REPORT OF GEOTECHICAL INVESTIGATION
WASTE WATER TREATMENT PLANT IMPROVEMENTS
LIVINGSTON, MONTANA

JUNE 2016

CLIENT: Advanced Engineering & Environmental Services
Scott Buecker, PE
1050 East Main Street, Suite 2
Bozeman, MT 59715

ENGINEER: TD&H Engineering
Peter Klevberg, PE

Great Falls • Bozeman • Kalispell • Shelby, Montana
Spokane, Washington • Lewiston, Idaho
Watford City, North Dakota • Media, Pennsylvania

234 E. Babcock, Suite 3 • Bozeman, MT 59715 • (406) 586-0277

Job No. B16-014
# Table of Contents

1.0 EXECUTIVE SUMMARY ............................................................................................................. 1

2.0 INTRODUCTION ......................................................................................................................... 2
   2.1 Purpose and Scope .................................................................................................................... 2
   2.2 Project Description .................................................................................................................... 2

3.0 SITE CONDITIONS ..................................................................................................................... 3
   3.1 Geology and Physiography ...................................................................................................... 3
   3.2 Surface Conditions .................................................................................................................... 4
   3.3 Subsurface Conditions ............................................................................................................. 5
       3.3.1 Soils ............................................................................................................................... 5
       3.3.2 Ground Water ............................................................................................................... 8

4.0 ENGINEERING ANALYSIS ...................................................................................................... 9
   4.1 Introduction ............................................................................................................................. 9
   4.2 Site Grading and Excavations ................................................................................................. 9
   4.3 Shallow Foundations ............................................................................................................. 9
   4.4 Foundation and Retaining Walls ............................................................................................ 10
   4.5 Floor Slabs and Exterior Flatwork .......................................................................................... 10
   4.6 Pavements .............................................................................................................................. 10

5.0 RECOMMENDATIONS ............................................................................................................. 11
   5.1 Site Grading and Excavations ............................................................................................... 11
   5.2 Shallow Foundations ............................................................................................................. 12
   5.3 Foundation and Retaining Walls ......................................................................................... 13
   5.4 Floor Slabs and Exterior Flatwork ....................................................................................... 13
   5.5 Pavements ............................................................................................................................. 15

6.0 SUMMARY OF FIELD AND LABORATORY STUDIES ............................................................ 16
   6.1 Field Explorations ............................................................................................................... 16
   6.2 Laboratory Testing ................................................................................................................. 16

7.0 LIMITATIONS .......................................................................................................................... 18
APPENDIX

- Boring Location Map (Figure 1)
- Logs of Exploratory Borings (Figures 2 through 8)
- Laboratory Test Data (Figures 9 through 13)
- Soil Classification and Sampling Terminology for Engineering Purposes
- Classification of Soils for Engineering Purposes
1.0 EXECUTIVE SUMMARY

The geotechnical investigation for the improvements to the existing waste water treatment plant, located on the east side of Livingston, Montana, encountered sands and gravels with minor silt. The seismic site class is D, and the risk of seismically-induced liquefaction or soil settlement is considered low and does not warrant additional evaluation. The primary geotechnical concern regarding this project is the presence of lenses of relatively compressible soil. The site is further complicated by the presence of shallow ground water within the boundaries of the Livingston solvent plume (Superfund site). The site is suitable for shallow foundations bearing on native soils with a recommended allowable bearing of 3,000 pounds per square foot provided the recommendations included in this report are followed.
2.0 INTRODUCTION

2.1 Purpose and Scope

This report presents the results of our geotechnical study for the proposed waste water treatment plant improvements to the existing Livingston plant. The purpose of the geotechnical study is to determine the general surface and subsurface conditions at the proposed site and to develop geotechnical engineering recommendations for support of the proposed structure and design of related facilities. This report describes the field work and laboratory analyses conducted for this project, the surface and subsurface conditions encountered, and presents our recommendations for the proposed foundations and related site development.

Our field work included drilling seven soil borings across the proposed site. Samples were obtained from the borings and returned to our Great Falls laboratory for testing in an environmentally isolated facility by hazardous waste trained personnel. Laboratory testing was performed on selected soil samples to determine engineering properties of the subsurface materials. The information obtained during our field investigations and laboratory analyses was used to develop recommendations for the design of the proposed foundation systems.

This study is in general accordance with the scope of work submitted by Mr. Kyle Scarr, P.E. of our firm dated March 15, 2016. Our work was authorized to proceed by Scott Buecker of Advanced Engineering & Environmental Services (AE2S) by his signed acceptance of our proposal.

2.2 Project Description

It is our understanding that the proposed project consists of, in part, a large new building housing a modified sequencing batch reactor (SBR) and a small ultraviolet (UV) disinfection building. Both buildings will be single-story structures. The SBR building will consist of multiple cells of reinforced concrete approximately 20 feet high, and this building may have a brick veneer. It will be roughly 60 by 120 feet and located near the southwestern side of the site (Figure 1). The small UV building will be near the east side of the site close to the existing UV structure. Structural loads had not been developed at the time of this report. However, for the purpose of our analysis, we have assumed that wall loads will be less than four kips per lineal foot and column loads, if any, will be less than 30 kips.

Site development will most likely include landscaping and exterior concrete flatwork. If the assumed design values presented above vary from the actual project parameters, the recommendations presented in this report should be reevaluated.
3.0 SITE CONDITIONS

3.1 Geology and Physiography

The site is geologically characterized as Yellowstone Valley alluvium. Livingston is sited at the bend in the Yellowstone River where it exits the Absarokee (Absaroka) Mountains north of Yellowstone National Park and turns east. North of Livingston are largely sedimentary strata with minor folding and faulting and some intrusive rocks. South of Livingston are dramatically faulted and folded sedimentary rocks with metamorphic and volcanic rocks that form the mountains through which the canyon of the Yellowstone River cuts. These include prominent limestone strata that form the mouth of the canyon immediately south of Livingston. Major west-east thrust faults are mapped along with smaller normal faults oriented more north and south. Gravel-capped terraces line the valley east of Livingston. Ordinary alluvial deposits are present in the valley bottom.

Northeast-dipping sedimentary rocks outcrop directly west and north of the project site. These rocks are mapped as an anticline-syncline pair, with the anticline west of the treatment plant and the syncline to the northwest. The anticline is mapped as plunging to the northwest, with the exposed core of the fold consisting of materials of the Cokedale Formation. If the Livingston Waste Water Treatment Plant unconsolidated deposits rest on or above the eroded core of this fold (i.e. if no fault truncates the fold), then the bedrock underlying the unconsolidated deposits is probably from the Cokedale Formation or the Miner Creek Formation. The Cokedale Formation is described as “andesitic siltstone and sandstone with claystone, tuff, bentonite, and coal.” The Miner Creek Formation is described as “andesitic siltstone and sandstone with beds of tuff and bentonite in lower part.” These descriptions are similar to the sandstone and claystone encountered in borings LW-1 and LW-2 (and indicated from LW-3) during this investigation. Overlying the Cokedale and Miner Creek Formations are very similar rocks of the Billman Creek Formation. These formations are considered equivalents to the Sedan Formation and form part of the Livingston Group. More thickly-bedded sandstone that outcrops less than a mile southeast of the treatment plant on the opposite side of the valley is mapped as Eagle Formation; this suggests a fault (not mapped) somewhere beneath the unconsolidated valley bottom deposits.

