1.0 INTRODUCTION

Cascade Geotechnical Ltd. (Cascade) understands that the Regional District of Central Okanagan is considering upgrading the Falcon Ridge water system. A new reservoir is needed to provide additional storage for domestic demand, fire demand for existing users, and increased capacity for a potential service area expansion.

We have carried out a geotechnical investigation of the soil and groundwater conditions at a proposed new reservoir site, and at a proposed infiltration pond area located close to Mission Creek. This report presents the results of the subsurface investigation, and recommendations for site preparation and foundation design.

2.0 PROJECT DESCRIPTION

The existing Falcon Ridge Water System is located 8 km east of Kelowna on Highway 33 E. An existing water source is a shallow well located on the flood plain close to Mission Creek. The well pumps water to an existing reservoir located within a privately owned property at 8000 Highway 33 E.

We understand that the proposed development may include the construction of an infiltration pond located close to the existing shallow well near Mission Creek. Water collected by the pond would continue to be pumped up to another reservoir being proposed near the existing reservoir.

3.0 FIELD INVESTIGATION

On September 23, 2014, five test pits were excavated using a JD 310E rubber-tired backhoe tracked excavator provided by AG Appel Enterprises Ltd. Three test pits were excavated in the proposed pond area and two test pits were excavated near the existing reservoir. The excavation of the test pits was supervised and logged in the field by the author of this report.
The test pits were excavated to depths of between 1.4 and 3.3 m below ground elevation and were loose backfilled upon completion. The approximate location of the test pits are presented on the attached Figures 1 and 2, in Appendix A.

A written log of each test pit was produced and includes a description of the soil types encountered, depth and thickness of the soil types, and visual classifications and consistency of the subsurface soils. Detailed test pit logs are attached as Figure Nos. TP-01 to TP-05, in Appendix C.

4.0 SUBSURFACE CONDITIONS

Potential Infiltration Pond Site (TP-01 to 03)

The soil conditions encountered in the test pits excavated in the area of the proposed infiltration pond generally consisted of a 0.2 m thick layer of TOPSOIL underlain by SAND, which in turn was underlain by GRAVEL and SAND (or sand and gravel). A layer of sand and silt was encountered below the topsoil layer at test locations TP-02 and TP-03 (Photos 1 to 3).

The sand layer was fine grained, had some silt (to silty), and was loose, moist to wet and medium brownish grey. The sand layer in TP-02 was medium to coarse grained and had a trace of silt (Photo 2).

The gravel and sand was fine to coarse grained, cobbled, had occasional to frequent boulders, and was loose to compact and medium brown.

All three test locations had heavy seepage at a depth of 1.2 to 1.4 m below existing ground elevation.

Proposed Reservoir (TP-04 and 05)

The soil conditions encountered in the test pits excavated in the area of the proposed reservoir generally consisted of TOPSOIL underlain by SAND and GRAVEL.

The topsoil layer was typically 0.2 m thick, and was grassed.

The sand and gravel layer was fine grained, cobbled, had some silt, and was compact to dense, damp and light to medium brown (Photo 4).

No groundwater or seepage was encountered and the water table is considered to be 10’s of metres below bottom of reservoir elevation.

For a more detailed description of the soil conditions, please refer to the test pit logs in Appendix C.
5.0 DISCUSSION AND RECOMMENDATIONS

We understand that the proposed development will include the construction of an infiltration pond area located close to Mission Creek, and a new concrete reservoir located adjacent to the existing reservoir. The soil conditions encountered in the area of the infiltration pond generally consisted of sand or cobbly gravel and sand overlain by topsoil or sand and silt. The soil conditions encountered in the area of the proposed reservoir consisted of compact to dense, cobbly sand and gravel.

The following sections provide recommendations for site preparation and design of the proposed development.

Infiltration Pond

We recommend that the slopes of the infiltration pond be graded no steeper than 3.0H:1.0V.

Based on the low silt content of the sand or gravel and sand observed in the test pits, and the rate seepage entered the test pits, we estimate that the permeability of the clean sand or gravel and sand layers to be approximately $1.0 \times 10^{-4}$ m/s.

