LEVELTON

# GEOTECHNICAL ASSESSMENT REPORT
# MISSION CREEK DIKES – PHASE 1 EAST
# KELOWNA, BC

Prepared for:

City of Kelowna
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Attention: Mr. Todd Cashin
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# 1. INTRODUCTION

Levelton Consultants Ltd. (Levelton) presents herein our geotechnical assessment report to the City of Kelowna (CoK) for the proposed Mission Creek Dikes – Phase 1 East design project. The project consists of replacing a section of existing dike along the south side of Mission Creek as part of the Mission Creek Restoration Initiative (MCRI).

The scope of this geotechnical assessment was outlined in our proposal of January 27, 2015 (our file: P715-0287-00). Authorization to proceed with the proposed scope of work was received from CoK by e-mail on February 2, 2015.

Based on the available information at the time of this report, we understand there is a long term plan to realign the Mission Creek Dike on the south side of Mission Creek between Casorso Road and Gordon Drive. A preliminary dike alignment was provided to us from a past MCRI report, and our investigation and report is based on future dike development along the general alignment indicated on the attached Figure 1. The extent of our investigation included the east half of the alignment, from Casorso Road at the east end to the Mission Recreation Park fields at the west end.

Our assessment and recommendations for dike design are based on the following reference documents:

- Lower Mission Creek Hydraulic Capacity Study, Tetra Tech EBA, March 2014.
- Dike Design and Construction Guide, Best Management Practices for British Columbia, Province of British Columbia, BC Ministry of Forests, Lands and Natural Resource Operations, July 2003.
- Seismic Design Guidelines for Dikes, Province of British Columbia, 2nd Edition, BC Ministry of Forests, Lands and Natural Resource Operations, June 2014 (referred to hereafter as the "Seismic Guidelines").
- Design Guidance for Levee Underseepage, U.S. Army Corps of Engineers, May 2005

# 2. PROPOSED CONSTRUCTION

Based on the provided information, our analysis and design recommendations are based on the following:

- A new dike design is required for the proposed alignment south of the existing Mission Creek Dike, as illustrated on Figure 1;
- The new dike will feature a crest height of approximately 4m above surrounding grade (which we have approximated to be 345m geodetic). This equates to a proposed crest elevation of approximately 349m and is based on a predicted flood elevation of 348.26m at the Casorso Road bridge and includes a 0.6m freeboard;
- The new dike will be based on the "Setback Dike" template contained in the Dike Design Guidelines referenced above. Recommended side slopes, crest width and dike composition will be discussed in the course of this report;

- The CoK is interested in re-using the existing dike fill during construction of the realigned dike, and has access to a large stockpile of potential dike fill material along the east edge of 3850 Swamp Road. The approximate stockpile location is identified on Figure 1.

# 3. FIELD WORK AND LABORATORY TESTING

## 3.1 FIELD INVESTIGATION

The subsurface exploration was undertaken on February 11, 2015 and consisted of five solid stem auger holes (AH15-01 to AH15-05) advanced using a track mounted drill rig. The auger holes were advanced to a depth of between 3 and 9 m below existing grade. Dynamic Cone Penetration Tests (DCPTs) were conducted at AH15-01, AH15-03 and AH15-03 to assess the *in-situ* relative density / consistency of the soils. The approximate locations of the auger holes are shown on Figure 1.

Geotechnical personnel from Levelton selected the auger hole locations, logged the soil and groundwater conditions encountered at the auger holes, and collected disturbed soil samples from the auger flights for laboratory testing.

Soil logs with description of the soil and groundwater conditions encountered at the auger holes are attached in Appendix A.

## 3.2 LABORATORY TESTING

Disturbed soil samples collected from our subsurface investigation were submitted to our laboratory for testing. All samples were tested for moisture content, and select samples were subjected to a grain size analysis to assist in classifying the encountered soil types.

Levelton also collected a number of samples from bulk fill sources the CoK is considering for use in the new dike construction. The samples were collected from:

- The stockpile on 3850 Swamp Road – south end;
- The stockpile on 3850 Swamp Road – north end; and,
- Combined sample of existing dike fill sampled west of Casorso Road Bridge.

The results of the grain size analyses are attached in Appendix B.

# 4. GEOTECHNICAL INFORMATION

## 4.1 SURFICIAL GEOLOGY

It is of importance to understand the geologic setting of the site, as it provides evidence of past events that influence the strength and compressibility of a soil deposit. The surficial geology of the area was interpreted from Geological Survey of Canada Open File 6146, which describes the area as fluvial floodplain sediments consisting of sand, gravelly sand, gravel and organic debris.

## 4.2 SOIL CONDITIONS

The soil conditions encountered at the auger holes conducted by Levelton at the project site were generally consistent with the published surficial geology. A general summary of the soil conditions is provided in the following paragraphs. The description provided on the soil logs in Appendix A should be used in preference to the summary description provided below.

All five auger holes along the proposed dike alignment were conducted on farm land or rural vacant property; the ground cover at each auger hole consisted of low vegetation including grasses and fallow field crops. In general, the auger holes encountered surficial deposits of silt topsoil with organics to depths of 0.2 to 0.9m.

At AH15-01 to AH15-03, a deposit of loose grey sand was encountered below the topsoil, extending to depths of 2.2 to 2.4m. At AH15-02 and AH15-03, the loose grey sand was underlain by compact sand and gravel and compact sand to depths of 3m and 3.5m, respectively. AH15-02 was terminated in the sand and gravel deposit, while AH15-03 encountered a deposit of loose grey sand with organic silt seams extending to a depth of 4m, which was underlain by compact sand to the termination depth at 6m.

At AH15-01, the loose grey sand was underlain by a layer of very soft silt extending to a depth of 3m. The silt was in turn underlain by compact sand to the termination depth at 9m; the lowest 3m of the compact sand deposit featured occasional organic silt and ash seams.

AH15-04 and AH15-05 the topsoil was underlain by sandy silt that extended to a depth of 1m. In AH15-04, the sandy silt was underlain by loose grey sand to extending to a depth of 1.3m; the sand was in turn underlain by soft grey silt that extended to 1.8m below grade. The silt was underlain by compact sand that extended to the termination depth at 4.5. A 0.3m thick layer of loose sand with organic seams was encountered within the sand deposit at a depth of 3.2m.

In AH15-05, the sandy silt was underlain by compact sand and silty sand deposits, with occasional silt and ash seams at 3m and 8.4m depth. This auger hole was terminated in sand / silty sand at a depth of 9m below grade.

### 4.3 Surface and Groundwater Conditions

Based on available information from the CoK web map, we estimate that the boreholes were conducted at a geodetic elevation of approximately 345m. The water level observed in ditches and standing water throughout the site was at an approximate elevation of 344m during the field investigation. Based on available information, the average water level in Mission Creek is estimated to fluctuate around elevation 346m near the Casorso Road Bridge.

Groundwater was encountered at a depth of between approximately 0.7 and 0.9m below existing grade in the auger holes at the time of drilling. The groundwater elevation in the auger holes was generally consistent with the elevation of the standing water observed in ditches and low lying areas throughout the site, but is lower than the estimated Mission Creek water level. The groundwater level would be anticipated to fluctuate seasonally.

## 5. DISCUSSION & RECOMMENDATIONS

### 5.1 General

Based on the Levelton subsurface explorations, a new dike conforming to the "Setback Dike" template contained in the Dike Design Guidelines referenced above is considered feasible from a geotechnical perspective. The existing native soils will have adequate bearing capacity to support the proposed dike structure. Some consolidation of the soft / loose subgrade soils is expected due to the weight of the new dike fill, but it is expected that long term settlement will not greatly affect the proposed dike structure.

Our analysis indicates that, in general, a properly constructed section of dike as proposed herein will have satisfactory stability under static and seismic conditions, in accordance with the Seismic

Guidelines. In addition, it is our opinion that the dike section will be acceptably stable under rapid drawdown conditions.

The key to maintaining the long term stability of the dike will be in the selection, placement and compaction of suitable dike fill material.

## 5.2 DIKE TEMPLATE

We understand the proposed new dike alignment will require the design of a Setback Dike, as illustrated in Section 2.8.1 Figure 1 of the Dike Design and Construction Guide, Best Management Practices for British Columbia, July 2003 (Dike Design Guide). This figure is reproduced below.

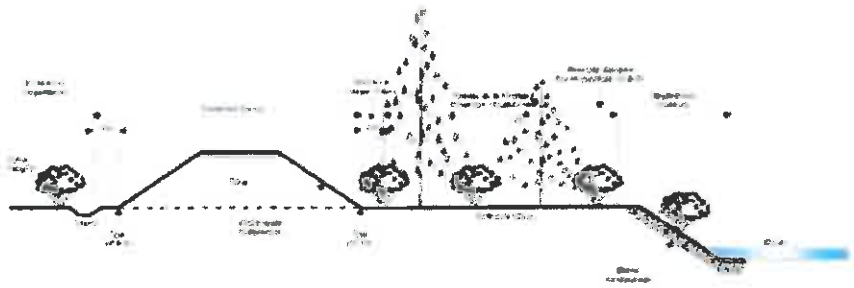

**Figure 1 – Setback Dike**

Based on the available information, our experience with dike design, and the current standards included in the Dike Design Guide, we are proposing a dike with the following general design:

- A dike crest width of 4m;
- A landside dike side slope of minimum 2.5H:1V (Horizontal:Vertical);
- A waterside dike side slope of minimum 3H:1V. A steeper waterside slope of 2H:1V could be considered with appropriate rip-rap armoring; and,
- A gravel running surface treatment on the dike crest.

## 5.3 SEISMIC CONSIDERATIONS

### 5.3.1 Dike Stability Considerations

***Seismic Requirements for Dikes***

The Seismic Guidelines are intended for use by those responsible for the seismic design, construction, inspection, alteration, and rehabilitation of "high consequence dikes." Based on the proximity of the dikes to low-lying residential areas, we have assumed the Mission Creek dikes will be considered as "high consequence" and the guidelines will generally apply.

The intent of the guidelines is to specify the level of performance that dikes should provide under the influence of three levels of design earthquake: the 1 in 100 year return period earthquake (Earthquake Shaking Level 1, or EQL-1), the 1 in 475 year return period earthquake (EQL-2), and the 1 in 2475 year return period earthquake (EQL-3). The specifications under the various return period earthquakes are summarized as follows:

- EQL-1: No significant damage to internal structures, and post-seismic flood protection ability is not compromised. Maximum allowable vertical and horizontal displacements are less than 0.3m.
- EQL-2: Some repairable damage to internal structures, and post-seismic flood protection is not compromised. Maximum allowable vertical displacement is 0.15m, and the maximum allowable horizontal displacement is 0.3m.
- EQL-3: Significant damage to internal structures, post-seismic flood protection ability is possibly compromised. Maximum allowable vertical displacement is 0.5m, and the maximum allowable horizontal displacement is 0.3 to 0.9m.

It should be recognized that the Seismic Guidelines do not explicitly mandate that "high consequence" dikes be designed as "post-disaster" structures; rather, the Seismic Guidelines provide specifications for dike performance that are generally consistent with a post-disaster definition under short and intermediate return period earthquakes, and partially consistent under long return period earthquakes, with consideration of the applicability and completeness of such specifications left to the local authorities having jurisdiction (in this case, the CoK).

### *Analyses*

For the review of the dike stability, a limit equilibrium analysis was completed under various conditions. A representative cross-section was developed for the dike alignment based on site observations and available information. Soil and groundwater conditions were determined from the auger hole investigation and estimated for the proposed dike structure. Limit equilibrium slope stability assessments were completed using the computer program Rocscience *SLIDE 5.0*, a two-dimensional slope stability analysis program. For the analysis a dike waterside slope of 2H:1V, with rip rap armoring, was considered; basing the analysis on the premise that this dike layout is considered more conservative than analyzing the more stable 3H:1V waterside slope model.

The soil units and parameters used for the slope stability analyses are provided in Table 1.

