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June 7, 2019

Derek Sutherland
Columbia Shuswap Regional District
555 Harbourfront Drive NE
PO Box 978
Salmon Arm, BC V1E 4P1

Dear Mr. Sutherland:

RE: Newsome Creek Erosion Mitigation Options
Our File 3234.013

We are pleased to submit herewith our technical memorandum which documents a feasibility study to mitigate erosion on Newsome Creek below Highway 1. This project was performed by Kerr Wood Leidal (KWL) and Westrek Geotechnical Services Ltd. (Westrek). The project results are summarized below.

The study area is the creek reach from Highway 1 to Shuswap Lake, a length of approximately 520 m, with a focus on the reach between Highway 1 and Dieppe Road. Thirteen properties are within the study area, eleven on Caen Road (right bank) and two on Passchendaele Road (left bank). This section of Newsome Creek mostly flows through a ravine with nearly vertical side walls, and has been subjected to erosion, channel destabilization, and bank instability. Eroding banks and falling trees, especially on the right bank (looking downstream) of the ravine, have resulted in a slope stability risk to houses along Caen Road.

In October 2018, Westrek[1] documented four properties on Caen Road (2809, 2819, 2821 and 2823) that could be affected by imminent bank failure, and therefore were at high risk of foundations being undermined. The underlying cause of the ravine instability is the creek undercutting the silty sand layers of the ravine, leading to progressive collapse of the ravine walls. The Westrek report documents the fact that the ravine instability is progressing downstream.

Nine potential mitigation options were identified and evaluated. After consideration of construction practicality, design life, and community feedback, three options remain for consideration. These options and associated indicative cost estimates are as follows:

Mitigation Option	Cost Estimate
Rock-Lined Channel	$4,800,000
Culvert (2700 mm Diameter)	$5,000,000
Sheet Pile Wall with Bed Stabilizers	$6,200,000
Note: Cost estimate includes construction cost, engineering / construction management, environmental compensation/enhancement and contingency.	

[1] Westrek Geotechnical Services Ltd, 2018. Monitoring Results and Summary Recommendations. Newsome Creek Erosion below Highway 1. Prepared for Columbia Shuswap Regional District – Shuswap Emergency Program.

The objective of mitigation works would be to stabilize the creek channel to reduce undercutting of the ravine slopes. While each of these options would limit further destabilization of the ravine, none of the options would fully stabilize the upper ravine slopes. In the end, some combination of these three options would probably provide the optimum approach to channel stabilization.

Once funding is secured, detailed engineering work would be needed to refine the final combination of options, prepare detailed design, and provide an updated cost estimate. A safe construction approach would also need to be developed.

Please contact us with any questions that arise.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

Jason Miller, P.Eng.
Water Resources Engineer

/dwm

Encl.
KWL Technical Memorandum, June 7, 2019
Westrek Technical Memorandum, June 7, 2019

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Technical Memorandum

DATE: June 7, 2019

TO: Derek Sutherland, P.Eng
Columbia Shuswap Regional District

FROM: Jason Miller, P.Eng
Alisson Seuarz, M.Eng, EIT

RE: **Newsome Creek Erosion Mitigation Options**
Our File 3234.013

1. Introduction

Kerr Wood Leidal Associates Ltd. (KWL) has been retained by the Columbia Shuswap Regional District (CSRD) to complete a feasibility study to mitigate erosion on Newsome Creek from Highway 1 to Shuswap Lake in Sorrento, BC. The study identifies and evaluates options to mitigate erosion within the Newsome Creek ravine. The options focus on preventing further erosion of the ravine, but do not address current ravine slope instability. KWL has partnered with Westrek Geotechnical Services Ltd. (Westrek) to provide geotechnical input for the potential erosion mitigation options and to provide an opinion on ravine bank stability.

2. Background

Newsome Creek is located in the South Shuswap of the Southern Interior of British Columbia. The watershed of Newsome Creek extends from its headwaters near the top of Black Mountain and Mount Hilliam to its mouth at Shuswap Lake in the community of Sorrento. Most of the watershed is within the Columbia Shuswap Regional District except for the top west tip of the watershed that lies within the Thompson Nicola Regional District.

The creek system includes two branches on the east side of the watershed that converge before joining a third branch at about 400 m northwest of the Notch Hill Road and Fredrickson Road intersection. A map of the watershed is shown on Figure 1.

The study area is the creek reach from Highway 1 to Shuswap Lake, a length of approximately 520 m, with a focus on the reach between Highway 1 and Dieppe Road. This section of Newsome Creek mostly flows through a ravine with nearly vertical side walls and has been subjected to erosion, channel destabilization, and bank instability. Eroding banks and falling trees, especially on the right (looking downstream) bank of the ravine, has put houses along Caen Road at risk of foundation failure.

3. Site Visit

On March 20, 2019, KWL conducted a site visit to assess Newsome Creek from Highway 1 to Shuswap Lake, focussing on the reach between Highway 1 and Dieppe Road. The current observations were compared to 2017 conditions, as documented a KWL technical memorandum Emergency Site Assessment of Newsome Creek[1]. In general, erosion and channel instability continues to cause banks to slough and numerous mature trees to topple. Specific observations are summarized below.

Bank toe erosion is leading to undercutting and slope failure with earthen blocks falling into the creek along a reach of 40 m downstream of the Highway 1 culvert outlet. A recent slope failure caused a channel blockage, with ponding of the creek and an outlet drop of 1.2 m. Photo 1 below shows the conditions looking upstream from the channel blockage.

Photo 1: Looking upstream at culvert outlet and erosion.

[1] Kerr Wood Leidal Associates Ltd, 2017. Emergency Site Assessment of Newsome Creek. Prepared for Columbia Shuswap Regional District – Shuswap Emergency Program

In the ravine below 2809 Caen Road, bank erosion has progressed to cause bank undercutting. Debris, including trees, shrubs, and sloughed material has obstructed the channel and pushed the flow to the right bank. Recent sloughed material was observed on snow piles at the slope toe with audible and active slope failure occurring. Photo 2 depicts the flow undercutting the right bank below the eroded slope.

Overall, debris including fallen trees and an old tree fort litter the gully bottom causing deflected flow and ponding water. In 2018, Forsite Forest Management Specialists flagged danger trees throughout the reach[2]. Photo 3 shows flagging tape for danger trees, along with a man-made structure on some of the toppled trees.

Photo 2: Erosion below 2809 Caen Road (looking downstream).

Photo 3: Looking downstream near 2817 Caen Road at toppled trees and manmade structures.

The right bank below 2819 Caen Road is affected by erosion along a reach of approximately 42 m. A portion of the bank is undercut by 2 m for 15 m at the apex of the erosion. A mature cedar located 30 m downstream is anticipated to imminently fall. The gully becomes more defined and narrows to approximately 4 m at the downstream extent of the erosion. Photo 4 shows the right bank erosion and the outbuilding (woodwork shop) at the top of the bank.

Below 2827 Caen Road, 20 m of erosion along the creek at the gully bottom is flanked by a steep 6 m high bank. Sedimentary layers are evident through the erosion with varying sizes and colours. Photo 5 indicates the layers of material and channel.

[2] FORSITE Forest Management Specialists, 2018. Newsome Creek Danger Tree Assessment. Prepared for Columbia Shuswap Regional District - Shuswap Emergency Program.

Photo 4: Looking across at undercut bank and high erosion at Civic address 2819.

Photo 5: Looking across at erosion below property No. 2827 from bench across.

Downstream, there are other areas of older erosion which were not affected by high flows in 2018. However, toppled trees continue to cause irregular flow paths which may exacerbate erosion in future high flows. The culverts at Dieppe Road have oblong inlets which may trap debris. Below Dieppe Road, the shallow creek gradient is subject to sediment deposition.

4. Site Conditions

4.1 Properties

Thirteen properties are within the study area, eleven on Caen Road (right bank) and two on Passchendaele Road (left bank).

In October 2018, the risk to these properties, from 2803 to 2829 Caen Road, 1185 Passchendaele Road and 1159 Passchendaele Road, was assessed by Westrek based on monitoring and field observations. The Westrek report[3] documented four properties on Caen Road (2809, 2819, 2821 and 2823) that could be affected by imminent bank failure and therefore were at high risk of foundation collapse. Further assessment was recommended.

4.2 Slope Stability

Westrek has completed a further geotechnical review of Newsome Creek downstream of Highway 1. Westrek has identified that highly erodible sand and gravel units have been exposed in recent years

[3] Westrek Geotechnical Services Ltd, 2018. Monitoring Results and Summary Recommendations. Newsome Creek Erosion below Highway 1. Prepared for Columbia Shuswap Regional District – Shuswap Emergency Program.

during high flow events, which in some places has undercut the bank 1 to 2 m (i.e. below 2809 to 2819 Caen Road). There is an overlying silt unit, which is fine grained in nature, but can stand at very steep slopes. This layer is prone to unpredictable collapse due to shear failure, or a toppling failure in locations of unfavourable joints. Either of these mechanisms can result in large volumes of material being introduced into the channel, which aggravates the erosion and destabilization process further as the sediment is transported downstream. There are active failures occurring within the ravine as well as relic failures.

Work in the gully could put workers and equipment at risk. Sudden toppling and sliding failures along the gully side slopes may occur suddenly with little warning; this is a concern for construction and public safety. Options to mitigate this risk include minimizing worker and equipment exposure, progressively working through the site while restricting workers to the more stabilized areas, carefully selecting access points, and working while the banks are in the most stable condition (i.e. winter when bank are frozen).

More detailed information about the geotechnical conditions and considerations are included in the attached Westrek technical memorandum.

4.3 Environment

A review of the Fish Inventories Data Query[4] indicated there were no observed fish within Newsome Creek. However, based on information provided by the Ministry of Transportation at a public meeting, new crossings being designed along Newsome Creek will consider fish passage. Therefore, fish passage is considered in option evaluation.

Fallen trees within the ravine has lead to alteration of the flow path and further destabilization of the channel. Removal of fallen trees will need to be considered in conjunction with an overall erosion protection and bank stabilization plan. The 2018 danger tree assessment identified categories of danger trees based on the potential risk to human life or infrastructure. Sixty four danger trees were identified, and treatment was also recommended.

The eroding bank material that is being deposited within the creek channel is being transported to Shuswap Lake. This is causing the delta at the mouth of the creek (adjacent to the Sorrento water intake) to increase in size. This will continue to occur until Newsome Creek is stabilized.

5. Hydrologic Analysis

A hydrologic analysis of Newsome Creek was performed to obtain peak flow estimates, including a climate change allowance. A design flood discharge is recommended.

5.1 Peak Flow Analysis

There are no hydrometric stations on Newsome Creek. The method for peak flow estimation is based on the 100-year return period peak instantaneous flow isolines developed by the BC Ministry of Environment, Land and Parks which were published as part of the BC Streamflow Inventory (1998). Additional data was gathered using the national hydrology network. The provincial 1:50,000 scale Digital Elevation Model (DEM) was used to provide watershed characteristics. Table 5-1 summarizes the compiled watershed information.

[4] http://a100.gov.bc.ca/pub/fidq/infoSingleWaterbody.do, accessed May 10, 2019

Table 5-1: Newsome Creek Watershed Parameters

Watershed	Area (km^2)	Mean Elevation (m)	Hydrologic Zone
Newsome Creek	18.5	851	Northern Columbia Mountains

Based on Newsome Creek watershed area and the provincial isoline of 25 m^3/s, the estimated 100-year return period peak instantaneous flow was derived. The 200-year return period peak instantaneous flow was estimated to be 15% higher than the 100-year peak instantaneous flow. Results of the hydrological analysis are summarized in Table 5-2.

