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Lot 9/10 Stormwater Replacement

Final Report
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1. Introduction

Kerr Wood Leidal Associates Ltd. (KWL) was retained by the District of Sechelt (the District) to review and evaluate construction options to repair a storm outfall pipe between lots 9 and 10, and upgrade a road section of Gale Avenue North in the Seawatch Subdivision. KWL was requested to undertake this evaluation based on its extensive involvement in subdivision development projects on the Sunshine Coast, as well as its specific involvement in evaluating previous sinkhole repair costs in the Seawatch Subdivision. KWL had no involvement with the original works and this report is not intended to be construed in any way as providing opinion on the work of others. The report relies on geotechnical evaluations and reports completed by others, and uses that information to undertake the program scope.

2. Scope

The scope of work was established in the Terms of Reference provided by the District and reconfirmed in KWL's proposal dated August 17, 2018. The key elements of the scope of work are summarized as follows:

- Information gathering and review;
- On-site meeting to confirm scope;
- Review construction options that are feasible, cost effective, and practical;
- Select a preferred option;
- List constraints, risks, and mitigation measures;
- Prepare a short technical memorandum outlining information sources, findings, conclusions, and recommendations; and
- Include a Class C Construction cost estimate and add 25 percent construction contingency and 15 percent engineering contingency.

The project kick-off meeting was held at the District Offices on September 7, 2018.

3. Background

The background information presented below is primarily drawn from a 2015 report¹ from Thurber Engineering Ltd. (Thurber), related reports and drawings from other consultants, and consultation with the District.

¹ The Shores – Phase 1 Subdivision Sinkhole Investigation and Geotechnical Assessment, July 15, 2015.

3.1 Site Location

The Seawatch Subdivision is approximately 4.5 km northwest of Sechelt, on the western side of Porpoise Bay, as depicted in Figure 3-1.



Figure 3-1: Seawatch Subdivision Site Location Relative to Sechelt (reproduced from Thurber)

The residential lot locations referenced in this report together with legal boundaries, topographic features and contours are depicted in Figure 3-2; however, it should be anticipated that contours on the northern side of this plan may have changed since the area was surveyed.

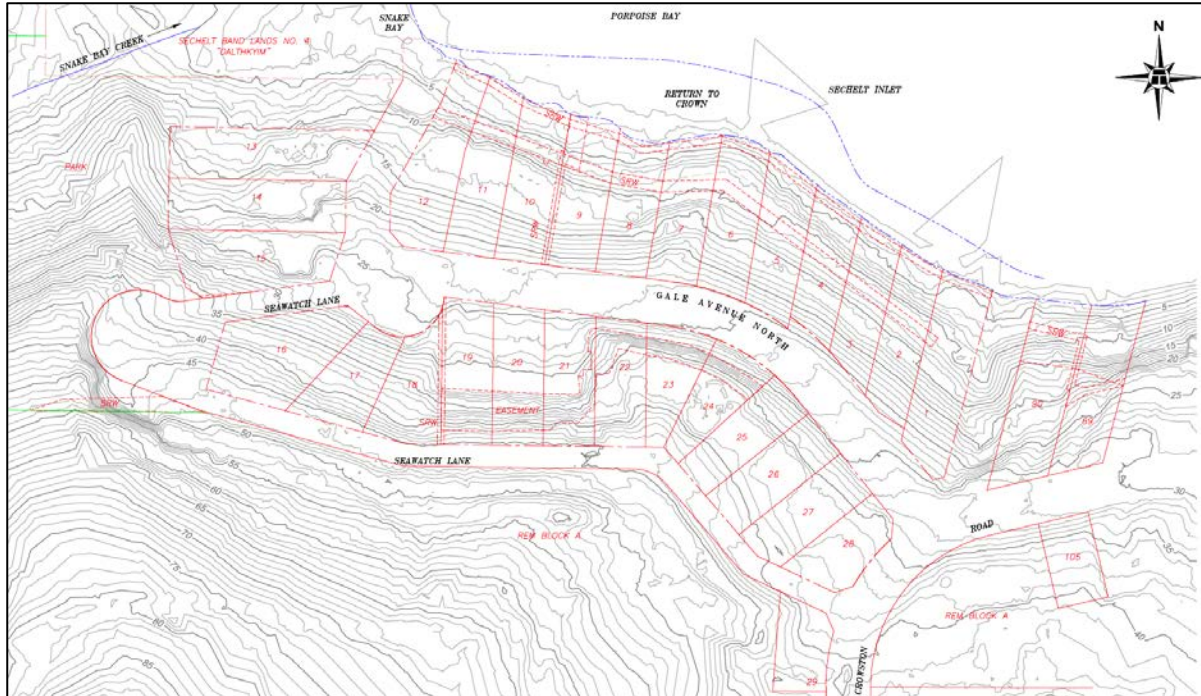


Figure 3-2: Base Plan Showing Legal Boundaries and Approximate Surface Features (reproduced from Thurber)

3.2 Geotechnical Project History

In 2004, a report forming the geotechnical basis for development of the Seawatch site was issued by GeoTacTics Engineering Ltd. (GeoTacTics). This report, and others, were reviewed in a geotechnical assessment report by Thurber in 2015. The Thurber report noted complex soil stratigraphy, high groundwater tables, spring features, and boggy areas. The report examined the processes of sinkhole formation, discussed existing and possible drainage measures, and provided recommendations for further actions.

Throughout the site development period, beginning in 2005, many seepage and stability related events were observed. These are summarized in Table 1 of the 2015 Thurber report and, briefly, include:

- slope stability challenges;
- seepage challenges;
- washout of significant sand and silt by springs (this includes an estimated 70 m³/d of soil volume loss due to some events);
- tension cracks in roadways; and
- sinkholes/depressions resulting in asphalt collapse and damage to at least one home (Lot 21).



Throughout development of the site, remediation measures were implemented, as also described in the 2015 Thurber report, including:

- drainage blanket installation in several areas; and
- sinkhole repair.

The Thurber report concluded that problems persist across the project site, and further action was necessary.

3.3 Scope Areas of Immediate Concern

Storm Sewer Between Lots 9 and 10

The scope of the present work is to address the specific area of the Seawatch Development where a storm outfall pipe is located between lots 9 and 10, as shown in Figure 3-3.

Groundwater management for the area apparently consisted of installing “filter blankets” over lots 1 to 12 constructed using a geotextile overlain with 150 mm thick layer of 19 mm minus crush and a 900 mm thick layer of 150 mm minus rock ballast. The filter blankets were installed immediately below the pre-existing grade elevation, where surface organic cover was stripped off.

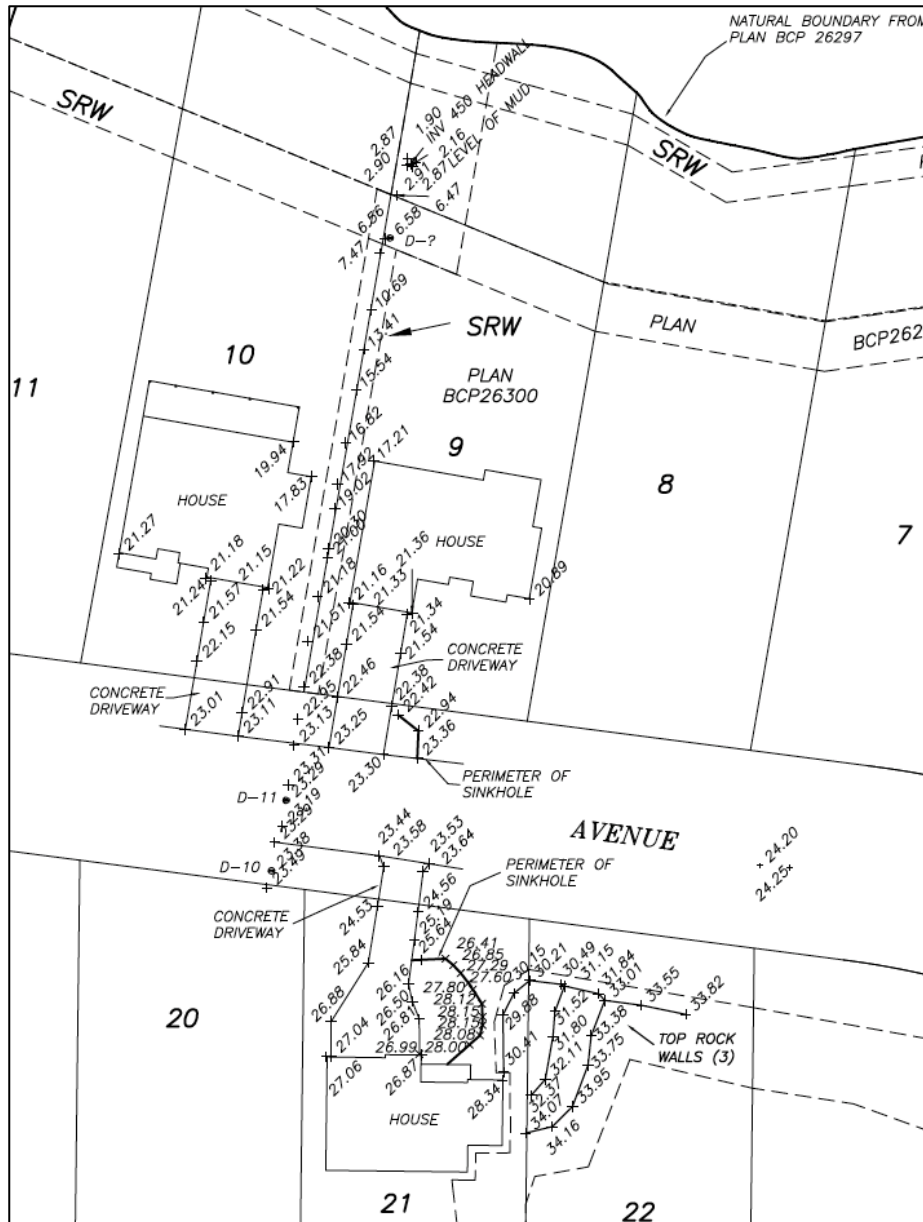


Figure 3-3: Illustration of Storm Outfall Right-Of-Way Between Lots 9 And 10 (reproduced from Strait Land Surveying Inc.)

Record information suggests that the existing storm outfall was constructed with 450 mm PVC pipe, accessed by four manholes, and backfilled with a soil cover ranging between 2 m and 6 m depth. The “as built” components of the outfall pipe are shown in green on Figure 3-4.

A subsequent investigation in 2015 confirmed that there is approximately 10 m of cover present in some areas, and one of the manholes (D-12 in Figure 3-4) has been entirely covered. In addition, the

measured storm outfall pipe profile varies considerably from the “as built” information. Some areas are “surcharged” by up to 7 m of fill, and the differences in profile and soil depth are shown in red on Figure 3-4.

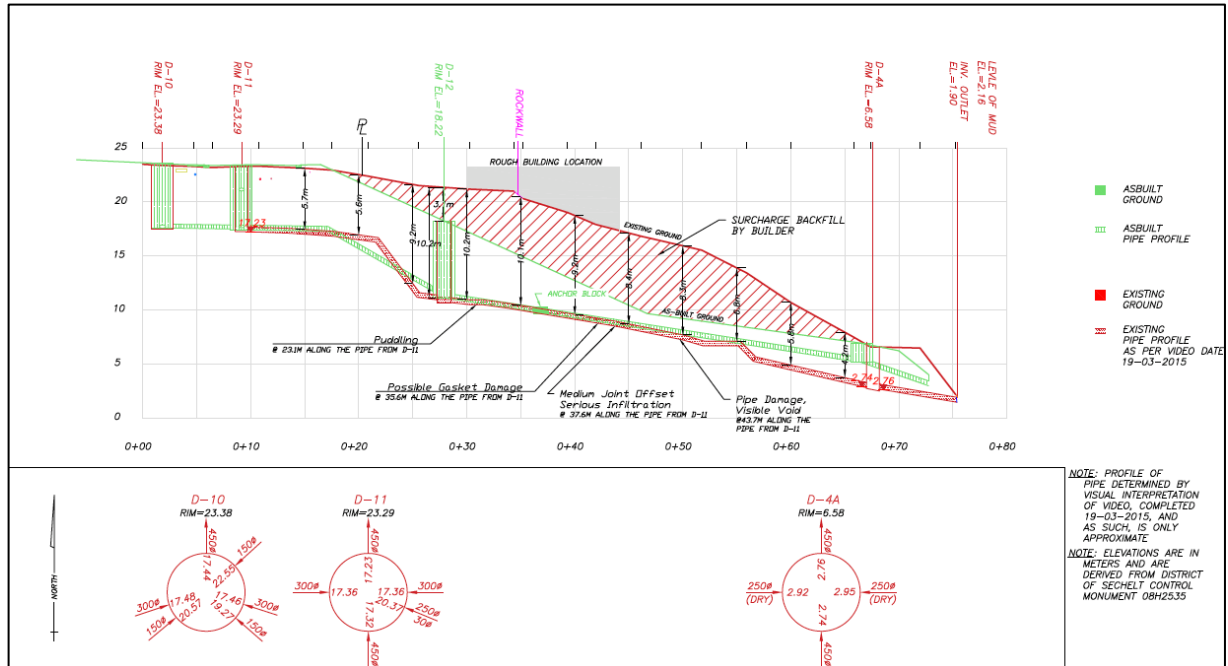


Figure 3-4: As Built and Existing Profile Views of the Storm Outfall Between Lots 9 and 10 (reproduced from Thurber)

This section of the outfall pipe was designed to convey surface stormwater and groundwater lows from manhole D-10 (which has 5 inlet pipes), manhole D-11 (which has 4 inlet pipes), manhole D-12 (which is buried), manhole D-4A, and an exit to daylight via a precast concrete culvert outlet headwall.

The District was concerned that the outfall pipe had been crushed downstream (north) of manhole D-12 and ordered an investigation.

Thurber conducted an extensive investigation of site conditions, and in their 2015 report, found that large 12-36 inch rock had been placed above the outfall between Lots 9 and 10 as a working pad for equipment. This, together with excessively high fill levels along the pipeline route were a potential cause of the apparent pipe bending and buckling.

Further investigations were completed by video inspection to assess pipe condition and flow paths. Based on video footage and supported by observations of the District staff, indications were that:

- The majority of stormwater source flows were contributions from the aforementioned manholes.
- There were two smaller pipe connections upstream of manhole D12. These are not shown on “as built” drawings and it is unknown whether they are connected for groundwater or stormwater collection purposes. If they are used for stormwater connection from Lots 9 and 10, they may be considered as potentially “illegal” connections.