**Table 1 – Estimated Soil Parameters for Seismic Slope Stability Analysis**

| Soil Unit | Friction Angle (degrees) | Unit weight ($KN/m^3$) | Cohesion ($KN/m^2$) |
|---|---|---|---|
| Rip-Rap | 45 | 20 | 0 |
| Engineered Dike Fill | 38 | 17 | 0 |
| Loose Sand | 32 | 15 | 0 |
| Soft Silt | 30 | 14 | 0 / 20* |
| Deep Compact Sand | 34 | 16 | 0 |

*apparent cohesion was applied for seismic and rapid-draw-down analyses

The soil properties were estimated based on laboratory testing, *in-situ* testing, published data, and engineering judgement. The soil layering and groundwater levels were inferred based on the information available when this report was prepared, and engineering judgement. The topography and water levels utilized for the development of the analysis were based on the available information.

Factors of Safety (FoS) against slope instability under static, and 1 in 2475 year return period (A2475) seismic conditions were determined. Based on the results of the A2475 seismic conditions, no additional seismic analysis was conducted for the 1 in 100 and 1 in 475 year return periods. The seismic loading was applied as a pseudo-static horizontal force based on the Peak

Ground Acceleration (PGA) values for the site. The following Peak Ground Acceleration (PGA) values for the 1:475 and 1:2475 earthquake return period were determined:

| Return Period | PGA |
|---|---|
| 1 :475 | 0.07g |
| 1 :2475 | 0.14g |

***Stability Results***

The results of the pseudo-static slope stability analyses are provided in Table 2.

**Table 2 – Dike Stability Analysis Results**

| Earthquake Condition | Peak Ground Acceleration | Factor of Safety |
|---|---|---|
| Static | 0 | 1.74 |
| Static (rapid drawdown) | 0 | 1.72 |
| A2475 (1 in 2475) | 0.14g | 1.66 |

***Compliance with Seismic Guidelines for Dikes***

The results of the analyses indicate that during the static loading case, rapid drawdown loading case, and the 1:2475 earthquake event the dike sections maintained a FoS greater than 1. These results indicates that the dike section would experience no significant instability induced movement; satisfying the EQL-1, EQL-2 and EQL-3 guidelines.

The results of the stability analyses are attached in Appendix C.

***Limitations***

The geotechnical assessment of the proposed dike was completed only over the extent of the current project area, and with consideration to the proposed dike layout described previously. Estimates of stability, displacements, and settlements were based on the subsurface exploration conducted by Levelton and information that was provided to Levelton prior to the preparation of the report. Changes to the design, including different configurations, construction limits, etc. may require additional review.

### 5.3.2 Liquefaction Susceptibility and Estimated Post-Liquefaction Movements

A liquefaction analysis was conducted using the Seed Simplified Method. The analysis was based on the A2475 $A_{max}$ values and a typical soil profile developed from the results of our subsurface investigation. Under the 1 in 100 year seismic loading condition, no zones of potentially liquefiable soils were identified and under the 1 in 475 year event, the liquefaction zones were minimal. Under the 1 in 2475 earthquake loading, there are zones of potentially liquefiable soils in the granular deposits. In the case of a design earthquake, it is expected that these soils could liquefy and result in an estimated vertical displacement on the order of 100mm and a horizontal displacement on the order of 400mm. Liquefaction movements of this magnitude are generally considered acceptable for dike sections of this type.

## 5.4 DIKE SEEPAGE CONSIDERATIONS

Seepage analysis was conducted for the proposed dike template and expected subgrade soils. Potential seepage losses through and below the dike were analyzed based on the calculated hydraulic gradient and assumed soil conditions for the dike fill and subgrade soils.

The values for the coefficient of hydraulic conductivity ($k_h$) in the horizontal direction adopted in the analysis for the various soil strata encountered in our subsurface investigation were based on correlations of soil properties and previous experience with similar soils. The values of horizontal hydraulic conductivity ($k_h$) used in the seepage analysis model are summarized in Table 3.

**Table 3 – Hydraulic Conductivity of Site Soils**

| Soil Unit | Coefficient of Hydraulic Conductivity, $k_h$ (m/sec) |
|---|---|
| Dike Fill (Silty Sand) | $1x10^{-7}$ |
| Sand some Silt | $5x10^{-6}$ |
| Silt trace Sand | $1x10^{-9}$ |

The results of the seepage analyses carried out for the typical dike section indicate that the seepage through and beneath the dike section modeled are estimated on the order of 1L / day / linear meter of dike. This amount of seepage is considered nominal, and it is expected that no landside toe drainage provisions would be required in the dike design.

An important consideration in the assessment of dike stability is the potential for underseepage or piping on the landward side of the dike. By determining the exit gradient at the landward toe of the dike and in the foundation soils further inland, a FoS against piping can be determined. Guidelines for severity of underseepage based on hydraulic gradient have been developed by the United States Army Corps of Engineers (USACE 2005). The Canadian Foundation Engineering Manual 4th Edition (2006) recommends a FoS of 2 to 3. Based on our analysis, the FoS of the analyzed dike cross-section is 4.7, which is considered acceptable.

## 5.5 DIKE SETTLEMENT

Construction of a new 4m high dike embankment will induce consolidation of the underlying native soils. Settlement analysis was conducted for a typical soil profile and a 4m high dike using the computer program *Settle 3d* by RocScience.

The majority of native soils encountered at the site to the depth explored are granular deposits that will exhibit immediate settlement during the placement and compaction of the dike fill. The immediate settlement will occur before the final fill grading and will not affect the constructed dike crest elevation. A number of boreholes encountered soft silt deposits at relatively shallow depth that would experience longer term consolidation due to the new load applied by the embankment fill. Long term post construction settlements of the dike crest are expected to be on the order of 100mm.

## 5.6 SITE PREPARATION

### 5.6.1 General

The conditions along the proposed dike alignment typically consist of vegetated silt topsoil underlain by granular deposits. Based on these conditions, it is expected that the proposed dike

fills could be placed near the existing grades following site clearing and stripping. The general construction steps would include stripping of surficial organics and topsoil from the dike footprint, compacting the anticipated granular subgrade, placing and compacting the new dike fill, and installing the surface treatment atop the dike crest.

### 5.6.2 Subgrade Preparation

Site preparation in the agricultural and vacant rural areas should consist of the removal of any vegetation, topsoil, and soft / loose deposits to expose competent subgrade consisting of the native loose to compact sand. Based on the auger holes, stripping depths of about 0.5 to 0.9m below existing grade may be necessary to remove these materials and expose competent inorganic soil subgrade. Greater or lesser stripping depths may be necessary in localized areas remote from the auger hole locations.

We recommend the granular subgrade be compacted with vibratory equipment prior to the placement of any fill. Subgrade soils should be compacted to not less than 95% of their Standard Proctor Dry Density (SPMDD) prior to fill placement. The Geotechnical Engineer should review the stripped and compacted subgrade prior to the placement of any fill.

Fill required to construct the dike to the required height and width should consist of dike fill as discussed in Section 5.8 (below).

## 5.7 Excavations

### 5.7.1 Unsupported Excavations

Temporary unsupported excavations should be conducted in accordance with the Workers Compensation Board WorkSafe BC regulations. A maximum inclination of 1H:1V is considered appropriate for temporary excavations deeper than 1.2 m where worker access is required. The water table is located at relatively shallow depth and was encountered at a depth of 0.7m to 0.9m at the time of the investigation. Excavations below the water table would require specialized dewatering.

Surcharge loads from soil stockpiles, construction vehicles, and construction material stockpiles should be avoided by keeping such items away from the excavation crest a minimum horizontal distance equal to the depth of the excavation. Temporary excavations that will be located adjacent to surcharge loads should be approved by a Geotechnical Engineer prior to excavation.

All temporary unsupported excavations requiring worker access should be approved in writing by a Geotechnical Engineer prior to workers entering or working adjacent to such excavations.

## 5.8 Engineered Fills

### 5.8.1 Gradation of Dike Fill

To limit seepage through the dike during flood events, utilization of low permeability fill for dike construction is required. We consider that fill which contains at least 15% silt or clay sized particles by weight will have a suitably low permeability, while still having generally good "constructability" characteristics. The silt or clay particles will fill the gaps between the coarser sand and gravel grains such that the permeability of the soil matrix will be equivalent to that of a silt deposit. A grain size distribution for the proposed dike fill is provided in Table 4.

**Table 4 – Recommended Dike Fill Material**

| Sieve Size | % Finer Than |
|---|---|
| 150 mm | 100 |
| 75 mm | 75 – 100 |
| 37.5 mm | 60 –100 |
| 19 mm | 50 – 90 |
| 4.75 mm | 40 – 70 |
| 0.425 mm | 25 – 50 |
| 0.075 mm | 15 – 35 |

Alternatively, the dikes could be constructed utilizing silt or clay soils (more than 50% by weight passing the 0.075mm sieve size) that have a moisture content within 2 percent of their optimum moisture content for compaction, as established by the Standard Proctor test (ASTM D-698).

### 5.8.2 Dike Fill Placement Recommendations

General dike fill placement recommendations are as follows:

1. All sources of candidate dike fill should be approved by the Geotechnical Engineer prior to placement at the site. This should include gradation analysis and Standard Proctor tests on representative samples of the material by the Geotechnical Engineer;
2. The existing surface vegetation and topsoil should be stripped and a competent sand subgrade exposed / prepared;
3. The approved fill should be compacted to not less than 97% of the material's SPMDD, as confirmed by in-place density testing by the Geotechnical Engineer. The moisture content of the compacted fill should be within 2% of optimum, as determined by the in-place density testing and Standard Proctor test;
4. Fill material should be placed and compacted in lifts no greater than 300mm in thickness using a smooth drum roller. A sheep foot roller may be required depending on the fines content of the actual dike fill. The lift thickness should be reduced to 150mm where a vibratory plate compactor is used. The lift thickness should not be increased without prior written approval from the Geotechnical Engineer;
5. The constructed fill slope should be over-built at least 300mm beyond its final position and then trimmed back to the final position after compaction;
6. The Geotechnical Engineer should be retained to conduct in-place soil density testing using a nuclear densometer on each lift of fill. Representative samples of the dike fill material should also be collected during construction for Standard Proctor and gradation analysis testing to confirm the material is consistent with the recommendations provided in this report.

As the recommended dike fill material contains a significant fine-grained component, its moisture content would need to be closely controlled during placement and compaction. This may cause construction delays if the material is placed in less than ideal weather conditions.

### 5.8.3 Filter Gradation

To prevent piping along utility lines, if any, that are to extend through the dike, a suitable granular filter should be placed adjacent to the pipes. Based on the specification for the dike fill material provided above in Table 4, we recommend that the filter material consist of sandy gravel / sand and gravel with the gradation provided in Table 5.

**Table 5 – Recommended Filter Material Gradation**

| Sieve Size | Percent Passing by Weight |
|---|---|
| 75 mm | 100 |
| 12.5 mm | 50 – 80 |
| 9.51 mm | 38 – 70 |
| 2.36 mm | 20 – 50 |
| 1.18 mm | 15 – 40 |
| 0.3 mm | 8 – 15 |
| 0.075 mm | 0 – 6 |

The filter zone should be 0.5m thick and be placed along the landside one third portion of the conduits. The remainder of the conduit should be backfilled with dike fill material as discussed above.

It should be noted that, because the specification for the dike fill material consists of an upper and lower limit for various particle sizes, some refinement of the filter material specification may be necessary based on the grain size distribution of the dike fill material actually used in construction. Levelton should be given the opportunity to review and conduct grain size analysis testing of the proposed dike fill and filter material prior to use to confirm the acceptability of the materials. Dike filter material should be compacted to 97% of its SPMDD.

### 5.8.4 Engineered Fill

We recommend that fill required to establish the desired grades, outside of the dike profile, consist of 100mm minus pit-run sand and gravel with less than 8% fines (material passing the 0.075 mm sieve) by weight, or a Geotechnical Engineer approved equivalent.

The engineered fill should be placed in discrete lifts of a maximum of 300mm in thickness and be compacted to not less than 100% of the material's SPMDD. The Geotechnical Engineer should conduct in-place soil density testing on the fill as it is being placed to confirm that adequate compaction is achieved.