Table 5-2: Newsome Creek Peak Flow Estimates

Flood Event	Peak Instantaneous Flow (m^3/s)
100-Year Return Period	6.6
200-Year Return Period	7.6

5.2 Climate Change

Climate change projections for the Northern Columbia region include increased temperature. The change will likely result in more precipitation falling as rain, higher peak flows, lower summer/fall flows, drier summers and more frequent wildfires.

The upper part of the watershed has been previously affected by wildfires. The last significant wildfire occurred in 2009, burning an area of approximately 28 km^2 on Black Mountain. More frequent wildfires would increasingly affect the hydrology of the area by reducing rainfall interception in the tree canopy, and reducing the capacity of the ground to absorb infiltration. Such hydrologic impacts may increase the frequency and magnitude of flooding.

In selecting a design flow, an allowance for climate change should be considered as per EGBC professional practice guidelines[5]. These guidelines recommend that in the absence of a historical trend, an additional 10% should be included on the peak flow estimates.

Table 5-3 below provides the peak flow estimate including climate change allowance.

Table 5-3: Newsome Creek Peak Flow Estimate including Climate Change Allowances.

Flood Event	Peak Instantaneous Flow with 10% Allowance (m^3/s)
200-Year Return Period	8.4

[5] Engineers and Geoscientists BC, 2018. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC.

5.3 Recommended Design Flow

The recommended 200-year return period design flow for the Newsome Creek ravine is 8.4 m^3/s. This estimate reflects a climate change allowance of 10%.

6. Hydraulic Analysis

The field observations and data collected from the field investigation was used to develop a preliminary hydraulic model. The hydraulic analysis consisted of modelling the main channel to obtain hydraulic parameters that will support identification and evaluation of erosion mitigation options.

6.1 Newsome Creek Model

A one-dimensional hydraulic model was built using HEC-RAS to estimate water levels, depths and velocities at different locations of the creek.

The model extends for 450 metres downstream of Highway 1 to just upstream of Dieppe Road. The Highway 1 and Dieppe Road culverts were not included in the model. Eighteen cross sections were incorporated into the model. Additional cross sections were also interpolated between the measured cross sections to facilitate the hydraulic calculations and obtain a representative profile.

Boundary Conditions

Model simulations were performed assuming a steady state condition and allowing for mixed flow regime calculations. Mixed flow calculations require a boundary condition at each end of the river; therefore, a normal depth with a channel gradient of 4% was assumed at the upstream and downstream ends of the model. The recommended design flow from Section 5.3 was adopted for the model. The simulations also assume the absence of channel blockages (i.e. debris, ice, etc.). Boundary conditions implemented in the model are summarized in table below.

Table 6-1: Newsome Creek Boundary Conditions for Hydraulic Model

Location	Peak Instantaneous Flow m^3/s
Upstream End (Downstream of Highway 1)	8.4
Downstream End (Upstream of Dieppe Road)	Normal Depth

Channel Roughness

The frictional resistance of the channel bed is defined using the Manning's n roughness values. For Newsome Creek, two scenarios were considered to capture the bed resistance of the channel under different conditions. Each scenario has a different roughness value throughout the entire modelled section.

The highest roughness value was selected to represent the current condition of the channel which is dominated by large woody debris such as trees and branches. The lowest roughness value was selected to represent future channel conditions with removal of the large woody debris and channel restoration.

Model Results

The model was initially run with a relatively high Manning's n roughness value of 0.1 to reflect the current (unimproved and hydraulically rough) condition of the creek. This scenario results in a relatively high water level. Table 6-2 shows computed flow depth and velocity for this scenario. The results indicate that the highest water depth occurs approximately 50 m downstream of Highway 1.

Table 6-2: Hydraulic Model Results for Current Condition

Manning's n = 0.1	Water Depth (m)	Velocity (m/s)
Average	1.3	1.6
Minimum	0.7	0.8
Maximum	1.9	2.7

The model was also run with a reduced Manning's n of 0.05 to reflect the improved (less rough) future condition of the creek. This scenario results in a relatively higher flow velocity. Table 6-3 shows computed flow depth and velocity for this scenario. The results indicate that the highest flow velocity occurs approximately 200 m downstream of Highway 1.

Table 6-3: Hydraulic Model Results for Future Condition

Manning's n = 0.05	Water Depth (m)	Velocity (m/s)
Average	0.9	2.6
Minimum	0.5	1.0
Maximum	1.6	4.5

To test the sensitivity of the hydraulic model to climate change, the model was also evaluated for a 200-year return period peak instantaneous flow with a climate change allowance of 20% (9.2 m^3/s), and for the same two channel roughness scenarios. For each scenario, the results indicate an increase in the average flow velocity and depth of approximately 2% and 6% respectively.

This hydraulic modelling work is considered preliminary, and should be revisited prior to proceeding with design of erosion mitigation measures.

7. Identification and Analysis of Erosion Mitigation Options

Several mitigation options have been identified and evaluated to mitigate the erosion of the creek channel and banks. The objective of such works is to reduce creek channel erosion and the undermining of the ravine slopes. By extension, this will reduce the risk of foundation failure of adjacent properties. Note that these options are not intended to mitigate the unstable ravine slopes. The attached Westrek technical memorandum (Section 5) documents geotechnical considerations for each option.

7.1 Option 1: Riprap Lined Channel

The construction of a riprap lined channel would involve erosion-resistant rock placed on the creek bed and banks to provide a stable creek channel. The advantages and disadvantages are listed in Table 7-1.

Table 7-1: Riprap Lined Channel Option Advantages and Disadvantages.

Advantages	Disadvantages
• Slows lateral and vertical channel migration. • May support fish passage through the channel. • Buttresses the toe of ravine slopes. • Long service life with maintenance.	• Some over-steepened banks would remain. • Slow construction with challenging access.

7.2 Option 2: Articulated Concrete Matt

Placement of an articulated concrete matt (precast concrete blocks that are tied together by steel wires) would increase erosion resistance. The advantages and disadvantages are listed in Table 7-2.

Table 7-2: Articulated Concrete Matt Option Advantages and Disadvantages.

Advantages	Disadvantages
• Can mitigate lateral (wall) and vertical (bed stabilizer) channel migration. • Work can generally be completed using heavy equipment with limited times when workers are required at toe of slope/bank. • Long design life.	• Large equipment required to access the site. • Need to reshape the ravine to allow placement of mattress. • Bank tie-in for mattress may be difficult. • Potential fish passage barrier.

7.3 Option 3: Gabion Baskets

Gabion baskets (steel mesh baskets filled with rocks) could be placed along the channel banks and within the creek bed to improve channel stability. Individual baskets are usually rectangular, and designed to form a stepped retaining wall. The advantages and disadvantages are listed in Table 7-3.

Table 7-3: Gabion Baskets Option Advantages and Disadvantages.

Advantages	Disadvantages
• Can be used to mitigate lateral (wall) and vertical (bed stabilizer) channel migration. • Baskets can be placed on uneven ground. • Fill with small equipment. • Can shape/bend around corners. • The baskets can tolerate some movement without failing.	• Need to import rock fill for baskets (no suitable material is present in ravine). • Basket installation requires workers to be working at toe of slope/bank (safety concern). • Baskets can fail over long-term by rusting. • Debris impact can damage gabions • Short design life.

7.4 Option 4: Lock Block Wall

A near-vertical lock block wall placed along the creek banks and within the creek bed to provide an interlocked revetment. The advantages and disadvantages are listed in the Table 7-4.

Table 7-4: Lock Block Wall Option Advantages and Disadvantages.

Advantages	Disadvantages
• Can mitigate lateral (block wall) and vertical (bed stabilizer) channel migration. • Significantly reduce the quantity of rock required to be in channel.	• Base preparation requires worker to be working at toe of slope/bank (safety concern). • Difficult to get smooth foundation surface on which to place blocks – blocks need to be battered (sloped). • Difficult to bend around corners. • Requires scour protection along toe of wall or blocks to be buried below scour depth. • Movement of a single block can compromise the structure.

7.5 Option 5: Mechanically Stabilized/Reinforced Earth/Soil

A mechanically stabilized earth/soil (MSE) can be constructed on the creek banks. The advantages and disadvantages are listed in table below.

Table 7-5: MSE Option Advantages and Disadvantages.

Advantages	Disadvantages
• Typically can be installed using small conventional equipment. • Can be used to mitigate lateral (wall) channel migration. • Some settlement of the wall could be tolerated. • Can bend around corners.	• Requires excavation into the slope to place reinforcing in backfill. • Wall installation requires worker to be working at toe of slope/bank (safety concern). • Requires scour protection along toe of wall. • Requires specialized construction crews.

7.6 Option 6: Culvert

The creek channel could be replaced with a long culvert along the approximately 450 m section of creek (a culvert diameter of about 2700 mm may be appropriate). The advantages and disadvantages are listed in Table 7-6.

Table 7-6: Culvert Option Advantages and Disadvantages.

Advantages	Disadvantages
• Erosion mitigation for all flows up to culvert capacity. • All flow conveyed through culvert up to a design flow. • Installation possible with current alignment and slope. • Can fill in part of ravine to reduce overall depth.	• Flow capacity limited to design. • Potential for blockage at inlet, with uncontrolled overflow. • A debris rack may be needed to mitigate the risk of inlet blockage (regular maintenance would be required). • An overflow channel may also be needed to mitigate inlet blockage risk and convey local rainfall runoff. • The culvert would be a fish barrier.

7.7 Option 7: Wood Drop Structures

A series of wood drop structures (step-pool structures built at low height across the entire width of the creek) could be constructed through the ravine to reduce channel instability. The advantages and disadvantages are listed in Table 7-7.

Table 7-7: Wood Drop Structures Option Advantages and Disadvantages.

Advantages	Disadvantages
• Reduces erosion by decreasing the flow velocity/energy. • Series of drop structures can minimize drop height at each structure. • Re-use of on-site material (i.e. cedar/fir trees). • Natural appearance and functionality. • Lower cost than rock structures. • Can be designed for fish passage.	• Success rate decreases as stream gradient increases above 5%. • Need to be anchored to creek bank. • Requires ongoing monitoring and maintenance. • Limited design life due to wood decay.

7.8 Option 8: Timber Cribbing

A timber crib wall (timber crib structures against the creek banks to produce a gravity retaining wall made of interlocked logs) could also reduce creek instability. The advantages and disadvantages are listed in Table 7-8.

Table 7-8: Timber Cribbing Option Advantages and Disadvantages.

Advantages	Disadvantages
• Re-use of on-site material (i.e. cedar/fir trees). • Relatively easy to install. • Natural appearance and functionality. • Can help improve fish habitat.	• Reduces width of creek cross section. • Need to provide backfill (imported and/or local). • Labour and equipment intensive. • Limited design life due to wood decay. • Requires periodic monitoring and maintenance.

7.9 Option 9: Sheet Piles

A sheet pile structure (elongated piles that are embedded into the ground, closely placed and locked together to form a continuous wall) could provide effective erosion protection. The advantages and disadvantages are listed in Table 7-9.

Table 7-9: Sheet piles Option Advantages and Disadvantages.