- Significant groundwater flows entered the outfall pipeline along its route. This was evidenced by the high sediment load in the outfall effluent following two events which disturbed the soil upstream of the storm pipe; namely:
 1. drilling of a borehole by Thurber; and
 2. the collapse of the sinkhole on Lot 21.
- The pipe was displaced from its original alignment and grade.
- Several defects were noted including damaged gaskets, offset joints, and damaged pipe.
- Groundwater flow was likely entering the pipe through broken sections within the water table.

These observations suggest that the stormwater pipe is not currently performing as designed and does not properly convey stormwater and groundwater to Porpoise Bay. It is apparent that there is significant infiltration that brings sediment and fines into the pipeline downstream of manhole D-11. This is most likely causing piping in the soils surrounding the pipe, and could be contributing to the formation of sinkholes in the area. Sinkholes are observed on Lot 21 (across the street from the outfall), and in the front yard of Lot 9 (next to the upstream end of outfall), as depicted in Figure 3-5. Loss of soil via subsurface erosion, piping, and entry into the pipeline should be considered as a contributing factor to subsequent pipe collapse.

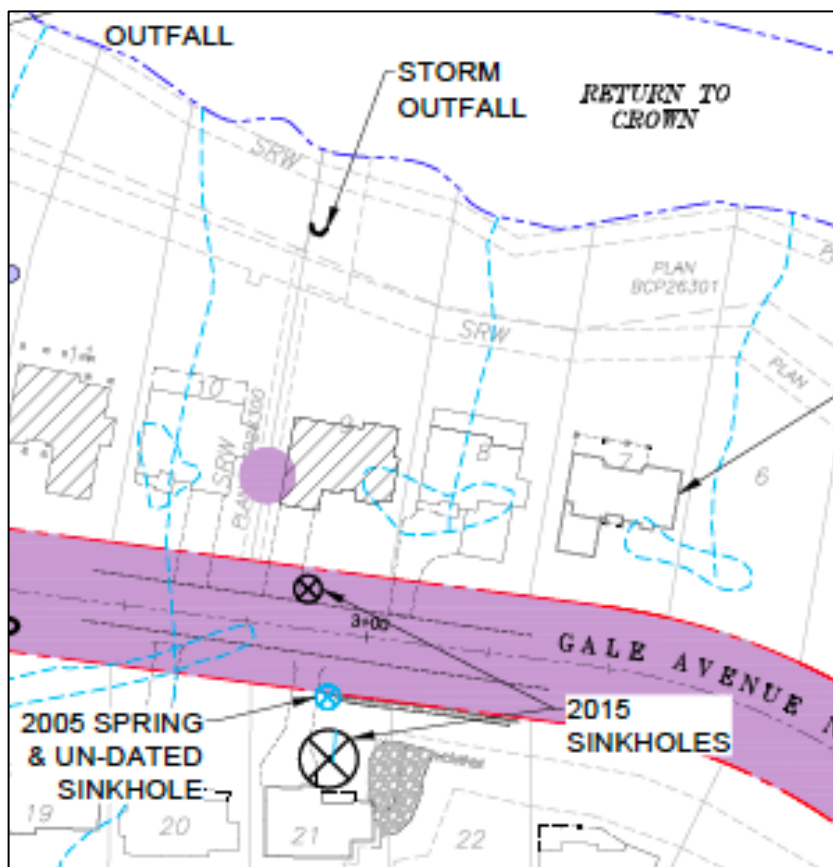


Figure 3-5: Sinkholes in the Vicinity of the Stormwater Outfall (reproduced from Thurber)



Finally, it should be noted that rainfall events are marked by high turbidity plumes in Porpoise Bay with their location reflective of existing stormwater outfalls. Not only is this an indication of soil loss from the subdivision, it also has an impact on the receiving environment, as it could be disrupting fish habitat. The Fisheries Act prohibits the discharge of a deleterious substance to fish habitat. The BC Water Quality Guidelines limit total suspended solids (TSS) concentrations to 25 mg/L, or 100 mg/L in storm events. Further investigation of the turbidity events are needed to determine the extent and impacts on the marine environment and mitigation requirements.

Gale Avenue North

The scope also requires a review and assessment of options to repair the existing road to provide increased protection for the short term. The Thurber report explains the mechanics of sinkhole formation in great detail, and provides locations of several sinkholes both within the roadway pavement area as well as within the road right-of-way.

KWL's previous study on repair of sinkholes in this area was relatively comprehensive for the longer term horizon, and included safeguarding the integrity of existing infrastructure. The extent of road upgrades under this assignment has not been defined, however, pricing will be developed per metre length over the full road width. This will allow the District to put a Class C cost estimate to the selected length of road to be upgraded.

Of significance, the Thurber report provides significant background information during the construction phase of the road, and refers specifically to the sinkhole formation north of Lot 21 across the road between lots 9 and 10. During clearing and excavation operations, a spring developed that reportedly discharged some 200 gpm of groundwater together with some 70 cu.m per day of fines. Efforts to staunch the flow were unsuccessful and temporarily abandoned for approximately four weeks, during which time, the calculated loss of fines was in the order of 2,000 cu.m.

Eventually, the spring was controlled reportedly using a layer of filter fabric, overlain by approximately 900 mm thick layer of 19 mm crushed rock, and a 300 mm thick layer of 150 mm rock as ballast. This filter blanket was extended across the road. Given that this occurred in a low point of the road which was described as being located on boggy ground developed by spring discharge, the solution included raising the road between STN 2+60 and STN 3+17 by some five (5) metres. Coincidentally, this work is located fronting lots 8, 9, and 10 on the north side of Gale Avenue North.

3.4 Summary of Challenges to Construction

The Thurber report provides significant background information that needs to be considered when developing construction techniques for the various options. These include, but are not necessarily limited to the following:

- Location of previously encountered boggy areas, and where springs developed during construction – refer to Appendix A;
- Complex stratigraphy that includes five strata of sands and silts – refer to Appendix B, and summarized as follows:
 - a. upper sand with 10 percent to 30 percent silt;
 - b. upper silty sand/sandy silt with 60 percent to 100 percent silt;
 - c. lower sand with 10 to 30 percent silt. The groundwater table is interpreted to be at the base of this layer;



- d. lower silty sand with 25 percent to 90 percent silt. This layer is interpreted to be saturated; and
- e. basal silt with 80 percent to 100 percent silt. This is the least permeable stratum.
- Groundwater elevation which can vary significantly over the year - refer to Appendix C. Note that highest groundwater table elevations occur in March and April, so preferred construction should be carried out in autumn;
- Direction of groundwater flow and hydraulic gradient – refer to Appendix D. Note that gradients exceed critical values that have the potential to migrate fines out of the soil matrix;
- Widespread use of “drainage blankets” to control seeps and springs, which reportedly have not performed as intended; and
- Use of large rocks to construct work platforms, which were subsequently left in place.

The Thurber report also explains how sinkholes develop – refer to Appendix E. Understanding the process is important when selecting appropriate construction techniques, and how they will impact on future performance of the works.

Three critical elements for potential sinkhole development are present throughout the site. These are:

- *In situ* fine silt native materials that can be transported downgradient when two further conditions occur, namely;
- Critical exit hydraulic gradients are exceeded, which has been shown to be the case for the majority of the site; and
- Pathways have been created for soil migration to occur.

The Thurber report suggests that there are several mechanisms that allow potential pathways for soil migration to occur, and these include:

- possible failure of the drainage blankets that allow soil migration into the voids;
- potential scour underneath the drainage blanket on sloping ground;
- all perforated pipes below the groundwater table;
- all solid pipes located below the groundwater table that may have been damaged; and
- all pipe trench bedding and backfill below the ground water table.

Subsequent sinkholes occur where fines have migrated out of the soil structure and cause progressive collapse of overlying soils.

The Golder report noted that the drainage blankets were constructed with Propex 2006, and would not be capable of permitting free flow of groundwater into the drainage blanket from below. This would lead to likely development of springs due to excess water pressure until the drainage blanket was displaced or ruptured.

The foregoing suggests that location and stage of sinkhole development is quite random and unpredictable throughout the site, and any construction should assume “worst case scenario” conditions to be present.



3.5 Future Risks

Based on the Thurber report and the aforementioned summary, it must be recognized that any action taken to undertake remedial construction, mitigate sinkhole development or divert groundwater flow in the development has the potential to destabilize meta-stable and precarious ground conditions. This could cause the transfer of risks to other areas within the subdivision. Accordingly, all options must be reviewed and implemented on the basis of a thorough geotechnical examination and direction.

4. Remediation Criteria

The scope of work requires that remediation of the stormwater pipe should be feasible, cost effective, and practical. Notably, it should:

- convey stormwater to Porpoise Bay via a 450 mm conduit (as designed previously and assumed to have sufficient design capacity); and
- stop exfiltration and infiltration to the existing stormwater pipe.

The extent of outfall remediation would be limited to rights-of-way and undeveloped land.

Remediation of the road section requires satisfactory performance for the short term horizon of 10 years, and in that timeframe should:

- mitigate risk of sinkhole development on Gale Avenue North;
- protect existing in-road utilities from damage due to road repairs; and
- have an extent limited to the width of the road right-of-way.

It should be noted that the criteria used are relative with respect to the remediation to be performed at this specific site. Because the site is very complex, remediation costs will be significantly higher than those anticipated for “standard” construction methods, and will be reflected in subsequent development of cost estimates.

5. Construction Options for Lots 9 and 10

5.1 Preliminary Identification of Options

As part of the overall review process, several options were identified that could potentially fit the remediation criteria listed above. The options that were considered at this stage include the following:

1. shallow storm sewer replacement (Web/Golder option);
2. sheet piling full length;
3. divert storm outfall;
4. deep open cut sewer replacement;
5. pile supported storm sewer;
6. injection grouting;
7. soil stabilization;
8. pipe lining; and
9. horizontal directional drilling (HDD) trenchless.

The Thurber report addresses the suitability, practicality and viability of several of the above noted options. In general, the report references several risks associated with some construction techniques, and specifically highlights the following:

- Option 4 – Deep open cut sewer replacement. This option considers the use of open trench methods and bank protection either with shoring or trench cages. The intent would be to excavate down to below the level of the existing pipes, install an appropriate filter blanket, pipe, and backfill. Given the extreme depth of excavation (over 10 m in places), this option would not be cost effective, and may be too challenging given the proximity to existing buildings, and need for extensive groundwater management. This option may destabilize adjacent soils, and potentially undermine adjacent buildings. Accordingly, this option was not considered further.
- Option 5 – Pile supported storm sewer. This option considers the use of deep piles adjacent to the route of the original sewer alignment. The piles would penetrate the stiffer basement strata and provide support for manholes and pipes. While feasible, and potentially cost effective, this option would not improve the subsurface issues within the right-of-way corridor. As a result, ongoing erosion, sinkhole forming, and fill consolidation processes would continue unabated. Accordingly, this option was not considered further.
- Option 6 – Injection grouting. This option considers the use of any of a number of grouting options that could infill any of the flow paths in the soil, and prevent soil migration. This option would be feasible; however, its greatest drawback would be the reduction of soil pore space thereby reducing permeability. The net effect would be to redirect flows to other areas of the site, potentially increase adjacent site hydraulic gradients, and transfer risk of damage to adjacent buildings. Accordingly, this option was not considered further.
- Option 7 – Soil stabilization. This option considers the use of a number of techniques to consolidate soils through external application of energy. In this regard:
 - a. Dynamic Compacting where heavy loads are dropped from height was considered to be potentially disruptive to adjacent buildings;
 - b. Rapid Impact Compacting was considered to be only effective to a depth of 5 to 10 metres, and very disruptive to adjacent surfaces, utilities and buildings; and
 - c. Vibro-compaction. This technique is effective in sandy soil but not in fine silts which would generate excess pore water pressure. In addition it has the greatest potential to cause subsidence in adjacent properties.

Based on the foregoing limitations, this option was not considered further.

- Option 8 – Pipe lining. This option considers the use of pipe lining and pipe bursting techniques to restore the function of the stormwater water pipe to pre-existing conditions. Both options would prevent ingress of sediment into the storm sewer. Of the two, the pipe bursting technique would be the more successful and least expensive option, however it would only solve one component of the sediment transport issue. Pathways are also assumed to exist within the crushed rock bedding and trench backfill, and in erosion zones underneath the filter blankets. As a result, ongoing erosion, sinkhole forming, and fill consolidation processes might be reduced but not eliminated. This option, while feasible and relatively inexpensive, would be seen as a temporary fix at best. Accordingly, this option was not considered further.
- Option 9 – Horizontal directional drilling. This option considers the use of trenchless technology to replace the existing sewer by pulling a pipe through a pre-reamed hole. If successful, it could also be seen as a feasible and relatively inexpensive option. However, as with Option 8, it would at best



only solve one component of the sediment transport issue. Pathways are also assumed to exist within the crushed rock bedding and trench backfill, and in erosion zones underneath the filter blankets. As a result, ongoing erosion, sinkhole forming, and fill consolidation processes might be reduced but not eliminated. In addition, back-reaming in saturated silts may be impossible if the soil structure is too weak to prevent collapse into the reamed opening. Accordingly, this option was not considered further.

Based on the foregoing discussion, Options 4 to 9 inclusive have been deemed to be either prohibitively expensive, impractical, or unsuitable to satisfy the remediation criteria. Accordingly, the remaining options are discussed in the following section.

5.2 Option 1: Shallow Storm Sewer Replacement (Web/Golder Option)

The benchmark repair strategy presented in this report is presented in a drawing by WEB Engineering Ltd. (WEB), provided by the District, dated April 2015. This illustrates the option referenced in a Golder Associates (Golder) memorandum, dated April 2, 2015, recommending use of grout to fill the existing storm sewer, upon replacement by a shallower storm sewer. A letter from WEB to the District, dated August 24, 2015, specifies a shallow replacement main, noting that Golder has recommended filling the existing main with concrete in conjunction with the main replacement. In summary, this remediation strategy involves constructing the following components:

- Excavating, locating, and tie-in with Uniflange restraint couplings to the existing 450 mm dia. existing pipe, approximately 7 m downstream of storm manhole D-11.
- Constructing approximately 60 m of 450 mm dia. SDR 35 PVC replacement storm sewer complete with restraint couplings. The new storm sewer would extend from this tie-in to the existing outfall at a depth between 1 and 6 m from existing ground surface than the existing storm sewer.
- Construction of four trench dams over the steeper sections of the storm sewer route.
- Construction of three new manholes (assumed to be 1,200 mm dia.) with depths ranging from 2 to 4 metres.
- Tie-in to a replacement Type 2 headwall complete with energy dissipator, as supplied by Langley Concrete.
- Finally, the entire existing storm sewer downstream of the tie-in location, together with manholes D-12, and D-4A would be plugged with concrete, as recommended, and as specified by Golder in their April 2, 2015 memorandum.