---

1 Berg, Richard B., David A. Lopez, and Jeffrey D. Lonn. 2000. *Geologic Map of the Livingston 30’ x 60’*
Based on the subsurface conditions encountered, the site falls under seismic Site Class D. The 2012 International Building Code (IBC), seismic design parameters for the site include site coefficients of 1.347 and 2.091 for $F_a$ and $F_v$, respectively. The recommended design spectral response accelerations at short periods ($SD_s$) and at 1-second period ($SD_t$) are 0.510g and 0.246g, respectively. These values represent two-thirds of the mapped response accelerations following correction for the appropriate site classification.

Potentially liquefiable soils are present in the form of fine-grained, poorly-graded sands. However, these occur as relatively thin, laterally limited bodies with free-draining sands and gravels above and below them. Thus, the likelihood of seismically-induced soil liquefaction or settlement for this project is low and does not warrant additional evaluation.

3.2 Surface Conditions

The proposed project site is located at the existing Waste Water Treatment Plant in Livingston, Montana, and presently consists of a primary building constructed in 1960 and a variety of other structures housing the original anaerobic digestion system and improvements made in 1980. Based on background information and site observations, the site slopes downward toward the east at slopes ranging from 0 to 2 percent. The topography is best described as nearly level.
3.3 Subsurface Conditions

3.3.1 Soils

The subsurface soil conditions appear to be somewhat variable based on our exploratory drilling and soil sampling. In general, the subsurface soil conditions encountered within the borings consist of mixed sand and gravel deposits with minor interbeds of fine sand and silt. The mixed sand and gravel exhibits a variable but minor content of fines. Where bedrock was encountered at the southwest side of the project, the sand and gravel unit extends from the surface to the bedrock, but farther east in boring LW-3, it extends to a depth of at least 40.4 feet, which was the maximum depth investigated.

The subsurface soils are described in detail on the enclosed boring logs and are summarized below. The stratification lines shown on the logs represent approximate boundaries between soil types and the actual in situ transition may be gradual vertically or discontinuous laterally.

MIXED SANDS AND GRAVELS
The predominant depositional unit at the site is a mixture of alluvial and higher energy deposits ranging from poorly-graded sand with gravel to well-graded gravel with clay and sand. Most of these rocks are hard, well-rounded to subrounded pebbles, but cobbles and boulders occur throughout the unit. Transitions are largely gradational vertically and discontinuous laterally, which is typical alluvial architecture. Materials encountered in the UV building borings, LW-6 and LW-7, which were drilled closest to the river, encountered materials indicative of lower energy, which is more akin to modern alluvial deposits. Gravel encountered a depth of 32 feet in boring LW-3 was a mixture of basalt (or possibly basaltic andesite) and claystone rip-up clasts. Gravel higher in the section was a more diverse mix of lithologies, including quartz, argillite, plutonic lithologies, and quartzites. Some of the sand exhibited noticeable quantities of pyrite.

The mixed sands and gravels unit is medium dense to very dense, as indicated by penetration resistance values which ranged from 19 to greater than 100 blows per foot (bpf) and averaged 39 bpf. Samples of the mixed sand and gravel materials contained between 32.3 and 57.1 percent gravel, between 36.7 and 63.3 percent sand, and between 3.8 and 8.7 percent silt and clay (fines). The average of eight sieve analyses was 48.5 percent gravel, 45.8 percent sand, and 5.7 percent fines. The presence of cobbles and boulders is inferred from drilling action and occasional rocks extracted from boreholes. The natural moisture contents varied from 3 to 25 percent and averaged 12 percent.
Soils included in this unit include the following:

- poorly-graded sand with gravel
- poorly-graded sand with clay and gravel
- poorly-graded gravel with sand
- poorly-graded gravel with clay and sand
- well-graded gravel with clay and sand

These soil types tend to grade into each other, though some contacts are relatively sharp and identifiable. Individual soil textures cannot be traced laterally between borings, suggesting lensoidal deposition (bar-type deposits) or gradational changes laterally. These relationships are indicated on the borings logs in the appendix.

These soil textures have low frost susceptibility, low compressibility, and good bearing capacity. This unit provides a superior bearing stratum.

**FINE-GRAINED INTERBEDS**

Limited intervals of finer-grained soils were encountered in most of the borings. These lenses or interbeds consist of poorly-graded sand, silty sand, and sandy silt. These materials are loose to medium dense as indicated by penetration resistance values which ranged from 9 to 24 bpf and averaged 16 bpf. Sieve analysis was performed of two samples of the fine-grained materials. A sample of fine-grained sand from boring LW-4, 7.0 to 9.0 feet, contained 10.4 percent gravel, 86.7 percent sand, and 2.9 percent silt and clay. A sample of sandy silt from boring LW-6, 4.0 to 5.0 feet, contained 2.7 percent gravel, 45.4 percent sand, and 51.9 percent fines. The sandy silt was determined to be granular and nonplastic. The natural moisture contents varied from 8 to 31 percent and averaged 16 percent.

**Summary of Observed Fine-Grained Interbeds**

<table>
<thead>
<tr>
<th>Boring</th>
<th>Depth (feet)</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>LW-1</td>
<td>33.5 – 34.5</td>
<td>Clayey SAND/Silty SAND/Sandy SILT</td>
</tr>
<tr>
<td>LW-2</td>
<td>14.0 – 14.6</td>
<td>Poorly-Graded SAND</td>
</tr>
<tr>
<td>LW-3</td>
<td>12.2 – 14.5</td>
<td>Sandy SILT</td>
</tr>
<tr>
<td></td>
<td>23.0 – 24.2</td>
<td>Poorly-Graded SAND</td>
</tr>
<tr>
<td></td>
<td>29.0 – 32.0</td>
<td>Sandy SILT</td>
</tr>
<tr>
<td>LW-4</td>
<td>14.8 – 16.5+</td>
<td>Poorly-Graded SAND with Gravel</td>
</tr>
<tr>
<td>LW-5</td>
<td></td>
<td>No potentially problematic lense or interbed observed.</td>
</tr>
<tr>
<td>LW-6</td>
<td>3.8 – 5.5±</td>
<td>Sandy SILT</td>
</tr>
<tr>
<td>LW-7</td>
<td></td>
<td>No potentially problematic lense or interbed observed.</td>
</tr>
</tbody>
</table>
Contacts between the lenses/interbeds and predominant sands and gravels are sometimes sharp and sometimes gradational, which can be expected if depositional current strengths waxed and waned or there were hiatus in deposition. Where gravel content increases, the compressibility of the soil and its liquefaction potential decrease. Considerable silt content was evidenced by a color change in the drilling water to a dark brownish red. The silty soils are frost susceptible where near the surface. Clean, poorly-graded sands were also encountered; these ranged from very fine-grained to coarse-grained but were predominantly fine-grained. The clean, fine-grained sands are potentially liquefiable but were encountered only as small, isolated lenses.

