ft): 6.3

Water Table Depth (ft):

Remarks: Approximately 20 feet southwest of tank center. Auger refusal at 6.3 feet. Took bulk 5 gallon bucket sample at cuttings at 0.0 - 4.0 feet.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
												0.0 - 2.8' **Sandy CLAY** Medium brown to reddish brown (when wet), dry, very dense, plastic.	
	SS1	49	64	1.30			CL		15				
	SS2	100+	100+	0.70								2.8 - 4.8' **Sandy SILT to Silty SAND with Gravel** Gray brown and orange, dry, very dense, gravel is sandstone fragments. [Glacial Till]	
	SS3	56	63	1.40									
5	SS4	100+	100+	1.20								4.8 - 6.0' **Silty CLAY** Brown, moist, very stiff, plastic. [Glacial Till]	
												6.0 - 6.3' **GRAVEL** Red, dry, very dense. [Weathered Bedrock]	

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Hydrometrics, Inc.

Consulting Scientists and Engineers
Helena, Montana

Soil Boring Log

Hole Name: BH-2

Date Hole Started: 12/20/2012 Date Hole Finished: 12/20/2012

Client: MT DEQ
Project: Sand Coulee
COORDINATES
Northing: 1151973.9847
Easting: 1553452.3734
Ground Elevation:

County: Cascade
Property Owner:
Legal Description: T19N R4E S14 SE1/4
Location Description: Approx. 20 feet SE of Tank Center

State: Montana

Recorded By: JRG
Drilling Company: Boland
Driller: Jason
Drilling Method: Hollow Stem Auger
Drilling Machine: CME 55
Drilling Fluid: None

Sample Hammer Drop System: 140 lb Cathead
Inner Rod Size (ID/OD, in):
Hole Diameter (in): 6"
Total Depth Drilled (ft): 2.5
Water Table Depth (ft):

Remarks: Approximately 20 feet southeast of tank center. Auger refusal at 2.5 feet.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
												0.0 - 0.2' **Topsoil** 0.2 - 2.5' **GRAVEL and COBBLE** Purple red, dry, very dense, angular sandstone fragments. [Weathered Bedrock]	

Hydrometrics, Inc.

Consulting Scientists and Engineers
Helena, Montana

Soil Boring Log

Hole Name: BH-3

Date Hole Started: 12/20/2012 Date Hole Finished: 12/20/2012

Client: MT DEQ
Project: Sand Coulee
COORDINATES
Northing: 1152002.1214
Easting: 1553449.4873
Ground Elevation:

County: Cascade
Property Owner:
Legal Description: T19N R4E S14 SE1/4
Location Description: Approx. 20 feet NE of Tank Center

State: Montana

Recorded By: JRG
Drilling Company: Boland
Driller: Jason
Drilling Method: Hollow Stem Auger
Drilling Machine: CME 55
Drilling Fluid: None

Sample Hammer Drop System: 140 lb Cathead
Inner Rod Size (ID/OD, in):
Hole Diameter (in): 6"
Total Depth Drilled (ft): 2.5
Water Table Depth (ft):

Remarks: Approximately 20 feet northeast of tank center. Auger refusal at 2.5 feet.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
												0.0 - 1.5' **Sandy CLAY** Damp, very stiff, plastic. [Glacial Till]	
	SS1	100+	100+	1.00								1.5 - 2.5' **Silty SAND with Gravel** Red and tan, dry, very dense, angular sandstone fragments. [Weathered Bedrock]	

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Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-2

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151859.646

Easting: 1553518.34

Ground Elevation: 3685.4

County: Cascade

Property Owner:

Legal Description: T19N R4E S14 SE 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 6.2

Water Table Depth (ft):

Remarks: Time 09:40. Refusal on weathered bedrock (?) at 6.2 feet. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.80								0.0 - 0.6' **Silty CLAY** Brown, moist, low plasticity, abundant roots, grades into below. [Topsoil] 0.6 - 2.7' **Silty SAND with Gravel (broken angular weak sandstone fragments)** Buff, dry, very dense. [Glacial Till]	
5	M2			2.90								2.7 - 5.2' **CLAY with some Sand** Grayish brown, dry, very stiff, shattered, moderate plasticity. [Glacial Till] 5.2 - 5.4' **Sandy GRAVEL** Orange-brown, dry, very dense, weathered sandstone. [Glacial Till] 5.4 - 6.2' **CLAY** Grayish brown, dry, very stiff, shattered, moderate plasticity. Refusal at 6.2 feet on bedrock. [Glacial Till]	

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Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-5

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151435.302

Easting: 1554128.66

Ground Elevation: 3505.0

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft): 2.6

Remarks: Environmental sample SCR-1301-100 taken from 0.2 to 1.8 feet. Time 13:55. Hole offset 3 feet west from planned location. Water encountered at about 2.5 feet below ground surface. Installed 1-inch PVC standpipe piezometer with stickup of 2.45 feet.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.40								0.0 - 0.2' **Clayey SAND** Reddish brown, moist, medium dense. 0.2 - 1.8' **Sandy CLAY** Dark brown with black coal fragments, moist, medium stiff, plastic (contains coal). [Fill]	
												1.8 - 5.2' **Clayey SAND with Gravel** Reddish/orange, moist to wet with depth, dense, estimated 15% fines, 25% subround gravel to 1.5 inch diameter, 60% medium to coarse sand, homogeneous. [Fill]	
5												5.2 - 5.5' **SAND** Very moist, light gray with some orange staining, fine-grained sand (SP), possibly just fragment in glacial till. [Glacial Till]	
	M2			3.20			CL		11			5.5 - 8.0' **Sandy CLAY with Occasional Gravel** Reddish brown, moist, stiff, low plastic, weathered sandstone fragment at 7.0 feet (Glacial Till), contains red pebbles (<5%), up to 45% fine to medium sand. [Glacial Till]	

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-7

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1152097.507

Easting: 1554847.789

Ground Elevation: 3495.8

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 14:40. Offset 5 feet west from planned location. Easy hammering. Installed 1-inch PVC standpipe piezometer with 2.2-feet stickup. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.10								0.0 - 0.6' **Silty SAND** Brown with black and red fragments, medium dense, dry, contains organics, some coal. [Fill/Disturbed] 0.6 - 2.5' **Clayey SAND with Some Gravel** Medium brown with some orange pockets, medium dense, damp, slight plastic fines, gravel <10%, appears in place. [Glacial Till]	
												2.5 - 4.7' **Clayey SAND with Some Gravel** Light brown with some orange pockets, medium dense, dry, slightly plastic fines, gravel <10%, appears in place. [Glacial Till]	
5	M2			2.70								4.7 - 6.3' **Fine SAND** Stratified brown, buff and tan, dry, medium dense, very fine, uniform sand (SP). [Glacial Till]	
							CL-ML		6			6.3 - 8.0' **Sandy Silty CLAY** Brown, damp, stiff, low plastic, contains few subround to angular gravel fragments, 40% sand, and trace fine black pockets (approximately 5%). [Glacial Till]	

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Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-8

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151706.332

Easting: 1554476.088

Ground Elevation: 3499.1

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 7.6

Water Table Depth (ft): 7.3

Remarks: Time 13:30. Environmental sample SCR-1301-101 taken from 1.5 to 3.2 feet. Hole offset 6 feet west. Hole cored to 7.6 feet rather than 8.0 feet because macro felt full. Groundwater encountered at 7.3 feet BGS.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
												0.0 - 1.5' **Gravelly CLAY** Moist, multicolored (matrix reddish brown with black, white and red small brick fragments), very stiff, low plastic. [Fill]	
	M1			3.90								1.5 - 3.2' **Silty SAND with Gravel** Black (with red (brick) and white fragments), slightly moist, very dense, contains abundant coal. [Fill/Coal Slack]	
												3.2 - 4.6' **Sand CLAY** Brown to gray brown, moist, very stiff, low plastic, contains some sand and gravel fragments. [Fill]	
5	M2			2.90								4.6 - 7.0' **Clayey SAND with Gravel** Orange, reddish brown with black (coal) fragments, moist, very dense, estimated 15% fines, 50% fine to coarse sand, 30% subround and angular (MB) gravel fragments, random orientation of fragments (i.e., opposed to gravity). [Fill]	
												7.0 - 7.4' **Sandy CLAY** Brown, moist, very stiff, plastic, appears in place. [Glacial Till]	
												7.4 - 7.6' **SAND** Slightly moist, greenish gray, very dense, fine silty sand. [Glacial Till]	

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-9

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151940.147

Easting: 1554986.98

Ground Elevation: 3492.4

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 15:30. Environmental sample SCR-1301-102 taken from 0.0 to 2.2 feet. Easy hammering. Installed 1-inch PVC standpipe piezometer with stickup of 2.18 feet. No groundwater encountered. Offset 17 feet east and 7 feet south from planned location.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.20								0.0 - 2.2' **SAND with Gravel** Black with pockets of white, red, orange, moist, dense, with fine angular gravel (20%), may be burned trash with coal fragments. [Coal Slack/Fill]	
												2.2 - 2.4' **GRAVEL** Gray, sandstone fragments. [Fill]	
												2.4 - 2.7' **CLAY** Red, moist, very stiff, plastic, with coal fragments. [Fill]	
												2.7 - 3.2' **SAND with Gravel** Gray, slightly moist, dense, angular sandstone fragments. [Fill]	
5	M2			3.00								3.2 - 8.0' **Clayey SAND with Gravel** Brown/reddish brown with black, red and orange pockets (mixed), slightly moist, dense, does not appear in place (random particle orientation and black fragments). [Fill]	

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-10

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1152100.853

Easting: 1555343.778

Ground Elevation: 3486.8

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 12:10. Environmental sample SCR-1301-105 taken from 0.0 to 1.9 feet. Hole offset 18 feet west from planned location. Hard hammering except for last 1.5 feet. Installed 1-inch PVC standpipe, stickup 2.2 feet AGS. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.70								0.0 - 1.9' **Sandy SILT with Trace Gravel** Dark brown with white and orange pockets, stiff, low plasticity, contains abundant coal debris. [Fill]	
												1.9 - 2.2' **Silty Fine SAND** Reddish brown, medium dense, slightly moist. [Glacial Till]	
												2.2 - 3.2' **Gravelly SAND** Gray and orange, dry, very dense, gravel: weak sandstone fragments. [Glacial Till]	
5											5	3.2 - 7.3' **Silty Gravelly SAND** Medium brown-gray brown, dry, dense, estimated 40% subangular gravel and 60% sand with some silty subangular and some subround gravel, homogeneous. [Glacial Till]	
	M2			2.90								7.3 - 7.8' **Silty SAND** Reddish brown, dry, dense, fine sand. [Glacial Till]	
												7.8 - 8.0' **CLAY** Reddish brown, slightly moist, very stiff, plastic, trace black coal fragments. [Glacial Till]	