Although constructability was not discussed in the aforementioned reports, the narrow confines of the right-of-way limit conventional depth of excavation to approximately 3.6 m with use of a 3 m deep shoring cage and 1.5H:1V side slopes. This approach may be suitable for the shallower sections, but not for the initial excavations that will need to be in the order of 6 m deep. For this component, temporary sheet piles are proposed to approximately 5 metres below the basal stratum to control any potential groundwater flow.

A drawing depicting this remediation strategy is presented in Figure 5-1.

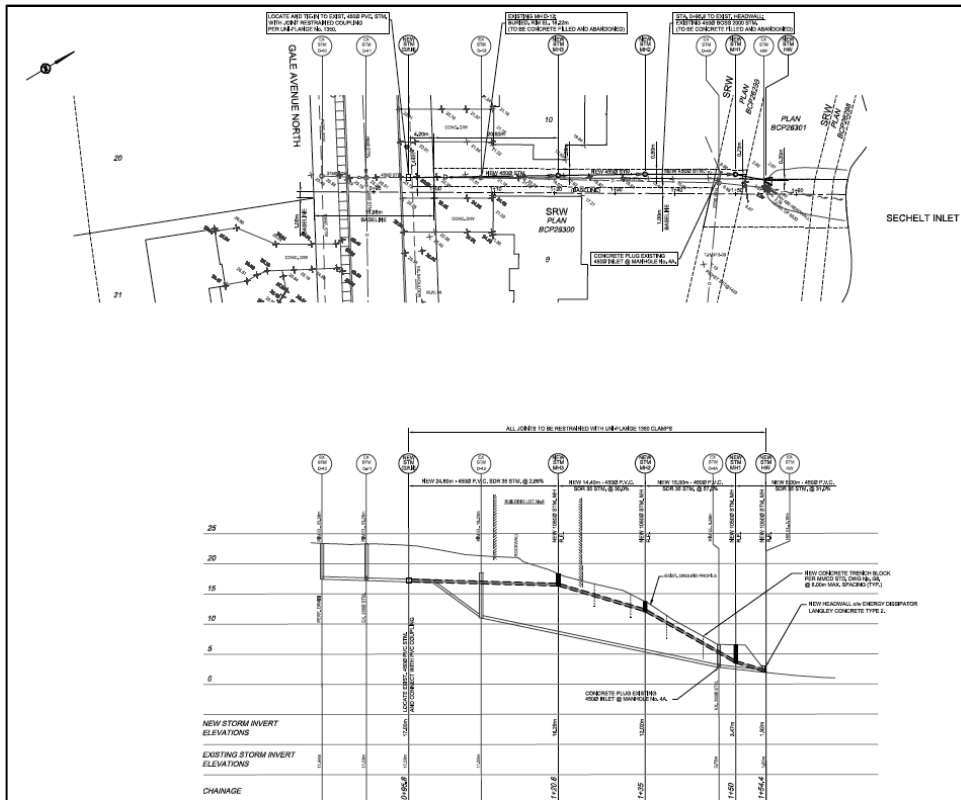


Figure 5-1: Shallow Storm Outfall Remediation Strategy (as proposed by WEB/Golder)

Of significance, the profile shows a sharp change in profile to the north of MH 12 at approximate chainage 0+17. This would normally require a manhole to accommodate the change in slope. Since none is shown, the profile information should be considered as suspect.

5.3 Option 2: Complete Isolation via Sheet Piling

This option is presented as a potentially suitable option that may satisfy all the remediation criteria. The strategy is to provide temporary groundwater control through use of restrained cut-off sheet piles that allow excavation of the entire corridor to great depth within the narrow utility corridor. The use of sheet piles instead of ground water well points ensures that groundwater elevations remain unchanged by construction.

The key components of this option are identified as follows:

- Installation of approximately 65 metres of parallel sheet piling along the length of the utility right-of-way penetrating down to a depth of approximately 5 metres below existing basal silt layer, or as directed by the geotechnical engineer to act as a groundwater cut-off;
- Installation of two layers of approximately 3 metres width of perpendicular sheet piling across the utility right-of-way in close proximity to existing manhole D-12 to allow for tie-in to the existing storm sewer pipe;



- Excavation of the first metre of material within the sheet pile corridor, and installation of a restraint frame to safeguard the continued excavation;
- Excavation of the entire material contents within the cofferdam corridor down to the basal layer. This would include overlying fill materials, original trench backfill materials, geotextiles, pipe, pipe bedding, trench anchor, and manholes, etc. This would allow for examination of the basal surface to record quantity, size and depth of any existing piping pathways. These would also be excavated out as part of the remediation process;
- Backfilling and compaction of trench up to the underside of the proposed sewer trench profile with material selected by the geotechnical engineer. This is assumed to include appropriate geotextile material surround extending in width to the edges of the sheet piles;
- Installation of approximately 65 metres of 450 mm dia. 35 SDR PVC pipe complete with appropriate bedding as required by the geotechnical engineer. Alignment and grade as suggested in Option 1;
- Installation of four trench anchors at locations shown in Option 1;
- Installation of three 1,200 mm dia. manholes at locations and depths shown in Option 1;
- Installation of outfall as shown in Option 1;
- Removal of sheet pile restraint frame;
- Tie-in to existing storm sewer using restraint coupling;
- Backfilling and compaction of select materials to grade; and
- Removal of all sheet piles.

The conceptual trench cross section of this option is presented in Figure 5-2 below.

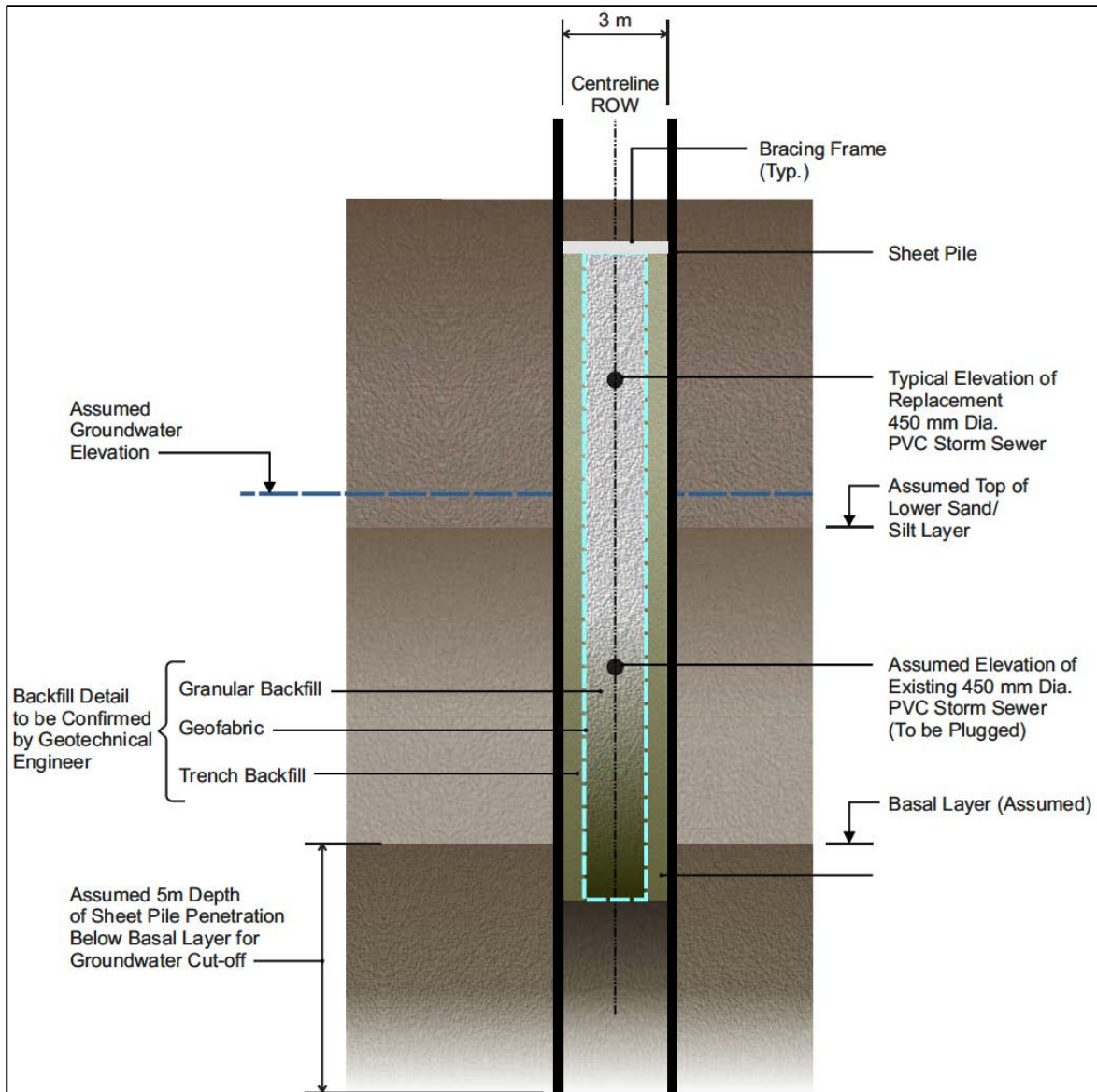


Figure 5-2: Complete Isolation Via Sheet Piling Option

5.4 Option 3: Divert Storm Outfall

This option presents an alternative that involves diversion of the existing storm outfall from the 3 m right-of-way (ROW) to a different and more accessible location. Two alternatives were examined, namely:

- A wider (~19 m) ROW located to the west of Lot 12. The new sewer would flow west along Gale Avenue North. This option would require approximately 150 m of new 450 mm watermain. Of this, 75 m would be buried under the existing roadway, following the existing storm sewer path, but with the western end of the pipe at a 2 m lower elevation to allow flow (assumes 1 m/75 m slope)



currently, to be replaced with 1 m/75 m slope in the opposite direction). The remaining 75 m would follow the wider right-of-way to a new outfall. This option would include replacement of two manholes along Gale Avenue North, as well as constructing three new manholes along the ROW, and modification of MH11.

- b. Relocation to a new right-of-way across Lot 6. The new sewer of approximately 70 m length would flow east along Gale Avenue North towards existing MH13, and then flow approximately 50 m north along a new utility right-of-way across the west side of Lot 6. One option would be to tie-in to the existing 250 mm dia. stormwater pipe located within the 5 m wide utility corridor that flows westwards back towards, and discharges to, the existing MH 4A. At this concept stage, it is assumed that the existing 250 mm dia. stormwater pipe would have insufficient capacity to convey all design flows arriving at MH 11. Accordingly, the flow exit suggested is to a new outfall to Snake Bay at the north side of Lot 6.

By inspection, Option b. is suggested as the preferred routing.

This option is presented as a potentially suitable option that may satisfy all the remediation criteria. Similar to Option 2, the construction strategy is to provide temporary groundwater control through use of restrained cut-off sheet piles that allow excavation to suitable depth within a narrow corridor located between the gas main on the north side of the road, and the property line. The use of sheet piles instead of ground water well points ensures that groundwater elevations remain unchanged by construction.

The key components of this option are identified as follows:

- Location and marking location of the gas main, gas, telephone, power, and water services; sanitary and stormwater connections are at the northern lot frontage;
- Shallow excavation down to service connections for temporary rerouting;
- Installation of approximately 75 metres of parallel sheet piling along the length of the corridor fronting Lots 9, 8, 7, and west side of Lot 6. The sheet piles would penetrate down to a depth of approximately 5 metres below existing basal silt layer or as directed by the geotechnical engineer to act as a groundwater cut-off;
- Installation of approximately 1.5 metres width of perpendicular sheet piling across the corridor, with one side located on the east side of Lot 10, and the other on the east side of the stormwater route on Lot 6;
- Excavation of the first metre of material within the sheet pile corridor, and installation of a restraint frame to safeguard the continued excavation;
- Excavation of the entire material contents within the cofferdam corridor down to the basal layer. This would include overlying fill materials, original trench backfill materials, geotextiles, filter blanket, and section of 450 mm dia. stormwater sewer between MH 11 and MH 12. This would allow for examination of the basal surface to record quantity, size and depth of any existing piping pathways. These would also be excavated out as part of the remediation process;
- Backfilling and compaction of trench up to the underside of the proposed sewer trench profile with material selected by the geotechnical engineer. This is assumed to include appropriate geotextile material surround extending in width to the edges of the sheet piles;
- Construction of two 1,200 mm dia. manholes, one to intercept flows between MH 11 and MH 12, and the other at Lot 6 to change direction;



- Installation of approximately 70 metres of 450 mm dia. 35 SDR PVC pipe complete with appropriate bedding as required by the geotechnical engineer; depth will be at approximately 6 m to 7 m below existing grade;
- Installation of approximately 55 metres of parallel sheet piling along the length of the corridor on the west side of Lot 6. The sheet piles would penetrate down to a depth of approximately 5 metres below existing basal silt layer or as directed by the geotechnical engineer to act as a groundwater cut-off;
- Installation of approximately 1.5 metres width of perpendicular sheet piling across the corridor, with one side located on the south side of Lot 6, and the other on the north side of the Lot 6 boundary;
- Excavation of the first metre of material within the sheet pile corridor, and installation of a restraint frame to safeguard the continued excavation;
- Excavation of the entire material contents within the cofferdam corridor down to the basal layer. This would include overlying fill materials, original backfill materials, geotextiles, and filter blanket. This would allow for examination of the basal surface to record quantity, size and depth of any existing piping pathways. These would also be excavated out as part of the remediation process;
- Backfilling and compaction of trench up to the underside of the proposed sewer trench profile with material selected by the geotechnical engineer. This is assumed to include appropriate geotextile material surround extending in width to the edges of the sheet piles;
- Installation of a 1,200 mm dia. manhole at the Lot 6 north boundary;
- Installation of a new outfall;
- Removal of sheet pile restraint frame;
- Backfilling and compaction of select materials to grade;
- Removal of all sheet piles; and
- Reconnection of all services, driveway crossings, landscaping etc.