### 5.8.5 Potential Dike Fill Sources

The samples of three potential sources of dike fill material were submitted to our laboratory for grain size analysis. The grain size distribution results for the three samples are provided in

Appendix B, and the results have been plotted against the gradation specification recommended for dike fill in Section 5.8.1 above.

In general, the material sampled from the berm stockpile on 3850 Swamp Road consisted of sand and gravel with a fines content (material passing the 0.075mm sieve) varying from 14.5% to 20.5%. These samples generally conform to our recommended dike fill specification, and it is our opinion that the stockpiled material would be suitable for use as dike fill based on the samples collected.

The material sampled from the existing dike consisted of gravel and sand, some silt. This material is in general conformance with the recommended dike fill gradation; however the fines content is only 10.2% and is less than the minimum of 15% recommended. Since the material contains less fines than recommended, it may have a higher permeability than the recommended dike fill. Therefore, if the existing dike fill will be re-used to construct the new dike, consideration should be given mixing the existing dike fill with a soil having a higher fines content in order to produce a material meeting the dike fill gradation recommendation.

The grain size analyses and comments provided above are based on discrete test results from localized test samples. Additional samples should be collected and tested prior to use as dike fill to determine the consistency of the materials and suitability for use as dike fill.

### 5.8.6 Dike Running Surface

It is recommended that, if the surface of the dike is to remain unpaved, the running surface consist of 19 mm minus crushed sand and gravel a minimum of 150 mm in thickness placed over the Geotechnical Engineer approved compacted dike fill and compacted to not less than 100% of the material's SPMDD. A gravel running surface of this material and thickness would be suitable for maintenance access by foot, occasional service vehicles and potential pedestrian path use.

If more frequent traffic for service vehicles is required, Levelton can provide additional recommendations for a more robust road structure or an asphalt concrete surface.

## 5.9 Erosion Control

If armoring is required on the waterside slope of the dike to control erosion, it is recommended that the dike design include "rip-rap" angular rock protection.

The rip-rap size would be based on river flow velocities and bank slope angles. Detailed recommendations for rip rap size can be provided once river hydraulics information is available. As an initial guideline, assuming a design flow velocity of 4m/s and a dike waterside slope of 2H:1V or flatter, Class 250 kg rip-rap would be recommended.

As an initial preliminary guideline the angular rock layer placed on the waterside dike face should consist of MOTI Class 250 Rip-Rap with a nominal thickness of 1000mm. The average dimension of angular rock should be approximately 565mm, and the specified gradation is provided in Table 6.

**Table 6: Gradation of MOTI Class 250 Rip-Rap**

| Percentage Larger Than Given Rock Mass (kg) | | |
|---|---|---|
| 85% | 50% | 15% |
| 25 | 250 | 750 |

The controlled placement of rock shall produce a rock mass of at least the nominal thickness along the waterside dike face. The rock shall be manipulated as necessary to provide a stable mass and a uniform surface with the least voids possible.

The rip-rap would need to be underlain by a suitable filter layer or appropriate geotextile to limit the potential for erosion of soil beneath the rip-rap.

## 6. FURTHER GEOTECHNICAL SERVICES

The design was in a preliminary stage when this report was prepared and our analysis and design recommendations are based on information available at the time it was prepared. The Geotechnical Engineer should be retained to review the geotechnical aspects of the drawings and specifications during the detailed design stage. Further analysis may be required for revised dike configurations, or to respond to queries from approving authorities.

Further guidance on the scope of construction reviews can be given during the detailed design phase, but generally the Geotechnical Engineer should be retained to review the following aspects of the construction:

- Review the stripped surfaces prior to fill placement to establish they are in accordance with the this report and the design;
- Review candidate sources of dike fill and filter materials prior to placement; and,
- Monitor the placement and compaction of the dike fill, filter materials and rip-rap armoring to establish compliance with the design.

## 7. LIMITATIONS & CLOSURE

This geotechnical assessment report has been prepared by Levelton Consultants Ltd. exclusively for the City of Kelowna, and their appointed agents. The opinions, conclusions and recommendations contained in this report reflect our judgment in light of the information provided to us at the time that it was prepared.

Any use of this report by third parties, or any reliance on or decisions made based on it, are the responsibility of such third parties. Levelton does not accept responsibility for damages suffered, if any, by a third party as a result of their use of this report.

The soil logs appended to this report provide description of the soil and groundwater conditions encountered at discrete auger holes. Soil conditions along the dike alignment in areas remote from the auger hole locations may differ from those encountered at the auger hole locations.

The attached Terms of Reference should be read in conjunction with and form an integral part of this report.

We trust this information meets your immediate requirements. If you have any questions or require further information, please contact the undersigned.

**LEVELTON CONSULTANTS LTD.**

Original Signed By:

Per: Thomas Dueckman, EIT
Junior Geotechnical Engineer

Per: Paul Ell, P.Eng.
Senior Geotechnical Engineer

Reviewed By: Michael Gutwein, P.Eng.
Senior Geotechnical Engineer

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LEVELTON

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The terms of reference for geotechnical reports issued by Levelton (the "Terms of Reference") contained in the present document provide additional information and caution related to standard of care and the use of the Report. The Client should read and familiarize itself with these Terms of Reference.

## 2. COMPLETENESS OF THE REPORT

All documents, records, drawings, correspondence, data, files and deliverables, whether hard copy, electronic or otherwise, generated as part of the services for the Client are inherent components of the Report and, collectively, form the instruments of professional services (the "Instruments of Professional Services"). The Report is of a summary nature and is not intended to stand alone without reference to the instructions given to Levelton by the Client, the communications between Levelton and the Client, and to any other reports, writings, proposals or documents prepared by Levelton for the Client relative to the specific site described in the Report, all of which constitute the Report.

TO PROPERLY UNDERSTAND THE INFORMATION, OBSERVATIONS, FINDINGS, SUGGESTIONS, RECOMMENDATIONS AND OPINIONS CONTAINED IN THE REPORT, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. LEVELTON CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT AND ITS VARIOUS COMPONENTS.

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## 4. USE OF THE REPORT

The information, observations, findings, suggestions, recommendations and opinions contained in the Report, or any component forming the Report, are for the sole use and benefit of the Client and the team of consultants selected by the Client for the specific project that the Report was provided. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION OR COMPONENT WITHOUT THE WRITTEN CONSENT OF LEVELTON. Levelton will consent to any reasonable request by the Client to approve the use of this Report by other parties designated by the Client as the "Approved Users". As a condition for the consent of Levelton to approve the use of the Report by an Approved User, the Client must provide a copy of these Terms of Reference to that Approved User and the Client must obtain written confirmation from that Approved User that the Approved User will comply with these Terms of Reference, such written confirmation to be provided separately by each Approved User prior to beginning use of the Report. The Client will provide Levelton with a copy of the written confirmation from an Approved User when it becomes available to the Client, and in any case, within two weeks of the Client receiving such written confirmation.

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# TERMS OF REFERENCE FOR GEOTECHNICAL REPORTS ISSUED BY LEVELTON CONSULTANTS LTD. (continued)

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a. **Nature and Exactness of Descriptions**: The classification and identification of soils, rocks and geological units, as well as engineering assessments and estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1 above. The classification and identification of these items are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations or assessments utilizing the standards of Paragraph 1 involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to changes over time and the parties making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or when the Client has special considerations or requirements, the Client must disclose them to Levelton so that additional or special investigations may be undertaken, which would not otherwise be within the scope of investigations made by Levelton or the purposes of the Report.

b. **Reliance on information**: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site investigation and field review and on the basis of information provided to Levelton. Levelton has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Levelton cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of misstatements, omissions, misrepresentations or fraudulent acts of persons providing information.

c. **Additional Involvement by Levelton**: To avoid misunderstandings, Levelton should be retained to assist other professionals to explain relevant engineering findings and to review the geotechnical aspects of the plans, drawings and specifications of other professionals relative to the engineering issues pertaining to the geotechnical consulting services provided by Levelton. To ensure compliance and consistency with the applicable building codes, legislation, regulations, guidelines and generally-accepted practices, Levelton should also be retained to provide field review services during the performance of any related work. Where applicable, it is understood that such field review services must meet or exceed the minimum necessary requirements to ascertain that the work being carried out is in general conformity with the recommendations made by Levelton. Any reduction from the level of services recommended by Levelton will result in Levelton providing qualified opinions regarding adequacy of the work.

## 6. ALTERNATE REPORT FORMAT

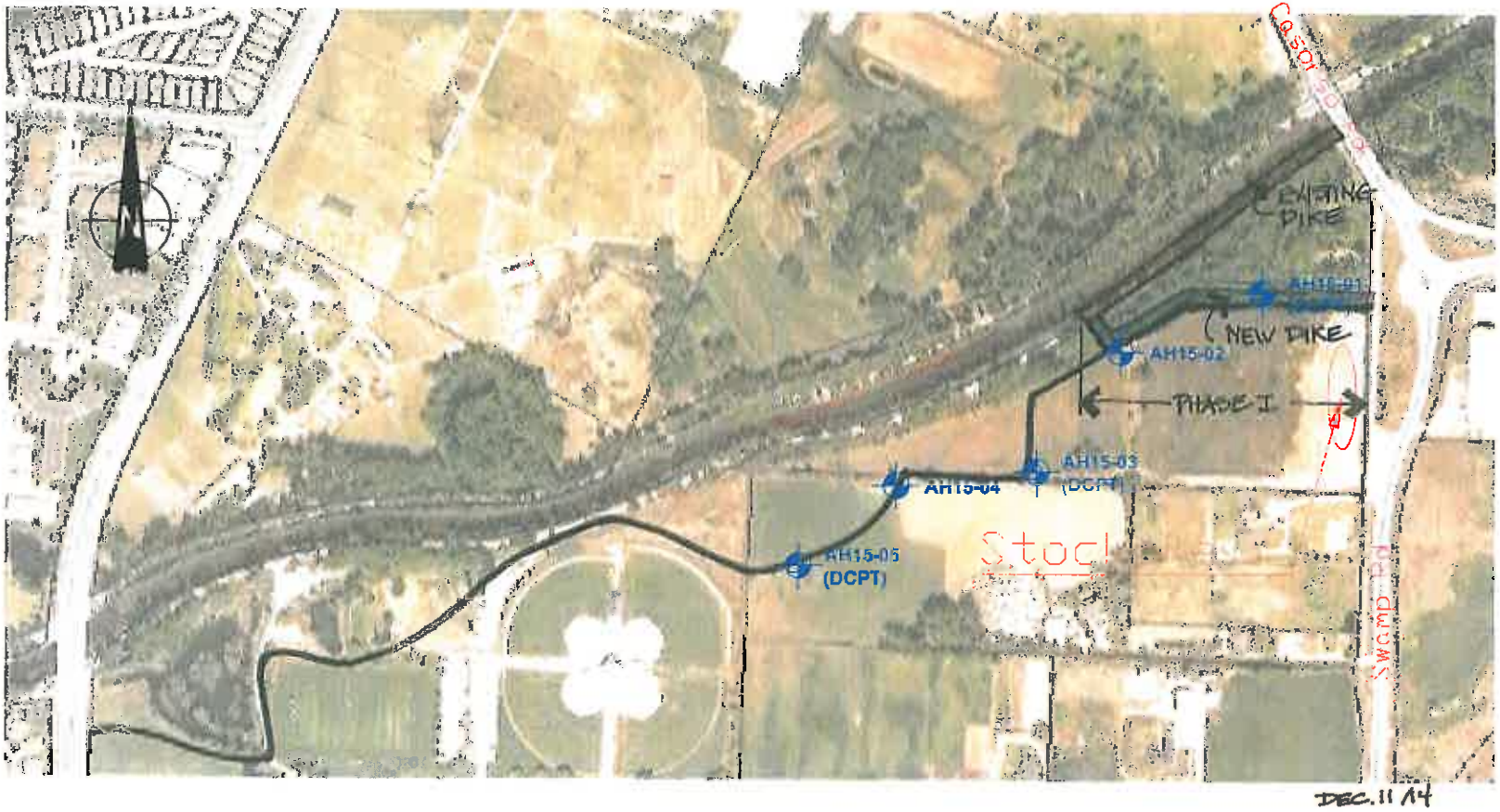
When Levelton submits both electronic and hard copy versions of the Instruments of Professional Services, the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding upon Levelton. The hard copy versions submitted by Levelton shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancy, the hard copy versions shall govern over the electronic versions; furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed and sealed versions of the Instruments of Professional Services maintained or retained, or both, by Levelton shall be deemed to be the overall originals for the Project.