Advantages	Disadvantages
• Can be used to mitigate lateral (wall) and vertical (bed stabilizer) channel migration. • Work can generally be completed using heavy equipment with limited times when workers required at toe of slope/bank.	• Vibration for pounding pile could cause slope failures or damage buildings at top of ravine. • Large equipment required to access the site. • Specialized equipment necessary. • Soil conditions below surface unknown and piles may not be suitable to pound into the bed.

8. Indicative Construction Cost Estimates

After consideration of construction practicality, design life and community feedback, the above nine mitigation options were narrowed to the following three short-listed options:

- riprap-lined channel;
- culvert; and
- sheet pile wall with bed stabilizers.

An indicative construction cost estimate (+/- 40%) has been prepared for each of these three options. Overall, it is estimated that the cost to mitigate further erosion within Newsome Creek between Highway 1 and Dieppe Road could be between $4.8 million and $6.2 million.

Table : Summary of Indicative Construction Cost Estimate

Mitigation Option	Cost Estimate
Rock-Lined Channel	$4,800,000
Culvert (2700 mm)	$5,000,000
Sheet pile Wall with Bed Stabilizers	$6,200,000

The cost estimates include allowances for engineering and construction management (20%) and contingency (40%), but do not include an allowance for property acquisition.

The cost can be better estimated once the option or combination of options is selected, and when there is more certainty regarding geotechnical requirements, environmental requirements, other regulatory requirements, and the proposed upstream work by MOTI.

Any works constructed will also incur maintenance costs which will vary between options, and from year to year for each option. The cost estimates do not include maintenance costs.

9. Implementation Considerations

A summary of the key actions required for the implementation of the potential creek works are listed below. The actions are grouped based on the different implementation phases.

9.1 Detailed Design

Completion of design would include the actions noted below.

- Select a preferred mitigation option (or combination of options) that provides a sufficient level of risk reduction, accepting the fact that some level of residual risk will remain (i.e. upper slope stability).
- Obtain a topographic survey of the ravine.
- Conduct a further geotechnical investigation (i.e. slope stability analysis) to confirm adequate factor of safety for the selected design option(s).
- Complete an environmental assessment to support design and permitting.
- Submit approval and/or authorization applications.
- Resolve private property access issues and/or challenges.
- Consider need for land acquisition.
- Develop an appropriate funding mechanism(s) for construction and maintenance.

9.2 Construction

Construction would include the actions noted below.

- Develop an appropriate approach for procuring construction services.
- Address resident concerns.
- Investigate and establish access routes to the ravine.
- Develop a safety plan for the people and equipment working on-site.
- Establish an appropriate construction timeline (i.e. consider construction during winter versus fish window).
- Develop an effective plan for dewatering the creek during construction (bypass versus short diversions).
- Develop an erosion and sediment control plan.
- Remove trees as needed to enable construction (consider merchantability of timber).
- Conduct engineering inspections and environmental monitoring during construction.
- Conduct a post-construction survey.
- Prepare record drawings to reflect as-constructed conditions.

9.3 Operation and Maintenance

Operation and maintenance would include the actions noted below.

- Determine the future need for inspection, monitoring, routine maintenance, repairs, and post-event restoration.
- Document operation and maintenance requirements, possibly through an operation and maintenance manual.
- Assign responsibility for each maintenance provision.
- Clarify and obtain land tenure.
- Establish adequate access routes for future inspections and repairs.

10. Summary and Recommendations

KWL completed a field assessment on Newsome Creek on March 20, 2019. The creek is unstable with irregular lateral migration, bank toe erosion, and bank sloughing. In two cases, the sloughing now threatens the foundation stability of houses at the top of bank. Westrek Geotechnical Services has completed an independent review of the general bank stability, concluding that the ravine is likely to remain unstable until lateral migration and scour of the creek channel is reduced, and an equilibrium is restored.

Following a hydrotechnical analysis, nine options were identified to mitigate creek instability. Each option was assessed at a high level, and construction cost estimates were completed for three short-listed options.

Option 1 (riprap-lined channel) appears to be the most promising option. While there are less expensive options, the rock lined channel affords the most flexibility to adjust to the undulating creek channel and creek sedimentation from sloughing of the ravine slopes. The rock may be placed with conventional equipment, but there would be challenges to obtain access to and within the ravine. The indicative construction cost estimate for this option is $4.8 million.

The two other preferred options are: enclosing the creek in a culvert at a cost of approximately $5.0 million; or use of a sheet pile wall with bed stabilizers at a cost of approximately $6.2 million.

Each construction cost estimate includes allowances for engineering and construction management (20%) and contingency (40%), but does not including property acquisition (if required). Allowances for future operation and maintenance are also not included.

In the end, it may be most appropriate to select a combination of options for implementation. The construction cost could be reduced by incorporating less expensive materials, such as with a rock/wood combination, however the design life would be reduced.

Each option would increase channel stability within the ravine, thereby reducing the likelihood of continued undermining of the ravine slopes. It is important to recognize that none of the identified options would directly mitigate the upper ravine slope instability, therefore some residual risk would need to be accepted.

As the ravine slopes are unstable, any work in the ravine would require a specific safety plan, and a geotechnical opinion prior to entry and/or construction.

Submission

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
2019-06-08
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ABS/JM/

Encl.: Figure 1, Geotechnical Considerations – Newsome Creek Gully Stability Below Highway 1 (Westrek Tech Memo)

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the intended recipient. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

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Revision History

Revision #	Date	Status	Revision Description	Author
0	June 7, 2019	Final		ASB/JM
A	May 13, 2019	Draft	Draft for Internal Review	ASB/JM

OQM CERTIFIED

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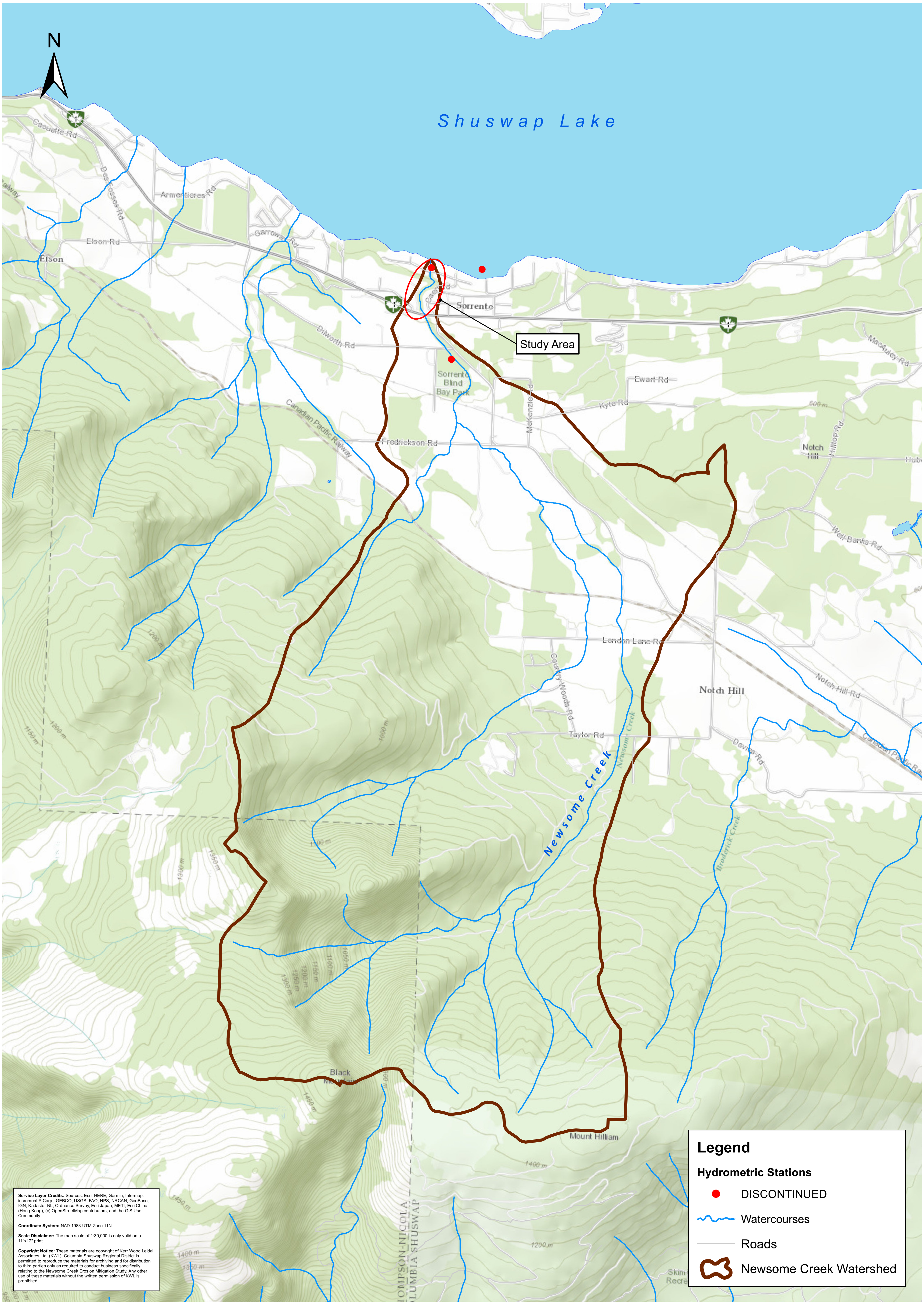
Columbia Shuswap Regional District

Newsome Creek Erosion Mitigation Study

KERR WOOD LEIDAL consulting engineers



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Project No. 3234-013

Date June 2019

Scale 0 250 500 1,000 (m)
1:30,000

Newsome Creek Watershed

Figure 1

westrek
geotechnical services ltd.
100 – 1383 McGill Road, Kamloops, BCV2C 6K7
www.westrekgeotech.com

TECHNICAL MEMORANDUM

Date: June 7, 2019

To: Jason Miller PEng
Kerr Wood Leidal Associates Ltd.

Re: Geotechnical Considerations - Newsome Creek Gully Stabilization below Highway 1, Sorrento, BC

1 Introduction and Scope

Erosion during the 2017 and 2018 freshet flows has affected the gully sidewalls along Newsome Creek between Highway 1 and Shuswap Lake, and this has threatened a number of residences and structures built along the gully edge. The Columbia Shuswap Regional District (CSRD) retained Kerr Wood Leidal Associates Ltd. (KWL) to study the feasibility of stabilizing this reach. Westrek Geotechnical Services Ltd. (Westrek) was asked by KWL to provide geotechnical input to assist in the development of the stabilization options.

KWL first assessed the erosion issues in this reach in May 2017. Westrek has been monitoring the progression of instability in the reach since May 2018. Background information was summarized in reports submitted to the CSRD entitled *Monitoring Results and Summary Recommendations, Newsome Creek Erosion below Highway 1*, dated October 6, 2018, and *December 2018 Monitoring Results, Newsome Creek Erosion below Highway 1*, dated December 18, 2018.

The scope of this assessment was outlined in a proposal to KWL dated January 24, 2019, and included the following:

- Conduct a field review along the impacted section to characterize the location and extent of slope stability hazards (e.g. slope failure, block fall / collapse, outburst flood potential, etc.);
- Provide geotechnical input concerning the sensitivity of the gully side slopes for stabilization of the channel, and provide geotechnical input related to access management, constructability, and worker safety; and
- Provide preliminary geotechnical design input for the stabilization options that will be presented to the CSRD.