Of significance, the remainder of the pipelines and manholes within the existing right-of-way between Lots 9 and 10 would need to be grouted as per Option 1. This would leave the two “illegal” drain connections disconnected from MH 12. Accordingly, the lines would need to be extended to their respective north boundary stormwater service tie-in locations.

The conceptual plan and cross section of this option is presented in Figure 5-3 below.

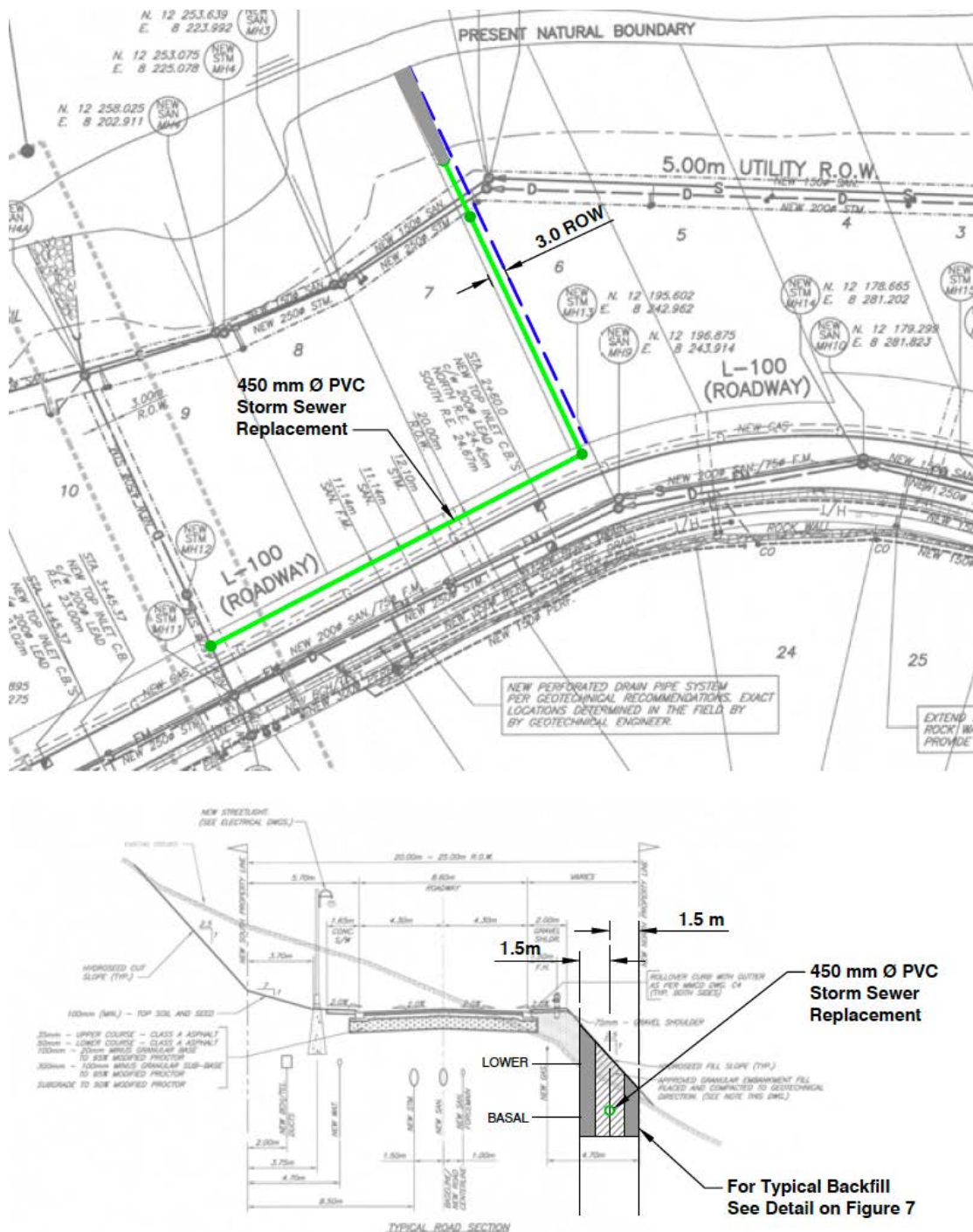


Figure 5-3: Routing Option – Plan and Detail



6. Outfall Option Cost Estimates

Based on the foregoing discussion, Class C type cost estimates have been prepared for each of the three options. The breakdown details of the estimates are included in Appendix F and summarized as follows:

- Option 1: \$550,000;
- Option 2: \$885,000; and
- Option 3: \$1,027,000.

The estimates include a 25 percent contingency for construction, and 15 percent allowance for engineering. Class C cost estimates are suitable for high level planning purposes, and provide a framework for moving forward to the pre-design stage of the program where the necessary investigations can take place to confirm feasibility.

7. Comparison of Options: Constraints and Opportunities

7.1 Stormwater Conveyance

All three options would provide adequate conveyance of stormwater from Gale Avenue North to Snake Bay. This is based on the assumption that a 450 mm diameter PVC storm sewer, at minimum grade is sufficient to convey the design flows. Study of design flows and pipe capacities was beyond this scope of the current report. Of significance, because the conveyance system would be a new construction, it should be anticipated that there would be minimal infiltration or exfiltration associated with the pipe.

7.2 Groundwater Control and Potential for Mitigating Sinkhole Formation

This parameter examines how each option deals with groundwater flows, and by extension, sinkhole formation.

Option 1 does not address subsurface conditions, and groundwater flows will continue to flow through existing pathways surrounding the pipe. It should be anticipated that the sinkhole forming processes will continue, although at a reduced rate.

Options 2 and 3 address this issue through proactive means. This includes temporary groundwater control during construction, excavation of all materials down to the piping pathways, and installation of appropriate geofabric and backfill materials that would mitigate the flow of fines out of surrounding soils. Option 2 uses the same corridor as the present stormwater system between Lots 9 and 10.

Option 3 uses a new route that provides an opportunity to permanently control groundwater passage through Lots 9, 8, and 7. Groundwater would be intercepted by the cut-off trench containing the storm sewer, thereby potentially arresting or significantly slowing down the sinkhole forming processes for these lots. This could be expanded to other adjacent lots, and possibly to other areas within the subdivision. In addition, the routing passes through the sinkhole on the south side of Lot 9, and provides an opportunity to make significant repairs as part of the trench backfilling process. It should be noted that while the groundwater cut-off trench will potentially reduce some of the sinkhole forming processes on the north side of the road, it is unknown what effects it may have on the adjacent road. Construction of Option 3 should not be construed as a reason to re-open the road in this vicinity without referring to assessment by a geotechnical engineer.



7.3 Control of “Illegal” Inflows

Based on Video footage there are two connections that could potentially be “illegal” inflows to the storm sewer pipe. These have the potential to exfiltrate through cracks into the groundwater and contribute to the sinkhole forming process.

Options 1 and 2 do not directly address this issue, as the tie-ins would be retained as part of those systems. Any work that requires temporary shut-off and tie-back into the system will occur in the District’s right-of-way.

Option 3 addresses this issue as it requires that if these connections originate from Lots 9 and 10, then they need to be re-routed to the north property lines. This work will need to be completed within the individual Lot property lines, as the existing stormwater collector will be plugged and abandoned.

7.4 Constructability

Each option presents significant construction challenges that may have considerable impact on the feasibility and viability of the proposed works. Much of the uncertainty, and therefore risk, is based on the limited information available regarding the composition and extent of subsurface construction works. These works include “filter” blankets of various composition, boulder pads, and any other unrecorded potential impediments. Records show that there was a major spring that developed within the existing right-of-way and that several attempts were made to staunch flows with various materials. Records also show that boulder pads were constructed within the right-of-way.

Option 1 will need to use a mix of sheet pile/deep trench shoring techniques (coupled with groundwater control) over the deeper sections of excavation, and conventional trench cages for installation shallower than 3.6 m. The pipe profile suggests that this option may be shallower than the boulder pads which apparently are located between the two existing buildings. The sheet piles/deep trench shoring will need to contend with filter blankets that are assumed to exist.

Option 2 relies on sheet pile construction throughout the right-of-way. Aside from the challenges of having to contend with the boulder pads and the filter blanket, there will be a significant challenge of trying to work within a narrow, constricted space to accommodate machinery for sheet pile installation. Sheet piling can be installed using either dynamic loading or vibratory equipment. Close proximity to the existing buildings will require careful evaluation of risks to property before this option is considered.

Option 3 relies on sheet pile construction within the road-right-of-way, and a yet to be established utility right-of-way over Lot 6. This option avoids many of the challenges presented in Option 2, and only needs to contend with penetrating the filter blankets. Because of the relative distance from existing buildings, construction impacts would be considerably reduced. Of significance, there is a lot of flexibility in selecting the final routing within the road and utility right-of-way.

7.5 Long-Term System Integrity

This section looks at each option, and examines to what extent existing sinkhole forming processes within the utility right-of-way will be mitigated.

Option 1, by inspection, is the least able to affect subsurface conditions. Essentially, this option simply replaces the conveyance pipe to a higher elevation, and plugs the existing pipe. On its face, it would seem that constructing pipelines and manholes in fills that appear to have low density, and where soil erosion processes continue to exist at the level of the existing pipe, could pose potential settlement issues that as yet have not been addressed. To what extent and how effective this option approach will

be to mitigating sinkhole formation and utility settlement potential, is best left to the geotechnical professionals to analyse.

Options 2 and 3 have the best potential system integrity outcomes on the basis that both options are based on excavating out all materials down to the basal layer, and building pipe foundations from the base up. This provides an opportunity to plug any existing piping pathways that are evident, and replacing any areas of low-density soils.

7.6 Preferred Option

Based on the above discussion, Option 3, despite its higher cost, appears to be the option that satisfies all the selected criteria, has a lot of flexibility in design, and has the potential to provide longer term mitigation to reduce the rate of sinkhole formation at the south boundaries of Lots 9, 8, and 7. Accordingly, Option 3 is recommended as the preferred option to move to the pre-design stage.

8. Road Remediation

8.1 General

The length of road to be remediated is undetermined at this stage, and so the scope of work examines per metre Class C costs over the full width of the road.

Several options were reviewed with respect to strengthening the road including non-destructive pressure grouting to restore surface elevations, and various surface structural material options. In all cases, the most appropriate and commonly used methods rely on use of geotextile reinforced soil.

Given the foregoing, only one option is presented for consideration and as follows:

- Option 1, based on replacement of the top road structure layer with reinforced geotextile soils; two additional sub-options are included for consideration at the Class D level. These include:
 - Option 1A based on underlying soil remediation by preload; and
 - Option 1B based on excavation down to the lowest infrastructure utility, and reconstruction.

These options are discussed in greater detail below.

8.2 Option 1: Surface Only Restoration

This option is based on adhering to the specific requirements of the scope and is intended to provide temporary bridging for a limited design time frame.

The philosophy associated with this option is to use subgrade reinforcement provided by geogrid mats. This would be the bare minimum amount of work to meet the scope, however, it does nothing to attempt to consolidate the subgrade fills in areas of potential sinkhole development. While *in situ* compaction may be possible with vibratory rollers, it presents a safety risk, especially when the structural support capacity has not been established or documented throughout the site

The work plan requires the following:

- Asphalt removal and disposal off site;
- Concrete curb and sidewalk removal and disposal off site;



- Road fill removal to temporary stockpiles for re-use. Depth assumed to be 0.6 m below road structure, but no deeper than shallow services (e.g., gas, power, telephone, etc.);
- Installation of heavy-duty geotextile (e.g., geogrid TX 160) complete with geofabric underlay for fines migration;
- Overlay with 300 mm thickness of selected fill from temporary stockpile and compaction;
- Installation of second layer of heavy-duty geotextile;
- Overlay with selected fill from temporary stockpile and compacted in maximum 300 mm thick layers to the underside of the roadway structure;
- Install 300 mm thick 75 mm minus compacted subbase gravels;
- Install 100 mm thick 19 mm minus compacted base gravels;
- Install concrete barrier curb and gutters;
- Install concrete sidewalk pavement 1.5 m wide;
- Install two lift asphalt paving 85 mm thick complete with tack coats;
- Repair and replace private property exposed aggregate driveways; and
- Install landscaping topsoil 150 mm thickness together with grass sod.

The geotextile is assumed to extend over a 16-metre width of the 20-metre-wide right-of-way. The intent is to have an equal area of geotextile “anchoring” (i.e., 4 metres either side) as there is paved surface (approximately 3.6 metres per lane).

The conceptual plan and cross section of this option is presented in Figure 8-1 below.

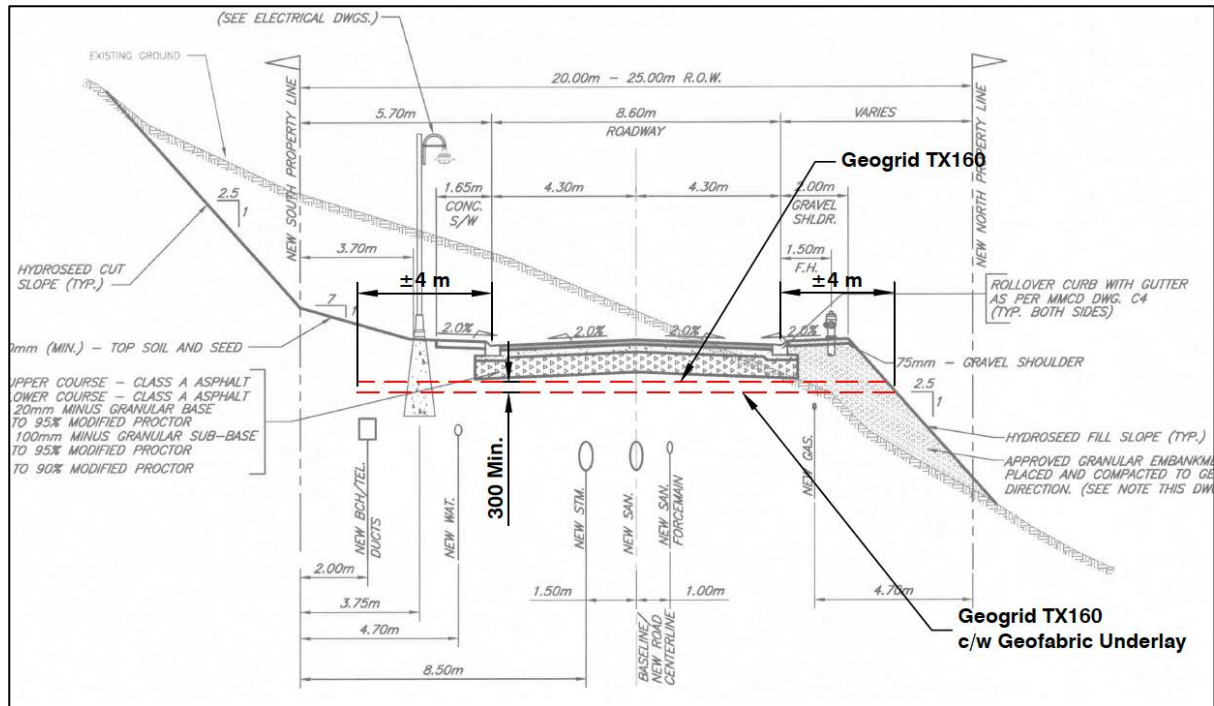


Figure 8-1: Road Remediation Section

8.3 Option 1A: Preload

To overcome some of the safety concerns, soil preload has been added as an optional extra at the Class D level. This option allows for consolidation of the underlying subgrade soils without use of mechanical vibratory equipment.