GEOTECH_COMPLETE K:\GINT\PROJECTS\12106 - GEOTECHNICAL.GPJ HYDHLN2.GDT 2/6/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-11

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1151637.113

Easting: 1555472.041

Ground Elevation: 3544.1

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 13:00. Hole offset 20 feet northwest to flat bench off of steep road. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
5	M1			2.60								0.0 - 1.0' **Clayey SAND with Gravel** Dark brown with black and light red fragments, damp to moist, medium dense, slightly plastic fines, with angular gravel up to 20%, contains some coal fragments. [Fill] 1.0 - 1.4' **Sandy CLAY** Brown with orange, white and black pockets, damp, stiff, low plastic. [Fill] 1.4 - 3.5' **Silty SAND with Gravel** Dark brown/black with orange fragments, dry, dense, contains coal. [Fill] 3.5 - 4.4' **CLAY** Grayish brown, dry, very stiff, shattered, medium plasticity, possibly disturbed native material. [Fill] 4.4 - 7.0' **Gravelly SAND** Brown matrix with orange/pink/black pockets and fragments, dense, estimated 30% gravel (subangular) and 10% clayey sand, possibly in place. [Fill/Glacial Till] 7.0 - 8.0' **Gravelly CLAY** Medium brown with orange and gray fragments (sandstone), dry, very stiff, plastic with up to 25% angular gravel, appears in place although some fragments have random orientation. [Glacial Till]	
	M2			3.10									

GEOTECH_COMPLETE K:\GINT\PROJECTS\12106 - GEOTECHNICAL.GPJ HYDHLN2.GDT 2/6/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-12

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1152216.864

Easting: 1555661.898

Ground Elevation: 3483.4

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Cored through pavement to approximately 0.8 feet, then pulled rods and re-cored. Time 10:50. Environmental sample SCR-1301-103 taken from 0.0 to 2.9 feet. Hole offset 7 feet west of planned location. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
5	M1			4.40								0.0 - 0.1' **ASPHALT/CHIPSEAL Fragments and Silty SAND with Fine GRAVEL** Dark brown and gray brown, slightly moist, very dense. [Fill] 0.1 - 2.9' **Clayey SAND with Gravel** Black, gray brown, white, orange, light purple zone from 0.9 to 1.5 feet, slightly moist, dense, with fine and medium subround and angular gravel (approximately 30%), similar to MB-9. [Coal Slack/Fill]	
	M2			3.90			CL		10			2.9 - 5.2' **Sandy SILT to Silty SAND** Reddish brown, moist, very stiff/dense, trace fine embedded black (coal) fragments, estimated 60% fine sand, 40% slightly plastic fines, grades into below fines content increases at approximately 3.5 feet. [Glacial Till] 5.2 - 8.0' **Silty CLAY** Reddish brown, slightly moist, stiff, low plasticity, contains some sand (approximaterly 10%), trace embedded fine black (coal) fragments, white pockets and mottling. [Glacial Till]	

GEOTECH_COMPLETE K:\GINT\PROJECTS\12106 - GEOTECHNICAL.GPJ HYDHLN2.GDT 2/6/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-13

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1152562.664

Easting: 1555714.916

Ground Elevation: 3479.5

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 10:20. Hole offset 18 feet east of planned location. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.60								0.0 - 1.1' **TOPSOIL and Silty Fine SAND** Dark brown with black (coal), orange, and gray fragments, lower 1/3, dry, medium dense, some gravel near bottom. [Fill]	
												1.1 - 1.9' **Sandy SILT to Silty SAND** Reddish brown with some black and orange fragments, dry, stiff/dense, low plasticity. [Glacial Till]	
												1.9 - 4.0' **Sandy SILT with Trace Subround Gravel** Reddish brown, dry, medium stiff, estimated up to 40% fine sand, low plasticity. [Glacial Till]	
5	M2			3.40								4.0 - 4.5' **Gravelly SAND** Medium brown, dry, loose, fine and medium sand and approximately 20% fine subround gravel. [Glacial Till]	
5												4.5 - 6.0' **Sandy CLAY to Clayey Fine SAND** Reddish brown, dry, stiff, low plasticity, contains trace coal fragments and calcitic veins. [Glacial Till]	
												6.0 - 8.0' **Gravelly SAND** Dry, brown, pink and orange, medium dense, estimated 30% subround and subangular gravel, 70% slightly silty sand, stratified. [Glacial Till]	

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-14

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1152520.243

Easting: 1556017.36

Ground Elevation: 3483.5

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 SW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 4.2

Water Table Depth (ft):

Remarks: Time 11:20. Environmental sample SCR-1301-104 taken from 2.1 to 3.3 feet. Hole offset 6 feet east from planned location. Refusal at 4.2 feet - gray sandstone fragments in shoe. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
5	M1			3.90								0.0 - 2.1' **CLAY** Brown/gray brown, slightly moist to moist, plastic, scattered gravel fragments, irregular pattern (non-native). [Fill]	
												2.1 - 3.3' **COAL DEBRIS** Orange and white zones, scattered fine gravel. [Coal Slack/Fill]	
	M2			0.00								3.3 - 4.0' **Sandy SILT to Silty SAND** Reddish brown, moist, very stiff/dense, trace fine embedded black (coal) fragments, estimated 60% fine sand, 40% slightly plastic fines. Refusal at 4.2 feet. [Glacial Till]	
5													

GEOTECH_COMPLETE K:\GINT\PROJECTS\12106 - GEOTECHNICAL.GPJ HYDHLN2.GDT 2/6/13

Hydrometrics, Inc.

Consulting Scientists and Engineers

Helena, Montana

Geotechnical Boring Log

Hole Name: MB-15

Date Hole Started: 1/3/2013 Date Hole Finished: 1/3/2013

Client: MT DEQ

Project: Sand Coulee

COORDINATES

Northing: 1153014.698

Easting: 1556243.559

Ground Elevation: 3474.1

County: Cascade

Property Owner:

Legal Description: T19N R4E S13 NW 1/4

Location Description:

State: Montana

Recorded By: JRG

Drilling Company: Hydrometrics, Inc.

Driller: Rick Lane

Drilling Method: Powerprobe

Drilling Machine: AMS PowerProbe

Drilling Fluid: None

Sample Hammer Drop System:

Inner Rod Size (ID/OD, in):

Hole Diameter (in):

Total Depth Drilled (ft): 8

Water Table Depth (ft):

Remarks: Time 11:40. Hole offset 9 feet west from planned location. Refusal at 8 inches, then offset 1 foot. Very hard hammering to 2.3 feet. No groundwater encountered.

DEPTH	SAMPLE NUMBER	SPT(N) BPF	(N1)60 BPF	RECOVERY (feet)	Qu (tsf) PENETROMETER	Cu (tsf) SHEAR VANE	USCS	DRY DENSITY (pcf)	PI (%)	MOISTURE CONTENT (%)	GRAPHICS	GEOLOGICAL DESCRIPTION	PIEZOMETER COMPLETION
	M1			3.90								0.0 - 1.2' **ASPHALT/CHIPSEAL Debris and Clayey SAND** Black and dark brown, dry, very dense. [Fill] 1.2 - 1.6' **Gravelly SAND** Orange, dry, dense, fractured sandstone fragments. [Glacial Till] 1.6 - 2.0' **Sandy CLAY** Dark brown, damp, very stiff, low plastic. [Glacial Till] 2.0 - 2.6' **Broken SILTSTONE/FINE SANDSTONE Fragments** [Glacial Till] 2.6 - 3.5' **Clayey SAND with Gravel** Brown matrix with orange, brown, and white fragments, dry, dense. [Glacial Till]	
5	M2			2.90								3.5 - 4.8' **Clayey SAND with Gravel** Brown matrix with orange, brown, and white fragments, dry, dense, increase in clay content. [Glacial Till] 4.8 - 5.8' **Clayey SAND** Medium brown, dry, dense, with orange and black pockets and calcitic veins. [Glacial Till] 5.8 - 6.4' **CLAY with Some Sand** Dark brown, very stiff, moderate plastic, with black (coal) pockets. [Glacial Till] 6.4 - 8.0' **Sandy CLAY and Gravelly SAND** Lenses of clay and sand (broken weathered gravel), brown, gray, and orange, dry, very dense/very stiff. [Glacial Till]	

GEOTECH_COMPLETE K:\GINT\PROJECTS\12106 - GEOTECHNICAL.GPJ HYDHLN2.GDT 2/6/13

APPENDIX C

CALCULATIONS

Sand Coulee Water Tank
12106

BH	SS size	Sample	DEPTH INTERVAL		INT 1	INT 2	INT 3	N	Avg. Density	Avg Depth	SWL [1]	σ' =	C_{HS}	C_E	C_N	C_{ROD}	TYPE	(N1)60
	in		From	To	fist 6"	second 6"	last 6"	bpf	pcf	ft	ft bgs	tsf						bpf
BH-1	2x1.5	SS1	1	2.5	15	20	29	49	100	2		0.09	1.17	1.00	1.50	0.75	CL	64
	2x1.5	SS2	2.5	3.3	31	50		NA	100	3		0.16	1.17	1.00	1.50	0.75	ML/SM	100+
	2x1.5	SS3	3.5	5	29	32	24	48	100	4		0.21	1.17	1.00	1.50	0.75	ML/SM	63
	2x1.5	SS4	5	6.3	9	18	50	NA	100	5		0.26	1.17	1.00	1.50	0.75	CL	100+
BH-3	2x1.5	SS1	1	2.3	7	35	50	NA	100	1		0.06	1.17	1.00	1.50	0.75		100+

$(N_1)_{60}$ = $N \times C_{HS} \times C_E \times C_N \times C_{ROD}$ Average 64

Where:

N = Blow counts recorded in the field

ER = Ratio of actual hammer efficiency to 60% standard

C_{HS} = Sampler and soil type correction (2x1.5 inch sampler, no liner):

Cohesive 1.2

Cohesionless 1.17

C_E = Correction for hammer efficiency

= Hammer Efficiency / 60%

C_N = Correction for overburden

= $1 / \sigma'^{1/2}$

Where: Effective overburden pressure in tons/sq.ft

C_{ROD} = Correction for short rod lengths at shallow depths

75%

85%

95%

100%

Hammer efficiency: 0.6

[1] Input depth to water only at and below respective depth.