The purpose of the work was to assist KWL and the CSRD in determining the most feasible options to be explored should funding be secured to assist with the project. Detailed investigation, numerical modelling (slope stability analysis) and detailed geotechnical engineering was beyond the scope of our assessment. The services are subject to the terms and conditions set out in the *Interpretation and Use of Study and Report and Limitations*, which is attached in Appendix A and incorporated herein by reference.

2 Fieldwork

Kevin Turner PEng and/or Leslie Abel PGeo MEng, who represented Westrek, visited the site on April 1 and 2, 2019 to characterize the gully side slopes. KWL had already mapped and flagged five cross-sections in the field. Westrek logged the surficial deposits along four of the cross-sections, including No. 206, 207, 208, and 212 (see attached Figure 1), and another site on the west bank of the gully about 20 m downstream of the Highway 1 embankment (below 1185 Passchendaele Road). The stratigraphy at KWL's cross-section No. 209 was not mapped as a large slope failure occurred between the time KWL and Westrek visited the site. Due to the significant safety issues at the site, we understand that KWL surveyed the cross-sections using a laser rangefinder and GPS system. For the same reason, Westrek completed the surficial mapping using a laser rangefinder and handheld clinometer. Because of this, the relative thickness and depths / heights are likely only accurate to +/- 1 m.

Select representative samples were collected for grain size distribution analysis. The test results are attached and summarized below.

On April 16, 2019, KWL presented preliminary results to the Newsome Creek Watershed Action Group at a public meeting in Sorrento. Westrek attended this meeting, and general geotechnical input on the options presented at that meeting is provided below.

3 Site Conditions

Surficial geological mapping by Fulton (1974)[1] indicates the lower reach of the creek is mapped as a lacustrine complex of clay, silt, sand, and gravel that represent open freshwater and shoreline deposits. This deposit is well-exposed in the eroded gully sidewalls immediately below Highway 1 (see Figure 1). The unit generally comprises two main surficial units, as described below:

1) A thick banded **silt** deposit forms the upper stratigraphic unit in this area. The unit is typically 4 to 6 m thick and forms the upper slope in the gully sidewall. It is prominently exposed in the near-vertical bluffs on the left (west) side of the gully along 1185 Passchendaele Road. The bands are centimetre to decametre-scale in thickness and distinctly tan or dark grey / black in color. The slope of this deposit is typically very steep, and varies from 80% to near-vertical bluffs. The silt is compact and moist.

[1] Fulton, R.J. 1974. *Surficial geology, Shuswap Lake (west of sixth meridian), British Columbia.* Geological Survey of Canada. Map 1391A. Scale 1:126,720.

The grain size distribution curves of two samples of the unit are attached and summarized below.

Sub-unit	Gravel	Sand	Silt	Clay	Remarks
Tan Silt	0%	4%	93%	3%	Inferred non-plastic
Dark grey / black Silt	0%	34%	62%	4%	Inferred non-plastic

2) The second unit underlies the silt and is generally coarse grained but variable, with two main facies that generally coarsen downwards. It usually forms the lower part of the gully sidewall slope.

Decameter-scale thick layers of dark grey / black **sand and silt** were observed in the upper part of the lower unit. Gradation testing on one sample indicated it was composed of 2% fine-grained gravel, 58% sand, and 40% silt. The layer was generally loose. Interlayered in this deposit were layers of **sand and silt** as noted above.

Lower down, this unit is composed mainly of dark grey / black, well-graded **sand and gravel** with trace to some silt. The stratigraphic layers are typically decametre to metre-scale. Gradation testing on two samples of this unit indicated it was composed of 45% to 47% gravel, 44% to 48% sand, and 6% to 11% silt. Maximum nominal particle size was about 75 mm but boulders up to 0.6 m in size were observed in the channel downstream. The layer was generally loose, but in some areas immediately under the **silt** unit, cementation was observed.

4 Slope and Channel Hazards

Bank erosion from the recent freshet flows has de-stabilized the channel starting immediately below the Highway 1 embankment. This has exposed the highly erodible **sand and gravel** unit, which in some places has undercut the overlying **silt** unit 1 to 2 m, i.e. below 2809 to 2819 Caen Road. Despite its fine-grained nature, the silt unit can stand at very steep slopes but once undercut, is prone to unpredictable collapse due to shear failure or else as a toppling failure where the unit has unfavourable joints. Either of these mechanisms can suddenly introduce a significant volume of material into the channel, as occurred in 2019. However, given the nature of the undercutting relative to the size of the gully and the lack of any strain-related features on the slope along the edge of the gully, the introduced volume is unlikely to be large enough to fully block the gully and create the potential for an outburst flood. Sediment from these failures is likely to be bypassed and gradually eroded by the creek.

Failure of the **silt** unit can also occur as comparatively small, shallow saturated landslides where seepage is emerging on steep slopes. There is an active failure of this nature below 2809 Caen Road (cross-section 209), and the scarp from this feature is progressing uphill. Relict failures of this type were also observed below the residence at 2807 Caen Road.

In 2017, KWL reported that severe erosion and bank failures were occurring behind 2809 and 2819 Caen Road, by 2018 this had progressed downstream to 2821 Caen Road. By 2019, bank undercutting was starting to increase in severity below 2827 Caen Road. Based on this, it appears that the gully sidewall destabilization is progressing downstream.

Channel instability is also destabilizing large trees along the lower part of the gully sidewall and the top of the prominent bluff along 1185 Passchendaele Road. Several trees have fallen since 2018 and more are likely. The CSRD commissioned a study in 2018 to map out the vulnerable trees, but to date none have been felled or removed.

Channel instability in the upper part of the watershed was briefly discussed in Westrek's October 6, 2018 report. Follow-up studies to characterize this have not been done, but the distance from the upper watershed and its alluvial fan to Highway 1 suggests that there is a very low potential for debris floods to directly impact this reach. Over time, fine grained sediment transported from the upper watershed could reach the channel below Highway 1 during flooding, so this should be taken into account when designing stabilization measures.

5 Stabilization Measures

KWL presented several potential options to stabilize the gully at the April 16, 2019 public meeting. Most of the options can reduce further downcutting or lateral shifting of the channel that erodes the toe of the gully sidewall slopes, but they will not necessarily improve the stability of the upper part of the slope. Where residences and buildings have been built at the crest, these structures would still be vulnerable to slope instability associated with the upper silt unit. This is further discussed in Section 5.9. Summarized below are geotechnical considerations to be taken into account for each option.

5.1 Rock-lined Channel

This is a common method for channel stabilization. Given the characteristics of the gully and the slope undercutting that has occurred, it will be a difficult option and likely expensive, but should result in a relatively robust solution. Compared with most other options, little channel foundation preparation is necessary as the system is flexible and able to accommodate differential settlement. Furthermore, less labour is typically required with this option, which reduces worker exposure. Geotechnical comments associated with this option include:

- It would be beneficial to raise the channel elevation starting immediately downstream from Highway 1, which will reduce the amount of work required to stabilize the toe of undercut slopes, except along 1185 Passchendaele Drive where the bluffs are near-vertical and relatively high.
- Reshaping the channel (subgrade) will be difficult where the slopes are undercut. For this we recommend that uniform, rounded coarse gravel and cobble material be used to backfill undercut slopes, as this material can be placed by allowing it to roll into place and without the need for compaction. Angular rock is less effective for this purpose.
- Rock could be end-dumped into the channel along the Highway 1 / 1185 Passchendaele Drive bluff to partially support that slope while work is progressing. Dump sites will have to be carefully selected.
- Rock material would have to meet the acid rock drainage / metal leaching criteria.
- This option would not improve the stability of the upper slope of the gully.

5.2 Concrete Mattress Channel Lining

This method has similar technical challenges as a rock-lined channel, but requires a more uniform and relatively competent foundation, as the system is more sensitive to differential settlement. This system is difficult to build in a narrow, deep gully like the reach below Highway 1. Geotechnical comments associated with this option include:

- To obtain a uniform competent foundation, organic and soft material will have to be stripped, which could result in high volumes. Backfilling to the new channel subgrade elevation will require a high-quality sand and gravel material that is compacted to uniform compact density.
- Re-shaping the channel (subgrade) will be difficult where the slopes are undercut. For this we recommend that uniform, rounded coarse gravel and cobble material be used to backfill undercut slopes, as this material can be placed by allowing it to roll into place and without the need for compaction. Angular rock is less effective for this purpose.
- This option would not improve the stability of the upper part of the slope.

5.3 Gabion Baskets

This method was proposed to stabilize the Highway 1 embankment, the toe of the gully sidewall slope, and possibly to curtail channel downcutting. Gabion walls are likely an effective option immediately downstream from the Highway 1 embankment and along the near-vertical bluffs currently along 1185 Passchendaele Drive where the site is less constrained.

Geotechnical comments associated with this option include:

- Gabion walls are favourable in circumstances like this as they are relatively flexible and require less critical foundation preparation than other wall options (although some preparation is required).
- Gabion walls that support the slope toe would have to be anchored in some locations, as the site may be too constrained for geosynthetic reinforced fill.
- They have to be designed and built with adequate scour protection.
- They require good access to transport rock material to the site to fill the units.
- This option could be used to stabilize local sections where undercutting has occurred. The area between the gabion wall and undercut area could then be backfilled with uniform, rounded coarse gravel and cobble material.
- A gabion wall option is likely only suitable for toe stabilization to prevent further undercutting and channel migration. They would have to be very high structures to improve the stability of the upper part of the slope, which would make them difficult to stabilize and therefore not cost effective. Gabion walls can also be useful for weirs across the channel, which could reduce the potential for further creek downcutting into the existing channel.

5.4 Lock Block Walls

This option requires a competent foundation and this will be very difficult to achieve in most areas of the reach. Geotechnical comments associated with this option include:

- The wall has to be supported on a dense sand and gravel foundation, which will be difficult to achieve along parts of the gully floor.
- They need to be protected from instability due to scour at the toe.
- Lock Block walls will have to be anchored in some locations due to steep slopes above, as geosynthetic reinforcement of the backfill may not be possible.
- Lock Block walls would have to be very high to improve the stability of the upper slopes. This would make them difficult to stabilize and therefore not cost effective.

5.5 Mechanically Stabilized Earth Walls

Like gabion walls, mechanically stabilized earth (MSE) walls may be an effective way of stabilizing the Highway 1 embankment and protecting the lower slopes from further undercutting. Geotechnical comments associated with this option include:

- MSE walls can be built on a less competent or variable foundation as they are relatively flexible structures, but some preparation is still needed, which could be difficult.
- MSE wall locations require geosynthetic reinforcement to be installed, and the higher the wall, the longer the reinforcement that is required. They cannot be anchored. This likely constrains the sites where MSE walls can be considered.
- The area between the reinforced backfill and undercut area could then be backfilled with uniform, rounded coarse gravel and cobble materials.
- MSE walls would have to be very high to improve the stability of the upper part of the slope, which would make them difficult to stabilize and therefore not cost effective.

5.6 Wood Drop Structures / Timber Cribbing

These are typical short-term structures unless provisions are made for replacement of the wood members. Unfortunately they require a lot of manual labour which can introduce worker safety issues. Geotechnical comments associated with this option include:

- These structures are relatively flexible and can have a variable foundation.
- Timber crib walls would have to be anchored in some locations, as constrained site precludes geosynthetic reinforcement.
- There is limited life expectancy associated with this option (i.e. 10-15 years).
- These structures may be effective in stabilizing channels but would be the least effective of all options in stabilizing the toe of the gully sidewall slope.
- Wood drop structures and timber cribbing are unlikely to improve the stability of the upper part of the slope because they can only be built to a limited height.