During drilling, the sand frequently heaved, which made drilling and sampling difficult. The silt frequently washed out with the coarser cuttings. One sample with apparent good recovery was obtained of poorly-graded sand (LW-4, 7.0 – 9.0 feet), and one was obtained of the sandy silt (LW-6, 4.0 – 5.0 feet). These samples were used for sieve analysis.

The primary geotechnical concern with the interbeds is their compressibility relative to the dense to very dense sands and gravels and their very limited lateral extent. This could potentially result in objectionable differential settlements if subjected to high applied bearing pressures. If encountered near the ground surface, the silty soils could pose a risk from frost heave.

**BEDROCK**

Sedimentary bedrock was encountered in borings LW-1 and LW-2. This consisted of very soft (probably weathered) to medium hard claystone and sandstone, locally silty and slightly calcareous, in thinly-bedded strata. The bedrock is very competent, as indicated by penetration resistance values which ranged from 50 blows for 0.2 feet to 50 blows for 0.4 feet (i.e. greater than 100 bpf). The elevation at the top of bedrock and the material encountered varied significantly between borings LW-1 and LW-2, and it was not encountered to a depth of 40.4 feet in boring LW-3. This indicates that the bedrock surface is quite irregular or sloping. Outcrops of the sedimentary strata visible to the west-northwest of the site dip to the northeast. This dip probably continues beneath the treatment plant, and it is possible the bedrock surface slopes down to the east toward the Yellowstone River with these same strata continuing beneath the site. While the bedrock materials are relatively incompressible, an irregular or sloping bedrock surface can often cause objectionable differential settlement due to the differences in soil thickness beneath a structure. However, the dense to very dense sands and gravels overlying the bedrock should effectively mitigate this potential geotechnical problem.
3.3.2 Ground Water

Ground water was encountered within all of the borings at depths ranging from six to ten feet below the ground surface. Based on the ground surface elevations, this equates to water level elevations ranging from 4,452.1 to 4,455.6 feet. In general, the highest ground water elevations were those farthest from the river. Water levels were measured at the time of drilling using a steel measuring tape. The measuring tape was decontaminated after each use in accordance with TD&H's environmental work plan, which was approved by the Montana Department of Environmental Quality.

The presence and elevation of observed ground water may be directly related to the time of the subsurface investigation, and shallower ground water may occur at other times of the year or during especially wet years. The site is within the mapped contaminant plume from the solvent release at the locomotive shop (Livingston Superfund site). No environmental sampling was included in this investigation, and TD&H cannot comment on the degree to which ground water may be impacted by tetrachloroethylene (also known as perchorethylene or PCE). Numerous factors contribute to seasonal ground water occurrences and fluctuations, and the evaluation of such factors is beyond the scope of this report.
4.0 ENGINEERING ANALYSIS

4.1 Introduction

The primary geotechnical concern regarding this project is the presence of occasional interbeds or lenses of finer grained, less competent sands and silts. The lenses or interbeds are laterally limited and can therefore be expected to induce varying amounts of settlement across the footprint of the proposed building. The extent to which this may be a problem depends on the subsurface geometry, the intensity of loading applied by the building and the contained SBR treatment cells, and the amount of differential settlement that can be tolerated.

4.2 Site Grading and Excavations

The ground surface at the proposed site is nearly level and slopes between 0 and 2 percent down toward the east (toward the Yellowstone River). Based on our field work, and assuming a finished floor elevation no more than three feet above existing grade, mixed sand and gravel soils will be encountered in foundation excavations to the depths anticipated. Based on the borings, ground water should be below the anticipated depths of footing and utility excavations; however, depending on the time of year, ground water may rise, and ground water near the base of excavation should be anticipated. It is particularly desirable to avoid excavating to or below ground water to avoid potentially encountering tetrachloroethylene contamination.

4.3 Shallow Foundations

Considering the subsurface conditions encountered and the nature of the proposed construction, the structures can be supported on conventional spread footings or mat foundations bearing on native sands and gravels. Based on the theory of elasticity, the soil conditions encountered in boring LW-3 (apparent worst case), and using an allowable bearing pressure of 3,000 psf, we estimate the total settlement for footings will be less than one inch. Differential settlement across the UV building should be on the order of one-half this magnitude. This degree of settlement is not considered objectionable for most building projects.

The lateral resistance of spread footings is controlled by a combination of sliding resistance between the footing and the foundation material at the base of the footing and the passive earth pressure against the side of the footing in the direction of movement. Design parameters are given in the recommendations section of this report.
4.4 Foundation and Retaining Walls

Ground water was encountered at depths of six to ten feet and may be shallower at certain times of the year. Excavations that encounter ground water provide potential for exposure to tetrachloroethylene (PCE) and will therefore require an approved environmental work plan and protective procedures for this hazardous waste. Structures that would require deep excavations or soil retaining walls should therefore be avoided, and are not anticipated for this project.

4.5 Floor Slabs and Exterior Flatwork

The natural on-site soils, exclusive of topsoil, are suitable to support lightly to moderately loaded, slab-on-grade construction. A leveling course of granular fill directly beneath the slab is recommended to provide a structural cushion and a drainage medium.

4.6 Pavements

No paved roadway section is anticipated for this project. Existing drive areas are gravel surfaced and are intended to remain in use.
5.0 RECOMMENDATIONS

5.1 Site Grading and Excavations

1. All topsoil and organic material, concrete and related construction debris should be removed from the proposed SBR and UV building areas and any areas to receive site grading fill. For planning purposes, a minimum stripping thickness of 6 inches is recommended for the SBR building. Thicker stripping depths may be warranted to remove all detrimental organics as determined once actual stripping operations are performed. While organic materials were not observed in the UV building borings, silty soils were present that may require removal to mitigate frost susceptibility.

2. All fill and backfill should be non-expansive, free of organics and debris and should be approved by the project geotechnical engineer. The on-site soils, exclusive of topsoil, are suitable for use as backfill and general site grading fill on this project. All fill should be placed in uniform lifts not exceeding 8 inches in thickness for fine-grained soils and not exceeding 12 inches for granular soils. All materials compacted using hand compaction methods or small walk-behind units should utilize a maximum lift thickness of 6 inches to ensure adequate compaction throughout the lift. All fill and backfill shall be compacted to the following percentages of the maximum dry density determined by a standard proctor test which is outlined by ASTM D698 or equivalent (e.g. ASTM D4253-D4254).

   a) Fill Beneath Foundations or Spread Footings.............................. 95%
   b) Below Slab-on-Grade Construction........................................ 95%
   c) Exterior Foundation Backfill ............................................. 92%
   d) General Landscaping or Nonstructural Areas............................... 90%
   e) Utility Trench Backfill, To Within 2 Feet of Surface ............... 95%

For your consideration, verification of compaction requires laboratory proctor tests to be performed on a representative sample of the soil prior to construction. These tests can require up to one week to complete (depending on laboratory backlog) and this should be considered when coordinating the construction schedule to ensure that delays in construction or additional testing expense is not required due to laboratory processing times or rush processing fees.