This optional extra is assumed to be a 3-metre-high tarpaulin-protected preload to cover the paved road surface. The expected side slope would be 1.5 H:1V, and so base cover would be a total of 17 metres. Because the north side lots slope away, concrete guards will need to be placed at an optimum location to prevent down slope spillage.

8.4 Option 1B: Deep Excavation

The aforementioned Option 1 provides in the first case, the minimum requirements required by this scope, and in the second case, Option 1A, an opportunity to consolidate some of the underlying roadway fills and soils. These, however, do not address some of the other underlying issues noted in other reports, notably the Urban report that classifies the existing infrastructure condition as fair to poor. The concerns that neither Option 1 nor Option 1A address are threefold, namely:

- Infiltration and exfiltration associated with major utilities (stormwater and sanitary);
- Cross contamination, leakage and outright failure of the water system infrastructure; and
- Sediment transport through existing trench gravels.

Any one of these situations can exacerbate sinkhole forming processes, with potentially catastrophic results.



This option is presented at the overview level so as to provide an order-of-magnitude cost in relation to Option 1. This option has three key benefits:

- Allows examination, repair, or replacement of any substandard or failed utilities;
- Allows examination and replacement of pipe bedding and backfill materials if they do not satisfy the general intent of reducing the risk of sinkhole formation; and
- Allows alternative implementation of stormwater Option 3 presented in Section 6 by moving the routing to the middle of the road to replace the existing storm sewer. It allows the design of that utility to include a cut-off trench with perforated collector pipe to intercept and divert all upland groundwater flows. These would be redirected to Snake Bay as per Option 3. Of significance, this approach while outside the scope of this assignment, allows for future examination of excavating a deep groundwater cut-off trench on the south side of the road right-of-way. This could potentially mitigate future sinkhole forming processes by virtue of controlling and redirecting the upland groundwater flow paths. Conceptually, this could be extended to other sections of the subdivision based on geotechnical review.

Construction would require extensive groundwater control, either by cantilevered sheet pile shoring, or by well-pointing.

9. Road Restoration Cost Estimates

Based on the foregoing discussion, cost estimates have been prepared per metre length for each of the three options. The breakdown details of the estimates are included in Appendix G and summarized as follows:

- Option 1: \$5,600 (rounded up Class C);
- Option 1A: Together with pre-load (Class D) - \$10,600; and
- Option 1B: Together with Option 1, Deep Excavation (Class D) - \$20,600.

Class C cost estimates include a 25 percent contingency for construction, and 15 percent allowance for engineering.

Class D cost estimates are made at an overview level with minimal information. Unknowns are greater, so cost estimates include a larger 35 percent contingency for construction, and 20 percent allowance for engineering.

Class C and D cost estimates are suitable for high level planning purposes, and provide a framework for moving forward to the pre-design stage of the program where the necessary investigations can take place to confirm feasibility.



10. Report Submission

We trust that the report meets with your expectations for this planning level exercise, and provides you with sufficient information to move forward with a higher level of confidence to the pre-design investigations required to confirm feasibility, and selection of criteria to be used at the design stage.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Shona Robinson, EIT, Ph.D.
Junior Project Engineer

Prepared by:

Jurek Janota-Bzowski, P.Eng.
Senior Project Engineer

Reviewed by:

Colin Kristiansen, P.Eng., MBA
Senior Technical Review Engineer

This document is a copy of the sealed and signed original retained on file.
The content of the electronically transmitted document can be confirmed by referring to the filed original.



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Revision History

Revision #	Date	Status	Revision Description	Author
0	November 20, 2018	Final		SJR/JJB



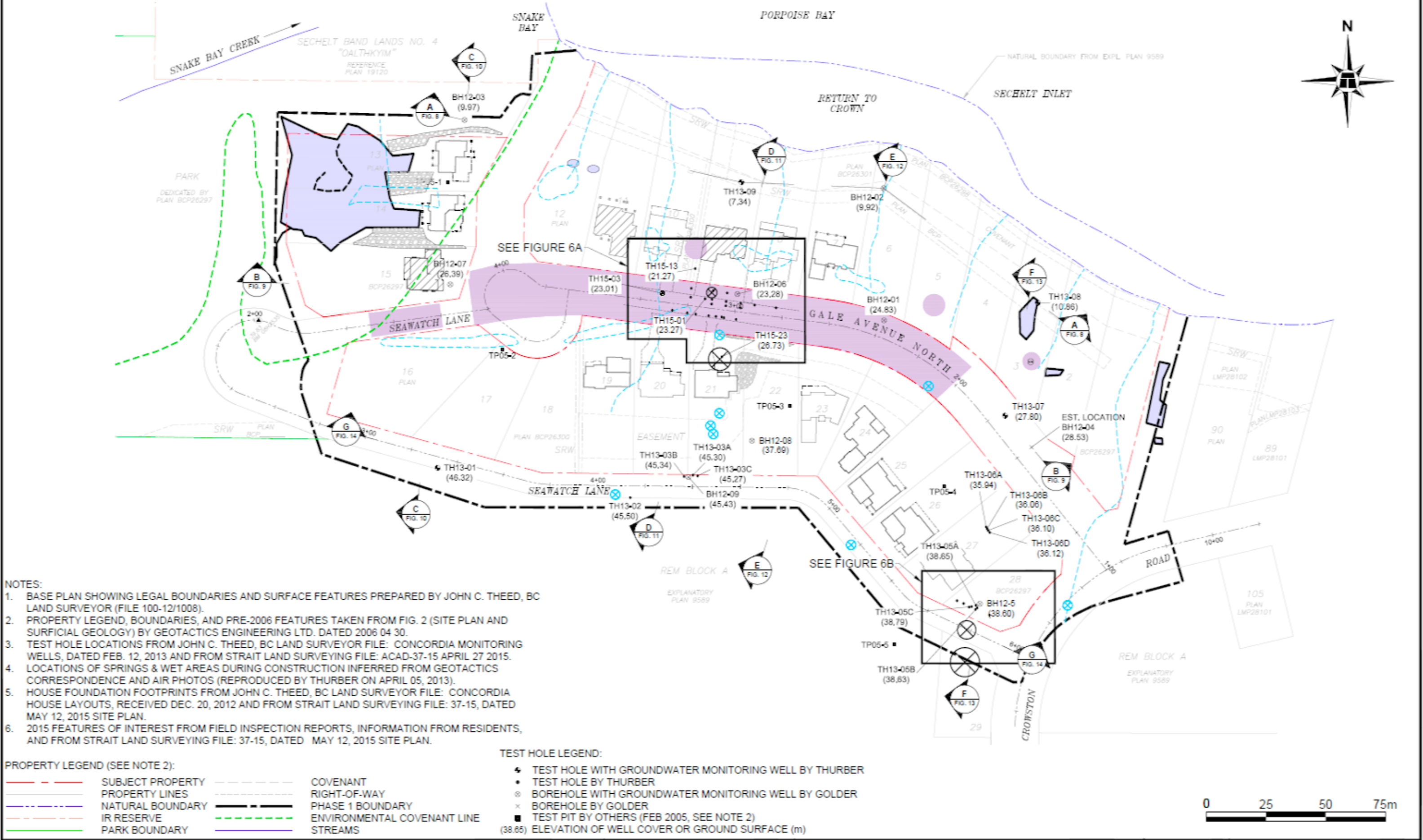


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Appendix A

Plan Showing Test Hole Locations and Groundwater Features

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.



- NOTES:**
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
 2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
 3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
 4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
 5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
 6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.

- PROPERTY LEGEND (SEE NOTE 2):**
- | | | | |
|-----|------------------|-----|-----------------------------|
| --- | SUBJECT PROPERTY | --- | COVENANT |
| --- | PROPERTY LINES | --- | RIGHT-OF-WAY |
| --- | NATURAL BOUNDARY | --- | PHASE 1 BOUNDARY |
| --- | IR RESERVE | --- | ENVIRONMENTAL COVENANT LINE |
| --- | PARK BOUNDARY | --- | STREAMS |
- TEST HOLE LEGEND:**
- ⊕ TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
 - TEST HOLE BY THURBER
 - ⊗ BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
 - ⊗ BOREHOLE BY GOLDER
 - TEST PIT BY OTHERS (FEB 2005, SEE NOTE 2)
 - (38.65) ELEVATION OF WELL COVER OR GROUND SURFACE (m)

- FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):**
- | | | | |
|---|---|---|---|
| ⊗ | PRE 2006 SINKHOLE | ▨ | HOUSE INCOMPLETE OR UNOCCUPIED |
| ⊗ | PRE 2006 SPRING OR STREAM | ▨ | PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION |
| ⊗ | POST 2006 SINKHOLE | ▨ | 2015 SPRING OR WET AREA |
| ⊗ | ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED) | | |

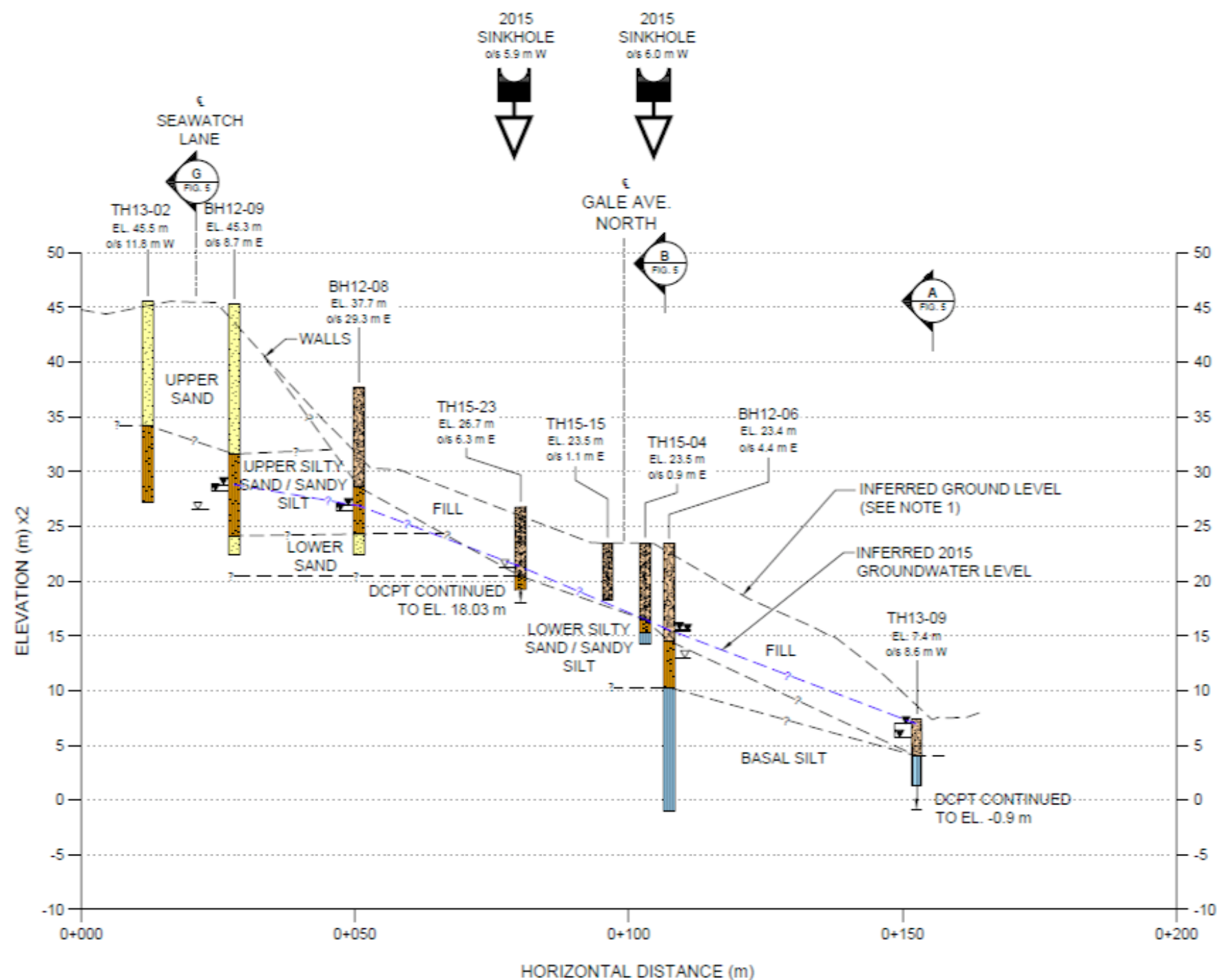
 THURBER ENGINEERING LTD.	CLIENT	DISTRICT OF SECHelt		
	TEST HOLE LOCATION AND SITE PLAN			
	THE SHORES - PHASE 1 SUBDIVISION		SECHelt, BC	
		DESIGNED	DRAWN	APPROVED
		CHS	NAK	DJT
		DATE	SCALE	
		JULY 16, 2015	AS SHOWN	
		PROJECT No.	FIG. No.	REV.
		14-214-4	5	-



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Appendix B

Typical Geological Section



LEGEND FOR SOIL STRATIGRAPHY:

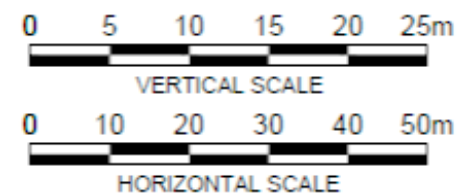
	Variable mix of SILT, SAND and GRAVEL and occasional cobbles locally
	Typically SAND with trace silt and occasionally trace to some silt, occasionally trace gravel
	Typically silty SAND to sandy SILT and occasionally trace gravel
	Typically SILT with trace to some sand, occasionally with trace clay and occasionally trace gravel

NOTES:

- GROUND LEVEL INFERRED FROM FROM STRAIT LAND SURVEYING'S MARCH 03, 2015 SURVEY.
- TYPICAL SOIL DESCRIPTIONS DERIVED AFTER THURBER 2013 AND 2015 TEST HOLE LOGS AND TEST HOLE LOGS INCLUDED IN GOLDER ASSOCIATES' NOV. 15, 2012 REPORT TITLED 'GEOTECHNICAL REVIEW AND ASSESSMENT, PHASE 1 SEAWATCH RESIDENTIAL SUBDIVISION, SECHTEL, BC', PROJECT NO. 12-1447-0230.
- INFERRED GEOLOGICAL BOUNDARIES VARY BETWEEN TEST HOLES.
- GROUNDWATER MONITORING WELL SCREENED INTERVALS ARE DEFINED ON THE TEST HOLE LOGS.