RANKINE EARTH PRESSURES

1 (Bowles, 1997)
2 (McCarthy, 2002)
3 (Hunt, 1984), Table 3.31; Soil type CL

ϕ = 32 degrees
0.559 radians
β = 0 degrees
0.000 radians
γ = 120.0 pcf

Pressure Cases [1]

Active = γK_a
Active = 36.9 pcf

Passive = γK_p
Passive = 391 pcf

At-Rest = γK_o
At-Rest = 56.4 pcf

Active Earth Pressure [1]

$$K_a = \cos\beta \times \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$$

$$K_a = \frac{0.4701}{1.5299}$$

K_a = 0.307

Passive Earth Pressure [1]

$$K_p = \frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}$$

$$K_p = \frac{1.5299}{0.4701}$$

K_p = 3.255

At-Rest Pressure [2]

$K_o = \sigma_h/\sigma_v$

Where:

$\sigma_v = \gamma z$

$\sigma_h = \sigma_v(\mu/1-\mu)$

γ =	120.0	pcf [3]
μ =	0.320	poisson's ratio
z	4	feet

σ_v = 480.0 lbs/foot

σ_h = 225.6 lbs/foot

K_o = 0.470

APPENDIX D

GEOTECHNICAL LABORATORY DATA

Hydrometrics, Inc.

Consulting Scientists and Engineers

PHYSICAL PROPERTIES OF AGGREGATES/SOILS

CLIENT NAME: MT DEQ	PROJECT NO.: 12106
ADDRESS:	DATE OF REPORT:
ATTN:	
PROJECT: Sand Coulee	SAMPLE NO.: BH-1, 0.0-4.0 ft
LOCATION: Sand Coulee, MT	SAMPLE DEPTH/DESCRIPTION:
	TESTED BY: CD
SAMPLED BY: J Gilstrap DATE: 12/20/2012	UNIFIED SOIL CLASSIFICATION: CL
SUBMITTED BY: Hydrometrics, Inc. DATE:	SOURCE OF MATERIAL: GEOTECHNICAL BORING
	LAB NO.

SIEVE ANALYSIS

TEST STANDARDS ARE ASTM UNLESS OTHERWISE NOTED

SIEVE SIZE	CUMULATIVE % PASSING	CONTROL BAND	DESIGN RANGE	TESTS		RESULTS	SPECIFICATIONS	TEST STANDARD
6				FLAT AND ELONGATED PARTICLES,%				D 4791
5				FRACTURED FACES	AT LEAST 1 FACE, %			D 5821
4					2 OR MORE FACES, %			D 5821
3	100.0%			COEFFICIENT of UNIFORMITY (C_u)		ND		
2	100.0%			COEFFICIENT of CURVATURE (C_c)		ND		
1 1/2	100.0%			SAND EQUIVALENT VALUE				D 2419
1	100.0%			LIQUID LIMIT / PLASTICITY INDEX		34.6 / 15.4		D 4318
3/4	95.7%			MOISTURE / DENSITY RELATIONSHIP	MAX. DRY DENSITY, pcf	111.7	STANDARD & PROCEDURE	
1/2	95.2%				OPTIMUM MOISTURE, %	15.2	ASTM D698	
3/8	94.1%				METHOD	C		
#4	89.4%			FINENESS MODULUS				C 125
#8				LIGHTWEIGHT PIECES, %				C 123
#10	85.5%			CLAY LUMPS & FRIABLE PARTICLES, %				C 142
#20	82.6%			ORGANIC IMPURITIES				C 40
#30				SPECIFIC GRAVITY	BULK			C 127/128
#40	80.4%				BULK SSD			C 127/128
#60	78.4%				APPARENT			C 127/128
#80					ABSORPTION, %			C 127/128
#100	76.2%			HYDROMETER				D 422
#200	73.4%			AS RECEIVED MOISTURE CONTENT, %				C 566

3020 Bozeman Avenue
Helena, MT 59601
(406) 443-4150

Hydrometrics, Inc.

Consulting Scientists and Engineers

PHYSICAL PROPERTIES OF AGGREGATES/SOILS

CLIENT NAME: MT DEQ	PROJECT NO.: 12106
ADDRESS:	DATE OF REPORT:
ATTN:	
PROJECT: Sand Coulee	SAMPLE NO.: MB-5, 5.5-8.0 ft
LOCATION: Sand Coulee, MT	SAMPLE DEPTH/DESCRIPTION:
	TESTED BY: CD
SAMPLED BY: J Gilstrap DATE: 1/3/2013	UNIFIED SOIL CLASSIFICATION: CL
SUBMITTED BY: Hydrometrics, Inc. DATE:	SOURCE OF MATERIAL: GEOTECHNICAL BORING
	LAB NO.

SIEVE ANALYSIS

TEST STANDARDS ARE ASTM UNLESS OTHERWISE NOTED

SIEVE SIZE	CUMULATIVE % PASSING	CONTROL BAND	DESIGN RANGE	TESTS		RESULTS	SPECIFICATIONS	TEST STANDARD
6				FLAT AND ELONGATED PARTICLES,%				D 4791
5				FRACTURED	AT LEAST 1 FACE, %			D 5821
4				FACES	2 OR MORE FACES, %			D 5821
3	100.0%			COEFFICIENT of UNIFORMITY (C_u)		ND		
2	100.0%			COEFFICIENT of CURVATURE (C_c)		ND		
1 1/2	100.0%			SAND EQUIVALENT VALUE				D 2419
1	100.0%			LIQUID LIMIT / PLASTICITY INDEX		28.5 / 11.3		D 4318
3/4	100.0%			MOISTURE /	MAX. DRY DENSITY, pcf		STANDARD & PROCEDURE	
1/2	100.0%			DENSITY	OPTIMUM MOISTURE, %			
3/8	100.0%			RELATIONSHIP	METHOD			
#4	95.9%			FINENESS MODULUS				C 125
#8				LIGHTWEIGHT PIECES, %				C 123
#10	92.6%			CLAY LUMPS & FRIABLE PARTICLES, %				C 142
#20	88.4%			ORGANIC IMPURITIES				C 40
#30					BULK			C 127/128
#40	80.5%			SPECIFIC	BULK SSD			C 127/128
#60	70.8%			GRAVITY	APPARENT			C 127/128
#80					ABSORPTION, %			C 127/128
#100	60.7%			HYDROMETER				D 422
#200	50.9%			AS RECEIVED MOISTURE CONTENT, %				C 566

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Consulting Scientists and Engineers

PHYSICAL PROPERTIES OF AGGREGATES/SOILS

CLIENT NAME: MT DEQ	PROJECT NO.: 12106
ADDRESS:	DATE OF REPORT:
ATTN:	
PROJECT: Sand Coulee	SAMPLE NO.: MB-7, 6.3-8.0 ft
LOCATION: Sand Coulee, MT	SAMPLE DEPTH/DESCRIPTION:
	TESTED BY: CD
SAMPLED BY: J Gilstrap DATE: 1/3/2013	UNIFIED SOIL CLASSIFICATION: CL-ML
SUBMITTED BY: Hydrometrics, Inc. DATE:	SOURCE OF MATERIAL: GEOTECHNICAL BORING
	LAB NO.

SIEVE ANALYSIS

TEST STANDARDS ARE ASTM UNLESS OTHERWISE NOTED

SIEVE SIZE	CUMULATIVE % PASSING	CONTROL BAND	DESIGN RANGE	TESTS		RESULTS	SPECIFICATIONS	TEST STANDARD
6				FLAT AND ELONGATED PARTICLES,%				D 4791
5				FRACTURED	AT LEAST 1 FACE, %			D 5821
4				FACES	2 OR MORE FACES, %			D 5821
3	100.0%			COEFFICIENT of UNIFORMITY (C_u)		ND		
2	100.0%			COEFFICIENT of CURVATURE (C_c)		ND		
1 1/2	100.0%			SAND EQUIVALENT VALUE				D 2419
1	100.0%			LIQUID LIMIT / PLASTICITY INDEX		21 / 6.2		D 4318
3/4	100.0%			MOISTURE /	MAX. DRY DENSITY, pcf		STANDARD & PROCEDURE	
1/2	100.0%			DENSITY	OPTIMUM MOISTURE, %			
3/8	100.0%			RELATIONSHIP	METHOD			
#4	94.6%			FINENESS MODULUS				C 125
#8				LIGHTWEIGHT PIECES, %				C 123
#10	90.2%			CLAY LUMPS & FRIABLE PARTICLES, %				C 142
#20	86.9%			ORGANIC IMPURITIES				C 40
#30					BULK			C 127/128
#40	83.0%			SPECIFIC	BULK SSD			C 127/128
#60	74.9%			GRAVITY	APPARENT			C 127/128
#80					ABSORPTION, %			C 127/128
#100	66.3%			HYDROMETER				D 422
#200	55.3%			AS RECEIVED MOISTURE CONTENT, %				C 566

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Hydrometrics, Inc.

Consulting Scientists and Engineers

PHYSICAL PROPERTIES OF AGGREGATES/SOILS

CLIENT NAME: MT DEQ	PROJECT NO.: 12106
ADDRESS:	DATE OF REPORT:
ATTN:	
PROJECT: Sand Coulee	SAMPLE NO.: MB-12, 5.2-8.0 ft
LOCATION: Sand Coulee, MT	SAMPLE DEPTH/DESCRIPTION:
	TESTED BY: CD
SAMPLED BY: J Gilstrap DATE: 1/3/2013	UNIFIED SOIL CLASSIFICATION: CL
SUBMITTED BY: Hydrometrics, Inc. DATE:	SOURCE OF MATERIAL: GEOTECHNICAL BORING
	LAB NO.