3. Imported structural fill, if used, should be non-expansive, free of organics and debris, and selected per the following gradation requirements:
<table>
<thead>
<tr>
<th>Screen or Sieve Size</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-inch</td>
<td>100</td>
</tr>
<tr>
<td>1½-inch</td>
<td>80 – 100</td>
</tr>
<tr>
<td>¾-inch</td>
<td>60 – 100</td>
</tr>
<tr>
<td>No. 4</td>
<td>25 – 60</td>
</tr>
<tr>
<td>No. 200</td>
<td>12 maximum</td>
</tr>
</tbody>
</table>

If frost susceptibility must be minimized (i.e. non-frost-susceptible fill), the percent passing the No. 635 sieve must not exceed 5 percent.

4. Develop and maintain site grades which will rapidly drain surface and roof runoff away from foundation and subgrade soils; both during and after construction.

5. Site utilities should be installed with proper bedding in accordance with pipe manufacturer’s requirements.

6. It is the responsibility of the Contractor to provide safe working conditions in connection with underground excavations. Temporary construction excavations greater than four feet in depth, which workers will enter, will be governed by OSHA guidelines given in 29 CFR, Part 1926. For planning purposes, subsoils encountered in the borings are considered Type C for the native soils. The soil conditions on site can change due to changes in soils moisture or disturbances to the site prior to construction. Thus, the contractor is responsible to provide an OSHA knowledgeable individual during all excavation activities to regularly assess the soil conditions and ensure that all necessary safety precautions are implemented and followed.

7. Excavation should be limited to soils above the saturated zone as much as possible. Shallow ground water (less than ten feet deep) was encountered in all borings, and ground water may be shallower at some times of the year. The site is mapped within the Superfund solvent plume, and minimizing potential contact with ground water is recommended. Site geology is highly permeable and not conducive to dewatering. No basement or retaining structure is recommended for use on this project.

5.2 Shallow Foundations

The design and construction criteria below should be observed for a spread footing foundation system. The construction details should be considered when preparing the project documents.
8. Both interior and exterior footings should bear on the native sands and gravels or on suitable engineered fill per Item 3 above and should be designed for a maximum allowable soil bearing pressure of 3,000 psf provided settlements as outlined in the Engineering Analysis are acceptable.

9. If heavier loads or lower tolerable settlements than those outlined in the Engineering Analysis are acceptable, preloading of the site should be considered to induce settlement prior to construction. We should be retained to assist with the planning and monitoring of similar preloading operations in order to verify that the performance requirement can be achieved following this operation.

10. Soils disturbed below the planned depths of footing excavations should either be re-compacted or be replaced with suitable compacted backfill approved by the geotechnical engineer.

11. Footings shall be sized to satisfy the minimum requirements of the applicable building codes while not exceeding the maximum allowable bearing pressure provided in Item 8 above.

12. Exterior footings and footings beneath unheated areas should be placed at least 48 inches below finished exterior grade for frost protection. or on non-frost-susceptible soil. For thickened-edge slabs, use of rigid board, extruded polystyrene insulation (XEPS) is recommended to provide adequate frost protection. One inch of XEPS is approximately equivalent to 1 foot of soil cover. Footings placed on non-frost-susceptible material extending to a minimum depth of 48 inches below finished exterior grade is acceptable if approved by the local building official.

13. The bottom of the footing excavations should be free of cobbles and boulders to avoid stress concentrations acting on the base of the footings.

14. Lateral loads are resisted by sliding friction between the footing base and the supporting soil and by lateral pressure against the footings opposing movement. For design purposes, a friction coefficient of 0.45 and a lateral resistance pressure of 350 psf per foot of depth are appropriate for spread footings, or mat/thickened-edge-slab foundations bearing on and backfilled with native mixed sands and gravels. Similar design values would also be acceptable for the use of structural fill (Item 3), if needed.
15. A representative of the project geotechnical engineer should be retained to observe all footing excavations and backfill phases prior to the placement of concrete formwork.

5.3 Foundation Walls

16. Backfill around foundation walls should be placed and compacted per the recommendations provided in Item 2 above. During backfill, fill should be placed in lifts of equal thickness which alternative between the interior and exterior of the foundation. Additionally, only hand operated compaction equipment should be utilized within five feet of foundation walls.

17. At this time we are not aware of the need for any below grade spaces (i.e. crawlspace or basements) for the proposed construction which would require the use of a foundation drain system. Should construction plans be altered through the design process we should be consulted to determine if foundation drain systems may be needed.

5.4 Floor Slabs and Exterior Flatwork

18. For normally loaded, slab-on-grade construction, a minimum 6-inch cushion course consisting of free-draining, crushed gravel should be placed beneath the slabs and compacted to the requirements of Item 2 above. This material should conform to the requirements outlined in Section 02235 of the Montana Public Works Standard Specifications (MPWSS) and incorporate a maximum particle size of ¾-inch. Prior to placing the cushion course, the upper six inches of subgrade should be compacted per Item 2.

19. Concrete floor slabs should be designed using a modulus of vertical subgrade reaction no greater than 500 pci when designed and constructed as recommended above.

20. Geotechnically, an underslab vapor barrier is not required for this project. A vapor barrier is normally used to limit the migration of soil gas and moisture into occupied spaces through floor slabs. The need for a vapor barrier should be determined by the architect and/or structural engineer based on interior improvements and/or moisture and gas control requirements. Attention should be paid to the potential for contaminated ground water beneath the slab and the role of a vapor barrier in mitigating possible vapor migration.
5.5 Continuing Services

Three additional elements of geotechnical engineering service are important to the successful completion of this project.

21. Consultation between the geotechnical engineer and the design professionals during the design phases is highly recommended. This is important to ensure that the intentions of our recommendations are incorporated into the design, and that any changes in the design concept consider the geotechnical limitations dictated by the on-site subsurface soil and ground water conditions.

22. Observation, monitoring, and testing during construction is required to document the successful completion of all earthwork and foundation phases. A geotechnical engineer from our firm should be retained to observe the excavation, earthwork, and foundation phases of the work to determine that subsurface conditions are compatible with those used in the analysis and design.