LEGEND FOR GROUNDWATER:

- BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
-
-



THURBER ENGINEERING LTD.

CLIENT

DISTRICT OF SECHTEL

GEOLOGICAL SECTION D-D

THE SHORES - PHASE 1 SUBDIVISION

SECHTEL, BC

DESIGNED

CHS

DRAWN

NAK

APPROVED

DJT

DATE

JULY 16, 2015

PROJECT NO.

14-214-4

SCALE

AS SHOWN

FIG. NO.

11

REV.

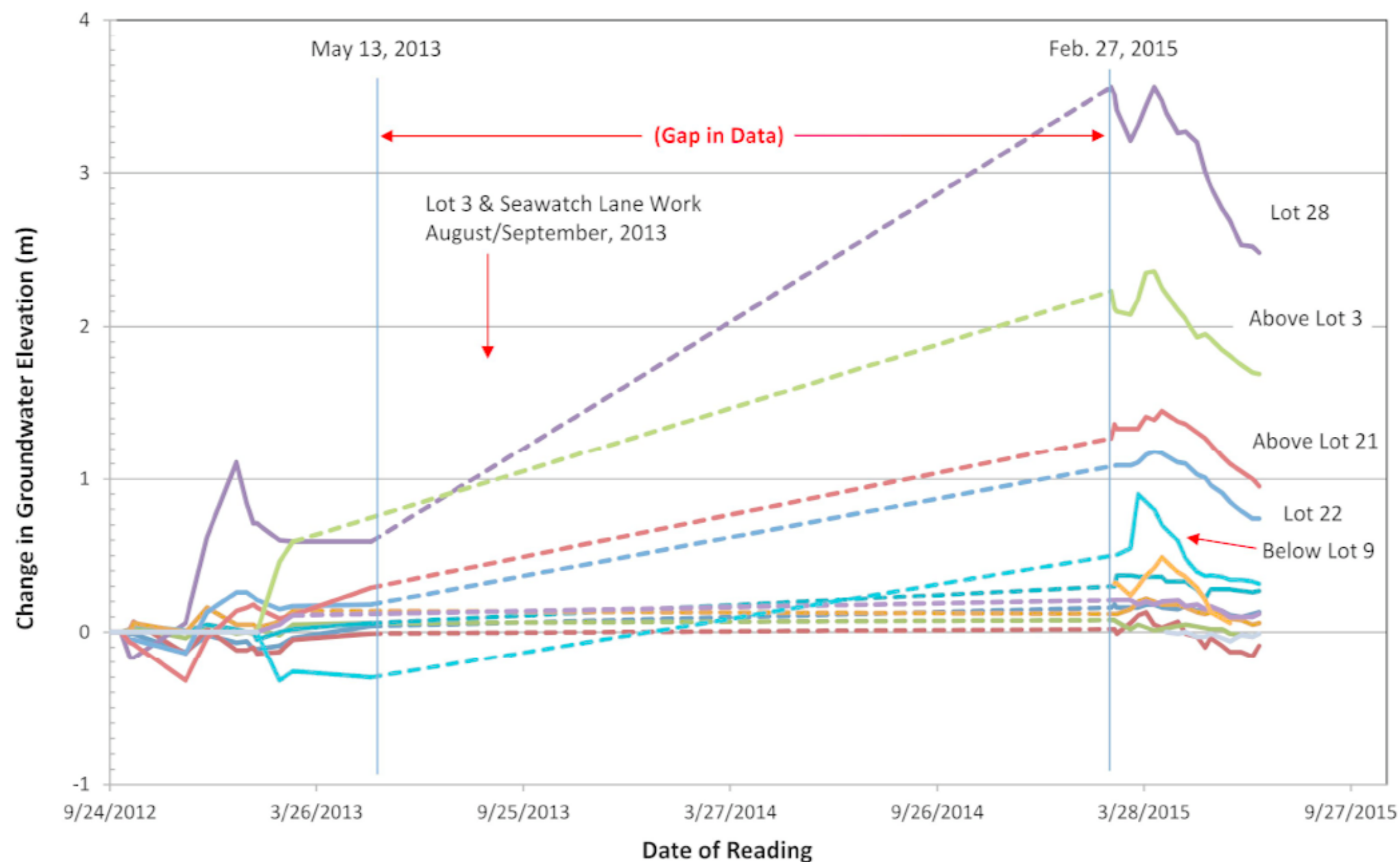
-



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Appendix C

Groundwater Elevation at Monitoring Wells Over Time



Monitoring Wells

BH12-01	BH12-02	BH12-03	BH12-05	BH12-06	BH12-07	BH12-08
BH12-09	TH13-07	TH13-08	TH13-09	TH13-01	TH15-03	

LEGEND:

NOTES:

1. PLOTS ARE BASED ON GROUNDWATER MONITORING DATA AVAILABLE TO THURBER.



THURBER ENGINEERING LTD.

CLIENT

DISTRICT OF SECHLT

CHANGE IN GROUNDWATER ELEVATION SINCE INITIAL READING

THE SHORES - PHASE 1 SUBDIVISION

SECHLT, BC

DESIGNED

CHS

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NAK

APPROVED

DJT

DATE

JULY 16, 2015

PROJECT No.

14-214-4

SCALE

AS SHOWN

FIG. No.

21

REV.

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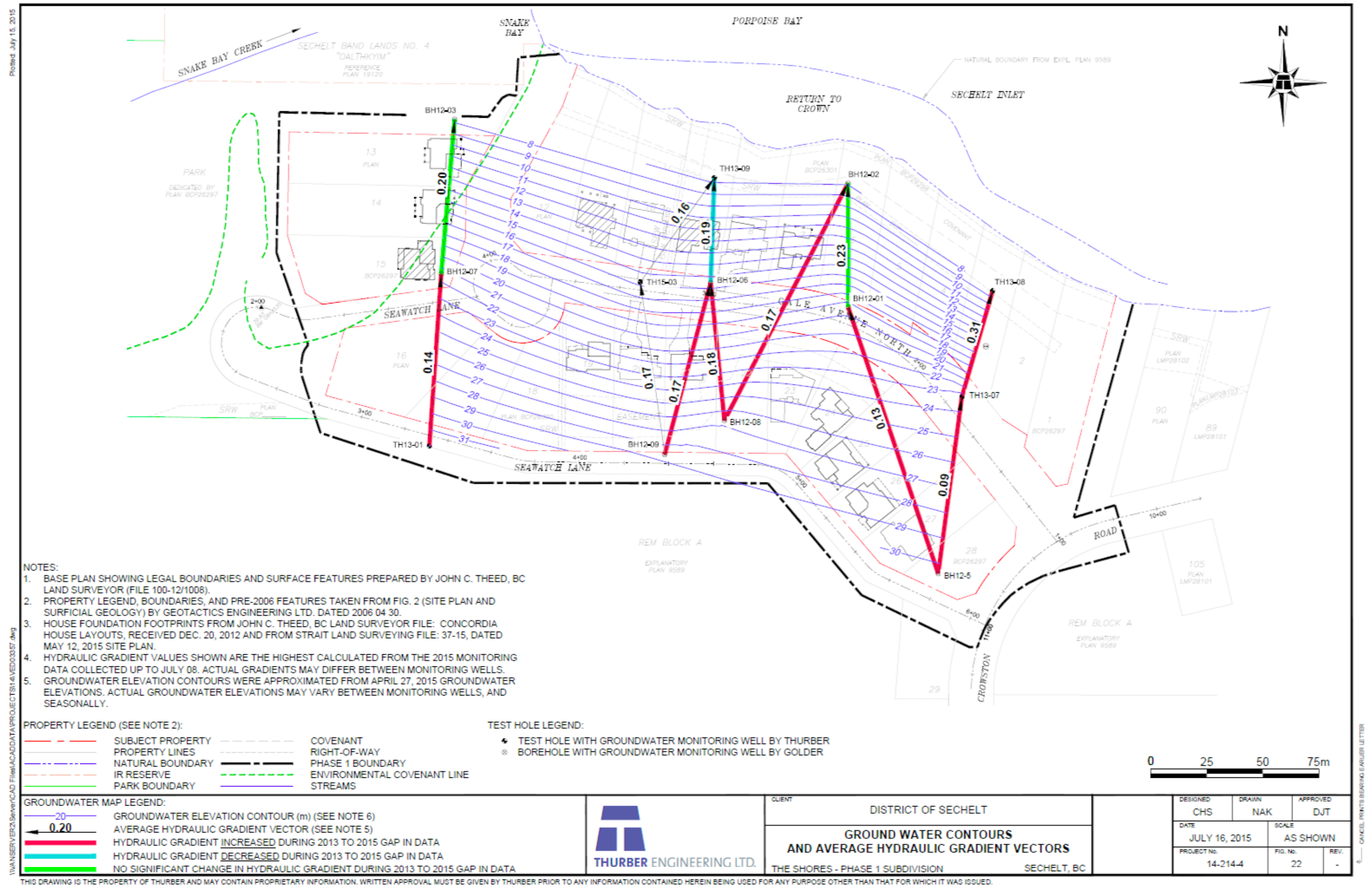
CANCEL PRINTS BEARING EARLIER LETTER



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Appendix D

Groundwater Contours and Average Hydraulic Gradient Vectors



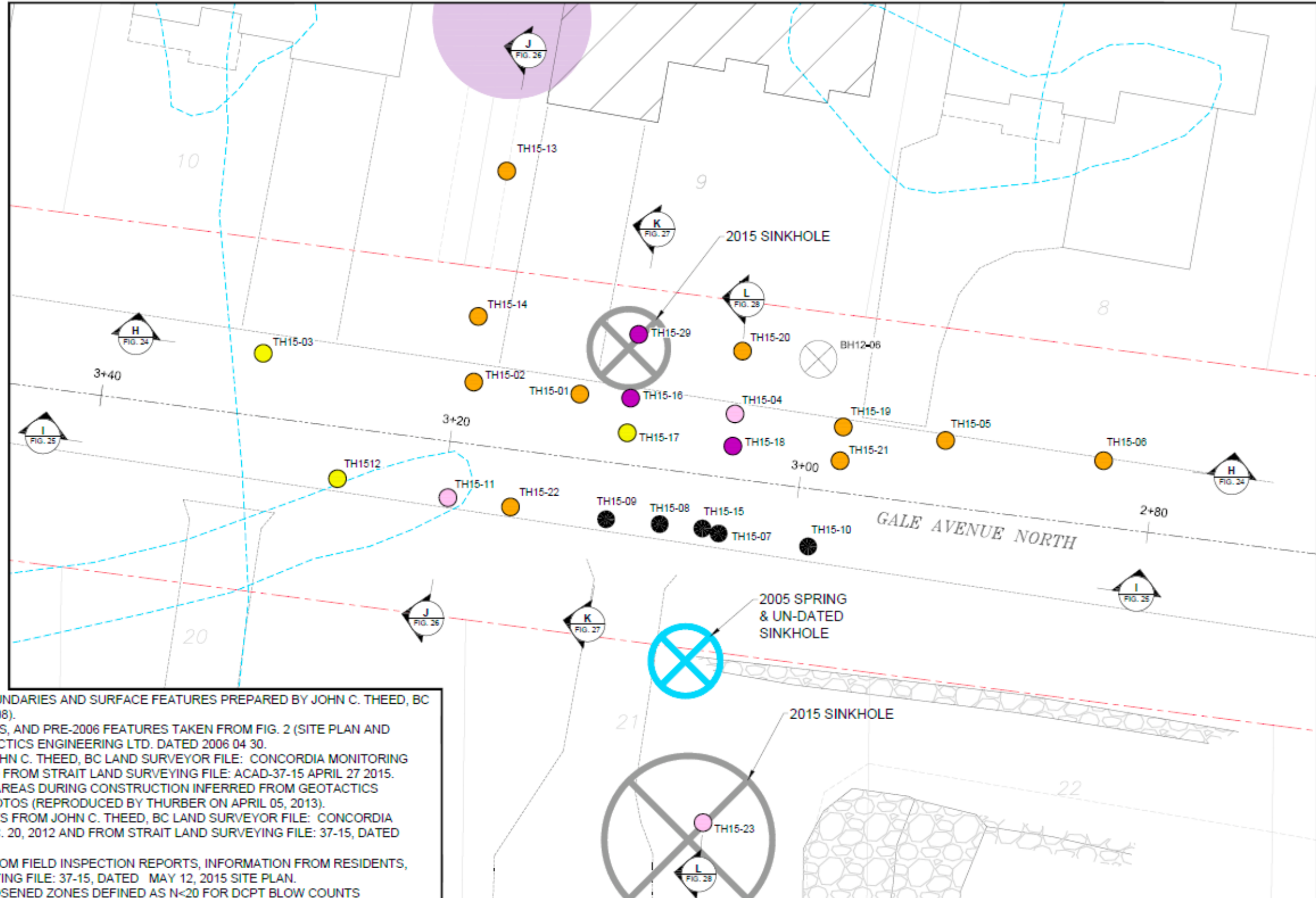


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Appendix E

Sinkhole Development Interpretation

CANCEL PRINTS BEARING EARLIER LETTER



- NOTES:
1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
 2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
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 6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
 7. FOR SCREENING PURPOSES LOOSENED ZONES DEFINED AS N<20 FOR DCPT BLOW COUNTS VERY LOOSE ZONES DEFINED AS N<4 FOR DCPT BLOW COUNTS.