The Client agrees that the electronic file and hard copy versions of Instruments of Professional Services shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Levelton. The Client warrants that the Instruments of Professional Services will be used only and exactly as submitted by Levelton.

The Client recognizes and agrees that Levelton prepared and submitted electronic files using specific software or hardware systems, or both. Levelton makes no representation about the compatibility of these files with the current or future software and hardware systems of the Client, the Approved Users or any other party. The Client further agrees that Levelton is under no obligation, unless otherwise expressly specified, to provide the Client, the Approved Users and any other party, or any or all of them, with specific software and hardware systems that are compatible with any electronic submitted by Levelton. The Client further agrees that should the Client, an Approved User or a third party require Levelton to provide specific software or hardware systems, or both, compatible with the electronic files prepared and submitted by Levelton, for any reason whatsoever included but not restricted to an order from a court, then the Client will pay Levelton for all reasonable costs related to the provision of the specific software or hardware systems, or both. The Client further agrees to indemnify and hold harmless Levelton, its officers, directors, employees, agents, representative or sub-consultant, or any or all of them, against any claim or any nature whatsoever brought against Levelton, whether in contract or in tort, arising or related to the provision or use or any specific software or hardware provided by Levelton.

## Mission Creek Restoration Initiative

REMOVE EXISTING DIKE
BUILD NEW DIKE
LONG TERM - NEW DIKE




Note: Test Hole Locations are Approximate

LEGEND
AH15-XX — AUGER HOLE
AH15-XX (DCPT) — AUGER HOLE WITH DYNAMIC CONE PENETRATION TEST

ADAPTED FROM: N/A
DATE: N/A
PROJECT NO.: N/A



LEVELTON
108-3677 Hwy 97 N,
Kelowna, BC, V1X 5C3
p:250-491-9778
f:250-491-9729
www.levelton.com

| | | | |
|---|---|---|---|
| TITLE: Site Plan - Augerhole Locations | DSN: | SCALE: NTS |
| PROJECT: Mission Creek Dike Replacement | CHK: PE | DATE: Feb. 27 2015 |
| ADDRESS: 3830, 3850, 3990 Swamp Road | DWN: TD | PROJECT NO.: R715-0268-00 |
| CLIENT: The City of Kelowna | | DRAWING NO.: FIGURE 1 |

# Appendix A

# Soil Logs

LEVELTON
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Fax: 250-491-9729
www.levelton.com

# 3830, 3850, 3990 Cassorso Road
# Kelowna, BC
# Dike Replacement

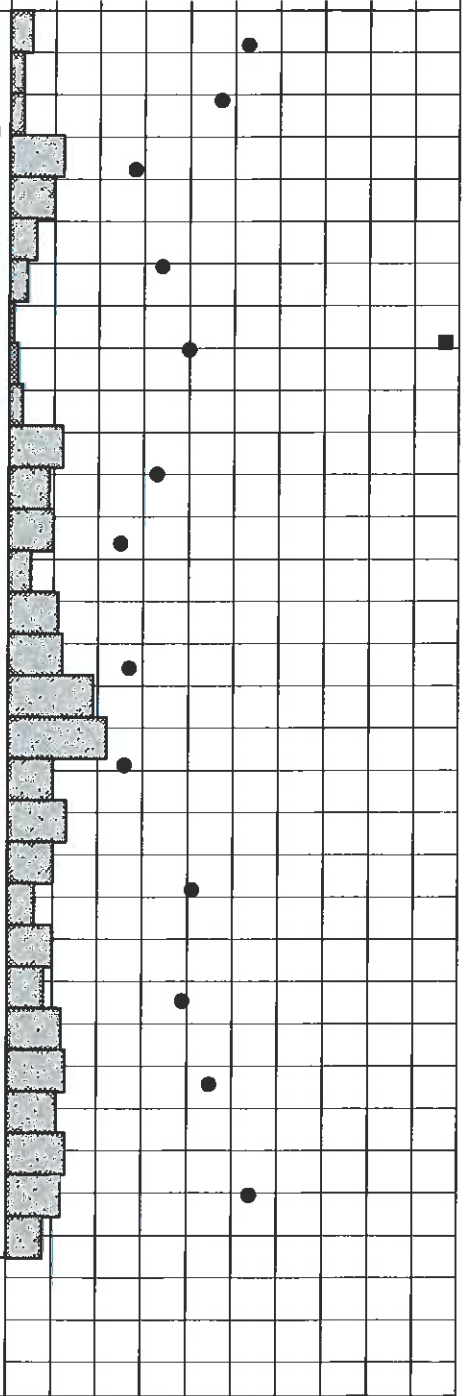
**AH15-01**



Project No: R715-0268-00

Northing: 5524245 Easting: 322590

| Depth (m) | Depth (ft) | Description | C | N | Type | Water Level |
|---|---|---|---|---|---|---|
| | | Soft brown SILT topsoil, trace sand, roots and organics, moist. | | | G | |
| | 2 | Very loose, grey SAND some silt, wet. | | | G | Feb 11 2015 |
| | 4 | Compact, grey brown silty SAND, mottled, wet. | | | G | |
| | 6 | Loose, grey SAND, some silt, wet. | | | G | |
| 2 | 8 | Very soft, grey SILT, trace sand, wet. | | | G | |
| | 10 | Compact, grey SAND, some silt, wet. | | | G | |
| | 12 | | | | G | |
| 4 | 14 | | | | | |
| | 16 | | | | G | |
| | 18 | | | | G | |
| 6 | 20 | Interlayered compact, grey SAND, some silt, and firm, grey brown silty SAND. | | | G | |
| | 22 | Occasional organic silt and ash seams 50-100mm thick. | | | | |
| | 24 | | | | G | |
| 8 | 26 | | | | G | |
| | 28 | | | | G | |
| | 30 | Bottom of hole at 9.00 meters | | | | |
| | 32 | | | | | |




**C: Condition of Sample**
Good
Disturbed
No Recovery

**Type: Type of Sampler**
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

**N: Number of Blows**
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type: Trip Hammer

DYNAMIC CONE PENETRATION TEST:
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

- Moisture Content %
- Plastic Limit %
- Liquid Limit %
- Ground Water Level
- Shear strength in kPa (Torvane or Penetrometer)
- Shear strength in kPa (Unconfined)
- Shear strength in kPa (field vane)
- Remolded strength in kPa
- Percent Passing # 200 sieve

Drill Method: Solid Stem Auger / DCPT

Date Drilled: 11/02/2015

By: TD

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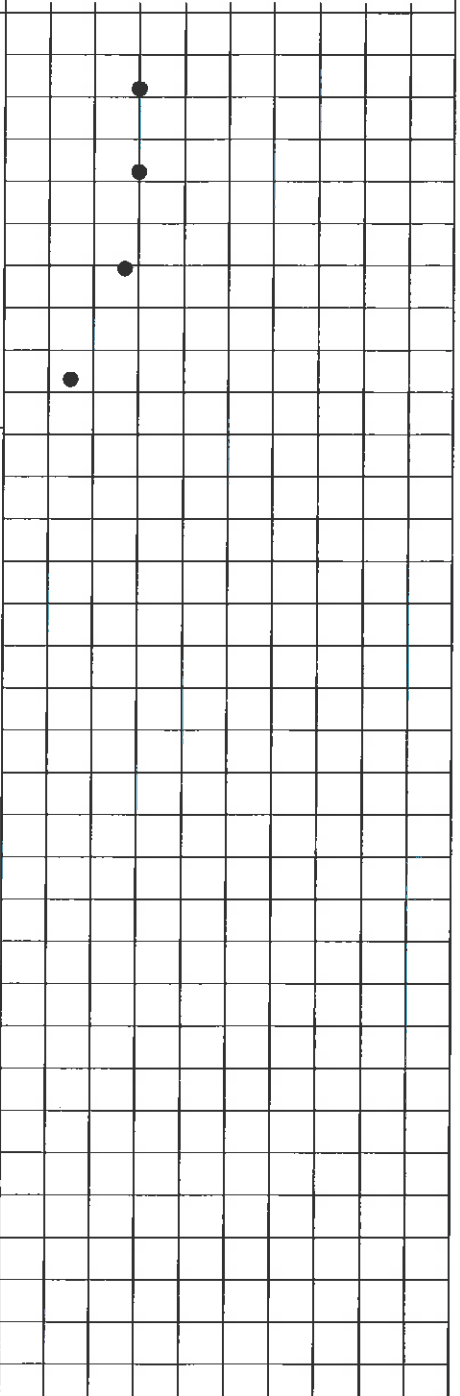
3830, 3850, 3990 Cassorso Road
Kelowna, BC
Dike Replacement

# AH15-02



Project No: R715-0268-00
Northing: 5524202 Easting: 322448

| Depth (m) | Depth (ft) | Description | C | N | Type | Water Level |
|---|---|---|---|---|---|---|
| | 2 | Soft brown SILT topsoil, trace sand, roots and organics, moist. | | | G | Feb 11 2015 |
| | 4 | Loose, grey SAND, some silt, wet. | | | G | |
| 2 | 6 | | | | G | |
| | 8 | Compact, grey SAND and gravel, trace silt, wet. | | | G | |
| | 10 | Bottom of hole at 3.00 meters | | | | |
| | 12 | | | | | |
| 4 | 14 | | | | | |
| | 16 | | | | | |
| | 18 | | | | | |
| 6 | 20 | | | | | |
| | 22 | | | | | |
| | 24 | | | | | |
| 8 | 26 | | | | | |
| | 28 | | | | | |
| | 30 | | | | | |
| | 32 | | | | | |




**C: Condition of Sample**
Good
Disturbed
No Recovery

**Type: Type of Sampler**
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

**N: Number of Blows**
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type:

- Moisture Content %
- Plastic Limit %
- Liquid Limit %
- Ground Water Level
- Shear strength in kPa (Torvane or Penetrometer)
- Shear strength in kPa (Unconfined)
- Shear strength in kPa (field vane)
- Remolded strength in kPa
- Percent Passing # 200 sieve

Drill Method:
Solid Stem Auger
Date Drilled: 11/02/2015
By: TD

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# 3830, 3850, 3990 Cassorso Road
# Kelowna, BC
# Dike Replacement