SIEVE ANALYSIS

TEST STANDARDS ARE ASTM UNLESS OTHERWISE NOTED

SIEVE SIZE	CUMULATIVE % PASSING	CONTROL BAND	DESIGN RANGE	TESTS		RESULTS	SPECIFICATIONS	TEST STANDARD
6				FLAT AND ELONGATED PARTICLES,%				D 4791
5				FRACTURED	AT LEAST 1 FACE, %			D 5821
4				FACES	2 OR MORE FACES, %			D 5821
3	100.0%			COEFFICIENT of UNIFORMITY (C_u)		ND		
2	100.0%			COEFFICIENT of CURVATURE (C_c)		ND		
1 1/2	100.0%			SAND EQUIVALENT VALUE				D 2419
1	100.0%			LIQUID LIMIT / PLASTICITY INDEX		25.2 / 10.0		D 4318
3/4	100.0%			MOISTURE /	MAX. DRY DENSITY, pcf		STANDARD & PROCEDURE	
1/2	100.0%			DENSITY	OPTIMUM MOISTURE, %			
3/8	100.0%			RELATIONSHIP	METHOD			
#4	99.9%			FINENESS MODULUS				C 125
#8				LIGHTWEIGHT PIECES, %				C 123
#10	99.8%			CLAY LUMPS & FRIABLE PARTICLES, %				C 142
#20	99.5%			ORGANIC IMPURITIES				C 40
#30					BULK			C 127/128
#40	98.7%			SPECIFIC	BULK SSD			C 127/128
#60	96.7%			GRAVITY	APPARENT			C 127/128
#80					ABSORPTION, %			C 127/128
#100	94.1%			HYDROMETER				D 422
#200	88.7%			AS RECEIVED MOISTURE CONTENT, %				C 566

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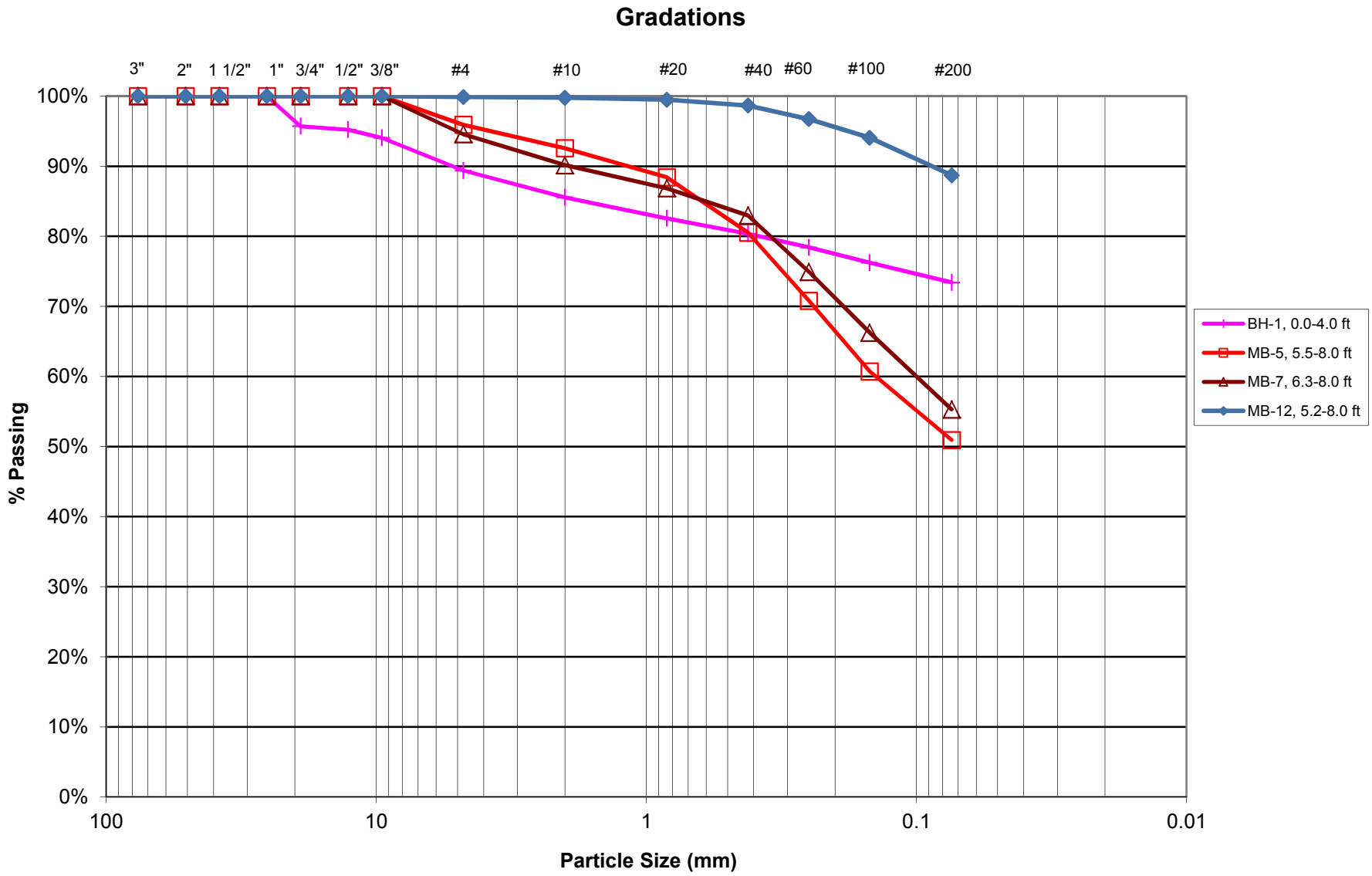


K:\project\12106\Geotech\Lab\Gradation spreadsheet.xls

Project: Sand Coulee
Project No.: 12106

Date Tested: 12/27/2012
Tested By: CD, JG

Sample: BH-1, Cuttings 0.0-4.0 ft

Sampled By: JG
Date Sampled: 12/20/2012

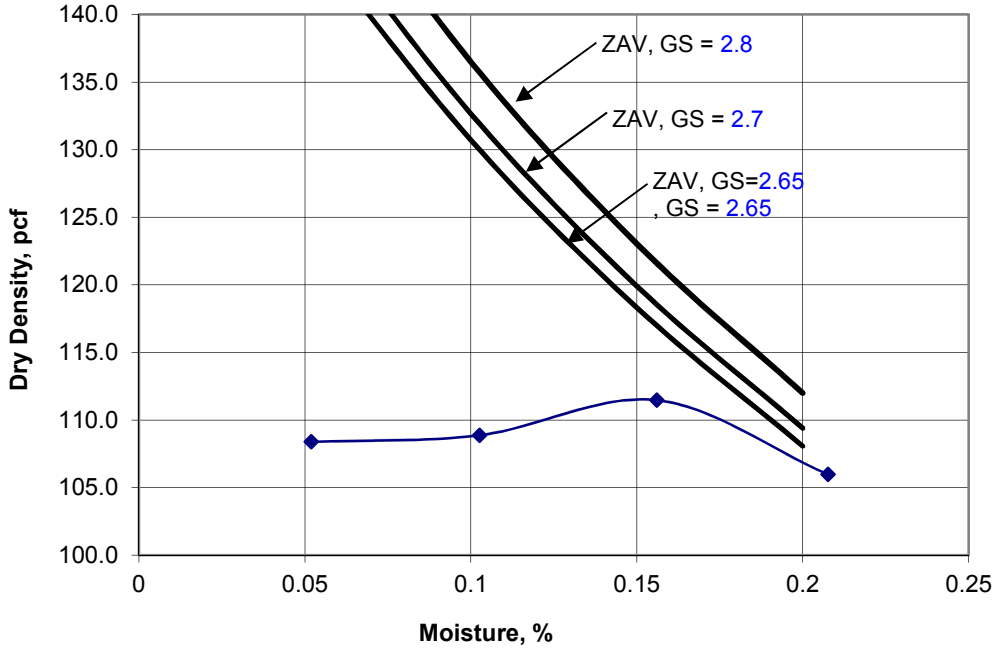
	Maximum Dry Density	**111.7**	**lb/ft^3**
	Optimum Moisture Content:	**15.2**	**%**
	Specific Gravity:	**N/A**	

Method: ASTM D-698, Method C

MOISTURE DETERMINATION	Test No.	1	2	3	4	5
	Tare No.	43	21	10	16	46
	Wet Sample + Tare (g):	74.32	83.68	63.1	71.55	69.08
	Dry Sample + Tare (g):	71.33	77.16	56.43	61.6	57.65
	Container Tare (g):	13.79	13.65	13.68	13.67	13.71
	Dry Sample (g):	57.54	63.51	42.75	47.93	43.94
	Water Weight (g):	2.99	6.52	6.67	9.95	11.43
	% Moisture:	5.2%	10.3%	15.6%	20.8%	26.0%

DENSITY DETERMINATION	Test No.	1	2	3	4	5
	Wet Soil + Tare (lb):	22.93	23.38	24.04	23.98	23.36
	Mold Tare (b):	14.37	14.37	14.37	14.37	14.37
	Wet Soil Weight (lb):	8.55	9.01	9.67	9.60	8.98
	Volume of mold (cf):	0.075	0.075	0.075	0.075	0.075
	Wet Density (pcf):	114.0	120.0	128.9	128.0	119.8
	Dry Density (pcf):	108.4	108.9	111.5	106.0	95.0

Moisture-Density Curve



APPENDIX E

ENVIRONMENTAL LABORATORY DATA

ANALYTICAL SUMMARY REPORT

February 01, 2013

MT DEQ-Abandoned Mines
PO Box 200901
Helena, MT 59620-0901

Workorder No.: H13010120

Project Name: 12106 Sand Coulee

Energy Laboratories Inc Helena MT received the following 6 samples for MT DEQ-Abandoned Mines on 1/8/2013 for analysis.

Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
H13010120-001	SCR-1301-100	01/04/13 13:55	01/08/13	Soil	Metals by ICP/ICPMS, Total Acid/Base Potential Conductivity, Saturated Paste Extract Mercury, TCLP Lime Requirement, SMP Buffer pH, Saturated Paste Digestion, Mercury by CVAA Lime Percentage Saturated Paste Extraction Sulfur Forms TCLP Extraction, Mercury TCLP Extraction, Non-volatiles
H13010120-002	SCR-1301-101	01/04/13 13:30	01/08/13	Soil	Same As Above
H13010120-003	SCR-1301-102	01/04/13 15:30	01/08/13	Soil	Same As Above
H13010120-004	SCR-1301-103	01/04/13 10:50	01/08/13	Soil	Same As Above
H13010120-005	SCR-1301-104	01/04/13 11:20	01/08/13	Soil	Same As Above
H13010120-006	SCR-1301-105	01/04/13 12:10	01/08/13	Soil	Same As Above

The analyses presented in this report were performed by Energy Laboratories, Inc., 3161 E. Lyndale Ave., Helena, MT 59604, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

The results as reported relate only to the item(s) submitted for testing.