PROPERTY LEGEND (SEE NOTE 2):

	SUBJECT PROPERTY		COVENANT
	PROPERTY LINES		RIGHT-OF-WAY
	NATURAL BOUNDARY		PHASE 1 BOUNDARY
	IR RESERVE		ENVIRONMENTAL COVENANT LINE
	PARK BOUNDARY		STREAMS

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

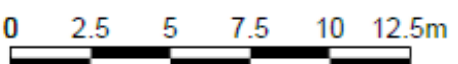
	PRE 2006 SINKHOLE		HOUSE INCOMPLETE OR UNOCCUPIED
	PRE 2006 SPRING OR STREAM		PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
	POST 2006 SINKHOLE		2015 SPRING OR WET AREA
	ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)		

TEST HOLE LEGEND:

- TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- TEST HOLE BY THURBER
- BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
- ELEVATION OF WELL COVER OR GROUND SURFACE (m)

INTERPRETATION LEGEND (SEE NOTE 7):

- VOIDS AND / OR VERY LOOSE ZONES > 5 m TOTAL THICKNESS
- VERY LOOSE ZONES 1 to 5 m TOTAL THICKNESS
- LOOSENED ZONES > 3 m TOTAL THICKNESS
- LOOSENED ZONES 0.5 TO 3 m TOTAL THICKNESS
- SIGNS OF LOOSENING NOT ENCOUNTERED WITHIN ZONE INVESTIGATED

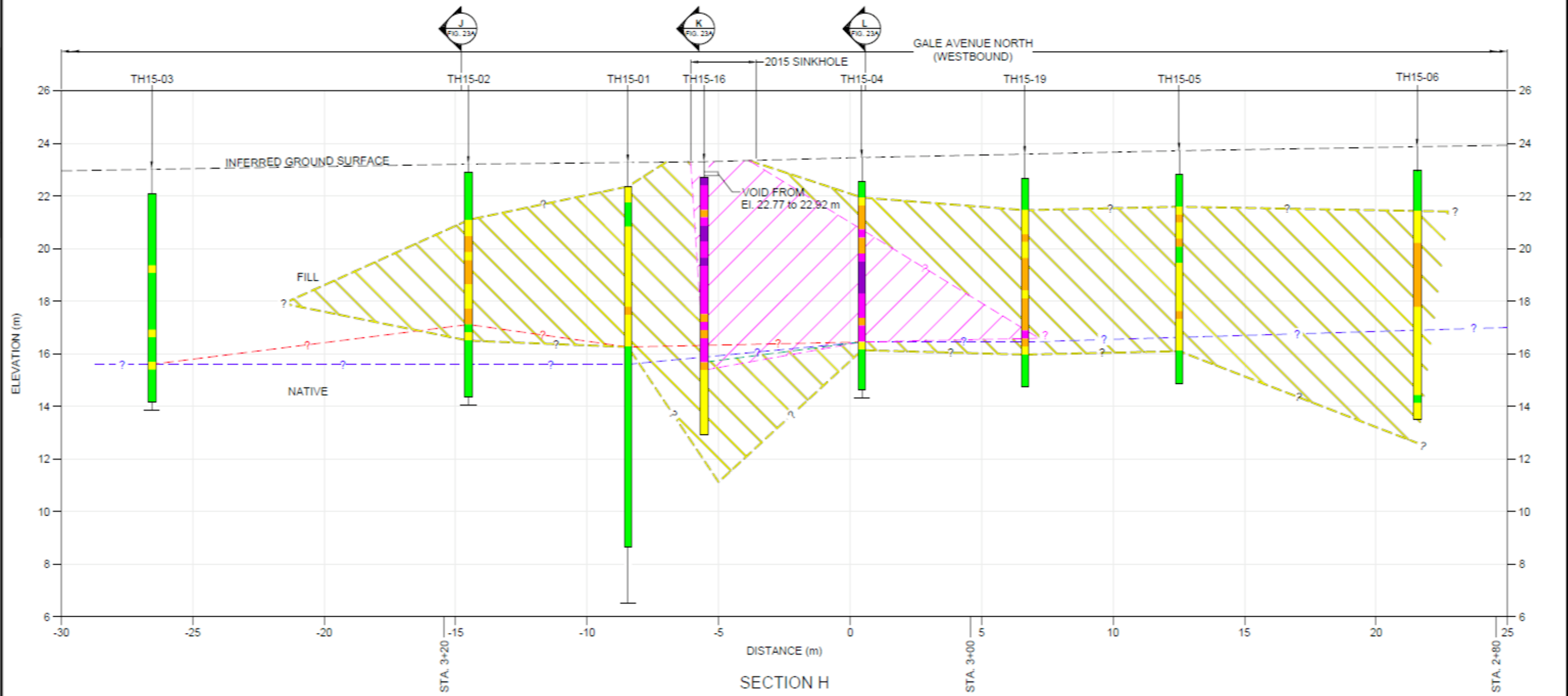


THURBER ENGINEERING LTD.

CLIENT	DISTRICT OF SECHLT
	SINKHOLE DEVELOPMENT INTERPRETATION
	GALE AVENUE NORTH
	THE SHORES - PHASE 1 SUBDIVISION
	SECHLT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK	DJT
DATE	SCALE	
JULY 16, 2015	AS SHOWN	
PROJECT No.	FIG. No.	REV.
14-214-4	23A	-

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Plotted: July 16, 2015



LEGEND FOR INTERPRETATION:	
	(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
	(N = 2 to 4) Severe Apparent Loosening
	(N = 5 to 10) Moderate Apparent Loosening
	(N = 11 to 20) Minor Apparent Loosening
	(N = 21 or greater) No Apparent Loosening
	Interpreted Base of Fill
	Interpreted Water Table
	Interpreted Extent of Severely Loosened Zone
	Interpreted Extent of Loosened Zone

- NOTES:
- INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
 - INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
 - REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.

LEGEND:	
	TEST HOLE ID WITH
	OFFSET DISTANCE FROM SECTION LINE (OFFSETS LESS THAN 0.3 m NOT SHOWN)

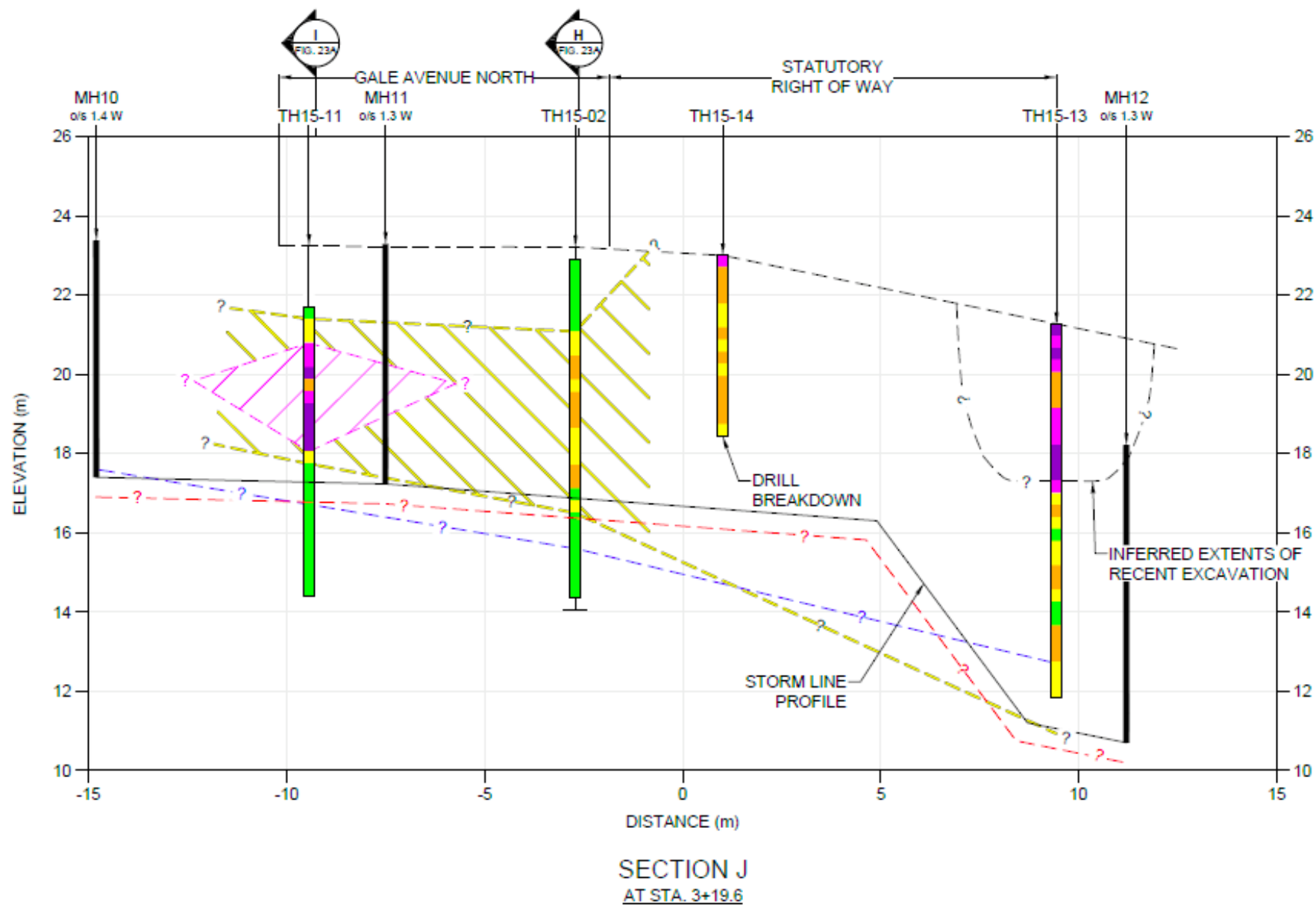


CLIENT	DISTRICT OF SECHLT
INTERPRETATION SECTION H-H	
THE SHORES - PHASE 1 SUBDIVISION	SECHLT, BC



DESIGNED CHS	DRAWN NAK	APPROVED DJT
DATE JULY 16, 2015	SCALE AS SHOWN	
PROJECT No. 14-214-4	FIG. No. 24	REV. -

Plotted: July 15, 2015
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THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.



LEGEND FOR INTERPRETATION:

	(N = 0 to 1 or Static Weight of Hammer) Void or Very Severe Apparent Loosening
	(N = 2 to 4) Severe Apparent Loosening
	(N = 5 to 10) Moderate Apparent Loosening
	(N = 11 to 20) Minor Apparent Loosening
	(N = 21 or greater) No Apparent Loosening
	Interpreted Base of Fill
	Interpreted Water Table
	Interpreted Extent of Severely Loosened Zone
	Interpreted Extent of Loosened Zone

NOTES:

1. INTERPRETATIONS MADE ON THE BASIS OF DRILLING OBSERVATIONS AS DETAILED IN THE TEST HOLE LOGS.
2. INFERRED BOUNDARIES MAY VARY BETWEEN TEST HOLES.
3. REFER TO TEST HOLE LOGS FOR DETAILED INFORMATION.
4. STORM LINE PROFILE APPROXIMATED FROM FILE: 03-23-2015 GROUND COMPARISON BASED ON PIPE VIDEO INTERPRETATION.

LEGEND:

BH12-06 ← TEST HOLE ID WITH
o/s 3.7 m N ← OFFSET DISTANCE FROM SECTION LINE
(OFFSETS LESS THAN 0.3 m NOT SHOWN)



THURBER ENGINEERING LTD.

CLIENT

DISTRICT OF SECHLT

INTERPRETATION SECTION J-J

THE SHORES - PHASE 1 SUBDIVISION

SECHLT, BC



DESIGNED CHS	DRAWN NAK	APPROVED DJT
DATE JULY 16, 2015	SCALE AS SHOWN	
PROJECT No. 14-214-4	FIG. No. 26	REV. -

CANCEL PRINTS BEARING EARLIER LETTER



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Appendix F

Class C Cost Estimates for Storm Sewer Replacement

Class 'C' Cost Opinion for Option 1

Item	Description	Unit	Estimated Quantity	Unit Rate	Cost	Total Price \$
1	General Requirements					
1.01	Mobilization/Demobilization:					
1.01.1	General Contract 5%	L.S.	1	\$16,000.00	\$16,000	\$16,000
1.01.2	Sheeting Contractor	L.S.	1	\$20,000.00	\$20,000	\$20,000
1.02	Bonding/Insurance 2%	L.S.	1	\$7,000.00	\$7,000	\$7,000
	Subtotal				\$43,000	\$43,000
2	Site Work					
2.01	Groundwater Control and Deep Trench Shoring by Use of Sheet Piles (approx. 55 m length by 12 m deep)	sq. m	680	\$100.00	\$68,000	\$68,000
2.02	Pump Rental	week	3	\$5,000.00	\$15,000	\$15,000
2.03	Fuel for Genset	day	15	\$200.00	\$3,000	\$3,000
2.04	Attendance	day	15	\$1000.00	\$15,000	\$15,000
	Subtotal				\$101,000	\$101,000
3	Drainage					
3.01	450 mm Dia. SDR 35 Pipe in Drain Rock and Filter Cloth Surround (depth greater than 3.5 m)	Lin. m	25	\$1,600.00	\$40,000	\$40,000
3.02	450 mm Dia. SDR 35 Pipe in Drain Rock and Filter Cloth Surround (depth less than 3.5m)	Lin. m	35	\$1,000.00	\$35,000	\$35,000
3.03	450 mm Restraint Couplings	each	20	\$2,500.00	\$50,000	\$50,000
3.04	Manholes 1,200 mm Dia.	each	3	\$10,000.00	\$30,000	\$30,000
3.05	Trench Dams	each	4	\$2,500.00	\$10,000	\$10,000
3.06	Outfall Structure Replacement	L.S.	1	\$10,000.00	\$10,000	\$10,000
3.07	Tie in to Existing Service Pipe	L.S.	1	\$5,000.00	\$5,000	\$5,000
3.08	Temporary Storm Water/Groundwater Bypass	L.S.	1	\$5,000.00	\$5,000	\$5,000
3.09	Grout Filling of Existing Pipe and Manholes	cu.m	25	\$1,000.00	\$25,000	\$25,000
	Subtotal				\$210,000	\$210,000

Item	Description	Unit	Estimated Quantity	Unit Rate	Cost	Total Price \$
4	Landscaping					
4.01	Top Soil 150 mm Thick	sq. m	200	\$30.00	\$6,000	\$6,000
4.02	Sod Grass	sq. m	200	\$20.00	\$4,000	\$4,000
Subtotal					\$10,000	\$10,000
Subtotal Items 1 to 4						\$364,000
Construction Contingency Allowance (25%)						\$91,000
Subtotal Construction						\$455,000
Engineering Allowance (15%)						\$68,000
Total Amount (excl. GST)						\$523,000
GST at 5% (rounded)						\$27,000
Total Amount (incl. GST)						\$550,000
General Notes: 1 Based on temporary sheet pile installation along the deeper section of trench excavation with restraint cage. Requires geotechnical verification and structural design for implementation. 2 Assume borrow pit area 0.5 km to the south of the site is used as temporary stock pile for reuse as general fill. 3 Costs are in 2018 dollars. 4 Costs assume excavation during dry season. Wet weather will increase costs. 5 Change in scope related to the items may increase or decrease quantities and costs for other items. 6 Quantities are based on take-off from Web/Golder drawing included as Figure 6 in the report. 7 Replacement of existing stormwater system is intended to comply with general conformance with performance objectives, geotechnical constraints, and construction considerations. This report is at the Class C type level which is intended for planning purposes and initial budgetary purposes. No warranty is expressed that the option is feasible. Further investigations, structural, and geotechnical assessments are required to confirm feasibility. 8 The excavation geometry follows the cut slopes suggested in the geotechnical reports. 9 We have assumed that all excavated fill can be re-used into the work. Accordingly, we have not provided pricing for imported backfill materials above the pipe zone, which would increase costs significantly.						