5.7 Culvert

This method has similar technical challenges as a rock-lined channel, but requires a more uniform and relatively competent foundation, as piping tends to be sensitive to differential settlement. Geotechnical comments associated with this option include:

- It would be beneficial to raise the channel elevation starting immediately downstream from Highway 1. This would simplify construction and reduce worker safety issues.
- High exit velocities at the pipe outfall will require erosion mitigation measures.
- A permanent overland flow channel will still be required in the event a culvert blockage occurs or its capacity is exceeded. This could allow the channel to be raised in elevation and therefore stabilize the toe of the side slopes along a longer reach of the gully.
- The gully channel elevation could be further backfilled after the culvert is installed. While this would improve the stability of the lower part of the slope, it would not improve the stability of the upper slope. The residences or structures built near the crest of the slope may still not have an adequate factor of safety.
- A culvert could potentially allow supplemental slope stabilization structures to stabilize the upper slope to be constructed more cost effectively.

5.8 Sheet Piles

Sheet piles could likely be an option to help stabilize the upper slope of the gully sidewall as well as stabilize the toe of the steep sidewall slopes where they are being undercut, and therefore may be an option where residences or structures were built at the edge of the gully. Geotechnical comments associated with this option include:

- Sheet piles should be capable of being driven into sand and gravel, but some zones of cemented sand and gravel were observed. Toe embedment will be important to minimize scour at the toe. A drilling program to investigate specific sites for each sheet pile wall would be required.
- High sheet piles would need anchoring, especially where they are present below the upper slope that extends above it and is very steep.
- The undercut areas behind sheet piles could be backfilled with uniform, rounded coarse gravel and cobble material, as this material can be placed by allowing it to roll into place and without the need for compaction.

5.9 Concluding Remarks

Should an attempt be made to stabilize the channel, it is likely that a combination of options will be necessary to achieve the stabilization objectives. Aside from a culvert, which would remove most of the risk associated with further scour by the creek, the most feasible options for this site appear to be the following:

- a rock-lined channel along the majority of the gully;

- gabion or MSE wall(s) at the toe of the Highway 1 embankment and along the near-vertical bluff adjacent to 1185 Passchendaele Road; and
- sheet pile walls or gabion walls where site geometry dictates.

Planning for these measures will require an up-to-date detailed survey plan to be developed. Aside from the requisite hydrotechnical studies, each of these options requires geotechnical and/or structural engineering to design and construct.

All of the above techniques will only be useful in stabilizing the channel and lower part of the gully side slopes, but will not likely be effective in restoring the upper side slopes. The structures and residences built along the edge of the gully may still be vulnerable to slope instability, with or without the channel protection in place. The owners have been advised to undertake their own studies to assess the level of risk to their property. If the channel and lower slopes are stabilized, they would have a few options including:

- shifting the structures away from the crest;
- underpinning the structures so they are founded on a deeper, more stable surficial deposit; and/or
- stabilizing the upper silt deposit using soil nails or similar systems.

5.10 Public and Worker Safety

All options require workers and equipment to be present in the gully, which places them at risk. Both the toppling and sliding failure mechanisms along the gully side slopes can occur suddenly with little advanced sign of movement, and this is a major concern with respect to public safety and construction site safety.

Options to mitigate the risk to workers include:

- Select construction methods and material handling processes that minimize worker and equipment exposure.
- Advance work progressively from one end (up or down), and restrict workers as much as possible to the stabilized sections.
- Carefully select gully access points, especially near the sites where near-vertical or undercut slopes exist. These would be seasonally dependent.
- Work while the gully sidewalls are frozen.

Any work within this gully would require written instructions from a qualified registered professional engineer, as required by Section 20.78 of the *Occupational Health and Safety Regulation*.

6 Closure

We trust this memo provides the information required at this time. If there are any questions, please contact the undersigned at your convenience.

Westrek Geotechnical Services Ltd.

This is an electronic replica of the original signed and sealed report and has been provided for convenience. Westrek has retained the original signed / sealed report on file and can provide an authenticated document if required.

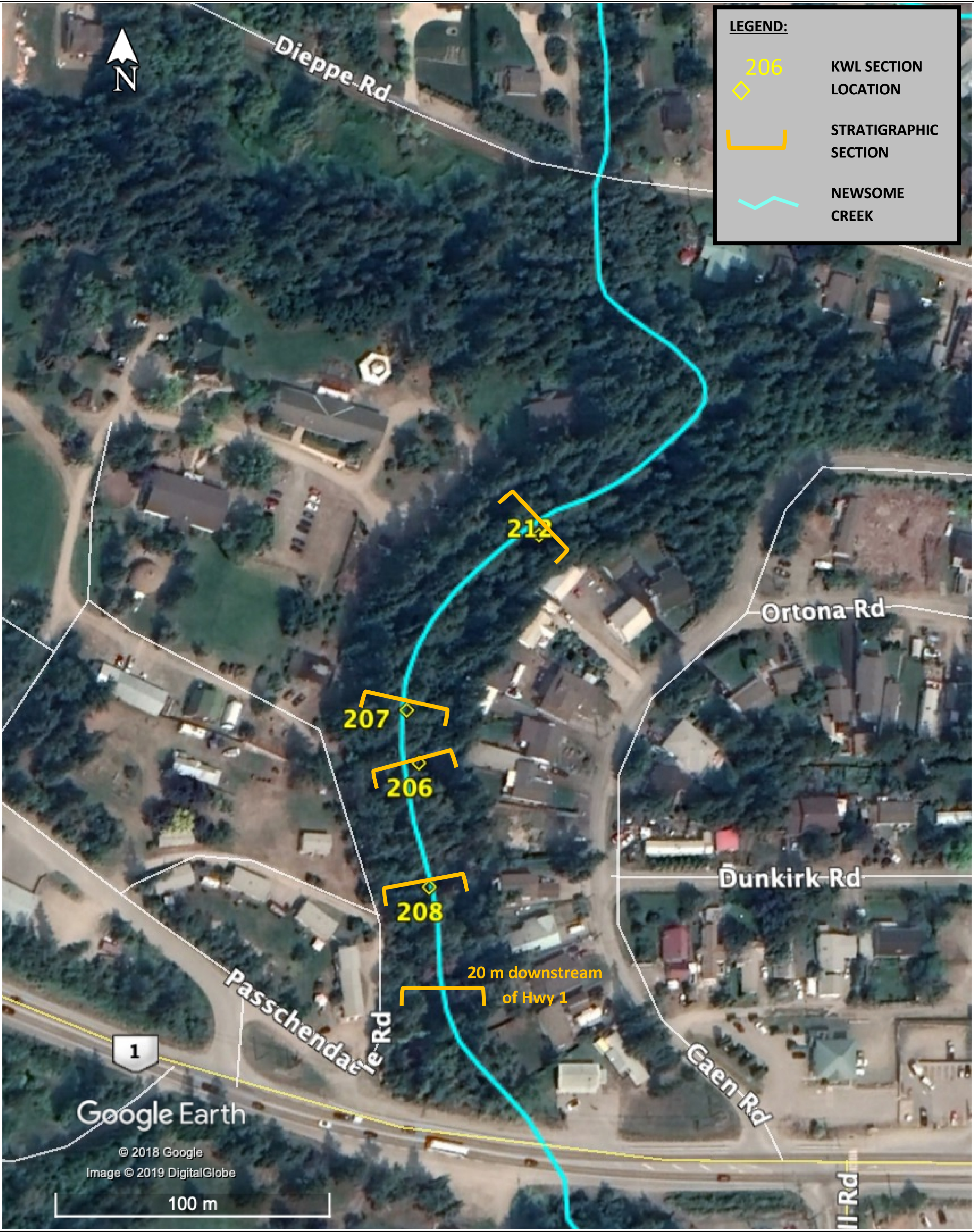
2019-06-07

Leslie Abel PGeo MEng
Geoscientist

Jun 7, 2019

Kevin Turner PEng
Senior Geotechnical Engineer

Attached: Figure 1 - Stratigraphic section locations
Figure 2 – Site Photograph
Annotated KWL Slope Cross-sections
Laboratory Test Results
Appendix A *Interpretation and Use of Study and Report and Limitations*



westrek geotechnical services ltd.

westrek geotechnical services ltd.	NEWSOME CREEK – STRATIGRAPHIC SECTIONS KERR WOOD LEIDAL ASSOCIATES LTD.	FIGURE 1
	Source: Google Earth™ image dated 2018. / Project: 019-006	

westrek geotechnical services ltd.

NEWSOME CREEK – STRATIGRAPHIC UNITS

FIGURE 2

Source: Westrek photo dated April 1, 2019

Project: 019-006

westrek geotechnical services ltd.

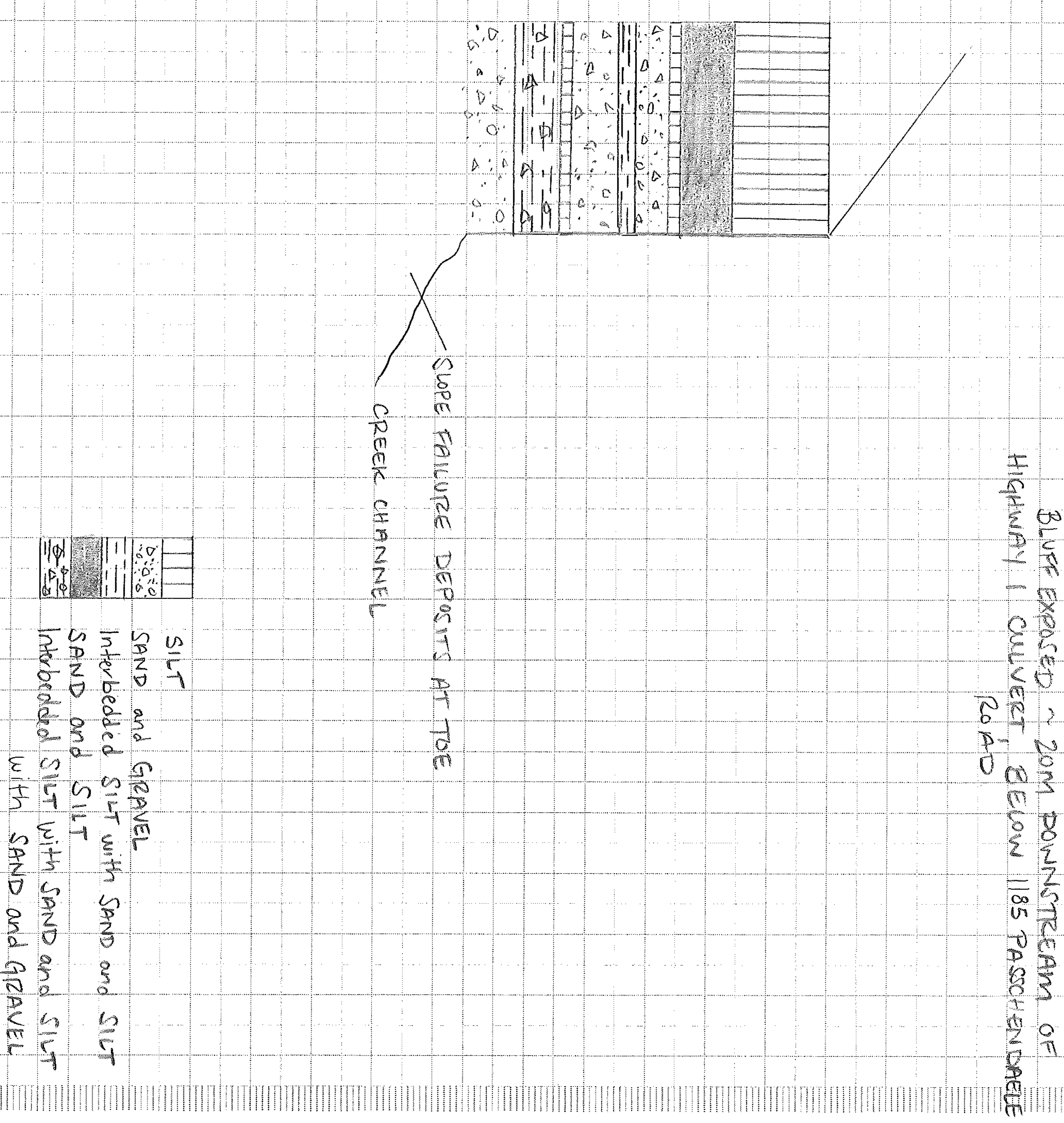
100-1383 McGill Road
Kamloops, BC V2C 6K7
Tel: 778 765 9525