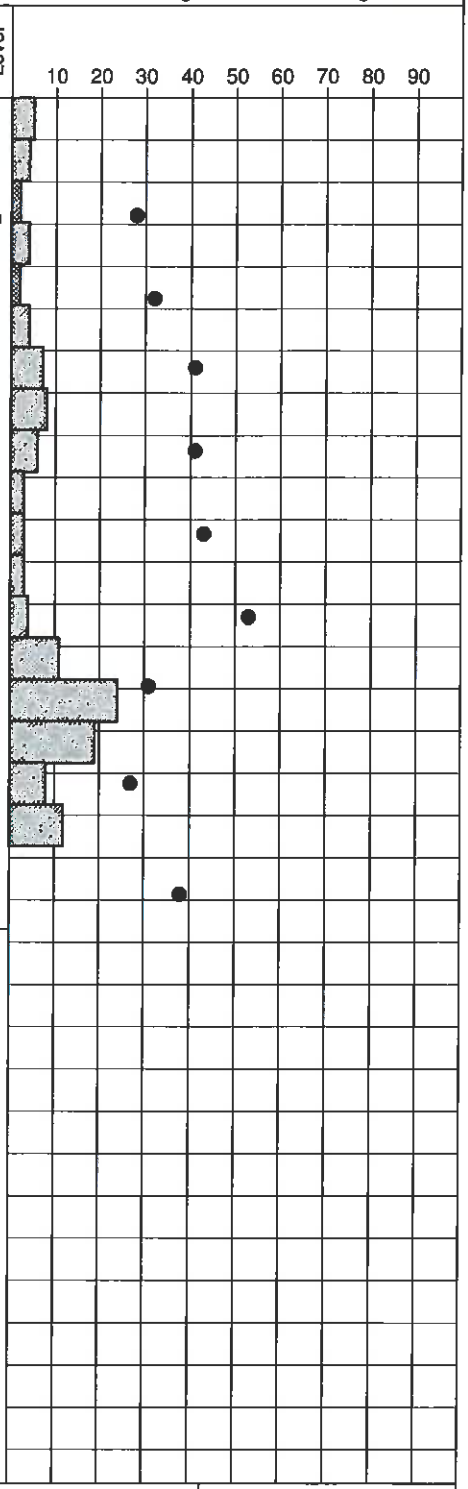
**AH15-03**



Project No: R715-0268-00

Northing: 5524118 Easting: 322376

| Depth (m) | Depth (ft) | Description | C | N | Type | Water Level |
|---|---|---|---|---|---|---|
| | 2 | Soft, brown SILT topsoil, trace sand, roots and organics, moist. | | | G | Feb 11 2015 |
| | 4 | Loose, grey SAND, some silt, wet. | | | G | |
| 2 | 6 | | | | G | |
| | 8 | Compact, grey brown silty SAND, mottled, wet. | | | G | |
| | 10 | Compact, grey SAND, some silt, wet. | | | G | |
| | 12 | Loose grey SAND, some silt, wet. Occasional organic silt seams 50-100mm thick. | | | G | |
| 4 | 14 | Compact, grey SAND, trace silt, trace gravel, interlayered fine and coarse deposits. | | | G | |
| | 16 | | | | G | |
| | 18 | | | | G | |
| 6 | 20 | Bottom of hole at 6.00 meters | | | | |
| | 22 | | | | | |
| | 24 | | | | | |
| 8 | 26 | | | | | |
| | 28 | | | | | |
| | 30 | | | | | |
| | 32 | | | | | |




**C: Condition of Sample**
Good
Disturbed
No Recovery

**Type: Type of Sampler**
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

**N: Number of Blows**
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type: Trip Hammer

DYNAMIC CONE PENETRATION TEST:
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

- Moisture Content %
- Plastic Limit %
- Liquid Limit %
- Ground Water Level
- Shear strength in kPa (Torvane or Penetrometer)
- Shear strength in kPa (Unconfined)
- Shear strength in kPa (field vane)
- Remolded strength in kPa
- Percent Passing # 200 sieve

Drill Method: Solid Stem Auger / DCPT
Date Drilled: 11/02/2015
By: TD

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# 3830, 3850, 3990 Cassorso Road
# Kelowna, BC
# Dike Replacement

**AH15-04**



Project No: R715-0268-00

Northing: 5524086 Easting: 322249

| Depth (m) | Depth (ft) | Description | C | N | Type | Water Level |
|---|---|---|---|---|---|---|
| | | Loose, brown SILT topsoil, trace sand, roots and organics, moist. | | | G | |
| | 2 | Soft, brown sandy SILT, wet. | | | G | |
| | | Occasional organic silt seams 50mm thick. | | | | Feb 11 2015 |
| | 4 | Loose, grey SAND, some silt, wet. | | | G | |
| | | Soft, grey SILT, some sand, wet. | | | G | |
| | 6 | Occasional organic silt and ash seams 50mm thick. | | | | |
| 2 | | Compact, grey SAND, some silt, wet. | | | G | |
| | 8 | | | | | |
| | 10 | | | | G | |
| | | Loose, grey SAND trace silt, wet. | | | G | |
| | 12 | Occasional organic silt seams 50mm thick. | | | | |
| 4 | | Compact, grey SAND trace silt, wet. | | | G | |
| | 14 | | | | | |
| | | Bottom of hole at 4.50 meters | | | | |
| | 16 | | | | | |
| | 18 | | | | | |
| 6 | 20 | | | | | |
| | 22 | | | | | |
| | 24 | | | | | |
| 8 | 26 | | | | | |
| | 28 | | | | | |
| | 30 | | | | | |
| | 32 | | | | | |

10 20 30 40 50 60 70 80 90

**C: Condition of Sample**
Good
Disturbed
No Recovery

**Type: Type of Sampler**
SPT : 2 In. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

**N: Number of Blows**
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type:

- Moisture Content %
- Plastic Limit %
- Liquid Limit %
- Ground Water Level
- Shear strength in kPa (Torvane or Penetrometer)
- Shear strength in kPa (Unconfined)
- Shear strength in kPa (field vane)
- Remolded strength in kPa
- Percent Passing # 200 sieve

Drill Method: Solid Stem Auger

Date Drilled: 11/02/2015

By: TD

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www.levelton.com

# 3830, 3850, 3990 Cassorso Road
# Kelowna, BC
# Dike Replacement

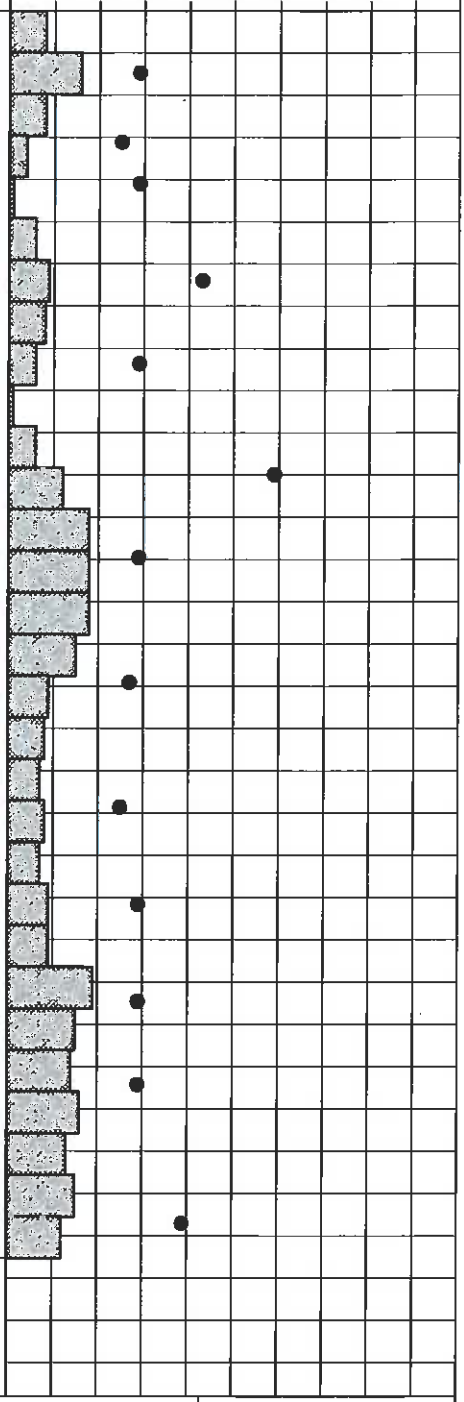
**AH15-05**



Project No: R715-0268-00

Northing: 5524038 Easting: 322161

| Depth (m) | Depth (ft) | Description | C | N | Type | Water Level |
|---|---|---|---|---|---|---|
| | | Soft to firm, brown SILT topsoil, trace sand, roots and organics, moist. | | | G | |
| | 2 | Soft, brown sandy SILT, wet. | | | G | Feb 11 2015 |
| | 4 | Compact, grey brown silty SAND, mottled, wet. | | | G | |
| | 6 | Compact, light grey SAND, some silt, wet. | | | G | |
| 2 | 8 | Compact, grey brown silty SAND, mottled, wet. | | | G | |
| | 10 | Interlayered compact, grey SAND, trace silt and compact, grey brown silty SAND, wet. | | | G | |
| | 12 | Occasional organic silt and ash seams 50mm thick. | | | | |
| | | Compact grey SAND, trace silt, wet. | | | G | |
| 4 | 14 | | | | | |
| | 16 | | | | G | |
| | 18 | | | | | |
| 6 | 20 | | | | G | |
| | 22 | | | | G | |
| | 24 | | | | G | |
| 8 | 26 | | | | | |
| | 28 | Interlayered compact, grey SAND, trace silt, and compact, grey brown silty SAND, wet. | | | G | |
| | 30 | Occasional organic silt and organics in seams 50mm thick. | | | | |
| | | Bottom of hole at 9.00 meters | | | | |
| | 32 | | | | | |




**C: Condition of Sample**
Good
Disturbed
No Recovery

**Type: Type of Sampler**
SPT : 2 in. standard
ST : Shelby
FP : Fixed Piston
G : Grab
CORE

**N: Number of Blows**
WH : Weight of Hammer
WR : Weight of Rod
Standard Penetration Test : ASTM D1586
Hammer Type: Trip Hammer

DYNAMIC CONE PENETRATION TEST:
Blow Count: Number of blows of a 140 lb (64 kg) hammer dropped 30in. (750mm) to produce 12in. (300mm) of penetration of a 2in. (50mm) diameter cone.

- Moisture Content %
- Plastic Limit %
- Liquid Limit %
- Ground Water Level
- Shear strength in kPa (Torvane or Penetrometer)
- Shear strength in kPa (Unconfined)
- Shear strength in kPa (field vane)
- Remolded strength in kPa
- Percent Passing # 200 sieve

Drill Method: Solid Stem Auger / DCPT

Date Drilled: 11/02/2015

By: TD

# Appendix B

# Grain Size Analysis Results

# Levelton Consultants Ltd.

**Fraser Valley Group and Southern Interior**

LEVELTON

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Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

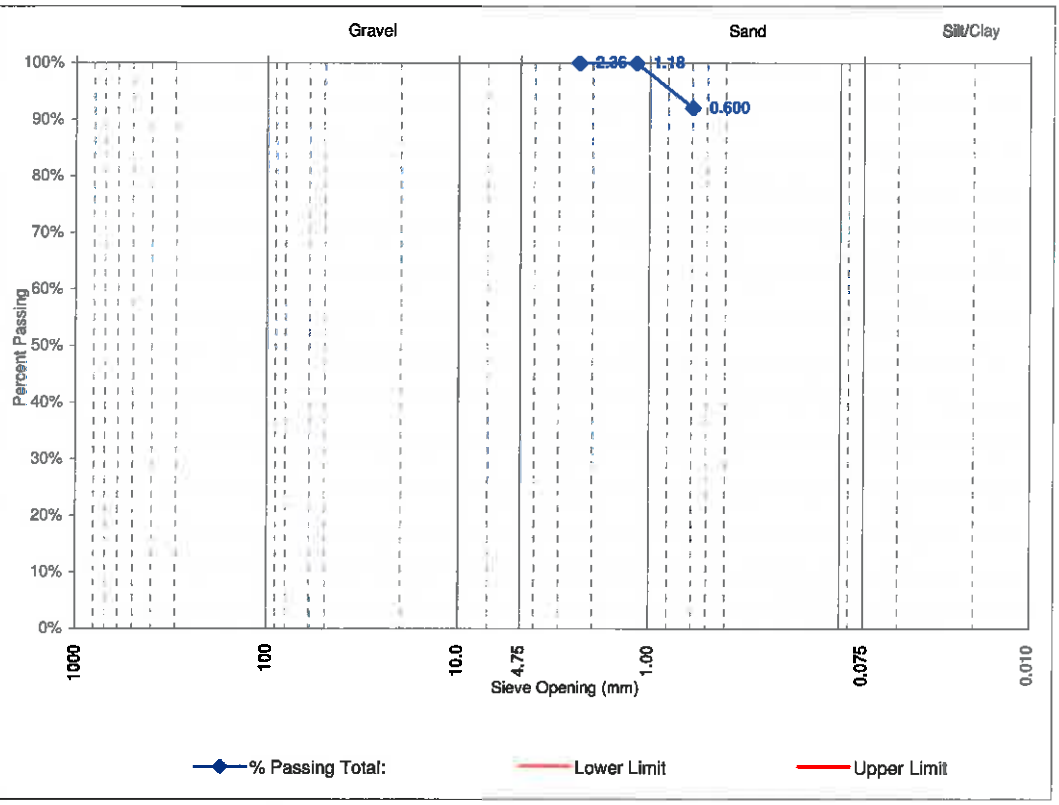
**Sample Location:** AH1501-G5
**Supplier:**
**Material Type:** SILT, trace Sand
**Usage:**
**Specification:**

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 19, 2015
**Sieve No.** 1

**Moisture Content (as received):** 35%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| 150.0 | | | |
| 100.0 | | | |
| 75.0 | | | |
| 50.0 | | | |
| 37.5 | | | |
| 25.0 | | | |
| 19.0 | | | |
| 12.5 | | | |
| 9.51 | | | |
| 4.75 | | | |
| 2.36 | | | |
| 1.18 | | | |
| 0.600 | 100.0% | | |
| 0.425 | | | |
| 0.300 | 100.0% | | |
| 0.150 | 100.0% | | |
| 0.075 | 92.2% | | |




Remarks: _____

**Levelton Consultants Ltd.**

Reporting of these results constitutes a testing service only.
No engineering interpretation of the results is expressed or implied.
Engineering review and interpretation of these results can be provided upon written request.