23. During site grading, placement of all fill and backfill should be observed and tested to confirm that the specified density has been achieved. We recommend that the Owner maintain control of the construction quality control by retaining the services of an experienced construction materials testing laboratory. We are available to provide construction inspection services as well as materials testing of compacted soils and the placement of Portland cement concrete and asphalt. TD&H Engineering is also able to provide testing personnel who are trained in working with hazardous materials should site conditions during construction require additional safety precautions to be taken.
6.0 SUMMARY OF FIELD AND LABORATORY STUDIES

6.1 Field Explorations

The field exploration program was conducted on May 3-5, 2016. A total of seven borings were drilled to depths ranging from 16.5 to 40.4 feet at the locations shown on Figure 1 to observe subsurface soil and ground water conditions. The borings were advanced through the subsurface soils using a CME-55 drill rig equipped with 6-inch O.D. hollowstem augers and an Odex downhole (pneumatic percussive) hammer. The subsurface exploration and sampling methods used are indicated on the attached boring logs. The borings were logged by Mr. Peter Klevberg, P.E. of TD&H Engineering. The location and elevation of the borings were determined by TD&H surveying staff and referenced to nearby monuments.

Samples of the subsurface materials were taken using 1½-inch I.D. split spoon samplers. The samplers were driven 18 inches, when possible, into the various strata using a 140-pound drop hammer falling 30 inches onto the drill rods. For each sample, the number of blows required to advance the sampler each successive six-inch increment was recorded, and the total number of blows required to advance the sampler the final 12 inches is termed the penetration resistance (“N-value”). This test is known as the Standard Penetration Test (SPT) described by ASTM D1586. Penetration resistance values indicate the relative density of granular soils and the relative consistency of fine-grained soils. Logs of all soil borings, which include soil descriptions, sample depths, and penetration resistance values, are presented on Figures 2 though 8.

Measurements to determine the presence and depth of ground water were made in the borings by lowering a steel measuring tape through the open boring or auger shortly after the completion of drilling. The tape was decontaminated each time it was used in accordance with TD&H's environmental work plan, which was approved by the Montana Department of Environmental Quality prior to the work. The depths or elevations of the water levels measured and the date of measurement are shown on the boring logs.

6.2 Laboratory Testing

Samples obtained during the field exploration were returned to our materials laboratory where they were observed and visually classified in general accordance with ASTM D2487, which is based on the Unified Soil Classification System. Representative samples were selected for testing to determine the engineering and physical properties of the soils in general accordance with ASTM or other approved procedures.
Tests Conducted:  To determine:

Natural Moisture Content  Representative moisture content of soil at the time of sampling.

Grain-Size Distribution  Particle size distribution of soil constituents describing the percentages of clay/silt, sand and gravel.

Atterberg Limits  A method of describing the effect of varying water content on the consistency and behavior of fine-grained soils.

The laboratory testing program for this project consisted of 65 moisture-visual analyses, 10 sieve (grain-size distribution) analyses, and one Atterberg Limits analysis. The results of the water content analyses are presented on the boring logs, Figures 2 through 8. The grain-size distribution curves and Atterberg Limits are presented on Figures 9 through 13.
7.0 LIMITATIONS

This report has been prepared in accordance with generally accepted geotechnical engineering practices in this area for use by the client for design purposes. The findings, analyses, and recommendations contained in this report reflect our professional opinion regarding potential impacts the subsurface conditions may have on the proposed project and are based on site conditions encountered. Our analysis assumes that the results of the exploratory borings are representative of the subsurface conditions throughout the site, that is, that the subsurface conditions everywhere are not significantly different from those disclosed by the subsurface study. Unanticipated soil conditions are commonly encountered and cannot be fully determined by a limited number of soil borings and laboratory analyses. Such unexpected conditions frequently require that some additional expenditures be made to obtain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

The recommendations contained within this report are based on the subsurface conditions observed in the borings and are subject to change pending observation of the actual subsurface conditions encountered during construction. TD&H cannot assume responsibility or liability for the recommendations provided if we are not provided the opportunity to perform limited construction inspection and confirm the engineering assumptions made during our analysis. A representative of TD&H should be retained to observe all construction activities associated with subgrade preparation, foundations, and other geotechnical aspects of the project to ensure the conditions encountered are consistent with our assumptions. Unforeseen conditions or undisclosed changes to the project parameters or site conditions may warrant modification to the project recommendations.

Long delays between the geotechnical investigation and the start of construction increase the potential for changes to the site and subsurface conditions which could impact the applicability of the recommendations provided. If site conditions have changed because of natural causes or construction operations at or adjacent to the site, TD&H should be retained to review the contents of this report to determine the applicability of the conclusions and recommendations provide considering the time lapse or changed conditions.

Misinterpretation of the geotechnical information by other design team members is possible and can result in costly issues during construction and with the final product. We strongly advise that TD&H be retained to review those portions of the plans and specifications which pertain to earthwork and foundations to determine if they are consistent with our recommendations and to suggest necessary modifications as warranted. In addition, TD&H should be involved throughout the construction process to observe construction, particularly the placement and compaction of all fill, preparation of all foundations, and all other geotechnical aspects. Retaining the geotechnical engineer who
prepared your geotechnical report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

This report was prepared for the exclusive use of the owner and architect and/or engineer in the design of the subject facility. It should be made available to prospective contractors and/or the contractor for information on factual data only and not as a warranty of subsurface conditions such as those interpreted from the boring logs and presented in discussions of subsurface conditions included in this report.

Prepared by: Peter Klevberg, P.E.
Geotechnical Engineer

Reviewed by: Craig R. Nadeau, P.E.
Geotechnical Engineer
TOPSOIL: Sandy Lean CLAY, appears firm, medium brown, slightly moist, medium brown; organics (sod)/Poorly-Graded GRAVEL with Clay and Sand, dense to very dense, light to medium grayish brown, very slightly moist above 9 feet (wet below 10 ft.); contains occasional cobbles and boulders; fines content varies

Poorly-Graded SAND with Clay and Gravel, dense, light brown to dark brownish gray; contains rounded and subrounded pebbles of quartz, argillite, plutonic lithologies, considerable pyrite; apparent occasional larger rocks, gravel zones; sand heaving

Poorly-Graded GRAVEL with Sand, appears very dense, light brown to medium grayish brown, wet; zones of fines, some zones classify as Poorly-Graded SAND; hard drilling

Clayey SAND/Sandy SILT, appears medium dense, light brown to medium reddish brown

SANDSTONE bedrock: soft to medium hard, thinly-bedded, silty/calcareous, fine-grained, light brown

Bottom of Boring

LEGEND

SPT blows per foot
Field Moisture content
Groundwater Level
Grab/composite sample
1-3/8-inch I.D. split spoon
2-1/2-inch I.D. split spoon
2-1/2-inch I.D. ring sampler
3-inch I.D. thin-walled sampler
No sample recovery

Atterberg Limits
Plastic Limit
In-Situ Water Content
Liquid Limit
Plasticity Index
GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.
TOPSOIL: Sandy Lean CLAY, appears firm, medium brown, slightly moist, medium brown; organics (sod).
Poorly-Graded GRAVEL with Clay and Sand, dense to very dense, light to medium grayish brown, very slightly moist above 9 feet (wet below 10 ft.); contains occasional cobbles and boulders; fine content varies very hard drilling--auger dancing on cobbles

Poorly-Graded SAND, medium dense to dense, light brown to dark brownish gray, wet; some zones classify as Poorly-Graded GRAVEL with Sand zone of Poorly-Graded GRAVEL with Clay and Sand about 10 - 12 ft.

zone of fine sand 14.0 - 14.6 ft.