Reservoir Site

Site preparation for the proposed reservoir should include the removal of topsoil or vegetation, and any loose, soft, wet, weathered or disturbed soils to expose the underlying compact to dense sand and gravel. The exposed subgrade should be inspected by a geotechnical engineer prior to any structural fill placement or placement of forms. Where structural fill is required to bring the site up to grade, the fill should extend beyond the footing for a distance at least equal to the depth of the fill placed below the footing, as described below.

- Granular Structural Fill: If the grade beneath the reservoir needs to be raised, we recommend that granular structural fill be used. Granular structural fill material should generally be well graded, with a maximum size of 150 mm and with not more than 8% passing the #200 sieve. Structural fill should be compacted to a minimum of 100% of Standard Proctor maximum dry density in accordance with ASTM D698, and within 2% of optimum moisture content. We recommend that the density of structural fill should be determined with in-situ density tests.

  We would consider the on-site sand and gravel suitable for reuse as structural fill.

- Foundation Design: The reservoir area should first be prepared as outlined above. Foundations supported on the compact to dense sand and gravel, or on granular structural fill which has been compacted to a minimum of 100% of Standard Proctor maximum dry density, as outlined above, may be designed on the basis of an allowable bearing pressure of 150 kPa.

- Frost Protection: The frost protection depth should be a minimum of 0.6 m for all exterior footings.
• Test Pits: The test pits were excavated at the approximate locations as indicated on Figure 2. In the situation where a portion of any proposed reservoir is found to be located over a test pit, we recommend that the test pit be over excavated and the loose soil replaced with granular structural fill compacted to a minimum of 100% of SPMDD.

• Sulphates: Based on the soil type encountered on the site, we believe that the degree of sulphate attack on concrete would be negligible; therefore, sulphate resistant concrete will not be required for this site.

• Temporary Excavations: Temporary excavations should be graded at a slope no steeper than 1.0(H):1.0(V) for the natural soils. Temporary cuts should be cleaned of cobbles and boulders prior to workers entering the excavation.

To maintain the stability of an excavation, all material excavated from the foundation area should be placed a minimum distance away from the excavation, equal to the depth of the excavation.

All work conducted in and around excavations should be carried out in accordance with requirements specified by Work Safe BC Guidelines.

• Slope Stability: We understand that the foundation elevation for the proposed reservoir will be approximately 4.0 m below existing ground elevation. The proposed reservoir location is bordered to the east by a road cut leading to Cardinal Creek Road. The cut has an average grade of approximately 80%. No indication of slope instability (sloughing, leaning tress, etc.), seepage or overland flow was observed. We recommend that the reservoir be located a minimum of 5 m back from the crest of the slope cut.

• Earth Pressures: We assume that walls of the proposed reservoir will be designed to resist lateral earth pressures, in the at-rest condition. The walls should be designed based on the following expression, which assumes a triangular pressure distribution:

Pressure at any given depth - \( p_o = K_o \ (\gamma h + q) \), and

Total force acting on full height of wall - \( P_o = 0.5 \ K_o \ \gamma H^2 + K_o q \)

Where:

\( P_o \) = lateral earth force at rest condition (kN).
\( K_o \) = coefficient of earth pressure, for the onsite sand and gravel use 0.45.
\( \gamma \) = bulk unit weight of soil for backfill, use 20.0 kN/m\(^3\) for the onsite, cobbly sand and gravel.
\( q \) = any surcharge pressure at ground elevation within a 45\(^\circ\) projection from the bottom of the foundation wall (kPa).
\( H \) = total depth below final grade.
\( h \) = depth in metres.
If compaction is required behind the wall, the lateral pressure distribution should include a uniform pressure of 15 kPa to a depth of 2.5 m, and below that depth, increasing at 5.5 kPa per metre depth. Large vibratory roller compactors should not be used adjacent to the wall to compact fill.

6.0 CLOSURE

The recommendations contained in this report have been prepared for the proposed Falcon Ridge Water System Upgrade described in Section 2.0 of this report, and can be relied upon by Agua Consulting Inc., and the Regional District of Central Okanagan. Should the intended use for the property, at any time, vary from our understanding of the project, Cascade should be given the opportunity to review the project to ensure that our recommendations are both accurate and sufficient. Refer also to the Geotechnical Report - General Conditions, provided in Appendix D.

We trust that you will find our recommendations sufficient at this time. If you require any additional details please do not hesitate to contact us.

Yours truly,
CASCADE GEOTECHNICAL LTD.