Per: _____

# Levelton Consultants Ltd.

**Fraser Valley Group and Southern Interior**

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Kelowna, BC V1X 5C3
Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

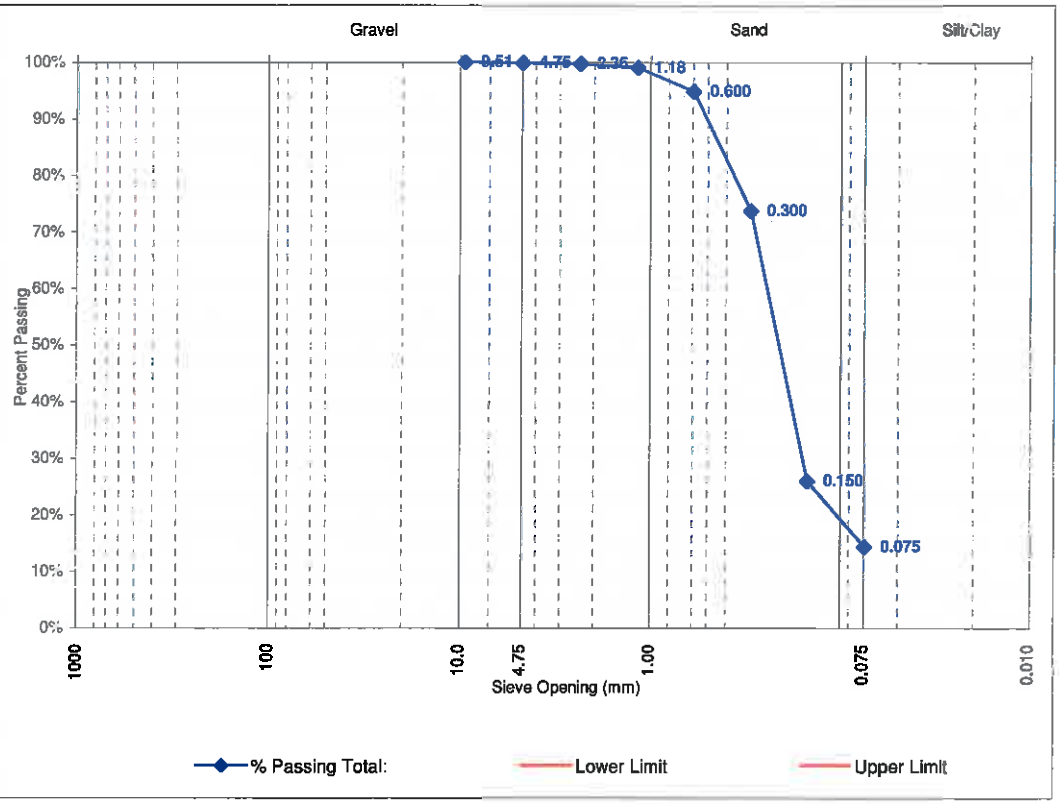
**Sample Location:** AH1502-G2
**Supplier:**
**Material Type:** SAND, some Silt
**Usage:**
**Specification:**

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 19, 2015
**Sieve No.** 2

**Moisture Content (as received):** 28%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| 150.0 | | | |
| 100.0 | | | |
| 75.0 | | | |
| 50.0 | | | |
| 37.5 | | | |
| 25.0 | | | |
| 19.0 | | | |
| 12.5 | | | |
| 9.51 | 100.0% | | |
| 4.75 | 99.9% | | |
| 2.36 | 99.7% | | |
| 1.18 | 99.0% | | |
| 0.600 | 94.8% | | |
| 0.425 | | | |
| 0.300 | 73.7% | | |
| 0.150 | 26.0% | | |
| 0.075 | 14.4% | | |




Remarks: _____

**Levelton Consultants Ltd.**

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Per: _____

# Levelton Consultants Ltd.

**Fraser Valley Group and Southern Interior**

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#108, 3677 Hwy 97N
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Tel: (250) 491-9778
Fax: (250) 491-9729
Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

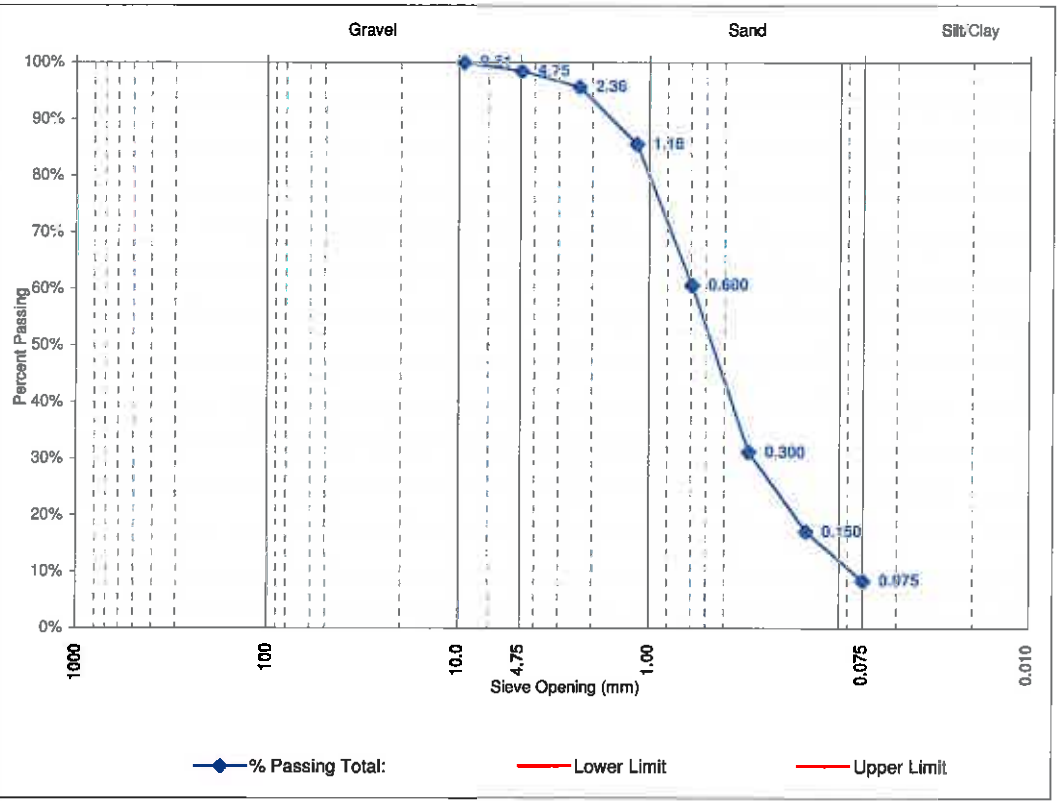
**Sample Location:** AH1503-G8
**Supplier:**
**Material Type:** SAND, trace silt, trace gravel
**Usage:**
**Specification:**

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 19, 2015
**Sieve No.** 3

**Moisture Content (as received):** 24%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| 150.0 | | | |
| 100.0 | | | |
| 75.0 | | | |
| 50.0 | | | |
| 37.5 | | | |
| 25.0 | | | |
| 19.0 | | | |
| 12.5 | | | |
| 9.51 | 100.0% | | |
| 4.75 | 98.5% | | |
| 2.36 | 95.7% | | |
| 1.18 | 85.6% | | |
| 0.600 | 60.6% | | |
| 0.425 | | | |
| 0.300 | 31.0% | | |
| 0.150 | 17.0% | | |
| 0.075 | 8.3% | | |




Remarks: _____

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**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

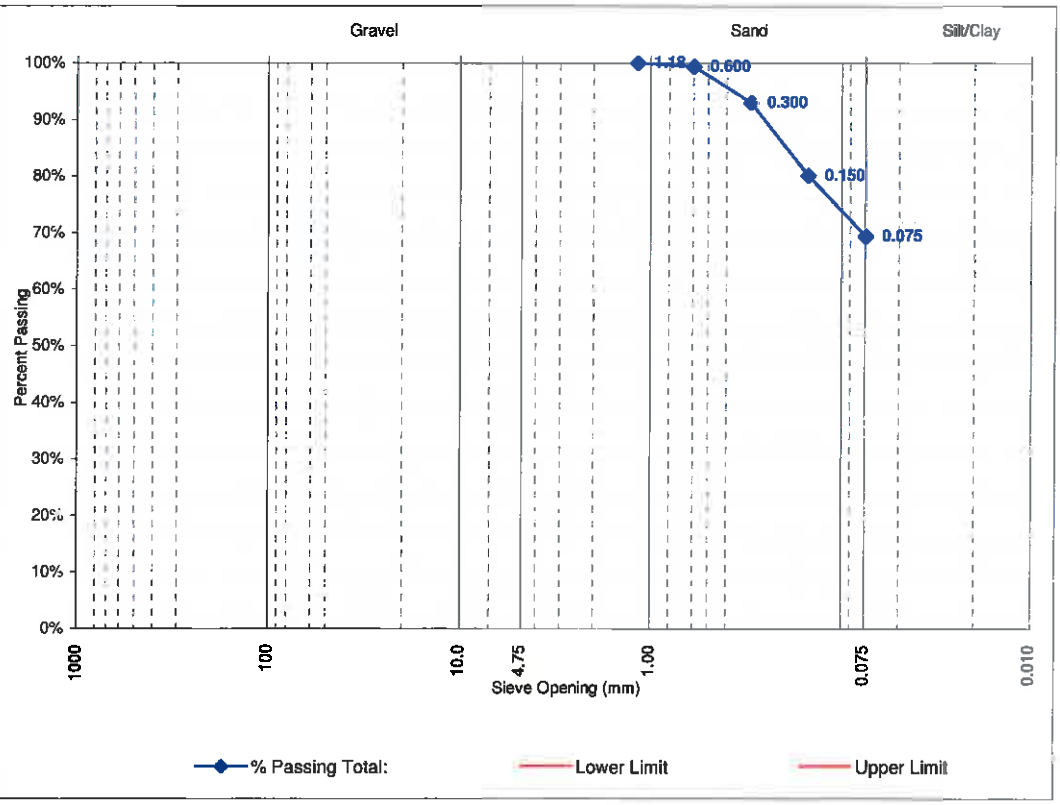
**Sample Location:** AH1504-G2
**Supplier:**
**Material Type:** Sandy SILT
**Usage:**
**Specification:**

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 19, 2015
**Sieve No.** 4

**Moisture Content (as received):** 30%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| *150.0* | | | |
| *100.0* | | | |
| *75.0* | | | |
| *50.0* | | | |
| *37.5* | | | |
| *25.0* | | | |
| *19.0* | | | |
| *12.5* | | | |
| *9.51* | | | |
| *4.75* | | | |
| *2.36* | | | |
| *1.18* | 100.0% | | |
| *0.600* | 99.3% | | |
| *0.425* | | | |
| *0.300* | 93.0% | | |
| *0.150* | 80.1% | | |
| *0.075* | 69.4% | | |




Remarks: _____

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Fax: (250) 491-9729
Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