929 Mattick's Wood Lane
Victoria, BC V18Y 3H6
Tel: 604 512 3250

1851 23rd Street NE
Salmon Arm, BC V1E 3M6
Tel: 250 515 3250

☐ PO Box 1191, 2914 Eby Street
Terrace, BC V8G 2X5
Tel: 250 922 4349

Client	KWL	Contact	
Project	NEWSOME CREEK 019-006	Date	2019-06-05
Phone No.	Fax No.	Prepared by LA	Sheet No. 1 of 5



KERR WOOD LEIDAL
consulting engineers

Calculations

File

CLIENT	DESIGNED BY	Page 3 of 5
PROJECT	CHECKED BY	DATE
SUBJECT XS-206		

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	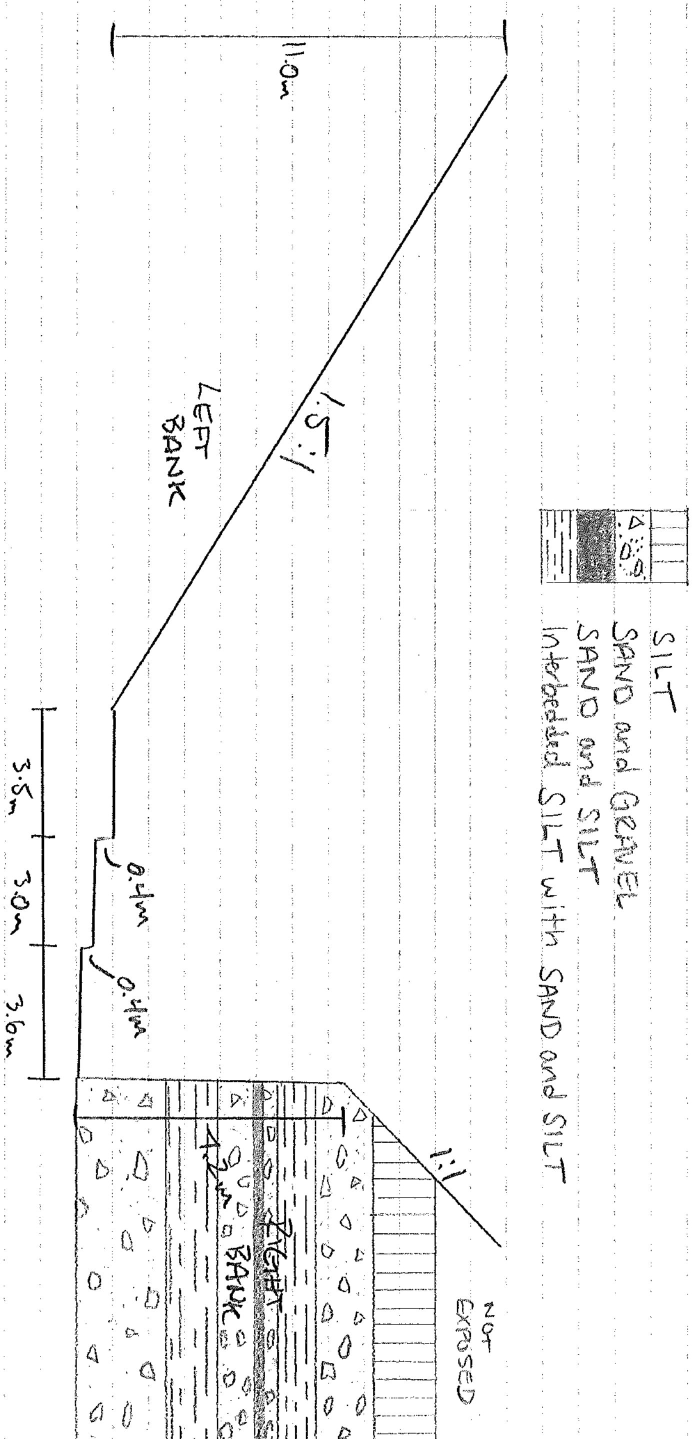	

KERR WOOD LEIDAL
consulting engineers

Calculations

File

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PROJECT	CHECKED BY	DATE
SUBJECT XS-207		

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	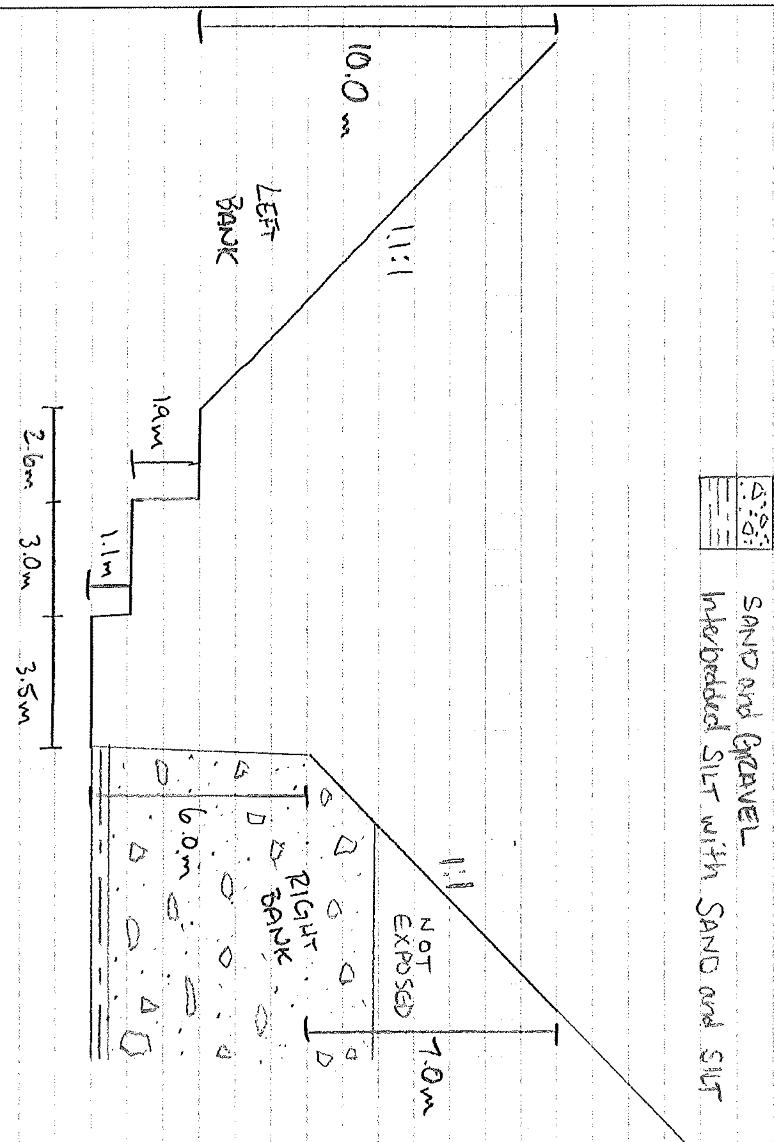	

KERR WOOD LEIDAL
consulting engineers

Calculations

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PROJECT	CHECKED BY	DATE
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	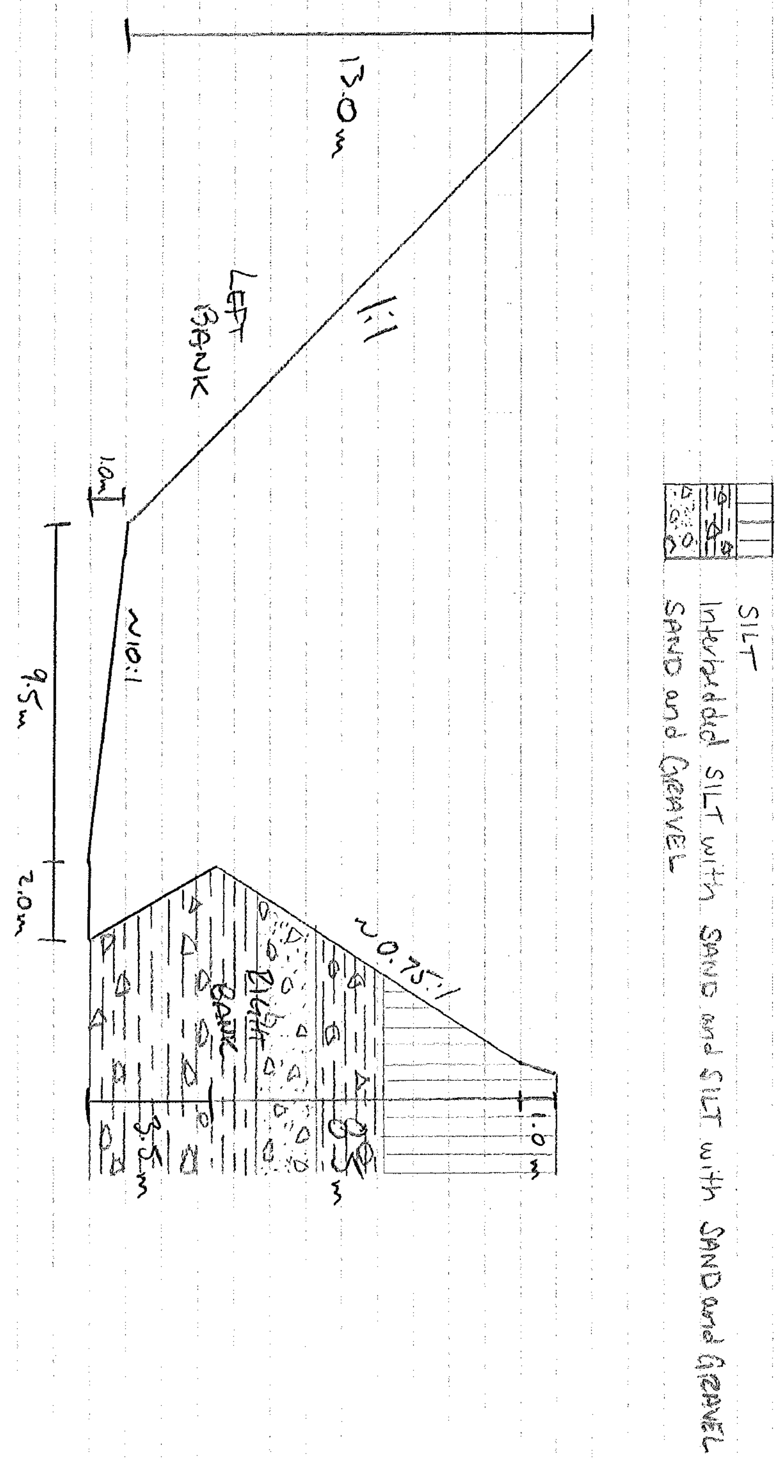	