Prepared by:

Ron Campbell, P.Eng.
Geotechnical Engineer

Attachments:

Appendix A - Figures 1 and 2
Appendix B - Photos 1 to 4
Appendix C - Test Pit Logs
Appendix D - Geotechnical Report - General Conditions
APPENDIX B
**Photo 1:** Looking at the completion of TP-01 into cobbly gravel and sand.

**Photo 2:** Looking at the completion of TP-02, with the clean sand layer overlain by a layer of sand and silt.
Photo 3:  Looking at the completion of TP-03 into cobbly gravel and sand.

Photo 4:  Looking at the completion of TP-04 into compact to dense, cobbly sand and gravel.  TP-05 had similar soil conditions.
**Log of Testpit TP-01**

**Project:** Falcon Ridge Water System Upgrade  
**Location:** Highway 33  
**Client:** Agua Consulting Inc.  
**Cascade Project No:** J14-1130

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
<th>Number</th>
<th>Type</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ground Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><strong>TOPSOIL,</strong> grass and forest litter.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><strong>SAND,</strong> fine grained, silty, some gravel, loose, damp, light to medium greyish brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>GRAVEL and SAND,</strong> medium to coarse grained, cobbly, frequent boulders, trace silt, compact, moist, medium grey.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-below 1.2 m, heavy seepage into the pit and bouldery.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 3         | **REFUSAL ENCOUNTERED AT 2.2 m ON BOULDERS.**  
**GROUNDWATER ENCOUNTERED AT 1.2 m.**  
**TEST PITS SLOUGHS EASILY.** |        |      |                  |

**Investigation Date:** September 23, 2014  
**Northing:** 0  
**Easting:** 0  
**Elevation:** 0  
**Equipment:** JD 310E, Rubber-Tired Backhoe  
**Logged By:** RC  
**Figure No:** TP-01
### Log of Testpit TP-02

**Project:** Falcon Ridge Water System Upgrade  
**Location:** Highway 33  
**Client:** Agua Consulting Inc.  
**Cascade Project No:** J14-1130

<table>
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<th>Depth (ft)</th>
<th>Description</th>
<th>Number</th>
<th>Type</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ground Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>TOPSOIL, grass and forest litter.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SAND, fine grained, silty, some gravel, loose, damp, light to medium greyish brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SAND and SILT, very fine grained, loose, wet, light to medium grey.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SAND, medium to coarse grained sand with silty fine grained sand layering, trace silt, gravelly, compact, wet, light brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-below 1.2 m, heavy seepage into the pit.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-becoming cobbley and fine to medium grained sand below 1.7 m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>SAND and GRAVEL, fine to coarse grained, cobbley, occasional boulders, trace silt, loose to compact, wet, light brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>END OF TEST PIT AT 2.5 m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GROUNDWATER ENCOUNTERED AT 1.2 m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>TEST PIT SLOUGHS EASILY.</td>
<td></td>
<td></td>
<td></td>
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**Investigation Date:** September 23, 2014  
**Northing:** 0  
**Easting:** 0  
**Elevation:** 0  
**Figure No:** TP-02  
**Contractor:** A.G. Appel Enterprises Ltd.

Cascade Geotechnical Ltd.
201-1889 Spall Road
Kelowna, B.C.
### Log of Testpit TP-03

**Project:** Falcon Ridge Water System Upgrade  
**Location:** Highway 33  
**Client:** Agua Consulting Inc.  
**Cascade Project No:** J14-1130

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
<th>Number</th>
<th>Type</th>
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<th>Northing</th>
<th>Easting</th>
<th>Elevation</th>
<th>Figure No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft</td>
<td>Ground Surface</td>
<td>JD 310E, Rubber-Tired Backhoe</td>
<td></td>
<td>10 20 30 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP-03</td>
</tr>
<tr>
<td>1 m</td>
<td>TOPSOIL, and grass.</td>
<td>A.G. Appel Enterprises Ltd</td>
<td></td>
<td>10 20 30 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP-03</td>
</tr>
<tr>
<td>2 m</td>
<td>SAND and SILT, fine grained, loose, moist, medium brown.</td>
<td>A.G. Appel Enterprises Ltd</td>
<td></td>
<td>10 20 30 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP-03</td>
</tr>
<tr>
<td>3 m</td>
<td>SAND, fine grained, some silt, loose, moist, light brown with rust mottling.</td>
<td>A.G. Appel Enterprises Ltd</td>
<td></td>
<td>10 20 30 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP-03</td>
</tr>
<tr>
<td>3 m</td>
<td>SAND and GRAVEL, cobbly, occasional boulders, trace silt, compact, wet, light greyish brown.</td>
<td>A.G. Appel Enterprises Ltd</td>
<td></td>
<td>10 20 30 40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP-03</td>
</tr>
</tbody>
</table>
| 5 m   | END OF TEST PIT AT 1.4 m.  
GROUNDWATER ENCOUNTERED AT 1.1 m.  
TEST PIT SLOUGHS EASILY. | A.G. Appel Enterprises Ltd |      | 10 20 30 40               | 0        | 0       | 0         | TP-03     |