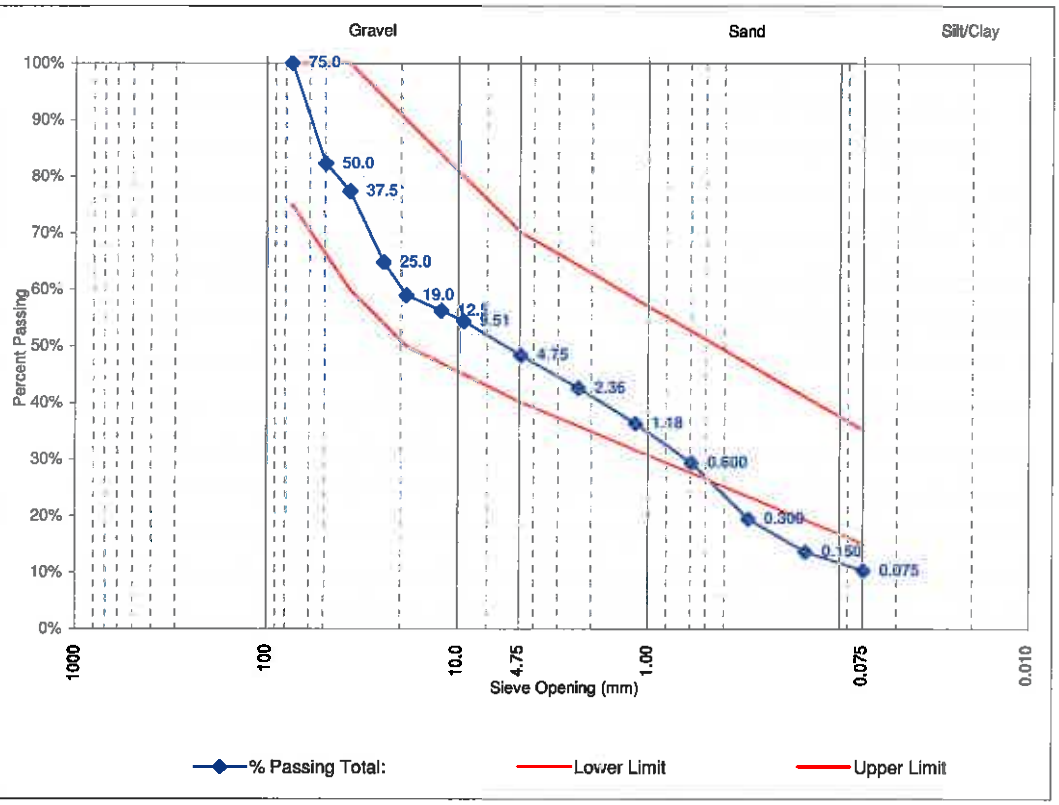
**Sample Location:** Existing Dike Fill
**Supplier:**
**Material Type:** GRAVEL and SAND, some Silt
**Usage:**
**Specification:** 5.8.1 Recommended Dike Fill Material

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 12, 2015
**Sieve No.** 5

**Moisture Content (as received):** 15%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| *150.0* | | | |
| *100.0* | | | |
| *75.0* | 100.0% | 100 | 75 |
| *50.0* | 82.2% | | |
| *37.5* | 77.3% | 100 | 60 |
| *25.0* | 64.8% | | |
| *19.0* | 59.0% | 90 | 50 |
| *12.5* | 56.3% | | |
| *9.51* | 54.4% | | |
| *4.75* | 48.3% | 70 | 40 |
| *2.36* | 42.5% | | |
| *1.18* | 36.3% | | |
| *0.600* | 29.3% | | |
| *0.425* | | 50 | 25 |
| *0.300* | 19.4% | | |
| *0.150* | 13.5% | | |
| *0.075* | 10.2% | 35 | 15 |




Remarks: _____

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Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

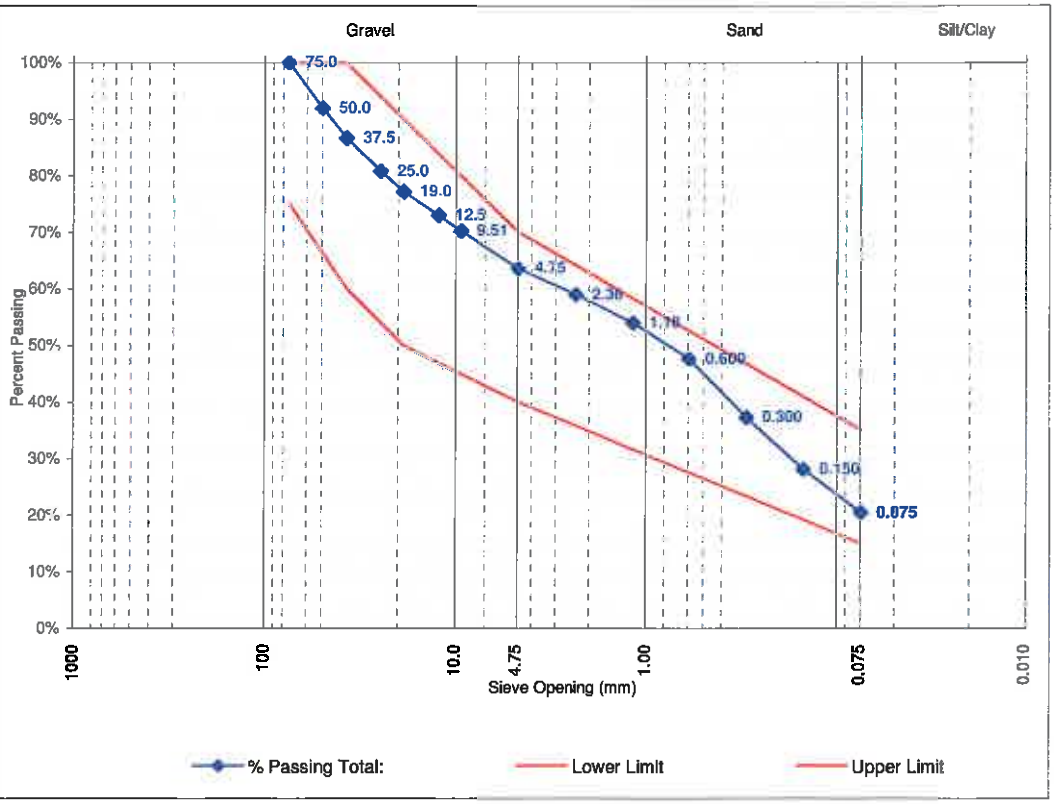
**Sample Location:** Stockpile - North Berm
**Supplier:**
**Material Type:** Silty SAND and Gravel
**Usage:** Engineered Fill
**Specification:** 2.8.1 Recommended Dike Fill

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 17, 2015
**Sieve No.** 6

**Moisture Content (as received):** 15%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| *150.0* | | | |
| *100.0* | | | |
| *75.0* | 100.0% | 100 | 75 |
| *50.0* | 92.0% | | |
| *37.5* | 86.7% | 100 | 60 |
| *25.0* | 80.8% | | |
| *19.0* | 77.2% | 90 | 50 |
| *12.5* | 73.1% | | |
| *9.51* | 70.2% | | |
| *4.75* | 63.6% | 70 | 40 |
| *2.36* | 58.9% | | |
| *1.18* | 54.0% | | |
| *0.600* | 47.6% | | |
| *0.425* | | 50 | 25 |
| *0.300* | 37.2% | | |
| *0.150* | 28.1% | | |
| *0.075* | 20.5% | 35 | 15 |




Remarks: _____

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Email: kelowna@levelton.com


**Client:** Mr Todd Cashin - City of Kelowna
**Project:** Mission Creek Dike - Phase 1 East
**Site Address:** Casorso Road to Gordon Drive, Kelowna, BC

**File No.:** R715-0268-00
**Task:**

## Report of Grain Size Analysis

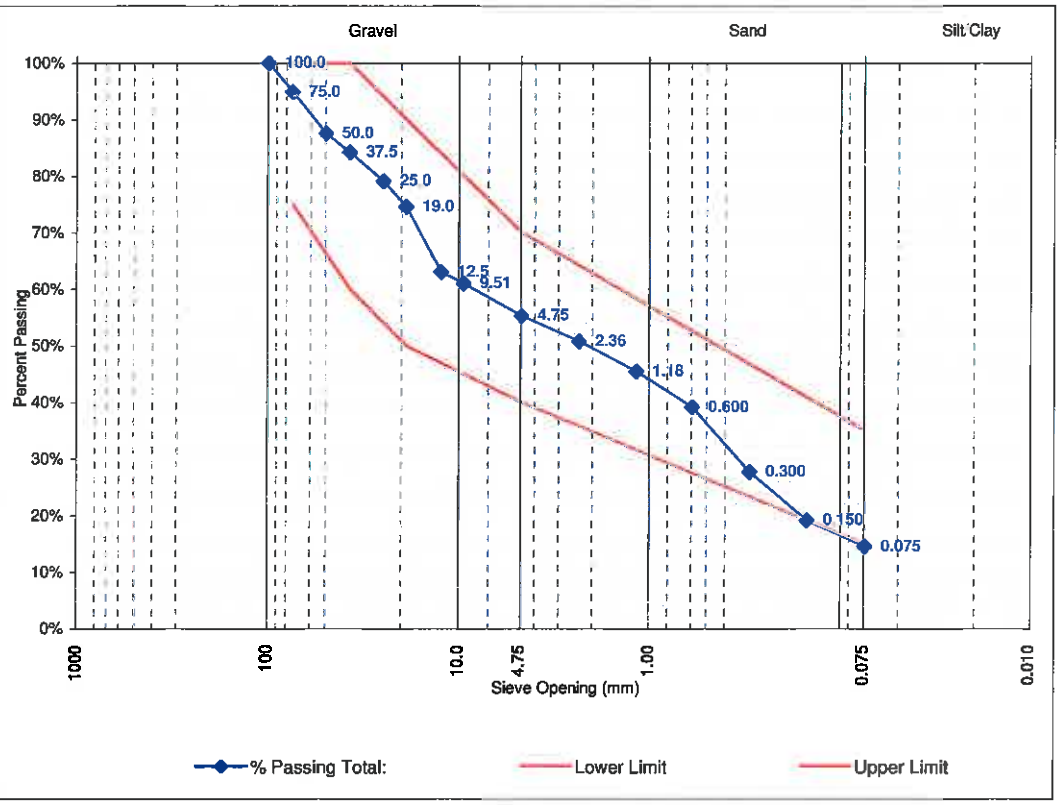
**Sample Location:** Stockpile - South Berm
**Supplier:**
**Material Type:** GRAVEL and SAND, some silt
**Usage:** Engineered Fill
**Specification:** 2.8.1 Recommended Dike Fill

**Sampled By:** TD
**Tested By:** MP
**Date Sampled:** February 11, 2015
**Date Tested:** February 19, 2015
**Sieve No.** 7

**Moisture Content (as received):** 11%

**Washed Sieve**

| Screen Opening (mm): | % Passing Total: | Specification | |
|---|---|---|---|
| | | Upper Limit | Lower Limit |
| 150.0 | | | |
| 100.0 | 100.0% | | |
| 75.0 | 94.9% | 100 | 75 |
| 50.0 | 87.5% | | |
| 37.5 | 84.2% | 100 | 60 |
| 25.0 | 79.1% | | |
| 19.0 | 74.5% | 90 | 50 |
| 12.5 | 63.0% | | |
| 9.51 | 61.0% | | |
| 4.75 | 55.3% | 70 | 40 |
| 2.36 | 50.7% | | |
| 1.18 | 45.5% | | |
| 0.600 | 39.1% | | |
| 0.425 | | 50 | 25 |
| 0.300 | 27.7% | | |
| 0.150 | 19.1% | | |
| 0.075 | 14.5% | 35 | 15 |