If you have any questions regarding these test results, please call.

Report Approved By:

CLIENT: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Sample Delivery Group: H13010120

Report Date: 02/01/13

CASE NARRATIVE

Tests associated with analyst identified as ELI-B were subcontracted to Energy Laboratories, 1120 S. 27th St., Billings, MT, EPA Number MT00005.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-001
Client Sample ID SCR-1301-100

Report Date: 02/01/13
Collection Date: 01/04/13 13:55
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	6.8	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	ND	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	6.0	s.u.		0.1		ASAM10-3.2	01/15/13 07:15 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	5.0	mmhos/c		0.1		ASAM10-3	01/15/13 12:23 / sah
ACID BASE							
Sulfur, Pyritic	0.10	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
Neutralization Potential	11	t/kt				Sobek Modifie	01/14/13 09:38 / rgk
Acid Potential	3.3	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	7	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	0.82	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
Sulfur, Hot Water Extractable	0.43	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
Sulfur, HCl Extractable	0.09	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
Sulfur, HNO3 Extractable	0.10	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
Sulfur, Residual	0.20	%		0.01		Sobek Modifie	01/16/13 12:25 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/14/13 21:22 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/14/13 21:22 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/14/13 21:22 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/14/13 21:22 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/14/13 21:22 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/11/13 17:01 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/14/13 21:22 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/14/13 21:22 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-002
Client Sample ID SCR-1301-101

Report Date: 02/01/13
Collection Date: 01/04/13 13:30
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	6.6	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	3	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	6.0	s.u.		0.1		ASAM10-3.2	01/15/13 07:16 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	3.1	mmhos/c		0.1		ASAM10-3	01/15/13 12:24 / sah
ACID BASE							
Sulfur, Pyritic	0.14	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
Neutralization Potential	9	t/kt				Sobek Modifie	01/14/13 09:47 / rgk
Acid Potential	4.5	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	5	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	0.69	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
Sulfur, Hot Water Extractable	0.17	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
Sulfur, HCl Extractable	0.03	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
Sulfur, HNO3 Extractable	0.14	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
Sulfur, Residual	0.35	%		0.01		Sobek Modifie	01/16/13 12:39 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/14/13 21:25 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/14/13 21:25 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/14/13 21:25 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/14/13 21:25 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/14/13 21:25 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/11/13 17:08 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/14/13 21:25 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/14/13 21:25 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-003
Client Sample ID SCR-1301-102

Report Date: 02/01/13
Collection Date: 01/04/13 15:30
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	6.1	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	6	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	4.6	s.u.		0.1		ASAM10-3.2	01/15/13 07:17 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	3.0	mmhos/c		0.1		ASAM10-3	01/15/13 12:24 / sah
ACID BASE							
Sulfur, Pyritic	0.05	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
Neutralization Potential	5	t/kt				Sobek Modifie	01/14/13 09:56 / rgk
Acid Potential	1.6	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	3	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	0.55	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
Sulfur, Hot Water Extractable	0.08	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
Sulfur, HCl Extractable	0.04	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
Sulfur, HNO3 Extractable	0.05	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
Sulfur, Residual	0.38	%		0.01		Sobek Modifie	01/16/13 12:50 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/14/13 21:28 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/14/13 21:28 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/14/13 21:28 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/14/13 21:28 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/14/13 21:28 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/11/13 17:15 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/14/13 21:28 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/14/13 21:28 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-004
Client Sample ID SCR-1301-103

Report Date: 02/01/13
Collection Date: 01/04/13 10:50
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	6.9	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	ND	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	6.3	s.u.		0.1		ASAM10-3.2	01/15/13 07:17 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	3.2	mmhos/c		0.1		ASAM10-3	01/15/13 12:24 / sah
ACID BASE							
Sulfur, Pyritic	0.12	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
Neutralization Potential	41	t/kt				Sobek Modifie	01/14/13 10:03 / rgk
Acid Potential	3.6	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	37	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	0.45	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
Sulfur, Hot Water Extractable	0.05	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
Sulfur, HCl Extractable	ND	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
Sulfur, HNO3 Extractable	0.12	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
Sulfur, Residual	0.28	%		0.01		Sobek Modifie	01/16/13 13:19 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/14/13 21:31 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/14/13 21:31 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/14/13 21:31 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/14/13 21:31 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/14/13 21:31 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/11/13 17:28 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/14/13 21:31 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/14/13 21:31 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-005
Client Sample ID SCR-1301-104

Report Date: 02/01/13
Collection Date: 01/04/13 11:20
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	5.5	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	11	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	3.6	s.u.		0.1		ASAM10-3.2	01/15/13 07:19 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	3.3	mmhos/c		0.1		ASAM10-3	01/15/13 12:24 / sah
ACID BASE							
Sulfur, Pyritic	0.14	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
Neutralization Potential	0	t/kt				Sobek Modifie	01/14/13 10:19 / rgk
Acid Potential	4.3	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	-5	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	1.1	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
Sulfur, Hot Water Extractable	0.04	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
Sulfur, HCl Extractable	0.05	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
Sulfur, HNO3 Extractable	0.14	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
Sulfur, Residual	0.90	%		0.01		Sobek Modifie	01/16/13 13:46 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/18/13 19:53 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/18/13 19:53 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/18/13 19:53 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/18/13 19:53 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/18/13 19:53 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/17/13 15:53 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/18/13 19:53 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/18/13 19:53 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Project: 12106 Sand Coulee
Lab ID: H13010120-006
Client Sample ID SCR-1301-105

Report Date: 02/01/13
Collection Date: 01/04/13 12:10
DateReceived: 01/08/13
Matrix: Soil

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
CHEMICAL CHARACTERISTICS							
pH, SMP Buffer	7.3	s.u.		0.1		ASA12-3	01/15/13 15:30 / sah
Lime Requirement, SMP buffer	ND	Tons/100		1		ASA12-3	01/15/13 15:30 / sah
SATURATED PASTE							
pH, sat. paste	6.8	s.u.		0.1		ASAM10-3.2	01/15/13 07:19 / rgk
SATURATED PASTE EXTRACT							
Conductivity, sat. paste	1.2	mmhos/c		0.1		ASAM10-3	01/15/13 12:24 / sah
ACID BASE							
Sulfur, Pyritic	0.02	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
Neutralization Potential	21	t/kt				Sobek Modifie	01/14/13 10:29 / rgk
Acid Potential	0.8	t/kt	D	0.3		Sobek Modifie	01/14/13 11:52 / rgk
Acid/Base Potential	20	t/kt				Sobek Modifie	01/14/13 11:52 / rgk
Sulfur, Total	0.10	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
Sulfur, Hot Water Extractable	ND	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
Sulfur, HCl Extractable	ND	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
Sulfur, HNO3 Extractable	0.02	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
Sulfur, Residual	0.07	%		0.01		Sobek Modifie	01/16/13 13:58 / rgk
METALS, TCLP EXTRACTABLE							
Arsenic	ND	mg/L		0.5	5	SW6020	01/14/13 21:34 / eli-b22
Barium	ND	mg/L		10	100	SW6020	01/14/13 21:34 / eli-b22
Cadmium	ND	mg/L		0.1	1	SW6020	01/14/13 21:34 / eli-b22
Chromium	ND	mg/L		0.5	5	SW6020	01/14/13 21:34 / eli-b22
Lead	ND	mg/L		0.5	5	SW6020	01/14/13 21:34 / eli-b22
Mercury	ND	mg/L		0.002	0.2	SW7470A	01/11/13 17:34 / eli-b40
Selenium	ND	mg/L		0.1	1	SW6020	01/14/13 21:34 / eli-b22
Silver	ND	mg/L		0.5	5	SW6020	01/14/13 21:34 / eli-b22