Poorly-Graded GRAVEL with Clay and Sand, very dense, light brown to medium grayish brown, wet; contains zones of Poorly-Graded SAND with Gravel

Poorly-Graded GRAVEL with Sand, appears very dense, light brown to medium grayish brown, wet; very hard drilling, probably contains cobbles and boulders

CLAYSTONE bedrock: very soft rock, light yellowish/grayish brown, very slightly moist; sandy, appears very weathered

SANDSTONE: soft rock, dark reddish brown, slightly moist; appears argillaceous

CLAYSTONE bedrock: very soft rock, light yellowish/grayish brown, very slightly moist; sandy

Bottom of Boring

LEGEND

SPT blows per foot
Field Moisture content
Groundwater Level
Grab/composite sample
1-3/8-inch I.D. split spoon
2-1/2-inch I.D. split spoon
2-1/2-inch I.D. ring sampler
3-inch I.D. thin-walled sampler
No sample recovery

Afterberg Limits
Plastic Limit
In-Situ Water Content
Liquid Limit
Plasticity Index

Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.
**SOIL DESCRIPTION**

**TOPSOIL**: Sandy Lean CLAY, appears firm, medium brown, slightly moist, medium brown; lots of organics (sod)

Poorly-Graded GRAVEL with Sand, medium dense becoming dense downhole, light to medium gray to brown, very slightly moist above 6 feet (wet below); contains occasional cobbles and boulders; fines content varies

- Hard drilling - hammering through cobbles/boulders
- Considerable fines near bottom of interval

3-inch black clay ball at 10.5 ft. with detectable tetrachloroethylene

Sandy SILT (or Silty SAND), appears loose to medium dense, medium reddish brown, wet

- Poorly-Graded SAND with Gravel, medium dense to dense, light brown to dark brownish gray; heaving sand
- Poorly-Graded SAND, probably medium dense, gray, wet
- Poorly-Graded SAND with Gravel, very dense, light brown to medium grayish brown, wet; zones of fines
- Sandy SILT (or Silty SAND), appears loose to medium dense, medium reddish brown, wet

Well-Graded GRAVEL with Sand, appears dense to very dense, dark gray, wet; gravel dominated by basalt

Poorly-Graded GRAVEL with Clay and Sand, appears very dense, gray and brown, wet; consists of basalt (basaltic andesite?) gravel mixed with claystone fragments

---

**LEGEND**

- SPT blows per foot
- Field Moisture content
- Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- No sample recovery

**Atterberg Limits**

- Plastic Limit
- In-Situ Water Content
- Plasticity Index
- Liquid Limit

**Granular and Nonplastic**

**LOG OF SOIL BORING LW-3**

City of Livingston Waste Water Treatment Plant
Livingston, Montana

Logged by: P. Klevberg
Drilled by: Boland Drilling/B. Hardy

CME-45 HSA to 5 ft., Odex downhole hammer below

May 4, 2016 B16-014
Clayey GRAVEL with Sand, appears very dense, mixed dark gray and light brown, wet; consists of basalt gravel and claystone fragments with more clay (sealed off water 35.5 - 38 ft.)

Poorly-Graded GRAVEL with Clay and Sand, appears very dense, gray and brown, wet; consists of approximately two-thirds basalt gravel mixed with one-third claystone fragments

Bottom of Boring
TOPSOIL: Sandy Lean CLAY, appears firm, medium brown, slightly moist, medium brown; organics (sod)/Clayey SAND with Gravel/Poorly-Graded SAND with Clay and Gravel, medium dense, medium brown becoming gray down hole, very slightly moist above 7 ft. (wet below); occasional cobbles/boulders

Poorly-Graded SAND, appears medium dense, dark gray, wet; medium-grained

Well-Graded GRAVEL with Clay and Sand, very dense, light brown to dark gray, wet

Poorly-Graded SAND with Gravel, loose, medium reddish brown, wet; appears to contain considerable silt, possibly varying with depth

Bottom of Boring
**SURFACE:** lawn (grass)
**SURFACE ELEVATION:** 4462.2

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>GROUND WATER</th>
<th>SPT BLOW COUNTS</th>
<th>SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td></td>
<td>2-14-17</td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td></td>
<td>18-26-31</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
<td>5-27-30</td>
<td></td>
</tr>
<tr>
<td>16.5</td>
<td></td>
<td>7-14-17</td>
<td></td>
</tr>
</tbody>
</table>

**LOG OF SOIL BORING LW-5**

City of Livingston Waste Water Treatment Plant
Livingston, Montana

Logged by: P. Klevberg
Drilled by: Boland Drilling/B. Hardy
CME-45 Odex downhole percussive hammer entire depth

May 5, 2016 B16-014

---

**LOG OF SOIL DESCRIPTION**

<table>
<thead>
<tr>
<th>TOPSOIL: Sandy Lean CLAY, appears firm, medium brown, slightly moist, medium brown; organics (sod)/Well-Graded SAND with Clay and Gravel/Poorly-Graded GRAVEL with Clay and Sand, dense, medium brown/gray, very slightly moist; occasional cobbles/boulders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-Graded GRAVEL with Clay and Sand, dense to very dense, medium reddish brown to dark brown (grayer down hole); very slightly moist above 8.6 ft. (wet below); increasing gravel down hole; variable silt content</td>
</tr>
<tr>
<td>Well-Graded GRAVEL with Clay and Sand, dense to very dense, light brown to medium brownish gray, wet; contains intervals of Poorly-Graded SAND with Clay and Gravel (grayish brown) and Silty SAND/Sandy Silt (medium reddish brown to dark brown) that appear medium dense</td>
</tr>
</tbody>
</table>

heaving sand

Bottom of Boring

**LEGEND**

- SPT blows per foot
- Field Moisture content
- Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- No sample recovery

**Alterberg Limits**

- Plastic Limit
- In-Situ Water Content
- Liquid Limit

NP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.
Clayey SAND with Gravel, medium dense, light brown to medium grayish brown, very slightly moist; occasional cobbles

Sandy SILT, appears loose to medium dense, medium reddish brown, moist; contains some gravel by 5.5 feet

Poorly-Graded SAND with Gravel, medium dense to very dense, brown to medium gray (salt and pepper), wet; contains intervals of Poorly-Graded GRAVEL with Sand; considerable pyrite in sand

more gravel below 11.5 ft.

more silt below 13.5 ft. and browner color, with diminishing silt content down hole; fines nearly absent by 15 ft.

tetrachloroethylene present 15-16.5 ft. but too low to quantify

Bottom of Boring
Poorly-Graded GRAVEL with Clay and Sand, loose to very dense, medium brown, slightly moist; probably fill