Remarks: _____

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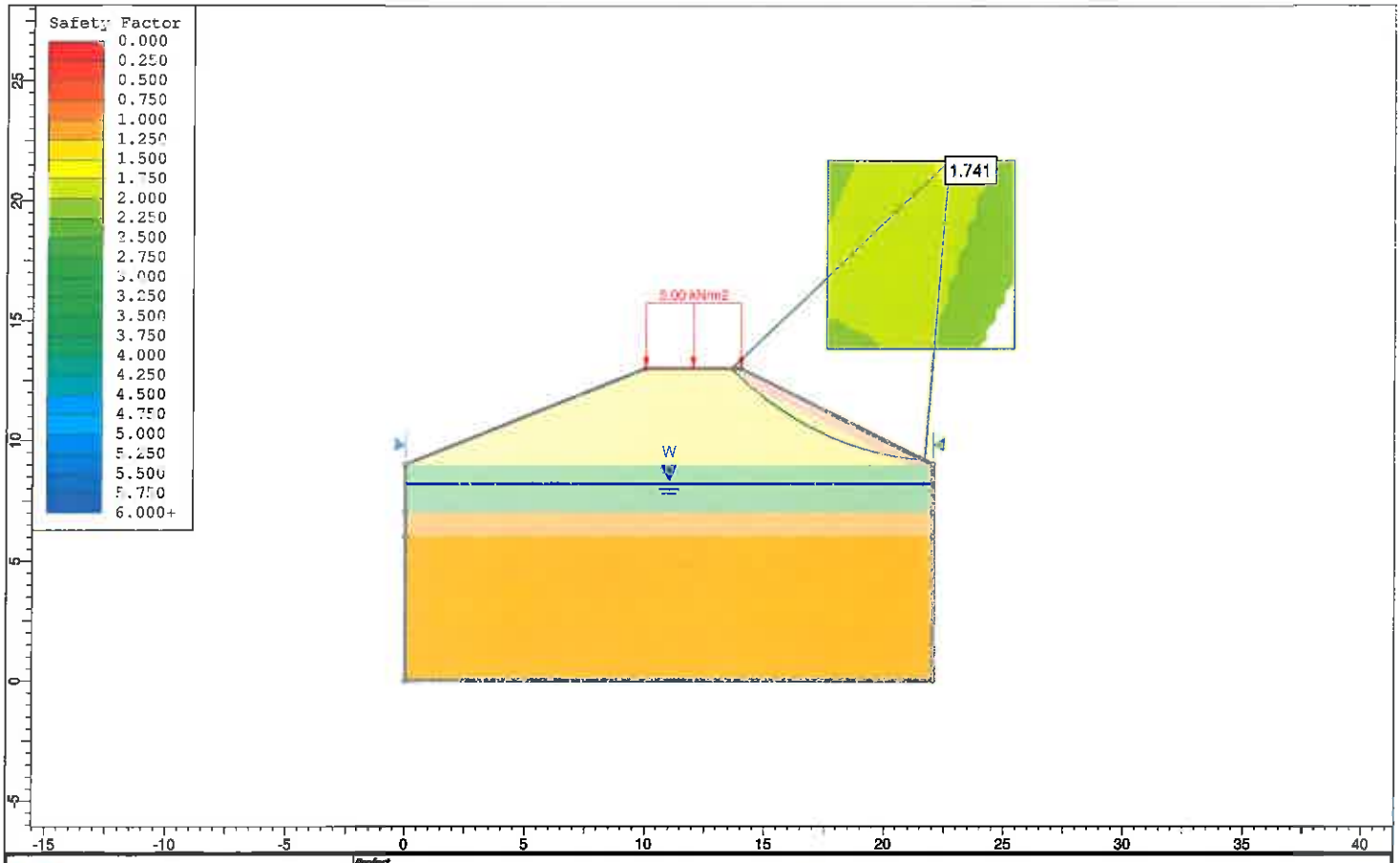
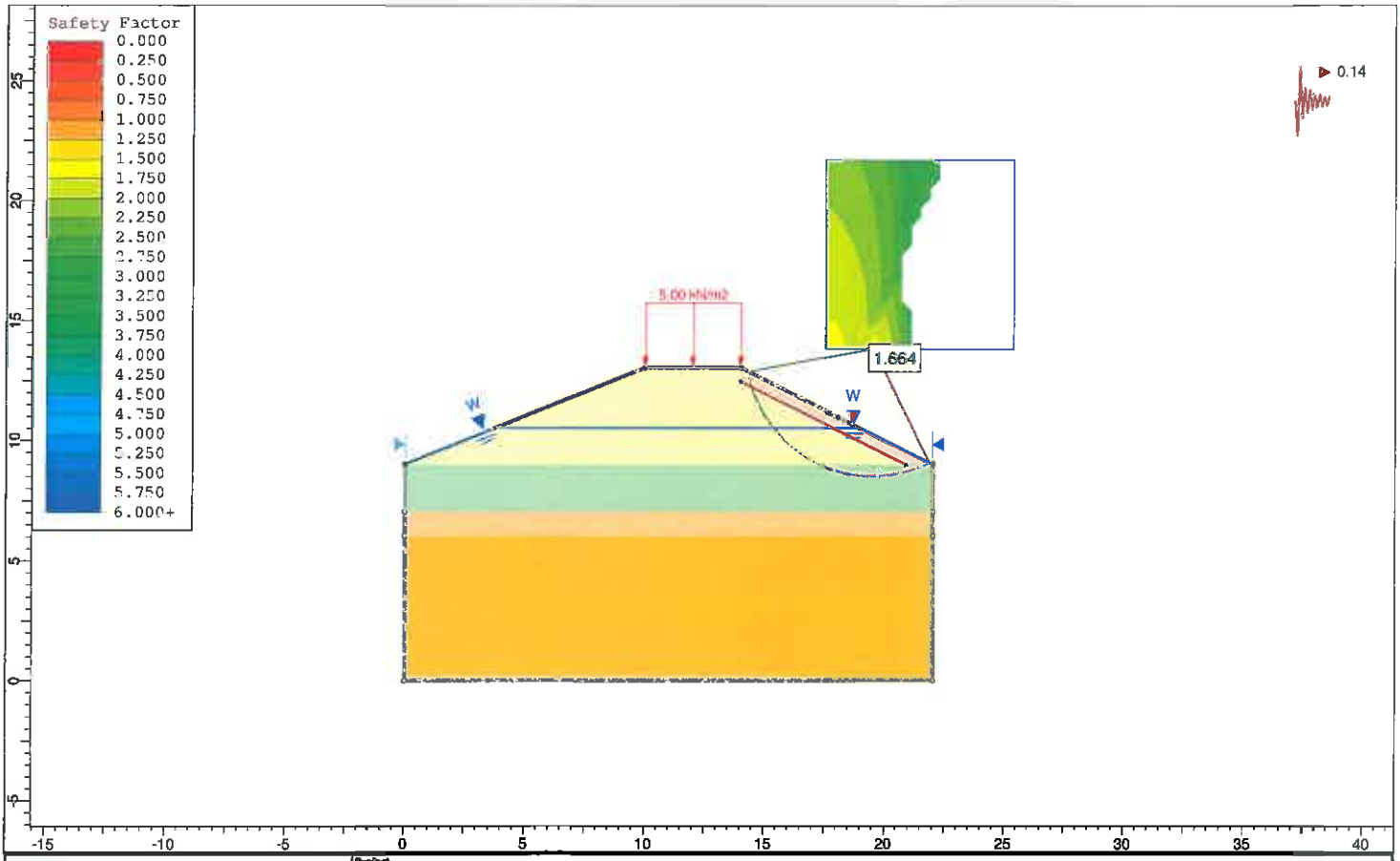
# Appendix C

# Slope Stability Analysis Results



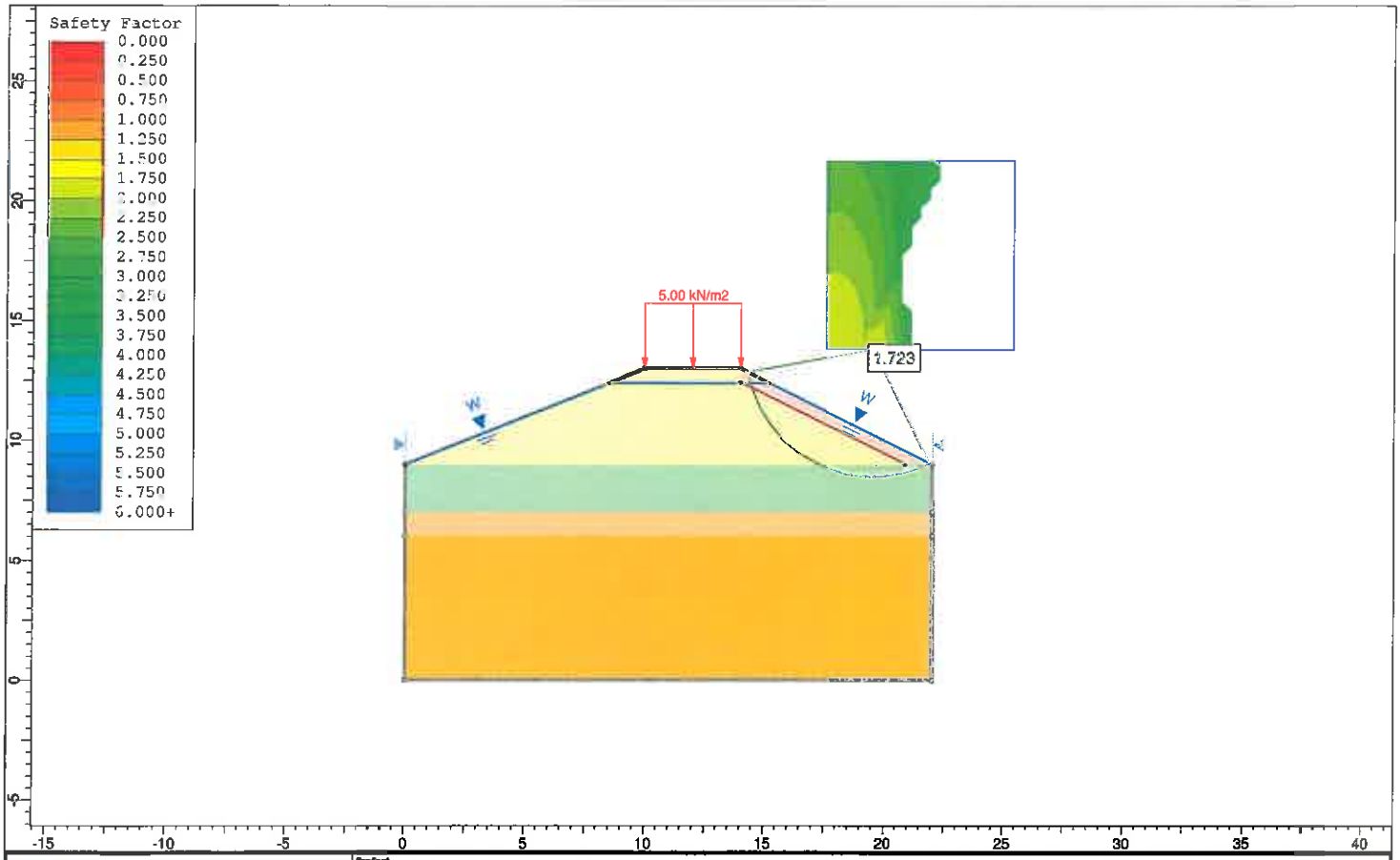

| | | | | |
|---|---|---|---|---|
| Project | Mission Creek Dike | | | |
| Analysis Description | 4m high dike with 2:1 slope - static | | | |
| Drawn By | TD | Scale | 1:224 | Company: Levelton |
| Date | 26/02/2015, 8:48:10 AM | | | File Name: Mission Creek 2 to 1 4m dike.slim |

SLIDEINTERPRET 6.033




| | | | | |
|---|---|---|---|---|
| rocscience | Project | Mission Creek Dike | | |
| | Analysis Description | 4m high dike with 2:1 slope - seismic | | |
| | Drawn By | TD | Scale 1:224 | Company Levelton |
| | Date | 26/02/2015, 8:48:10 AM | | File Name Mission Creek 2 to 1 4m dike.slim |

SLIDEINTERPRET 6.033




| | | | | |
|---|---|---|---|---|
| rocscience | Project | Mission Creek Dike | | |
| | Analysis Description | 4m high dike with 2:1 slope - rapid draw down | | |
| | Drawn By | TD | Scale 1:224 | Company Levelton |
| | Date | 26/02/2015, 8:48:10 AM | | File Name Mission Creek 2 to 1 4m dike.slim |

SLIDEINTERPRET 6.033