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
D - RL increased due to sample matrix.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: ASA12-3										Batch: R85781
Sample ID: H13010120-005ADUP	2	Sample Duplicate				Run: SOIL PH METER_130115A			01/15/13 15:30	
pH, SMP Buffer		5.43	s.u.	0.10						
Lime Requirement, SMP buffer		11.0	Tons/1000T	1.0						
Sample ID: LCS-16262		Laboratory Control Sample				Run: SOIL PH METER_130115A			01/15/13 15:30	
pH, SMP Buffer		7.55	s.u.	0.10	100	70	130			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: ASAM10-3									Analytical Run: SOIL EC_130115A	
Sample ID: ICV_1_130114_1	Initial Calibration Verification Standard								01/15/13 12:25	
Conductivity, sat. paste		18.8	mmhos/cm	0.10	94	90	110			
Sample ID: ICV_1_130115_1	Initial Calibration Verification Standard								01/16/13 08:58	
Conductivity, sat. paste		20.4	mmhos/cm	0.10	102	90	110			
Sample ID: CCV_1_130114_1	Continuing Calibration Verification Standard								01/15/13 12:23	
Conductivity, sat. paste		1.38	mmhos/cm	0.10	98	90	110			
Sample ID: CCV1_1_130114_1	Continuing Calibration Verification Standard								01/15/13 12:23	
Conductivity, sat. paste		5.12	mmhos/cm	0.10	102	90	110			
Sample ID: ICV_1_130114_1	Initial Calibration Verification Standard								01/15/13 12:23	
Conductivity, sat. paste		18.8	mmhos/cm	0.10	94	90	110			
Method: ASAM10-3									Batch: 130114_1_COND-S-PASTE	
Sample ID: LCS-19253	Laboratory Control Sample					Run: SOIL EC_130115A			01/15/13 12:25	
Conductivity, sat. paste		4.33	mmhos/cm	0.10	92	80	120			
Sample ID: H13010120-004ADUP	Sample Duplicate					Run: SOIL EC_130115A			01/15/13 12:24	
Conductivity, sat. paste		3.29	mmhos/cm	0.10				2.9	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: ASAM10-3.2									Analytical Run: SOIL PH METER_130116A	
Sample ID: ICV_1_130114_1	Initial Calibration Verification Standard								01/15/13 07:11	
pH, sat. paste		10.0	s.u.	0.10	100	98	102			
Sample ID: ICV_1_130115_1	Initial Calibration Verification Standard								01/16/13 07:30	
pH, sat. paste		10.0	s.u.	0.10	100	98	102			
Sample ID: CCV_1_130114_1	Continuing Calibration Verification Standard								01/15/13 07:14	
pH, sat. paste		7.02	s.u.	0.10	100	95	105			
Sample ID: CCV1_1_130114_1	Continuing Calibration Verification Standard								01/15/13 07:14	
pH, sat. paste		4.02	s.u.	0.10	100	95	105			
Sample ID: ICV_1_130114_1	Initial Calibration Verification Standard								01/15/13 07:15	
pH, sat. paste		10.0	s.u.	0.10	100	98	102			
Method: ASAM10-3.2										Batch: 19260
Sample ID: H13010120-004ADUP	Sample Duplicate					Run: SOIL PH METER_130116A			01/15/13 07:18	
pH, sat. paste		6.27	s.u.	0.10				0.2	30	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: E200.8									Analytical Run: SUB-B198205	
Sample ID: QCS	7	Initial Calibration Verification Standard							01/14/13 09:57	
Arsenic		0.0469	mg/L	0.0050	94	90	110			
Barium		0.0472	mg/L	0.10	95	90	110			
Cadmium		0.0237	mg/L	0.0010	95	90	110			
Chromium		0.0472	mg/L	0.010	94	90	110			
Lead		0.0467	mg/L	0.010	93	90	110			
Selenium		0.0480	mg/L	0.0050	96	90	110			
Silver		0.0228	mg/L	0.0050	91	90	110			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: Sobek Modified									Batch: R85779	
Sample ID: LCS1301161214	6	Laboratory Control Sample				Run: LECO632_130116A			01/16/13 12:14	
Sulfur, Pyritic		0.23	%	0.010	98	69	131			
Sulfur, Total		0.68	%	0.010	93	90	110			
Sulfur, Hot Water Extractable		0.13	%	0.010	67	77	123			S
Sulfur, HCl Extractable		0.11	%	0.010	118	52	148			
Sulfur, HNO3 Extractable		0.23	%	0.010	98	69	131			
Sulfur, Residual		0.21	%	0.010	99	82	118			
Sample ID: H13010120-004A	6	Sample Duplicate				Run: LECO632_130116A			01/16/13 13:31	
Sulfur, Pyritic		0.10	%	0.010						
Sulfur, Total		0.47	%	0.010				3.4	30	
Sulfur, Hot Water Extractable		0.071	%	0.010				28	30	
Sulfur, HCl Extractable		ND	%	0.010					30	
Sulfur, HNO3 Extractable		0.10	%	0.010				12	30	
Sulfur, Residual		0.29	%	0.010				4.2	30	
Method: Sobek Modified									Batch: 19252	
Sample ID: LCS-19252		Laboratory Control Sample				Run: MAN-TECH_130114A			01/14/13 09:31	
Neutralization Potential		69	t/kt		97	70	130			
Sample ID: H13010120-004ADUP		Sample Duplicate				Run: MAN-TECH_130114A			01/14/13 10:09	
Neutralization Potential		41	t/kt					0.1	20	
Method: Sobek Modified									Batch: 19252	
Sample ID: H13010120-004ADUP	2	Sample Duplicate				Run: MISC SOILS_130116B			01/14/13 11:52	
Acid Potential		3.2	t/kt	0.31				12	20	
Acid/Base Potential		38	t/kt					1.0	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

S - Spike recovery outside of advisory limits.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: SUB-B198205	
Sample ID: QCS	7	Initial Calibration Verification Standard							01/14/13 20:43	
Arsenic		0.0472	mg/L	0.0010	95	90	110			
Barium		0.0479	mg/L	0.0010	96	90	110			
Cadmium		0.0238	mg/L	0.0010	95	90	110			
Chromium		0.0480	mg/L	0.0010	96	90	110			
Lead		0.0462	mg/L	0.0010	92	90	110			
Selenium		0.0484	mg/L	0.0010	97	90	110			
Silver		0.0224	mg/L	0.0010	90	90	110			
Sample ID: ICSA	7	Interference Check Sample A							01/14/13 20:49	
Arsenic		-0.000240	mg/L	0.0010						
Barium		0.000160	mg/L	0.0010						
Cadmium		0.000510	mg/L	0.0010						
Chromium		0.000970	mg/L	0.0010						
Lead		0.000120	mg/L	0.0010						
Selenium		-0.000650	mg/L	0.0010						
Silver		9.00E-05	mg/L	0.0010						
Sample ID: ICSAB	7	Interference Check Sample AB							01/14/13 20:52	
Arsenic		0.0102	mg/L	0.0010	102	70	130			
Barium		9.00E-05	mg/L	0.0010		0	0			
Cadmium		0.0103	mg/L	0.0010	103	70	130			
Chromium		0.0214	mg/L	0.0010	107	70	130			
Lead		0.000140	mg/L	0.0010		0	0			
Selenium		0.0102	mg/L	0.0010	102	70	130			
Silver		0.0194	mg/L	0.0010	97	70	130			
Method: SW6020									Batch: B_68346	
Sample ID: MB-68346	7	Method Blank				Run: SUB-B198205			01/14/13 21:04	
Arsenic		ND	mg/L	0.004						
Barium		0.5	mg/L	0.0007						
Cadmium		ND	mg/L	0.002						
Chromium		0.004	mg/L	0.001						
Lead		ND	mg/L	0.001						
Selenium		ND	mg/L	0.005						
Silver		ND	mg/L	0.001						
Sample ID: B13010847-028ADIL	7	Serial Dilution				Run: SUB-B198205			01/14/13 22:02	
Arsenic		ND	mg/L	0.10		0	0		10	
Barium		2.32	mg/L	0.50		0	0	3.4	10	
Cadmium		ND	mg/L	0.010		0	0		10	
Chromium		ND	mg/L	0.10		0	0		10	
Lead		0.00900	mg/L	0.10		0	0		10	N
Selenium		ND	mg/L	0.010		0	0		10	
Silver		ND	mg/L	0.020		0	0		10	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