Poorly-Graded SAND with Gravel, medium dense, medium brownish gray (multicolored), very slightly moist; occasional cobbles; silt content varies with depth

Well-Graded GRAVEL with Sand, very dense, medium grayish brown, wet; silty at base of interval

Poorly-Graded SAND with Clay and Gravel, medium dense, medium grayish brown, wet; abundant pyrite

Bottom of Boring
Particle Size Distribution Report

<table>
<thead>
<tr>
<th>SIEVE</th>
<th>PERCENT FINER</th>
<th>SIEVE</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○  □ △</td>
<td></td>
<td>○  □ △</td>
</tr>
<tr>
<td>1.5&quot;</td>
<td>100.0</td>
<td>#4</td>
<td>47.6</td>
</tr>
<tr>
<td>1&quot;</td>
<td>82.6 100.0</td>
<td>#10</td>
<td>37.0 53.2</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>77.4 96.3 100.0</td>
<td>#20</td>
<td>27.8 44.5</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>66.2 87.2 97.2</td>
<td>#40</td>
<td>18.5 26.7</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>59.5 80.0 94.7</td>
<td>#60</td>
<td>13.1 13.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#80</td>
<td>10.5 8.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#100</td>
<td>9.5 7.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#200</td>
<td>6.3 4.4 2.9</td>
</tr>
</tbody>
</table>

| D60   | 9.7784 3.1106 0.7171 |
| D30   | 1.0203 0.4770 0.4571 |
| D10   | 0.1651 0.2014 0.2760 |

<table>
<thead>
<tr>
<th>COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cc 0.64 0.36 1.06</td>
</tr>
<tr>
<td>Cu 59.24 15.44 2.60</td>
</tr>
</tbody>
</table>

Location: LW-2 Depth: 10.4 - 11.9 ft Sample Number: A-13204
Location: LW-3 Depth: 25.0 - 29.0 ft Sample Number: A-13219
Location: LW-4 Depth: 7.0 - 9.0 ft Sample Number: A-13229

REMARKS:
○ Report No. A-13204-206
□ Report No. A-13219-206
△ Report No. A-13229-206

Material Description:
○ Poorly-Graded GRAVEL with Clay and Sand
□ Poorly-Graded SAND with Gravel
△ Poorly-Graded SAND
<table>
<thead>
<tr>
<th>GRAIN SIZE - mm.</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3&quot;</td>
<td>% GRAVEL</td>
</tr>
<tr>
<td>0.0</td>
<td>57.1</td>
</tr>
<tr>
<td>0.0</td>
<td>53.2</td>
</tr>
<tr>
<td>0.0</td>
<td>49.9</td>
</tr>
</tbody>
</table>

**Material Description**

- Well-Graded GRAVEL with Clay and Sand
- Well-Graded GRAVEL with Clay and Sand
- Well-Graded GRAVEL with Clay and Sand

**REMARKS:**

- Report No. A-13230-206
- Report No. A-13235-206
- Report No. A-13237-206

**Client:** AE2S  
**Project:** City of Livingston Waste Water Treatment Plant  
**Location:** LW-4  
**Depth:** 10.0 - 11.5 ft  
**Sample Number:** A-13230  
**Location:** LW-5  
**Depth:** 5.0 - 6.5 ft  
**Sample Number:** A-13235  
**Location:** LW-5  
**Depth:** 10.0 - 11.5 ft  
**Sample Number:** A-13237
### Material Description
- **Sandy SILT**
- **Poorly-Graded SAND with Gravel**

### Remarks
- Report No. A-13241-206
- Report No. A-13246-206

### Grain Size - mm.

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>% GRavel</th>
<th>% SAND</th>
<th>% SILT</th>
<th>% CLAY</th>
<th>USCS</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>2.7</td>
<td>45.4</td>
<td></td>
<td>51.9</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>45.2</td>
<td>50.7</td>
<td></td>
<td>4.1</td>
<td>SP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sieve Percents Finer

#### Sieve Percent Finer Table

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>100.0</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>100.0</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>100.0</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>100.0</td>
</tr>
<tr>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>50.0</td>
<td>100.0</td>
</tr>
<tr>
<td>25.0</td>
<td>100.0</td>
</tr>
<tr>
<td>12.5</td>
<td>100.0</td>
</tr>
<tr>
<td>6.3</td>
<td>100.0</td>
</tr>
<tr>
<td>3.1</td>
<td>100.0</td>
</tr>
<tr>
<td>1.54</td>
<td>100.0</td>
</tr>
<tr>
<td>0.76</td>
<td>100.0</td>
</tr>
<tr>
<td>0.38</td>
<td>100.0</td>
</tr>
<tr>
<td>0.19</td>
<td>100.0</td>
</tr>
<tr>
<td>0.099</td>
<td>100.0</td>
</tr>
<tr>
<td>0.049</td>
<td>100.0</td>
</tr>
<tr>
<td>0.0245</td>
<td>100.0</td>
</tr>
<tr>
<td>0.01225</td>
<td>100.0</td>
</tr>
<tr>
<td>0.006125</td>
<td>100.0</td>
</tr>
<tr>
<td>0.0030625</td>
<td>100.0</td>
</tr>
<tr>
<td>0.00153125</td>
<td>100.0</td>
</tr>
<tr>
<td>0.000765625</td>
<td>100.0</td>
</tr>
<tr>
<td>0.0003828125</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### Coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_c$</td>
<td>0.25</td>
</tr>
<tr>
<td>$C_u$</td>
<td>28.72</td>
</tr>
</tbody>
</table>

### Sample Details
- **Location:** LW-6  Depth: 4.0 - 5.0 ft  **Sample Number:** A-13241
- **Location:** LW-6  Depth: 10.0 - 15.0 ft  **Sample Number:** A-13246

---

**Client:** AE2S  
**Project:** City of Livingston Waste Water Treatment Plant  
**Livingston, Montana**  
**Project No.:** B16-014  

**Tested By:** KR  
**Checked By:** Craig K. Nadeau
### Particle Size Distribution Report

**Material Description**
- ○ Poorly-Graded SAND with Gravel
- □ Well-Graded GRAVEL with Sand

**Remarks:**
- ○ Report No. A-13251-206
- □ Report No. A-13253-206

**Client:** AE2S  
**Project:** City of Livingston Waste Water Treatment Plant  
Livingston, Montana  
**Project No.:** B16-014  
**Figure:** 12

<table>
<thead>
<tr>
<th>Location: LW-7 Depth: 5.0 - 10.0 ft</th>
<th>Sample Number: A-13251</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: LW-7 Depth: 10.0 - 15.0 ft</td>
<td>Sample Number: A-13253</td>
</tr>
</tbody>
</table>