KERR WOOD LEIDAL
consulting engineers

Calculations

File

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PROJECT	CHECKED BY	DATE
SUBJECT XS-212		

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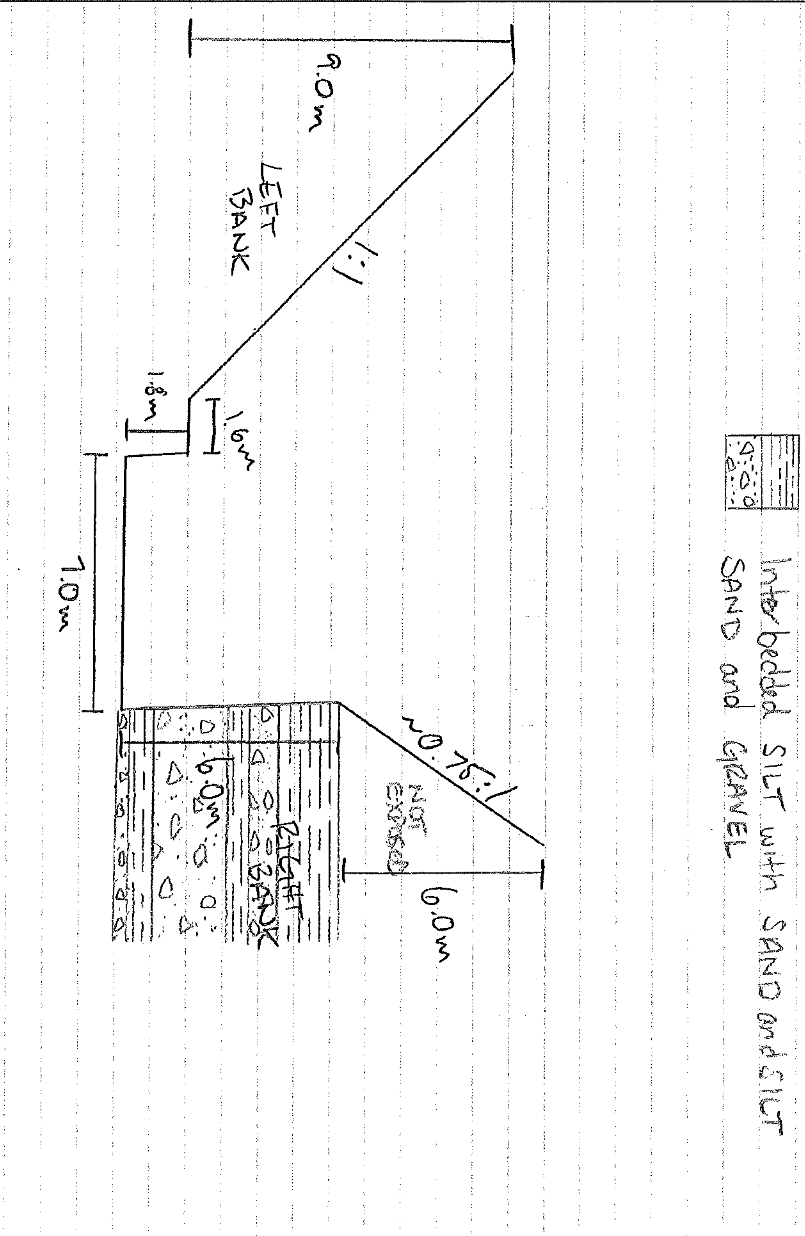
		

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Leslie Abel / Kevin Turner

Project Name: Newsome Creek - Sorrento

OFFICE: Kamloops, BC
PROJECT: KX13690
DATE: April 10, 2019

TEST NO: 19 -035-1

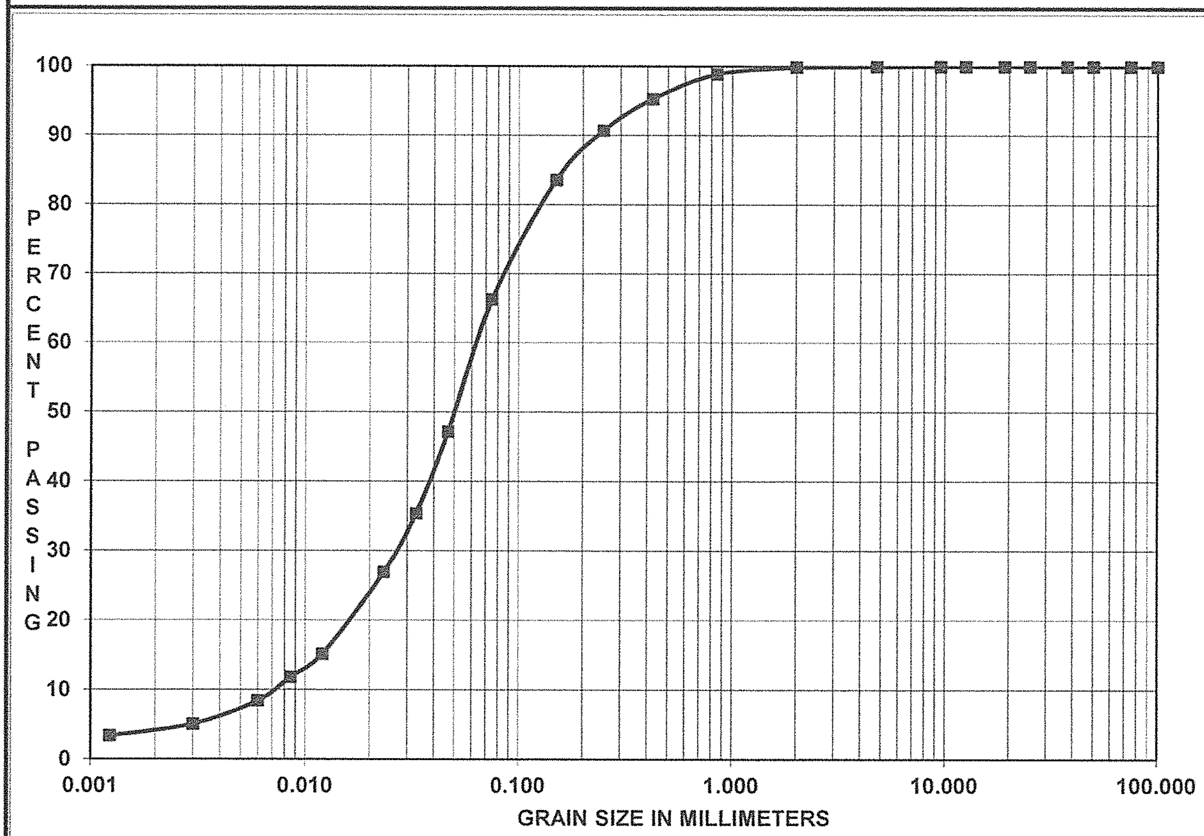
DATE Rec'd: April 4, 2019

DATE TESTED: April 9, 2019

SAMPLED BY: Client

SOURCE: X Section 200A - GS #5

SAMPLE TYPE: Black Silt



SUMMARY

Grain size (mm)	Passing (%)
75.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	100.0
12.5	100.0
9.5	100.0
4.75	100.0
2.00	99.9
0.850	98.9
0.425	95.3
0.250	90.7
0.150	83.6
0.075	66.2
0.0467	47.1
0.0330	35.4
0.0234	26.9
0.0121	15.2
0.0085	11.8
0.0060	8.4
0.0030	5.1
0.0012	3.4

REMARKS:

GRAVEL	0.0%
SAND	33.8%
SILT	62.1%
CLAY	4.1%

TECHNICIAN: B. Shearer

Reporting of these test results constitutes a testing service only.

Engineering interpretation or evaluation of the test results is provided only on written request.

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Leslie Abel / Kevin Turner

Project Name: Newsome Creek - Sorrento

OFFICE: Kamloops, BC
PROJECT: KX13690
DATE: April 10, 2019

TEST NO: 19 -035-2

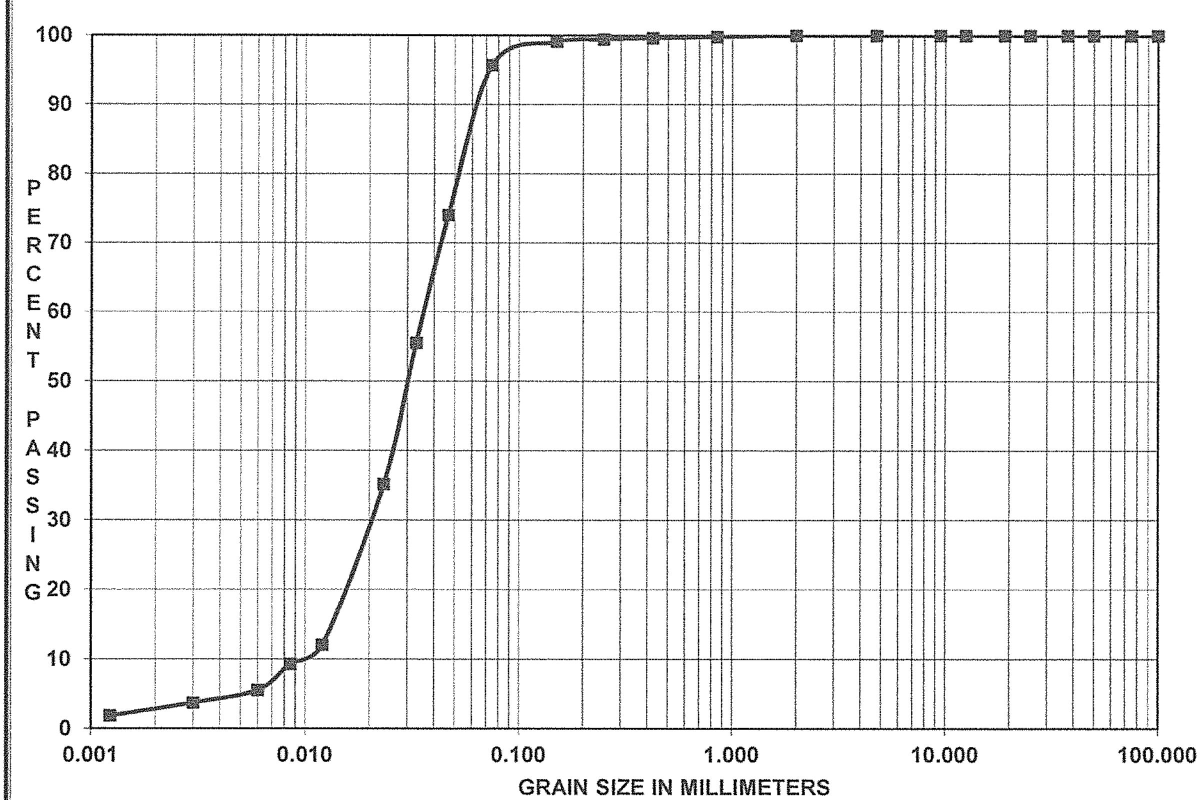
DATE Rec'd: April 4, 2019

DATE TESTED: April 9, 2019

SAMPLED BY: Client

SOURCE: X Section 208 - GS #1

SAMPLE TYPE: Tan Silt



SUMMARY

Grain size (mm)	Passing (%)
75.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	100.0
12.5	100.0
9.5	100.0
4.75	100.0
2.00	100.0
0.850	99.8
0.425	99.6
0.250	99.4
0.150	99.1
0.075	95.7
0.0467	74.0
0.0330	55.5
0.0234	35.2
0.0121	12.0
0.0085	9.3
0.0060	5.6
0.0030	3.7
0.0012	1.9