N - The analyte concentration was not sufficiently high to calculate a RPD for the serial dilution test.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Report Date: 02/01/13
Project: 12106 Sand Coulee
Work Order: H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020										Batch: B_68346
Sample ID: LCS-68346	7	Laboratory Control Sample				Run: SUB-B198205				01/14/13 22:05
Arsenic		0.490	mg/L	0.10	98	85	115			
Barium		5.62	mg/L	0.50	94	85	115			
Cadmium		0.241	mg/L	0.010	96	85	115			
Chromium		0.495	mg/L	0.10	98	85	115			
Lead		0.501	mg/L	0.10	100	85	115			
Selenium		0.481	mg/L	0.010	96	85	115			
Silver		0.0467	mg/L	0.020	93	85	115			
Sample ID: LCSD-68346	7	Laboratory Control Sample Duplicate				Run: SUB-B198205				01/14/13 22:08
Arsenic		0.495	mg/L	0.10	99	85	115	0.0	20	
Barium		5.77	mg/L	0.50	97	85	115	0.0	20	
Cadmium		0.243	mg/L	0.010	97	85	115	0.0	20	
Chromium		0.499	mg/L	0.10	99	85	115	0.0	20	
Lead		0.510	mg/L	0.10	102	85	115	0.0	20	
Selenium		0.482	mg/L	0.010	96	85	115	0.0	20	
Silver		0.0486	mg/L	0.020	97	85	115	0.0	20	
Sample ID: H13010120-001B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:37
Arsenic		0.497	mg/L	0.10	98	75	125			
Barium		5.81	mg/L	0.50	91	75	125			
Cadmium		0.239	mg/L	0.010	94	75	125			
Chromium		0.483	mg/L	0.10	96	75	125			
Lead		0.496	mg/L	0.10	99	75	125			
Selenium		0.478	mg/L	0.010	94	75	125			
Silver		0.0470	mg/L	0.020	94	75	125			
Sample ID: H13010120-002B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:40
Arsenic		0.478	mg/L	0.10	95	75	125			
Barium		5.94	mg/L	0.50	90	75	125			
Cadmium		0.234	mg/L	0.010	92	75	125			
Chromium		0.479	mg/L	0.10	95	75	125			
Lead		0.481	mg/L	0.10	96	75	125			
Selenium		0.463	mg/L	0.010	91	75	125			
Silver		0.0458	mg/L	0.020	91	75	125			
Sample ID: H13010120-003B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:43
Arsenic		0.484	mg/L	0.10	97	75	125			
Barium		6.06	mg/L	0.50	90	75	125			
Cadmium		0.234	mg/L	0.010	94	75	125			
Chromium		0.483	mg/L	0.10	96	75	125			
Lead		0.488	mg/L	0.10	97	75	125			
Selenium		0.467	mg/L	0.010	93	75	125			
Silver		0.0468	mg/L	0.020	94	75	125			
Sample ID: H13010120-004B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:46
Arsenic		0.510	mg/L	0.10	102	75	125			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020										Batch: B_68346
Sample ID: H13010120-004B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:46
Barium		6.21	mg/L	0.50	94	75	125			
Cadmium		0.247	mg/L	0.010	98	75	125			
Chromium		0.508	mg/L	0.10	101	75	125			
Lead		0.518	mg/L	0.10	103	75	125			
Selenium		0.490	mg/L	0.010	98	75	125			
Silver		0.0493	mg/L	0.020	99	75	125			
Sample ID: H13010120-006B	7	Sample Matrix Spike				Run: SUB-B198205				01/14/13 22:49
Arsenic		0.494	mg/L	0.10	99	75	125			
Barium		7.15	mg/L	0.50	93	75	125			
Cadmium		0.240	mg/L	0.010	96	75	125			
Chromium		0.499	mg/L	0.10	99	75	125			
Lead		0.510	mg/L	0.10	101	75	125			
Selenium		0.475	mg/L	0.010	95	75	125			
Silver		0.0480	mg/L	0.020	96	75	125			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020									Analytical Run: SUB-B198516	
Sample ID: QCS	7	Initial Calibration Verification Standard							01/18/13 19:10	
Arsenic		0.0486	mg/L	0.0010	97	90	110			
Barium		0.0486	mg/L	0.0010	97	90	110			
Cadmium		0.0246	mg/L	0.0010	98	90	110			
Chromium		0.0488	mg/L	0.0010	98	90	110			
Lead		0.0463	mg/L	0.0010	93	90	110			
Selenium		0.0498	mg/L	0.0010	100	90	110			
Silver		0.0234	mg/L	0.0010	94	90	110			
Sample ID: ICSA	7	Interference Check Sample A							01/18/13 11:04	
Arsenic		7.00E-05	mg/L	0.0010						
Barium		0.000120	mg/L	0.0010						
Cadmium		0.000540	mg/L	0.0010						
Chromium		0.000940	mg/L	0.0010						
Lead		8.00E-05	mg/L	0.0010						
Selenium		2.00E-05	mg/L	0.0010						
Silver		0.000170	mg/L	0.0010						
Sample ID: ICSAB	7	Interference Check Sample AB							01/18/13 11:10	
Arsenic		0.0102	mg/L	0.0010	102	70	130			
Barium		7.00E-05	mg/L	0.0010		0	0			
Cadmium		0.0106	mg/L	0.0010	105	70	130			
Chromium		0.0224	mg/L	0.0010	112	70	130			
Lead		0.000120	mg/L	0.0010		0	0			
Selenium		0.00987	mg/L	0.0010	99	70	130			
Silver		0.0202	mg/L	0.0010	101	70	130			
Method: SW6020									Batch: B_68481	
Sample ID: MB-68481	7	Method Blank				Run: SUB-B198516			01/18/13 19:50	
Arsenic		ND	mg/L	0.004						
Barium		0.6	mg/L	0.0007						
Cadmium		ND	mg/L	0.002						
Chromium		0.008	mg/L	0.001						
Lead		0.003	mg/L	0.001						
Selenium		ND	mg/L	0.005						
Silver		ND	mg/L	0.001						
Sample ID: B13011099-001ADIL	7	Serial Dilution				Run: SUB-B198516			01/18/13 20:13	
Arsenic		ND	mg/L	0.10		0	0		10	
Barium		0.896	mg/L	0.50		0	0	2.0	10	
Cadmium		ND	mg/L	0.010		0	0		10	
Chromium		ND	mg/L	0.10		0	0		10	
Lead		ND	mg/L	0.10		0	0		10	
Selenium		ND	mg/L	0.010		0	0		10	
Silver		ND	mg/L	0.020		0	0		10	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW6020										Batch: B_68481
Sample ID: LCS-68481	7	Laboratory Control Sample				Run: SUB-B198516				01/18/13 20:16
Arsenic		0.500	mg/L	0.10	100	85	115			
Barium		6.47	mg/L	0.50	107	85	115			
Cadmium		0.243	mg/L	0.010	97	85	115			
Chromium		0.515	mg/L	0.10	101	85	115			
Lead		0.492	mg/L	0.10	98	85	115			
Selenium		0.484	mg/L	0.010	97	85	115			
Silver		0.0478	mg/L	0.020	96	85	115			
Sample ID: LCSD-68481	7	Laboratory Control Sample Duplicate				Run: SUB-B198516				01/18/13 20:19
Arsenic		0.496	mg/L	0.10	99	85	115	0.0	20	
Barium		6.53	mg/L	0.50	108	85	115	0.0	20	
Cadmium		0.240	mg/L	0.010	96	85	115	0.0	20	
Chromium		0.512	mg/L	0.10	101	85	115	0.0	20	
Lead		0.505	mg/L	0.10	101	85	115	0.0	20	
Selenium		0.478	mg/L	0.010	96	85	115	0.0	20	
Silver		0.0485	mg/L	0.020	97	85	115	0.0	20	
Sample ID: H13010120-005B	7	Sample Matrix Spike				Run: SUB-B198516				01/18/13 20:24
Arsenic		0.500	mg/L	0.10	100	75	125			
Barium		6.46	mg/L	0.50	107	75	125			
Cadmium		0.241	mg/L	0.010	96	75	125			
Chromium		0.514	mg/L	0.10	101	75	125			
Lead		0.600	mg/L	0.10	107	75	125			
Selenium		0.476	mg/L	0.010	95	75	125			
Silver		0.0486	mg/L	0.020	97	75	125			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW7470A									Analytical Run: SUB-B198104	
Sample ID: QCS		Initial Calibration Verification Standard							01/11/13 14:09	
Mercury		0.0019	mg/L	0.0020	97	90	110			
Method: SW7470A									Batch: B_68340	
Sample ID: MB-68340		Method Blank				Run: SUB-B198104			01/11/13 16:06	
Mercury		ND	mg/L	8E-05						
Sample ID: LCS-68340		Laboratory Control Sample				Run: SUB-B198104			01/11/13 16:09	
Mercury		0.0096	mg/L	0.0020	96	80	120			
Sample ID: LCSD-68340		Laboratory Control Sample Duplicate				Run: SUB-B198104			01/11/13 16:14	
Mercury		0.0094	mg/L	0.0020	94	80	120	2.1	10	
Sample ID: B13010593-001ADIL		Serial Dilution				Run: SUB-B198104			01/11/13 16:22	
Mercury		ND	mg/L	0.0020		0	0		10	
Sample ID: H13010120-001B		Sample Matrix Spike				Run: SUB-B198104			01/11/13 17:05	
Mercury		0.0092	mg/L	0.0020	93	75	125			
Sample ID: H13010120-002B		Sample Matrix Spike				Run: SUB-B198104			01/11/13 17:11	
Mercury		0.0092	mg/L	0.0020	92	75	125			
Sample ID: H13010120-003B		Sample Matrix Spike				Run: SUB-B198104			01/11/13 17:18	
Mercury		0.0093	mg/L	0.0020	93	75	125			
Sample ID: H13010120-004B		Sample Matrix Spike				Run: SUB-B198104			01/11/13 17:31	
Mercury		0.0098	mg/L	0.0020	98	75	125			
Sample ID: H13010120-006B		Sample Matrix Spike				Run: SUB-B198104			01/11/13 17:37	
Mercury		0.0093	mg/L	0.0020	93	75	125			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines **Report Date:** 02/01/13

Project: 12106 Sand Coulee **Work Order:** H13010120

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: SW7470A									Analytical Run: SUB-B198450	
Sample ID: QCS		Initial Calibration Verification Standard							01/17/13 15:28	
Mercury		0.0020	mg/L	0.0020	99	90	110			
Method: SW7470A									Batch: B_68491	
Sample ID: MB-68491		Method Blank				Run: SUB-B198450			01/17/13 15:41	
Mercury		ND	mg/L	8E-05						
Sample ID: LCS-68491		Laboratory Control Sample				Run: SUB-B198450			01/17/13 15:44	
Mercury		0.010	mg/L	0.0020	100	80	120			
Sample ID: LCSD-68491		Laboratory Control Sample Duplicate				Run: SUB-B198450			01/17/13 15:49	
Mercury		0.010	mg/L	0.0020	100	80	120	0.0	10	
Sample ID: H13010120-005B		Serial Dilution				Run: SUB-B198450			01/17/13 15:56	
Mercury		ND	mg/L	0.0020		0	0		10	
Sample ID: H13010120-005B		Sample Matrix Spike				Run: SUB-B198450			01/17/13 15:59	
Mercury		0.0099	mg/L	0.0020	99	75	125			

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

Standard Reporting Procedures

Lab measurement of analytes considered field parameters that require analysis within 15 minutes of sampling such as pH, Dissolved Oxygen and Residual Chlorine, are qualified as being analyzed outside of recommended holding time.

Solid/soil samples are reported on a wet weight basis (as received) unless specifically indicated. If moisture corrected, data units are typically noted as –dry. For agricultural and mining soil parameters/characteristics, all samples are dried and ground prior to sample analysis.

Workorder Receipt Checklist

MT DEQ-Abandoned Mines H13010120

Login completed by: Tracy L. Lorash
Date Received: 1/8/2013
Reviewed by: BL2000\sdull
Received by: wjj
Reviewed Date: 1/11/2013
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time? (Exclude analyses that are considered field parameters such as pH, DO, Res Cl, Sulfite, Ferrous Iron, etc.)	Yes ☑	No ☐	
Temp Blank received?	Yes ☐	No ☑	Not Applicable ☐
Container/Temp Blank temperature:	6.8°C On Ice		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☐	Not Applicable ☑

Contact and Corrective Action Comments:

Client letter has collection date of 1/3/13 - COC has 1/4/13. Per Mark, COC is correct.
Client letter requests ABA with Modified Sobek - COC requests Sobek. Per Mark, letter is correct. TI 1/11/13.

CHAIN OF CUSTODY RECORD

Hydrometrics, Inc.

3020 Bozeman Avenue • Helena, Montana 59601 • (406) 443-4150

H13010120

PROJ. NO.	PROJECT NAME
12106	SAND COULEE

SAMPLERS: *(Signature)* Josh C

DATE	TIME	COMP	GRAB	SAMPLE NUMBER	NO. OF CON-TAINERS	Commons UF/RAW	Nutrients UF/H_2SO_4	Diss. Metal F/HNO_3	CN UF/NaOH	Total Metals UF/HNO_3	Total Recoverable Metals UF/HNO_3	BTEX	TPH	pH	Conductivity, ISC	Acid - Base Accounting - SOBEK	Lime Req., SMP Buffer	TCLP, RCRA 8			REMARKS
1/4/13	13:55		X	SCR-1301-100	1									X	X	X	X	X			SOIL
↓	13:30		↓	101	↓									↓	↓	↓	↓	↓			↓
	15:30			102																	
	10:50			103																	
	11:20			104																	
↓	12:10		↓	105	↓									↓	↓	↓	↓	↓			↓

Relinquished *(Signature)*	Date/Time	Received by: *(Signature)*	Lab	P.O. #	Shipped via: Bus, Fed Ex, UPS
Josh C	1/8/13 14:52				Other Air Bill #
Relinquished (Signature)	Date/Time	Received by: *(Signature)*	Remarks: Temp. 8 on Ice.		
Relinquished (Signature)	Date/Time	Received for Laboratory by: *(Signature)*	Date/Time: 1-8-13 14:53	Enclosed: ☐ Parameter sheet w/detection limits ☑ QA/QC standard mixing instructions ☐ Cover letter ☐ Other	

Split Samples: [] Accepted [] Declined _____ Signature

HFORM-1-5/99

Return results & electronic copy to:

Hydrometrics, Inc.
consulting scientists and engineers

3020 Bozeman Avenue
Helena, MT 59601
(406) 443-4150
Fax: (406) 443-4155
www.hydrometrics.com

Energy Laboratories, Helena
3161 E Lyndale Ave
PO Box 5688
Helena, MT 59604-5688

Re: TCLP, ABA, pH, SC, SMP Soil Matrix Samples

Delivered are six (6) soil matrix samples which were collected in the town of Sand Coulee, Montana on January 3, 2013, under the direction of the Montana Department of Environmental Quality. As sample volumes are minimal, please process these samples in the following order if total volume is insufficient for all analysis:

1) Toxicity Characteristic Leaching Procedure (TCLP) (Metals, RCRA 8)
2) pH
3) SC/Conductivity
4) Acid-Base Accounting, Modified Sobek Method
5) Lime Requirement, SMP Buffer Method

Please invoice MT DEQ directly:
MT DEQ Invoice Contact:

Mr. Tom Henderson
Department of Environmental Quality
P.O. Box 200901
Helena, MT 59601

Let me know if you have any questions.