#### Grain Size - mm.

<table>
<thead>
<tr>
<th>GRAIN SIZE</th>
<th>% GRANULAR</th>
<th>% SAND</th>
<th>% SILT</th>
<th>% CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3&quot;</td>
<td>0.0</td>
<td>46.2</td>
<td>50.0</td>
<td>3.8</td>
</tr>
<tr>
<td>□</td>
<td>0.0</td>
<td>51.9</td>
<td>44.3</td>
<td>3.8</td>
</tr>
</tbody>
</table>

#### Sieve PERCENT FINER

<table>
<thead>
<tr>
<th>SIEVE number size</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>53.8</td>
</tr>
<tr>
<td>#10</td>
<td>35.7</td>
</tr>
<tr>
<td>#20</td>
<td>23.8</td>
</tr>
<tr>
<td>#40</td>
<td>12.3</td>
</tr>
<tr>
<td>#60</td>
<td>7.2</td>
</tr>
<tr>
<td>#80</td>
<td>5.6</td>
</tr>
<tr>
<td>#100</td>
<td>5.1</td>
</tr>
<tr>
<td>#200</td>
<td>3.8</td>
</tr>
</tbody>
</table>

#### Coefficients

<table>
<thead>
<tr>
<th>COEFFICIENTS</th>
<th>Cc</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>D60</td>
<td>5.7773</td>
<td>7.4937</td>
</tr>
<tr>
<td>D30</td>
<td>1.3138</td>
<td>1.6668</td>
</tr>
<tr>
<td>D10</td>
<td>0.3520</td>
<td>0.2398</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location: LW-7 Depth: 5.0 - 10.0 ft</th>
<th>Sample Number: A-13251</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: LW-7 Depth: 10.0 - 15.0 ft</td>
<td>Sample Number: A-13253</td>
</tr>
</tbody>
</table>
# LIQUID AND PLASTIC LIMITS TEST REPORT

Dashed line indicates the approximate upper limit boundary for natural soils.

<table>
<thead>
<tr>
<th>MATERIAL DESCRIPTION</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>%&lt;#40</th>
<th>%&lt;#200</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy SILT</td>
<td>NV</td>
<td>NP</td>
<td>NP</td>
<td>95.9</td>
<td>51.9</td>
<td>ML</td>
</tr>
</tbody>
</table>

**Project No.** B16-014  **Client:** AE2S  
**Project:** City of Livingston Waste Water Treatment Plant  
Livingston, Montana  
**Location:** LW-6  **Depth:** 4.0 - 5.0 ft  **Sample Number:** A-13241

**Remarks:**  
● Report No. A-13241-207  

---  

**Tested By:** KR/CRN  
**Checked By:** Craig K. Naishaw
Flow Chart For Classifying Coarse-Grained Soils (More Than 50% Retained On The No. 200 Sieve)

- **Gravel (% gravel > % sand)**
  - <5% fines
    - Cu64 and IgCg32
    - Cuc64 and or 1>Cu32
    - GW
  - >5% fines
    - Cu64 and IgCg32
    - Cuc64 and or 1>Cu32
    - GP

- **Sand (% sand > % gravel)**
  - <5% fines
    - Cu64 and IgCg32
    - Cuc64 and or 1>Cu32
    - GW-GM
  - >5% fines
    - Cu64 and IgCg32
    - Cuc64 and or 1>Cu32
    - GM

Flow Chart For Classifying Fine-Grained Soils (50% Or More Passes The No. 200 Sieve)

- **Plots on or above "A" line**
  - LL-50 (Inorganic)
    - 6xPl27 and plots on or above "A" line
      - CL-ML
  - PI-0 or plots below "A" line
    - <30% plus No. 200
      - 15% plus No. 200
        - CL
        - 15% plus No. 200
          - Lean CLAY
          - Lean CLAY with sand
          - Lean CLAY with gravel
          - Sandy lean CLAY
          - Sandy lean CLAY with gravel
          - Gravelly lean CLAY
          - Gravelly lean CLAY with sand

- **Plots on or above "A" line**
  - LL-50 (Inorganic)
    - PI plots on or above "A" line
      - CH
      - MH

- **Plots below "A" line**
  - PI plots below "A" line
    - <30% plus No. 200
      - 15% plus No. 200
        - SLT
        - SLT with sand
        - SLT with gravel
        - Sandy SLT
        - Sandy SLT with gravel
        - Gravelly SLT
        - Gravelly SLT with sand

- **Plots on or above "A" line**
  - LL-50 (Inorganic)
    - PI plots on or above "A" line
      - CH

- **Plots below "A" line**
  - PI plots below "A" line
    - MH

**ASTM D2487**

**CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES**

Great Falls, Kalispell, Bozeman, MT

Spokane, WA; Lewiston, ID, Watford City, ND
STANDARD PENETRATION TEST (ASTM D1586)

<table>
<thead>
<tr>
<th>Granular, Noncohesive (Gravels, Sands, &amp; Silts)</th>
<th>Standard Penetration Test (blows/foot)</th>
<th>Fine-Grained, Cohesive (Clays)</th>
<th>Standard Penetration Test (blows/foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose</td>
<td>0-4</td>
<td>Very Soft</td>
<td>0-2</td>
</tr>
<tr>
<td>Loose</td>
<td>5-10</td>
<td>Soft</td>
<td>3-4</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>11-30</td>
<td>Firm</td>
<td>5-8</td>
</tr>
<tr>
<td>Dense</td>
<td>31-50</td>
<td>Stiff</td>
<td>9-15</td>
</tr>
<tr>
<td>Very Dense</td>
<td>+50</td>
<td>Very Stiff</td>
<td>15-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>+30</td>
</tr>
</tbody>
</table>

* Based on Sampler-Hammer Ratio of 8.929 E-06 ft/lbf and 4.185 E-05 ft^2/lbf for granular and cohesive soils, respectively (Terzaghi)

PARTICLE SIZE RANGE

<table>
<thead>
<tr>
<th>Sieve Openings (inches)</th>
<th>Standard Sieve Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>3&quot;</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>No.4</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>No.10</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>No.40</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>No.200</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>&lt;No.200</td>
</tr>
</tbody>
</table>

BOULDERS  COBBLES  GRAVELS  SANDS  SILTS & CLAYS

Coarse  Fine  Coarse  Medium  Fine  (Distinguished by Atterberg Limits)

PLASTICITY CHART

For classification of fine-grained soils and the fine-grained fraction of coarse-grained soils.

Equation of "A"-line
Horizontal at PI = 4 to LL = 25.5,
then PI = 0.73 (LL-20)

Equation of "U"-line
Vertical at LL = 16 to PI = 7,
then PI = 0.9 (LL-8)

GW - Well-graded GRAVEL
GP - Poorly-graded GRAVEL
GM - Silty GRAVEL
GC - Clayey GRAVEL
SW - Well-graded SAND
SP - Poorly-graded SAND
SM - Silty SAND
SC - Clayey SAND
CL - Lean CLAY
ML - Silt
OL - Organic SILT/CLAY
CH - Fat CLAY
MH - Elastic SILT
OH - Organic SILT/CLAY