**Investigation Date:** September 23, 2014  
**Contractor:** Cascade Geotechnical Ltd.  
**Equipment:** JD 310E, Rubber-Tired Backhoe  
**Logged By:** RC  
**Northing:** 0  
**Easting:** 0  
**Elevation:** 0  
**Cascade Geotechnical Ltd.**  
201-1889 Spall Road  
Kelowna, B.C.
### Log of Testpit TP-04

**Project:** Falcon Ridge Water System Upgrade  
**Location:** Highway 33  
**Client:** Agua Consulting Inc.  
**Cascade Project No:** J14-1130

| Depth (ft) | Description | Number | Type | Moisture Content  
<table>
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<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>Ground Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><strong>TOPSOIL</strong>, and grass.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>SAND and GRAVEL</strong>, fine grained, cobbley, frequent boulders, some silt, compact to dense, damp, light to medium brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-occasional boulders below 1.5 m.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 3.3        | END OF TEST PIT AT 3.3 m.  
TEST PIT DRY UPON COMPLETION.  
MINOR SLOUGHING. |        |      |                  |

**Investigation Date:** September 23, 2014  
**Northing:** 0  
**Easting:** 0  
**Equipment:** JD 310E, Rubber-Tired Backhoe  
**Elevation:** 0  
**Logged By:** RC  
**Figure No:** TP-04
**Project:** Falcon Ridge Water System Upgrade  
**Location:** Highway 33  
**Client:** Agua Consulting Inc.  
**Cascade Project No:** J14-1130  

<table>
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<th>Depth (ft)</th>
<th>Description</th>
<th>Number</th>
<th>Type</th>
<th>Moisture Content Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ground Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TOPSOIL, and grass.</td>
<td>5-1</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SAND and GRAVEL, fine grained, cobbley, frequent boulders, some silt, compact to dense, damp, light to medium brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 3 | END OF TEST PIT ON BOULDERY LAYER AT 3.1 m.  
TEST PIT DRY UPON COMPLETION.  
MINOR SLOUGHING. | | | |

**Investigation Date:** September 23, 2014  
**Contractor:** A.G. Appel Enterprises Ltd.  
**Equipment:** JD 310E, Rubber-Tired Backhoe  
**Logged By:** RC  
**Northing:** 0  
**Easting:** 0  
**Elevation:** 0  
**Figure No:** TP-05  

Cascade Geotechnical Ltd.  
201-1889 Spall Road  
Kelowna, B.C.
APPENDIX D
This report incorporates and is subject to these “General Conditions”.

1. **USE OF REPORT AND OWNERSHIP**

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment. This report and the recommendations contained in it are intended for the sole use of Cascade’s client. Cascade does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Cascade’s client unless otherwise authorized in writing by Cascade. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Cascade. Additional copies of the report, if required, may be obtained upon request.

2. **NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS**

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned. Classification and identification of geological units are judgmental in nature as to both type and condition. Cascade does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice. Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

3. **LOGS OF TEST HOLES**

The test hole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

4. **STRATIGRAPHIC AND GEOLOGICAL INFORMATION**

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Cascade does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

5. **SURFACE WATER AND GROUNDWATER CONDITIONS**

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

6. **PROTECTION OF EXPOSED GROUND**

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.
7. SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

8. INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

9. OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

10. DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

11. BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

12. SAMPLES

Cascade will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the client's expense upon written request, otherwise samples will be discarded.

13. STANDARD OF CARE

Services performed by Cascade for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practiced under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14. ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Cascade has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.