Mark Rhodes, P.E.

ANALYTICAL SUMMARY REPORT

February 08, 2013

MT DEQ-Abandoned Mines
PO Box 200901
Helena, MT 59620-0901

Workorder No.: H13010312

Project Name: 12106 Sand Coulee

Energy Laboratories Inc Helena MT received the following 1 sample for MT DEQ-Abandoned Mines on 1/25/2013 for analysis.

Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
H13010312-001	SCR-1301-106	01/24/13 16:00	01/25/13	Soil	Conductivity, Saturated Paste Extract Saturated Paste Extraction Resistivity of soil extract

The analyses presented in this report were performed by Energy Laboratories, Inc., 3161 E. Lyndale Ave., Helena, MT 59604, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

The results as reported relate only to the item(s) submitted for testing.

If you have any questions regarding these test results, please call.

Report Approved By:

LABORATORY ANALYTICAL REPORT

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Client Sample ID SCR-1301-106
Lab ID: H13010312-001
Matrix: Soil

Project: 12106 Sand Coulee
Collection Date: 01/24/13 16:00
DateReceived: 01/25/13
Report Date: 02/08/13

Analyses	Result	Units	Qualifiers	RL	MDL	Method	Analysis Date / By	Prep Date	RunID	Run Order	BatchID
SATURATED PASTE EXTRACT											
Conductivity, sat. paste	0.5	mmhos/cm		0.1		ASAM10-3	01/30/13 12:23 / sah		SOIL EC_130204A : 20	30129_1_COND-S-PA	
RESISTIVITY OF SOIL											
Resistivity, Sat. Paste	2010	ohm-cm		1		Calculation	02/04/13 09:15 / sah		SOIL EC_130204A : 23		R86129

Report Definitions: RL - Analyte reporting limit. MCL - Maximum contaminant level. ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Report Date: 02/08/13
Project: 12106 Sand Coulee
Work Order: H13010312

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: ASAM10-3									Analytical Run: SOIL EC_130204A	
Sample ID: ICV_1_130131_1		Initial Calibration Verification Standard								02/01/13 08:56
Conductivity, sat. paste		20.5	mmhos/cm	0.10	102	90	110			
Sample ID: CCV_1_130129_1		Continuing Calibration Verification Standard								01/31/13 09:03
Conductivity, sat. paste		1.50	mmhos/cm	0.10	106	90	110			
Sample ID: CCV1_1_130129_1		Continuing Calibration Verification Standard								02/04/13 09:15
Conductivity, sat. paste		5.15	mmhos/cm	0.10	103	90	110			
Sample ID: ICV_1_130129_1		Initial Calibration Verification Standard								02/04/13 09:15
Conductivity, sat. paste		21.3	mmhos/cm	0.10	107	90	110			
Method: ASAM10-3									Batch: 130129_1_COND-S-PASTE	
Sample ID: LCS-19378		Laboratory Control Sample				Run: SOIL EC_130204A				01/31/13 09:03
Conductivity, sat. paste		4.30	mmhos/cm	0.10	91	80	120			
Sample ID: H13010312-001ADUP		Sample Duplicate				Run: SOIL EC_130204A				01/30/13 12:23
Conductivity, sat. paste		0.520	mmhos/cm	0.10				4.2	20	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

QA/QC Summary Report

Prepared by Helena, MT Branch

Client: MT DEQ-Abandoned Mines
Report Date: 02/08/13
Project: 12106 Sand Coulee
Work Order: H13010312

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
Method: Calculation										Batch: R86129
Sample ID: H13010312-001ADUP	Sample Duplicate					Run: SOIL EC_130204A				02/04/13 09:15
Resistivity, Sat. Paste		1920	ohm-cm	1.0				4.2	50	

Qualifiers:

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

Standard Reporting Procedures

Lab measurement of analytes considered field parameters that require analysis within 15 minutes of sampling such as pH, Dissolved Oxygen and Residual Chlorine, are qualified as being analyzed outside of recommended holding time.

Solid/soil samples are reported on a wet weight basis (as received) unless specifically indicated. If moisture corrected, data units are typically noted as –dry. For agricultural and mining soil parameters/characteristics, all samples are dried and ground prior to sample analysis.

Workorder Receipt Checklist

MT DEQ-Abandoned Mines H13010312

Login completed by: Tracy L. Lorash
Date Received: 1/25/2013
Reviewed by: BL2000\sdull
Received by: elm
Reviewed Date: 1/30/2013
Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
Custody seals intact on shipping container/cooler?	Yes ☐	No ☐	Not Present ☑
Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
Chain of custody present?	Yes ☑	No ☐	
Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
Chain of custody agrees with sample labels?	Yes ☑	No ☐	
Samples in proper container/bottle?	Yes ☑	No ☐	
Sample containers intact?	Yes ☑	No ☐	
Sufficient sample volume for indicated test?	Yes ☑	No ☐	
All samples received within holding time? (Exclude analyses that are considered field parameters such as pH, DO, Res Cl, Sulfite, Ferrous Iron, etc.)	Yes ☑	No ☐	
Temp Blank received?	Yes ☐	No ☐	Not Applicable ☑
Container/Temp Blank temperature:	-3.2°C Blue Ice		
Water - VOA vials have zero headspace?	Yes ☐	No ☐	No VOA vials submitted ☑
Water - pH acceptable upon receipt?	Yes ☐	No ☐	Not Applicable ☑

Contact and Corrective Action Comments:

We are to take the sample information from the COC, not the client letter. We are to take the analysis from the client letter. TI 1/28/13.

Hydrometrics, Inc.

CHAIN OF CUSTODY RECORD

3020 Bozeman Avenue • Helena, Montana 59601 • (406) 443-4150

H1301031 2

PROJ. NO.	PROJECT NAME
12106	Sand Coulee

SAMPLERS: *(Signature)*

DATE	TIME	COMP	GRAB	SAMPLE NUMBER	NO. OF CONTAINERS	Commons UF/RAW	Nutrients UF/H_2SO_4	Diss. Metal F/HNO_3	CN UF/NaOH	Total Metals UF/HNO_3	Total Recoverable Metals UF/HNO_3	BTEX	TPH	Minimum Resistivity Cal: 643							REMARKS
1/24/13	16:00	X		SCR-1301-106	1									X							SOIL

Relinquished *(Signature)*	Date/Time	Received by: *(Signature)*	Lab	P.O. #	Shipped via: Bus, Fed Ex, UPS
	1/25/13 15:50				Other Air Bill #
Relinquished (Signature)	Date/Time	Received by: *(Signature)*	Remarks SEE ATTACHED LETTER TEMP -3.2 on ice Hard		
Relinquished (Signature)	Date/Time	Received for Laboratory by: *(Signature)*	Date/Time	Enclosed: ☐ Parameter sheet w/detection limits ☐ QA/QC standard mixing instructions ☐ Cover letter ☐ Other	
			1/25/13 15:50		

HEORM-1-5/99

Return results & electronic copy to:

Split Samples:
[] Accepted [] Declined _____ Signature

Hydrometrics, Inc.
consulting scientists and engineers

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Energy Laboratories, Helena
3161 E Lyndale Ave
PO Box 5688
Helena, MT 59604-5688

Re: Soil Matrix Sample, Minimum Resistivity

Delivered is one (1) soil matrix sample that was collected in the town of Sand Coulee, Montana on December 20, 2012, under the direction of the Montana Department of Environmental Quality. Please run a minimum resistivity test, method California 643, on sample SCR-1301-106.

Please invoice MT DEQ directly:
MT DEQ Invoice Contact:

Mr. Tom Henderson
Department of Environmental Quality
P.O. Box 200901
Helena, MT 59601

Let me know if you have any questions.

Mark Rhodes, P.E.

APPENDIX F

MACRO CORE TUBE PHOTOS

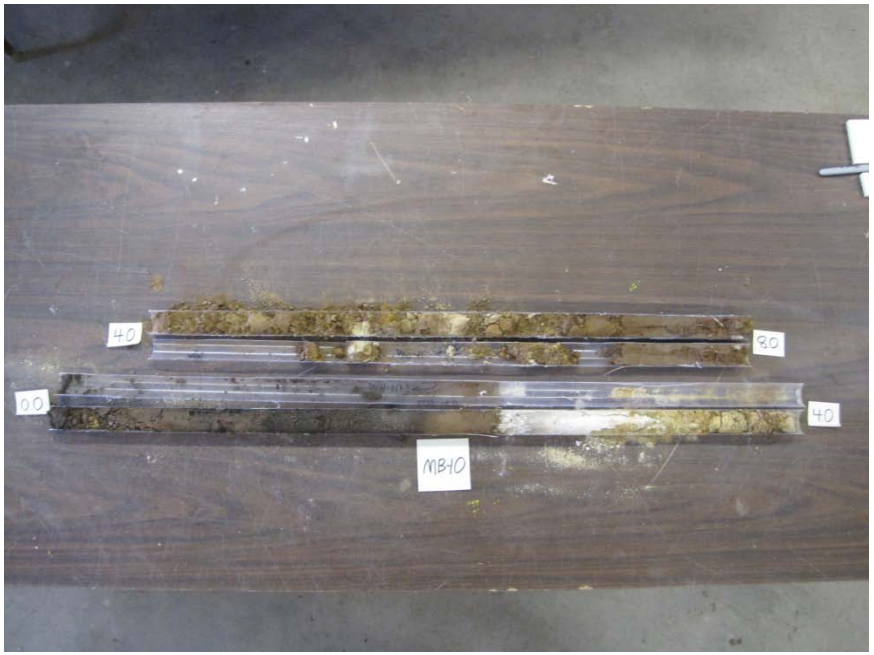
MB-2

MB-5

MB-7

MB-8

MB-9



MB-10

MB-11

MB-12

MB-13

MB-14

MB-15