REMARKS:

GRAVEL	0.0%
SAND	4.3%
SILT	93.0%
CLAY	2.7%

TECHNICIAN: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
100-1383 McGill Road
Kamloops, BC
V2C 6K7

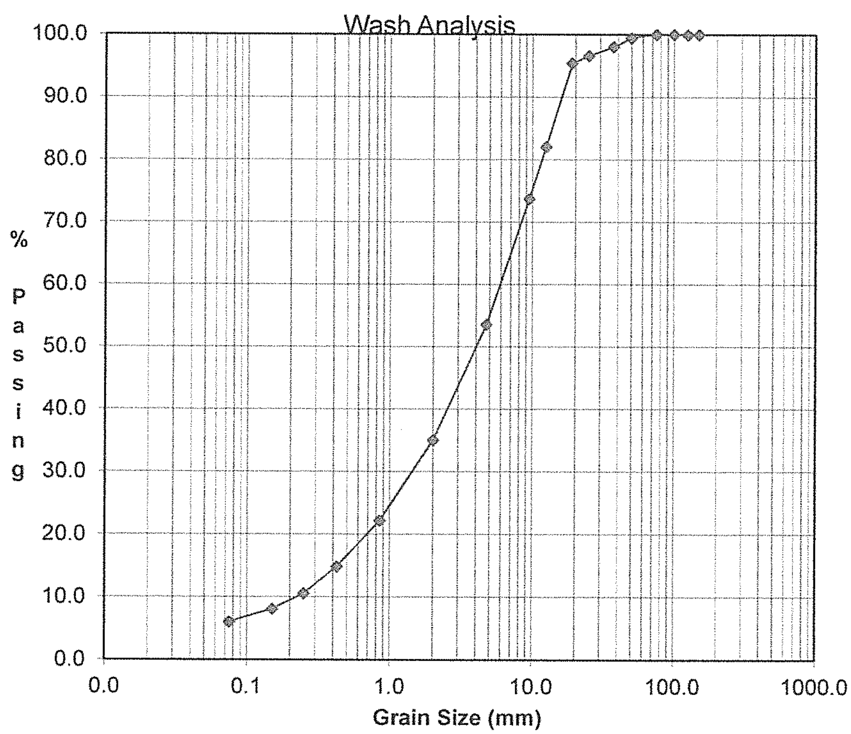
Project No:KX13690
Date: April 9, 2019

Attn: Leslie Abel / Kevin Turner

Project Name: Newsome Creek Sorrento

Test No.: 19 - 035 -1 | Source: 207 - GS #4 | Sample Type: Bulk

Date Rec'd : April 4, 2019 | By: Client | Date Tested: April 8, 2019



Wash Sieve Analysis				
Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.5	99.5		
37.5	1.5	98.0		
25.0	1.4	96.6		
19.0	1.2	95.4		
12.5	13.4	82.1		
9.5	8.3	73.7		
4.75	20.2	53.5		
2.000	18.4	35.1		
0.850	12.9	22.2		
0.425	7.3	14.9		
0.250	4.3	10.5		
0.150	2.5	8.1		
0.075	2.1	6.0		
PAN	6.0			

Sieve Mass (g): 48857.1

Gravel	46.5 %
Sand	47.5 %
Fines	6.0 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
100-1383 McGill Road
Kamloops, BC
V2C 6K7

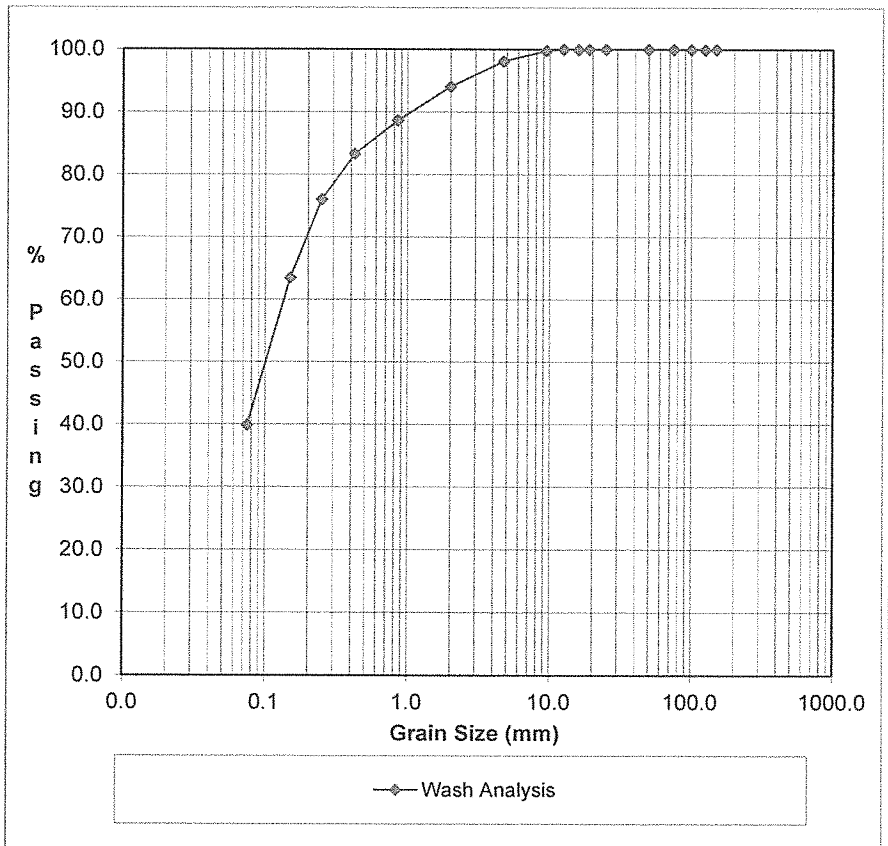
Project No:KX13690
Date:April 9, 2019

Attn: Leslie Abel / Kevin Turner

Project Name: Newsome Creek Sorrento

Test No.: 19 - 035 - 2 | Source: 208 GS# 2 | Sample Type: Bulk

Date Rec'd: April 4, 2019 | By: Client | Date Tested: April 5, 2019



Wash Sieve Analysis

Wash Sieve Analysis				
Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
25.0	0.0	100.0		
19.0	0.0	100.0		
16.0	0.0	100.0		
12.5	0.0	100.0		
9.5	0.2	99.8		
4.75	1.7	98.1		
2.000	4.0	94.1		
0.850	5.4	88.7		
0.425	5.3	83.3		
0.250	7.3	76.0		
0.150	12.5	63.5		
0.075	23.7	39.8		
PAN	39.8			

Sieve Mass (g): 805.3

Gravel	1.9 %
Sand	58.2 %
Fines	39.8 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
100-1383 McGill Road
Kamloops, BC
V2C 6K7

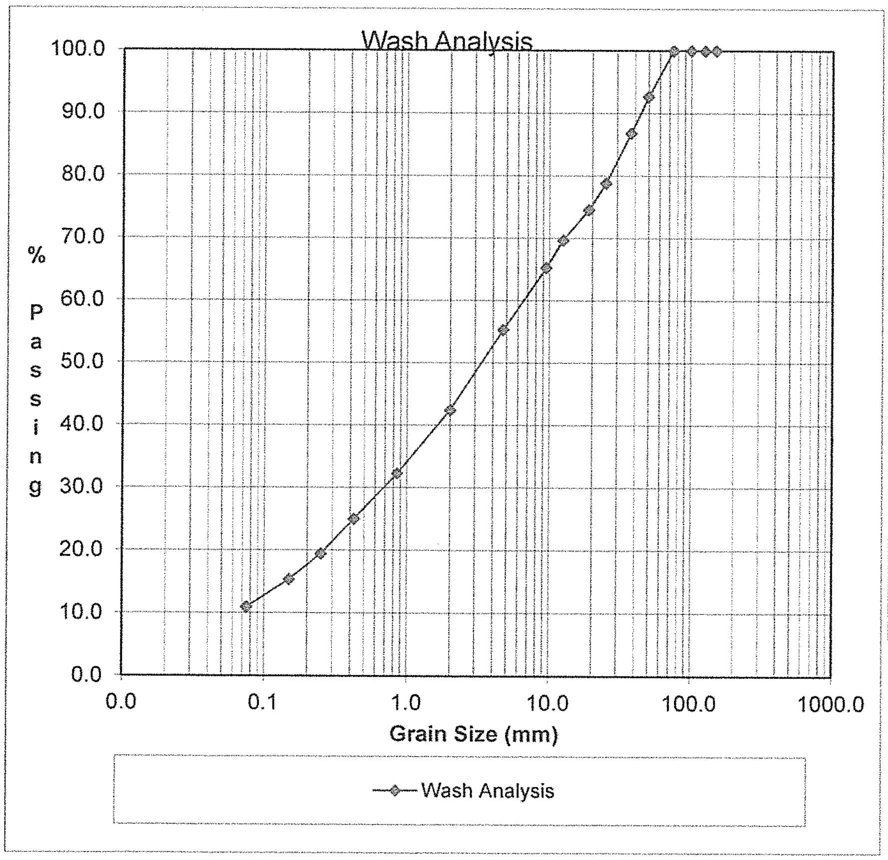
Project No:KX13690
Date: April 9, 2019

Attn: Leslie Abel / Kevin Turner

Project Name: Newsome Creek Sorrento

Test No.: 19 - 035 -3 | Source: 208 - GS #3 | Sample Type: Bulk

Date Rec'd : April 4, 2019 | By: Client | Date Tested: April 8, 2019



Wash Sieve Analysis				
Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	7.3	92.7		
37.5	5.9	86.8		
25.0	8.0	78.8		
19.0	4.2	74.6		
12.5	4.9	69.7		
9.5	4.5	65.2		
4.75	9.9	55.3		
2.000	12.9	42.4		
0.850	10.2	32.3		
0.425	7.3	25.0		
0.250	5.5	19.5		
0.150	4.1	15.4		
0.075	4.4	10.9		
PAN	10.9			

Sieve Mass (g): 4256.4

Gravel	44.7 %
Sand	44.4 %
Fines	10.9 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.

APPENDIX A
INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors 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 utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising 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 change over time and those 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 the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek's liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the "Claim"), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

   i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

   ii. if the Claim cannot be satisfied by the re-performance of the Services and:

      1. if Westrek's professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek's total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

      2. if Westrek's professional liability insurance applies to the Claim, shall be limited to the coverage amount available under Westrek's professional liability insurance at the time of the Claim. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in the amount of $2,000,000 per occurrence, $2,000,000 in the aggregate, for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client's expense.

      It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek's liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

   i. Substantial performance of the Services,

   ii. Suspension or abandonment of the Services provided under this agreement, or

   iii. Termination of Westrek's Services under the agreement,

   whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.