District of Sechelt

Class 'C' Cost Opinion for Option 2

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$
1	General Requirements					
1.01	Mobilization/Demobilization					
1.01.1	General Contract 5%	L.S.	1	\$25,500.00	\$25,500	\$25,500
1.01.2	Sheeting Contractor	L.S.	1	\$20,000.00	\$20,000	\$20,000
1.02	Bonding/Insurance 2%	L.S.	1	\$10,500.00	\$10,500	\$10,500
	Subtotal				\$56,000	\$56,000
2	Site Work					
2.01	Groundwater Control and Deep Trench shoring by Use of Sheet Piles (approx. 140 m length by 12 m deep)	m ²	2,000	\$75.00	\$150,000	\$150,000
2.02	Restraint Frame Installation	L.S.	1	\$25,000.00	\$25,000	\$25,000
2.03.1	Trench Excavation and Trucking Off Site	m ³	1,800	\$40.00	\$72,000	\$72,000
2.03.2	Excavation of Manholes, Pipe, Anchors, etc., and Removal Off Site	L.S.	1	\$25,000.00	\$25,000	\$25,000
2.04.1	Pump Rental	week	3	\$5,000.00	\$15,000	\$15,000
2.04.2	Fuel for Genset	day	15	\$200.00	\$3,000	\$3,000
2.04.3	Attendance	day	15	\$1,000.00	\$15,000	\$15,000
2.05	Backfill to Underside of Pipe Bedding c/w Filter Fabric	m ³	1,000	\$60.00	\$60,000	\$60,000
	Subtotal				\$365,000	\$365,000
3	Drainage					
3.01	450 mm Dia. SDR 35 Pipe in Rain Rock and Filter Cloth Surround (trench width 1.1 m)	Lin. m	65	\$800.00	\$52,000	\$52,000
3.02	Additional Backfill for Remainder of 1.9 m Trench	m ³	400	\$60.00	\$24,000	\$24,000
3.03	Manholes 1,200 mm Dia.	each	3	\$10,000.00	\$30,000	\$30,000
3.04	Trench Dams	each	4	\$2,500.00	\$10,000	\$10,000
3.05	Outfall Structure Replacement	L.S.	1	\$10,000.00	\$10,000	\$10,000
3.06	Tie-in to Existing Service Pipe	L.S.	1	\$5,000.00	\$5,000	\$5,000
3.07	Temporary Storm Water/Groundwater Bypass	L.S.	1	\$5,000.00	\$5,000	\$5,000
	Subtotal				\$136,000	\$136,000

Class C Cost Estimate for Outfall Repairs
Lot 9/10 Stormwater Replacement
November 2018

District of Sechelt

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$
4	Landscaping					
4.01	Top Soil 150 mm Thick	sq. m	200	\$30.00	\$6,000	\$6,000
4.02	Sod Grass	sq. m	200	\$20.00	\$4,000	\$4,000
Subtotal					\$10,000	\$10,000
Subtotal Items 1 to 4						\$567,000
Construction Contingency Allowance (25%)						\$142,000
Subtotal Construction						\$709,000
Engineering Allowance (15%)						\$106,000
TOTAL AMOUNT (rounded and excl. GST)						\$815,000
GST at 5% (rounded)						\$40,000
TOTAL AMOUNT (incl. GST)						\$855,000
General Notes: 1 Based on temporary sheet pile installation along the deeper section of trench excavation with restraint cage. Requires geotechnical verification and structural design for implementation. 2 Assume borrow pit area 0.5 km to the south of the site is used as temporary stock pile for reuse as general fill. 3 Costs are in 2018 dollars. 4 Costs assume excavation during dry season. Wet weather will increase costs. 5 Change in scope related to the items may increase or decrease quantities and costs for other items. 6 Quantities are based on take-off from Web/Golder drawing included as Figure 7 in the report. 7 Replacement of existing stormwater system is intended to comply with general conformance with performance objectives, geotechnical constraints, and construction considerations. This report is at the Class C type level which is intended for planning purposes and initial budgetary purposes. No warranty is expressed that the option is feasible. Further investigations, structural, and geotechnical assessments are required to confirm feasibility. 8 We have assumed that little if any excavated fill can be re-used into the work. Accordingly, we have provided pricing using imported backfill materials above and below the pipe zone, which has increased costs significantly.						

Class 'C' Cost Opinion for Option 3

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$
1	General Requirements					
1.01	Mobilization/Demobilization					
1.01.1	General Contract 5%	L.S.	1	\$32,000.00	\$32,000	\$32,000
1.01.2	Sheeting Contractor	L.S.	1	\$20,000.00	\$20,000	\$20,000
1.02	Bonding/Insurance 2%	L.S.	1	\$13,000.00	\$13,000	\$13,000
	Subtotal				\$65,000	\$65,000
2	Site Work					
2.01	Groundwater Control and Deep Trench shoring by Use of Sheet Piles (approx. 270 m length by 12 m deep)	m ²	3,000	\$75.00	\$225,000	\$225,000
2.02	Restraint Frame Installation	L.S.	1	\$25,000.00	\$25,000	\$25,000
2.03.1	Trench Excavation and Trucking Off Site	m ³	1,200	\$40.00	\$48,000	\$48,000
2.03.2	Excavation of Services, temporary repair and restoration	each	12	\$2,000.00	\$24,000	\$24,000
2.04.1	Pump Rental	week	4	\$5,000.00	\$20,000	\$20,000
2.04.2	Fuel for Genset	day	20	\$200.00	\$4,000	\$4,000
2.04.3	Attendance	day	20	\$1,000.00	\$20,000	\$20,000
2.05	Backfill to Underside of Pipe Bedding c/w Filter Fabric	m ³	700	\$60.00	\$42,000	\$42,000
2.06	Grout fill for Pipe and Manholes	m ³	25	\$1000.00	\$25,000	\$25,000
	Subtotal				\$433,000	\$433,000
3	Drainage					
3.01	450 mm Dia. SDR 35 Pipe in Rain Rock and Filter Cloth Surround (trench width 1.5 m)	Lin. m	130	\$800.00	\$104,000	\$104,000
3.02	Additional Backfill for Remainder of Trench	m ³	300	\$60.00	\$18,000	\$18,000
3.03	Manholes 1,200 mm Dia.	each	3	\$10,000.00	\$30,000	\$30,000
3.04	Trench Dams	each	4	\$2,500.00	\$10,000	\$10,000
3.05	Outfall Structure Replacement	L.S.	1	\$10,000.00	\$10,000	\$10,000
3.06	Tie-in to Existing Service Pipe	L.S.	1	\$5,000.00	\$5,000	\$5,000
3.07	Temporary Storm Water/Groundwater Bypass	L.S.	1	\$10,000.00	\$10,000	\$10,000
	Subtotal				\$187,000	\$187,000

**Class C Cost Estimate for Outfall Repairs
Lot 9/10 Stormwater Replacement
November 2018**

District of Sechelt

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$
4	Landscaping					
4.01	Top Soil 150 mm Thick	sq. m	200	\$30.00	\$6,000	\$6,000
4.02	Sod Grass	sq. m	200	\$20.00	\$4,000	\$4,000
4.03	Driveway Repair	L.S.	1	\$15,000.00	\$15,000	\$15,000
Subtotal					\$25,000	\$25,000
Subtotal Items 1 to 4						\$710,000
Construction Contingency Allowance (25%)						\$178,500
Subtotal Construction						\$888,500
Engineering Allowance (15%)						\$132,500
TOTAL AMOUNT (rounded and excl. GST)						\$1,021,000
GST at 5% (rounded)						\$51,000
TOTAL AMOUNT (incl. GST)						\$1,072,000
General Notes: 1 Based on temporary sheet pile installation along the deeper section of trench excavation with restraint cage. Requires geotechnical verification and structural design for implementation. 2 Assume borrow pit area 0.5 km to the south of the site is used as temporary stock pile for reuse as general fill. 3 Costs are in 2018 dollars. 4 Costs assume excavation during dry season. Wet weather will increase costs. 5 Change in scope related to the items may increase or decrease quantities and costs for other items. 6 Quantities are based on take-off from Figure 8 in the report. 7 Replacement of existing stormwater system is intended to comply with general conformance with performance objectives, geotechnical constraints, and construction considerations. This report is at the Class C type level which is intended for planning purposes and initial budgetary purposes. No warranty is expressed that the option is feasible. Further investigations, structural, and geotechnical assessments are required to confirm feasibility. 8 We have assumed that little if any excavated fill can be re-used into the work. Accordingly, we have provided pricing using imported backfill materials above and below the pipe zone, which has increased costs significantly.						



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Appendix G

Class C Cost Estimates for Road Remediation

Class C Cost Estimate for Temporary Road Repairs
Lot 9/10 Stormwater Replacement
November 2018

District of Sechelt

Class 'C' Cost Opinion for Option 1

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$	Comment
1	General Requirements						
1.01	Mobilization/Demobilization 5%	L.S.	1	\$175.00	\$175	\$175	
1.02	Bonding/Insurance 2%	L.S.	1	\$70.00	\$70	\$70	
Subtotal					\$245	\$245	
2	Site Work						
2.01	Asphalt Removal						
2.01.1	Removal and trucking off-site	m ³	0.7	\$40.00	\$28	\$28	
2.01.2	Tipping fee at landfill	tonne	1.4	\$300.00	\$420	\$420	
2.02	Concrete Removal						
2.02.1	Removal of curb and sidewalk and trucking off-site	m ³	0.25	\$40.00	\$10	\$10	
2.02.2	Tipping fee at landfill	tonne	0.6	\$300.00	\$180	\$180	
2.03	Road fills removal to temporary stock piles						
2.03.1	Road subgrade gravels	m ³	4	\$35.00	\$140	\$140	
2.03.2	Road subbase fills	m ³	10	\$35.00	\$350	\$350	
2.04	Geogrid Installation (16m wide)						
2.04.1	Bottom layer of geogrid with filter fabric	m ²	16	\$10.00	\$160	\$160	
2.04.2	Top layer of geogrid	m ²	16	\$7.50	\$120	\$120	
2.05	Road fill subgrade reconstruction from temporary stock piles	m ³	10	\$50.00	\$500	\$500	
Subtotal					\$1,738	\$1,738	
3	Roads and Paving						
3.01	300 mm thick subbase gravels	m ²	12	\$45.00	\$540	\$540	
3.02	100 mm thick base gravels	m ²	8	\$15.00	\$120	\$120	
3.03	Barrier curb and gutter	Lin. m	2	\$120.00	\$240	\$240	
3.04	Sidewalk pavement 1.5 m wide	m ²	1.5	\$100.00	\$150	\$150	
3.05	Two lift asphalt paving 85 mm thick c/w tack coats	m ²	8	\$60.00	\$480	\$480	
3.06	Private property exposed aggregate driveway	m	0.4	\$200.00	\$80	\$80	
Subtotal					\$1,470	\$1,470	

Item	Description	Unit	Estimated Quantity	Material Unit Rate	Material Cost	Total Price \$	Comment
4	Landscaping						
4.01	Top soil 150 mm thick	sq. m	5	\$30.00	\$150	\$150	
4.02	Sod grass	sq. m	5	\$20.00	\$100	\$100	
Subtotal					\$250	\$250	
Subtotal Items 1 to 4						\$3,703	
Construction Contingency (25%)						\$926	
Subtotal						\$4,629	
Engineering Contingency (15%)						\$694	
Total Amount (rounded and excl. GST)						\$5,323	
GST (5%) and rounded						\$267	
Total Amount (incl. GST) Cost per metre length of Road						\$5,590	
General Notes: 1. Assume borrow pit area 0.5 km to the south of the site is used as temporary stock pile for reuse as general fill. 2. Costs are in 2018 dollars. 3. Costs assume excavation during dry season. Wet weather will increase costs. 4. Change in scope related to the items may increase or decrease quantities and costs for other items. 5. Quantities are based on take-off from Concordia Home Construction Record Drawings provided by the District of Sechelt, including drawing 1437-R-08 typical road cross section for roadway L-100. Additional information relied on is Thurber Engineering report dated June 30, 2017. 6. We have assumed that all excavated fill can be re-used into the work. Accordingly, we have not provided pricing for imported materials, which would increase costs significantly. 7. Costs have been developed on a "per metre" basis. Total costs can vary considerably depending on length of road constructed.							

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